Cost-Benefit Analysis of an Agricultural Project Involving a Smallholder Production System

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December 2013

A thesis submitted to McGill University in partial fulfillment of the requirements of the degree of Master of Science

ABSTRACT

The appraisal of government-sponsored agricultural projects should examine the costs and benefits for society as a whole. The present thesis was developed in a context where the Ecuadorian government included poor small farmers from the province of Manabi as suppliers of *Jatropha curcas*, an endemic plant that produces oil seeds, which can be used as feedstock for biofuel. The government assumed that this initiative would improve the income of the involved farmers, but this assumption was not measured in quantitative terms. A study published in support of the project's development performed a financial evaluation that excluded the value of input resources to the national economy. Given this, the main objectives of this thesis were to measure the changes in welfare for the target group, and to construct a government cash flow that determined the project's net benefits with respect to the national economy.

Cost-benefit analysis quantifies the impacts to all members of society arising from the implementation of a project or policy. In particular, the selected methodology was directed to agricultural projects involving smallholders. This method also proposes alternative projects and compares the net benefits with the status quo. In this case, the status quo was proposed by the government, and it involved farmers collecting *Jatropha curcas* seeds from living fences growing throughout the province. The alternative, proposed in this thesis, entailed that the smallholders cultivate the plant on their lands. Thus, financial analysis evaluated the farmer's resources placed in the project at market values, which resulted in the net benefits for the project's duration. On the other hand, the economic analysis considered values that represent the opportunity cost of input resources, and measured the project's impact to the national economy.

The financial analysis determined that the annual net benefit in the status quo did not cover the farmer's investment. On the other hand, the alternative project showed positive total and incremental net benefits, implying that investment and operating costs would be covered. The government cash flow statements for the current and the proposed projects showed cumulative deficits. The economic analysis determined that the alternative project's incremental net benefit was positive. The net present value of the alternative project at the individual level was positive, representing a 41% increment with respect to the status quo. At the aggregate level, the net present value of the project's incremental net benefit was positive, which signifies an addition to the national economy.

The results of financial analysis suggest that if the farmer switches from the status quo to the proposed alternative, his annual income would increase. It was also determined that the current government's initiative does not offer sufficient monetary incentive for farmers to engage in it. However, the net income change expected from the alternative project is positive, and is able to cover the initial investment and operating expenditures. The government's cash flow indicated that the project does not generate sufficient income to cover for the investment and recurrent costs. The results of the economic analysis suggest that the alternative project would produce a positive change in the net national income. Therefore, the analysis and results presented in this thesis might be used as a model for future evaluations of government investment intended to assist poor smallholders.

RESUME

L'évaluation des projets agricoles financés par le gouvernement devrait examiner les coûts et les revenus par rapport à la société dans son ensemble. Cette thèse s’est développée dans un contexte où le gouvernement équatorien a mis en effet un projet dans lequel les agriculteurs pauvres de la province de Manabi sont devenus fournisseurs de *Jatropha curcas*, une plante endémique qui produit des graines huileuses utilisées comme matière première de biocarburants. Le gouvernement a supposé que cette initiative permettrait d'améliorer le revenu des agriculteurs concernés, mais cette hypothèse n'a pas été mesurée en termes quantitatifs. Une étude publiée pour soutenir le développement du projet a effectué une évaluation financière qui exclut la valeur des ressources à l'économie nationale. Dans ce contexte, les principaux objectifs de cette thèse sont : l’estimation des changements dans le bien-être du groupe ciblée, et la construction d'un flux de trésorerie du gouvernement qui puisse déterminer les revenus nets du projet par rapport à l'économie nationale.

L’analyse coûts-bénéfices quantifie les impacts à tous les membres de la société résultant de la mise en œuvre d'un projet ou d'une politique. En particulier, la méthode choisie ici évalue les projets agricoles impliquant les petits propriétaires. Cette méthode propose également des projets alternatifs et compare les bénéfices nets avec le statu quo. Dans ce cas, le statu quo a été proposé par le gouvernement, et il s'agit de récolter des graines de *Jatropha curcas* des clôtures vivantes semées à travers la province. Le projet alternatif, proposé dans cette thèse, implique que les petits agriculteurs cultivent la plante sur leurs terres. Ainsi, l'analyse financière a évalué la valeur des ressources de l'agriculteur placés dans le projet en prix de marché, dont le résultat est les bénéfices nets pour la durée du projet. D'autre part, l'analyse économique a considéré les valeurs qui représentent le coût d'opportunité des ressources, qui estime l'impact du projet pour l'économie nationale.

L'analyse financière a déterminé que le bénéfice net annuel dans le statu quo ne couvre pas l'investissement de l'agriculteur. D'autre part, le projet alternatif a rapporté des bénéfices nets totaux et différentiels positifs, ce qui signifie que l'investissement et les coûts opératifs seraient couverts. Les états des flux de trésorerie du gouvernement pour le projet actuel et le projet proposé ont montré des déficits cumulés. L'analyse économique a déterminé que le bénéfice net différentiel du projet alternatif a été positif. La valeur actuelle nette du projet alternatif au niveau individuel a été positive, ce qui représente une augmentation de 41% par rapport au statu quo. La valeur actuelle nette du bénéfice agrégat a été positive, ce qui signifie une addition monétaire à l'économie nationale.

Les résultats de l'analyse financière suggèrent que si l'agriculteur passe du statu quo à l'alternative proposée, son revenu annuel augmenterait. Il a également été déterminé que l'initiative actuelle proposée par le gouvernement n'offre pas d’avantage monétaire attractif aux agriculteurs. Cependant, la variation espérée du revenu net du projet alternatif est positif; par conséquent, l'investissement initial et les dépenses de fonctionnement seraient couverts. Les flux de trésorerie du gouvernement ont indiqué que le projet ne génère pas de revenus suffisants pour couvrir les coûts d'investissement et de fonctionnement. Les résultats de l'analyse économique suggèrent que le projet alternatif produirait un changement positif dans le revenu national net. De ce fait, l'analyse et les résultats présentés dans cette thèse peuvent être recréés dans futures évaluations de l'investissement du gouvernement visant à améliorer la situation socio-économique des petits propriétaires agricoles.

Acknowledgements

I would like to take this opportunity to thank all the persons that offered their support during the development of this thesis. First, I'd like to thank my husband, Juan Tamayo, for his assistance in many parts of this work. Thanks for the revisions, the composition tips and your continuous support.

My parents have also been of great assistance in completing this thesis. Thank you for the time taken to help out and for the encouragement.

I would also like to extend a heartfelt thanks to my sister, my father in law, my mother in law and my sister in law.

I would also like to thank my classmates for their constructive criticism and their encouragement.

A final acknowledgement goes to the professors supervising this thesis, Dr. John Henning and Dr. Anwar Naseem, for their guidance and meaningful contribution aiding to the completion of this research.

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Chapter 1: Introduction

1.1 Overview

The present thesis performed financial and economic evaluations of a hypothetical agricultural project that involved Ecuadorian small-farmers producing *Jatropha curcas* as feedstock for biofuel. Three aspects are distinctive in this setting. First, the targeted population –Ecuadorian small-farmers– share certain characteristics. They are small landowners, in a low-income group, whose farm work displays low productivity. This population segment has also few alternative prospects for earning income, and scarce employment opportunities. The second distinctive aspect is the project's location. It takes place in Manabi, a coastal province of Ecuador, in South America. Specifically, the study is directed to areas with a dry climate and low rainfall, where infrastructure is not available, which makes agricultural activity difficult. A third aspect of the proposed project is the low input agricultural system. The proposed cropping pattern not only relies on low levels of agricultural input (e.g. water, fertilizers, or pest control chemicals), but also on a small capital stock and low initial investment. In addition, one particular component of the farming system is *Jatropha curcas* as an energy crop. This thesis will determine if a project with these characteristics is viable, and what changes in the participants' welfare it could provoke.

The need to address rural poverty worldwide is indisputable, and in Ecuador, the situation is no less relevant. Worldwide, as in Ecuador, the incidence of poverty is deepest in rural areas (Norton et al., 2010), and socio-economic indicators show a harsh reality for rural inhabitants. The National Institute of Statistics and Census (INEC, acronym in Spanish) is the official source that provides data describing the rural background in Ecuador. In the case of Manabi, 96% of rural households live in poverty conditions, of which 58% subsist in extreme poverty (INEC, 2010)[1]. The lack of

[1] INEC is the Ecuadorian governmental entity that makes available official statistics. Its webpage offers more references: http://www.inec.gob.ec/. This institution offers various indicators of poverty; one of them is called "poverty from unsatisfied necessities," which identifies household living conditions as a sign of poverty and

employment is also an issue in rural Manabi. INEC, in its National Labour Market Census, found that from December 2007 to December 2012 the average rate of unemployment in rural Manabi was 3.7%. In the same period, the rate of underemployment[2] was 76.7%. That is, the total portion of rural population not fully employed in Manabi amounts to 80.4% (INEC, 2012). In an effort to present solutions to this difficult reality, the Ecuadorian government is developing agricultural programs. In this case, the government proposes that local farmers collect a native oil seed (*Jatropha curcas*) growing in living fences, and sell it to government wholesalers. The wholesalers would purchase the raw material at a set price, and process the seeds to manufacture oil, which would then supply the electric stations in the Galapagos Islands.

This thesis proposes a hypothetical project as an alternative to the current government program. In this alternative project the farmers would cultivate *Jatropha curcas* instead of simply collecting the fruit from living fences. Thus, this thesis will evaluate if the proposed alternative represents a viable project, and if the change from the current government program would signify a welfare improvement for the participant agents.

The idea of welfare in economic theory is based on the concept of Pareto efficiency, which in a broad sense, occurs when it is not possible to improve an agent's position without making another worse off (Jehle and Reny, p. 183). In the present context, where the research examines a project that produces intermediate goods, Boardman (2011) indicated that in order to evaluate welfare changes, it was necessary to compare income differences in two settings: "without the project" versus "with the project." Therefore, the terms "welfare," "welfare position," and "income level" are used interchangeably in this study, as they represent the change in total income for the participant farmers.

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extreme poverty. The indicator looks at overcrowding, the quality of sanitary installments and the house construction materials to attest for the socio-economic level of its inhabitants.

[2] Underemployment, as defined by the methodological publication from the National Labour Market Census, includes "people who worked or had employment during the reference period, but were available and willing to modify their employment situation in order to augment the duration or productivity of their labour."

When comparing the two settings, with and without the project, two issues are important. First is the small-farmer's situation. Knowing that a great percentage of the rural population in Manabi needed employment or had more time to work, it became apparent that their income could increase. In this sense, this work will answer the question: will farmers find economic incentives to move from their present occupation and adopt the proposed project? The second issue is the government's investment. Given that it has invested in building processing plants, implementing wholesaler purchase points, and in funding agricultural research, this study will analyze if the project is able to cover these expenses.

Another particularity of this hypothetical project is the farming system. Following recommendations from the Food and Agriculture Organization of the United Nations (FAO), this thesis has incorporated the principles for "Conservation Agriculture." This concept is based on three characteristics: minimal mechanical disturbance to the soil; maintenance of organic residual matter to cover the soil; and, cropping patterns that include rotations and diversification (FAO, 2010). Incorporating the principles of conservation agriculture also implied that the targeted group would engage in a production system that relies on their own labour and a low investment. In contrast to commercial plantations of *Jatropha curcas*, based on high agricultural inputs to obtain higher yields, the smallholder system formulated in this thesis was rain fed, and used chemical fertilization only in the first year, while recycling its own residual organic material to replenish lost nutrients for the rest of the project's duration.

An additional component in this hypothetical project is *Jatropha curcas* cultivation. Even though feasibility studies of *Jatropha curcas* as feedstock for biofuel are numerous in the literature, most of these publications rely on commercial farming to supply the production chain. The present research seeks to find out if a system of small farmers producing under conservation agriculture is economically viable. The reason is that the social and economic traits that characterize the small-farmers can limit the project's success. This group owns a small area of land of 5.4 hectares per farm[3]. Their productivity is low, mainly because they work half of their total farmland, while keeping areas of fallow land and forestry in the other half (Limongi et al., 2003). This group also owns a small capital stock, comprised of minor constructions, as well as certain agricultural tools. Therefore, this thesis will ascertain the economic worth of a project that is based on all the previously mentioned characteristics – production system, socio-economic conditions and cultivation of *Jatropha curcas*.

What is the relevance of including smallholders and conservation practices in the production chain of biofuel? At the local level, the main reason is to introduce a vulnerable population sector into remunerative activities, in order to increase their income. But there are global implications, too. The next section will look into the compatibility of the small-farmers' background and conservation agriculture systems, and how this scenario addresses current global issues.

1.2 The targeted population: attending to the needs of the rural poor

Rural populations in Ecuador face challenging circumstances. Social and economic indicators show a dire prospect for rural areas, revealing major differences from the urban setting. The Integrated System of Social Indicators (SIISE, acronym in Spanish) is an aggregated database containing information from all surveys and censuses in Ecuador. SIISE (2012) provides statistics showing a gap between rural and urban realities. First, income in rural areas is lower than in the cities. For instance, in 2012, the average personal salary in urban areas was USD 486 per month, while in rural areas it was USD 276. SIISE also showed that extreme poverty in rural areas is more severe than in the cities. In 2006, the lowest decile in per capita income in real terms was USD 12 per month in rural areas, while for urban dwellers it was USD 28. Of all rural households, 19.4% lived in extreme poverty in 2006, while the same was true for only 3% of all urban homes. At the national level, the portion of all Ecuadorians living under extreme poverty was 16%. In rural areas, extreme poverty represented 33% of the

[3] Data analysis of landownership in Manabi indicated that the expected value of the farm size is 5.4 hectares for the category "fewer than ten hectares."

population, while in urban areas, it was 9%. By 2012, the situation improved, but the reality was still problematic for the rural poor. In 2012, the lowest earning segment of the rural population received USD 15.85 of monthly income, while for urban inhabitants it was USD 41.45. The percentage of all Ecuadorians living in extreme poverty in 2012 was 11%: for rural inhabitants it was 23% of the population, but for urban inhabitants, only 5%. These numbers show that while there have been steps forward in combatting poverty; the rural population faces a harsher reality than urban inhabitants. Hence, for the rural poor in Ecuador, the incidence of poverty is deeper.

The situation in Manabi, the province where the proposed project takes place, suggests no improvements relative to the national data. Social statistics for this province are below the national averages. In Manabi, the percentage of the population in extreme poverty is 40%; for rural inhabitants this indicator represents 58% of the population, while for the urban it is 26% (SIISE, 2012). The National System of Information[4] (SNI, acronym in Spanish) provides additional indicators, which suggest an urgent need for government investment. For instance, there is a profound necessity to improve living conditions and housing infrastructure. In 2011, in rural Manabi, the percentage of households that used vegetable or animal residues for cooking was 40% (SNI, 2011). The percentage of rural households living in overcrowded conditions, that is, homes that accommodate three or more persons per bedroom, was 24%. Further, housing infrastructure was “inadequate” in 90% of the cases (SNI, 2011). SNI (2011) describes the term *inadequate* as houses where the floor’s material is dirt, the toilet does not have a connection to public sewer or does not exist, water is not provided by the public service, and where overcrowding exists.

Moreover, economic indicators for the province of Manabi are also below the national average. A brief examination of the labour market exhibits a critical situation. For instance, by December 2011, the percentage of workers that received remuneration below the minimal salary was 56%; in rural areas this indicator increased to 66% (SNI,

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[4] The National System of Information is an aggregated database containing statistics relevant to the objectives of the Ministry of Social Development. More information is available at the database’s website: http://www.sni.gob.ec/

2011). The rate of underemployment in Manabi in June 2012 was 63%, while in rural areas the rate was 76% (SNI, 2012). That is, in rural Manabi, three quarters of the labour force were not fully employed. These statistics show that at the provincial level, the socio-economic conditions are critical. Manabi's reality lies well below national averages, and the need for improved opportunities is evident.

After defining the general socio-economic background in Manabi, it is now necessary to identify the targeted population. A first particularity is the geographical location. Two points are under study: Boyaca, a parish in the municipality of Chone; and Tosagua, a municipality. Both places display the elements this research studies. The first element is the socio-economic factor, compatible with Manabi's rural outlook, as already described. A second element is the natural setting, which includes climate and soil quality. The Ecuadorian Ministry of Agriculture (MAGAP, acronym in Spanish) provides geographical data for Ecuador. MAGAP defines the climate in these areas as tropical-dry, which has an annual precipitation of 300 to 500 millimeters, concentrated in the first three to four months of the year, with very little precipitation otherwise. Plus, the average temperature in this area is 24C (MAGAP, 2012). On the other hand, the soil characteristics are rather problematic. The landscape surrounding Tosagua and Boyaca contains slopes. Further, the soil quality is considered marginal land for agriculture (MAGAP, 2012). For these reasons, the range of agricultural activities available to farmers is reduced. They may cultivate only those crops suitable for the conditions, or maintain cattle, and do not count on mechanization or irrigation (MAGAP, 2012). Thus, the location is not the most favourable for agriculture: climate is dry and rainfall is scarce, plus, the sloped landscape makes mechanization and infrastructural implementation difficult. This setting suggests a low opportunity cost for the farmer's land.

A second characteristic of the target population is their endowment of production factors. The farmers have land and a small capital stock, plus, they provide the labour to cover farm operations. It is also necessary to examine land tenure in Manabi. This study focused on farmers that own fewer than ten hectares, as described by the National

Agricultural Census (INEC and MAGAP, 2000) in table 1.1. In order to evaluate economic feasibility, this study set up the model farm size to be 5.4 hectares. Statistical analysis determined this area as the expected value for farms with fewer than ten hectares. As table 1.1 shows, in Manabi there are near 144,000 hectares that conform to this farm size. This number represents only 9% of the total land under some form of proprietorship in Manabi, but it has the capability to provide employment to 63% of agricultural producers, as Table 1.2 demonstrates.

Table 1.1: Land Ownership in Manabi, Ecuador.

Proprietorship by farm size		Total Ha.	Percentage of total area	Land tenure (in hectares) Self-owned	Occupied with title	Rented	Shared cropping	Coop	Other type	Mixed-tenure
Fewer than 10 Ha.		143,739	9.1%	84,723	13,549	3,320	706	291	13,870	27,280
10 to fewer than 50 Ha.		462,606	29.2%	343,724	30,285	5,612	2,911	1,058	25,705	53,311
50 to fewer than 100 Ha.		283,566	17.9%	237,101	10,177	5,359	2,318	690	9,211	18,710
100 Ha. and above		693,713	43.8%	619,394	12,257	3,628	641	6,875	25,184	25,734
Total hectares by land tenure type				1,284,942	66,268	17,919	6,576	8,914	73,970	125,035
% of tenure type to total				81.1%	4.2%	1.1%	0.4%	0.6%	4.7%	7.9%
% of size category to total by tenure type	Fewer than 10 Ha.			6.6%	20.5%	18.5%	10.7%	3.3%	18.8%	21.8%

Source: National Agricultural Census (CNA, 2000).

A second element of the farmer's endowment is labour. As said, the production system proposed in this thesis takes advantage of manual labour, instead of mechanical input. This thesis has assumed that farm operations followed guidelines for conservation agriculture practices, as defined by the Food and Agriculture Organization. Implementing conservation agriculture enables farmers to undertake farming operations without mechanical input. As a result, the requirement for an initial investment is very low.

The final piece in the endowment is capital stock. These farmers possess a few agricultural tools, such as fumigation pumps, and minor constructions, such as drying facilities.

Table 1.2: Number of producers per farm size category

Farm Size	Fewer than 10 Ha.	10 to fewer than 20 Ha.	20 to fewer than 50 Ha.	50 to fewer than 100 Ha.	100 to fewer than 200 Ha.	200 Ha. and above	Total
Number of producers	47,285	9,621	10,697	4,172	1,769	1,131	74,675
Percentage to total	63.32%	12.88%	14.32%	5.59%	2.37%	1.51%	-

Source: National Agricultural Census (CNA, 2000).

In summary, the proposed project displays two defining aspects. First, the geographical setting conditions the opportunity cost of land. Second, the farmers have an endowment of production factors. They possess capital stock and land. In addition, farmers will provide manual labour. The next section will review the project currently operating in the area, its policy context and its business model.

1.3 Current Business Model

The policy context for the current project is under the Ecuadorian Ministry of Electricity and Renewable Energy. One branch of this ministry deals with "Renewable and efficient energy," and its main purpose is to design policy, strategies and projects involving renewable energy and efficient energy use (M. Electricity, 2013). One of these projects is titled, "Production of *Jatropha curcas* oil for electricity generation in the Galapagos Islands." As the project's webpage describes, its main objective is to substitute vegetable oil for (fossil) diesel used in electric generation, through the agro-industrial development of *Jatropha curcas* from living fences in Manabi (M. Electricity, 2013). The Ecuadorian government implemented this initiative with assistance from the Inter-American Institute for Cooperation in Agriculture (IICA), which prepared an ex-ante study. As IICA (2008) attests, the Ecuadorian government is also executing a policy to eliminate the use of fossil fuels in the Galapagos Islands. Thus, the project intends to cover the demand for electricity generation with *Jatropha curcas* oil. A first phase will be executed on Floreana Island, with an annual fuel requirement of 24,000 litres (IICA, 2008). Further, the total annual fuel demand for the Galapagos Islands is 8 million litres (IICA, 2008). The government also invested in adapting machinery for electric generation from vegetable oil on Floreana Island, as well as in research in Manabi to improve *Jatropha curcas* productivity, and in a processing facility (IICA, 2008). The project's webpage also reports that in the period 2009 – 2012, the processing plant collected 350 tonnes of *Jatropha curcas* seed, with an oil yield of 99,200 litres (M. Electricity, 2013). Further, in 2012 the project benefitted more than 3,000 producers (M. Electricity, 2013).

IICA (2008) provides more insights about the project's production chain. Farmers in Manabi plant *Jatropha curcas* to use the trees as living fences. These fences serve as separation from other properties, or make inner divisions that protect the fields from cattle. Farmers also cultivate *Jatropha curcas* to manufacture soap. The government proposes that the farmers collect *Jatropha curcas* from the living fences and sell it to wholesalers, also from the government. This initiative also places Tosagua and Boyaca as referential locations.

However, the project's proposal, IICA (2008), and its socio-economic survey, Garcia (2011), assume that because of the dire conditions present, the project *must* improve the farmers' situation. None of the reports provide estimates that demonstrate how the farmers' position will be improved, and therefore, cannot effectively conclude that the government's investment is an efficient resource allocation. Further, the cited reports fail to examine if the farmers' resource allocation is also efficient. In this context, this thesis proposes a modification to the current government project. If the farmers use their land to cultivate *Jatropha curcas* under a productive system that follows conservation agriculture practices, would that improve their welfare position? For that purpose, this study will conduct a cost-benefit analysis of the current and proposed projects and compare the two results. Thus, the first conclusion this thesis attempts to find is in terms of economic feasibility; i.e. are the projected net benefits positive? A second point will be a comparison between the current project and the proposed; that is, the changes in welfare.

1.4 Conservation Agriculture

As previously mentioned, the Food and Agriculture Organization (FAO) defines Conservation Agriculture (CA) as a productive system based on three principles: (1) minimal mechanical soil disturbance; (2) maintenance of a mulch of carbon-rich organic matter covering and feeding the soil; and, (3) rotations or sequences and crops diversification (FAO, 2010). The FAO promotes conservation practices in agriculture for three reasons. First, these practices offer mitigation to climate change. This mitigation arrives mainly from water and soil conservation, and sinks of Greenhouse gases. In this sense, CA constitutes a sustainable set of practices to cultivate agricultural products, especially food. This prospect of sustainable agriculture provides a second motivation, food security. Third, the system is recommendable for small-farmers. Thus, the proposed project adopted conservation agriculture principles for farm activities.

In addition, conservation agriculture takes advantage of the socio-economic background found in the target group. Specifically, two practices make this system compatible with the proposed project: soil nutrient management and diversified production. In the first aspect, conservation agriculture recommends a diminished use of synthetic fertilizers, supplemented by an increased input of organic matter in the soil (FAO, 2010). The use of organic matter to replenish soil nutrients coincides with the second principle of conservation agriculture, which states that maintaining a mulch layer sustains soil microorganisms that improve moisture and nutrients in the soil (FAO, 2010). At the same time, the proposed project incorporates recycling residual organic matter from farm operations. For instance, the literature indicates that the organic matter from pruning *Jatropha curcas* trees contains essential nutrients, i.e. nitrogen, phosphorus, potassium and calcium (Francis et al., 2005; Karanam and Bhavanasi, 2012); and that it should be sufficient to maintain the balance of soil nutrients (Karanam and Bhavanasi, 2012). Further, the use of *Jatropha curcas* cake, a residual matter from oil processing, as fertilizer is also included. The cake contains all essential nutrients; namely, nitrogen, phosphorus and potassium (Behera et al., 2010; Francis et al., 2005). Hence, the cropping pattern takes in conservation agriculture principles for soil nutrient management.

The second aspect of conservation agriculture relevant to the proposed project is diversified production. This concept recommends crop rotation and intercropping with plants capable of fixing nitrogen in the soil (FAO, 2010). The cropping pattern proposed in this thesis is an intercropping system that includes *Jatropha curcas*, maize and peanut. Second, fertilization with commercial material occurs only in the first year. From then on, *Jatropha curcas* cake will be used as fertilizer. Chemical pest control is minimal, and it is instead the crop rotation that handles pests and diseases, as per recommendations from the literature (Karanam and Bhavanasi, 2012; Ullauri et al., 2004). Thus, the cropping pattern incorporates diversified production and takes advantage of its effects.

Finally, conservation agriculture presents an advantageous economic rationale for the project proposed in this thesis. As the FAO (2001) affirms, conservation agriculture systems generate reduced costs, especially input costs from purchasing less fertilizer and insecticide, not renting mechanical implements, and requiring a lower labour input. A low initial investment is another advantage of the economic rationale. Conservation agriculture takes advantage of manual labour instead of mechanical input. As well, this system relies on minimal soil preparation, and minimal land change, which reduces initial investment. Low operation costs and initial investment are compatible with the socio-economic background in our target population. That is, conservation agriculture takes advantage of the factors that the small-farmer owns, labour and land, and reduces the need for those unavailable factors, financial and mechanical capital.

Thus, the proposed cropping pattern is compatible with conservation agriculture principles and it successfully incorporates its recommendations. Further, the project is designed to support its economic rationale. As a result, the production system based on conservation agriculture implies a better fit for the available resources.

1.5 *Jatropha curcas* as feedstock for biofuel

A final element of examination in this thesis is *Jatropha curcas* as an energy crop. As said, publications studying the economic feasibility of projects that involve *Jatropha curcas* as feedstock for biofuel are numerous. However, these publications rely for the most part on commercial plantations with intensive farming practices to establish positive economic value. This thesis will evaluate economic feasibility in a different context. After reviewing the background scenario for the proposed project, which entails a socio-economic aspect, particular natural conditions in climate and soil quality, and a non-intensive agricultural system; this research will determine if positive economic results are possible.

Evidently, the current project implemented by the Ecuadorian government already decided that *Jatropha curcas* will be the feedstock for biofuel production, motivated by its abundance. It is estimated that there are 6.8 thousand kilometers of living fences in the province, which would generate 17.8 tonnes of seed per year, resulting in 6.4 million litres of *Jatropha curcas* oil (IICA, 2008). Considering that the projected demand for vegetable oil from the Galapagos Islands amounts to 7 million litres per year (IICA, 2008), then the existing *Jatropha curcas* would be able to cover it. However, these data describe a potential supply, not the actual production occurring in the status quo. The extent to which this *potential* supply from living fences could become *actual* oil production depends on the farmer's willingness to engage in the current project.

Economic feasibility is partly based on *Jatropha curcas* cultivation, because the plant's attributes fit the project's background. A first aspect is the plant's resistance to unfavourable climate. The fact that *Jatropha curcas* from living fences, growing without inputs, is potentially capable of providing for the Galapagos Islands demand, attests for the plant's resilience. Indeed, the literature confirms the plant's resistance to water scarcity (Abou and Atta, 2009; Achten et al., 2008; Karanam and Bhavanasi, 2012); and there are publications that confirm its economic performance in rain fed cultivations in climate types with even lower rainfall than the area targeted here (Lima, 2008).

Another aspect in *Jatropha curcas* resilience is its capacity to be productive in low-quality soils. A good example to support this affirmation is the governmental policy for widespread cultivation in India. According to Wani and Chander (2012), the Indian government has identified 13.4 million hectares of marginal lands to cultivate *Jatropha curcas* as feedstock for biodiesel. These authors describe these degraded areas in a semi-arid climatic zone, in principle, even drier and with less rainfall than the targeted area in this thesis. Not only does *Jatropha curcas* have the ability to produce in degraded lands, but also, according to these authors, it has the capacity to rehabilitate them. This initiative of the Indian government responds to a need to improve income in poor small landowners of degraded soils, a characteristic that this thesis shares. Thus, *Jatropha curcas* cultivation integrates small-landowners of degraded soils into the supply chain of biofuel, a possibility that favours the target group in this thesis. Finally, *Jatropha curcas* is a perennial crop. Literature affirms that it has a productive span of 30 to 40 years (Barahona, 2013; Basili and Fontini, 2012; Lima, 2008), with 24 - 25 years of stable production. As a result, the small-farmer would require only one initial investment in the project's duration, and thus, it should be possible to initiate the project with a low debt level.

Jatropha curcas' attributes also assist the proposed productive system. The plant requires low maintenance, which makes it possible for the small-farmer to cover these tasks with minimal hired labour. Further, no mechanical input is necessary, because the minimal soil disturbance principle of conservation agriculture diminishes field preparation, one of the most time consuming farm operations. Therefore, *Jatropha curcas* facilitates implementation of conservation agriculture systems.

In sum, *Jatropha curcas* is a crucial entry in the productive system. The plant's attributes assist the project's success because they fit its context. The plant's resistance to water scarcity helps our targeted group, which doesn't count on irrigation infrastructure. On the other hand, *Jatropha curcas* allows nutrient recycling, which makes plantations productive in low-quality soils. That is, *Jatropha curcas* cultivation supports conservation agriculture principles.

1.6 Methodological Aspects

As previously mentioned, the methodology chosen for this thesis is Cost-Benefit Analysis (CBA). CBA determines economic feasibility for private projects or government policy. That is, the methodology calculates the impact not only for private parties, but also, for the society as a whole. This methodology is also useful to determine welfare changes in the participant agents. By comparing the economic value of a current situation to a prospective initiative, CBA can be used to analyze if the change may be positive in quantitative terms. Now, what does CBA entail?

Boardman (2011) defines CBA as an assessment method that quantifies in monetary terms policy impacts to all members of society. In a broad sense, CBA evaluates the cost of inputs versus the benefit from outputs to determine the project's value. A comparison between the value of a current activity and the projected value of a proposed change reveals which position is better in quantitative terms. Thus, CBA is an objective methodology to assess if investors (private or public) are efficiently allocating their resources.

On the other hand, Gittinger (1982) proposed a methodology specific to agricultural initiatives. The main part of this assessment method is Farm Investment Analysis (FIA). FIA studies resources and outputs in four broad categories: land, labour, financial capital and production. The main objective of this evaluation method is to determine the financial attractiveness of an investment to farmers and to the society as a whole (Gittinger, 1982). The final step in FIA is the farm budget, which calculates a stream of *incremental* benefits for the project's duration. This result compares net benefits from a proposed project and the status quo, allowing the farmer to evaluate if there will be enough monetary incentives to change a current occupation for an alternative.

Another advantage of Gittinger's structure is the model farm format. This methodology prescribes a design of the cropping pattern, which determines what crops will be cultivated, how they will be distributed and in what area. This pattern allows a more accurate projection of agricultural input needs, including fertilizer and pest control chemicals. The structure also assesses labour requirements. The analyst examines the necessary farm operations and calculates the monthly working hours. As a result, the analyst can accurately estimate labour requirements in excess of the farmer's input. Finally, the incremental working capital section displays capital movements. This format analyzes money inflows and outflows, and it enables the analyst to assess credit needs and cost of capital.

In sum, CBA is an objective method to determine the project's impact to all involved agents. Particularly, Gittinger (1982) presented a methodology customized for agriculture, providing an evaluation format useful to farmers and investors.

1.7 Problem Statement

With the social, economic and natural setting already described, the main purpose of this thesis is to establish the economic feasibility of an agricultural project involving *Jatropha curcas* cultivation as feedstock for biofuel. As mentioned, there are already numerous studies of the same subject, but their production system is generally based on intensive agricultural practices. The present research plans to base its production on conservation agricultural practices and small-farmers as its principal actors.

Second, this thesis seeks to determine changes in welfare for small-farmers involved in a government program. The Ecuadorian government implemented a policy to eliminate fossil fuels from electricity generation in the Galapagos Islands. To supply this initiative, the government executed a project where rural inhabitants in the province of Manabi collect *Jatropha curcas* from living fences. The collected fruit is used as feedstock for biofuel which powers the Galapagos Islands. At the same time, the Ecuadorian government sees this initiative as an aid program, which is expected to improve the participant's income; but no quantitative analysis supports this assumption. The present study intends to evaluate whether the government initiative does indeed represent an income improvement for rural inhabitants in Manabi. Further, this thesis proposes an alternative to the government's program, where farmers cultivate *Jatropha curcas* instead of collecting it. By calculating and comparing incremental benefits, this research will determine the changes in welfare.

Finally, the present work will conduct a survey of current policy assisting the project's success and make recommendations. It is apparent that the Ecuadorian government installed various institutions to support agriculture, biofuel production and sensitive populations, but, are they working? If not, what is lacking?

1.8 Research objectives

This thesis will pursue three objectives. First, a financial analysis will determine if there are monetary incentives for farmers to engage in the proposed project, or instead maintain their current way of living.

Second, CBA will also determine changes in welfare for the participant farmers. The comparison of incremental net benefits as a result of the current and proposed projects determines if the involved farmers may increase their income.

Third, an evaluation of government income sources and expenditures will establish if its resource allocation is positive.

Finally, this thesis will survey the existing policy that may aid the project's success and suggest changes or additions. The result sought here is an evaluation of the policy setting for small-farmers. Are the institutions, regulations and programs working to assist this sector?

Specifically, the present research will address the following questions:

- Are the current and proposed projects economically feasible under the described background?
- Can "sustainable agriculture" as prescribed by the FAO be economically viable? Is *Jatropha curcas* indeed a productive plant under problematic natural conditions?
- Are there positive changes in welfare to the participant population? Do they find incentives to engage in this program?
- Are the government's resource allocations effective? Is the impact worth the expenses to society as a whole?
- What policy and government programs foster the project's success? Are the government interventions assisting a vulnerable sector in Ecuador? What can be added or eliminated?

Chapter 2 will review the literature relevant to this thesis, in three areas. The first is conservation agriculture as a production system, including its principles and characteristics. The second area reviews publications describing *Jatropha curcas* and its agricultural performance. The third topic is a survey of evaluation methods for agricultural projects, including cost-benefit analysis. The review of cost-benefit analysis examines its fundamental concepts and its structure.

Chapter 3 explains the methodology and data used in this study. Particularly, this chapter presents the background calculations necessary to perform economic analysis following the chosen method, including farm investment analysis.

Chapter 4 presents the results and discusses their implications. Results for the financial analysis offer the monetary incentives that the farmer may expect from engaging in a project. Also presented is the government cash flow, which is a statement of income sources and expenditures, as a result of the project's development. Finally, the economic analysis evaluates the net national income change expected from the project's implementation, as well as the measures of project worth, including the net present value and the benefit-cost ratio. The last section discusses the implications to individuals and to the economy as a whole.

Chapter 5 offers conclusions and policy recommendations. The policy section surveys the current government interventions associated to the project, and makes recommendations. In addition, this chapter covers the limitations of this thesis and proposes other areas for future research.

Chapter 2: Literature Review

2.1 Introduction

Jatropha curcas is a tree that produces seeds containing oil, suitable for biodiesel production. According to Openshaw (2000), the plant originated in tropical zones in the Americas, but has spread around the world to areas with tropical and subtropical climates in Asia and Africa. On the other hand, Abou and Atta (2009) found that it is also possible to cultivate *Jatropha curcas* in semi-arid landscapes, in their case, Egypt. In the case of Ecuador, *Jatropha curcas* is a native plant, and it grows in different climatic zones that include semi-arid to humid, as well as different altitudes, from sea level to 1,500 meters above (Zambrano and Mendoza, 2010).

The plant has been selected as feedstock for biofuel for its numerous advantages. Input requirements are reduced, as compared to other energy plants, including African oil palm (Lima, 2008). As a result, low investment and maintenance costs foster the inclusion of smallholders in energy crops. The plant can be productive in marginal lands, including semi-arid areas and deteriorated soils, and with low water requirements (Achten et al., 2008). The tree is adaptable to rain fed plantations in cases where irrigation is not available (Abou and Atta, 2009). Consequently, *Jatropha curcas* plantations can be implemented in lands with low opportunity costs, without displacing food production (Basili and Fontini, 2012).

Also, *Jatropha curcas* attributes are compatible with conservation agriculture principles, which guided the project proposed in this thesis. These characteristics will be discussed in more detail in the next section.

2.2 Conservation Agriculture

The present thesis proposes a project whose operations are based on conservation agriculture techniques. The Food and Agriculture Organization (FAO) of the United Nations, promotes conservation agriculture as a means for sustainable and profitable agriculture (FAO, 2012). As the FAO (2001) stated, conservation agriculture is based on three principles. The first is soil disturbance minimization, which comprises any practices that require minimal or zero tillage. The second principle directs the preservation of a layer of residual organic matter to cover the soil. The purpose is to provide nutrients from the residual matter and to keep soil moisture. Further, decomposition would maintain microorganisms and fauna that, according to FAO (2001), eventually should take up the soil-mixing function of tillage. Third, conservation agriculture suggests crop rotation and intercropping patterns, both as a means to manage pests and diseases, and to preserve soil nutrients.

In relation to the present thesis, adopting conservation agriculture as a production system addresses two necessities. First, implementing conservation agriculture created cost reductions and, second, it generated a shift from mechanical input to manual labour. In the proposed project's context, these techniques produce an advantageous use of factors, because manual labour was available, while mechanical input and financial capital remained scarce.

How do these techniques produce an advantageous use of factors in the proposed project? Conservation agriculture recommends diversified plantation patterns and crop rotation. Such cropping patterns are necessary for an integrated management, which, as Hobbs (2007) stated, results in a holistic system that incorporates agriculture with the households. As a result, the farmer is able to meet economic needs while practicing sustainable agriculture (Hobbs, 2007). Specifically to the plantation, the system has various effects. According to Hobbs (2007), weeds, pest and diseases are reduced; the retention of soil nutrients and microbial activity increases, and soil moisture improves. In the long-term, the system maintains soil nutrients because of matter recycling and microbial action (Hobbs, 2007).

The plantation pattern proposed in this thesis included *Jatropha curcas*, maize and peanut in intercropping. Intercropping can provide a better economic support to small producers than monoculture plantations. Cultivating annual crops, such as maize and peanut, should provide a flow of income during the growing stage of *Jatropha curcas*, when its productivity is low. In addition, the literature recommended crop rotation as a strategy to control pests and disease. For instance, publications indicated that rotating crops could break the disease cycle and contribute with different soil nutrients (FAO, 2012; Ullauri et al., 2004). Barahona (2013) suggested that pest incidence may be higher in monoculture plantations of *Jatropha curcas*. As a result, conservation agriculture practices implied reduced expenses in fertilizer and pesticides. By adopting rotational cultivation, the farmer would not rely entirely on insecticides to manage pests and disease, reducing costs.

Adopting conservation agriculture practices also responds to economic necessity. FAO (2001) studied the areas of cost reduction as a result of implementing conservation agriculture practices. The most relevant areas include: reduction in maintenance costs, corresponding to decreased labour and mechanical input; and, cost reduction in agricultural inputs as a result of resource conservation. Field preparation tasks under conservation agriculture techniques generate savings on investment costs. As Basili and Fontini (2012) reported, a good portion of investment costs arrived from site preparation (including tillage and digging). The minimal and zero tillage used in conservation systems implied a reduction in time dedicated to site preparation activities. At the same time, conservation agriculture practices imply a greater reliance on manual labour, as opposed to mechanical input. Field preparation tasks include no-tillage (or minimal), no land clearing (or minimal) and direct planting, which can be performed by manual labour in an efficient manner (Valverde, 2003). Savings from not renting or acquiring mechanical input for site preparation should also be considered. In addition, labour is a factor in under use in the targeted area, while capital is expensive. Shifting mechanical input for manual labour represents a reduction in investment and maintenance costs.

Conservation agriculture techniques also foster agricultural performance and conservation of resources. According to Knowler and Bradshaw (2007), these systems increase soil fertility, which results in higher yields at the long-term. Conservation agricultural systems also decrease soil erosion and downstream sedimentation (Knowler and Bradshaw, 2007). Hobbs (2007) argued that conservation tillage conserves fauna, soil moisture, soil structure and its nutrients. Conversely, a few sources identified tillage by tractor as responsible for drying the upper layer of soil, removing fauna, and damaging the soil structure (Godwin (1990) cited in FAO, 2012; Hobbs, 2007). The conservation of natural resources should decrease the dependence on agricultural inputs to maintain the plantation's performance, which in turn would reduce costs.

The present study suggests that *Jatropha curcas* agricultural performance is compatible with conservation agriculture recommendations, due to the plant's resilience and its low maintenance requirements. Even though the publications recording *Jatropha curcas* performance are numerous, the varieties of natural landscapes in which the studies were conducted have made it difficult to assign standard values to agricultural indicators. The next section examined the plant's performance as recorded in the literature, and its attributes.

2.3 *Jatropha curcas* Agricultural Performance

Three aspects of *Jatropha curcas* cultivation are crucial to implement conservation agriculture systems: field operations, fertilization requirements, and suitability for intercropping.

Following conservation agriculture practices, field preparation for planting should be executed with manual labour, rather than mechanical input, to avoid excessive soil disturbance (Hobbs, 2007). Thus, the design of farm operations in the proposed project was intended to have all tasks completed with the farmer's workforce. The analysis of labour use indicated that the most time-consuming agricultural operations were field preparation and plantation maintenance. Various publications described these operations for a *Jatropha curcas* plantation, recommending minimal tillage and residual matter recycling (Achten et al., 2008; Barahona, 2013; Behera et al., 2010; Brittaine et al., 2010; IICA, 2008; Mendoza et al., 2011). Thus, field preparation considered minimal tillage in the first year, and zero tillage from year two onwards. In addition, land preparation tasks included minor land clearing, and pit making. Plantation maintenance included weeding (chemical and manual) and pruning *Jatropha curcas* trees.

Another point that differentiates conservation agriculture from commercial farming is fertilization. Conservation agriculture suggests maintaining and fostering soil nutrition through residual organic matter, which reduces chemical inputs (FAO, 2010). Thus, the production system proposed in this thesis requires chemical fertilization only in the first year. Karanam and Bhavanasi (2012) indicated that *Jatropha curcas* should require chemical fertilization only in this period, when the plants grow at an accelerated pace. Once the plantation is established, it was possible to replenish soil nutrients with *Jatropha curcas* residual matter, because the trees provide nutritious content from falling leaves and pruned twigs (Francis et al., 2005). As Table 2.1 shows, Karanam and Bhavanasi (2012) found several elements in fallen leaves, including nitrogen, phosphorus, potassium, sulfur, calcium and magnesium. In addition, the cake, a leftover from oil processing, can be used as organic fertilizer (Achten et al., 2008; Behera et al., 2010; Francis et al., 2005). Such a fertilization mechanism is compatible with conservation agriculture and, at the same time, diminishes the small-farmer's dependence on chemical input, whose high cost may create financial vulnerability.

Table 2.1: Nutrient availability from fallen dry leaves in *Jatropha curcas* plantations.

Nutrient	Available content in grams/plant	Available nutrient in Kg/Ha
Nitrogen	127.4	318.5
Phosphorus	8.75	22
Potash	81.2	200
Sulphur	5.95	15
Calcium	93.45	234
Magnesium	36.75	92

Source: Karanam and Bhavanasi (2012).

Jatropha curcas cultivation also supported conservation agriculture principles, because it is suitable for intercropping. Publications that have originated in the area targeted in this study recommended intercropping for family farms. Such is the case of Mendoza et al. (2011) who pointed out that *Jatropha curcas* is suitable for intercropping with short-term crops, such as maize and peanut, and for agroforestry.

In addition to its suitability to conservation agriculture, it was necessary to examine *Jatropha curcas* agronomic performance under these principles. That is, a literature review should conclude that the plantation can be productive while adopting conservation agriculture practices. Further, the production system should incorporate the available resources while diminishing its reliance on those factors that are expensive or scarce, given the fact that the proposed project deals with smallholder agriculture. For instance, family labour should be the main workforce to cover farm operations for the model farm of 5.4 hectares. Because financial capital is scarce for the farmer, agricultural input should be reduced. On the other hand, irrigation infrastructure is not available in the targeted area, thus, the plant should be resilient to water scarcity. Two indicators of agricultural performance are most relevant in this setting, water requirements and seed yield.

Most authors agree that the water requirements for *Jatropha curcas* commercial production are rather low. For fully grown plants, Karanam and Bhavanasi (2012) argued that a minimal annual rainfall should be 400 millimeters, while Achten et al. (2008) affirmed that it should be 500 to 600 millimeters. As a result, rain-fed plantations are plausible, and numerous publications were available describing *Jatropha curcas* performance in such a setting (Basili and Fontini, 2012; Behera et al., 2010; IICA, 2008; Lima, 2008). However, during the first year, when the plantation is establishing, the literature recommended to maintain good soil moisture (Karanam and Bhavanasi, 2012). Thus, a number of authors suggested implementing the plantation with the first seasonal rains and then providing additional water for growing plants during the first year (Achten et al., 2008; Barahona, 2013; Behera et al., 2010; Karanam and Bhavanasi, 2012). Irrigation infrastructure is not part of the farmer's endowment; therefore, a rain fed plantation suited the needs.

Jatropha curcas productivity under smallholders' production systems was not clear. Most publications are based on commercial plantations, which differ from smallholder's agriculture in terms of the intensity of their operations and practices. Intensive agriculture requires more input in all areas: labour, financial capital, and natural resources. Lima (2008) examined industrial production of biodiesel from *Jatropha curcas* in Brazil, counting on smallholders to partially supply raw material. According to this source, the expected seed yield was three tonnes per hectare. However, other variables should be taken into account when estimating our model's productivity. For instance, the literature remarked that climatic conditions were determinant to the plantation's performance. Brittaine et al. (2010) surveyed several publications reporting the plant's performance in different conditions. In a semi-arid climate in India, these authors cite Wani et al. (2008) who reported a seed yield of one tonne per hectare; Ghokale (2008), also in India, reported 1.25 tonnes per hectare in an area with higher annual precipitation than the targeted area in this thesis. Achten et al. (2008) reported annual yields in a range of two to three tonnes per hectare for semi-arid areas, and five tonnes per hectare in "optimal conditions." This last author concluded that a reasonable expected annual yield should be in a range of four to five tonnes per hectare. In the targeted area, IICA (2008) reported two tonnes per linear kilometer, which corresponded to fruit collected from living fences. In terms of seed yield, the information was diverse, and it varied according to local conditions.

In sum, the literature review determined that *Jatropha curcas* characteristics make it suitable for conservation agriculture. Further, the review also confirmed that the plant can be productive under the proposed production system. The first indicator was *Jatropha curcas* low-maintenance, including low water needs, which make it possible to establish rain fed plantations. Also, field preparation tasks could be carried out with manual labour. Second, chemical fertilization was required only during the first year. After this period, it should be possible to maintain soil nutrients with residual matter from *Jatropha curcas* trees, and the seed cake, which can be used as organic fertilizer. Third, *Jatropha curcas* can be cultivated in intercropping patterns, and publications from the targeted area recommended it.

Of course, a thorough project analysis should provide precise results. In any case, a final point to remark is that the difficult conditions under which *Jatropha curcas* can be productive make it possible to prevent land use trade-offs with food agriculture. In our context, the land held a low opportunity cost, mainly because there was no infrastructure to assist agricultural productivity and, most importantly, because the climate and soil conditions prevented farmers from cultivating crops with lower resilience.

The next section reviews the extent of land trade-offs between food production and biodiesel agriculture. In particular, Bryan et al. (2010) analyzed what conditions motivate a farmer to switch from food production to bio-fuels. In addition, the authors provided insights on how agricultural profitability may be influenced by government intervention. Both issues are of interest for this thesis. This analysis is followed by a section that examines different methods to evaluate agricultural projects based on *Jatropha curcas* as feedstock for biofuel in conditions similar to those proposed in the present study.

2.4 Evaluation of agricultural projects and projects based on *Jatropha curcas*

This section surveys methods to determine value in an agricultural project directed to biofuel production. Two objectives motivated this review. The first was to survey what authors have done to evaluate agricultural projects, especially those involving *Jatropha curcas*. At the same time, it was important to determine if the literature did find a positive value for projects based on this plant. Second, this review examined what factors were most influential to the project's value; and, in particular to this thesis, it was important to establish what conclusions the authors drew about *Jatropha curcas* performance.

Several publications have examined the financial feasibility of projects based on *Jatropha curcas*. Basili and Fontini (2012) analyzed a project to produce oil from *Jatropha curcas* as a substitute of fossil fuel, and its financial value as a call option on a stock. Lima (2008) studied the production chain of biofuel from *Jatropha curcas* in semi-arid and rain-fed conditions, and evaluated it by calculating the liquid present value and the internal rate of return.

A first publication under review was Bryan et al. (2010), which evaluated land use trade-offs as a result of the change in profitability of biofuel agriculture driven by climate change and government interventions.

Bryan et al. (2010) assessed the effects of replacing food production by biofuel agriculture in an economically viable area of arable land in Australia. Through a computer simulation, this study evaluated the production and the profitability of both food and biodiesel agriculture under baseline climatic conditions. Then, the simulation was modified under three scenarios of mild, moderate and severe climate change. The authors also included three levels of increasing carbon subsidies, to be paid to biofuel producers as a reward for greenhouse gas emission abatement. The study calculated how these factors would affect profitability, which in turn would modify the area of arable land dedicated to food agriculture by making biofuel more or less attractive to farmers.

This study considered an area of 5.5 million hectares. The climatic zones ranged from semi-arid to Mediterranean, including both irrigated and rain fed lands. The study also assumed that farming systems exerted low impact to soil, namely, no-till technique. A computer program calculated a baseline prospect of agricultural production with two ends, food and biofuels. This baseline scenario included the maximum area of arable land, the climatic zones, and the available water through irrigation or rain. In addition, no subsidies to agricultural production were considered.

After the baseline scenario, the simulation calculated variations under the influence of several factors. The first factor was carbon credit. For each tonne of CO_2 abatement, the calculation considered three subsidy levels of ten, twenty and thirty Australian dollars. In addition, the paper considered that carbon abatement occurred as a result of switching food production to biofuel agriculture. The second factor was climate change. The simulation considered three scenarios of climatic warming and drying: mild, moderate and severe. These factors resulted in various production levels, as a result of the levels of climate change and carbon subsidies, three scenarios of warming/drying and three levels of carbon subsidy. Food agriculture included three activities, wheat production, lupines production and grazing, which in turn included wool and meat production. Biofuel agriculture comprised wheat and canola production as raw materials for ethanol and biodiesel, respectively.

The paper evaluated four areas: net GHG emissions, economic returns, trade-offs and impacts, and net energy. However, only results about economic returns and land trade-offs will be discussed here.

Bryan et al. (2010) carried out the economic assessment by calculating the expected profit at full equity at the farm gate. Profit at full equity was calculated as the revenue from sales of all agricultural produce minus all fixed and variable costs, and assuming no debt. Expected profit was calculated as the average profit over the farming system rotation, simulated in a computer program for a period of 125 years. According to the paper, price and cost data were held constant, expressing monetary figures in Australian dollars of 2001.

The profit equation included revenue for each agricultural land use. For food agriculture, it included wheat, lupines and grazing, with their secondary products; and for biofuels agriculture, the equation comprised wheat and canola, along with biofuel production. Revenue was calculated within the baseline climate scenario, plus the three drying/warming variations already mentioned. Revenue from carbon subsidies was also included and calculated at four levels: \$0, \$10, \$20, \$30 per tonne of CO_2 abatement (where the zero-subsidy level was the baseline scenario). Revenue from carbon subsidies was exclusive to biofuel production. Finally, variable and fixed costs associated to land were deducted.

Next, the authors designated a simple economic rule to establish land trade-offs. The farmer would decide to adopt biofuel production when this activity became more profitable than food agriculture (Bryan et al., 2010, p. 336).

To examine the results, the present review took into account production and profit, but not the effects from variations due to climate change. Only baseline results were analyzed, which consisted of current climate with zero carbon credits. The results section reported a food baseline productivity of 4.6 million tonnes per year of grain; 2.9 million head of lamb sold for meat per year; and 28.9 million Kg of wool per year. They also reported productivity of biofuel feedstock of 4.3 million tonnes of wheat and 2.4

million tonnes of canola per year, which produced 2.6 million kiloliters of biofuels per year. Data suggested that both food and biofuels productivity were higher in wetter areas.

The second part of results surveyed trade-offs and impacts. The study suggested that under the baseline scenario, biofuel agriculture would offer more incentives to producers. They reported annual profits from food agriculture of 482.6 million Australian dollars. On the other hand, annual profit from biofuels agriculture was higher, at 516.9 million Australian dollars. Profitability was higher for both agricultural ends in wetter areas. However, dry areas were sizeably less profitable for biofuel agriculture. In the aggregate, there were gains in profit when producers chose to change from food agriculture to biofuels. Consequently, food production was greatly reduced due to replacement with biofuels.

Bryan et al. (2010) concluded that first generation biofuels, based on edible crops, could provoke land use trade-offs. Switching land use from food production to biofuels could increase food prices, as a result of lower productivity, which, in turn, may hamper food security (Bryan et al., 2010). An indirect implication was that an increase in food prices may create incentives in other areas of the world to convert natural areas to food production, which could intensify land degradation and greenhouse gas emissions from agriculture (Bryan et al., 2010). Another important suggestion was that profitability constitutes the most determinant incentive to land use trade-offs. Switching land use depended almost uniquely on economic incentives available to producers, according to this study. Therefore, the incidence of government interventions could create further stimuli.

These authors also pointed to the vulnerability of first generation biofuels (in this case, ethanol from wheat and biodiesel from canola) to dry climates and water scarcity. Under such circumstances, productivity was greatly reduced, and major increases in fertilizer were necessary, which enlarged costs. At the same time, the authors recommended policy implementation to mitigate the impact of biofuel production on food security. These policies should include regulation or incentives to cultivate feedstock for biofuels only in less productive soils.

One of the outstanding limitations in this study was the lack of variations in prices and costs in future periods. The price variability of food and fuel are currently major global issues, and should be taken into account for projections.

The conclusions drawn from Bryan et al. (2010) relevant to this thesis are numerous. For instance, their work suggested a great possibility for land trade-offs from food agriculture to biofuels. This thesis proposes cultivation of underused lands, with a low opportunity cost due to their soil quality and lack of agricultural infrastructure. Further, *Jatropha curcas* is a non-edible feedstock for biofuel. Therefore, its cultivation will not provoke trade-offs with food production. Also, the authors indicated that first generation biofuels face a vulnerability to dry climates and water scarcity. In turn, *Jatropha curcas* shows resilience to such factors, as the agronomic performance section demonstrated.

Basili and Fontini (2012) considered *Jatropha curcas* oil production in Kenya, with a project intended to cover fuel demand in a touristic area (90,000 liters per year). To evaluate the financial investment, the project was considered as a call option on a stock; then the option premium and net present value were calculated.

The project's evaluation as a call option was justified for two reasons. Firstly, the authors identified the elements of irreversibility in the project. For instance, it was necessary to modify a press machine and an electricity generator for exclusive use in the project. These changes were necessary because the final source of income was *Jatropha curcas* oil (not biodiesel) and were also irreversible. Once the press machine and generator were modified for *Jatropha curcas* oil there could be no other usage for the machinery. Also, the authors considered land preparation expenses as sunk costs, because *Jatropha curcas* was produced in monoculture plantations, and its produce (oil) cannot be used for other purpose than as biofuel. Secondly, the authors considered the uncertainty attached to the project caused by diesel price variability, the substitute for *Jatropha curcas* oil.

For these reasons, the authors analyzed the project as a call option on a stock. As James (2003) indicated, a call option is a contract that gives the holder the right to buy a unit of an underlying asset at a set price. This transaction, buying the asset, would be done at an exercise price, or strike price, fixed in the contract. In the case of Basili and Fontini (2012) the underlying asset was the project's value, and the exercise price was the investment cost (Basili and Fontini, 2012).

To evaluate financial feasibility, the authors calculated the project's Net Present Value (NPV) and option premium. The NPV is the investment's financial worth, calculated as the difference between the project's cash flow minus the initial investment (Basili and Fontini, 2012). The option premium in an exchange market would be the option's current trade price, usually set daily (James, 2003). In the context of the investment in Kenya, the option premium represented its opportunity cost, created from expenses in purchasing fossil fuel as an alternate source of energy (Basili and Fontini, 2012). Because of the project's irreversibility, the model considered the expected time for the investment decision. At this time, the developer would decide to undertake the investment, and start the project. Otherwise, the developer would delay the investment, and opportunity cost would arise from the need to pay for fuel to cover energy demands. The investor would therefore consider the option premium to decide whether to invest or wait.

An important aspect in this methodology was the analysis by parametric variations. The authors first analyzed a referential case A, with baseline parameters in yield and land area. Two variations were also evaluated: case B, with lower yield than A, and C, with higher yield. The authors assumed four tonnes per hectare for case A, two tonnes per hectare to case B, and six tonnes per hectare to case C. These data were taken from the literature, not from on-site reports, and through sensitivity analysis the authors examined the project's performance with higher and lower production numbers. This method presents a good response to the lack of precise information regarding production per hectare for *Jatropha curcas*, and it should certainly be a credible resource in ex-ante analysis, as is the case in this thesis. Other important data for each of the cases are displayed in Table 2.2, below.

Table 2.2: Yield and costs for *Jatropha curcas* oil.

Parameters	Case A	Case B	Case C
Seed yield	4 tonnes/Ha	2 tonnes/Ha	6 tonnes/Ha
Oil yield	1,050 Kg/Ha	525 Kg/Ha	1,575 Kg/Ha
Land area (in Hectares)	80	160	53.3
Total labour cost (120 man days/Ha/year)	USD 19,200	USD 38,400	USD 12,792
Investment cost	USD 65,000	USD 110,000	USD 65,000
Investment cost components			
Plants (1,600/Ha)	USD 12,800	USD 25,600	USD 8,528
Site preparation (85 man days/Ha)	USD 13,600	USD 27,200	USD 9,061
Presses	USD 12,000	USD 12,000	USD 12,000
Fertilizer (USD 220/Ha)	USD 17,600	USD 35,200	USD 11,726

Source: Basili and Fontini (2012).

Other indicators studied in this analysis were the initial value of the underlying asset and the cost of initial investment. The net value of the underlying asset was equivalent to the profit at time zero, calculated as the price per liter of *Jatropha curcas* oil minus the average cost per unit, times the total production. The project's initial value in case A was USD 63,343; in case C, with the highest yield, USD 69,760; and in case B, with the lowest productivity, USD 44,184. It was evident that the initial value of the project depended on productivity, and thus, one should presume lower financial performance when lower yields were expected.

On the other hand, the cost of investment encompassed expenses on several items, both on agricultural and industrial aspects. As table 2.2 shows, the initial investment included the costs of purchasing land, seed, fertilizer, site preparation, processing machines, and the opportunity costs derived from fossil fuel purchases and generator modification expenses, not included in the table (Basili and Fontini, 2012). For the referential case A, and for case C, the investment cost totalled USD 65,000. For case B, with the greatest plantation area, the investment cost amounted to USD 110,000. The higher investment level in case B was mainly a consequence of increased expenses to purchase seeds, higher fertilizer input and higher costs for site preparation. Therefore, greater land areas for *Jatropha curcas* cultivation imply higher levels of initial investment. This conclusion should also apply to the proposed model in this thesis, because fertilization in the initial year and site preparation are common agricultural operations, and they both depend on total area.

The final element examined in parametric variation was the discount rate. The discount rate included two components, the payout rate and the risk-adjusted interest rate. The payout rate was equivalent to the yearly percentage gain per production unit; in this case, the revenue per liter of *Jatropha curcas* oil (Basili and Fontini, 2012). The risk-adjusted interest rate included the riskless interest rate plus a risk premium (Basili and Fontini, 2012). The authors calculated the referential discount rate to be 13.5%, and considered the variations at 6%, 10% and 15% (Basili and Fontini, 2012).

With the parametric variations set, Basili and Fontini (2012) performed sensitivity analyses. This review examined only the cases for the net present value and option premium, because these results represent the project's financial performance. Along with the different yields and discount rates, the authors calculated the net present value for variations of the reference strike price. As said, in this paper, the strike price is equivalent to the investment cost, which was USD 65,000 for cases A and C. The authors also considered multiples of this baseline number: three, six and nine times the referential investment.

In this first sensitivity analysis, the project reached its highest net present value with the lowest discount rate, 6%, and the lowest investment cost, USD 65,000 for cases A (USD2.2 million), B (USD2.4 million) and C (USD 1.4 million). At the lowest discount rate, 6%, and considering the multiples of initial investment, it was case B that presented the best performance with NPV going from its highest at USD 2.4 million for an initial investment of USD 65,000, to USD 1.9 million for an initial investment of USD 585,000. The second best was A, the case with the baseline yield (4 tonnes per hectare) and land area (80 hectares) with a NPV going from USD 2.2 million to USD1.7 million. For all other values of the discount rate, 10%, 13.5% and 15%, the project's financial performance was lower, going from USD 1.2 million for case B at 10%, to negative numbers at an investment cost of USD 585,000 with 13.5% and 15% of discount rate. The influence of discount rate on the financial performance was evident. A low discount rate becomes essential to reach high net present value.

The second sensitivity analysis examined the option premium. As mentioned, the option premium was associated to the opportunity cost of irreversible expenses, which came from two sources. The first was sunk costs for land and machinery, the second was the use of *Jatropha curcas* oil exclusively as biofuel. In addition, the authors associated the price of *Jatropha curcas* oil to the price of its substitute, diesel, which came with an element of risk from oil price volatility. To the investor, an extremely high option premium would cancel the investment decision, even for positive project values (Basili and Fontini, 2012).

The option premium was very high for the highest levels of initial investment. For an investment cost of USD 585,000, the option premium ranged from USD 359,000 at 6% discount rate to USD 234,000 at 15%. The authors also calculated the delay time for the investment decision, which at the highest option premium was 28 years. On the other hand, the option premium was zero for all discount rates at the lowest initial investment (USD 65,000) as was the waiting time. This situation is explained, according to the authors, by the opportunity cost of land. The authors had initially considered that due to the use of marginal lands in the project, the opportunity cost of land was zero (Basili and Fontini, 2012). To account for cases where the opportunity cost was positive and high, they included in the sensitivity analysis the multiples of the investment cost, which includes the cost of land. In the cases where the opportunity cost was high, that is, at highest levels of initial investment, the investor would prefer to delay the investment decision (Basili and Fontini, 2012).

In conclusion, the authors found the project viable. The net present value was positive and could be high, which compensates for its volatility (Basili and Fontini, 2012). Further, *Jatropha curcas* presented various advantages. Its cultivation does not conflict with food production, which would not threaten food security. At the same time, *Jatropha curcas* could become an alternative for conservation, because chemical fertilizers can be replaced by organic, and because the plant can manage scarce irrigation (Basili and Fontini, 2012). Also, the authors considered *Jatropha curcas* as an important prospect for bio-energy production on marginal soils in tropical regions, and as a decentralized renewable source of energy for rural and remote areas (Basili and Fontini, 2012).

Some elements in this publication were common to the project proposed in this thesis. One of them was the rain fed plantations; another was the use of *Jatropha curcas* cake as fertilizer. Both these features decrease expenses, and therefore, should contribute to the project's positive performance. Finally, the parametric variation presented a useful analytical method for this thesis, especially to account for seed yield. As mentioned in the agricultural performance section, productivity indicators for *Jatropha curcas* plantations differ widely depending on a number of factors (climate conditions and input intensity are examples). Thus, the analytic approach that considers referential numbers and variations could present a viable solution when the final aim is to study *Jatropha curcas*' economic performance.

The last publication under review was Lima (2008), who assessed the financial feasibility for the agricultural and industrial aspects of *Jatropha curcas* oil and biodiesel production. This author based the study on present conditions in Brazil, and evaluated financial value by obtaining the Internal Rate of Return (IRR) and the Liquid Present Value (LPV) of existing projects. The production chain was partially based on rain fed plantations and small-farmers as suppliers.

The IRR, or breakeven discount rate, is the rate at which the net present value of a project or policy becomes zero (Boardman, 2011). Thus, the IRR equals the discount rate at which NPV is positive. Another useful interpretation is that alternative projects with a comparable size that present the same IRR have an equivalent value (Boardman, 2011). In addition, as Boardman stated, if the IRR is greater than the social discount rate, the rate that reflects the opportunity cost of financial capital to the society, then the project is acceptable.

The LPV is the difference between the present value of expected benefits minus the investment costs, calculated with the Minimal Rate of Attractiveness (MRA) as the discount rate (Lima, 2008). The MRA is used mainly in financial analysis. It is the forgone interest rate for the next best use of capital Clemente (2002) cited in Lima (2008).

This publication investigated the financial viability of the agricultural production and the industrial process separately, and as an integrated project. In order to calculate IRR and LPV, the author collected data from real agents in the economy, and simulated performance for a thirty-year period (assumed to be the life cycle of a *Jatropha curcas* plantation). Another variable that the author considered was capital structure. Simulations were performed for capital structures where (1) 100% of the capital was borrowed, (2) 100% of the capital was owned, and (3) 50% of the capital was borrowed and 50% was owned. Finally, there are two sources of income for these projects: *Jatropha curcas* oil sales and *Jatropha curcas* biodiesel sales.

Prior to discussing the findings in Lima (2008), it is necessary to present the production chain and its context. The author showcased a business model with five economic agents: the agricultural producer, with both commercial and cooperative farmers; the wholesaler, which centralizes feedstock supply; the financial agent; and the distribution channel. The industrial processor was not included as an agent, and its tasks were not included in the structure, but the processor's economic efficiency was evaluated as a project. Finally, the wholesaler developed three tasks: buying all feedstock to act as a centralized supplier, organizing agricultural production, and providing technical support to farmers.

A particular aspect in this context was the inclusion of small-farmers in the productive chain. Incorporating small-farmers in the supply responded to social responsibility and sustainability, in both the socio-economic and the environmental facets (Lima, 2008). The model consisted of a corporate entity as the industrial processor, which integrates small-producers by a contractual relation. To support this mechanism, the government provided incentives in the form of tax credits to the corporate party, and quality certificates for the final product.

The geographic characteristics present in this study were also relevant. The region that the author chose was semi-arid in northern Brazil, where great land extensions would be available for cultivation. Instead, most of these lands have remained inactive (Lima, 2008).

In a first part of the conclusions, the author highlighted the agricultural performance of *Jatropha curcas*. The variables determinant to optimal performance were productivity (dry seed yield in kilograms per hectare); percentage of oil content per weight unit of feedstock (oil yield); and, planting and harvesting costs (Lima, 2008). In addition, the author pointed out the attributes of *Jatropha curcas* that contributed to financial feasibility. *Jatropha curcas* was considered a low-cost crop because of it minimal maintenance requirements, and its resistance to water stress. These characteristics made this crop suitable for the semi-arid conditions present in the area of study. Also, *Jatropha curcas* has a short wait period for income in comparison to other energy crops, in particular, African oil palm (Lima, 2008). The plant initiates production after the first year of planting, and it maximizes production by the fourth year (Lima, 2008). In sum, the plant's attributes relevant to financial feasibility were its climatic adaptability; a long production cycle that allows for a long-term investment; and, the high oil productivity rate per hectare of plantation (Lima, 2008).

This study also found a positive financial performance for the project. First, production costs were low. The yearly average agricultural cost per hectare was CAD 441; oil production cost per kilogram was CAD 0.38; and biodiesel production cost per liter was CAD 0.44[5] (Lima, 2008). Second, the evaluation presented favourable indicators, as showed in all phases of the productive chain. In the industrial phase, composed of oil extraction and trans-esterification, the Internal Rate of Return (IRR) was 34.5%. In the integrated phase, comprised of both agricultural and industrial activities, the reported IRR was 25.16%. In the agricultural phase, the IRR was 15.04%.

[5] The figures in Canadian dollars were calculated with the exchange rate to Brazilian reals in August 2012.

It is worth noting here that the author only presented results for investments done with 100% own capital.

In the complete institutional and financial context, the research found seven variables most relevant to the successful implementation of the project: yield (in Kilograms/Hectare), potential to expand plantation area (land availability), percentage of oil content per weight unit of feedstock, production and harvesting cycles, the business model, taxes (namely, tax exemption opportunities), and available financing programs (Lima, 2008).

A survey of existing policy pointed to the elements assisting the agents. Brazilian legislation promotes the inclusion of familial and cooperative farmers by providing tax exemptions to industrial processors that acquire at least 50% of their feedstock from small farmers (Lima, 2008). Another support program is a certification that stimulates small-farmer integration into the production chain. It is called “Social Seal” and it works both as a sustainable product certification and a quality certification. Also, the government has made available financial products directed to cooperative and familial farmers with a low interest rate and a grace period.

Several conclusions in Lima (2008) were relevant to the project proposed in this thesis. First, the financial assessment confirmed viability in an agricultural project based on *Jatropha curcas*. Second, the study indicated which characteristics of *Jatropha curcas* contribute to a positive performance, both financial and agricultural. The plant showed a superior productivity in semi-arid and non-irrigated conditions, as compared to other energy crops cultivated in Brazil. *Jatropha curcas* required low costs at critical steps, such as planting, plantation maintenance and harvesting. Finally, *Jatropha curcas* required a short wait period for income, of one year, and of four years for stable production (again, as compared to other bio-energy crops produced in Brazil). This publication also surveyed the existing policy assisting the agents involved in the project, which provided an insight of interventions that could help small-farmers.

This section reviewed methods of evaluation of agricultural projects, especially those based on *Jatropha curcas*. Two general objectives were pursued. The first was to survey the methodology that has been used to evaluate financial performance. At the same time, it was important to determine if the literature supported the presumption that projects based on *Jatropha curcas* did result in positive financial values. The second objective was to establish the critical factors to the project's success. In particular to *Jatropha curcas*, what aspects in its agricultural performance were the most determinant?

Bryan et al. (2010) assessed economic return as the expected profit at the farm gate. This is an aggregate measure of return based on gross revenue from sales of agricultural produce. It was calculated for a period of 125 years, and it reported average yearly profits based on production simulations. As an advantage, this method presented aggregated results for large areas of productive land for a very long period. Such a context, provided ample information to analyse how government interventions and climate change could induce land use trade-offs. The disadvantage was that the analysis did not present a projection of increasing costs due to inflation, or of price variability, which could also be crucial factors that influence profitability, and thus, land use trade-offs.

Basili and Fontini (2012) analyzed a project based on *Jatropha curcas* as a call option on a stock, where the investment cost was the exercise price, and the local diesel price was the underlying asset. This method used a continuous measurement of value, as opposed to the more common alternative, discounted cash flow, a discrete accounting method. The analysis included the possibility to postpone the investment decision, considering high opportunity costs and risk. Discounted cash flow, on the other hand, assumes that the investment will be made. Basili and Fontini (2012) evaluated how high opportunity costs may divert investors, and introduced this context to explain why major financial capitals have not been shifted to biofuels. On the other hand, risk associated to volatility of fossil fuel price is a prevalent factor, especially if the product is a direct substitute for *Jatropha curcas* fuel. Finally, the methodology included analysis by variations of three fundamental elements: investment costs, discount factors and seed yields. Sensitivity analysis was another method to examine critical factors. In particular, sensitivity analysis examined net present value and option premium as indicators of financial performance.

One of the advantages in this publication was the incorporation of price variability during the project's lifetime. Also, the analysis by variations covered for the lack of precise indicators of *Jatropha curcas* agricultural performance. The disadvantage was that the method of measurement of economic value did not present incremental costs and benefits, as happens in cash flow. Discounted cash flow allows for incremental figures in determinant investment factors, such as credit payments and cash allowances.

Lima (2008) calculated liquid present value and internal rate of return to examine the financial performance of the biodiesel industry in three facets: agricultural production, industrial processing and the two combined as an integrated project. In addition, this author examined the institutional structure available to assist the production chain, including incentives to incorporate small agricultural producers.

The advantages arrived from the fact that this publication consisted in an ex-post analysis. One advantageous point was the use of primary sources, and "proven" data, as opposed to secondary sources and data from literature. The disadvantage was, again, the lack of incremental figures, which are mostly important for small producers. This author presented a positive internal rate for return for the agricultural phase for the whole duration of the project, which included both commercial and small plantations. Such a figure may not provide the small-farmer with the actual earnings and costs per crop cycle; this type of information would be essential to make the investment decision.

Therefore, it should be necessary to examine alternative methods of evaluation. To that end, the next section will review Cost Benefit Analysis.

2.5 Cost Benefit Analysis

In this section, the present review surveys methods to carry out Cost Benefit Analysis (CBA) as described by two authors. First, Gittinger (1982) presented a methodology to assess agricultural projects both financially and economically. Second, Boardman (2011) offered a methodology not particular to the agricultural sector, but to any policy implemented at all levels. This work also showed how to calculate changes in welfare in all participant agents.

This section also includes critical views to CBA as a method to measure economic value. A first part discusses the theoretical incongruences behind CBA, and how the method may fail to correctly measure changes in welfare. This last problem is of particular importance to this work, since it seeks to establish changes in welfare in a target population. In order to establish that a government initiative is improving their position, an effective evaluation method must be in place. Therefore, it is important to acknowledge these theoretical issues and to suggest how to handle them.

Boardman defined Cost Benefit Analysis as “a policy assessment method that quantifies in monetary terms the value of all consequences of a policy to all members of society” (Boardman, 2011, p. 2). CBA is therefore a criterion for decision-makers at the public and private level congruent with an investment. It is also a methodology to establish the impact (benefits and costs) of a public or private program.

On the other hand, Gittinger (1982) displays the economic analysis in a “project format.” In a general view, this structure involves a set of required activities, which use available resources to obtain a stream of benefits. In the development program context, this author stated that a project is a productive unit relevant to government initiatives. Thus, the project format becomes a useful tool to evaluate investment and expenditure by assessing the true scarcity of resources. Gittinger (1982) calculates value in the same manner as Boardman (2011): by obtaining a stream of benefits and expenditures for the project’s duration. Nevertheless, the methodologies differ in several aspects. In the next section, this review will cover these differences.

2.5.1 A comparison of methodologies

According to Boardman, CBA assesses a project or policy by calculating its Net Social Benefits (NSB). Indeed, the policy’s value is equivalent to the NSB, calculated as the difference between its social benefits and its social costs (Boardman, 2011, p. 2).

More specifically, Boardman identifies nine steps to carry out CBA; these steps are: (1) specifying a set of alternative projects; (2) defining “standing;” (3) identifying impact categories and appropriate indicators to measure them; (4) predicting impacts quantitatively over the project’s life; (5) impacts monetization; (6) discounting benefits and costs to obtain present values; (7) computing Net Present Values for each alternative; (8) performing sensitivity analysis; and (9) making recommendations.

Boardman (2011) pointed out that the analyst’s perspective is what determines the extent of the evaluation. For instance, in step one the analyst is required to indicate a number of comparable projects. Exactly how many alternative projects are relevant, and their degree of importance is the analyst’s decision. Step two, also called “standing," entails identifying the affected parties (i.e. who will take part in the project’s costs and benefits). At this second stage the analyst should also determine the “levels" of relevant analysis; will the project have a local, provincial, regional, national or global scope? In spite of the guidelines present in the methodology, the role of the analyst perspective is fairly evident, as she chooses what to include and exclude. The next steps in CBA also show this possibility.

In the third step, the analyst should identify impacts and determine how to measure them. As Boardman (2011) indicated, these impacts consist of inputs and outputs necessary to the project’s development. The analyst deems the impacts' relevance and whether they are categorized as benefits or costs. As mentioned, the analyst determined in step two who are the stakeholders and the scope of analysis. Thus, the scope wherein these impacts have relevance lies within standing. As Boardman (2011) explained, the analyst should be interested only in impacts that affect agents with standing. Finally, the analyst must also include indicators to measure impacts. According to Boardman (2011), the indicators should be based on data availability and the capacity to “monetize” the measurements.

In the next four steps, the analyst must assign and calculate monetary values. Step four identifies yearly impacts in each alternative project and describes them quantitatively. Step five puts impacts in money value. Step six puts all future benefits and costs in present value. These calculations are used in step seven to estimate the Net Present Value (NPV) of each alternative project. NPV is the difference between the present value of benefits minus the present value of costs, as shown below.

NPV = PV(B) – PV(C);

Where $PV(B) = \sum_{t=0}^{n} \frac{B_t}{(1+s)^t}$; and $PV(C) = \sum_{t=0}^{n} \frac{C_t}{(1+s)^t}$

According to Boardman (2011), two reasons justify discounting future benefits and costs to obtain their present value. First, present value allows a decision-maker to establish the *current* opportunity cost of the resources at stake in the project. Second, the discount factor accounts for individual time preference, a concept which broadly states that current consumption is usually preferred to future consumption. These concepts, opportunity cost and individual time preference, as well as the mechanism to discount future value, will be discussed in later sections.

Once NPV is calculated, it is possible to establish whether a policy or project is recommendable. As Boardman (2011) indicated, the general decision rule is to adopt a project when its NPV is positive. There are a number of variations to the Net Present Value decision rule, including situations where not just one project has positive NPV. In such case, the rule should choose the project with the higher net present value (Boardman, 2011). Finally, when none of the proposed projects has positive NPV, then none of the alternatives are superior to the status quo, which should remain in place (Boardman, 2011).

The last two steps in Cost Benefit Analysis comprise analysis of variations, and final recommendations. Step eight, sensitivity analysis, evaluates variants of critical factors in the CBA. Once again, it is at the analyst’s election both the level of variations, as well as the chosen variables in the sensitivity analysis. The final step establishes the result of the decision rule, and whether the analyst finds the project recommendable.

A final important note about the process arises at this point. As Boardman (2011) pointed out, the final goal of CBA is to make a recommendation based on a decision rule. It is not the analyst's role to *make a decision* to undertake a project or not. In Boardman's words, "CBA concerns how resources should be allocated. [CBA] is normative. It does not claim to be positive theory of how resource allocation decisions are actually made" (Boardman, 2011, p. 15).

Comparing the above process with Gittinger (1982), a first difference is the orientation. This author presented project analysis to evaluate agricultural initiatives. In line with Boardman (2011), who indicated different levels of analysis (or *standing*) Gittinger also described the national, regional, provincial or local scopes. This author also referred to specific differences in financial versus economic analysis, which will be discussed later. First, we will consider the structure of Gittinger's methodology, namely the six steps in project preparation.

The six phases in project preparation and analysis include: technical, institutional-organization-managerial, social, commercial, financial and economic. The objective of the preparation stage is to determine financial return capacity or economic worth (Gittinger, 1982).

The first step is the technical study, which considers the inputs and outputs of real goods and services in the project. On the supply side, the analysis is concerned with the availability of such agricultural inputs as water (be it through irrigation or rainfall), soil quality, crop varieties, production inputs and pest-control, as well as an inventory of pests found in the project's geographic zone. On the output side, the technical aspect deals with projected yields, optimal agricultural practices, and the option of implementing multi-cropping. The technical aspect should also take into account the marketing and storage facilities available, and the processing systems.

In addition, the technical study should note information gaps and plan to mend them at either the beginning of the project or early in the implementation stage. Not only would it be necessary to conduct surveys of the area's natural traits; it is also crucial to collect information about the farmers, because current farming methods and social values are important to technological implementation.

The second phase in project preparation comprises institutional, organizational and managerial aspects. The institutional area entails examining the customs and culture of the farmers involved in the project. An institutional analysis must also contemplate any required changes in the customary methods farmers use to work, and any provisions necessary to change those customs. Other important institutional issues to consider are land tenure regimes, existing agencies and supporting staff. The organizational aspect examines the existing hierarchy and its functioning. Conflicts with the project's implementation are possible depending on the existing organizational structure. Also included in this section must be provisions to implement changes from existing to proposed organizational structure and training. The managerial section has to do with the administration, the human resources and their compatibility to the project. Managerial skills are a crucial aspect to take into account, not only in the administrative staff, but also, in the farmers. If there is a lack of managerial skills, the project must consider carrying out proper training.

The third phase in project preparation is the social analysis, which considers the income distribution of the target population. This analysis should include all changes implemented with the project that will influence the social standing of the target population. Gittinger (1982) pointed specifically to issues on employment, and how agricultural projects may affect certain vulnerable sectors (e.g. women's employment or agricultural labour displacement). A final note in this section is worth to mention. The author considered that alternative projects should be put in practice to improve "life quality" of the involved population; examples are health and water services, or children's education. It is not clear whether these alternative projects should be part of the original endeavor in terms of measuring further impacts.

The fourth part in project preparation is the commercial phase. As in the technical phase, the commercial part deals with the input side and the output side. The input side manages project supplies, while the output side deals with the marketing of agricultural production.

The output analysis of the commercial phase deals with a variety of issues. An important step is the study of the market where the agricultural output will be offered for sale, as well as the demand conditions. The author highlighted the importance of ensuring that there exists sufficient demand and price for the project's output. Another important topic is to analyze potential changes in market and price, and how these will affect the project's future benefits. Potential financial necessities to fulfill the proper marketing of produce (and their costs) are also part of this research.

On the other hand, the input analysis of the commercial phase is concerned with the availability of agricultural supplies. In this part of the study, the analyst must review the input channels and if technological changes are needed. There is also concern in this section for the financial needs required to purchase inputs and implement technological improvements. Finally, the study must also analyze if new equipment is necessary and how it will be acquired.

The next two aspects of project preparation are the most extensive in Gittinger's methodology. The fifth step is the financial analysis, which incorporates all parties involved in the project. In this sense, the financial analysis will study the credit and investment prospects of all participants; this includes the farmers, the government, the private firms and the agencies. In addition, this section examines the financial aspects of administrative and operating expenses, including investment needs and government interventions (subsidies and policy change). In all cases, the author indicated, budgets must be prepared in order to reflect the terms of credit that may be needed by the participants. The budget must therefore determine financial efficiency, needs for credit and liquidity.

The final phase in project preparation is the economic analysis. Gittinger (1982) stated that economic analysis should establish the contribution of a project to the total economy, and that this contribution should exceed the cost of resources in use. Further, the author considers financial and economic analysis to be complementary. Financial analysis should be used to assess feasibility at the individual or firm level, while the economic study determines the contribution of a project to the whole economy. The methodology to calculate feasibility is the same for both authors – discounted net cash flow.

Three differences are notable between financial and economic accounting. The first difference is in tax and subsidy accounting. For a financial study, taxes are simply treated as costs and subsidies as benefits; however, in terms of economic worth, subsidies and taxes are analyzed differently. Taxes are transferred from the project to the government, and thus are not counted as costs. Subsidies are, on the other hand, transfers from the government to the project, and thus a cost to society.

Second, economic analysis uses economic valuation instead of market prices, used only in financial analysis. Gittinger (1982) briefly defined economic values as a price that also contains social values. The third difference between economic and financial analysis is the accounting of interest paid for the use of capital. Interest paid to investors in a financial study is deducted as a cost, while in an economic study it is considered part of a social gain. As such, interest paid for capital is not deducted from the gross return, and it is considered a benefit for capital use from society as a whole. Gittinger (1982) coincides with Boardman (2011) in the views about economic versus financial analysis.

2.5.2 Conceptual remarks

It is important to remark how Gittinger (1982) identifies benefits and costs in the agricultural project context. Benefits in the agricultural project context can arise either from an increased value of production or from reduced costs (Gittinger, 1982, p. 56). *Increased production* is a benefit category of common use in Cost Benefit Analysis that includes activities or physical additions allowing for a higher production. Other benefits that arise from higher production may come from capital availability (financing for new arable areas), or increased production for self-consumption (Gittinger, 1982, p. 56). This latter example will be of good use in this study. Increased agricultural produce for the farmer augments not only national net benefit, but perhaps more importantly, the family's net benefit. There are two components to the farmer's net benefit important to note: higher own consumption and higher available cash. Gittinger (1982) noted that excluding self-consumption may underestimate the value of agricultural projects when compared to projects that produce commercial crops. On the other hand, if production rises, it is expected that the farmer should receive more cash from greater sales. This new cash available is an indicative of the farmer's reinvestment capacity, also important to account for. In this study, the project aims at incrementing income by directly paying farmers for their feedstock production.

Gittinger's method also noted secondary costs and benefits. These were classified as impact categories generated outside the *main* project. A particular group denominated as "technological externalities" draws attention. These externalities entail environmental damage as a consequence of changes in infrastructure or technology upgrades. For instance, Gittinger (1982) presented the effects of constructing a dam, such as lower river streams and water scarcity for irrigation as secondary costs. These external costs and benefits should be included in the analysis, and for that matter, the author proposed two solutions. First, the analysis should include the secondary impacts, either by viewing them as direct costs, or by adjusting prices. This adjusted price was called *shadow price* and it was based on the opportunity cost or the willingness to pay for the impact. As Gittinger (1982) clarified, opportunity costs and willingness to pay comprise the added value to the project originated in all sectors of society. The next section will look into these concepts with more detail.

2.5.3 Using the right price

Gittinger (1982) stated that market prices can be good estimates of value and of opportunity costs if properly collected. For that matter, the author distinguished two methods to establish a good price estimate of goods and services. The first was the price at the point of sale, a proper indicator when the product's place of sale is a fairly competitive market. The second way was the farm-gate price or the product's price at the boundary of the production point. The farm-gate price excludes the value-added to a product by marketing services, including processing or transportation. As the author explained, marketing services should be considered as benefits from a project separate from production. In this study case, the project does not consider processing. Moreover, farm-gate price should be appropriate for any farm products whose first buyer is the processor, whose sale price is the quoted price for the producer, and when the product is collected by the marketer at the farm (Gittinger, 1982, p. 70).

Gittinger (1982) also suggested cases where the farm-gate price could be an inaccurate indicator of opportunity cost. A common example occurs when the government has manipulated sale prices as a protectionist measure. This occurs when, for instance, the government sets differentiated prices for production in excess of domestic demand that goes for export, or when production quotas are imposed (Gittinger, 1982, p. 71). This author considered that these manipulations create distortions to sale prices, setting them at a lower or higher level than what the market would. As a result, the market price would not reflect economic value, and it should be adjusted during the analysis (Gittinger, 1982, p. 71).

2.5.4 Economic Concepts behind CBA

This section briefly discusses the main concepts behind CBA. These are Pareto Efficiency, Willingness to Pay (WTP) and opportunity cost.

Net benefits are calculated based on opportunity cost and Willingness to Pay (WTP). These two concepts provide a framework to place monetary values on the inputs and outputs involved in a project or policy. First, it is necessary to examine Pareto Efficiency, a concept that supports the use of opportunity costs and WTP for valuation.

Pareto efficiency is the theoretical justification to establish that Cost Benefit Analysis presents optimal results. Jehle and Reny (2011) defined a Pareto efficient allocation as one in which it is not possible to make someone better off without making someone else worse off. Pareto efficiency implies that as long as a project reflects positive Net Benefits (NB) it is possible to reallocate resources and compensate those made worse off by a policy (Boardman, 2011).

According to Boardman (2011), opportunity cost is a monetary measure of the inputs society forgoes by placing them in a given project. Gittinger (1982) corroborated this idea, and defined opportunity cost as, "the benefit foregone by using a scarce resource for one purpose, instead of for its best alternative use" (Gittinger, 1982, p. 68). In short, opportunity cost brings a measure of scarcity to input resources.

On the other hand, willingness to pay values the outputs from a project or policy. It can be conceived as a hypothetical payment made by an incumbent party in a policy or project, as Boardman (2011) asserted. In CBA, this implies that a party would be willing to pay a given amount to make effective a policy, program or project. By opposition, a "negative" payment indicates that a participant does not want a policy to be effective, and thus, will require compensation. In the latter case, the affected party is "willing to accept" a compensation in order to make the policy effective. In relation to net benefits, it means that valuing the project's net present value in terms of WTP and opportunity costs implies that if there are positive net benefits, then there is potential to compensate parties incurring in "negative" payments. Giving compensation to those made worse off results in Pareto Efficiency, as no parties remain in a worse position, while some are better off (Boardman, 2011).

In the context of a government development program involving various agents, it could be difficult to determine the proper compensations and to pay off all affected parties. Thus emerges the concept of Pareto *Potential* Efficiency (PPE), which explains that actual compensation payments are not contemplated. It is only necessary to contemplate for the *potential* feasibility of compensation. Boardman explains the reasons not to include actual compensations in CBA -- they range from issues of analytic difficulty to administrative costs. It is probably more relevant to mention the Kaldor-Hicks criterion (K-H criterion), the supporting background for PPE.

The K-H criterion states that, "a policy should be adopted if and only if those who will gain could fully compensate those who will lose and still be better off" (Boardman, 2011, p. 32). Such a principle justifies the use of *potential compensation payments* to losing parties (as opposed to calculating *actual* payments) in CBA. Therefore, the K-H criterion constitutes the theoretical support of positive net benefit as a decision rule in CBA: a policy will increase efficiency if it presents the possibility of Potential Pareto Improvements. That is, if a policy results in sufficient net gains that could provide potential compensation to losing parties, then it is acceptable.

2.5.5 Discounting

The purpose of discounting a stream of net benefits is to obtain the project's net present value; that is, to assess the value in today's money of an investment calculated for a period of time in the future. This exercise reflects the notion that money spent today is more valuable than the same amount spent in the future. According to Boardman (2011), this idea is justified for two reasons. The first is to grasp the opportunity cost of money when there is the possibility of investing it and obtaining a higher return. The second is the usual preference to consume immediately rather than to save for the future.

The financial and economic evaluations performed in cost-benefit analysis are used to calculate a stream of net benefits for each year of the project's duration. The discount rate is used to determine the net present value of the project, which is its value in present terms. The discount rate is also necessary to calculate other important measures of project worth, such as the benefit-cost ratio, or the internal rate of return. The next section will review the theory behind the choice of social discount rate.

2.5.6 The Social Discount Rate

It is possible to calculate the present value of a project based on the financial cost of the money invested in it, based on the market interest rate for a loan, or from the investor's own capital. However, using the market rate would not incorporate the value that society attaches to the invested money. According to Boardman (2011), the market rate presents three main issues. The first is whether or not the market value of money is a good measure of individual preference regarding immediate versus future consumption. The second considers if the market rate reflects the value that future generations would give to money invested today. Third, the discount rate should consider society's preference between a dollar invested and a dollar consumed.

According to Sassone (1978), the choice of the discount rate must reflect the present social values attached to a particular investment, and it is thus called, the social discount rate (SDR). This author presents three arguments to justify a choice of social discount rate.

The first suggests a low social discount rate, compared to the market rate. According to this argument, a low SDR results from the difference between the individual's consumption preferences, and their preferences as members of society. Thus, individual utility would be a function of individual consumption, society's consumption in the present generation, and the prospect of future individual consumption. In this model, the individual will prefer to favour investing in the future, as a part of a collective choice. If the market rate reflects the discounting that an individual would apply to their own future consumption, then when acting in collective action, this individual would give more value to investing in the future than what the market rate expresses. Therefore, the proper social discount rate must be lower than the market rate.

The second argument suggests the adoption of a higher social discount rate than what the market reflects. According to this reasoning, the SDR must reflect the true opportunity cost of an investment. That is, the social discount rate should result in a positive NPV only when a public investment creates higher returns than a private endeavour. In a model economy where only corporations and government provide goods, the discount rate should exceed the returns that an investment would earn in the private sector. The private sector discount rate in this model includes the expected return from the private investment, plus a risk factor and income taxes, resulting in a SDR that is more or less double the expected rate of return from private investments.

The third argument combines both the previous cases, and it is based on what is called the social opportunity cost of capital. In this case, the opportunity cost of money is reflected in the investment's costs and not in the discount rate. Hence, the choice of discount rate may be low, but the opportunity cost of resources is embedded in the project's costs as the social opportunity cost of capital (SOCC). The analyst must then calculate the SOCC as a factor that is subtracted from the project's present value of benefits calculated with a *low* discount rate.

More recently, Boardman (2011) presented a derivation of the SDR based on a model of growth with infinite periods designed by Frank Ramsey[6]. This derivation results in the consumption rate of interest (CRI), interpreted as society's marginal rate of time preference. That is, the rate at which society trades off immediate consumption for future consumption. Following the Ramsey model, the SDR equals the social rate of time preference, plus the long-rate of growth in per capita consumption (Boardman, 2011, p. 247). The social rate of time preference would reflect society's impatience or its changing preference for immediate versus future consumption. The rate of growth in per capita consumption indicates society's disposition to distribute per capita consumption in more equal terms in each inter-temporal period. The SDR derived from the Ramsey model should be lower than the average return on private investments, according to Boardman.

A last topic in this review of concepts relevant to CBA, should consider if the methodology presents fundamental problems. The next section provides various points of criticism about the application of economic concepts in CBA.

2.5.7 Criticism over CBA

Critical views are mainly based on theoretical inconsistencies suggesting that the principles behind CBA fail in certain instances. To examine these inconsistencies, the first publication reviewed was Gowdy (2004), who collected various points of criticism to CBA from a theoretical view. The second work under review was Boardman (2011),

[6] Frank P. Ramsey, "A Mathematical Theory of Saving," *Economic Journal* 38(152) 1928, 543-559; as cited in Boardman (2011). The Ramsey growth model cited here consists in a social welfare function that seeks to maximize utility in terms of inter-temporal consumption (private and public) boosted by the choice of investment.

whose critique to CBA pointed mainly at the use of WTP to calculate changes in welfare.

Gowdy's critique pointed at theoretical problems behind the concept of Pareto Potential Improvement (PPI). As mentioned, theory explains that a PPI calculation is justified by the K-H criterion. In turn, the K-H criterion requires the potential of compensation among winning and losing parties to establish a Pareto improvement. Actual compensation is not necessary. However, Scitovszky (1941), cited in Gowdy (2004), demonstrated in his Reversal Paradox that a Pareto improved position can also be considered a Pareto improvement when moved back to the original point. For example, if losers were able to bribe the winners in a Pareto improved position to go back to an original position; this latter move could also imply a Pareto Improvement. The reversal paradox was overcome by imposing Scitovsky's double criterion, wherein a Pareto improvement should entail not only that winners may be able to potentially compensate losers, but also, that the losers may not be able to bribe the winners to return to the original position (Gowdy, 2004).

On the other hand, Boardman (2011) noted problems with WTP as a measure of aggregate benefits. At the aggregate level, fundamental economic principles may not hold. One such instance was transitivity, which is not always guaranteed when ranking policies in terms of acquired benefits (Boardman, 2011, p. 34). Transitive choices require that if a consumer chooses B over A, and C over B, then it must be true that C is also preferred to A. Transitivity is an element of the axiom of consumer preferences, which, according to Jehle and Reny (2011), constitutes a foundation of consumer theory, and the guideline of consumer behavior. If the axiom breaks down, the result is a cyclical ordering of preferences. That is, a decision based on net benefits may not always result in a transitive ordering of the policies. The ranking of choices becomes ambiguous in that it wouldn't be possible to establish whether project A or project B is an improvement. Consequently, it would be no longer possible to claim that positive Net Benefits bring optimal results.

Moreover, the axioms of consumer preference represent individual choices. In contrast, CBA attempts to apply the same principle to an aggregate of incumbent agents. CBA aims to establish a policy's monetary impact to all implicated members of society; i.e. a social choice rule. As Boardman (2011) pointed out, Arrow (1963) formulated a theorem demonstrating that any social choice rule under certain conditions can result in intransitive ordering. For a setting of two or more agents ranking two or more choices, Arrow's theorem specified the conditions that constitute a fair social choice rule. First, the axiom of unrestrictive domain indicates that the agents can have their own ranking preferences over the possible alternatives. Second, the axiom of Pareto choice suggests that if one alternative is preferred unanimously, then the second choice will not be decided under the social choice rule. Third, the axiom of independence states that the ranking of two alternatives should not depend on the other available alternatives. Fourth, the axiom of non-dictatorship indicates that the social choice rule must not allow a given party to impose the selections on others. Thus, Arrow's theorem provided a situation in which a social choice rule cannot result in a transitive ordering of proposed policies or projects (Boardman, 2011). This setting includes the rule of positive net benefits; if it violates any of the axioms, it would not be able to result in a transitive ordering of project alternatives.

To Boardman (2011), it should be necessary to impose restrictions on the utility functions associated with consumer's preferences to ensure that the rule of Net Benefits results in a transitive social ranking. These restrictions entail that, (1) the utility function must display diminishing marginal utility; (2) it must be possible to aggregate the demand curves associated to individual utility; and (3) all individuals must face the same set of prices.

A final point of criticism questioned if net benefits accurately deal with wealth distribution. As Boardman noted, individuals may be willing to pay higher or lower amounts depending on their wealth. Wealth also implies differences in marginal utilities for individuals. In this sense, a cost imposed on an agent with low wealth could have a bigger impact than a gain on a high-wealth agent. Aggregated results may not reflect high impacts in spite of positive net benefits, because the theory behind WTP contemplates Pareto *potential* improvements, which don't require actual compensation payments. As a consequence, a policy that imposed costs or benefits in groups with different wealth levels will not be sufficiently justified based on potential Pareto efficiency. In the end, once a policy is implemented, costs will be tangible, not potential, and the wealth level makes a difference when facing costs.

In reality, during the evaluation stage, the analyst can implement measures to take into account these points of criticism. As Boardman suggested, the analyst could select a market segment where the demand curves were easily shown to be linear, in order to make aggregation possible; she could reduce the study to an industry, market or product that ensures the same or similar set of prices; or she could examine a population segment with the same social and economic characteristics, so as to ensure the same willingness to pay.

The present review has covered the concepts and methods relevant to this work. This review started by examining *Jatropha curcas* and its geographic productive range, as well as its advantages as feedstock for biofuel. Next, the concept of conservation agriculture, fundamental to the productive system proposed in this thesis, was reviewed. Along with this concept, this review also covered its relevance to the proposed project; specifically, how it produces an advantageous use of factors. The third section covered publications recording *Jatropha curcas* agricultural performance in conditions similar to those in the proposed project. In addition, this section presented *Jatropha curcas* agricultural performance under conservation agriculture practices. Next, a survey of different methods to evaluate agricultural projects, including projects based on *Jatropha curcas*, was proposed. It concluded that the reviewed methods lacked in areas crucial to the smallholder context, including results about incremental net benefits to the farmers. In addition, an economic analysis of the proposed project was necessary. For that reason, Cost Benefit Analysis was reviewed.

The section covering Cost Benefit Analysis comprised the introduction of the methodology; followed by a comparison between two methods, as well as a review of the economic concepts that support the method. Finally, a brief critique of the economic principles supporting Cost Benefit Analysis was included.

Cost Benefit Analysis, as suggested by Gittinger (1982), focuses on smallholder agriculture, as is the case of the proposed project. This method displays immediate changes in income for the farm family, which would ultimately become an incentive to engage the farmers. Further, the methodology performs an economic evaluation of the proposed project, which is necessary to conclude if it improves the position of all involved agents. As a result, the method displays results so that decision-making is based on quantitative analysis.

In addition, the review acknowledged the flaws proposed for the methodology in the critique, and will address them in the methodology chapter. Finally, the literature review indicated the methodology to be used in the present thesis, including which points from each author should be incorporated.

Chapter 3: Methodology

3.1 Introduction

The present chapter discusses the method and assumptions upon which this study was based. The first section specifies the data sources for socio-economic indicators, costs, prices and agricultural operations, and it explains how future prices were projected. The second section, economic valuation, explains the background calculations necessary to construct the financial and economic analysis. The valuation method was based on Gittinger (1982). Therefore, this section explains the data and the assumptions employed in this thesis to apply this methodology.

3.2 Data

Two sources provided the data to construct the socio-economic background of the target group. The first was the National Agricultural Census (CNA, acronym in Spanish)[7]. The CNA constitutes an official source of data collected *in situ*, concerning production, crops, agricultural practices, landownership, and the socio-economic background of agricultural producers and their family. It is worth noting that the last National Agricultural Census was done in 2000. More recent data on land tenure and proprietorship at the provincial level were not available. Therefore, the results reported in this thesis should serve as an approximation, considering the rather ample assumption that the land situation in Manabi has not changed in thirteen years.

The second data source was the Survey of Agricultural Areas and Continuous Production (ESPAC, acronym in Spanish)[8]. ESPAC is a database that continuously collects data relevant to the agricultural sector in Ecuador. However, this survey does not contain the variety of socio-economic data that CNA did. For that reason, it was necessary to use the two sources. ESPAC provided more current information regarding

[7] More information about the CNA is available at http://servicios.agricultura.gob.ec/sinagap/index.php/censo-nacional-agropecuario.
[8]The data and more information about ESPAC are available at http://www.ecuadorencifras.com/cifras-inec/main.html.

production and land use. This database is updated yearly; as a result, the oldest information from that source is from 2011.

Agricultural practices and operations are a crucial aspect in the methodology. It was therefore necessary to conduct an extensive review of literature indicating agricultural practices for the selected crops, which should also be compatible with the proposed production system and the farmer's endowment. Maize and peanut cultivation are widely practiced in the target area. An important database is made available by the National Institute of Agricultural Research (INIAP, acronym in Spanish)[9]. This government institution conducts research about best agricultural practices, agricultural economics, genetic improvements and other subjects, aiming to enhance the agricultural sector in Ecuador. This entity also publishes cultivation guides, which offer information for specific crops, including maize and peanut. The cultivation guides are directed to small farmers and to the different climatic zones of Ecuador. These include cost assessment, guidance in agricultural practices, recommendations for fertilizer use and crop management. Thus, this source provided information that is representative of current agricultural uses.

However, manuals for *Jatropha curcas* cultivation in Ecuador were not available. As a result, a literature review of recommended practices for *Jatropha curcas* cultivation was conducted. The review should not only find recommendations for farm operations, but also, practices compatible with the proposed production system and the climatic characteristics. Hence, this study adopted the recommendations that suited the most important parameters; that is, practices compatible with conservation agriculture, and in similar geographic characteristics, namely, annual precipitation and climatic zone.

Another data source used was the System of National Information for Agriculture (SINAGAP, acronym in Spanish)[10]. This is an aggregated database made available by the Ecuadorian Ministry of Agriculture, which contains information about the production chain and marketing of main agricultural products. SINAGAP includes costs, sale

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[9] INIAP's publications database can be found at http://www.iniap.gob.ec/nsite/index.php?option=com_sobipro&task=search&sid=58&Itemid=230.

[10] SINAGAP can be found at http://servicios.agricultura.gob.ec/sinagap/.

prices, and related policy. In particular, this study referred to this source to collect data on supply costs and historical sale prices. In addition, SINAGAP contains a portal with geographic information at the national and provincial level. This study referred to the geographic portal for maps containing information about land use, climatic zones, and precipitation levels.

Cost data came from various sources. In order to construct an estimate of operating expenditure, cost data for agricultural inputs were necessary. Information for fertilizers, herbicides and pesticides was available from SINAGAP. Whenever available, quotes from the province of Manabi were collected. Following the local literature dealing with pest and disease management, as well as for fertilization, this study selected the recommended substances and calculated their average price, which was the quote used to calculate operating expenditure.

Another element in operating expenditure was seed cost. This study assumed that farmers would get certified seed from the Ministry of Agriculture, and the price quoted by SINAGAP was used to calculate operating expenditure. Finally, labour cost came from primary data, collected at the targeted area in June 2011.

The next issue are prices for agricultural outputs. For maize, the Ecuadorian government sets floor prices by law (Ministry of Agriculture, 2012). Also, a program to buy maize during the high supply season was implemented, aiming to prevent major losses to producers due to price declines (Ministry of Agriculture, 2010). Therefore, the market price for maize used in this study is the price published by the control governmental agency. On the other hand, the price of *Jatropha curcas* is set by government wholesalers at the point of sale (García, 2011).

Finally, the peanut price is set in a fairly competitive market. SINAGAP reports monthly market prices for several products of current consumption in Ecuador, including peanut. This study collected samples from January 3rd, 2012 to May 14th, 2013 originated at the closest point of sale. The price used in this study was established from the mode of samples observed in May and June, the harvest time.

Another critical subject in the methodology was the projection of future prices and costs. The purpose of price projection is to estimate throughout time (i.e. through the project's duration) the relation between input costs and output prices, and the subsequent change in benefits for the involved agents. To project the future prices of inputs and outputs, this study collected historical data from the Central Bank of Ecuador (BCE, acronym in Spanish)[11] and from the National Institute of Statistics and Census (INEC, acronym in Spanish)[12].

The method for price projection consisted of calculating the average annual variation of price indexes in real terms – the rate of inflation – which was used to estimate the future value of the corresponding item. In the case of labour, the monthly wage index is made available by the Central Bank of Ecuador. The average annual rate of variation was calculated for the period 2002 to 2013, and used to estimate the future value of wages.

There were two cases for the calculation of future output prices. One was the case of *Jatropha curcas* and peanut, traded only domestically, with no imports or exports. As a result, their future prices could be forecasted from domestic inflationary trends, which were calculated as the average annual variation (inflation) of the Consumer Price Index[13] for the period 2007 – 2012. On the other hand, maize is an item that is imported and exported. For that reason, this study projected its future prices based on the Commodity Price Index published by the World Bank (2013).

As for input costs, this study referred to the Producer Price Index, published by the National Institute of Statistics and Census (INEC) and calculated its annual variation to project future quotes.

[11] The Ecuadorian Central Bank webpage is http://www.bce.fin.ec/index.php.
[12] INEC manages and produces all official statistics in Ecuador for different aspects, including demographics, economics, environment and geography. Its webpage contains more information http://www.inec.gob.ec/nuevo_inec/index.html.
[13] The Consumer Price Index for the category "Food and Non-Alcoholic Beverages" published by the Central Bank of Ecuador.

3.3 Economic Valuation

As previously mentioned, the methodology that guides this thesis is based on Gittinger (1982) and Boardman (2011). Particularly, Boardman (2011) contributed with the theoretical background supporting welfare calculations. On the other hand, Gittinger (1982) provided a structure to perform financial analysis of agricultural projects. This author also indicated parameters to convert the financial results into economic terms and carry out an economic valuation.

The first step in an economic valuation is financial analysis. To obtain the financial value of an agricultural project, Gittinger (1982) suggested a useful structure called Farm Investment Analysis. Its components are displayed in table 3.1, below.

Table 3.1: Principal Elements of Farm Investment Analysis

Element	In table number
Farm resource use	
Land Use	3.4
Labour Use	
Farm operations	3.5
Monthly labour requirements	3.6
Farm Production	
Yields	3.7
Production	3.8
Valuation	3.10
Farm Inputs	
Investment	3.11
Operating expenditure per hectare	3.12
Farm Budget	

Source: Adapted from Gittinger (1982).

The above structure is divided into three areas of analysis. The first is farm resource use which evaluates production factors, including land and labour. Table 3.4, land use, divides total area destined for production, and assigns areas for each land use. Labour is analysed in two formats. The first is by farm operations, stated in Table 3.5, where the analyst must assign working times to each operation necessary for the plantation's development, and calculate the annual labour requirements. The second is by monthly labour requirements, which calculates monthly labour inputs, enabling the analyst to evaluate the needs for hired labour, and the critical operations.

The second area of analysis is farm production, which deals with output and assesses its value. Table 3.7 states the yields for each crop. Table 3.8 specifies the expected production per hectare per crop. Table 3.10 establishes the value of the farm production for both the current and the proposed projects.

The third area of analysis is farm inputs, which deals with capital requirements. Table 3.11, investment, determines the costs that the farmer must cover to implement the proposed project. Table 3.12 assesses the operating expenditures per hectare, necessary to compute total operating expenditures.

The farm investment analysis concludes with the farm budget, which displays all yearly expenses and earnings for the farm family during the project's span. Ultimately, the farm budget determines the financial incentives for the participants, including net benefits and annual incremental earnings, as well as the project's measures of net worth, especially the net present value. An important result in the farm budget is the incremental net benefit, calculated as the difference between the net benefits before the project implementation and the projected net benefits with the proposed project. Therefore, the incremental net benefits show the extra financial benefit the farmer can expect from engaging in the proposed project.

Once financial analysis is done, all values expressed in the financial farm budget are converted to economic values. In this case, the incremental net benefits represent the net national income change that the proposed project will add to (or subtract from) the whole economy.

3.3.1 Land Use

The land use section determined how to distribute the total farm area to each agricultural activity. Land use design was formulated based on recommendations from literature that originated in the area where the proposed project takes place, and socio-economic information made available by the CNA and the ESPAC.

Following Gittinger (1982), the first step is to determine the size of the model farm. For this purpose, the present study reviewed data about land tenure and farm sizes in Manabi. Table 3.2, below, displays this information.

Table 3.2: Land tenure types and farm sizes in the province of Manabi, Ecuador.

Farm size categories	Total Hectares	% of size category to total	Land tenure type (hectares) Self-owned with title	Occupied with no title	Rented	Shared cropping	Coop	Other type	Mixed tenure
Fewer than 10 Ha.	143,739	9%	84,723	13,549	3,320	706	291	13,870	27,280
10 Ha. - Fewer than 50 Ha.	462,606	29%	343,724	30,285	5,612	2,911	1,058	25,705	53,311
50 Ha. - Fewer than 100 Ha.	283,566	18%	237,101	10,177	5,359	2,318	690	9,211	18,710
100 Ha. and above	693,713	44%	619,394	12,257	3,628	641	6,875	25,184	25,734
Total hectares by land tenure type			1,284,942	66,268	17,919	6,576	8,914	73,970	125,035
% of tenure type to total			81%	4%	1%	0.4%	0.6%	5%	8%

Source: CNA (2000).

The present research focused on farms with areas under ten hectares, which represented 9% of the total cultivated area in Manabi, or close to 144,000 hectares, as table 3.2 shows. In addition, the most common type of tenure was privately owned farms, which represent 81% of the total. In order to establish a size for the model farm, this study selected the set of privately-owned farms with fewer than ten hectares and calculated the mean of the farm size, which was 5.4 hectares.

3.3.1.1 Cropping Pattern

Next, according to Gittinger (1982), it is necessary to design the cropping pattern for the model farm. The cropping pattern assigns land areas to each particular use (e.g. crops or grazing). The present study considered two factors to establish the cropping pattern. The first was conservation agriculture principles, which recommend crop rotation and diversification (FAO, 2010) among other practices. The second factor was maintaining the usual practices in the target area. Thus, it is necessary to review data about present agricultural practices and land use in Manabi, in table 3.3, below.

Table 3.3 Land Use in the province of Manabi, Ecuador (in hectares).			
LAND USE Categories	TOTAL AREA of Farms with fewer than 10 Ha	% TO TOTAL of Farms with fewer than 10 Ha	% of land use category compared to total cultivated land in Manabi
Perennial crops	53,528	37.23%	25.59%
Annual crops and fallow land	33,186	23.08%	29.06%
Long-term fallow land	8,017	5.58%	15.28%
Cultivated grazing land	21,628	15.04%	2.66%
Natural grazing land	1,450	1.01%	6.02%
Forests and shrubbery	20,892	14.53%	6.13%
Other uses	5,077	3.53%	16.25%
TOTAL	143,778		

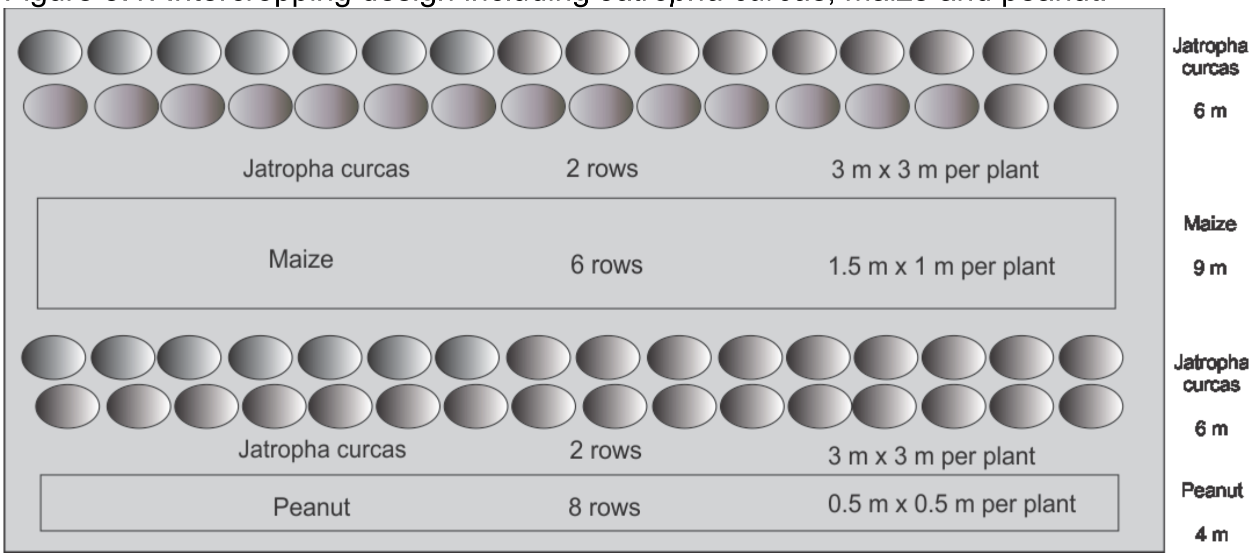
Source: (CNA, 2000).

As Table 3.3 shows, perennial and annual crops were the two major land uses in the province of Manabi. According to the Map of Land Use of Manabi, most of the cultivated land in the targeted area produced annual crops (SINAGAP, 2012). Thus, it is reasonable to conclude that the production of annual crops is a common practice for local farmers.

In addition, various studies made recommendations for intercropping patterns that include *Jatropha curcas* and annual crops. Mendoza et al. (2011) suggested intercropping of *Jatropha curcas* with different annual crops, including maize and peanut. Indeed, the most widely cultivated annual crop in Manabi was maize (ESPAC, 2011). Reyes et al. (2003) also recommend maize for the targeted climatic zone, tropical dry, because it can be cultivated and harvested during the rainy season, making it suitable for rain-fed plantations. For these reasons, maize should be an appropriate choice in an intercropping pattern, as conservation agriculture recommends.

For an intercropping system that includes *Jatropha curcas* and annual crops, Mendoza et al. (2011) suggested alternating either single or double rows of *Jatropha curcas* followed by rows of maize and peanut, as illustrated in Figure 3.1, below. Based on the previous information, this thesis proposed a cropping pattern including *Jatropha Curcas*, peanut and maize.

Figure 3.1: Intercropping design including *Jatropha curcas*, maize and peanut.



The above intercropping design also indicates plant spacing. These specifications were adopted from publications that originate in the targeted area. For instance, Reyes et al. (2003) recommended sowing maize in monoculture plantations with plant spacing of one meter by forty centimeters. For peanut, Ullauri et al. (2004) indicated a spacing of sixty by forty centimeters per plant. Spacing for *Jatropha curcas* was adapted from Mendoza et al. (2011).

Following the methodology, it is also necessary to include the original land use structure, labelled as “without project.” Going back to Table 3.3, with the current land use in Manabi, it shows that farmers have usually maintained an area of fallow land for crop rotation, along with a plantation. A review of related literature could not find publications indicating explicitly the usual area of fallow land on small farms that produce annual crops in the project’s area. However, Limongi et al. (2003) studied farm patterns that mix forestry with annual crops in Manabi, and they found that farmers dedicate half of their land to the annual crops. The farms under study where larger (12.5 hectares in average) and included pasture for cattle, fallow land and a forest area (Limongi et al. 2003, p. 22). These authors also indicated that fallow land (including the forest) usually corresponds to 21% of the farm area. Consequently, the original land use structure would contain an area for cultivation of annual crops, an area dedicated to agroforestry, an area of forest and fallow land, a pasture and the house plot.

On the other hand, the land use in the proposed project design would include an area for cultivation of maize, peanut and *Jatropha curcas*, an area with fallow land and forest, and a small area for housing. With the previous information in mind, this thesis proposed a land use structure as shown in Table 3.4, below.

Table 3.4: Land use for a 5.4 hectare intercropping system.

Type of use and crop	Without project		With project 30 years	
Cultivated area	3.15		4.40	
Maize		1.20		1.30
Peanut		0.40		1.30
Jatropha curcas		0		1.80
Trees		1.55		0
Pasture	1.05		0	
Forest/fallow land	1.15		0.95	
House plot	0.05		0.05	
Total farm area	5.4		5.4	

After establishing the farm's cropping system and land use, the next step in the methodology consists in estimating the labour requirements.

3.3.2 Labour use

A second factor to examine is labour. Gittinger (1982) stated that in order to determine labour requirements, two aspects should be considered, farm operations and monthly tasks.

The literature review determined the farm operations necessary for each crop in the present project. For *Jatropha curcas*, there is the complication that studies were not directed to optimize practices in family/small scale agriculture, which would be compatible with the proposed project. Instead, the literature review on *Jatropha curcas* found data based on experimental settings, namely, government research centers. However, the recommendations were applicable to the cropping system as described in the past section, and were compatible with the climatic conditions in the targeted area. On the other hand, publications indicating best practices for maize and peanut in small scale settings were numerous, and they have taken into account the climatic conditions in the targeted area.

It is also necessary to consider the labour requirements without the proposed project. Following conclusions in Limongi et al. (2003), the original production system included maize cultivation in agroforestry, peanut cultivation, and cattle. To estimate labour requirements in the original production system, the present study followed guidelines found in Villavicencio and Vasquez (2008) for agroforestry systems that include cattle and maize production, and for peanut cultivation. Limongi et al. (2003) indicated that farmers with agroforestry systems give maintenance not only to the crops, but also to the trees, mainly to avoid competition for resources. Thus, maize production has included this activity.

Farm operations in the status quo also included labour requirements for *Jatropha curcas* collected from living fences, the original production scheme proposed by government agencies. Farm operations for each crop are listed in table 3.5, below.

Table 3.5: Farm operations and estimated workdays per year.

Crop and operation	Without project	With project		
Maize	Yearly	Year 1	Years 2 - 4	Years 5 – 30
Land preparation and planting	1.2	4.4	6.2	6.2
Field maintenance	48.3	41.6	41.6	41.6
Fertilization	4.8	5.2	5.2	5.2
Pest & disease management	6	3.9	3.9	3.9
Harvesting	12	13	13	13
Total	**72.3**	**68**	**70**	**70**
Peanut	Yearly	Year 1	Years 2 - 4	Years 5 – 30
Land preparation and planting	0.4	1.3	6.2	6.2
Field maintenance	10.4	41.6	41.6	41.6
Fertilization	0	0	0	0
Pest & disease management	0.8	2.6	2.6	2.6
Harvesting	20	23.4	23.4	23.4
Peeling & Drying	20	20	20	20
Total	**31.6**	**89**	**94**	**94**

Table 3.5: Farm operations and estimated workdays per year (continued).				
Crop and operation	Without project	With project		
Jatropha curcas				
Land preparation and planting	0	33	0	0
Field maintenance	0	45.2	53.2	53.2
Fertilization	0	2	2	2
Pest & disease management	0	1	1	1
Irrigation	0	8	2	2
Harvesting	16	0	20	20
Peeling & Drying	2	0	2	3
Total	**18**	**89.2**	**80.2**	**81.2**
Livestock				
Pasture maintenance	5	0	0	0
Herding	84	0	0	0
Health control	8	0	0	0
Total	**97**	**0**	**0**	**0**
All operations per year	218.9	246.2	244	245

The numbers in Table 3.5 represent the total annual time dedicated to each farm operation. The unit of labour is one workday, which entails the work of one man for eight hours in one day. Farm operations were calculated with reference to the total cultivated area for each crop, as specified in Table 3.4. Also important to note is that the methodology assumes that labour would be provided by the farm family. For simplicity, the present study assumed that only the working time from one family member was available for farm operations. Therefore, the terms "family labour" and "farmer labour" may be used interchangeably, as they are equivalent almost at all times[14]. Labour requirements in excess of what the farm family provides would be considered hired labour, as is evaluated in the next section, monthly labour requirements.

A first element in determining the time spent in farm operations was the production system. Field preparation and planting in conservation agriculture systems incorporate different agricultural tools and techniques. Valverde (2003) reported a project to introduce conservation agriculture practices to Ecuadorian small farmers, which indicated favourable economic returns to minimal and zero tillage techniques. Field preparation and planting were based on conclusions found in Valverde (2003). Thus, it

[14] There are exceptional cases where additional family labour was incorporated. One example is post-harvest activities, where it was assumed that another family member could carry out certain tasks. The monthly labour requirements section analyses the topic in further detail.

was assumed that field preparation in the first year consisted of minimal tillage and digging done with a tiller and digging machine. In addition, planting would be done by the farmer, a task which, according to Villavicencio and Vasquez (2008), required one workday per hectare.

From the second year onward, field preparation and planting would be necessary only for the annual crops. Following recommendations from Valverde (2003), it was assumed zero tillage and direct planting with a manual digger. This publication reported that manual digging could be performed at 4 workdays per hectare.

The rest of the operations necessary to maintain the annual crops were estimated from the literature and government publications meant as guidelines for best agricultural practices. These publications present the advantage that because they originated in the same geographic area as the proposed project, they are adjusted to the climatic conditions. That is the case of Carrillo et al. (2008), Ullauri et al. (2004), Ullauri et al. (2003), Reyes et al. (2003) and Guaman and Andrade (2010) directed to maize and peanut production in the dry areas of coastland Ecuador. In addition, Villavicencio and Vasquez (2008) published a technical guide for various crops, containing information about labour requirements and unit costs for maize and peanut. This cultivation guide was the main source for Table 3.5.

As for *Jatropha curcas*, there were a few publications from the targeted area that provided indications about best agricultural practices. Examples are Mejía and Mendoza (2010), Mendoza et al. (2011) and Mendoza et al. (2009). Specific data indicating the estimated time required for operations for *Jatropha curcas* were found in Karanam and Bhavanasi (2012), Openshaw (2000) and Lima (2008).

3.3.2.1 Monthly labour requirements

A second part of the labour use section examines labour requirements in more detail. Gittinger (1982) recommended an accounting of the monthly labour requirements that are necessary for each crop. This method allows the analyst to point out the major time-consuming farm operations, and the critical months for labour input. As a result, the analyst would be able to assess the need for hired labour more accurately.

A first step in evaluating monthly labour requirements was to construct the land use calendar both for the proposed cropping pattern and the pattern without the project. According to Gittinger (1982), the land use calendar should specify all the monthly tasks needed to set up and maintain the plantation. In order to organize farm operations in the month in which they should take place, this study referred to the literature to find recommendations for each crop.

First, it is useful to state all assumptions related to agricultural practices applied in the previous and the proposed production systems. Regarding the current scheme, identified as "without project," agricultural practices for the annual crops and the livestock came from Villavicencio and Vasquez (2008), who collected recommended practices and estimated work time for various crops in Ecuador. For maize and peanut, this publication indicated no tillage and direct planting with a rented tractor, and manual planting. For livestock, this study adopted recommendations for cattle production in pastures mixed with forestry systems, compatible with Limongi et al. (2003). The present study adopted all other agricultural practices as recommended in this cultivation guide, including fertilization, weed control, pest control and harvesting. Lastly, the original production system also assumed that *Jatropha curcas* production came only from picking living fences for sixteen workdays per year, as described in IICA (2008).

The proposed project assumed conservation agriculture principles, which involve slight land clearing, minimal tillage and direct planting. Field maintenance included chemical and manual weeding, and *Jatropha curcas* trees pruning. Fertilization decreases with time, going from frequent applications in the first year of the plantation to two annual applications from the fourth year onwards. As well, the literature review found that irrigation was recommended for *Jatropha curcas* once per month during the first year, and after the second year, two times during the dry season. The rest of the farm operations, pest control and harvesting, would be done manually. As for the post-harvest tasks, it was assumed that removing peanut husks and maize grains was done mechanically, while *Jatropha curcas* fruits were peeled manually. The next section provides more details about the frequencies and the time dedicated to each farm operation for each crop.

3.3.2.2 Crops calendar

Having established the assumptions for agricultural practices, it is possible now to construct the crops calendar. Publications originated at the targeted area made recommendations for maize and peanut. For maize, Reyes et al. (2003) suggested sowing maize when the first precipitations of the rainy season begin, by the end of December. For peanut, Ullauri et al. (2004) indicated that planting is possible at any time of the year. However, these authors recommended harvesting during the dry season, which goes from the end of May to December. Therefore, annual crops should be set up when the rainy season begins.

On the other hand, there was no literature referring to agricultural practices for *Jatropha curcas* specific to the targeted area. However, this study carried out a review of best agricultural practices and adapted them to the proposed project, since it has its particular setting. For instance, the most recommended propagation method as found in the literature was by seedlings. However, because this resource was not available in the targeted area, this study assumed that the propagation method was direct seed sowing. Achten et al. (2008) recommended planting at the beginning of the rainy season, as is the case for the annual crops. Following these recommendations, planting should be done at the beginning of January, and thus, land preparation should occur by the end of December.

Field maintenance tasks change with the plantation's development. In the first year, field maintenance comprised mainly weeding, an operation that varied for each crop. For *Jatropha curcas*, Karanam and Bhavanasi (2012) recommended weeding immediately after establishing the plantation. Ecuadorian authors also recommended manual weeding once per month, in addition to chemical control every three to four months. For maize, Carrillo et al. (2008) advised to apply chemical weed control one or two times during the crop cycle. For peanut, manual weeding was required especially during the first thirty-five days after planting. Carrillo et al. (2008) suggested a second chemical control for peanut after plant emergence.

An additional field maintenance activity that several authors recommended was pruning *Jatropha curcas* trees. During the first year, Barahona Nieto (2013) suggested pruning the terminal shoots to promote branch growth. From year two onwards, Karanam and Bhavanasi (2012) suggested pruning once per year, immediately after the harvest. Several authors recommended pruning the trees at their dormant stage, during the dry season, when they shed all their leaves.

In sum, field maintenance comprised three tasks, chemical weed control, manual weeding and pruning. Following the above recommendations, chemical weed control should be scheduled by the end of February, on mid-April, mid-August and mid-December. Manual weeding was required once per month during the first year. During the second year, manual weeding was scheduled in the months where chemical control is not applied, and every five weeks during the dry season, which totals six operations per year. Pruning, on the other hand, was scheduled from year two onwards, once annually, at the beginning of September. During the first year, *Jatropha curcas* trees are small and thus, pruning should not require much time. For that reason, pruning in year one was included in manual weeding.

Regarding fertilization, this study adopted recommendations from literature that originated at the targeted area. Fertilization requirements change with the development of *Jatropha curcas* trees, and they are higher during the first year. This study considered Mejía and Mendoza (2010) who suggested fertilization at crop planting, and then at thirty, sixty and ninety days. From the second year on, many authors suggested that fertilization was necessary to replenish nutrients after harvests (Achten et al., 2008; Francis et al., 2005; Karanam and Bhavanasi, 2012). That is, once after the harvest in May, and once by the end of August, when *Jatropha curcas* trees lose their leaves.

Guidelines for fertilization of the annual crops came from Carrillo et al. (2008). The indication for maize was to apply at twenty days and at flowering. For peanut, fertilization was not deemed necessary. Therefore, following guidelines for maize, fertilizer should be applied in mid-February and Mid-April.

Pest and disease management are crucial to ensure the plantation's establishment and future productivity, as the literature review suggested. Pest and disease management for annual crops indicated that many diseases and insects could attack peanut and maize, which would reduce yields. Performance studies of the selected certified seeds for peanut and maize indicated resistance to insects and diseases, but fumigation was still recommended (Guaman and Andrade, 2010; Reyes et al., 2003). This operation should be applied as soon as the first symptoms or insects were present (Carrillo et al., 2008; Ullauri et al., 2004). On the other hand, the reviewed publications did not report pest and disease management for *Jatropha curcas*. Given the lack of precise instructions, this work assumed that pest and disease treatment for the entire plantation should be necessary at some point, and thus, this task was scheduled twice per year, once in mid-March, and once in Mid-September.

Harvesting in the first year was necessary only for the annual crops. Carrillo et al. (2008) stated that the crop cycle for maize is 120 days, and for peanut goes from 100 to 120 days. Thus, in the first year, the farmer should expect to harvest maize and peanut by mid-May. From year two on, *Jatropha curcas* trees are productive, and thus, harvesting time should increase accordingly. Andrade and Cevallos (2009) found that farmers in the province of Manabi usually harvest *Jatropha curcas* in March and April. Therefore, it was assumed that the harvesting during in years 2, 3 and 4 should occur during April. Once *Jatropha curcas* trees reach their stable production, from the fifth year onward, the harvesting season should last for about five weeks, beginning in March and ending in April.

Post-harvest operations are peeling and drying, necessary for all three crops. For maize, it was assumed that grain removal would be done mechanically; therefore, this task was not included in the crop calendar. For peanut, the post-harvest tasks demand more working time. Carrillo et al. (2008) recommended that peanut harvesting should be done by tearing out the plants, and putting them to dry. After harvesting, the husks must be separated from the dry plants. According to Villavicencio and Vasquez (2008) these post-harvest activities, performed manually, should take twenty workdays per hectare.

Similarly, the estimated post-harvest time dedicated to *Jatropha curcas* was two workdays per hectare, used for laying out the fruits to dry and peeling them. During the plantation's maturity stage, when more produce is expected, and should require more time to peel, the work-time assigned to post-harvest tasks was three workdays per hectare. All post-harvest operations would occur after harvesting, that is, at the end of April for *Jatropha curcas*, and at the end of May for the annual crops.

With the operations calendar concluded, it is now possible to construct monthly labour requirements, in Table 3.6, below.

Table 3.6: Monthly Labour Requirements (in workdays), per crop, and per period.

Crop & Activity	Unit In Ha	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Total
Without project														
Plantation	1.60	6.6	9.4	4.8	22.6	14.8	36.8	0	6.5	0	6.5	0	6.5	116.3
Livestock	1.05	9	7	7	8	7	9.5	9	8	8	7	7	10.5	97
Total	2.65	15.6	16.4	11.8	30.6	21.8	48.1	9	14.5	8	13.5	7	17	213.3
Family L		20	20	20	24	22	24	20	20	20	20	20	20	250
Hired L		0	0	0	0	0	24	0	0	0	0	0	0	31
With Project														
Year 1														
Maize	1.3	3	2.6	3.9	10.4	3.9	18.2	0	5.2	2.6	5.2	5.2	5.2	65.4
Peanut	1.3	0	1.3	2.6	7.8	2.6	48.6	0	5.2	2.6	5.2	5.2	5.2	86.3
Jatropha c.	1.8	0	35	4	10.2	4	8.2	8.2	8.2	3	8.2	8.2	8.2	105.4
Total	4.4	3	38.9	10.5	28.4	10.5	75	8.2	18.6	8.2	18.6	18.6	18.6	257
Family L		3	24	20	24	20	24	20	20	20	20	20	20	235
Hired L		0	15	0	4.5	0	51	0	0	0	0	0	0	70.5
Years 2 – 4														
Maize	1.3	7.8	1	3.9	9.1	3.9	18.2	5.2	0	2.6	5.2	5.2	5.2	67.3
Peanut	1.3	7.8	1	2.6	7.8	2.6	48.6	5.2	0	2.6	5.2	5.2	5.2	93.8
Jatropha c.	1.8	2	0	4	8.2	26	9.2	7.2	8.2	4	16.2	8.2	7.2	100.4
Total	4.4	17.6	2	10.5	25.1	32.5	76	17.6	8.2	9.2	26.6	18.6	17.6	261.5
Family L		20	2	20	24	24	24	20	20	20	24	20	20	238
Hired L		0	0	0	1	8.5	52	0	0	0	2.5	0	0	64
Years 5 – 30														
Maize	1.3	7.8	1	3.9	9.1	3.9	18.2	5.2	0	2.6	5.2	5.2	5.2	67.3
Peanut	1.3	7.8	1	2.6	7.8	2.6	48.6	5.2	0	2.6	5.2	5.2	5.2	93.8
Jatropha c.	1.8	2	0	4	14	17	9.2	7.2	8.2	4	16.2	8.2	7.2	97.2
Total	4.4	17.6	2	10.5	30.9	23.5	76	17.6	8.2	9.2	26.6	18.6	17.6	258.3
Family L		20	22	20	24	24	24	20	20	20	24	20	20	238
Hired L		0	0	0	7	0	52	0	0	0	2.5	0	0	61.5

A labour week in Ecuador is 40 hours. Therefore, it was assumed that the farmer would work five days a week, eight hours per day. That is, 240 workdays of labour provided by the farmer are available annually. However, the working week could extend to six days, resulting in 24 workdays per month. This resource was included in such critical periods as the harvest season. In Table 3.6 critical months are those that require 24 workdays or more. Especially critical are April and May, which require two extra labourers when harvest and post-harvest activities are performed. Another critical task was field preparation and planting in the first year, when the three crops should be established. To set up the plantation in year one, it should be necessary to hire one extra labourer.

The assessment of monthly labour requirements concludes the section analyzing Farm Resources, including land use, farm operations and labour requirements. The next section deals with farm production in three phases, yields, expected production and its monetary valuation.

3.3.3 Farm Production

The first part of this section presents the expected yields per year, for each product on the farm.

The reviewed literature did not provide a yield per hectare for *Jatropha curcas* that exactly fitted the conditions in this study. Publications from the targeted area recorded production data for *Jatropha curcas* trees up to the second year. The existing literature clearly stated that agricultural practices and climatic conditions dramatically affect the plantation's performance, thus it is difficult to estimate a yield. Another issue to take into consideration was the intercropping pattern, as most studies were directed to monocultures. Nonetheless, the present work is an *ex-ante* cost benefit analysis. Therefore, it is not based on an existing development, rather than an attempt to propose the feasibility conditions of a *hypothetical* project.

Using reliable data is essential to attain an accurate assessment. In order to obtain a reliable yield that fits the conditions presented in this thesis, a survey of studies that included these features was conducted. Three aspects were particularly important: the lack of irrigation, the climate type and the low agricultural input. For instance, Achten et al. (2008) reported that a reasonable expected production was 2,000 to 3,000 kg of *Jatropha curcas* dry seed per hectare for semi-arid areas and wastelands. Francis et al. (2005) who conducted a study of *Jatropha curcas* production in India, found that the total annual seed yield per hectare was 1,800 kg from year five onwards, in conditions of wasteland cultivation. This same source stated that in the growth period, years one to four, the expected annual seed yield per hectare was 444 Kg (year one), 1,111 Kg (year two), 1,333 Kg (year three), and 1,556 Kg (year four). Brittaine et al. (2010) cited Heller (1996) and Tewari (2007) to state that seed production in semi-arid areas should be expected in a range of 2,000 to 3,000 kg per hectare. However, other reports cited in this same publication stated seed yields closer to 1,000 kg per hectare in plantations in sub-optimal conditions in India. Wani and Chander (2012) reported a seed yield of 1,290 Kg per hectare for four year old plantations in experimental plots in marginal areas. With the use of chemical fertilization (Nitrogen and Phosphorus), this source reported an increase in seed yield that ranged between 1,320 and 1,610 Kg per hectare. Sato et al. (2007) cited Openshaw (2000) reporting a productivity range of 2,500 to 3,500 Kg per hectare in rain-fed conditions in Mali. This publication also cited Swot (2002) that reported an average productivity of 2,400 Kg per hectare in similar conditions. Lima (2008) studied a production chain of *Jatropha curcas* biodiesel partially supplied by small farmers. This publication assumed an average expected productivity of 3,000 Kg per hectare for rain-fed monocultures in a semi-arid zone.

In addition, two publications examined *Jatropha curcas* in the area where the current project was developed. The first, Zambrano and Mendoza (2010), recorded the genetic and agronomic characteristics of *Jatropha curcas* in an experimental plantation with similar agricultural practices to those proposed in this thesis. Further, the plants originated in the same area where the present study takes place. This publication reported that at twenty months the expected seed yield was 0.07 Kg per plant. The second study was Mejía and Mendoza (2010), which recorded the agronomic performance of selected genetic lines of *Jatropha curcas* in the same conditions as the first publication. Mejía and Mendoza (2010) reported an average seed yield of 433 Kg per hectare at the plantation's first year, which coincided with Francis et al. (2005). Nonetheless, the preceding results do not offer a conclusive basis to calculate production, because they only provide information for the first year.

Note again that the above data matched the climatic conditions and agronomic practices described in this thesis. The review pursued similarities in such factors as annual rainfall, dry or semi-arid climate type, rain-fed plantations, and reduced agricultural input. Considering all these factors, the average annual dry seed yield selected was 1,900 Kg per hectare in stable production (years five to thirty). During the growth period, years two to four, the average annual seed yield was assumed to be 1,000 Kg per hectare, while for the first year, no production was considered.

On the other hand, the publications with data for the annual crops in the targeted area were numerous. This thesis selected those studies that matched the climatic and production conditions in the proposed project. For maize, Reyes et al. (2003) indicated that the expected yield was 5,500 Kg per hectare. For peanut, Guaman and Andrade (2010) specified 2,300 Kg per hectare. With the complete data for the three crops, it is now possible to construct table 3.7, Yields per crop, below.

Table 3.7: Yields per crop (in Kg/hectare)

Crops	Without project	With project		
	Yearly	Year 1	Years 2 – 4	Years 5 – 30
Maize	5,500	5,500	5,500	5,500
Peanut	2,300	2,300	2,300	2,300
Jatropha curcas dry seed	1,100	0	1,000	1,900

For the purposes of calculating the changes in welfare, it will be necessary in future sections to compare the production in the proposed project with the production in the farmer's status quo. Thus, this study assumed that the model farmer uses the same seed for maize and peanut in the status quo and in the proposed project, as described in Reyes et al. (2003) and Guaman and Andrade (2010). This seed is a certified product made available by the Ministry of Agriculture of Ecuador, which makes this assumption plausible. As a result, the yield for the annual crops is the same in the status quo as in the proposed project. As for *Jatropha curcas*, the status quo for the model farmer entails collecting ripe fruit from existing living fences. Data about production estimates in this setting were found in IICA (2008)[15], which stated that in the dry climate zone of Manabi the production prospect was 2 Kg per linear meter. García (2011) reported a yield per tree in living fences between 0.5 and 1.5 kilograms, which at the same plantation density as in the proposed project[16] would give an average yield per hectare of 1,100 Kg.

A final important point is that the farmer in the proposed project would not continue to collect *Jatropha curcas* from living fences. There are two reasons for this. The first is that the time dedicated to this activity would increase the labour requirement during the harvest in the proposed project, which is already a critical task. The second is simplicity, because overlapping activities in the status quo and the proposed project could complicate the calculation of incremental net benefits, and therefore, of changes in welfare.

3.3.3.1 Expected Production and Valuation

Once the yield per hectare per crop is determined, the next step is to assess the expected yearly production. These results were calculated by multiplying the yields in table 3.7, by the area dedicated to each crop as indicated in table 3.4. These numbers are presented in table 3.8, below.

[15] As mentioned in previous chapters, the current business model was formulated by government agencies and NGO's, including the Inter-American Institute for Cooperation on Agriculture (IICA). The referred publication is a report that analyzes the status quo of the targeted area. It included socio-economic, geographic, and climatic aspects, as well as a proposal of the business model in the status quo.

[16] As the crop pattern diagram indicated, *Jatropha curcas* trees would be planted in a 3 m x 3 m space, which results in a density of 1,111 plants per hectare. Given the range of yield per tree from living fences, the expected yield per hectare was calculated with the middle point number, of 1 Kg per tree.

Table 3.8: Expected production (total in Kg per year)				
	Without project	With project		
Crops	Yearly	Year 1	Years 2 – 4	Years 5 – 30
Maize	6,600	7,150	7,150	7,150
Peanut	920	3,000	3,000	3,000
Jatropha curcas dry seed	200	0	1,800	3,420
Livestock	963	0	0	0

Because in the status quo the farmer did not dedicate land area to *Jatropha curcas* cultivation, the reported production of 200 Kg per year came from García (2011) who described the results for the first year of implementation of the current project. In addition, the farmer's endowment includes cattle. This work assumed that one cow and one bull were sold for slaughter each year as a regular practice. The reported production is the sum of the average weight of one bull and one cow sold live as reported in ASOGANSD (2013)[17].

The "with-project" production did not include livestock for two reasons. The first was simplicity. As in the yield section, overlapping productive activities in the two schemes would complicate the calculation of changes in welfare. The second is that the land use structure in the status quo dedicated 2.65 hectares to maintaining the cattle. In the proposed project structure, part of this area was transferred to the intercropping system. In future sections, it will be possible to verify the effect of the value of the remaining cattle. This amount was indeed included in the farm budget, and thus considered in the calculation of the incremental net benefit.

To complete the Farm Resource section, the next step is to project the production's yearly value for the project's duration. First, it is necessary to state the prices for all items involved in the farm investment analysis. Table 3.9 displays this information below.

[17] The Association of Cattle Producers of the province of Santo Domingo (ASOGANSD, acronym in Spanish) provided average weights for livestock sales in September 2013.

Table 3.9: Prices (in USD).					
Items and units	Year 1 (2013)	Years 2014 - 2021	Years 2022 - 2029	Years 2030 - 2037	Years 2038 - 2042
Farm Labour (per person per workday)	\$20.00	\$22.90	\$29.01	\$36.74	\$44.46
Maize (per Kg)	\$0.37	\$0.47	\$0.73	\$1.12	\$1.62
Peanut (per Kg)	\$1.60	\$2.01	\$2.96	\$4.38	\$6.14
Jatropha curcas dry seed (per sack of 45 Kg)	\$12.00	\$15.04	\$22.22	\$32.83	\$46.07
Livestock – bulls (per Kg)	\$1.36	-	-	-	-
Livestock – cows (per Kg)	\$1.13	-	-	-	-

As previously mentioned, the cost of labour was collected at the target area in June 2011. This price displays a peak season and low season price in rural areas. As the methodology recommended, if the proposed project would require most of the labour input during the peak season, the analyst should consider the peak season price, in order to best estimate its opportunity cost (Gittinger, 2008). This is indeed the case in the present study, where the most time-consuming tasks occur in May and June, during the peak season. Therefore, the selected price for labour is USD 20 per workday.

The daily wage results from dividing the lawful minimal monthly salary by the number of workdays per month[18]. To calculate the change in wage rate over time, this work referred to historical data from the Ecuadorian Central Bank. The change in average annual salary in real terms from 2002 to 2013 was 4.9% (BCE, 2013a). In order to obtain conservative results, it was assumed that future salaries would increment at a 3% annual rate.

A brief study of maize and peanut prices in Manabi determined the most probable price for the crops, according to the harvest time. The database made available by the Ministry of Agriculture, SINAGAP, publishes weekly prices for these two crops. Sample prices per kilogram of each product were collected for the period January 2012 to July 2013. The most probable price should occur in May and June, when harvesting

[18] The minimal monthly salary in Ecuador is USD318.00 per month, which sums up to close to USD370.00 with benefits (Ministry of Labour, 2013). This number is divided by 20, the number of working days per month, resulting in the daily wage of USD18.50. However, the market daily wage at the site of the proposed project was USD20.00.

happens. Thus, the mode for the price during the harvesting time was selected in each case.

Government policy establishes minimal prices for maize sold to wholesalers. This policy decrees a minimal price for a 45 Kg sack of maize sold during the peak season, which goes from May to June each year (Ministry of Agriculture, 2012). This policy effectively sets a floor under the farm gate price of maize, which is a point to take into account when converting the market price to economic values.

Peanut is traded domestically in Ecuador, with no imports or exports. To project future prices for peanut, this study made use of the historic inflation data in the category "food and non-alcoholic beverages" as set out by the Central Bank of Ecuador. The period under observation was 2005 – 2013, because in 2005 the National Institute of Statistics and Census of Ecuador changed the number of products included in its Consumer Price Index calculation. The annual average inflation rate in the aforementioned category was 6.57%. However, in order to obtain more conservative results, and to acknowledge the recent stable trend in inflation in Ecuador, the baseline annual variation was assumed to be 5%.

On the other hand, maize is internationally traded, and Ecuador is a net importer. In this case, an international commodity price index should provide a better price projection than domestic inflation. The World Bank issues a monthly collection of international commodity price indices in its "pink sheet" report. For the period 2000 – 2012 annual prices in real terms, for the category "grains," presented an increase of 7.15% per year, on average (World Bank, 2013). Once again, in order to obtain more conservative results, 5.5% was assumed as a baseline annual increase.

Jatropha curcas pricing shows an entirely different situation. There is no actual domestic market for this seed, only the direct demand from the Galapagos Islands electric stations. Thus, the government set up the farm-gate price for the product (García, 2011). Nonetheless, a minimal increase due to annual inflation could be assumed. Therefore, the same variation as peanut was included, a baseline annual percentage of 5%.

As in the case for the annual crops, the price of livestock is published by SINAGAP. Sample prices were collected for the period January 2012 to September 2013, reported every two weeks in sale points in Manabi (SINAGAP, 2013). Because the present study assumed that the farmer would sell one cow and one bull for slaughter per year, the mean value of the reported price per kilogram for each animal was calculated.

With the information about prices complete, it is now possible to construct Table 3.10, which contains the value of production for the first five years of the project. The valuation for the total duration of thirty years can be found in appendix 1.

Table 3.10: Production value (in USD).

Item	Maize	Peanut	J. curcas	Livestock	TOTAL
Without project					
Annual production	$2,442.00	$1,472.00	$53.33	$1,275.46	$5,242.79
With project					
Year 1	$2,645.50	$4,800.00	$0.00	$0.00	$7,445.50
Year 2	$2,777.78	$5,040.00	$504.00	$0.00	$8,321.78
Year 3	$2,916.66	$5,292.00	$529.20	$0.00	$8,737.86
Year 4	$3,062.50	$5,556.60	$555.66	$0.00	$9,174.76
Year 5	$3,215.62	$5,834.43	$1,108.54	$0.00	$10,158.59

The calculations in Table 3.10 establish a comparison between the farmer's current source of income and what the farmer may expect with the proposed project. The column labelled as "without project" represents the annual income the farmer obtained in the status quo, carrying out the productive activities previously described. The income from the first year of implementation of the proposed project exceeds the farmer's current income and it increases when *Jatropha curcas* trees start to be productive, until total production stabilizes, from the fifth year onwards.

Production valuation concludes the output assessment for the proposed project. The next section evaluates inputs.

3.3.4 Farm Inputs

Once production is evaluated, the next step in the methodology was to estimate the necessary inputs for the project. This section, Farm Inputs, includes three categories: Investment, Operating Expenditure and Incremental Working Capital.

3.3.4.1 Investment

Gittinger (1982) suggested a number of *usual* investment categories in agricultural projects. Examples are land improvement tasks, constructions, equipment acquisitions, and livestock purchases.

Land improvement activities include clearing of forest or native vegetation, and establishing pastures. The status quo production system was agroforestry, which included an area cultivated with maize and trees. Therefore, there is provision in the investment costs for land clearing. In addition, this study did not consider investment in pasture improvement, even though the targeted farmers indeed maintain livestock in the status quo. This conclusion is based on the Map of Land Cover of Manabi, which indicated that in the targeted area, most of the land corresponded to cultivated pastures (SINAGAP, 2012). Therefore, the land improvement category included labour dedicated to removing trees, labelled as “tree-cutting and de-stumping,” as well as the rental of a chainsaw to carry out this activity.

Before continuing with the next two items, construction and equipment, it becomes necessary to define the model farmer’s endowment of physical capital. According to the National Agricultural Census (CNA), in Manabi, farms with fewer than ten hectares in size usually had access to one tractor in 16% of the cases, one vehicle in 26% of the cases, one grain remover machine in almost half of the cases, one fumigation pump in 40% of the cases, one cattle pen in 28% of the cases, one facility for drying seeds in 30% of the cases, and a silo in 41% of the cases (CNA, 2000).

More specifically, the National Agricultural Census provided information about existing physical capital in the targeted areas[19]. In Chone, Boyaca's municipality, only 0.6% of productive units possessed a tractor, whereas 14% owned a vehicle, 52.5% of units had a fumigation pump, 3.6% of units had access to a silo, and 34% of units had a drying area in place (CNA, 2000). In Tosagua, only 0.8% of productive units owned a tractor, while 11% had a vehicle, 54% of units owned a fumigation pump, 1.5% had access to a silo, and 22% had a drying facility in place (CNA, 2000).

In the equipment category, conservation agriculture indicated the use of particular agricultural tools to perform field activities. From recommendations found in Valverde (2003), this study assumed that the necessary tools are: one mattock, for residue management, one pick for digging, and one manual perforator or seeder.[20] However, the CNA did not provide information about existing agricultural tools. Therefore, it was assumed that these items would be acquired as an investment, while the existing capital in the model farm included one fumigation pump, and one drying facility, as CNA (2000) suggested. Finally, this study assumed that all agricultural manual tools (mattock, pick, perforator and the existing items) would need replacement every three years.

On the other hand, no investment in construction was necessary; therefore, there were no entries in this category. With all this information it was possible to construct table 3.11, Investment, below.

Table 3.11: Investment cost (in USD)

Item and units	Unit Cost	Year 1	Year 4	Total
Land improvement				
Tree cutting & de-stumping (labour cost per workday)	$20	$62	$0	$62
Chainsaw rental (rental cost per day)	$50	$150	$0	$150

[19] As previously described, the places targeted are Tosagua, a municipality, and Boyaca, a parish. In Ecuador, parishes are annexed to municipal administration. In the case of Boyaca, its municipality is Chone. Municipalities were the smallest data disaggregation level in the National Agricultural Census.

[20] The FAO hosts a database with information about mechanical and manual tools for conservation agriculture practices in its website: http://www.fao.org/ag/catd/en/.

Table 3.11: Investment cost (in USD), continued.				
Item and units	Unit Cost	Year 1	Year 4	Total
Equipment & tools				
Mattock	$15	$15	$18.67	$33.67
Pick	$17	$17	$21.16	$38.16
Perforator	$50	$50	$62.24	$112.24
Existing manual tools (replacement cost)	$40	$0	$49.79	$49.79
Fumigation pump (replacement cost)	$130	$0	$161.81	$161.81
Minus existing equipment	-$190	-$190	-$20	-$210
Total Investment	-	$104	$293.67	$397.67

As mentioned, the existing equipment was a fumigation pump with market value of USD130, and a drying facility, with residual value of USD20. This last assumption seems plausible, because drying facilities usually have been in place for some time, and their value would be minimally accounted for if, for instance, the property was put on sale. Existing equipment would also include small hand tools that farmers usually own, such as a machete and a pitchfork, assumed to have a value of USD40. As the methodology suggested, if the existing equipment would be useful in the proposed project, it should be deducted from the expenditure in this investment category (Gittinger, 1982). Therefore, the total value of existing capital (USD 190) was deducted from equipment expenses in year one.

Investment costs presented in Table 3.11 came from a number of sources. Specifications for the land improvement section came from the FAO (1985), which provided guidelines for labour and equipment requirements for land clearing of forested areas. The area that required this work corresponded to 2.75 hectares dedicated in the status quo to agroforestry (maize cultivated with trees) as explained in previous sections. As indicated in table 3.11, it was assumed that the farmer would rent a chainsaw to carry out tree cutting and de-stumping. Equipment costs were estimated based on observations in stores dedicated to sales of agricultural equipment in June 2013. Finally, it was assumed that these tools would need replacement every three years, and thus, their future costs were projected.

Future costs of agricultural tools are based on the Producer Price Index for the category “Manufactured metallic products, excepting machinery and equipment” for the period 2001 – 2012 (INEC, 2012). The average annual increase rate for this period was 7.57%.

Having established initial investment, the next step in evaluating farm inputs is to calculate operating expenditures, in the following section.

3.3.4.2 Operating Expenditure

In order to calculate total operating expenditures for the project’s duration, it is necessary to estimate first the operating expenditure per hectare. To that end, the present study reviewed Ecuadorian publications that included cost assessments per hectare for maize and peanut. For instance, Villavicencio and Vasquez (2008) provided costs per hectare along with a cultivation guide for both crops. Ullauri et al. (2003) also offered a breakdown of cost categories for peanut cultivation in the same climatic zone as our proposed project.

These publications served as a guideline to define the operating expenditure categories for the proposed project. Once the expenditure categories were defined, it was possible to calculate operating expenditure per hectare by including the specifications for land and labour use found in the farm resource section, as well as input costs calculated from historical datasets. These cost categories were adapted to the operating expenditure rationale indicated by Gittinger (1982), which differentiates how depreciation is accrued. Cost assessment would calculate depreciation in a separate category as a cost, while operating expenditure implicitly accrues for depreciation in the discounted cash flow format.

Operating expenditures per hectare are displayed in Table 3.12, below.

Table 3.12. Operating expenditures per hectare (in USD).

Crop	Maize		Peanut		*Jatropha curcas*	
Cost Category	Item & unit	Cost per unit	Item & unit	Cost per unit	Item & unit	Cost per unit
Field preparation						
Mechanical input rental	2 days	$100	2 days	$100	2 days	$100
Subtotal field prep	Maize	$200	Peanut	$200	*J. curcas*	$200
Planting						
Hired labour	0	$0	0	$0	8.5 workdays	$20
Seed cost	15 Kg	$3	80 Kg	$3	2 workdays	$20
Subtotal planting	Maize	$45	Peanut	$240	*J. curcas*	$210
Field Maintenance						
Hired labour	1 workday	$20	1 workday	$20	1 workday	$20
Chemicals for weeding	3.8 liters	$23.56	3.8 liters	$23.56	3.8 liters	$23.56
Subtotal maintenance	Maize	$109.53	Peanut	$109.53	*J. curcas*	$109.53
Fertilization						
Fertilizer[21]	50 Kg sack	$10	n/a	$0	50 Kg sack	$43.24
Subtotal fertilization	Maize	$10	Peanut	$0	*J. curcas*	$43.24
Pest & disease management						
Chemicals	1.5 liters	$17.18	1.5 liters	$17.18	1.5 liters	$17.18
Subtotal P&D management	Maize	$17.18	Peanut	$17.18	*J. curcas*	$17.18
Harvesting (hired labour/Ha)	2 workdays	$20	17.5 workdays	$20	0	$0
Subtotal harvesting	Maize	$40	Peanut	$350.00	*J. curcas*	$0.00
Total (Year 1)	Maize	$421.71	Peanut	$916.71	*J. curcas*	$579.95
Total (Annual for years 2 – 4)	Maize	$221.71	Peanut	$716.71	*J. curcas*	$369.95
Total (Annual years 5 – 30)	Maize	$221.71	Peanut	$716.71	*J. curcas*	$259.95

Table 3.12 displays all expenditure categories necessary to develop and maintain each crop per hectare. There are variations in certain inputs because requirements vary with the growth stage of *Jatropha curcas* trees. For instance, year one presents higher input requirements in two areas. In soil preparation, additional input is required for mild tillage and pit digging following conservation agriculture practices. During the growth stage of *Jatropha curcas* trees (years one to four) purchases of chemical fertilizer were

[21] As per recommendations from the literature, the fertilizer for maize is urea, while the fertilizer for *Jatropha curcas* is ammonium phosphate. The quotes reflect the market prices for a sack of each product.

also necessary, which would be no longer required from year five onwards. From year five, fertilization would be done with *Jatropha curcas* cake, thus, the appropriate price was included. Also, once the stable production stage is reached, in year five, labour requirements increase in maintenance, harvesting and post-harvest activities. The last three rows of table 3.12 present the total operating expenditures per hectare for each period.

As the methodology recommended, only labour requirements in excess of family input should be accounted for in operating expenditures (Gittinger, 1982). That is, only hired labour is considered an operating expenditure. Hired labour requirements were calculated in Table 3.6, monthly labour requirements. Table 3.6 showed that hired labour would be necessary for field preparation, maintenance, and harvesting, which were the categories included in Table 3.12.

The calculation of operating expenditures per hectare concludes the methodological explanation necessary for farm investment analysis. The next steps in the methodology would be forecasting the total operating expenditures for the project’s duration, and setting up the farm budget; that is, the results of financial analysis, presented in the next chapter. However, an important part of financial analysis is debt service. The next section will discuss a few necessary points about financing for the proposed project.

3.3.4.3 Financing and debt service

Following the accounting convention in Gittinger (1982), a loan is contracted at the end of a given year and debt service begins at the end of the next year, assuming that a grace period was not granted. For the proposed project, the model farmer would engage in a loan at the end of year 0, receive the funds prior to the beginning of the project, and start servicing debt at the end of year 1. The period of repayment is two years, year 1 and year 2, with two equal installments for half of the loaned capital.

The present thesis assumed that the model farmer engaged in a micro credit offered by the Ecuadorian Bank of Development[22]. This product offers an annual nominal interest rate of 11%, for loans of up to USD 5,000 (BNF, 2013).

Table 3.13. Financing for a 5.4 hectare project

Category	Year 0	Year 1	Year 2
Funds received	$1,300	$0	$0
Repayment of principal	$0	$650	$650
Interest payments	$0	$143	$71.50
Total service	$0	$793	$721.50
Net financing	$1,300	-$793	-$721.50

It is assumed that the farmer asks for a loan of USD 1,300. Following guidelines in Gittinger (1982), the loan corresponds to a 100% of the investment cost (USD 405, rounded), 100% of the working capital during the investment period (years 1 to 4) of USD 120, and 75% of operating expenditure for *Jatropha curcas* in year 1 (USD 785). The funds are received prior to land preparation and planting, at the end of year zero. Repayment of capital was done in two equal installments of USD 650, plus interest payments beginning at the end of year 1 and ending at the end of year 2.

The analysis of debt service presented in Table 3.13 results in the yearly net financing. This result is incorporated at the end of the farm budget to calculate the *net benefit after financing*, which represents the farm family net benefit (Gittinger, 1982, p. 129). This amount is equivalent to the farm family's yearly income, because it represents the amount that the family has to live on each year (Gittinger, 1982). A farmer would probably arrive to an approximate result on his/her own through more informal means, in order to estimate whether engaging in a proposed project is more convenient than the status quo. Therefore, the net benefit after financing turns out to be the direct financial incentive for the farmer to change his/her status quo.

[22] Even though specialized financial institutions for the agricultural sector were created in Ecuador as early as 1928, the National Bank of Agricultural Development (BNF, acronym in Spanish) was set up in 1974 to provide credit to agricultural producers that had received land as a result of the Agrarian Reform. This institution was closed at the beginning of the nineties and recently reactivated. More information is found at its webpage https://www.bnf.fin.ec/.

3.3.5 Government Cash Flow

Following Gittinger (1982), the government cash flow summarizes inflows and outflows of funds from and to the government related to the project. The purpose of this analysis is to obtain an accurate statement of government expenditures and income sources, in order to arrive to a knowledgeable assessment of all fiscal effects associated to the program's development.

The data source to construct the government cash flow is IICA (2008). This publication describes the government's program, with an industrial and an agricultural component. As mentioned, the final end of the government's project is the production of *Jatropha curcas* oil for use as biofuel in the Galapagos Islands. Because the present research focuses only on agricultural production, the government cash flow emphasized the funds flow related to that component, while excluding sources of income and expenses associated to industrial processing. IICA (2008) included a cash flow statement of the current project, which has been the main source to construct the government cash flow.

Gittinger (1982) indicated the inflow and outflow categories to take into account. Inflows include charges levied on project beneficiaries, new tax revenues as a result of the project investment, surplus or profit made on project sales, and receipts from foreign loans made to finance the project. Outflow categories include the initial capital expenditure in the project, loans to project participants, equity positions, recurrent costs, debt service, and related costs in which the government must incur to carry out the project (such as infrastructure). Thus, this thesis took the data available in IICA (2008) and analysed it using the government cash flow format suggested by Gittinger (1982). This result is presented in the next chapter.

3.3.6 Adjusting financial prices to economic values

The farm budget summarizes various accounts, including production, investment and operating expenditure, based on market prices. As a result, the financial analysis estimates the real net income change that the participant agents would expect after engaging in the proposed project. In order to estimate the project's impact on the total economy, that is, the real net national income change, the project accounts have to be re-evaluated with prices that reflect the value to the economy of the used resources. This is attained by inputting *efficiency prices* in the project accounts.

Efficiency prices represent real resource use or consumption satisfaction, and are adjusted to eliminate direct and indirect transfers, such as taxes or subsidies (Gittinger, 1982, p. 245). The usual criterion to adjust financial prices is the opportunity cost, which is the value of a resource in its best alternative use (Gittinger, 1982). A second criterion is willingness to pay, which measures consumption value, and it is usually applicable to final goods and services (Gittinger, 1982).

This last section specifies the steps taken to re-adjust market prices in the financial accounts and convert them to efficiency prices. Gittinger (1982) stated that there are three steps in the adjustment process. The first is removing direct transfer payments, such as taxes, loans and subsidies.

The second step entails finding the economic value of items traded internationally. When inputs or outputs engaged in the project are either imported or exported, the analyst may encounter different cases of distortions that must be adjusted. In the project proposed here, two cases were analysed, tradable but non-traded items, and import parity prices.

Tradable but non-traded items may have been banned or restricted by the government, so that they are not freely traded internationally. In the project analysed here, this case occurred with imported maize seeds. According to Gittinger (1982), the efficient price of these items is not their international price outside of the national border, but the domestic price of the restricted imports.

The import parity price of an item results from obtaining its border price and adding up all internal importation costs, including port charges, paperwork, and internal transportation to the point of sale (Gittinger, 1982).

The third step finds the economic value of non-traded items, which are only traded domestically, with no imports and exports. In all but one of the cases of non-traded items engaged in the project, the market price was deemed a good measure of economic value, because the items are traded in fairly competitive markets, as suggested by Gittinger (1982). The adjustment process for each item in the proposed project and in the status quo is explained below.

The first example is labour. As the methodology recommended, the goal is to make the wage rate reflect the economic opportunity cost of shifting labour from the without project occupation, to its use with the proposed project. Gittinger (1982) stated that the economic value of labour is its marginal product, estimated as the labourer's marginal productivity. Thus, it was necessary to compare the marginal product of labour in the farmer's current activity and in the proposed project.

A good estimate of the opportunity cost of labour is the daily wage rate during the peak season (Gittinger, 1982). In the targeted area, the peak season occurs in May and June, the harvest time, when the market wage is USD 20. As the methodology suggested, if the proposed project requires the most labour during the peak season, as is the case here, then the market wage is a good estimate of the opportunity cost of labour. Thus, the market wage rate of USD 20 was used in the economic accounts.

In order to make an accurate evaluation of the net incremental income arising from family labour, it was also necessary to convert the opportunity cost of off-farm income in the without project occupation to economic values. This can be done by estimating the annual shadow wage. The annual shadow wage is the result of multiplying the economic daily wage by the number of peak season days in the year (Gittinger, 1982). In the case of Manabi, the peak season occurs during ninety days of the year.

Next, the output prices were adjusted. In the case of maize, Ecuador is a net importer, thus, the import parity price (IPP) was calculated. The IPP was based on the CIF price of maize reported by the Central Bank of Ecuador, plus import costs that included port, documentation and internal transport. Peanut is a non-traded item. It is not imported or exported, and its domestic market is fairly competitive. Thus, the market price of peanut was deemed as a good measure of its economic value. This is the same case for livestock, an item that is not imported or exported in Ecuador, and whose domestic market is fairly competitive. Therefore, market prices were maintained for economic analysis.

As mentioned, there is no market for *Jatropha curcas* dry seed, because its demand was created only to satisfy electricity generation in the Galapagos Islands. The item is not also traded in international markets. However, Brazil has established a market for different raw materials to produce biofuel, including *Jatropha curcas* dry seeds. Thus, the price for the item referred in Lima (2008) was used only for the purpose of evaluation, even if it would not reflect the local circumstances.

The next step was to adjust input costs in two accounts, investment and operating expenditures. Both accounts include rental of machinery and equipment. Gittinger (1982) suggested that only those items that include real resource use should be accounted for in economic valuation. The rental of physical capital was considered a transfer, and therefore not included in the economic accounts.

In the investment account, there were purchases of agricultural tools and a fumigation pump. The agricultural tools (both the existing and those acquired for the proposed project) are non-traded items. Indeed, these items are domestically produced and traded, not exported. It is possible though, to find imported items of similar qualities, but there were no restrictions to their imports. Thus, the market price of these items was deemed a good estimator of their economic value. If a consumer decides to purchase the domestic items even though the imported are available, the choice responds to consumption value (or willingness to pay); this criterion was suggested in Gittinger (1982).

On the other hand, fumigation pumps are exclusively imported. Therefore, the import parity price was calculated based on the FOB price at the port of Shanghai, China – a usual point of origin for fumigation pumps traded in Ecuador – plus freight, port costs and internal transportation.

In the operating expenditure account there were several items to re-evaluate. The first was the cost of seeds for cultivation. In the case of *Jatropha curcas*, the item was acquired (both in the without and with project settings) by collecting fruits from living fences. Therefore, the cost of *Jatropha curcas* seeds was valued based on the work time dedicated to the task. In the case of peanut, the item can be acquired only from domestic production. Thus, its market price was deemed a good measure of economic value. As for maize, it is possible to obtain the product both from domestic and imported production. The methodology suggested that in such cases, the market price of the imported product is a good measure of its economic value (Gittinger, 1982).

The next items in the operating expenditure accounts are agricultural inputs. Fertilizers, herbicides and pesticides are exclusively imported in Ecuador. Therefore, the import parity price was calculated based on international price reports from the World Bank, to which freight costs, port costs and internal transportation costs were added.

Chapter 4: Results and Discussion

4.1 Introduction

Gittinger (1982) proposed the methodology followed here, which performs financial and economic analysis of agricultural projects. As mentioned, the financial analysis is based upon market and other current prices, and assesses the monetary incentives a farmer would find when engaging in a given project. The economic analysis, on the other hand, establishes all accounts in the financial statement based upon prices that reflect the resource use in terms of its opportunity cost. At the individual level, the economic evaluation assesses the net benefits for the involved agents, which when evaluated at the social discount rate can be interpreted as changes in welfare (Boardman, 2011). Once the individual economic statement is aggregated to include all project participants, the incremental net benefits represent the project's total addition to the national income (Gittinger, 1982).

The statements at the individual level are presented in a format called Farm Budget, a statement of cash inflows and outflows for the project's duration. But first, it was necessary to establish the farm's total operating expenditure, presented in the first section of this chapter. In addition, the government cash flow was computed, indicating the sources of income and expenditures to implement the program under study, presented in section 4.4. Concluding the economic and financial analysis, this chapter presents two measures of project worth: the net present value and the benefit-cost ratio.

4.2 Total Operating Expenditure

Total operating expenditure was calculated by adding up the operating expenditures per hectare for each crop, multiplied by the area dedicated to their cultivation. An additional cost included here was operation and maintenance, calculated as the 5% of the annual investment cost in equipment and tools, as Gittinger (1982) indicated. Table 4.1 displays total operating expenditure for the first five years of the proposed project. Appendix 2 displays the full table for the project's duration.

Table 4.1. Total operating expenditure (in USD).						
Categories	Maize	Peanut	*Jatropha curcas*	Total crops	Operation & maintenance	TOTAL Operating Expenditure
Year 1	$ 536.52	$ 1,191.72	$ 1,043.91	$ 2,772.16	$ 8.50	$ 2,780.66
Year 2	$ 288.22	$ 931.72	$ 665.91	$ 1,885.86	$ 12.60	$ 1,898.46
Year 3	$ 296.87	$ 959.67	$ 685.89	$ 1,942.43	$ 13.55	$ 1,955.99
Year 4	$ 305.78	$ 988.46	$ 706.46	$ 2,000.70	$ 14.58	$ 2,015.28
Year 5	$ 365.39	$ 1,122.16	$ 526.04	$ 2,013.59	$ 15.68	$ 2,029.27

4.3 Financial Analysis

Following Gittinger (1982), all accounts for the agricultural project (production value, operating expenditures and investment) are summarized in the Farm Budget (table 4.3). This format computes a stream of benefits and costs for the project's duration, resulting in the expected net benefit (NB) for the farm. A second result is the incremental net benefit (INB), which accounts for the change in net benefit from switching into the proposed project. The first step in the financial analysis is to present the status quo. Table 4.2 shows the farm budget for the farmer's current occupation.

Table 4.2: Farm budget without project (in USD).	
Categories	Annual
Gross value of production	$5,242.79
Off-farm income	$2,880.00
Operating expenditure	$4,054.18
Total net benefit	$4,068.61

Table 4.2 shows the current stream of benefits for the model farm. The category "Gross value of production" accounts for on-farm production, including livestock, peanut and maize. One of the assumptions in the status quo is that the farmer maintains part-time work as a labourer off the farm. The annual net benefit for the farmer's current occupation is USD 4,068, which is to be compared with the expected income from the proposed project.

The farm budgets describing the alternative project considered two cases. In case 1 (table 4.3), the farmer sells all the livestock in year 1 and uses this capital to finance the initial investment necessary to set up the alternative project. In case 2 (table 4.4), the farmer contracts a loan to finance the investment. Table 4.3, below, displays the farm budget for case 1 in the first five years. The farm budget for the total duration of the project is found in appendix 3.

Table 4.3: Farm Budget, Case 1 (in USD).

Year	Total inflows	Investment	Incremental working capital	Operating expenditure	Total outflows	Total Net Benefits	NB without project	Incremental net benefits
Y1	$9,996.42	$104	$0	$2,780.66	$2,884.66	$7,111.76	$4,068.61	$3,043.15
Y2	$8,321.78	$0	$51.78	$1,898.46	$1,950.23	$6,371.54	$4,243.56	$2,127.98
Y3	$8,737.86	$0	$53.37	$1,955.99	$2,009.35	$6,728.51	$4,426.03	$2,302.48
Y4	$9,174.76	$293.67	$12.59	$2,015.28	$2,321.55	$6,853.21	$4,616.35	$2,236.86
Y5	$10,158.59	$0	$82.56	$2,029.27	$2,111.84	$8,046.76	$4,814.86	$3,231.90

Table 4.3 reports the farm budget for case 1 for which financing is not necessary, because the farmer sells the existing livestock in year 1 and is able to cover the investment. “Total inflows” includes all sources of income, including gross revenues, and the total working capital, which accounts for the financial resources necessary for the project’s maintenance. “Total outflows” is composed by three accounts, displayed in table 4.3. These are investment, incremental working capital and operating expenditure. The incremental working capital accounts for the annual financial resources necessary for the plantation’s maintenance. “Total net benefits” is the difference between total inflow and total outflow. As table 4.3 shows, the incremental net benefit for the farmer is positive on each year. This indicates that the farmer can expect greater net benefits from engaging in the alternative project than from maintaining the current occupation.

In case 2 the farmer contracts a loan to finance the investment. Table 4.4 shows the farm budget for the first five years. As in the previous case, the farm budget for the entire duration of the project is shown in appendix 4.

Table 4.4: Farm Budget, case 2 (in USD).									
Year	Total inflows	Total outflows	Total NB before financing	NB without project	Incremental NB before financing	Net financing	Total NB after financing	NB without project	Incremental NB after financing
Y1	$7,445.50	$2,884.66	$4,560.84	$4,068.61	$492.23	$1,300	$5,860.84	$4,068.61	$1,792.23
Y2	$8,321.78	$1,950.23	$6,371.54	$4,243.56	$2,127.98	-$793	$5,578.54	$4,243.56	$1,334.98
Y3	$8,737.86	$2,009.35	$6,728.51	$4,426.03	$2,302.48	-$721.50	$6,007.01	$4,426.03	$1,580.98
Y4	$9,174.76	$2,321.55	$6,853.21	$4,616.35	$2,236.86	$0	$6,853.21	$4,616.35	$2,236.86
Y5	$10,158.59	$2,111.84	$8,046.76	$4,814.86	$3,231.90	$0	$8,046.76	$4,814.86	$3,231.90

In table 4.4, the components of the inflow and outflow accounts were not displayed because they are the same as in table 4.3, which shows case 1. When financing is considered, Gittinger (1982) includes two additional accounts, the total net benefit after financing and the incremental net benefit after financing. These accounts result from deducting the net financing from the net benefit and from the incremental net benefit. The net benefit after financing represents the cash (or annual income) that the farmer would have available after servicing debt (Gittinger, 1982). Thus, the incremental net benefit is lower in the first years, when debt repayment is taking place. Still, the incremental net benefit is positive in all years, indicating that the net benefits in the alternative project would be higher than in the current occupation.

4.4 Government cash flow

The government cash flow is a statement of the sources of income and the expenditures carried out to implement the project. IICA (2008) provided the data to construct this statement. This publication was done in support of the current project, and it contains studies of the industrial and agricultural components. The government cash flow was based mainly on the agricultural component to determine the sources of income and expenses. As mentioned, the final purpose of the government's initiative is to provide *Jatropha curcas* oil for electricity generation in the Galapagos Islands, which entails industrial processing of *Jatropha curcas* seeds. Thus, the agricultural component entails purchasing this product as feedstock for oil production. In addition, this phase includes sales of *Jatropha curcas* cake, a residual matter from processing that can be used as fertilizer.

This section presents two cases of government cash flow. The first refers to inflows and outflows arising from the alternative project's implementation. Particularly, it includes the loans contracted by the participant farmers to set up the production system proposed in this thesis. Table 4.5 shows case 1.

Table 4.5: Government Cash Flow, case 1 (in USD).

Item	Cumulative
	Inflows
Funding IICA	$40,800
Sales of *Jatropha curcas* cake	$827,820
Debt service receipts (from farmers)	
Interest payment	$51,694.50
Principal repayment	$313,300
Total Inflow	$1,233,614.50
	Outflows
Investment cost agricultural component	$187,484
Investment cost processing plants	$311,019
Training	$73,244
Operation & maintenance agricultural component	$2,196,400
Loans to participants	$313,300
Total Outflow	$3,081,447
	Net cash flow
Cumulative surplus (deficit)	-$1,847,832.50

These results are cumulative, because the prices were held constant through the project's duration, calculated for a twenty-year period. As table 4.5 shows, there are three sources of income. The first was the Inter-American Institute for Cooperation in Agriculture (IICA), which provided a non-refundable financial contribution (IICA, 2008). The second income source was projected sales of *Jatropha curcas* cake as calculated in IICA (2008). This publication assumed a price of USD 50 per tonne and average yearly sales of 832 tonnes, for total annual sales of USD 41,600. The third income source was debt service from financial funds loaned to the involved farmers.

The outflows account contains expenditure items destined to the agricultural and industrial components of the project. This account included expenses for the industrial phase because they were sunk costs. For instance, "investment cost for processing plants" includes purchases of equipment necessary to process the raw material. The other items refer to the agricultural component, including investment, training, and operation and maintenance. "Loans to participants" displays the financial funds loaned to farmers to set up the alternative project.

The second case, in table 4.6, describes the government cash flow for the status quo, based on the budget for the current project, as found in IICA (2008). The main difference with case 1 is that is does not include loans to farmers.

Table 4.6: Government cash flow, case 2 (in USD)

Item	Cumulative
	Inflow
Funding IICA	$40,800.00
Sales *Jatropha curcas* cake	$827,820.00
Total Inflow	$868,620.00
	Outflow
Investment cost agricultural component	$187,484.00
Investment cost processing plants	$311,019.00
Training	$73,244.00
Operation & maintenance agricultural component	$2,196,400.00
Total Outflow	$2,768,147.00
	Net cash flow
Cumulative surplus (deficit)	-$1,899,527.00

As table 4.6 shows, the cumulative deficit for the agricultural component of the current project is even greater than in the proposed alternative. In this second case, debt service is eliminated, reducing the sources of income for the government. The government net cash flow is negative in the status quo and the proposed project.

4.5 Economic analysis

This section incorporates three aspects: the farm budget based on economic values, the aggregation of farm budgets for all participants in the project, and the measures of project worth.

The farm budgets presented in the financial analysis contain market prices. They result in the incremental net benefit, which shows the monetary incentive for the farmer to engage in a proposed project. When the accounts in the farm budget are converted to economic values and are aggregated for all the participants, the incremental net benefit represents the project's contribution to society as a whole. At the individual level, the incremental net benefits, valued in economic terms, can be interpreted as the farmer's change in welfare. To compare the welfare position in terms of annual income, it is necessary to display the farm budget describing the farmer's current occupation, in table 4.7.

Table 4.7: Annual farm budget without project in economic values (in USD).

Categories	Yearly
Gross value of production	$5,100.33
Off-farm income	$1,800.00
Operating expenditure	$4,954.32
Total net benefit	$1,946.01

Table 4.7 was calculated by re-evaluating table 4.2 with economic values. To establish the off-farm income in economic terms, the shadow price of labour was calculated. The total net benefit in the status quo is close to USD 2,000. This result will be compared with the net benefit for the proposed project, in table 4.8.

Table 4.8: Farm Budget in economic terms, proposed project (in USD).

Items	Year 1	Years 2 – 4 (per year)	Years 5 – 30 (per year)	Years 1 – 30 (Cumulative)
	Inflow			
Gross value of production	$7,302.50	$8,058.50	$8,738.90	$258,689.40
Livestock sales	$2,550.92	$0.00	$0.00	$2,550.92
Total working capital	$0.00	$0.00	$162.00	$162.00
Total inflow	$9,853.42	$8,058.50	$8,900.90	$261,402.32
	Outflow			
Investment	-$14.02	$200.02	$0.00	$586.04
Incremental working capital	$162.00	$0.00	$0.00	$162.00
Operating expenditure	$1,518.69	$1,518.69	$1,680.69	$49,772.80
Total outflow	$1,666.67	$1,718.71	$1,680.69	$50,520.84
	Net benefit			
Total proposed project	$8,186.75	$6,339.79	$7,220.21	$210,881.48
Total without project	$1,946.01	$1,946.01	$1,946.01	$58,380.26
Incremental Net Benefit	$6,240.74	$4,393.78	$5,274.20	$152,501.22

The numbers in table 4.8 were calculated based on nominal prices for 2013. Following Boardman (2011), the change in net social benefits can be estimated through the project's impact on the involved agents. In this particular case, when a project's objective is the production of intermediate goods, the added benefit can be estimated by the change in income for the involved agents (Boardman, 2011, p. 349). In table 4.8, the cumulative incremental net benefit for the project's duration amounts to USD 152,501.22. That is, the incremental benefit resulting from the farmer switching into the alternative project is positive, implying an increased income for the participant farmers.

4.5.1 Aggregated economic results

According to Gittinger (1982, p. 287), aggregation of economic accounts is done by taking the benefit and cost from the model farm and multiplying it by the number of farms involved in the project. This operation results in a summary of on-farm benefits and costs for the entire project, that is, for the total number of participant families. García (2011) stated that 241 families initiated the current project, which is the number used for aggregation. Table 4.9 shows these results.

Table 4.9: Total incremental net benefit for the economy as a whole (in USD).

Items	Year 1	Years 2 - 4 Cumulative	Years 5 - 30 Cumulative	Total
Total inflow	$1,759,902.50	$5,826,295.50	$55,773,039.40	$63,359,237.40
Total outflow	$401,668.29	$1,242,629.79	$10,531,224.84	$12,175,522.92
NB proposed project	$1,358,234.21	$4,583,665.71	$45,241,814.56	$51,183,714.48
Aggregated INB	$1,504,017.86	$3,176,701.49	$33,048,124.67	$37,728,844.02

Gittinger (1982) affirmed that the aggregated incremental net benefit from economic accounts, as shown in table 4.9, represents the project's addition to the economy as a whole. In this case, the project's addition to the economy is USD 37.7 million. The net benefit of the proposed project, the difference between gross income and gross expenditures, amounts to USD 51 million.

The summary statement in table 4.9 is also called economic cash flow. This statement, according to the methodology, should also include the government's balance of income and expenditures. However, most of the government expenses were part of a wider project that includes industrial processing, oil transportation and electricity generation. The extent to which these investments are traceable to the current or the alternative project is minimal: only a few items in the government cash flow were exclusively directed to the agricultural component.

4.5.2 Measures of project worth

The measures of project worth are indicators of the project's worth in terms of present values. The results previously reported are a net benefit stream for several years. The indicators of project worth provide a valuation in today's money, following the premise that money spent today is more valuable than in the future (Gittinger, 1982). The measures reported in this section are the net present value (NPV) and the benefit-cost ratio (BC).

In order to calculate the measures of project worth it is necessary to establish the discount rate. Gittinger (1982) stated that the proper discount rate for financial analysis should reflect the marginal cost of money to the farm, which would effectively be the rate at which the farmer is able to contract a loan. As discussed in chapter 3, this rate is 11% annually, used to calculate the present values of the incremental net benefit and the net benefit. It is assumed that the discount rate does not change over the thirty years of the project. Table 4.10 shows the total net present values for the farm budget where financing was necessary. Annual present values are presented in appendix 5.

Table 4.10: Total NPV for financial farm budget with financing

NPV of INB after financing	NPV of NB after financing
$35,702.19	$87,047.53

As table 4.10 shows, the net present value of both the incremental and the total net benefit from the alternative project are positive. Gittinger (1982) and Boardman (2011) stated that the decision rule is to accept projects that show a positive net present value. As Boardman (2011) stated, the selected discount rate affects the analyst's recommendation, because this number changes the net present value of the project.

For instance, at a discount rate of 11% the net present value of the proposed project at the farm level is a bit above USD 87,000. If we try with a lower rate, of 6%, the NPV increases to close to USD 92,000, while at a higher discount rate, of 16%, the NPV decreases significantly to USD 21,000.

The results expressed in table 4.10 correspond to the case where the farmer had to contract a loan to cover investment costs. In the case where the farmer was able to finance investment with their own capital, the annual incremental and the annual net benefits were higher. So, it can be concluded that the case financed with own capital would also show a positive net present value.

As Boardman (2011) indicated, in economic analysis the discount rate is called the social discount rate, which determines the net social benefits. Gittinger (1982) stated three criteria to determine the discount rate for economic analysis. The first is the opportunity cost of capital, described as the return obtained from the last investment that exhausted all available capital in an economy. The criterion is clearly theoretical, and thus, this author recommended an opportunity cost of capital for developing countries of 12%. The second criterion is also theoretical, called the "social time preference rate." It is defined as the discount rate that society gives to future returns (Gittinger, 1982) and it is usually perceived as lower than the opportunity cost of capital. The social time preference rate is associated to private investments, and does not include public programs, as the opportunity cost of capital does.

The third criterion is the rate a country pays on its foreign loans. Ecuador's foreign debt was close to USD 7.5 billion in 2013 (Finance Ministry, 2013). The yield for Ecuadorian bonds in international markets as reported in November 8th, 2013 was 6.5 (BCE, 2013b), which could be a referential discount rate. For the present analysis, the baseline discount rate was the suggested opportunity cost of capital of 12%. Table 4.11 shows the NPV of aggregated economic accounts, based on this assumption.

Table 4.11: Net present value, economic analysis (in million USD).

Items	Year 1	Years 2 - 4	Years 5 - 30	Totals
Total aggregated inflow	$1.8	$5.8	$55.8	$63.4
Total aggregated outflow	$0.4	$1.2	$10.5	$12.2
Total aggregated NB	$1.4	$4.6	$45.2	$51.2
Aggregated INB	$1.5	$3.2	$33.0	$37.7
Total NPV of aggregated INB	$1.3	$2.5	$10.0	$13.9

The total net present value of aggregated incremental net benefits shown in table 4.11 represents the present worth of the addition to the national income that the project contributed (Gittinger, 1982). This net present value is positive, implying that the proposed project is recommendable in terms of its contribution to the economy.

It is also important to consider how variations of the social discount rate affect the NPV of the project's addition to the national economy. For instance, at the market interest rate paid by the Ecuadorian government on its foreign debt, of 6.5%, the project's NPV was close to USD 20 million, an increment of 42%. At a higher social discount rate of 18% the NPV of the project's addition to the national economy is USD 10.5 million, a reduction of 24%. As already stated, the choice of the discount rate influences the analyst's recommendation. But, the social discount rate should also reflect society's perspective toward public investments. This includes, as mentioned in chapter two, risk, the opportunity cost of capital, and society's marginal rate of time preference. Therefore, the decision-maker should deem which factors appropriately describe social considerations of each of the elements that compose the social discount rate.

The next measure of project worth is the benefit-cost ratio, obtained by dividing the present value of the benefit stream from the present value of the cost stream (Gittinger, 1982). As in the previous case, the financial analysis was done with a discount rate of 11%. Table 4.12 shows the calculations for the benefit-cost ratio of the farm budget that included financing.

Table 4.12: Benefit-cost ratio for financial analysis at 11% discount rate				
Item	Gross inflows	PV inflows	Gross outflows	PV outflows
TOTALS	$556,662.53	$111,299.52	$110,950.19	$24,251.99

The benefit-cost ratio in table 4.12 equals 4.6, corresponding to the division between the present value of the total inflows (USD 111,300) by the present value of the total outflows (USD 24,200). Following Gittinger (1982), the selection criterion for projects is to consider acceptable those with a benefit-cost ratio equal or higher to 1, as in the case offered here. A benefit-cost ratio of 4.6 indicates the project's capacity to cover the investment and operating expenditures.

In the economic analysis, the benefit-cost ratio was calculated for the aggregated statement of inflows and outflows, as in the previous case, with a discount rate of 12%. Table 4.13 shows these results.

Table 4.13: Benefit-cost ratio for economic analysis at 12% discount rate (in million USD).				
Items	Year 1	Years 2 – 4 (yearly)	Years 5 – 30 (yearly)	Totals
Aggregated inflows	$2.4	$1.9	$2.1	-
PV aggregated inflows	$2.1	$4.7	$16.9	$23.7
Aggregated outflows	$0.4	$0.4	$0.4	-
PV aggregated outflows	$0.4	$1	$3.2	$4.6

In table 4.13 the benefit-cost ratio results from the division between the total present value of inflows (USD 23.7 million) and the total present value of outflows (USD 4.6 million). The benefit-cost ratio equal to 5.2 indicates the project's capacity to cover the investment and operating expenditures.

4.6 Discussion

In general, the results of the financial and the economic evaluations, at the individual and aggregated level show positive value for the proposed project from the farmer's perspective. However, the other party involved, the government, does not see positive returns from the investment in the project's agricultural component throughout its duration.

The first part of results covers the financial analysis, showing two cases. In the first, the farmer is able to use her own capital to finance the investment cost and operating expenditure to set up the alternative project. The results in case one show a total net benefit that is positive in each year of the project's duration, implying a positive return for the farmer' investment. The incremental net benefit is also positive in each year, implying that the farmer can expect a higher annual income when switching from her current occupation to the proposed project.

In case two, the farmer would contract a loan to finance the investment cost. Here the farm budget includes debt financing, which is deducted from the total and incremental net benefits. Total net benefits after financing were positive in each year of the project's duration. However, they were lower than in case one during the first four years. This result indicates that debt service would impact yearly net benefits. Thus, the farm family would have to adjust to a lower annual income in the first years if contracting a loan is necessary. The incremental net benefit after financing in case two is also positive in every year, indicating that even when financing is necessary the proposed project can offer a higher income that the farmer's current occupation.

Therefore, the farmer would find monetary incentives to engage in the proposed project whether she uses her own capital or requires financing to cover for investment and operating expenditures.

The government's cash flow reported cumulative deficit for the project's duration, taking into account that the present study only focuses on its agricultural component. Thus, the investment and recurrent costs are not expected to be recovered from the income sources associated to the agricultural phase. Two cases of government cash flow were presented. The first described the cash flow for the proposed project, including loans given to farmers. The second case described the status quo.

As said, in the first government statement, the net cash flow presented a cumulative deficit. That is, the sources of income for the agricultural component are too low to cover for the investment cost and operating expenses. Special attention needs to be put on recurrent costs, such as operation and maintenance, which were particularly high. In case two, which does not include loans to farmers, the cumulative deficit is even higher because income from debt service is eliminated.

The next section covered economic analysis in three aspects: the farm budget based on economic values, the aggregated economic results, and the measures of project worth.

The farm budget valued in economic terms presented positive incremental net benefits. As Boardman (2011) pointed out, the incremental net benefits represent a fair measure of the producer surplus that the farmer can expect from a change in policy. Therefore, the incremental net benefits imply a positive change in the farmer's welfare position from engaging in the proposed project.

Aggregated economic results showed an addition of close to USD 38 million, implying that the proposed project would cause a positive impact in the national economy.

The measures of project worth were the net present value and the benefit-cost ratio, calculated for the financial and the economic evaluations. For the farm budget in financial terms, the net present value of the incremental and total net benefits was positive. This result implies that the proposed project is recommendable (Boardman, 2011; Gittinger, 1982).

In the economic analysis, the net present value of the aggregated incremental net benefit was positive. That is, the proposed project is recommendable in terms of its potential contribution to the economy as a whole.

The benefit-cost ratios for both the financial and economic evaluations indicated that the project was able to cover the investment cost and operating expenditures and to obtain an additional return. As Gittinger (1982) stated, both facets are recommendable as they obtained benefit-cost ratios higher than one.

Chapter 5: Conclusions

5.1 Overview

The context of this thesis is comprised of the Ecuadorian government's initiative to eliminate the use of fossil fuels for electricity generation in the Galapagos Islands. A part of this context is the poor socio-economic reality in rural areas of the province of Manabi, Ecuador. The government created a program to engage smallholders from rural Manabi in the production chain of *Jatropha curcas* oil to supply electricity plants in the Galapagos Islands. In this government program, referred to in this study as the status quo, the farmers collect *Jatropha curcas* fruits and seeds from living fences growing throughout the province and sell the product to government wholesalers, that supply local processing plants. The program seeks to improve the income of these smallholders. However, quantitative analysis has not evaluated the program's contribution to the economy as a whole, or the changes in welfare for the participants. Therefore, the present thesis formulated an alternative project that incorporates the endowment of factors these farmers maintain, including small land holdings with low opportunity cost. The proposed project consists of cultivating *Jatropha curcas* on a larger area instead of collecting it from living fences. In addition, this study evaluated the financial and economic performance of both the status quo and the alternative project, and compared them. Particularly, this study pursued three objectives.

The first objective was to determine if there are monetary incentives for the farmers to engage in either the government's project or the alternative proposed in this thesis. To establish monetary incentives, this thesis performed a financial analysis using the method by Gittinger (1982). To obtain the financial value of an agricultural project, this author suggested a structure called Farm Investment Analysis, which evaluates three areas. The first is farm resource use, which organizes the distribution of land into productive activities, and accounts for the labour requirements to maintain the plantation. The second is farm production, which estimates the expected yields and production, and its monetary value for the project's duration. The third area is farm inputs, which evaluates the financial needs for the initial investment and operating expenditures. The final step of Farm Investment Analysis is the farm budget that incorporates all three areas of analysis and calculates the sources of income and expenditures for the project's duration. This accounting results in a stream of net benefits for the status quo and the proposed alternative. When the analyst subtracts the net benefit stream corresponding to the farmer's status quo from the net benefit stream of the proposed project, the result is the incremental net benefit that the farmer would expect from engaging in the new project. Thus, the incremental net benefit represents the monetary incentive to engage in a proposed initiative. The results suggested that the incentives to engage in the government's program are minimal, not even covering for the opportunity cost of labour. On the other hand, the incremental net benefits switching from the government's project to the proposed alternative were considerable, amounting to an annual average of USD 3,400 per farm, indicating an average monthly income of USD 615.

The second objective was to determine the changes in welfare for the participants, as well as the project's contribution to the economy as a whole. According to Boardman (2011), welfare concerns efficiency in resource allocation as well as equity. Welfare measurements add up the net benefits of consumers, producers, factors of production and government, each multiplied by the respective welfare weight for each group (Boardman, 2011). The purpose of welfare weights is to differentiate the effects of a program or policy for groups with different income levels, and to assess if the program is helping or hurting low-income groups[23]. Conversely, this thesis focuses on a particular group, characterized by the same socio-economic conditions and a similar endowment of production factors. Thus, welfare measurements in the case proposed in this thesis did not consider weights. Following Gittinger (1982), net benefits in the financial analysis are measured as the difference between total inflows and total outflows for the project's duration. If the analyst seeks to estimate the economic value of the proposed project for the society as a whole, then it is necessary to change these financial

[23] Boardman (2011) cites many other differences in groups involved in a project. Examples are, comparing effects on consumers versus producers versus taxpayers, citizens of a country versus non-citizens, and program participants versus non-participants. However, this author focused on effects over groups with different income levels, the criterion this thesis cites here.

accounts by converting market prices into economic values. Once the accounts in the farm budget are evaluated in economic values, the aggregated incremental net benefit would reflect the real net national income change (Gittinger, 1982). In this case, the results showed a total addition to the economy of close to USD 38 million (in constant dollars of 2013), for the total duration of the project (thirty years). This result represents a positive change in the welfare position of each farm family of USD 600 per year, on average[24].

The third objective was to evaluate the existing policy related to the project and to make recommendations. To this purpose, the present thesis surveyed and reported the policy relevant to the project's development (current and proposed) and made suggestions. The review of existing policy indicated that the majority of government interventions consisted of price control mechanisms. The most important recommendation suggested improving information in financial services to minimize transaction costs to small farmers.

In sum, the results suggest that the government's project does not offer sufficient monetary incentives for farmers, while the alternative could create an important welfare improvement. The financial evaluation found that the monetary incentives for the model farmer to engage in the status quo (the current government project) are not attractive. The additional income from collecting *Jatropha curcas* seeds does not cover the resource investment. But, if the farmer switches to the alternative project, the incremental net benefit is positive, implying that the investment and operating costs could be covered. The government cash flow presented a cumulative deficit for the duration of the project, implying that the agricultural component does not generate sufficient income to cover operating expenses and initial investment. Finally, the economic analysis showed that the proposed project would signify a positive addition to the net national income.

[24] The incremental net benefit resulting from the individual farm budget evaluated in efficiency prices showed a positive income change, which represents the change in welfare position.

The main particularity of the methodology is that family labour input is valued at its opportunity cost, giving the farmer a monetary value in return for his work. A second particular aspect is the comparison of two scenarios, “without the project” or the status quo, and “with the project,” the proposed alternative. Consequently, a farmer could establish a comparison of net benefits from the status quo and the alternative project. Such a format enables the analyst (and the involved agents) to determine if the income changes are enough incentive to encourage farmers to change their current production system to the proposed one.

5.2 Research limitations

The most outstanding limitation was obtaining data for *Jatropha curcas* productivity under the conditions presented in this study. One of these conditions was conservation agriculture, which involves low inputs of chemical fertilizers and pesticides. In fact, there were no local studies referring to best agricultural practices for *Jatropha curcas* plantations under any production system. Some recommendations were available, indicating the plant’s suitability for intercropping and its resilience to water scarcity (Mendoza, 2011; Mendoza et al., 2011). However, no recommendations for pest and disease management or fertilizer requirements were available. As a result, the present study surveyed *Jatropha curcas* production techniques in other countries where its cultivation was more commonly in practice.

Another data limitation occurred with *Jatropha curcas* productivity during its stable production stage. Most studies indicated *expected* yields, but ex-post studies indicating the yield per hectare over a considerable period of time after the fifth year were not numerous.

Finally, as mentioned in the methodology section, the National Agricultural Census (CNA, 2000) is no longer available. This census collected socio-economic data related to agricultural producers, as well as the endowment of factors, including land, and existing equipment. However, this census has not been carried out since 2000, and it was replaced by the Survey of Areas and Continuous Production (ESPAC, 2011) which collects only data related to agricultural production. The results presented in this thesis are limited by the assumption that the socio-economic situation of agricultural producers in Ecuador has not changed since 2000.

5.3 Policy recommendations

As mentioned, the current government business model was created under the national policy to eliminate fossil fuel use for electricity generation in the Galapagos Islands. At the same time, the demand for *Jatropha curcas* seed would respond almost entirely to this program[25]. Consequently, the price for the product was fixed by the government, and does not respond to a competitive market. This situation highly influences the net benefit that farmers can expect from engaging in the current and prospective projects. The results of this thesis suggest that the net benefit increments were not substantial, especially to motivate farmers to engage in the business model proposed by the government.

The Ecuadorian government has implemented an ample range of policy measures to control input and output prices in agriculture. The Ministry of Agriculture effectively supervises all aspects in the agricultural production chain, including production costs, transportation costs, wholesale prices, and imports of agricultural items that are also produced domestically. For instance, in the status quo, costs associated with agricultural inputs (namely pesticides and fertilizers) limited profitability. Consequently, the Ecuadorian government intervened by controlling the prices of agricultural inputs in two ways. In the “Regime of Free Prices under Surveillance,” importers, manufacturers and traders can freely set sales prices, but are obliged to report them to the Ministry of Agriculture each month (Executive decree, 2009). In the “Regime of Direct Price Control,” the executive branch sets the maximum sale price for fertilizers and chemical inputs, among other items (Executive decree, 2009).

The production chain of maize also includes government interventions in its production and marketing. The government regulates the wholesale price paid to producers by establishing a minimal seasonal price (Ministry of Agriculture, 2012). In

[25] Another traditional use for *Jatropha curcas* is to manufacture soap. The market is rather small, as Andrade and Cevallos (2009) suggested.

addition, the industrial sector is obliged to acquire all domestic maize production, and the government controls and approves maize imports in excess of domestic supply (Ministry of Agriculture, 2013).

One important assumption in this study was that transaction costs were minimal, especially regarding financial services. In spite of government efforts to make financial resources readily available to smallholders, it was evident that in order to receive proper information and attention when contracting a loan, a farmer would have to incur travel costs. Smallholders located in areas distant from bank agencies would have to travel the distance if they want to obtain the financial resources, because information was not available by phone. Considering such costs for a group with one of the lowest income levels in the country may become crucial: an agent could easily be discouraged if contracting financial services proves too difficult or costly. Therefore, it is recommended that the National Development Bank makes information about financial products and procedures readily available, so that vulnerable groups can minimize transaction costs. This recommendation could be easily carried out by implementing information centers by phone.

The literature suggested that conservation agriculture technologies must be introduced to small farmers, and continuously evaluated and corrected. The techniques go in hand with agricultural practices (such as mulch maintenance and stubble incorporation) that must be followed to ensure the system's success. Collaboration and technical advice from government research institutions, already present in the target area, could assist in maintaining and optimizing conservation agriculture technologies.

5.4 Further research

One area of future research would be the assessment of environmental goods and services associated with *Jatropha curcas* cultivation. A particular area to investigate would be the effects on green-house gases (GHG) in two contexts. The first is the use of *Jatropha curcas* cake as fertilizer, which should imply a decrease in carbon emissions at the very least from avoiding international transportation. World suppliers of chemical fertilizers are not numerous, and most countries depend on importing these items to cover the demand from agricultural production, as is the case of Ecuador. Literature suggests that *Jatropha curcas* cake contains many necessary elements; thus, its application would suffice to replenish nutrients into the soil (Karanam and Bhavanasi, 2012). However, more dedicated studies to the actual effects of *Jatropha curcas* cake into productivity and soil quality are necessary to confirm its suitability as an alternative to commercial fertilizers.

The reviewed literature about *Jatropha curcas* potential to reduce GHG emissions has mainly focused on carbon. Accounting for carbon emissions is necessary, because CO_2 is the GHG with the highest presence in the atmosphere (EPA, 2013). However, it is also necessary to account for other GHGs. Especially important to agricultural production are nitrous oxide emissions, arising from the addition of fertilizer to the soil (EPA, 2013). If, as the literature claims, *Jatropha curcas* cake can diminish GHG emissions, it is necessary to do further research in this area.

The second context for GHG effects meriting further research would be *Jatropha curcas* productivity in low quality soils. Studies suggested that *Jatropha curcas* cultivated in low quality soils, with a low opportunity cost, results in carbon sequestration, and it does not displace food production (Abou Kheira and Atta, 2009; Basili and Fontini, 2012). However, if productive lands are used for *Jatropha curcas* production, land use change has been proposed as a significant impact on GHG emissions, as it could be a factor for food production displacement (Bryan et al., 2010). If a case for the production of *Jatropha curcas* on marginal lands ca be confirmed, it would represent an advantage over other energy crops that require the use of land with higher productive capacity, such as African palm, soybean or sugar cane.

Additionally, there is uncertainty regarding best management practices that bring optimal productivity to *Jatropha curcas* plantations. Taking from Achten et al. (2008) yield depends on site characteristics, genetics, plant age and management. Plantation management includes as main practices, the propagation method, spacing, pruning, fertilization and irrigation. The literature review found that management practices vary depending on site characteristics and available resources. Future research should therefore include the specific characteristics found on site, instead of trying to impose uniform results per country or region.

For optimal plant performance, it is also paramount to investigate and determine physical and chemical characteristics of *Jatropha curcas* fruits and seeds. The literature review concluded that genetic selection should seek a balance between plant performance and seed characteristics. This last point is vital for oil extraction and processing, as the literature indicated that physical and chemical characteristics of *Jatropha curcas* oil influence its quality (Leela et al., 2011). Therefore, a genetic investigation should aim at not only plant performance, but also, selecting those seed characteristics that ensure a better oil quality.

In addition, genetic improvement is particularly important in the target area in this thesis, because certified seed for cultivation is not available. If, as it is suggested in the literature, *Jatropha curcas* presents various advantages when planted in degraded soil, selecting plants resistant to the local climatic conditions is imperative to ensure optimal yields and plant performance. Such a study should be done in the area where the project takes place, as *Jatropha curcas* characteristics and performance differ drastically even within small zones. Attention should be paid to matching the selected seeds with the present climatic conditions, namely, the precipitation level and climate type. Optimal plant performance depends on a good match of these parameters.

Finally, further research should also incorporate *Jatropha curcas* by-products in the chain. The literature review suggests that these by-products can increase value, including organic fertilizer from cake/husk, and biogas production and gasification from husk combustion (Achten et al., 2008). That is, the production chain that the Ecuadorian government proposed should eventually extend to processed products, not only raw materials, if it intends to improve the livelihoods of the target group. Further economic research should incorporate oil production, fertilizer production and commercialization, and possibly local energy production from biomass combustion.

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Appendices

Appendix 1: Production value for the project's duration (in USD)

Item	Maize	Peanut	J. curcas	Livestock	TOTAL
Without project					
Annual production	$2,442.00	$1,472.00	$53.33	$1,275.46	$5,242.79
With project					
Year 1	$2,645.50	$4,800.00	$0.00	$0.00	$7,445.50
Year 2	$2,777.78	$5,040.00	$504.00	$0.00	$8,321.78
Year 3	$2,916.66	$5,292.00	$529.20	$0.00	$8,737.86
Year 4	$3,062.50	$5,556.60	$555.66	$0.00	$9,174.76
Year 5	$3,215.62	$5,834.43	$1,108.54	$0.00	$10,158.59
Year 6	$3,376.40	$6,126.15	$1,163.97	$0.00	$10,666.52
Year 7	$3,545.22	$6,432.46	$1,222.17	$0.00	$11,199.85
Year 8	$3,722.48	$6,754.08	$1,283.28	$0.00	$11,759.84
Year 9	$3,908.61	$7,091.79	$1,347.44	$0.00	$12,347.83
Year 10	$4,104.04	$7,446.38	$1,414.81	$0.00	$12,965.23
Year 11	$4,309.24	$7,818.69	$1,485.55	$0.00	$13,613.49
Year 12	$4,524.70	$8,209.63	$1,559.83	$0.00	$14,294.16
Year 13	$4,750.94	$8,620.11	$1,637.82	$0.00	$15,008.87
Year 14	$4,988.48	$9,051.12	$1,719.71	$0.00	$15,759.31
Year 15	$5,237.91	$9,503.67	$1,805.70	$0.00	$16,547.28
Year 16	$5,499.80	$9,978.86	$1,895.98	$0.00	$17,374.64
Year 17	$5,774.79	$10,477.80	$1,990.78	$0.00	$18,243.37
Year 18	$6,063.53	$11,001.69	$2,090.32	$0.00	$19,155.54
Year 19	$6,366.71	$11,551.77	$2,194.84	$0.00	$20,113.32
Year 20	$6,685.05	$12,129.36	$2,304.58	$0.00	$21,118.99
Year 21	$7,019.30	$12,735.83	$2,419.81	$0.00	$22,174.94
Year 22	$7,370.26	$13,372.62	$2,540.80	$0.00	$23,283.68
Year 23	$7,738.78	$14,041.25	$2,667.84	$0.00	$24,447.87
Year 24	$8,125.72	$14,743.31	$2,801.23	$0.00	$25,670.26
Year 25	$8,532.00	$15,480.48	$2,941.29	$0.00	$26,953.77
Year 26	$8,958.60	$16,254.50	$3,088.36	$0.00	$28,301.46
Year 27	$9,406.53	$17,067.23	$3,242.77	$0.00	$29,716.53
Year 28	$9,876.86	$17,920.59	$3,404.91	$0.00	$31,202.36
Year 29	$10,370.70	$18,816.62	$3,575.16	$0.00	$32,762.48
Year 30	$10,889.24	$19,757.45	$3,753.92	$0.00	$34,400.60

Appendix 2: Total operating expenditure for the project's duration

Categories	Maize	Peanut	*Jatropha curcas*	Total crops	Operation & maintenance	TOTAL Operating Expenditure
Year 1	$ 536.52	$ 1,191.72	$ 1,043.91	$ 2,772.16	$ 8.50	$ 2,780.66
Year 2	$ 288.22	$ 931.72	$ 665.91	$ 1,885.86	$ 12.60	$ 1,898.46
Year 3	$ 296.87	$ 959.67	$ 685.89	$ 1,942.43	$ 13.55	$ 1,955.99
Year 4	$ 305.78	$ 988.46	$ 706.46	$ 2,000.70	$ 14.58	$ 2,015.28
Year 5	$ 365.39	$ 1,122.16	$ 526.04	$ 2,013.59	$ 15.68	$ 2,029.27
Year 6	$ 385.36	$ 1,163.23	$ 555.55	$ 2,104.14	$ 16.87	$ 2,121.01
Year 7	$ 406.42	$ 1,205.80	$ 586.72	$ 2,198.94	$ 18.15	$ 2,217.09
Year 8	$ 428.63	$ 1,249.93	$ 619.63	$ 2,298.20	$ 19.52	$ 2,317.72
Year 9	$ 452.06	$ 1,295.68	$ 654.40	$ 2,402.13	$ 21.00	$ 2,423.13
Year 10	$ 476.76	$ 1,343.10	$ 691.11	$ 2,510.97	$ 22.59	$ 2,533.56
Year 11	$ 502.82	$ 1,392.26	$ 729.88	$ 2,624.96	$ 24.30	$ 2,649.26
Year 12	$ 530.30	$ 1,443.22	$ 770.82	$ 2,744.34	$ 26.14	$ 2,770.48
Year 13	$ 559.28	$ 1,496.04	$ 814.07	$ 2,869.38	$ 28.12	$ 2,897.50
Year 14	$ 589.84	$ 1,550.79	$ 859.74	$ 3,000.37	$ 30.25	$ 3,030.62
Year 15	$ 622.08	$ 1,607.55	$ 907.97	$ 3,137.60	$ 32.54	$ 3,170.13
Year 16	$ 656.07	$ 1,666.39	$ 958.91	$ 3,281.37	$ 35.00	$ 3,316.37
Year 17	$ 691.93	$ 1,727.38	$ 1,012.70	$ 3,432.01	$ 37.65	$ 3,469.65
Year 18	$ 729.74	$ 1,790.60	$ 1,069.51	$ 3,589.85	$ 40.50	$ 3,630.35
Year 19	$ 769.62	$ 1,856.14	$ 1,129.51	$ 3,755.27	$ 43.56	$ 3,798.83
Year 20	$ 811.68	$ 1,924.07	$ 1,192.88	$ 3,928.63	$ 46.86	$ 3,975.49
Year 21	$ 856.04	$ 1,994.49	$ 1,259.80	$ 4,110.33	$ 50.41	$ 4,160.74
Year 22	$ 902.82	$ 2,067.49	$ 1,330.47	$ 4,300.79	$ 54.22	$ 4,355.01
Year 23	$ 952.16	$ 2,143.16	$ 1,405.11	$ 4,500.43	$ 58.33	$ 4,558.76
Year 24	$ 1,004.20	$ 2,221.60	$ 1,483.94	$ 4,709.74	$ 62.74	$ 4,772.48
Year 25	$ 1,059.08	$ 2,302.91	$ 1,567.19	$ 4,929.18	$ 67.49	$ 4,996.67
Year 26	$ 1,116.96	$ 2,387.20	$ 1,655.11	$ 5,159.26	$ 72.60	$ 5,231.86
Year 27	$ 1,178.00	$ 2,474.57	$ 1,747.96	$ 5,400.52	$ 78.10	$ 5,478.62
Year 28	$ 1,242.37	$ 2,565.14	$ 1,846.02	$ 5,653.53	$ 84.01	$ 5,737.54
Year 29	$ 1,310.27	$ 2,659.02	$ 1,949.58	$ 5,918.87	$ 90.37	$ 6,009.25
Year 30	$ 1,381.88	$ 2,756.34	$ 2,058.95	$ 6,197.17	$ 97.21	$ 6,294.38

Appendix 3: Farm Budget, Case 1. Thirty-year project.

Year	Total inflows	Investment	Incremental working capital	Operating expenditure	Total outflows	Total Net Benefits	NB without project	Incremental net benefits
Y1	$9,996.42	$104.00	$0.00	$2,780.66	$2,884.66	$7,111.76	$4,068.61	$3,043.15
Y2	$8,321.78	$0.00	$51.78	$1,898.46	$1,950.23	$6,371.54	$4,243.56	$2,127.98
Y3	$8,737.86	$0.00	$53.37	$1,955.99	$2,009.35	$6,728.51	$4,426.03	$2,302.48
Y4	$9,174.76	$293.67	$12.59	$2,015.28	$2,321.55	$6,853.21	$4,616.35	$2,236.86
Y5	$10,158.59	$0.00	$82.56	$2,029.27	$2,111.84	$8,046.76	$4,814.86	$3,231.90
Y6	$10,666.52	$0.00	$86.47	$2,121.01	$2,207.48	$8,459.04	$5,021.89	$3,437.15
Y7	$11,199.85	$0.00	$90.57	$2,217.09	$2,307.66	$8,892.19	$5,237.84	$3,654.35
Y8	$11,759.84	$0.00	$94.87	$2,317.72	$2,412.59	$9,347.25	$5,463.06	$3,884.19
Y9	$12,347.83	$0.00	$99.39	$2,423.13	$2,522.52	$9,825.32	$5,697.97	$4,127.34
Y10	$12,965.23	$0.00	$104.12	$2,533.56	$2,637.69	$10,327.54	$5,942.99	$4,384.55
Y11	$13,613.49	$0.00	$109.10	$2,649.26	$2,758.35	$10,855.13	$6,198.54	$4,656.60
Y12	$14,294.16	$0.00	$114.32	$2,770.48	$2,884.80	$11,409.36	$6,465.07	$4,944.29
Y13	$15,008.87	$0.00	$119.81	$2,897.50	$3,017.31	$11,991.56	$6,743.07	$5,248.49
Y14	$15,759.31	$0.00	$125.56	$3,030.62	$3,156.18	$12,603.13	$7,033.02	$5,570.11
Y15	$16,547.28	$0.00	$131.61	$3,170.13	$3,301.74	$13,245.54	$7,335.44	$5,910.09
Y16	$17,374.64	$0.00	$137.96	$3,316.37	$3,454.32	$13,920.32	$7,650.87	$6,269.45
Y17	$18,243.37	$0.00	$144.63	$3,469.65	$3,614.28	$14,629.09	$7,979.85	$6,649.24
Y18	$19,155.54	$0.00	$151.63	$3,630.35	$3,781.99	$15,373.56	$8,322.99	$7,050.57
Y19	$20,113.32	$0.00	$158.99	$3,798.83	$3,957.83	$16,155.49	$8,680.88	$7,474.62
Y20	$21,118.99	$0.00	$166.72	$3,975.49	$4,142.21	$16,976.77	$9,054.15	$7,922.62
Y21	$22,174.94	$0.00	$174.84	$4,160.74	$4,335.58	$17,839.35	$9,443.48	$8,395.87
Y22	$23,283.68	$0.00	$183.38	$4,355.01	$4,538.39	$18,745.29	$9,849.55	$8,895.74
Y23	$24,447.87	$0.00	$192.35	$4,558.76	$4,751.11	$19,696.76	$10,273.08	$9,423.67
Y24	$25,670.26	$0.00	$201.77	$4,772.48	$4,974.25	$20,696.01	$10,714.83	$9,981.18
Y25	$26,953.77	$0.00	$211.67	$4,996.67	$5,208.34	$21,745.43	$11,175.56	$10,569.86
Y26	$28,301.46	$0.00	$222.08	$5,231.86	$5,453.95	$22,847.51	$11,656.11	$11,191.40
Y27	$29,716.53	$0.00	$233.03	$5,478.62	$5,711.65	$24,004.88	$12,157.33	$11,847.56
Y28	$31,202.36	$0.00	$244.53	$5,737.54	$5,982.08	$25,220.29	$12,680.09	$12,540.19
Y29	$32,762.48	$0.00	$256.63	$6,009.25	$6,265.87	$26,496.61	$13,225.34	$13,271.27
Y30	$38,356.94	$0.00	$0.00	$6,294.38	$6,294.38	$32,062.56	$13,794.02	$18,268.53

Appendix 4: Farm Budget, Case 2. Thirty-year project.

Year	Total inflows	Total outflows	Total NB before financing	NB without project	Incremental NB before financing	Net financing	Total NB after financing	NB without project	Incremental NB after financing
Y1	$7,445.50	$2,884.66	$4,560.84	$4,068.61	$492.23	$1,300.00	$5,860.84	$4,068.61	$1,792.23
Y2	$8,321.78	$1,950.23	$6,371.54	$4,243.56	$2,127.98	-$793.00	$5,578.54	$4,243.56	$1,334.98
Y3	$8,737.86	$2,009.35	$6,728.51	$4,426.03	$2,302.48	-$721.50	$6,007.01	$4,426.03	$1,580.98
Y4	$9,174.76	$2,321.55	$6,853.21	$4,616.35	$2,236.86	$0.00	$6,853.21	$4,616.35	$2,236.86
Y5	$10,158.59	$2,111.84	$8,046.76	$4,814.86	$3,231.90	$0.00	$8,046.76	$4,814.86	$3,231.90
Y6	$10,666.52	$2,207.48	$8,459.04	$5,021.89	$3,437.15	$0.00	$8,459.04	$5,021.89	$3,437.15
Y7	$11,199.85	$2,307.66	$8,892.19	$5,237.84	$3,654.35	$0.00	$8,892.19	$5,237.84	$3,654.35
Y8	$11,759.84	$2,412.59	$9,347.25	$5,463.06	$3,884.19	$0.00	$9,347.25	$5,463.06	$3,884.19
Y9	$12,347.83	$2,522.52	$9,825.32	$5,697.97	$4,127.34	$0.00	$9,825.32	$5,697.97	$4,127.34
Y10	$12,965.23	$2,637.69	$10,327.54	$5,942.99	$4,384.55	$0.00	$10,327.54	$5,942.99	$4,384.55
Y11	$13,613.49	$2,758.35	$10,855.13	$6,198.54	$4,656.60	$0.00	$10,855.13	$6,198.54	$4,656.60
Y12	$14,294.16	$2,884.80	$11,409.36	$6,465.07	$4,944.29	$0.00	$11,409.36	$6,465.07	$4,944.29
Y13	$15,008.87	$3,017.31	$11,991.56	$6,743.07	$5,248.49	$0.00	$11,991.56	$6,743.07	$5,248.49
Y14	$15,759.31	$3,156.18	$12,603.13	$7,033.02	$5,570.11	$0.00	$12,603.13	$7,033.02	$5,570.11
Y15	$16,547.28	$3,301.74	$13,245.54	$7,335.44	$5,910.09	$0.00	$13,245.54	$7,335.44	$5,910.09
Y16	$17,374.64	$3,454.32	$13,920.32	$7,650.87	$6,269.45	$0.00	$13,920.32	$7,650.87	$6,269.45
Y17	$18,243.37	$3,614.28	$14,629.09	$7,979.85	$6,649.24	$0.00	$14,629.09	$7,979.85	$6,649.24
Y18	$19,155.54	$3,781.99	$15,373.56	$8,322.99	$7,050.57	$0.00	$15,373.56	$8,322.99	$7,050.57
Y19	$20,113.32	$3,957.83	$16,155.49	$8,680.88	$7,474.62	$0.00	$16,155.49	$8,680.88	$7,474.62
Y20	$21,118.99	$4,142.21	$16,976.77	$9,054.15	$7,922.62	$0.00	$16,976.77	$9,054.15	$7,922.62
Y21	$22,174.94	$4,335.58	$17,839.35	$9,443.48	$8,395.87	$0.00	$17,839.35	$9,443.48	$8,395.87
Y22	$23,283.68	$4,538.39	$18,745.29	$9,849.55	$8,895.74	$0.00	$18,745.29	$9,849.55	$8,895.74
Y23	$24,447.87	$4,751.11	$19,696.76	$10,273.08	$9,423.67	$0.00	$19,696.76	$10,273.08	$9,423.67
Y24	$25,670.26	$4,974.25	$20,696.01	$10,714.83	$9,981.18	$0.00	$20,696.01	$10,714.83	$9,981.18
Y25	$26,953.77	$5,208.34	$21,745.43	$11,175.56	$10,569.86	$0.00	$21,745.43	$11,175.56	$10,569.86
Y26	$28,301.46	$5,453.95	$22,847.51	$11,656.11	$11,191.40	$0.00	$22,847.51	$11,656.11	$11,191.40
Y27	$29,716.53	$5,711.65	$24,004.88	$12,157.33	$11,847.56	$0.00	$24,004.88	$12,157.33	$11,847.56
Y28	$31,202.36	$5,982.08	$25,220.29	$12,680.09	$12,540.19	$0.00	$25,220.29	$12,680.09	$12,540.19
Y29	$32,762.48	$6,265.87	$26,496.61	$13,225.34	$13,271.27	$0.00	$26,496.61	$13,225.34	$13,271.27
Y30	$38,356.94	$6,294.38	$32,062.56	$13,794.02	$18,268.53	$0.00	$32,062.56	$13,794.02	$18,268.53

Appendix 5: Annual present values for financial farm budget with financing

Year	PV of INB after financing	PV of NB after financing
Y1	$1,614.63	$5,280.04
Y2	$1,083.50	$4,527.67
Y3	$1,156.00	$4,392.27
Y4	$1,473.49	$4,514.42
Y5	$1,917.98	$4,775.36
Y6	$1,837.64	$4,522.55
Y7	$1,760.15	$4,283.00
Y8	$1,685.45	$4,056.02
Y9	$1,613.48	$3,840.96
Y10	$1,544.17	$3,637.20
Y11	$1,477.46	$3,444.15
Y12	$1,413.28	$3,261.26
Y13	$1,351.56	$3,088.00
Y14	$1,292.24	$2,923.86
Y15	$1,235.24	$2,768.37
Y16	$1,180.49	$2,621.09
Y17	$1,127.93	$2,481.57
Y18	$1,077.48	$2,349.42
Y19	$1,029.09	$2,224.25
Y20	$982.67	$2,105.70
Y21	$938.17	$1,993.41
Y22	$895.52	$1,887.06
Y23	$854.66	$1,786.35
Y24	$815.51	$1,690.97
Y25	$778.03	$1,600.64
Y26	$742.14	$1,515.10
Y27	$707.80	$1,434.10
Y28	$674.93	$1,357.40
Y29	$643.50	$1,284.77
Y30	$798.02	$1,400.58
TOTAL	$35,702.19	$87,047.53