AN ECONOMIC COMPARISON OF CONSERVATION AGRICULTURE TECHNOLOGIES WITH TRADITIONAL FARM PRACTICES USED IN RAIN FED CROPPING SYSTEMS OF CENTRAL MEXICO

By

Sarah Chambers

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Supervisor: Senior Associate Professor Malcolm Wegener

School of Natural and Rural Systems Management

The University of Queensland

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DECLARATION OF ORIGINALITY

I declare that the work contained in this report is the original effort of the author unless otherwise stated, and that the contents or any part thereof has not been submitted previously for assessment.

Sarah Chambers

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ABSTRACT

The dominant or traditional agricultural management system of the altiplano of Mexico is characterised by rain-fed cropping, conventional tillage, removal of crop residues after harvest, and the mono-cropping of maize. The long term effects of these practices can be summarised as reduced soil stability, loss of soil moisture, loss of soil through erosion, loss of production potential, and low and variable incomes for small farmers. Conservation agriculture technology is being developed as an alternative to such traditional practices in a bid to maintain high and stable crop yields, by using resource conserving technologies and minimizing external inputs. The three main components of CA are minimum soil disturbance, permanent ground cover, and crop rotation.

There has been little adoption of CA practices by most farmers in central Mexico, especially the small farmers. This is mainly due to lack of seeding implements, demand for crop residues as fodder, lack of information, and Mexican rural finance reforms that have limited the ability of farmers to get credit.

This study will make an economic comparison of the traditional agriculture management system (conventional tillage, removal of residue, and mono-cropping maize) with two conservation agriculture management systems: zero till with partial residue retention, and maize-wheat crop rotation; and permanent beds with partial residue retention and maize-wheat crop rotation. Yield data for the three management systems has been taken from the long term sustainability trial conducted at El Batan, Mexico, and costs of production has been gathered from a survey of small farmers.

The objective of this study was to undertake a benefit cost and risk analysis of the three management systems over a period of twelve years, to compare the economic gains and risks of the three systems, and to make recommendations as to whether it is financially viable for small farmers to invest in conservation technologies.

The cost of maize production for the conventional tillage system is 21% and 18% higher than for zero till and permanent beds respectively. The zero till management system has been ranked as the best system, because it has the highest net present value (MX$4,136/ha) and the highest internal rate of return (45.5%) over the twelve year assumed life of the project. Conventional tillage on the other hand had a net presents value of -MX$617/ha, which means that the present costs of this system are greater than the revenue it creates. In looking at the riskiness of these strategies by the rules of first degree stochastic dominance, the most preferred system was zero till, then permanent beds and lastly conventional tillage. The distribution of net present values for the zero till system ranges from MX$2,000/ha to MX$1400/ha, while the conventional tillage system was the riskiest option with a distribution of net present value's ranging from -MX$13,000 to 0.

The investment in the zero till management strategy was found to be the best option for farmers, where the short term costs of investment were far outweighed by the longer term benefits. This study has found that the conventional till management system exhibits two negative aspects of high production costs, and decreasing yields over time. It is recommended by this study that the conservation agriculture management system of zero till should be actively promoted as it is the best option available to small farmers to increase their incomes by cost savings and yield increases.

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1. Introduction

1.1 Background

Agriculture in the *altiplano* of central Mexico is practiced mainly in the temperate, sub-humid high valleys (1500-3000 metres above sea level)[1] (Sayre 2001). Farm size varies from large commercial (50-100ha) to small subsistence (2-10ha).Rain-fed cropping dominates, with rainfall (350-800mm) occurring during the 4-6 months summer period, followed by dry, frosty winters. Maize (*Zea mays L.*) is the dominant crop in the area, and is commonly grown as a continuous crop (no rotation), but there is also production of beans (*Phaseolus vulgaris L.*), wheat (*Triricum aestivium L.*), barley (*Hordeum vulgare L.*), oats (*Avena sativa L.)* and potato (*Solanum tuberosum L.*). All crops are planted at or just before the onset of the summer rains. Most rain events are intense afternoon storms with significant dry spells during the cropping season. The soil is bare for most of the year, with all crop residues removed for fodder, grazed and/or burned. Fields are tilled frequently, using mainly small tractor-drawn disc ploughs/harrows and field cultivators. Sloping fields, heavy tillage and lack of ground cover lead to extensive erosion and run-off, resulting in loss of water and production potential (Scherr and Yadav, 1996; Sayre *et al.,* 2001; Fischer *et al.,* 2002a). Modest fertiliser use is practised but cereal grain yields are low (<3t/ha), and crops are often weedy and nitrogen deficient. The soil structure is poor, and sheet and gully erosion are widespread (Bravo-Espinoza *et al.,* 1993). The combination of the factors contributing to loss in soil quality have led to the loss of production potential by farmers and ultimately resulted in very low and sometimes negative incomes, especially for small farmers.

For the purpose of this study, the dominant management system of the altiplano of Mexico which is characterised by rain-fed cropping, conventional tillage, removal of crop

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[1] Many studies have been conducted in this area by agronomists at the CIMMYT research station at El Batan. This chapter has drawn heavily from the excellent background information from past CIMMYT papers, especially Sayre, K., Mezzalama, M., & Martinez, M. (2001). Tillage, crop rotation and crop residue management effects on maize and wheat production for rainfed conditions in the altiplano of central Mexico. I World Congress on Conservation Agriculture. Madrid.

residues after harvest, and the mono-cropping of maize, will be called Traditional Agriculture (TA).

Conservation Agriculture (CA) technology is being developed as an alternative to such TA practices in a bid to maintain high and stable crop yields, as well as conserve and make more efficient use of the natural resources. This is achieved by practising integrated management of the available soil, water, crop, and other biological resources while minimizing external inputs (FAO 2006). The three main components of CA are minimum soil disturbance, permanent ground cover, and crop rotation. CA involves the use of resource conserving technologies, which reduce labour and machinery costs and enhance the efficiency of using agricultural inputs, in a bid to increase farm revenues.

1.2 The problem

Despite the fact that long-term, on-farm benefits of CA are widely recognised, the short term losses associated with its adoption are a major obstacle for small farmers. This is evident in Mexico where there has been little adoption of CA practices by most farmers in the central highlands, especially the small farmers (Sayre 2001). The specific reasons have been identified as:

- Lack of seeding implements (particularly those appropriate for small farmers) for planting into residues using reduced/zero tillage;
- Demand for crop residues as fodder; and
- Lack of information to formulate clear resource-conserving recommendations for farmers' conditions.

In addition to the problems listed above, the small farmer has been disadvantaged by other socio-political factors characteristic of rural Mexico. The rural finance reform, introduced in Mexico in 1989, streamlined and downsized the rural development bank. This reform has led to the closure of three hundred of the five hundred Banrural branches It has also led to the elimination of subsidies for rural credit and interest rate controls on private sector rural credit, as well as the reduction of the Government provision of insurance to use as collateral for loans (De Janvry 1997). Both of these factors have been effective in reducing the ability of the small farmer to develop their business by investing in new technologies, such as CA.

Farmers in this area tend to be risk averse, preferring to retain familiar practices and traditional, time-tested farming techniques, rather than adopt new technologies, of which the outcomes are not certain and the initial investment is high. This situation will inevitably endure unless sound, alternative, more economic and sustainable technologies can be developed with active farmer participation to engender credibility among the farmers.

1.3 The scope of this study

The region where this study was located is an area that covers parts of the states of Tlaxcala, Hidalgo and Puebla and lies within the altiplano region. The general area is coloured red in figure 1.

Figure 1. Map of the study area

This study will make an economic comparison between three tillage management practices for growing maize in the study area. The dominant system in the area TA will be compared with two alternative CA systems. These alternative systems are Zero Tillage with partial retention of crop residues and Permanent beds with partial retention[2] of crop residues. Both alternatives involve rotation cropping of maize with wheat. The alternative CA systems aim to solve the problems of erosion and decreasing yields, by maintaining a constant ground cover, while still allowing farmers the option of removing some residue, and improving soil quality through crop rotations.

The aim of this study is to conduct benefit cost analyses on the three systems, using:

- Yields data gathered from the long term sustainability trial being conducted at the CIMMYT research station in El Batan,
- Farmer costs of production, obtained in a survey of farmers in the trial area (states of Tlaxcala, Puebla and Hidalgo), and
- Costs of adoption of CA technology, including information of loans available to small farmers, and the cost of the new machinery

The production and CA adoption costs will be applied to the CIMMYT yield results in order to determine the economic feasibility of the adoption of CA technologies by farmers in the area. An economic risk analysis will then be undertaken to compare the three management systems.

Table 1. Schematic summary of three management systems for growing maize selected from treatments in CIMMYT's long-term sustainability trial, El Bata´n, Mexico

	TA system	**Alternative CA systems**	
Tillage	Conventional Tillage (CT)	Zero Tillage (ZT)	Permanent Beds (PB)
Residue mgt	Remove (R)	Partial (P)	Partial (P)

[2] The partial retention (P) of maize involves the removed of residues to below ear; and only 25-30 cm of the wheat stubble is left in the field.

Cropping	Maize-Maize (MM)	Maize-Wheat (MW)	Maize-Wheat (MW)

Source: Adapted from (Govaerts 2005)

1.4 Objectives

1. To undertake a benefit cost and risk analysis of the three management systems over a period of twelve years.
2. To compare the economic gains and risks associated with the CA systems, with those of the incumbent TA system currently being used by farmers in the area
3. To make recommendations as to whether it is financially viable for small farmers to invest in new CA technologies.

The reason behind the economic analysis is to consider the feasibility of farmers in the region adopting CA technologies. Realistic profit and cost margins need to be calculated and analysed, taking into account the transition period involved in the adoption, and the period of stabilisation. It is necessary to apply production costs of farmers from the study area to the yield results from the trial in order to extrapolate these results and obtain realistic figures that will be relevant to local farmers.

Risk Analysis of CA and TA technologies is necessary in order to determine the variability in outcomes. Comparisons will be made over a twelve year period, including the initial investment in the CA machinery, and the trends in yields associated with the different systems. As farmers in this area are considered to be risk averse, this analysis will be just as important as the economic analysis.

As well as comparing the risk and the economics of the CA and TA systems, it is necessary also to consider the feasibility of farmers adopting CA technologies. As a rule, FAO (2006) has noted that new technology must bring the farmer a visible and immediate benefit, economic or otherwise. The benefit must be substantial enough to convince the farmers to change their ongoing practices. For the technology to be adopted, the costs incurred must be covered by the returns it generates. The introduction of CA should be followed by an extension service for a long period of time. In order to determine if the above guidelines have been fulfilled, it is necessary to investigate different options to facilitate the high investment costs necessary for the adoption of the new technology.

1.5 Synopsis of the dissertation

Following this Introduction, the literature relating the biophysical and economic implications of the adoption of conservation agriculture will be reviewed in Chapter 2. This will include literature relating to the effects of tillage, residue management, and crop rotation on soil quality and yields. If will outline the effects of conservation agriculture on farm profitability, and risk, and will discuss the literature on the adoption of conservation agriculture and the processes that facilitate its adoption, especially in Latin America.

Chapter 3 will describe the Research Methods employed in this study, and Chapter 4 will describe and discuss the results and their implications. Chapter 5 will present the conclusions and recommendations of this study.

2. Literature Review

2.1 Conservation Agriculture

CA is a concept for resource-saving agricultural crop production that strives to achieve acceptable profits together with high and sustained production levels while concurrently conserving the environment (FAO 2006). It is estimated that CA, including zero-till production, is being practiced on 57 million ha of land, or 3% of the 1500million ha of arable land worldwide (FAO 2006). About 52% of zero-tillage farming is practiced in the USA and Canada, 44% in Latin America, 2% in Australia and 2% in the rest of the world, including Europe, Africa and Asia (FAO 2006).

There are three main components to the CA technology package:

1. minimum soil disturbance which is achieved by minimum/controlled tillage, zero tillage, or permanent beds;
2. permanent ground cover; and
3. crop rotation, which is the practice of growing two or more crops in the same field in sequence (Dixon 2003).

Since this technology is very sensitive to environmental conditions, the specific components of no-till packages differ across locations but still share some of the principles mentioned above (Ekboir (ed) 2002).

2.1.1 Tillage

There are various tillage practices that conform to minimum soil disturbance and which have similar overall advantages. In the case of zero tillage, the step of land preparation through tilling or cultivating the land is eliminated or minimised. Instead of ploughing up the soil, crops are sown directly into the stubble of the previous crop using special planting equipment. This decrease in soil disturbance is very effective in reducing soil erosion, and results in savings in field operational costs, as well as increasing organic matter within the soil profile, leading to improvements in soil physical, chemical, and biological conditions. (Crovetto 2003) (Baker 1996). It increases the population of macro-invertebrates in the soil, which contribute to decomposition and nutrient cycling, a porous soil structure, and natural pest control (Pimentel 1995). A study of zero till in Ghana demonstrated that zero tillage was responsible for improving soil moisture conservation and reducing the risk of crop failure in dry years (Ekboir 2002). Zero tillage plays an important role in minimizing the impact of agriculture on the global of CO2 increases, by conserving soil carbon dynamics which act to sequester CO2 from the air (Reicosky 2003).

One of the primary disadvantages of zero till is that initial adoption of the technology promotes higher weed diversity (Murphy 2006), including increases in perennial weeds, which require tillage for control (Nalewaja 2003). However, there is also evidence that over time zero till in combination with good crop rotation practice may reduce weed density and expenditures on weed management (Murphy 2006). In some areas the use of zero till has helped to control weeds, as cropping cycles are beginning earlier, and a lack of tillage to prepare soils also reduces weed germination (ACIAR 2006). There have been recent advances in zero-till technologies in relation to weed control, with the development of glyphosate tolerant crops and the use of pre and post harvest glyphosate applications, which essentially eliminate the perennial weed disadvantage (Nalewaja 2003).

Permanent bed cultivation is a farming technique in which fields are formed into a series of raised beds with intervening furrows and the crop is planted in rows on top of the beds (Sayre 2001). A system of controlled tillage is practiced, with zero tillage of the bed itself and occasional tillage in the furrows between the beds in order to maintain bed shape. This practice is used on many crops but especially with wheat in irrigated areas. The benefits of permanent beds include reductions in water-logging by enhanced field drainage, better plant water availability, improved field access and a reduction in soil compaction since all traffic is restricted to the furrows between the beds (Sayre 2001).

2.1.2 Residue Management

Ideal residue management for CA has a target of leaving at least 30% ground cover at any point in the season, and it discourages the removal or burning of crop residues (Sandretto 1996). The retention of crop residue on the soil surface provides a surface mulch which serves to protect to soil permanently from weather hazards, and a source of organic matter (Seguy 2003). Together these can enhance soil aggregation and water-infiltration capacity to increase stored soil moisture and reduce soil erosion, leading to increased yields and maintenance of natural capital or land value (Gregory 2004); (Holland 1987). . Cereal residue has also shown to have a suppressive effect on grass weeds (Fischer 2002). Higher infiltration rates and favourable moisture dynamics from residue retention under ZT can support an increase in yields of up to 30% (Govaerts 2006). However it has also been found that residue retention significantly increased maize root rot incidence compared to residue removal (Govaerts 2006).

Residue management is also the key component of zero till farming in carbon sequestration. The plant stubble that is left standing in the field will continue to undergo the photosynthetic process that is responsible for the plants carbon synthesis by absorbing the CO_2 from the atmosphere (Crovetto 2003). The ploughing of the soil surface layer or burying of stubble can lead to a rapid decomposition of organic matter and release of CO_2, which prevents the build up of organic carbon within the soil profile (Crovetto 2003).

In combination with zero till, full in-field retention of crop residues yields produces significantly higher yields, than with full removal of crop residues for both maize and wheat (Govaerts 2005). Experiments have also been performed with partial removal of crop residue, with zero tillage, which show equally high yields as with full retention. The removal or retention of crop residues with conventional tillage does not make a significant difference in relation to yields (Govaerts 2005).

2.1.3 Crop Rotation

Crop rotations tend to restore soil organic matter and nitrogen to the land, along with other advantages, such as reducing pressure on soils and potentially reducing pest and disease pressure, which are often associated with mono-cropping (Gregory 2004); (Woodmansee 1984). Experiments have shown that maize following wheat produces higher yields than continuous maize under all conditions of tillage, residue, and nitrogen fertilization (Fischer 2002), and that nutrients are utilized more efficiently in crop rotations than in continuous cropping (Zoltan 2001). The rotation of maize and wheat also decreased the incidence of maize root rot by up to 30% (Govaerts 2006). Continuous wheat yields are slightly better than wheat after maize, however there is a lower level of tan spot disease in zero till residue-retained wheat after maize than wheat after wheat (Fischer 2002).

2.2 Economics

2.2.1 Farm profitability

Most studies agree that, compared to conventional tillage, ZT systems reduce input costs such as fuel, labour, and machinery repairs and depreciation costs (Duffy 1983; Bradley 2000; Ribera 2004). They have been found to cut unit production costs (often up to 50%) and to reduce agricultural risks (Ekboir (ed) 2002). The cost and time saving of ZT production allows the household members of small farms to pursue off-farm activities, to gain an education, or generate extra income. The combination of these economic benefits has allowed small-scale farmers to use additional income and time to start other income-generating activities, and to raise the living standards for their families through access to more money for nutrition, education, and housing (Ekboir (ed) 2002).

However, this is not to say that there are no conflicts of interest in regards to CA technologies and farm profitability. Often in the case of small farms, risk is managed by running various activities, including crop and livestock production. Crops and livestock compete for the same resources and require proper management to meet CA objectives (Mueller 2003). The goal of residue management in CA is to balance the optimal level of ground cover based on soil, climatic, and other associated factors, in relation to crop residues available and the potential, alternate, economic uses for the residue (such as for livestock feed). The retention of crop residues in field can thus be interpreted as an opportunity cost of not using that residue for animal feed, or for selling as hay. The studies that have investigated the partial removal of residues on zero tillage (Govaerts 2005), will be of particular importance to these farmers.

Another source of concern for ZT and farm profitability is the potential increase in herbicide costs and/or decrease in yield when conservation tillage systems are used (Ribera et al., 2002). It is generally true that herbicide usage increases with less tillage, but herbicides require far less energy (and fossil fuels) in manufacture and use than tillage, an important benefit with increasing energy costs (Nalewaja 2003). The decrease in yields tends to be a short term effect related to of the adoption of CA technologies (FAO 2006).

2.2.2 Risks

The decision between multiple projects is not just determined by the economics of the outcome, but also by the decision maker's attitude to risk. A risk averter, a risk preferrer and a person indifferent to risk will make different decisions depending on their risk preferences, and the probability of success. The subjective expected utility (SEU) hypothesis shows how to integrate the two components of utility (preferences) and probability (degree of belief) to provide a means of ranking risky prospects, so enabling risky choices to be rationalised (Hardaker 1997). However the elicitation of a decision maker's utility function is one of the difficulties encountered when applying the SEU model. Therefore risk efficiency criteria were devised in an attempt to rank choices without specifying the utility function (Hardaker 1997).

The simplest way to rank the different projects according to risk is by comparing the Cumulative Distribution Functions (CDF) of their outcome values. It works by graphing a distribution of values (for example gross margins or net present values), according to the probability of gaining each level of outcome. By using the CDFs to compare risky agricultural alternatives, it is possible to make more informed decisions by seeing not only which has the highest average gross margin, but also the distribution of values around the mean. Two projects may have the same mean, but the risks may be different. For example one project may have wide distribution of values and therefore a small likelihood of gaining a higher gross margin than another project, but also a small chance of getting a lower gross margin than the other. The decision about which option to choose would then be dependent on the decision maker's attitude to risk. The safety first model chooses the best alternative depending on which has the greater probability of maintaining the gross margin above a certain level.

Risk averse behaviour of farmers using the safety first model has been explored by (Shahabuddin 1986), who derived an expression to capture peasant behaviour toward risk in Bangladesh. Through this model, it is possible to determine whether the farm family is forced to gamble or if they are allowed to trade expected return for reduced risk. The safety-first framework assumes that decision-makers are preoccupied with maximising their chances of survival, not with maximising income. If requirements are lower than expected income then the farm family can choose a less risky crop portfolio with lower expected returns. In this study, the risk coefficients are shown to be significantly related to a set of important socio-economic and structural variables that characterise peasant households in Bangladesh.

2.2.3 Machinery and Investment

The adoption of new CA technologies such as ZT and PB by farmers using TA involves the investment in new machinery suitable for the new practices. For both of these technologies, machinery for direct planting into standing stubble needs to be utilised, a task that is impossible for conventional tillage machinery. Overhead and investment costs must be examined in order to analyse the feasibility of adopting new technologies.

New equipment suitable for ZT for both small and large scale farmers in Latin America has been developed by institutions such as CIMMYT and IAPAR. For example the development of animal drawn ZT equipment started in South Brazil in 1985 when IAPAR designed prototypes of a planter and knife roller (Ribeiro 2003). However even with the relatively low cost of animal drawn equipment, these are not easily affordable by small-scale farmers (Ribeiro 2003). Most of animal-drawn equipment has been acquired through rural development programmes and private sector funding (from the tobacco industry).

2.3 Adoption

The adoption of CA technology is the outcome of a complex social process, and understanding the development and adoption of no-till farming requires a new framework for the socioeconomic study of technical change (Ekboir (ed) 2002). The main reasons for non adoption and adaptation of soil conservation technologies have been outlined by Dixon in a seminar given at CIMMYT in 2005.

The main points were determined as:

- Farmers feel that they are unlikely to reap expected benefits because of a lack of secure access to land

- Labour costs involved in the establishment and maintenance of technologies are too high, especially if farmers periodically work off farm
- Farmers believe that the economic contribution of their plots to their livelihoods is so small that it is not worth investing time and money in improving their plots
- Technologies often require farmers to take land out of production and they are unwilling to do this
- Farmers do not rate soil erosion as a key problem that needs to be addressed and so soil conservation recommendations are seen as a waste of time and effort
- Farmers do not feel that they own the technologies due to "transfer of technology" extension practices
- Farmers lack of access to the capital necessary to establish and maintain soil conservation technologies
- Soil conservation practices require changes in farming systems that do not suit the economic or cultural realities.

It has always been the case that the adoption of a new technology will be most significant in those areas that will stand to gain the most from its adoption. In the case of CA, there have been quite dramatic levels of adoption in tropical high rainfall areas, such as Brazil, where the immediate benefits of a reduction of soil erosion are greatest (FAO 2006). It is estimated that more than 90% of small-scale farmers in southern Brazil use no-till (Ekboir (ed) 2002). The adoption in temperate zones, such as the highlands of Mexico has not been as great due to the lack of such immediate benefits.

2.3.1 Theory of adoption of CA

Despite potential longer term benefits from adopting CA, the literature also points out that once adopted, CA can sometimes have a negative short term effect on farm incomes (FAO 2006). Figure 2 illustrates the phases involved in switching practices from TA to CA.

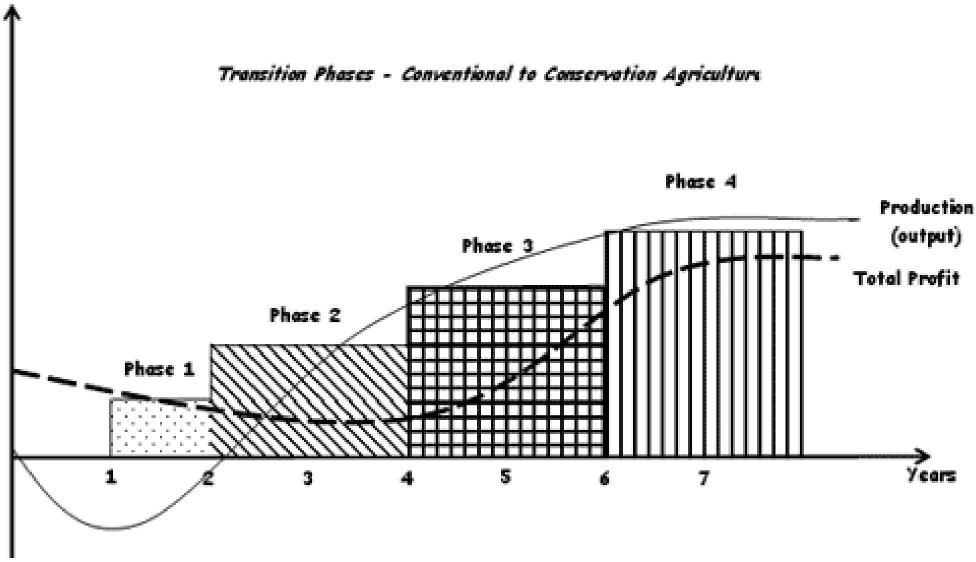

Figure 2. Transition phases moving from Traditional to Conservation Agriculture
(Source: (FAO 2006))

The phases are explained below:

- Phase 1 - Improvement in tillage techniques: The transition generally includes costly investments in new machinery suited to CA, along with reductions in production outputs due to farmers learning new techniques, and changes in agro-chemical use etc. However there will be reductions in production costs such as labour, time, and draught animal or motorised power.
- Phase 2 - Improvement in soil conditions and fertility: This phase involves further reductions in production costs and increases in yields due to improved efficiency by the farmers as well as the beneficial biological processes associated with CA.
- Phase 3 - Diversification of cropping pattern: This period is usually defined by increased and more stable yields, as well as improving soil fertility. Consequently, net farm income will rise.
- Phase 4 - Stability in production and productivity: The integrated farming system is functioning smoothly and all of the technical and economic advantages of conservation agriculture can be appreciated by the farmer.

2.3.2 Networks

The adoption of CA technologies by farmers is often dependent on the existence and effectiveness of networks for technology dispersion. Just as no-till packages are location-specific, no-till networks and their evolution are also unique. In South America, the main forces driving innovation are the commercial interests of input suppliers, and the commercial farmers' need for sustainable technologies (Ekboir (ed) 2002). However the drive can also come from government and non-government organisations.

In the Drift Prarie region of the US, a five year CA demonstration project was created with the aim of facilitating the adoption of CA technologies by farmers (Gregorie 2003). The demonstration program improved communications on three levels: the farm family and their team; an advisory board made up of farmers and agency representatives; and partners that include non-profit organisations, federal and state agencies. The resource analysis team worked directly with the farm family to develop a whole farm plan which addresses CA, the advisory board developed a program and found funding to facilitate CA, and the partners provide the funding, offer advice, and gain information to assist in agricultural policy making (Gregorie 2003). The inclusion of stakeholders from the level of primary producers through to the policy makers is very useful in creating sustainable networks and communication mechanisms for the continual dissemination and improvement of CA technologies.

In Brazil, a network of forty two Clubes Amigos de Terra (CAT's) and similar farmer organisations has been developed in the Cerrado tropical wet/dry savannah region (Landers 2003). These are solely for the purpose of promoting ZT, and are apolitical, non-commercial and run by farmers. They offer an effective network for on-farm technology development and dissemination of new technology through farmer to farmer exchanges of experiences (Landers 2003). The creation of this network was driven by farmers' concern over land degradation due to inadequate land use practices.

2.3.3 Promotion of and Investment in CA in Latin America

There are various organisations that are interested in CA throughout Latin America. The FAO has been promoting the CA concept for over ten years through the Conservation Agriculture Working Group (CAWG), within the FAO Agriculture Department. It promotes the dissemination of information through workshops and international meetings, the 2001 Madrid Congress being a current high-profile example (Benites 2003). It has Joint activities with CIMMYT, GTZ, CIRAD and ECAF. CIMMYT is a professional, non-profit organisation that has been working to promote CA in Latin America, and the development of CA science, technology, and production methods (Ekboir (ed) 2002). However although investing in CA has been shown to be profitable and wise, financial institutions seem reluctant to promote it through their agricultural programs (Dauphin 2003). Investment projects can successfully promote CA through temporary subsidies; support to research and development conducted in partnership with farmers and the private sector; awareness building, to change the attitudes of farmers and their advisors; and policy reform.

3. Research Methods

3.1 General approach

The planning of this study was initially undertaken under the guidance of production and soil specialists, with the intention of applying practical costs to a field study in order to make a comparative analysis between the three local management systems. Through the collection of production costs, yield information, and an understanding of the technologies and credit available to local farmers, an attempt has been made to come up with information representative of a small farm in the local area.

3.2 Data sources

3.2.1 Sustainability Trial Yield Data

The long term experiment considered here was conducted under rain fed conditions at the CIMMYT research station (El Batan), which is located near Texcoco in the state of

Mexico (19° N, 99° W; 2249 masl). The area is characterized by long term maximum and minimum temperatures of 24° and 6 °C and average rainfall of 633 mm (long term range of 432-891 mm), and soil has developed on alluvial sediments (fine, mixed, thermic and Cumulic Haplustoll), with the top 50cm, showing vertisol features, while deeper layers are coarser and more variable (Sandoval Estrada, 1997). Yield data from the period 1996 to 2004 are considered in this study.

Individual plots in the experiment were 7.5 m x 22 m. Standard practices in the study included the use of currently recommended crop cultivars, with maize planted at 60,000 plants ha^{-1} in 75 cm rows and wheat planted in 20 cm rows at 100 kg seed ha^{-1}. All crops were fertilized at the rate of 120 kg N ha^{-1} using NH^4NO^3 or urea depending on availability, with all N applied to wheat at the first node growth stage (broadcast) and to maize at the 5–6 leaf stage (surface-banded). Weed control used appropriate, available herbicides as needed and no disease or insect pest controls were utilized, except for seed treatments applied by commercial seed sources. Planting of both maize and wheat depended on the onset of summer rains but was usually done between 5 and 15 June.

The yields obtained for the three management systems from the CIMMYT trial are shown in Table 2.

Table 2. Experimental yields for maize and wheat under conventional tillage (CT), zero tillage (ZT), and permanent bed (PB) systems, either removing, or partially removal crop residue, 1996-2004, El Batán, Mexico (kg/ha)

	TA Maize	**CA Maize**		**CA Wheat**	
	CT	**ZT**	**PB**	**ZT**	**PB**
YEAR	**R**	**P**	**P**	**P**	**P**
1996	3488	4023	4238	2798	4233.5
1997	3959	6981	5989	3746	3802
1998	4494	5784	5839	4396	3102
1999	732	961	962	3660	2291
2000	4974	6899	7112	6326	5657
2001	1838	7010	7378.5	5498	5352.5
2002	5426	7578	7458	7876	0
2003	2375	4310	4314	4310	4015.5
2004	3429	5899	5465.5	6683	5031
Mean	3413	5494	5417	5033	3721
St.dev	1529	2097	2057	1664	1759
Min	732	961	962	2798	0

Max	5426	7578	7458	7876	5657

3.2.2 Yield Data Discounting

The yields from the sustainability trial are generally superior to the yields of the average farmer in the study area. This is illustrated in Figures 1and 2, and Table 3, where the yields from the trial are compared to the yields of farmers from the State of Tlaxcala for the years 1996-2004. The aim of this comparison is to find a discount factor for yields to be used in the economic analysis of this study. In order to generate realistic figures for farmers' income from these practices, it is necessary to use expected farmer yields as well as costs. Historical data on the Tlaxcala wheat and maize yields were found on the Mexican State Level Database (SAGARPA 2005).

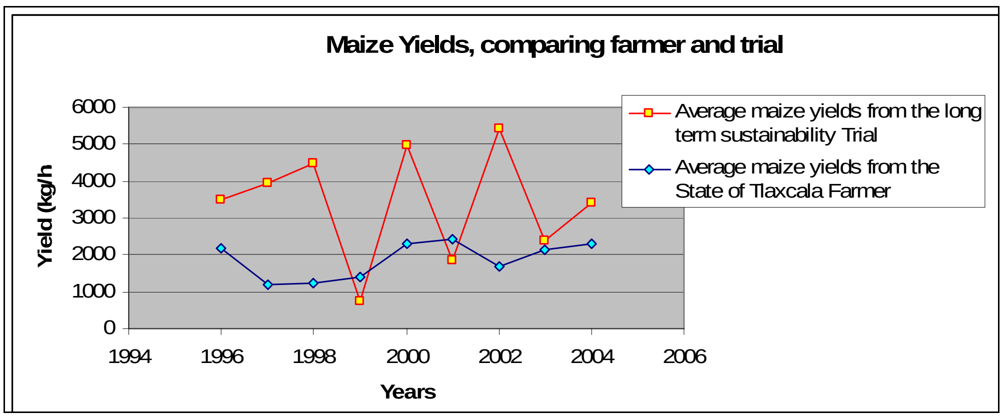

Figure 3. Average maize yields from the long term sustainability trial, El Batan and the Average maize production in the State of Tlaxcala, in the years 1996 to 2004

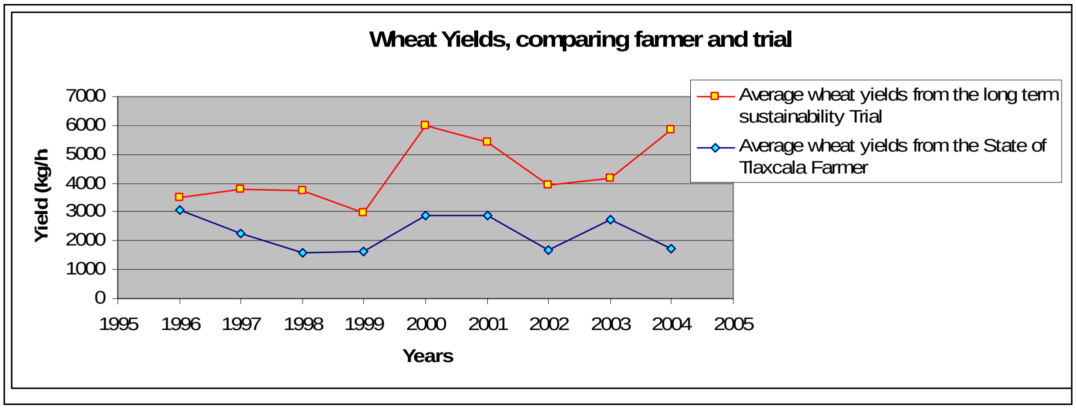

Figure 4. Average wheat yields from the long term sustainability trial, El Batan and the average wheat yield in the State of Tlaxcala, for the years 1996 to 2004

The average maize yields from the sustainability trial are the yields from the TA system from the years 1996-2004. The average wheat yields from the sustainability trial are the yearly averages of yields of wheat from the ZT and PB systems.

Table 3. Average yields for maize and wheat produced under rain fed conditions for the spring-summer period in the State of Tlaxcala, Mexico (kg/ha)

YEAR	Average Maize yields from the long term sustainability Trial	Average Maize yields from the State of Tlaxcala Farmer	Difference %	Average Wheat yields from the long term sustainability Trial	Average Wheat yields from the State of Tlaxcala Farmer	Difference %
1996	3488	2170	0.62	3515.75	3050	0.87
1997	3959	1210	0.31	3774	2240	0.59
1998	4494	1230	0.27	3749	1590	0.42
1999	732	1390	1.90	2975.5	1620	0.54
2000	4974	2290	0.46	5991.5	2880	0.48
2001	1838	2420	1.32	5425.25	2880	0.53
2002	5426	1680	0.31	3938	1670	0.42
2003	2375	2150	0.91	4162.75	2710	0.65
2004	3429	2300	0.67	5857	1750	0.30
Mean	3412.8	1871.1	0.75	4376.5	2265.6	0.54
St.dev	1529.19	492.94	0.55	1095.35	618.69	0.16
Min	732	1210	0.27	2975.5	1590	0.30
Max	5426	2420	1.90	5991.5	3050	0.87

From Table 3 we can see that the yields produced in the trial were higher than the average farmers' yields for wheat, in all years, and maize in most years. The farmers' yields were found as a percentage of the yield from the trial for each year. From this information it can be determined that the average farmers' maize and wheat yields are 75% and 54% respectively of the sustainability trial yield.

3.2.3 Survey Data

A series of on-farm surveys were conducted in the states surrounding the trial area (Tlaxcala, Puebla and Hidalgo) in June 2005[3]. The surveys were used to gather information from a small sample of small scale farmers on their individual costs of production, as well as their farming methods and systems in place. The translated version of the surveys used during this exercise can be found in APPENDIX 1 and 2. The cost tables derived from the information gathered in the surveys are found in Table 4 and Table 5 below.

Table 4. Cost table for Maize in the three management systems (MX$/ha)

	Traditional Agriculture	Conservation Agriculture	
	CT	**ZT**	**PB first year**
Labour	100	100	500 / 200
Land Preparation	1,500	0	0
Seeds	850	850	850
Sowing	400	400	400
Fertilizer	869	869	869
Herbicide	175	740	740
Fungicides	0	0	0.00
Harvesting	1,000	1,000	1,000
Machinery	167	167	167
Miscellaneous	225	225	225
Total	5,286	4,351	4,751 / 4,451

[3] 20 farmers were surveyed over a period of two weeks, ten wheat farmers and ten maize farmers. These farmers ranged from large to small. However it was later decided that this study would focus purely on the small scale farmers. This reduced the number of farmer surveys to three wheat farmers and three maize farmers.

Table 5. Cost table for Wheat in the CA management systems

	Conservation Agriculture	
	ZT	**PB**
Labour	100	500 / 200
Land preparation	0	0
Seeds	375	375
Sowing	250	250
Fertilizers	470	470
Herbicides	1,590	1,590
Fungicides	71	71
Harvesting	400	400
Machinery	0	0
Miscellaneous	150	150
Total	3,406	3,806 / 3,506

The price of labour was MX$100 per day (approximately AU$12), however the farmer is also expected to provide transport and meals for the labour that is hired. These extra costs are covered as miscellaneous costs. The cost of land preparation was highest for the TA management practice, CT (MX$1,500), and involved two passes with a plough and one pass of a furrow. There land preparation for permanent beds did not incur any extra cost, however the first year requires the labour intensive activity of forming the beds and the cepas, which leads to a labour cost of MX$500. However in the subsequent years, there is less need for labour as the beds only need maintenance and reshaping, therefore the labour costs reduce to MX$200 after the first year. The land preparation costs for ZT is also zero as the soil is left completely untouched after the previous crop. The cost of seed for wheat and maize reflected the prices paid by farmers in 2005. The sowing and harvesting costs are related to the renting or the running of the machinery.

The prices and application rates of fertilizers, herbicides and insecticides for the TA system are taken directly from the farmers. The products and application rates used by the farmers are different to those applied in the CIMMYT sustainability trial, which can explain their comparatively lower yields. The price and application rates of herbicide for the CA systems were taken from the CIMMYT trial. The CA literature has determined that the adoption of ZT generally is accompanied by an increase in weeds, which must be controlled by an increase in herbicides. The machinery costs in maize production are related to the depreciation or storage of machinery owned by the farmer. The detailed cost table of the small farmer can be found in APPENDIX 3.

3.3 Benefit Cost Analysis

A Benefit Cost Analysis (BCA) was performed on the three management systems in order to determine their net cash flows. The BCA is performed over a twelve year period, which is the life span of the zero tillage planters that need to be purchased in order to adopt CA technology. The costs will be representative of the costs of production of a small farm in the study region. The benefits will be representative of the yields and grain prices that small farmers of the study region can expect. The BCA is broken down into a project and a private BCA. These are described as follows:

1. **Project Analysis:** The Project benefit-cost analysis values all project inputs and outputs at private market prices (does not include tax, interest on loans etc.) and determines whether the project is efficient from a market perspective; and
2. **Private Analysis:** The Private benefit-cost analysis examines the proposed project from the private firm's perspective by taking the project analysis and netting out tax, interest and debt flows

This approach to BCA is taken from (Campbell 2005).

3.3.1 Financing

The adoption of CA technologies requires an initial investment by farmers into zero tillage planters for both maize and wheat. Small and inexpensive models, that are available to small farmer in the area, cost MX$120,000 and MX$150,000 respectively. In the study region, it is possible for farmers to invest communally in such machinery by joining a Society of Rural Production. This study assumes that nine farmers form a Society of Rural Production in order to communally invest together in the CA machinery. It is also assumed that the average farm size of the farmer is six ha.

A loan can be granted to members of the Societies of Rural Production for up to MX$300,000, for up to three years, at an interest rate of 12%. The machinery is assumed to have a life of twelve years and a salvage value of 10%. The cost of financing the investment is calculated in a per hectare form.

3.3.2 Price Indexing

Nominal prices for wheat and maize grain for the period, 1990-2005, for the state of Tlaxcala were taken from the Mexican State level Database *(SAGARPA 2005)* and were used to calculate index prices (Table 6).

Table 6. Nominal rural prices and real prices for wheat and maize in the State of Tlaxcala, spring to summer, 1996-2003 (MX$/kg)

		MAIZE price		WHEAT price	
Year	**CPI**	**Nominal**	**Real Price (2005)**	**Nominal**	**Real Price (2005)**
1990	0.19	0.63	4.32	0.56	3.80
1991	0.23	0.72	3.99	0.61	3.40
1992	0.26	0.75	3.62	0.60	2.90
1993	0.29	0.75	3.30	0.60	2.64
1994	0.31	0.60	2.47	0.60	2.47
1995	0.42	1.28	3.88	1.38	4.19
1996	0.56	1.55	3.52	1.27	2.88
1997	0.68	1.50	2.82	1.20	2.26
1998	0.78	1.67	2.70	1.29	2.09
1999	0.91	1.51	2.10	1.32	1.84
2000	1.00	1.23	1.56	1.20	1.52
2001	1.06	1.33	1.59	1.40	1.67
2002	1.12	1.42	1.62	1.33	1.51
2003	1.17	1.49	1.62	1.57	1.71
2004	1.22	1.69	1.75	1.58	1.64
2005	1.27	1.41	1.41	1.60	1.60

Source: (IMF-IFS 2005; SAGARPA 2005)

The prices obtained from the Mexican state level database are nominal prices and need to be corrected for inflation. The nominal price data was converted into real prices using the Consumer Price Index (CPI) for Mexico. The prices for each year were divided by the index number to come up with real price values. Real prices were then graphed to look for any trend (Figure 5).

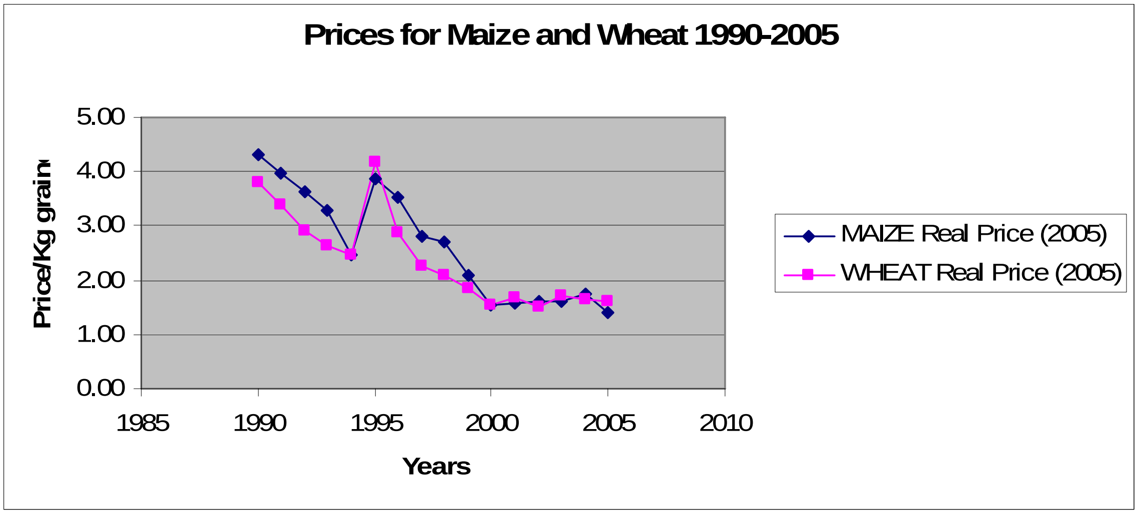

Figure 5. The Real Prices of Maize and Wheat in Mexico from 1990 to 2005

The gradual fall in prices from 1990 seem to have been interrupted in 1995, the year of NAFTA implementation. However after 1995 the prices have continued to fall at the previous rate, until 2000, after which the prices have maintained some stability for five years. The price for maize and wheat will be taken as an average of the Mexican real prices from 2000 to 2005. For maize and wheat the respective prices per kilogram of grain were MX$1.59/kg and MX$1.61/kg.

3.3.3 Yield Data Simulations

Because the yield data from the sustainability trial covers only nine years, an economic analysis program SIMETAR was used to simulate a distribution of yields for twelve years. Firstly, third order polynomial functions were fitted to the nine years of data were found for maize and wheat for the two CA management systems (Figure 6). The polynomial equation for each of the alternative CA management systems was then used to generate seven years of data following the same trend. The trend is meant to represent the first seven years in the adoption of CA technologies, where, according to CA theory, yield will decrease then increase and finally flatten out (Figure 1). This seems to be reflected perfectly in the CA management systems for both maize and wheat below, where in most cases the yields reduced, then rose and peaked at year seven.

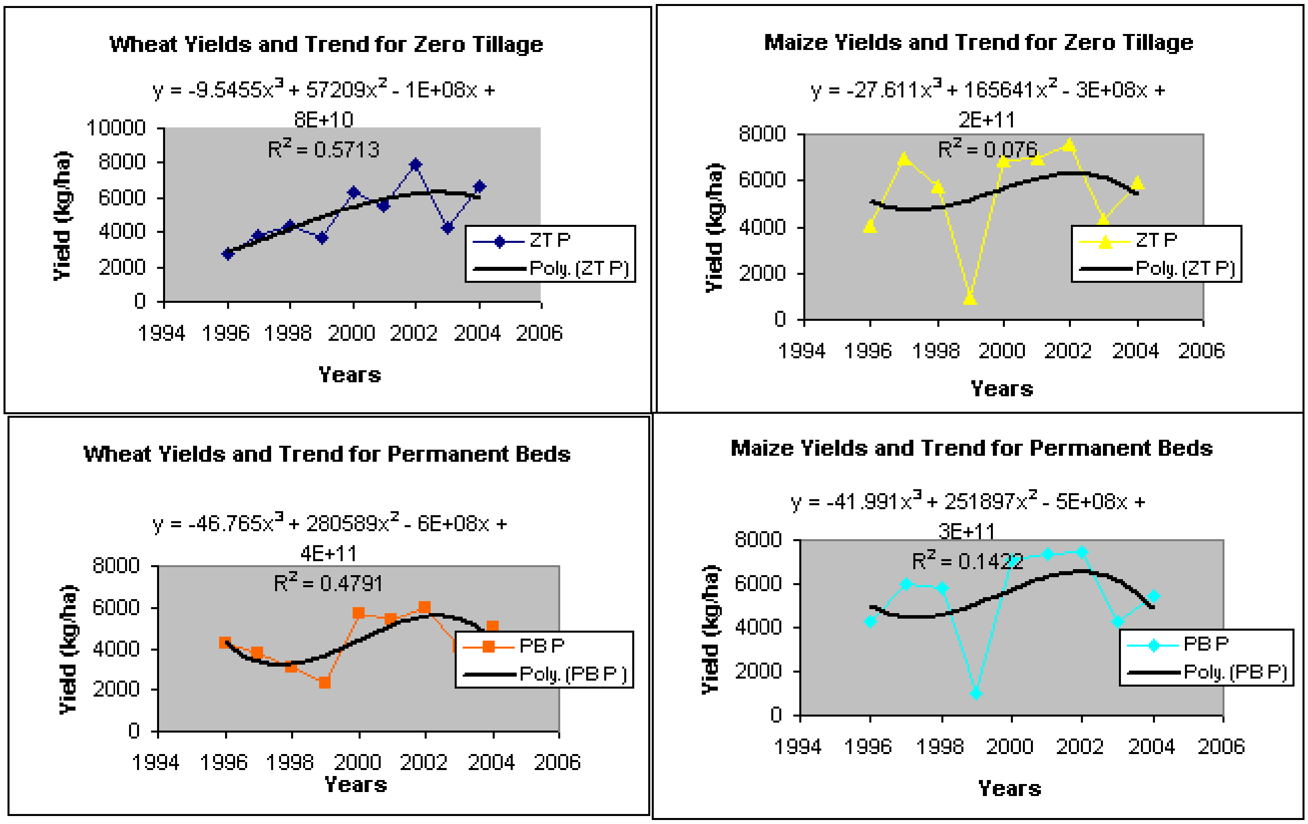

Figure 6. The Yield and Polynomial trends for Wheat and Maize in the two CA Management Systems

The TA management system was also graphed and a linear trend was added (Figure 7). Over the nine years, a negative trend was found and this was applied to the twelve years of simulated data.

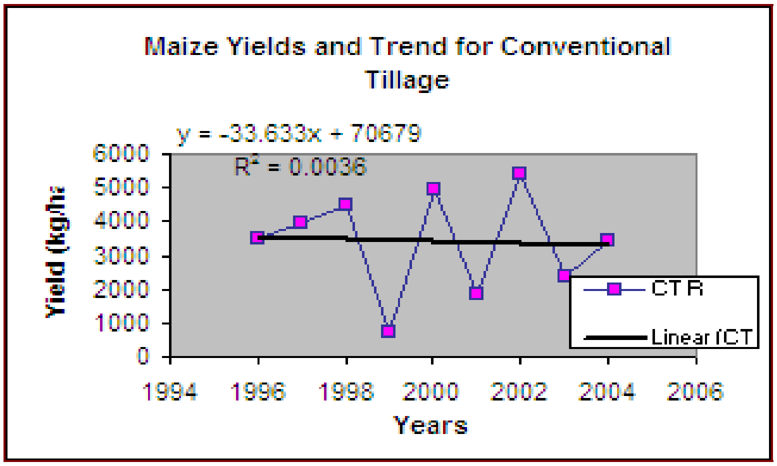

Figure 7. The Yield and Linear trend for Maize yield in the TA Management System

The yields to be used in this study must be representative of yields that can be produced by small farmers under rain fed conditions in the study area. (The average yields from farmers in the study area could not be used as a guide due to the large number of large farmers in the area, with increasing s efficiencies of scale and increasing average yields over time). The yield data to be used in this study will therefore be generated using the polynomial and linear trend data, calculated above, with a reasonable range of variability built into the data set, in order to represent the associated variable affects of farming in rain-fed conditions.

In order to simulate a suitable data set to represent twelve years of yields from the CA management systems, a PERT distribution function was employed to generate twelve random values using the minimum, maximum, and most likely values from the dataset of known values (nine years). The calculated trend line values were added as the median values in the PERT distribution for the first seven years. From the seventh year on until year twelve, the same value was used as the median. The minimum and the maximum values remained constant for the entire twelve years. The twelve linear trend values from the TA management practice were added as the median values in a PERT distribution function. This was used to simulate twelve years of decreasing yields with the random variability of the PERT function.

Due to the crop rotation in the CA management systems, all yield and cost of production information alternated from maize to wheat from year to year when it came to representing the data in a spreadsheet. Both ZT and PB used maize in the first year (Year 1), and wheat in the second year etc.

3.3.4 Derivation of Straw Yield Data

The straw yields from the sustainability trial were graphed against their associated grain yields for each management strategy in order to examine the relationship between the two variables. There was obvious correlation between the two, and it was decided that the straw data to be used in the study would be derived from the simulated grain yields. The straw yield was calculated as a percentage of the associated grain yield for each management strategy, and this percentage was then used to derive the straw data from the simulated yield data.

3.3.5 Discount rate

A discount rate of 12% has been used to reflect a risk margin of 4% above the long term Mexican Treasury Bond rate of 8%. The long-term bond rate can be considered to represent the social rate of time preference for money (Sinden 1995). The risk margin is necessary to incorporate the risks that are inherent in the rain-fed agricultural systems of the altiplano, due to both weather variability and commodity prices. The higher discount rate results in a lower present value of future benefits, which disadvantages the systems that have initial costs and future gains, such as the CA systems.

3.3.6 Net Present Values

The Net Present Value (NPV) of a project expresses the difference between the discounted present value of future benefits and the discounted present value of future costs: NPV = PV (Benefits) – PV (Costs) (Campbell 2005). The present value of future costs and benefits are discounted according to the discount rate. By applying the 12% discount rate to the private net cash flow, the discounted net cash flow can be found. The sum of the discounted cash flow is calculated to obtain the net present value of each system. The discount formula is:

Equation 1. Net Present Values

$$NPV = (B_t - C_t)/(1 + r)^t$$

Where t = a particular year of the management system, ranging from year 1 to year 30; $B_t - C_t$ = net cash flow in Year t; and r = the discount rate 0.12.

A positive NPV for a given project tells us that the project benefits are greater than its costs. A simple rule to follow is to accept any project that exhibits an NPV greater than zero, and when choosing between or ranking alternatives, choose the project with the greater NPV.

3.3.7 Internal Rate of Return

The internal rate of return (IRR) is the discount rate at which the NPV becomes zero (Campbell 2005). The IRR is a useful tool when it comes to determining whether the returns of the project will exceed the cost of financing the project. If the IRR is less than the discount rate, the project should be rejected. This IRR is only appropriate to use in cases where there is an initial investment and subsequent revenue, therefore it can only be used to compare the two CA management systems, as the TA management system requires no initial investment. The IRR and the NPV will give identical results for accept vs. reject decisions when considering an individual project. However, when comparing two mutually exclusive projects there is a chance that the IRR and NPV criteria will give conflicting results. This is only a problem when there is a cross over of discount rates, and in these cases the NPV should always be followed (Campbell 2005).

3.3.8. Payback Period

The payback period is the amount of time it takes for the initial outlay of investment money to be paid back, through the accumulation of positive net cash flows. It is a well known method of appraisal project investment possibilities (Anderson 1977).

3.4 Risk Analysis

In this study stochastic efficiency analysis, which is based on the notion of maximising expected utility, will be used to rank the risky alternatives. The risky decision alternatives are compared in terms of full distributions of outcomes, and comparisons are made at every point along the distribution.

3.4.1 Stochastic Dominance

The distributions were found by simulating 100 iterations of the NPV for each of the management strategies using the software program SIMETAR. An analysis of stochastic dominance with respect to a function (SDRF) was performed in order to find the most preferred management system. The systems were also compared according to their summary statistics. The results of the SDRF are illustrated in both stop light and cumulative distribution function graphs.

3.4.2 Cumulative Distribution Functions

Cumulative distribution functions show the probability of the farmer achieving a certain gross margin or NPV. The CDF shows the range of values that the NPV can take, and a probability of each individual value.

The cumulative distribution function (CDF) describes the probability distribution of a real-valued random variable, *X*. For every real number *x*, the CDF is given by:

Equation 2. Cumulative Distribution Function

$$F(x) = \mathrm{P}(X \leq x),$$

Which gives the probability of the random variable *X* taking on a value less than or equal to *x*.

3.5 Sensitivity analysis

The individual land holders may choose different discount factors to apply to their cash flow analysis depending on their different time preferences for money. Over a twelve year time span there is uncertainty over the appropriate discount rate so three discount rates were used: 8%, 12% and 16%. The NPVs for the different discount factors for the three management systems will be illustrated in CDF graphs.

The small farmer yields used to determine the cash flows for the three management systems were calculated as a percentage of the experimental yields obtained in the

CIMMYT long term sustainability trial. The average percentage difference was found to be 25% for maize and 50% for wheat. The average prices for maize was MX$1.59, and wheat was MX$1.61. A sensitivity analysis was performed on the three management systems to determine their likely NPV's in good, average and bad years, in relation to both yield and price. The bad and good yields and prices were +10% and -10% different from the means. Thus the maize and wheat yields were 65% and 40%; 75% and 50%; and 85% and 60% of the trial yields, in bad, average and good years respectively. The maize and wheat prices were MX$1.43 and MX$1.45; MX$1.59 and MX$1.61; and MX$1.75 and MX$1.77 in bad, average and good years respectively.

The number of farmers that invest communally in the machinery depends on the spatial proximity of farmers to each other, and the amount of land available to individual farmers. A sensitivity analysis was also performed to determine the NPV's of the two CA management systems with differing relationships between the variables Number of Farmers, and Size of Farm. From personal communication with Dagoberto Flores of CIMMYT El Batan, it was determined that the size of small farms in the study region ranges from two – ten ha. And the number of farmers that can form Societies of Rural Investment in order to communally invest collectively in machinery ranges from three to fifteen farmers (Flores, D., 2006, *Pers. Comm.)*. This analysis will investigate the feasibility of the project with communal investment by three, nine and fifteen farmers, with farm sizes ranging through two, six, and ten ha. This will determine the minimum number of farmers that can communally finance the projects in relation to their farm sizes. This is assuming that the farmers will divide the payment of investment on a per hectare basis.

The decision by small farmers to invest in machinery for CA management practices depends on the cost of machinery and the interest rates on loans. The machinery prices and interest rates available to farmers are likely to vary depending on the commercial sellers and banks that small farmers have access to. Low, Average and High machinery prices are found for PB and Very high machinery prices are considered as an extra option for ZT. The Low, Average and High interest rates used are 12%, 16% and 20% respectively.

4. Results and Discussion

This chapter presents the results of the private benefit cost analysis, the risk analysis of the management strategies, and the sensitivity analysis of each management strategy. The implications of the results of this study on the study group will also be discussed. This will include some discussion about the opportunities for the improvement of small farmer production, as well as other socio-economic factors that are relevant to the findings of this study.

4.1 BCA Results

Net Cash flows were found for the private BCA of each management system. The NPVs and IRRs for each system were calculated from these net cash flows. The NPV was calculated with a discount value of 12%. The rank was determined considering both the NPV and the IRR. The results are shown in Table 7.

Table 7. The net present value, internal rate of return and overall ranking of all three management systems

	NPV (12%)	IRR	Payback period	Rank
TA Management system				
CT	-617	N/A	N/A	3
CA Management systems				
ZT	4,136	45.5%	4 years	1
PB	2,738	27.0%	5 years	2

The ZT CA management system has been ranked as the best system, because it has the highest NPV and the highest IRR over the twelve year assumed life of the project.
Both the CA projects generated positive NPVs, but the NPV of the ZT option MX$4,136/ha was significantly higher than the NPV of the PB option, MX$2,738/ha. The CT TA management system on the other hand had an NPV of -MX$617/ha, which means that the costs of this system are greater than the revenue it creates. Over the twelve

years, that the system was evaluated there will be more negative outcomes than positive. ZT had an IRR of 46%, which is almost double that of the PB IRR of 27%.There is no IRR for the CT system because the TA management system does not require small farmers to make any initial investments. The payback period for the initial investment of MX$5,000 is four years for ZT, one year less than that of the PB management system. This is a reflection of the higher NPV of the ZT system.

4.2 Risk Analysis Results

The summary statistics for the risk analysis of each of the management options are shown in Table 8. This analysis shows that ZT has the highest mean at MX$6,120 NPV per hectare, and the lowest coefficient of variation. Both of these factors indicate that this is a low risk strategy that has a high probability of generating positive incomes for small farmers. The PB system has a negative mean NPVof -MX$73, and the highest coefficient of variation, which indicates that there is high variability in outcomes ranging from positive to negative. The CT system, which is most commonly used by small farmers, has a negative mean NPV of -MX$5,970/ha. The CT system has a low coefficient of variation, however coupled with its very low mean, this indicates that the probability of achieving a positive NPV is very low, in this base case scenario. ZT also has the greatest skewness at 0.57 and, looking at Figure 9, it is clear that this skewness is to the left. There is higher probability of generating an NPV at the lower end of the distribution.

Table 8. Risk Summary Statistics for the three Management Systems

Summary Statistics						
	Name	Mean	Std Dev	Coef Var	Skewness	Minimum
1	CT	-5,970.50	2,787.91	-46.69	-0.07	-12,794.40
2	PB	-73.19	1,980.23	-2,705.56	0.15	-4,654.49
3	ZT	6,119.53	2,354.15	38.47	0.57	1,552.46

The stochastic efficiency analysis was able to determine the most preferred management strategy by performing stochastic dominance with respect to a function analysis. Table 9 shows these results, which used a range of RACs ranging from -0.01 to +0.01. By the rules of first degree stochastic dominance the most preferred system was ZT, then PB and lastly CT. This means that the order of preference is not affected by attitude to risk. The preferred strategy, ZT, would be preferred by all decision makers.

Table 9. Results of the Analysis of Stochastic Dominance with Respect to a Function (SDRF) for the three management systems

Analysis of Stochastic Dominance with Respect to a Function (SDRF)					
	Efficient Set Based on SDRF at Lower RAC **-0.01**			Efficient Set Based on SDRF at Upper RAC **0.01**	
	Name	Level of Preference		Name	Level of Preference
1	ZT	Most Preferred	1	ZT	Most Preferred
2	PB	2nd Most Preferred	2	PB	2nd Most Preferred
3	CT	3rd Most Preferred	3	CT	3rd Most Preferred

Cumulative Distribution Functions for each of the management systems at a 12% discount rate are shown below in Figure 8. The fact that there is no cross over of the CDFs shows that the strategy to the right of the graph is the dominant strategy, will be preferred over all other strategies by all decision makers, irrespective of their attitude to risk. This graph therefore shows the undoubted superiority of the ZT system in regards to lower risk and higher returns. The ZT distribution ranges from about MX$2,000/ha to about MX$1,400/ha, and as mentioned before is strongly skewed toward the top end. The PB management system had a distribution ranging from about -MX$5,000 to about MX$5,000, and we can see that it crosses the y axes at 51%, indicating that it has about 50/50 chance of generating a positive NPV. The CT has the riskiest distribution of NPVs ranging from negative -MX$13,000 to about zero. It has the greatest spread, all of which is below zero, which guarantees that farmers that use this practice will generate not only negative NPVs, but are quite likely to be VERY negative NPVs.

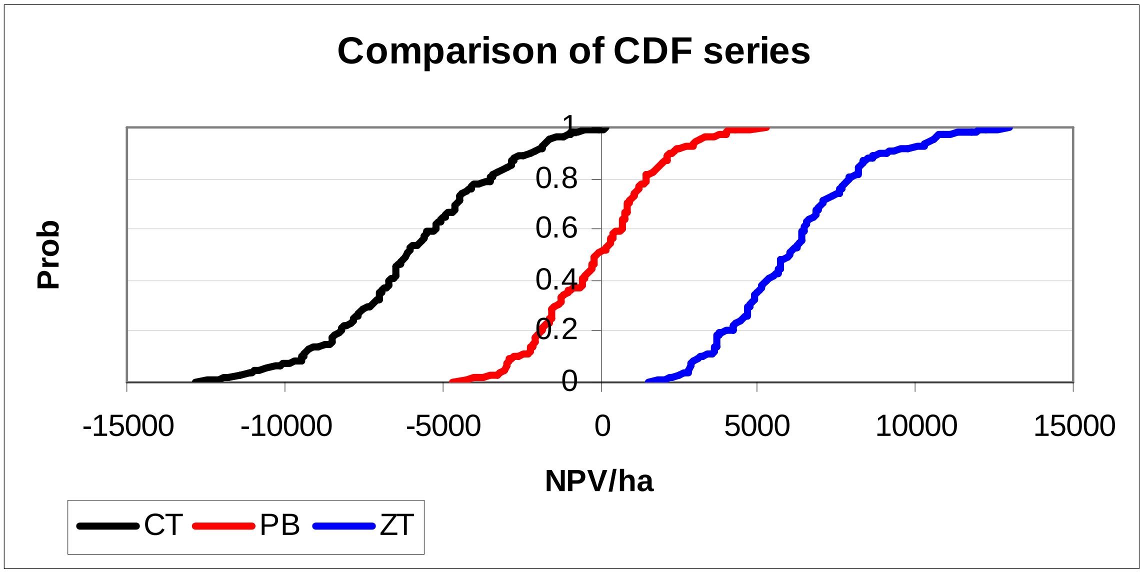

Figure 8. Cumulative Distribution Function for the three Management Systems

The Stoplight chart illustrated in Figure 9 shows the probabilities of each of the management systems generating NPVs less than zero or greater than MX$2,000/ha. The value of zero was chosen to show at what point NPVs are negative. The value of MX$2000 was chosen because on an average small farm size of six ha, the profit would be $12,000 which would be able to provide the family with a daily income of MX$100 for 120days, which is the average growth cycle of maize. The CT management system had a 99% probability of generating a negative NPV for the twelve years of the project, and there is no probability of generating an NPV greater than MX$2,000/ha. The PB system however has a 51% probability of producing an NPV of less than zero and a 15% probability of an NPV greater than MX$2,000/ha. The ZT management system on the other hand had a 99% success rate at producing NPV's greater than MX$2,000/ha.

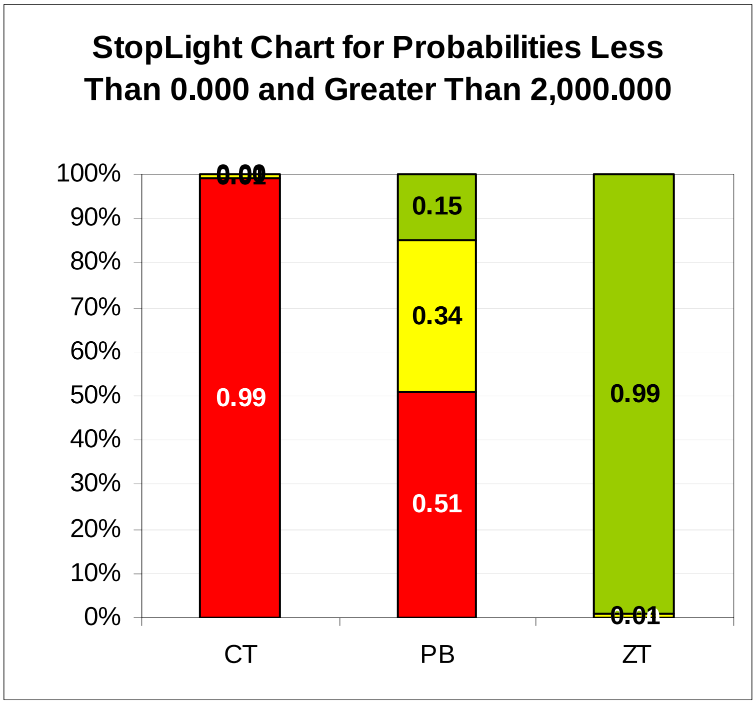

Figure 9. Stoplight Analysis for the 3 Management Systems

4.3 Sensitivity Analysis Results

4.3.1 Discount rates

CDFs of the individual management systems will be shown for 8%, 12% and 16% discount rates in order to determine the sensitivity of the NPVs to this variable. From this analysis we can conclude that the different options stay in the same order despite changing discount rates, and there are no cross-overs. The lower discount rates for each management systems, not surprisingly show greater NPVs than the higher discount rates. However because the NPVs of the TA system is always negative, the higher discount rates are seen to give less negative NPVs. The greater the discounting of future benefits at higher rates leads to this conclusion for TA. This could also be a reflection of the negative trend that was forced into the yields for the CT management system.

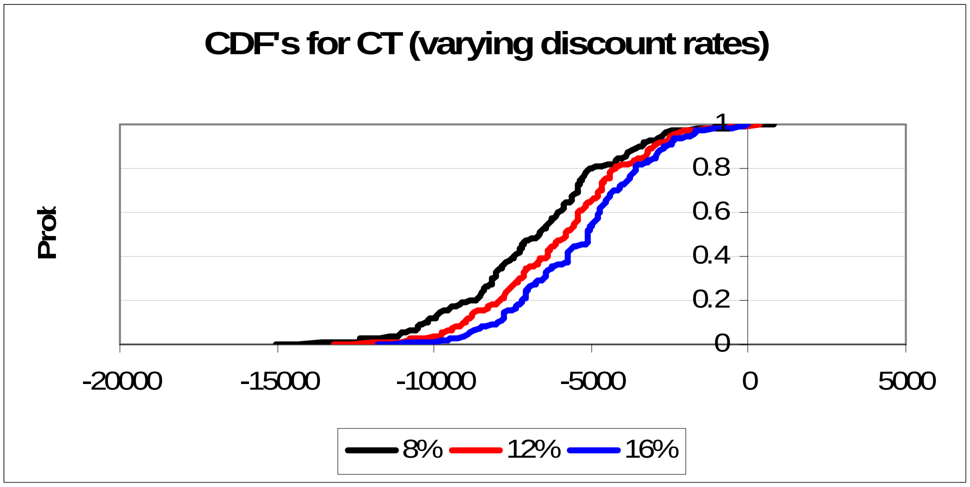

Figure 10. Cumulative Distribution Function for the TA management system, using 3 discount rates

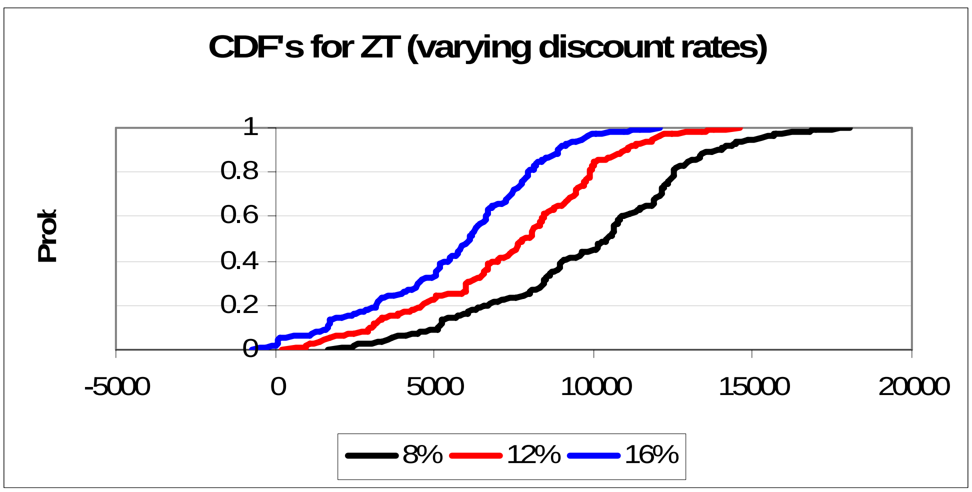

Figure 11. Cumulative Distribution Functions for the ZT management system (CA), using three discount rates

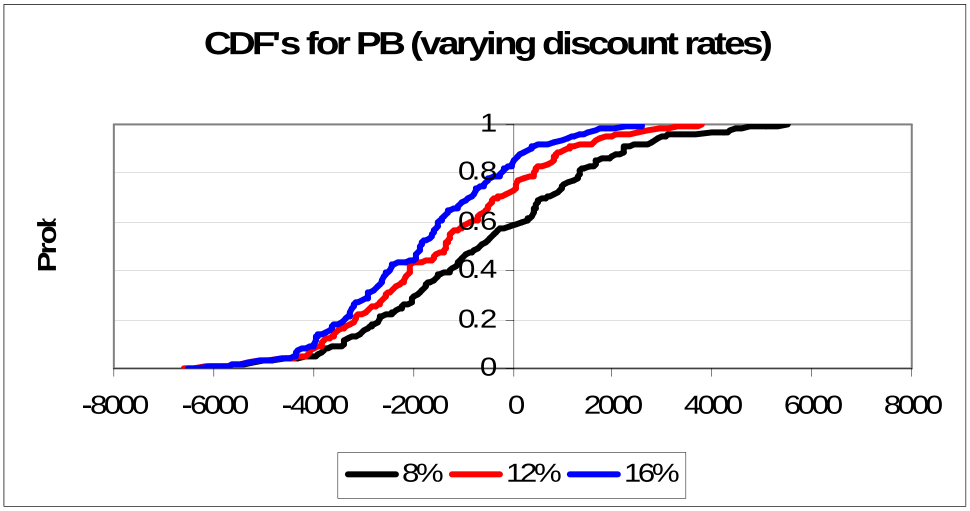

Figure 12. Cumulative Distribution Functions for the PB management system (CA), using three discount rates

4.3.2 Yield and Prices

The sensitivity of the values for the CT management system to the variability in yield and prices from bad to good is shown in Table 10. The NPVs will always be positive if there is a good yield. However with an average yield, there must be a high price in order for NPV to be positive. ZT demonstrates that it is capable of generating positive NPVs for all conditions except if both bad prices and bad yields occur together (Table 11). The sensitivity of the PB system to variability in yield and price is greater for PB than ZT. It runs the risk of generating larger negative NPVs when bad yields and bad prices are combined, however it produces higher NPVs than ZT in situations where yields are good (Table 12).

Table 10. Sensitivity Analysis for Yields and Price for Good, Average and Bad years in the CT Management System

Farmer Capacity output		**Prices (MX$)**		
CT		Maize 1.43	Maize 1.59	Maize 1.75
Yields		**Bad**	**Average**	**Good**
Maize=65%	**Bad**	$8,448.0	$5,699.2	$3,003.9
Maize=75%	**Average**	$3,590.4	**-$617.0**	$2,233.4
Maize=85%	**Good**	$928.4	$4,158.8	$7,362.3

Table 11. Sensitivity Analysis for Yields and Price for Good, Average and Bad years in the ZT Management System

Farmer Capacity output ZT		Prices (MX$)		
		Maize 1.43, Wheat 1.45	Maize 1.59, Wheat 1.61	Maize 1.75, Wheat 1.77
Yields		**Bad**	**Average**	**Good**
Maize=65%, Wheat=40%	**Bad**	-$989.3	$1,539.7	$4,003.5
Maize=75%, Wheat= 50%	**Average**	$1,469.9	**$4,136.1**	$6,780.9
Maize=85%, Wheat=60%	**Good**	$3,837.3	$6,708.5	$9,558.2

Table 12. Sensitivity Analysis for Yields and Price for Good, Average and Bad years in the PB Management System

Farmer Capacity output		Prices (MX$)		
		Maize 1.43, Wheat 1.45	Maize 1.59, Wheat 1.61	Maize 1.75, Wheat 1.77
Yields (%of experimental)		**Bad**	**Average**	**Good**
Maize=65%, Wheat=40%	**Bad**	-$4,704.4	-$2,239.8	$186.1
Maize=75%, Wheat= 50%	**Average**	-$91.0	**$2,738.3**	$5,553.5
Maize=85%, Wheat=60%	**Good**	$4,388.0	$7,639.3	$10,890.6

4.3.3 Size of Farms and Farmer Groups for CA Adoption

The feasibility of adopting CA technology by small farmers depends on the size of the farm and the size of the group of farmers that wish to invest collectively in the machinery. It was found in Table 13 that for the ZT project to be adopted it is not possible for farmer groups smaller than three farmers, unless they have farms over ten ha in size. Farmers with the small farm size of two ha, should not adopt the technology unless they form societies of 15 members. The NPVs will be positive if the farm size and farmer group size are both average (nine farmers, each with six ha of land) or higher. For the PB project, it is not feasible for societies of three members to invest in the machinery, no matter how large their farm size, and farmers with two ha or less will not generate positive NPVs no matter how many members in the society (Table 14). An average farm and farmer group size or higher will always generate positive NPVs.

Table 13. Sensitivity Analysis for the Size of Farms and Farmer Groups in the ZT Management System

Farmer Communal Buying ZT		Number of Farmers involved in communal investment		
		3 Farmers	9 Farmers	15 Farmers
Size of Farm		**Few**	**Average**	**Many**
2ha	**Small**	-$34,345.7	-$5,440.5	$305.5
6ha	**Average**	-$5,440.5	**$4,136.1**	$6,051.5
10ha	**Large**	$305.5	$6,051.5	$7,194.8

Table 14. Sensitivity Analysis for the Size of Farms and Farmer Groups in the PB Management System

Farmer Communal Buying PB		Number of Farmers involved in communal investment		
		3 Farmers	9 Farmers	15 Farmers
Size of Farm		**Few**	**Average**	**Many**
2ha	**Small**	-$36,850.6	-$7,095.1	-$1,195.1
6ha	**Average**	-$7,095.1	**$2,738.3**	$4,704.9
10ha	**Large**	-$1,195.1	$4,704.9	$5,884.9

4.3.4 Financing the Adoption of CA

The financing of an investment in machinery by the farmers is dependent upon the price of the machinery and the interest rate available on the loans. For the ZT project, it was found that it did not matter if the price or the interest rate was high, average, or low, the NPV would always be positive (Table 15). The same case applies for the PB project except that the NPV is lower for each condition (Table 16). However for both projects it can safely be said that the investment of machinery up to MX$330,000 would be feasible.

Table 15. Sensitivity Analysis for the Price of Machinery and the Loan Interest Rate in the ZT Management System

Adoption		Loan Interest Rate		
		20%	16%	12%
Machinery Price		**High**	**Average**	**Low**
Maize Planter $150,000, Wheat Planter $180,000	**High**	$2,457.0	$2,767.6	$3,072.0
Maize Planter $120,000, Wheat Planter $150,000	**Average**	$3,632.9	$3,887.0	**$4,136.1**
Maize Planter $60,000, Wheat Planter $150,000	**Low**	$4,808.8	$5,006.4	$5,200.2

Table 16. Sensitivity Analysis for the Price of Machinery and the Loan Interest Rate in the PB Management System

Adoption PB	Loan Interest Rate

		20%	16%	12%
Machinery Price MX$		**High**	**Average**	**Low**
Maize Planter 150,000, Wheat Planter 180,000	**High**	$1,030.6	$1,341.2	$1,645.7
Maize Planter 120,000, Wheat Planter 150,000	**Average**	$2,235.0	$2,489.1	**$2,738.3**
Maize Planter 60,000, Wheat Planter 150,000	**Low**	$3,439.5	$3,637.1	$3,830.9

4.4 Socio-economic Discussion

The results from this study have indicated that ZT P, and PB P, land management systems generate higher yields, lower costs, and higher incomes than the incumbent TA management system.

The ZT P system also demonstrates less income variability over years, indicating a decrease in risk. This outcome would lead to the conclusion that CA practices, especially those of ZT P should be encouraged for use by small farmers in the trial area.

One of the main findings of this study is that TA is generating negative returns for small farmers in the study area. Why is it then that so many farmers continue to use this practice when it is of no economic benefit to them?

During the surveys this issue was discussed with the small farmers and it was found that the farmers were deeply aware of the downward trend in their incomes and production over time. Small farmers today recognise that the economic viability of their farms is not the same as in the time of their fathers. However in the altiplano of Mexico, as in Australia, farming is a lifestyle which is passed down from generation to generation- not only is the land passed on, but also the practices. Therefore a change in the on-farm practices is seen as a change in lifestyle- it is unknown and therefore a major risk in social rather than economic terms.

As mentioned in the Chapter 2 a number of socio-economic reasons behind non-adoption of soil conservation technologies were outlined by Dixon, 2005. The most relevant reasons for this study are that:

1. Farmers feel that they are unlikely to reap expected benefits because of a lack of secure access to land.

The majority of small farmers in the study area live in a system of *ejido*, which is a form of communal farming brought into practice by President Alvaro Obregon (1920-1924) in order to redistribute large landholdings to Mexico's poor and exploited rural workers. Under this arrangement, a group of villagers could petition the government to seize private properties over a certain size. If their petition was successful the government would then expropriate the property and create an *ejido*. The villagers, now known as *ejidatarios*, were granted the right to farm the land, either in a collective manner or through the designation of individual *parcelas*, however the state retained title to the land. *The ejidatarios* therefore do not have complete property rights to land- their rights are attenuated to limit the use of their land, and therefore reduce their incentives to use their land in a long term and sustainable way. The *ejidatarios* land rights are not transferable, so they cannot sell or mortgage their land, but can only pass usufruct rights to their heirs. Nor are the land rights durable, as the *ejidatarios* have to work their land regularly in order to maintain rights over it. It is therefore very difficult for *ejidatarios* to gain access to loans as their land is not recognized as a guarantee. However the formation of Societies of Rural Production gives small farmers the opportunity to combine their resources in order for banks to recognize a guarantee. This does not however remove the doubt in the farmer's mind that one day the land may be taken away by the government, and therefore so long as the land is held in *ejido* the farmers will lack the incentive to invest in CA technologies that will improve the long term value of the land that they manage.

2. Farmers believe that the economic contribution of their plots to their livelihoods is so small that it is not worth investing time and money in improving their plots

The reason that small farmers in the study area are able to survive using the TA system is because it is not their only source of income. Other on- and off-farm activities help to supplement the income of the small farmer including:

- More intensive use of land (More than one crop/year)
- Keeping of livestock
- Planting a crop of beans for the family's personal use
- Taking off farm work

The long term sustainability trial used the land to produce one crop of wheat or maize per year, and it was left fallow for the rest of the year. This would almost never happen in a small farm situation where the opportunity cost of leaving the land vacant is too high. Therefore the results of this study would change if the yields were able to reflect a more intense use of the land. The negative returns of TA mean that the family on the farm would not survive unless they went to extra lengths to feed and finance themselves. It was found during the surveys that the majority of small farmers grew a small plot of beans for their own personal consumption.

The need for small farmers to seek off-farm employment to finance their on-farm activities brings into question the viability of the existence of small farmers now and in the future. This study has shown however that the adoption of CA technologies can reduce costs and increase farm profitability thereby reducing the need for farmers and their families to seek off farm employment. This could have benefits to the children of small farmers who will be given a better opportunity to gain education, rather than working to support the family. By increasing the economic gains to small farmers from their crops, the CA technologies can help to justify the continuing existence of small farmers in agriculture and therefore reduce their likelihood of them being forced from their land and away from their traditional lifestyle.

5. Conclusions and Recommendations

This study has found that there is a clear opportunity to improve the economic viability and long term sustainability of small farmers in the study area by the adoption of CA technologies.

Investment in the ZT management strategy was found to be the best option for farmers, where the short term costs of investment were far outweighed by the longer term benefits.

The CA management strategy was also found to be a much better option for the small farmers compared to their existing TA management system.

Through this study, the TA management system was found to exhibit two negative aspects of high production costs, and decreasing yields over time.

This study was not without limitations. The major problem was the short amount of time and planning available to conduct the surveys. Although a lot of information was gathered during the two week period that the author spent on the task, much of it was unable to be used, due to the focus of this study solely on small scale farmers. Some information, such as the cost of harvesting, was also gathered in a per hectare basis, instead of a per kilogram, which could cause slight biases in the results of this study in favor of CA technologies.

Another limitation of this study is that it only focused on two forms of CA technology. The CIMMYT long term sustainability trial includes 32 different combinations of crop rotation, residue management, and tillage operations, and more of these should be investigated as options for farmers in the study area. Of these it would be interesting to see the results of crop rotations with beans, or the mono-cropping of wheat or maize with other CA technologies, which would reduce the initial investment costs of the projects. The yield data from the CIMMYT long term sustainability trial was for nine years, but it would be interesting to see the longer term effects of these technologies on crop yields and to compare these with the simulated crop yields from this study.

From the conclusions of this study it is possible to come up with recommendations for future action concerning small farmers in the study area.

It is recommended that:

- Mexican SAGARPA give a policy response, by increasing the availability of both two and four row zero till planters for both maize and wheat and support the investment into these pieces of machinery by Societies of Rural Production.
- Small farmers should be encouraged to form Societies of Rural Production, as a form of empowerment, increasing their longer term viability and improving their ability to gain access to credit and other forms of support.
- Extension and training programs should be provided to these societies including extension of different options available to them in the suite of CA technologies and training in the bureaucratic processes involved in gaining access to credit.
- The CA management system of ZT should be actively promoted as it is the best option available to small farmers to increase their incomes by cost saving and yield increases. It is also the best option in terms of risk, with the lowest coefficient of variation, the highest mean, and the lowest likelihood of producing a negative NPV.
- Innovative farmers should be contacted about the opportunity to trial the management system on their farms. They should follow the procedure of forming a Society of Rural Production if they are not yet members, gain access to a loan, and purchase the zero till planters. The process should be highly publicized and annual open days should be held for other farmers to see the outcomes of their projects.

In conclusion this study establishes that the TA management systems of the small farmers of the states of Tlaxcala, Puebla and Hidalgo are not sustainable and that the costs of production are greater than the revenues. For small farmers to retain their lifestyles they must change their practices and the best way for this to be achieved is through the adoption of CA technologies.

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7. Appendices

Appendix 1: Survey format for on-farm research into operational costs for Wheat or Barley

Name of Producer:____
Address:____
State:________________________ Tel. ____________________
Name of land:______________________________
Name of owner:____________________________ Date: ______________

Production costs for wheat culture

Crop: Wheat or Barley

Land Preparation	No. times	$/ha/labour	Labour/ha (days)
Disc harrow			
Field cultivator			
Plough			
Disc harrow			
Levelling of the ground			
Furrowed for seedtime in beds			
Coating of the furrow for beds			
Stocks			

PLANTING Sowing **Sowing method:** 1=**Zero Till** 2= Conventional farming 3= Conservation farming	No. of man days	$/ha	**Variety**	kg./ha	$/kg.	**Seed source**
With machinery						
Manual (or with animal power)						
Seeding Disc harrow						

FERTILIZER	**Type of fertilizer**	kg./ha.	$/kg.	Labour/ha (days)
1st. application: With machinery **:** Manual :				
2nd. application: With machinery **:**				

Manual:				

Herbicide application	Applied product	Lt./ha.	kg./ha.	Active ingredient	$/lt./ $/kg.	Application cost	Labour/ha (days)
Machinery **Manual**							

Insecticide application	Applied product	Lt./ha	kg./ha .	Active ingredient	$/lt./ $/kg.	Application cost	Labour/ha (days)
Machinery **Manual**							

Fungicide application	Applied product	Lt./ha.	kg./ha.	Active ingredient	$/lt./ $/kg.	Application cost	Labour/ha (days)
Machinery **Manual**							

Harvest					
Combined ($/ha)	**Yield** kg./ha	**Price of wheat** ($/ton)	**Humidity**	**Discount** $/ton	**Transport** ($/ton)

Price of straw Straw price							
No. of bales	Kg./straw	$/ha collect straw	$/bale to bale	$/bale	$/kg straw unbaled	Pasture $/ha.	In Field $/ha.

OTHER COSTS	
Wage rate	
Family or hired labour	
Extra expenses (meals, transport)	
Crop rotation	
Do you have access to credit? /Source	

/Interest rate	

How long have you used this same system? ______ years.

Why did you choose this system? ____

What are the advantages of your system? _____________________________

What are the disadvantages of your system? __________________________

How did you learn this system? ____

Appendix 2. Survey format for on-farm research into operational costs for Maize

Name of Producer: ____
Address: ____
State: _________________________ Tel. ____________________
Name of land: _______________________________
Name of owner:_____________________________ Date: ______________

Production costs for maize culture

Crop: Maize

Land Preparation	No. times	$/ha/labour
Disc harrow		
Field cultivator		
Plough		
Disc harrow		
Furrow		
Cepas (dams in between furrows for permanent beds)		
Subsoil		

Planting	$/ha	Labour/ha (days)	**Variety**	Kg./ha	$/kg.	**Seed source**
With machinery						
With animal						
Manual						

Herbicide application	Applied product	Lt./ha	kg./ha	Active ingredient	$/lt./$/kg.	Application cost	Labour/ha (days)
Machinery **Manual**							

Insecticide application	Applied product	Lt./ha	kg./ha	Active ingredient	$/lt./$/kg.	Application cost	Labour/ha (days)
Machinery **Manual**							

Fertilizer	**Type of fertilizer**	kg./ha.	$/kg.	Labour/ha (days)
1st. application: With machinery **:** Manual :				
2nd. application: With machinery **:** Manual:				

Harvest	Threshing machine $/ha	Manual Cut and collect Labour/ha (days)	Transport $/ha $/ton	Yield Kg./ha	Price of the grain $/ton
Maize (grain)					
Cob					

En graño greña

Price of straw Straw price							
No. of bales	Kg./straw	$/ha collect straw	$/bale to bale	$/bale	$/kg straw unbaled	Pasture $/ha.	In Field $/ha.

Other Costs	
Wage rate	
Family or hired labour	
Extra expenses (meals, transport) $/ha	
Crop rotation	
Access to credit? /Source **/Interest rate**	

How long have you used this same system? _______ years.

Why did you choose this system? ____

What are the advantages of your system? ______________________________

What are the disadvantages of your system? ___________________________

How did you learn this system? ____

Appendix 3. Detailed Costs of Production of the Small Farmer in the trial area

Small Farmer Costs of Maize Production, Tlaxcala

MAIZE	Quantity	Price	Total
Land Preparation $/ha			
Plough (Barbecho)	2	500	1000
Furrow (Rastreo)	1	500	500
Planting $/ha (use of common seeder)			
Seeds bag/ha	1	850	850
Seeding	1	400	400
Labour	0.13	100	13
Fertilizer $/ha			
First Application w/ seeder			
Product 18-46-00	120	3.4	408
Second Application			
Product Urea	160	2.88	460.8
labour	0.3	100	30
Herbicide $/ha			
Product	1	175	175
Labour	0.13	100	13
Other cost machine	1	167	167
Harvesting $/ha			
Cost to harvest	1	1000	1000
Yield ton/ha	7	17000	119000
Price/ton		17000	
Cost to transport $/ton	1	60	60
Value of hay removed $/ha	1	500	500
Extra Costs	1	225	225

Small Farmer Costs of Maize Production, Tlaxcala

WHEAT	Quantity	Price	Total
Land Preparation $/ha			
Furrow (Rastreo)	2	300	600
Disc harrow (Subsuelo)	1	450	450
Planting $/ha (use of common seeder)			
Seeds kg/ha	125	3	375
Seeding	1	250	250
Labour	0.13	100	13
Fertilizer $/ha			
First Application w/ seeder			0
Product Urea kg/ha	100	3	300
Product 18-46-00	50	3.39	169.5
Labour	0.1	100	10
Herbicide $/ha			

Product Esteron	2	55	110
Product Harmony	0.2	130	26
Labour	0.3	100	30
Fungicide l/ha	0.125	570	71.25
Harvesting $/ha	1	400	400
Yield ton/ha	3.5	16000	56000
Price/ton		16000	
Cost to transport $/ton	1	50	50
Value of hay removed $/ha	1	360	360
Extra Costs	1	150	150

Summary of Small Farmer Costs of Maize Production, Tlaxcala

	Maize	Wheat
	CT	CT
Land preparation	1500	1050
Price of seed	850	375
Cost to sow	400	250
Fertilizers	868.8	469.5
Herbicides	175	136
Fungicides	0	71.25
Cost to harvest	1000	400
Extra costs	225	150
Labour	56	53
Machinery	167	0
Transportation costs	420	175
Variable Costs	4961.8	3129.75

Price of grain $/ton	17000	16000
Value of hay (in field)$/ha	500	360

Appendix 4. Benefit Cost Analysis for TA management system

Table 1: Key Variables			
Working Capital	Costs	interest rate	
interest	$4,286	15.0%	643
TOTAL			$643
Discount rate =	8.0%	12.0%	16.00%
Tax rate on profits =	15.0%		

-

MAIZE	
Operating Costs	
Independent	**Cost/ha**
Casual labor (days)	100
Land Preparation	1500
Seeds (60000seed bag)	850
Sowing	400
Fertilizer	869
Herbicide	175
Harvesting	1000
Machinery	167
Miscellaneous	225
Total	$5,286
Dependent	**Cost/kg**
Transport Grain (kg)	0.06
Revenues	**Price/kg**
Maize (kg)	1.59
Straw (kg)	0.27
Straw rshp with grain	1.78

	Farmer Capacity Output	
All Years	75%	-

TABLE 2: PROJECT NET CASH FLOW

ITEM/YEAR	0	1	2	3	4	5	6	7	8	9	10	11	12
Experimental yields													
Maize		5135	2074	4244	3953	4033	4138	4528	4149	3454	2675	4371	4064
Small Farm Yields													
Maize Yield		3851	1555	3183	2965	3025	3103	3396	3112	2591	2007	3279	3048
Straw Yield		6856	2769	5666	5278	5385	5524	6045	5539	4611	3572	5836	5425
Investment costs													
Working Capital		-642.9	-642.9	-642.9	-642.9	-642.9	-642.9	-642.9	-642.9	-642.9	-642.9	-642.9	-642.9
Total Investment		-642.9	-642.9	-642.9	-642.9	-642.9	-642.9	-642.9	-642.9	-642.9	-642.9	-642.9	-642.9
Operating Costs													
Independent		-5285.8	-5285.8	-5285.8	-5285.8	-5285.8	-5285.8	-5285.8	-5285.8	-5285.8	-5285.8	-5285.8	-5285.8
Dependent		-231.1	-93.3	-191.0	-177.9	-181.5	-186.2	-203.8	-186.7	-155.4	-120.4	-196.7	-182.9
Total Costs		-5516.9	-5379.1	-5476.8	-5463.7	-5467.3	-5472.0	-5489.6	-5472.5	-5441.2	-5406.2	-5482.5	-5468.7
Revenues													
Grain		6123.8	2473.1	5060.8	4714.5	4809.8	4934.0	5400.1	4947.5	4118.9	3190.5	5212.9	4845.9
Straw		1,851.0	747.5	1,529.7	1,425.0	1,453.8	1,491.4	1,632.3	1,495.5	1,245.0	964.4	1,575.7	1,464.8
Totals		7974.9	3220.6	6590.5	6139.6	6263.6	6425.4	7032.4	6443.0	5363.9	4154.8	6788.5	6310.7
Net Cash Flow		1815.1	-2801.4	470.9	33.0	153.4	310.5	900.0	327.6	-720.2	-1894.3	663.1	199.2
(Before Financing & Tax)													
	8%	**12%**	**16%**										
NPV=	**$11,447.9**	**$9,768.9**	**$8,498.1**										

TABLE 3: PRIVATE NET CASH FLOW													
ITEM/YEAR	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
(i) Financing													
Principal													
Loan													
Overdraft													
Interest													
Loan													
Overdraft													
Net Financing Flows													
NCF(equity, pre-tax)		1815.1	-2801.4	470.9	33.0	153.4	310.5	900.0	327.6	-720.2	-1894.3	663.1	199.2
(ii) Taxes													
Revenues		7974.9	3220.6	6590.5	6139.6	6263.6	6425.4	7032.4	6443.0	5363.9	4154.8	6788.5	6310.7
Operating Costs		-5516.9	-5379.1	-5476.8	-5463.7	-5467.3	-5472.0	-5489.6	-5472.5	-5441.2	-5406.2	-5482.5	-5468.7
Interest on loans		-642.9	-642.9	-642.9	-642.9	-642.9	-642.9	-642.9	-642.9	-642.9	-642.9	-642.9	-642.9
Profits (before tax)		1815.1	-2801.4	470.9	33.0	153.4	310.5	900.0	327.6	-720.2	-1894.3	663.1	199.2
15% Tax		272.3	-420.2	70.6	4.9	23.0	46.6	135.0	49.1	-108.0	-284.1	99.5	29.9
Taxes Liable		-272.3	0.0	-70.6	-4.9	-23.0	-46.6	-135.0	-49.1	0.0	0.0	-99.5	-29.9
(iii) Equity (after tax)													
Private Cash Flow		1542.8	-2801.4	400.2	28.0	130.4	263.9	765.0	278.5	-720.2	-1894.3	563.7	169.3
	8%	**12%**	**16%**										
NPV =	**-$768.6**	**-$617.0**	**-$503.5**										

Appendix 5. Benefit Cost Analysis for ZT management system

Table 1: Key Variables		MAIZE		WHEAT

Investment Costs	**No.**	**Price**	**Cost**
Fixed Investment	(units)	($)	
Maize Planter	1	120,000	120,000
Wheat Planter	1	150,000	150,000
Total			270,000
No. Farmers in Cooperative			9
Average farm size (ha)			6
Total Cost/ha			$5,000
Working Capital			
Interest Maize	3351	15.0%	$503
Interest Wheat	3006	15.0%	$451
Total			
Salvage Value			
Maize and Wheat Planter		10%	$500
Depreciation	**Life(yrs)**	**Amount p.a.**	
Maize Planter	12	1,111	
Wheat Planter	12	1,389	
Total		2,500	
Financing	**Amount**	**Interest**	Life (yrs)
Loan	$4,000	12.0%	3
Overdraft	$1,000	8.0%	1
Discount rate =	8.0%	12.0%	16.00%
Tax rate on profits =	15.0%		

Operating Costs		
Independent		**Cost/ha**
Labour		100
Land Preparation		0
Seeds (60000seed bag)		850
Sowing		400
Fertilizer		869
Herbicide		740
Fungicides		0
Harvesting		1000
Machinery		167
Miscellaneous		225
Total		$4,351
Dependent		**Cost/kg**
Transport Grain (kg)		0.06
Revenues		**Price/kg**
Maize (kg)		1.59
Straw (kg)		0.27
Straw rshp with grain		1.77
% Straw removed	70%	
Farmer Capacity Output		
All Years	75%	

Operating Costs		
Independent		**Cost/ha**
Labour		100
Land preparation		0
Seeds		375
Sowing		250
Fertilizers		470
Herbicides		1590
Fungicides		71
Harvesting		400
Machinery		0
Miscellaneous		150
Total		$3,406
Dependent		**Cost/kg**
Transport Grain (kg)		0.05
Revenues		**Price/kg**
Wheat (kg)		1.61
Straw (kg)		0.27
Straw rshp with grain		1.13
% Straw removed	60%	
Farmer Capacity Output		
All Years	50%	

TABLE 2: PROJECT NET CASH FLOW

ITEM/YEAR	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
Experimental Yields													

Maize		5538	1973	3916	3076	3514	4720	4918	3337	4561	5580	5136	3853
Wheat		4174	2076	1657	2418	2502	3242	2550	3814	3345	2756	2421	2420
Small Farm Yields													
Maize grain yield		4154	1480	2937	2307	2635	3540	3688	2503	3421	4185	3852	2890
Maize straw yield		7352	2619	5199	4083	4665	6265	6529	4430	6055	7407	6818	5115
Wheat grain yield		4355	2167	3130	3332	2947	2893	3113	2914	2162	2394	3347	2871
Wheat straw yield		4922	2449	3537	3765	3330	3269	3518	3293	2443	2706	3782	3244
Investment costs													
Fixed Investment	-5000.0												500
Working Capital		-502.6	-450.9	-502.6	-450.9	-502.6	-450.9	-502.6	-450.9	-502.6	-450.9	-502.6	-450.9
Total Investment	-5000.0	-502.6	-450.9	-502.6	-450.9	-502.6	-450.9	-502.6	-450.9	-502.6	-450.9	-502.6	49.1
Operating Costs													
Independent		-4350.8	-3405.8	- 4350.8	- 3405.8	- 4350.8	- 3405.8	- 4350.8	- 3405.8	- 4350.8	- 3405.8	- 4350.8	- 3405.8
Dependent		-249.2	-108.4	-176.2	-166.6	-158.1	-144.7	-221.3	-145.7	-205.3	-119.7	-231.1	-143.5
Total Costs		-4600.0	-3514.1	- 4527.0	- 3572.3	- 4508.9	- 3550.4	- 4572.1	- 3551.5	- 4556.1	- 3525.5	- 4581.9	- 3549.3
Revenues													
Grain		6604.1	3489.3	4669.9	5364.4	4190.3	4658.2	5864.6	4691.9	5439.5	3854.7	6124.9	4622.0
Straw		1985.0	661.2	1403.6	1016.6	1259.4	882.7	1762.7	889.1	1634.9	730.5	1840.9	875.9
Totals		8589.1	4150.5	6073.6	6381.0	5449.7	5540.9	7627.3	5581.0	7074.5	4585.2	7965.9	5497.9
Net Cash Flow	-5000.0	3486.5	185.6	1043.9	2357.8	438.2	1539.6	2552.6	1578.7	2015.8	608.9	2881.3	1997.8
(Before Financing & Tax)													

	8%	**12%**	**16%**
NPV=	**$7,879.4**	**$5,587.3**	**$3,907.4**
IRR=		**34.6%**	

TABLE 3: PRIVATE NET CASH FLOW													
ITEM/YEAR	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
(i) Financing													
Principal													

Loan	-4000.0	1185.4	1327.6	1487.0									
Overdraft		-1000.0											
Interest													
Loan		480.0	337.8	178.4									
Overdraft													
Net Financing Flows	-4000.0	1665.4	1665.4	1665.4									
NCF(equity, pre-tax)	-1000.0	1821.1	-1479.8	-621.5	2357.8	438.2	1539.6	2552.6	1578.7	2015.8	608.9	2881.3	1997.8
(ii) Taxes													
Revenues		8589.1	4150.5	6073.6	6381.0	5449.7	5540.9	7627.3	5581.0	7074.5	4585.2	7965.9	5497.9
Operating Costs		-4600.0	-3514.1	-4527.0	-3572.3	-4508.9	-3550.4	-4572.1	-3551.5	-4556.1	-3525.5	-4581.9	-3549.3
Interest on loans		-997.6	-803.6	-696.1	-465.9	-517.6	-465.9	-517.6	-465.9	-517.6	-465.9	-517.6	-465.9
Profits (before tax)		2991.5	-167.2	850.5	2342.8	423.2	1524.6	2537.6	1563.7	2000.8	593.9	2866.3	1482.8
15% Tax		448.7	-25.1	127.6	351.4	63.5	228.7	380.6	234.6	300.1	89.1	429.9	222.4
Taxes Liable		448.7	0.0	127.6	351.4	63.5	228.7	380.6	234.6	300.1	89.1	429.9	222.4
(iii) Equity (after tax)													
Private Cash Flow	-1000.0	1372.4	-1479.8	-749.0	2006.4	374.7	1310.9	2171.9	1344.1	1715.7	519.8	2451.4	1775.4
-													

	8%	**12%**	**16%**
NPV =	**$5,812.1**	**$4,136.1**	**$2,953.6**
IRR =		**45.5%**	

Appendix 6. Benefit Cost Analysis for PB management system

Table 1: Key Variables					MAIZE			WHEAT	
Investment Costs	**No.**	**Price**	**Cost**	-	**Operating Costs**		-	**Operating Costs**	
Fixed Investment	(units)	($)		-	**Independent**	**Cost/ha**		**Independent**	**Cost/ha**
Maize Planter	1	120,000	120,000		Labour	200		Labour	200

Wheat Planter	1	150,000	150,000
Total			270,000
No. Farmers in Cooperative			9
Average farm size (ha)			6
Total Cost/ha			$5,000
Working Capital			
Interest Maize	3,451	15.0%	$518
Interest Wheat	3,106	15.0%	$466
Total			
Salvage Value			
Maize and Wheat Planter		10%	$500
Depreciation	**Life(yrs)**	**Amount p.a.**	
Maize Planter	12	1,111	
Wheat Planter	12	1,389	
Total		2,500	
Financing	**Amount**	**Interest**	Life (yrs)
Loan	$4,000	12.0%	3
Overdraft	$1,000	8.0%	1
Discount rate =	8.0%	12.0%	16.00%
Tax rate on profits =	15.0%		

Land Preparation		0
Seeds (60000seed bag)		850
Sowing		400
Fertilizer		869
Herbicide		740
Fungicides		0
Harvesting		1000
Machinery		167
Miscellaneous		225
Total		$4,451
Extra Cost Labour (1st year)		300
Dependent		**Cost/kg**
Transport Grain (kg)		0.06
Revenues		**Price/kg**
Maize (kg)		1.59
Straw (kg)		0.27
Straw rshp with grain		1.4
% Straw removed	70%	
Farmer Capacity Output		
All Years	75%	

Land preparation		0
Seeds		375
Sowing		250
Fertilizers		470
Herbicides		1590
Fungicides		71
Harvesting		400
Machinery		0
Miscellaneous		150
Total		$3,506
Dependent		**Cost/kg**
Transport Grain (kg)		0.05
Revenues		**Price/kg**
Wheat (kg)		1.61
Straw (kg)		0.27
Straw rshp with grain		1.5
% Straw removed	60%	
Farmer Capacity Output		
All Years	50%	

TABLE 2: PROJECT NET CASH FLOW

ITEM/YEAR	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
Experimental Yields													
Maize		5260	4908	5754	3859	5364	5463	6246	6395	6706	6164	5518	6736
Wheat		5101	3040	1891	4655	3086	5598	5181	5085	6011	5567	3182	3009
Small Farm Yields													

Maize grain yield		3945	3681	4316	2895	4023	4097	4684	4796	5030	4623	4139	5052
Maize straw yield		5523	5153	6042	4052	5632	5736	6558	6714	7041	6473	5794	7073
Wheat grain yield		2550	1520	946	2327	1543	2799	2590	2543	3005	2784	1591	1505
Wheat straw yield		3825	2280	1419	3491	2314	4198	3886	3814	4508	4175	2387	2257
Investment costs													
Fixed Investment	-5000.0												450
Working Capital		-517.6	-465.9	-517.6	-465.9	-517.6	-465.9	-517.6	-465.9	-517.6	-465.9	-517.6	-465.9
Total Investment	-5000.0	-517.6	-465.9	-517.6	-465.9	-517.6	-465.9	-517.6	-465.9	-517.6	-465.9	-517.6	-15.9
Operating Costs													
Independent		-4150.8	-3505.8	-4450.8	-3505.8	-4450.8	-3505.8	-4450.8	-3505.8	-4450.8	-3505.8	-4450.8	-3505.8
Dependent		-236.7	-76.0	-258.9	-116.4	-241.4	-139.9	-281.1	-127.1	-301.8	-139.2	-248.3	-75.2
Total Costs		-4387.5	-3581.8	-4709.7	-3622.1	-4692.2	-3645.7	-4731.9	-3632.9	-4752.6	-3644.9	-4699.1	-3581.0
Revenues													
Grain		6272.9	2447.6	6861.9	3747.1	6396.7	4506.1	7448.2	4093.4	7996.9	4481.6	6580.6	2422.4
Straw		1043.9	369.4	1141.9	565.6	1064.5	680.1	1239.5	617.8	1330.8	676.4	1095.1	365.6
Totals		7316.8	2817.0	8003.8	4312.7	7461.2	5186.2	8687.7	4711.3	9327.7	5158.0	7675.7	2788.0
Net Cash Flow	-5000.0	2411.7	-1230.6	2776.4	224.7	2251.4	1074.6	3438.2	612.5	4057.5	1047.2	2459.0	-808.9
(Before Financing & Tax)													

	8%	**12%**	**16%**
NPV=	**$6,342.0**	**$4,215.6**	**$2,632.3**
IRR=		**26.7%**	

TABLE 3: PRIVATE NET CASH FLOW

ITEM/YEAR	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
(i) Financing													
Principal													
Loan	-4000.0	1185.4	1327.6	1487.0									
Overdraft		-1000.0											
Interest													
Loan		480.0	337.8	178.4									

Overdraft													
Net Financing Flows	-4000.0	1665.4	1665.4	1665.4									
NCF(equity, pre-tax)	-1000.0	746.3	-2896.0	1111.0	224.7	2251.4	1074.6	3438.2	612.5	4057.5	1047.2	2459.0	-808.9
(ii) Taxes													
Revenues		7316.8	2817.0	8003.8	4312.7	7461.2	5186.2	8687.7	4711.3	9327.7	5158.0	7675.7	2788.0
Operating Costs		-4387.5	-3581.8	-4709.7	-3622.1	-4692.2	-3645.7	-4731.9	-3632.9	-4752.6	-3644.9	-4699.1	-3581.0
Interest on loans		-997.6	-803.6	-696.1	-465.9	-517.6	-465.9	-517.6	-465.9	-517.6	-465.9	-517.6	-465.9
Profits (before tax)		1931.7	-1568.4	2598.0	224.7	2251.4	1074.6	3438.2	612.5	4057.5	1047.2	2459.0	-1258.9
15% Tax		289.8	-235.3	389.7	33.7	337.7	161.2	515.7	91.9	608.6	157.1	368.8	-188.8
Taxes Liable		289.8	0.0	389.7	33.7	337.7	161.2	515.7	91.9	608.6	157.1	368.8	0.0
(iii) Equity (after tax)													
Private Cash Flow	-1000.0	456.5	-2896.0	721.3	191.0	1913.7	913.5	2922.5	520.7	3448.9	890.2	2090.1	-808.9
-													

	8%	**12%**	**16%**
NPV =	**$4,230.3**	**$2,738.3**	**$1,668.8**
IRR =		**27.0%**	