53rd Annual Conference of the Australian Agricultural and Resource Economics Society

Cairns, 2009

Paper Title:

Non adoption of improved maize varieties in East Timor

By Daniel Gregg

Non adoption of improved maize varieties in East Timor

Daniel Gregg[1]

River Consulting, 68 Wellington Street, Townsville Q 4812

Telephone 07 4775 2448, E-mail address: daniel.gregg@riverconsulting.com.au

Paper presented at the 53rd Annual Conference of the
Australian Agricultural and Resource Economics Society
Cairns, 10-13 February 2009

Abstract

East Timor formally obtained its independence in 2002 following a protracted period of occupation by Indonesia which ended in 1999. It was initially faced with a series of issues such as a low level of infrastructure, poor quality germplasm for the major staple crops, and being one of the world's poorest nations (Piggin and Palmer, 2003). Many East Timorese experience annual periods of food shortage, sometimes exacerbated by droughts and pest damage (Piggin and Palmer, 2003). In response to a shortage of suitably adapted varieties for the major staple crops of East Timor, a project called Seeds of Life was developed in 2000 to locate and test local and international crop varieties with the aim of improving the germplasm stock in the country (Piggin and Palmer, 2003). Seeds of Life recruited willing farmers to participate in On-Farm Demonstration Trials (OFDTs) in 2006 which was hoped to result in independent replanting and seed dissemination by these participants to neighbouring farmers. Two international maize varieties were extended to participating farmers for trial – these were LYDMR (Late Yellow with Downy Mildew Resistance) and Suwan 5 (a popular Thai variety with Downy Mildew Resistance). Given the reported potential for the new varieties to increase farm maize yields, the self-selection of participants in the Seeds of Life program, and that the adoption process was only in its first phase, a significant proportion of non-adoption following OFDTs was observed (approximately 32% of participants).

A survey conducted in 2007 provided data for the estimation of a binary probit regression model to assess the reasons for non-adoption. Results obtained corroborated the findings of Seeds of Life researchers prior to variety extension; yet initial testing of varieties did not explicitly involve the inclusion of factors that were considered likely to affect the utility of prospective adopters. Non-inclusion of factors relevant to household utility when assessing new crop varieties may lead to the selection of less than optimal varieties.

Stochastic dominance methods are a potential solution to this issue allowing researchers to consider the impact of new crop varieties on household utility and thus adoption decisions prior to their extension. Stochastic dominance methods can be derived from the same utility maximisation framework as the probit regression model and easily incorporate non-normal distributions of returns. Their capabilities in assessing high numbers of potential innovations and their similarity in ease of application to existing methods such as mean-variance dominance analysis are also advantages. In this paper tests for stochastic dominance are retrospectively applied to the two introduced and the local maize varieties to demonstrate their application as a competitive and relevant *ex ante* technology assessment tool in developing countries.

---

[1] This paper presents the results of research conducted for completion of an Honours in Natural Resource Economics at the University of Queensland in 2007.

1. Introduction

East Timor (Timor-Leste) is the 95th most poverty stricken nation out of 108 developing countries (UNDP, 2008). The majority (78%) of the labour force in East Timor is employed in the agriculture, fishing and forestry sector (NSD, 2006). Whilst this sector accounts for a large proportion of the labour force, it only accounts for 32% of the GDP of East Timor (EIU, 2006). The low value of agricultural activity relative to its importance in terms of employment is due to a high proportion of farmers operating as subsistence or semi-subsistence (NSD, 2006). Food security in East Timor is a major concern – an estimated 40% of people living in East Timor experience chronic food insecurity (UNWFP, 2005). These data show that there exists a need to improve household and national food security in East Timor.

Seeds of Life (http://sponsored.uwa.edu.au/sol) is a non-profit organisation that has been researching improved crop varieties for farmers in East Timor since the year 2000 with the aims of (Piggin & Palmer, 2003 page 66):

1) Improving food security in East Timor and;

2) Enhancing the capacity of local scientists and technicians.

Seeds of Life is funded in partnership by the East Timorese Ministry of Agriculture Forestry and Fisheries (MAFF) and the Australian Government. It is run in partnership by the MAFF and the University of Western Australia (SoL, 2006).

Seeds of Life investigated different varieties of main food crops farmed in East Timor between 2001 and 2005. Of 76 maize varieties tested, two were selected for extension and On-Farm Demonstration Trials (OFDTs) during 2006. These varieties were: LYDMR (Late Yellow Downy Mildew Resistant – sourced from CIMMYT) and; Suwan 5 (derived from an important variety in Thailand with added resistance to downy mildew). Only open-pollinated maize varieties were considered for extension to farmers to ensure they could multiply and sell/trade/give away excess seed independently. Other crops tested and extended by the Seeds of Life staff were not considered in this research due to time and resource limitations.

The Seeds of Life programme involved two distinct extension phases. The first was the extension of the programme aims, methods and expected outputs to villages throughout East Timor. Its aim was to attract programme participants who would take part in OFDTs. The second phase involved the extension of new crop varieties to participating farmers using OFDTs. Participating farmers were invited to test the chosen varieties on a small section of their own cropping land over one growing season. The aim of this process was both to involve the farmers in the research and testing process directly and, allow them to grow their own seed for replanting in the following year (SoL, 2006).

Of approximately 200 farmers participating in the initial extension and OFDTs, 32% chose or were not able to continue replanting due to having eaten, given away, or lost seed through pest damage. This rate of non-adoption was higher than expected by Seeds of Life staff given that participants had voluntarily signed up to trial the seed in the first place, the technology did not involve any changes to farming systems and had a large potential increase in yield according to prior testing and, the large amount of effort given to extension by Seeds of Life staff.

This paper presents research into the reasons behind unexpectedly high rates of non-adoption for the maize varieties extended to participants in East Timor in 2006. A probit regression model is used to describe the factors affecting adoption of the varieties extended by Seeds of Life. The results from this analysis are used to show how stochastic dominance may help to select varieties for extension in the future and help Seeds of Life staff understand the adoption decision framework of targeted households.

The paper begins with a brief description of the farming system of subsistence households, the role that maize plays in East Timor and a review of relevant technology assessment and adoption literature. Section 2 presents the research methods outlining the development and estimation of the regression model and the methods of application of stochastic dominance rules to yield data. The results of the survey, regression and stochastic dominance tests are presented in section 3. Section 4 concludes with a discussion on the potential for stochastic dominance to provide an improved assessment of the ranking of prospective technologies with respect to utility maximisation and risk aversion criteria.

1.1 The subsistence farming system and the role of maize in East Timor.

East Timor is a highly mountainous country with the result that there is a shortage of land suitable for cropping and many farming households plant maize on steeply sloping land (EIU, 2006:de sa Benevides, 2003). Subsistence farming households in East Timor employ a multi-cropping strategy to manage food supply risk across the year (Fox, 2003). The main staple crop is maize which is usually interplanted with cassava, pumpkin, sweet potato, taro and other horticultural crops. Rice is grown in select areas where there is sufficient water and infrastructure.

East Timor is not currently self-sufficient in maize or rice production with the result that many households experience food shortages prior to the main maize harvest in March-August (UNDP, 2006). Alternative crops such as cassava provide an alternative food source for diversity and when there is a shortage of other grain. Farming households also utilise surrounding natural resources to enhance their welfare – those close to the coast often engage in fishing activities whilst others collect bush foods and wood for fires.

Farming capital is very basic for the majority of subsistence households in East Timor. Field clearing, planting, weeding, harvesting and grain processing is all carried out by hand, often in community or family labour groups, using basic implements (Viegas, 2003). The storage infrastructure for grain on individual farms is usually based on traditional methods such as storing grain in a specially constructed raised hut, above the fire place, hanging from trees, or in bamboo shafts (Oxfam, 2006). All of these methods do not result in an airtight seal and thus allow weevils to live and damage grain and seed stocks. Grain is also susceptible to rodent damage.

More than 80% of all households in East Timor grow maize (ADB, 2001) with virtually all maize varieties being of the open pollinated type which retain population characteristics between generations – this means that households growing maize do not need to purchase seed every season if they can store enough grain in a satisfactory way in the period between harvest and replanting. The historical trend in maize yield growth in East Timor is significantly below that of other countries including Indonesia – its immediate neighbour and occupier of 24 years (Oxfam, 2006).

Research and extension into higher yielding, open pollinated maize varieties has the potential to transform the agricultural sector of East Timor by improving food security and allowing its population to pursue economic opportunities within and beyond those provided by agriculture.

1.2 The assessment and adoption of new technologies

Technology is usually defined by economists as a stock of available techniques or a state of knowledge concerning the relationship between inputs and outputs (Colman & Young, 1989). Subsistence farmers face many issues that limit their capacity to improve their stock of technology. Limiting factors include such things as; farm size, land tenure, access to markets, lack of financial institutions, human capital, access to inputs (labour, capital) persistent food supply shocks and others (Feder *et al*., 1985).

Farmers will adopt prospective technologies only if they are consistent with their objectives/preferences and if they are superior to the technology stock in use (Torkamani, 2005). Thus, participants of the Seeds of Life programme base their adoption decision on a number of factors including but not limited to; yield, taste, cost and risk. These factors were considered by Seeds of Life staff prior to, during, and following the extension phase.

Seeds of Life staff tested new varieties against local “checks” using mean yield per hectare and variance measures to assess variability within varieties and between testing sites for particular varieties (Ceniceros, *et al.*, 2003). This method suggests the use of a mean-variance approach to technology assessment which Graves and Ringuest (2009) show is suitable if the distributions of returns for the technologies can be approximated by normal distributions. If the distributions are not normal then testing of the empirical or theoretical parametric distributions of returns should be undertaken using other methods (Graves and Ringuest, 2009). Seeds of Life staff described factors other than yield that may affect the desire of farmers to adopt the new maize varieties. These included factors such as poor storage of the new varieties (when using traditional methods), lower percentages of useful grain following processing (pounding), lower drought tolerance and, in some cases, a less desirable taste. Although these factors were known they were not explicitly considered in the statistical ranking and appraisal of the 76 tested maize varieties.

Fox (2008) shows that there is often disconnect between the *ex ante* assessment of new technologies and their true impacts on productivity/efficiency – dis-benefits, reliability, and utilisation aspects are commonly not considered or properly integrated into an *ex ante* assessment. Dis-benefit, reliability and utilisation aspects would logically be considered by prospective adopters in their decision on whether to adopt new technologies. Thus a framework that is consistent with farmers' decision making is likely to be the most appropriate when considering a suite of proposed technologies for extension. A logical group of candidates to represent a framework of decision making are those based on utility maximisation due to the extensive literature available showing their application to *ex post* assessment of adoption in developing countries (e.g. Lapar and Ehui, 2004; Neill and Lee, 2001) and their relevance to the modelling of choices (McFadden, 1980).

Stochastic dominance methods deal with all of the issues mentioned above – they easily handle non-normal distributions, can assess many different options at once and can be derived from a framework of utility maximisation and thus choice (Graves and Ringuest, 2009). Stochastic dominance methods are also similar in their ease of application to the methods used in the assessment of maize varieties by Seeds of Life – mean/variance approaches to technology assessment can be shown to be a special case of stochastic dominance where the distributions of technologies are normal (Graves and Ringuest, 2009).

2. Method

A survey of farmer participants in the Seeds of Life programme was conducted in July of 2007. Due to time and resource constraints, a subset of the population of participants was selected using stratified random sampling. Sample strata were identified at a sub-district level. Participants in Seeds of Life lived in eight sub-districts with all of these districts being included in the sampling frame. The number of respondents from each strata was decided to be double the number of non-adopters from each. Thus, an even number of adopters and non-adopters within each region were to be surveyed. A total of 118 potential survey respondents were identified along with 3 participants for pilot testing of the survey instrument. The response rate to the survey was 75% – 88 people provided responses in time to be included in the data analysis.

The survey was administered as an in-person interview. The regional Seeds of Life Research Assistant was selected to conduct the survey within their respective region. The Research Assistants generally had an intimate knowledge of the area and existing relationships with the survey respondents. Interviewers were introduced to the survey at a general training and team building weekend on the island of Atauro near Dili in early July following the pilot test.

The survey was two pages long and designed to be completed, with assistance from a research assistant, in approximately 10-15 minutes. A copy of the survey is attached as an appendix.

2.1 The regression model

Adoption of new technologies is often not simply observed as a dichotomy in states of nature – it will often involve a temporally staged process of adoption that increases or decreases in area or usage over time (Byerlee & de Polanco, 1986; Feder *et al*., 1985). Adoption can nevertheless be tested in a binary dependent variable regression model by specifying either a state of nature or threshold at which adoption is considered to be undertaken. This research used the observation of replanting of seeds from introduced maize varieties in the season following OFDTs as an indication of adoption – those that replanted were considered to have adopted the technology in that time period, those that had not were considered to have not adopted the technology.

The decision of a farmer to adopt a new technology (or continue in the adoption process) in any given period is generally assumed to result from the maximization of expected utility subject to production and other constraints (Feder *et al*., 1985). McFadden (1980) shows the assumption of expected utility maximisation can be used to derive random utility models in the form of discrete dependent variable regression models: for example a decision with outcomes that can be counted as integers. Using these results a binary probit regression model was chosen to facilitate description of the factors affecting adoption.

The regression model was estimated using the Bayesian method. There are three main reasons the Bayesian method was chosen over Maximum Likelihood (ML):

1.) Bayesian methods are exact for finite samples where ML methods are valid asymptotically. The sample acquired in this paper is considered to be limited in the number of observations. Griffiths *et al.* (2006) show that calculation of marginal probabilities is enhanced using Bayesian methods (compared to using maximum likelihood methods) in a finite sample.

2.) The *ex post* assessment of technology adoption in developing countries is not a new field – there exists substantial prior information on the likely effect of numerous socio-economic and production function variables in the literature. Existing information/beliefs on the effect of certain explanatory variables on the dependent variable can effectively be captured in a Bayesian methodology through specification of prior distributions for estimated parameters (Koop, 2003). Assumptions on the prior distributions are shown in Table 1 with reasoning provided following.

3.) Bayesian methods consider the parameters of variables to be random variables. In a socio-economic setting this is a reasonable assumption. It allows inferences to be drawn on the distributions of the parameters of interest in the form of posterior probability distributions which is of key interest in this research (Bolstad, 2004).

The estimation procedure was carried out in the R (version 2.7.0) program (available from: http://CRAN.R-project.org). The model was run using the package LearnBayes developed by Jim Albert (2008).

The original sample included 88 responses. Of these, 75 were included in the regression model – 13 were not included due to incomplete responses.

The regression model was specified as:

> *Adopt =* ***f****(Education, Age, Number of residents in the household, Ownership of cow(s) or buffalo [0,1], Perceived storage disadvantage of introduced varieties, Perceived yield advantage of introduced varieties, Presence of sealed storage for food grain [0,1], Presence of sealed storage for seed grain [0,1], Wife selects seed for next season [0,1], Months of shortage of grain, Hours to nearest market).*

Variables with "[0,1]" following their specification in the model are dummy variables with only the integers "0" or "1" representing FALSE or TRUE being observed.

Informative prior distributions were specified for the model variables. Details of the specified prior distributions are shown in Table 1. A positive (negative) prior mean for a parameter indicates an expectation that the variable will have a positive (negative) association with the probability of adoption. The variance indicates the level of certainty – a smaller variance indicates a higher level of certainty in the proposed effect of the relevant variable.

Table 1: Prior distributions for the model parameters ~ N(mean, variance)

	Mean	Variance
Education (years)	1	1
Age (years)	0	1
Number of residents	0	1
Own cow(s) or buffalo (yes=1)	0	1
Storage disadvantage	-1	1
Yield advantage	1	0.5
Sealed storage for food (yes=1)	1	0.5
Sealed storage for seed (yes=1)	1	0.5
Wife selects the seed? (yes=1)	0	1
Months of grain shortage	-1	0.5
Hours to nearest market	-1	0.5

The variables *Yield advantage, Sealed storage for food* and, *Sealed storage for seed* are expected to have a positive association with the probability of adoption. The positive association with *Yield advantage* is justified as it would reasonably be expected that the utility of a potential respondent increases with more of a particular good, *ceteris paribus*. Gross yield distributions (not accounting for storage and processing losses) for the introduced varieties suggested they, on average, produced more grain than the local varieties. Given their susceptibility to damage during storage from pests (SoL, 2006), the presence of sealed storage (represented by the variable *Sealed storage for food/*seed) is likely to have a positive impact on the likelihood of their adoption. Similarly, the expected negative association with *Storage disadvantage* is based on the proposal that households consider the storage performance of the introduced varieties in their decision to adopt. Less certainty is accorded to *Storage disadvantage* as it may not be important to households with modern (sealed) storage infrastructure.

The negative association with the variable *Months of grain shortage* is motivated by the consideration that longer periods of shortage will entail increasingly desperate searches for household sustenance.

The negative association with *Hours to nearest market* is based on the proposal that regions farther from (closer to) market centres are less (more) likely to be interested in producing a marketable surplus due to higher (lower) transaction costs. Further, they may be more risk averse due to the difficulties in obtaining food from markets during periods of shortage – the introduced varieties would likely be considered riskier prospects than the local varieties which have been farmed for many years.

The variable *Education* is considered to have a positive association with the probability of adoption but with less certainty. This assertion is proposed based on results of other adoption studies such as Lapar and Ehui (2004) and Feder *et al.* (1985).

Sensitivity testing was undertaken to check whether specification of particular prior distributions had significant effects on the posterior model parameters. Convergence of the draws used to simulate the posterior density of the model parameters was assessed visually by plotting the time-path of the series for each parameter.

2.2 Stochastic dominance

Torkamani (2005, pp 139) suggests that *ex ante* technology assessment should be:

"sufficiently comprehensive to provide adequate and appropriate information about the consequences and desirability of prospective technologies"

The derivation of stochastic dominance criteria can be obtained from the perspective of expected utility maximisation (Graves & Ringuest, 2009). Thus it has the potential to model farmers' decision making under the assumption of utility maximisation. It also aligns with *ex post* adoption assessment tools such as binary dependent variable models which can also be derived from a framework of utility maximisation (McFadden, 1980). Stochastic dominance assessments can be implemented under a scenario of limited or full information and thus are applicable to a wide range of circumstances to provide a subjectively sufficient understanding of the desirability of prospective technologies.

Anderson *et al.* (1988) provide support for the use of stochastic efficiency in cases where it is hard or impossible to obtain the utility functions of the target population – i.e. in the case of agricultural research and development and particularly in the areas involving subsistence or semi-subsistence farming systems.

Stochastic dominance methods can be applied, theoretically, up to any order of dominance with associated increasingly strict assumptions on the utility function of prospective adopters. Two types of stochastic dominance are explored in this paper – First-degree Stochastic Dominance (FSD) and Second-degree Stochastic Dominance (SSD) – these involve only minimal assumptions on the utility function of prospective adopters and will usually reduce the set of competing options at least to a more manageable number (Graves and Ringuest, 2009). They are briefly explained below.

The application of FSD involves only the assumption that the decision makers' utility function, $U(x)$ increases with x, $U'(x) \geq 1$ – i.e. utility increases with more of x (Graves & Ringuest, 2009). Under FSD, technology A will dominate technology B if and only if (Graves & Ringuest, 2009):

$$F_B(x) \geq F_A(x) \text{ for all } x \qquad (1)$$

This means that technology A will only dominate technology B if the cumulative distribution of returns for B is never below (to the right) that of A.

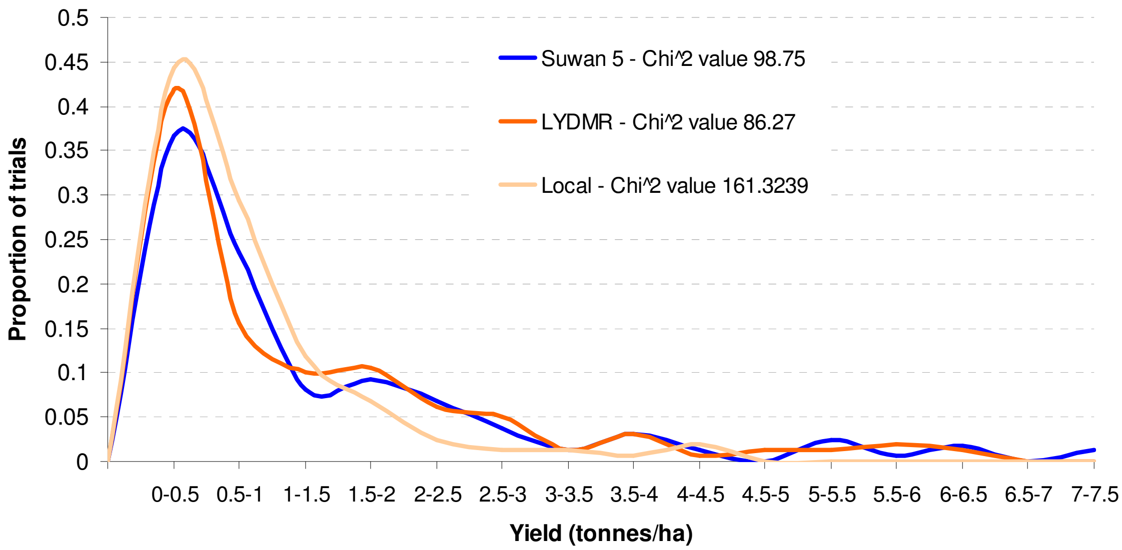
The application of SSD is generally undertaken when FSD does not provide a ranking – i.e. the cumulative distributions of technology A and technology B intersect. It requires the additional assumption that the decision maker is risk averse over x – i.e. $U''(x) \leq 0$ *for all* x. Under this additional assumption, technology A will dominate technology B if, in addition to *(1)*; (Graves & Ringuest, 2009)

$$\int_{-\infty}^{Z} [F_B(x) - F_A(x)]\, dx \geq 0 \qquad (2)$$

This means that technology A will only dominate technology B if the accumulated area under the cumulative distribution curve of B is no less than that of A for all x.

These methods are applied to gross yield data provided by Seeds of Life in addition to survey data. Data on the distributions of yield for maize varieties was only available for the Suwan 5, LYDMR, and Local varieties. Tests for normality of distributions showed that all were highly non-normal and that it would be most appropriate to use the empirical distributions of yield/ha for each variety. There were 160 observations available for each of the distributions which were used to test for FSD and SSD. Figure 1 shows probability density functions for the three varieties and Chi-squared distribution values derived from the Jarque-Bera test for normality. The critical value for the Chi^2 distribution of 5.991 (p=0.05 with two degrees of freedom) shows that we can reject the hypothesis that the gross yield distributions for any of the three varieties are normally distributed.

Figure 1: **Probability Density Functions for gross yields (per hectare) of three tested maize varieties. Chi-squared critical value is 5.991 (p=0.05 with two degrees of freedom)**



Seeds of Life staff observed that the poor storage characteristics (using traditional storage methods) may be important to prospective adopters in their decision to adopt. Staff tested the difference in storage life of Suwan 5 and LYDMR against the Local variety when stored with traditional and modern (sealed) methods. Results were reported as point estimates (mean) percentage grain losses from weevils for the three maize varieties (SoL, 2006). This information was not available when conducting tests on the performance of introduced varieties by Seeds of Life staff (Ceniceros, 2003). Given it is likely that storage characteristics will play a part in the decision framework of prospective adopters and approaching the issue from the paradigm of utility maximisation, this information should be included in assessments of technology suitability for farmers in East Timor.

Yield data was corrected for storage losses by multiplying by the expected proportion of storage losses for each maize variety. Table 2 shows the mean expected percentage weevil damage to the three relevant maize varieties.

Table 2: Weevil damage to three tested maize varieties when stored in traditional methods

	Percent grains with weevil damage	Percent cobs with no damage	Percent cobs with tight sheaths	Percent mean yield advantage
Suwan 5	37.6	50.9	42.1	50.3
LYDMR	24.7	64.1	52.3	29.9
Local	18.8	69.2	7.1	0

Source: Adapted from SoL, 2006; p49

Calculations for stochastic dominance were carried out in *Microsoft*^{TM} *Excel* using linear-segmented Probability and Cumulative Density Functions (PDFs and CDFs respectively). In the case where empirical distributions are available (as opposed to parametric distributions) use of linear segmented PDFs and CDFs is a simple way to assess stochastic dominance (Anderson *et al.*, 1977)

3. Results

Of respondents to the survey, 47% were continuing adopters of the introduced maize varieties and 53% were not continuing adoption following OFDTs.

Most respondents interviewed were a husband and wife couple – only five were single. The average age of singles was 31.6 years whilst husband and wife respondents on average aged 43.6 years and 35.7 years respectively.

Single farm-owners had, on average, a much higher level of education (11.33 years) than farms run by a husband (3.39 years) and wife (2.32 years) team.

There were three different types of external labour usage on respondent's farms. The majority used a combination of extended family (65%) and labour exchange (63%) for labour-intensive on-farm tasks. Labour exchange is a community organised scheme of rotating working groups of local farmers. Few (6%) respondents employed labour purely on a payment basis (cash or assets). All respondents utilised external labour resources at least once during the previous production season.

The average time taken to get to the nearest market was reported as one hour. Adopters on average took less time to reach the most proximate market (0.8 hours) compared with non adopters who took, on average, 1.1 hours to reach the closest market.

Respondents reported being short of maize grain for an average of 3.9 months prior to the most recent maize harvest. Adopters reported an average duration of shortage of 3.6 months whilst non adopters reported an average duration of shortage of 4.2 months.

Few respondents (14%) stored any food grain in modern (sealed) storage, the majority utilised only traditional (unsealed) storage methods for all of their food grain. More respondents utilised modern storage for seed supplies however – 39% of respondents used modern storage methods for seed grain whilst the remainder (61%) stored their seed grain in traditional methods. Most commonly both the husband and the wife selected the seed in farming households run by a couple (83%).

Respondents were asked to rate the yield advantage of the introduced varieties (Suwan 5 and LYDMR) compared to Local varieties. They were presented with a scenario of obtaining 10 bags of maize from a field planted to the Local varieties and were asked to record how much they would expect to have received if it had been planted to the introduced varieties. Respondents reported an average expectation of 16.4 bags (64% yield advantage) for Suwan 5 and 14.9 bags (49% yield advantage) for LYDMR.

Respondents were asked to provide an indication of their perception of the differences in storage between the local varieties and the introduced varieties. Respondents, on average, rated the viable storage duration of local varieties to be eight months, the Suwan 5 variety to be 5.4 months and the LYDMR variety to be 5.47 months.

3.1 Probit regression model

The Probit regression model results are presented below in Table 3. The lower and upper values for the 95% Highest Posterior Density region (HPD) are shown for each variable to provide an indication of the spread of values for the parameter estimates.

Sensitivity testing showed the model to be robust to prior specification. Simulated draws for the posterior distributions for the parameters were considered to have converged early by visual assessment. 100,000 draws were made using the Gibbs sampler from the LearnBayes package (Albert, 2008). The first 10,000 draws were discarded to ensure convergence prior to assembly of summary statistics and HPDs for each variable.

Table 3: Probit regression results

Variable	Mean	Highest Posterior Density (95%) values Lower tail	Upper tail	Marginal Effect
Education (years)	0.0207	-0.06378	0.10287	0.0076
Age (years)	-0.001	-0.02313	0.02144	-0.0003
Number of residents	0.101	-0.02124	0.22568	0.0372
Own cow(s) or buffalo (yes=1)	-0.3259	-1.0229	0.3407	-0.1199
Storage disadvantage	0.0055	-0.09757	0.10888	0.002
Yield advantage	0.1024***	0.03257	0.1708	0.0377
Sealed storage for food (yes=1)	1.056**	0.04213	2.0675	0.3886
Sealed storage for seed (yes=1)	0.1843	-0.4535	0.8408	0.0678
Wife selects the seed? (yes=1)	-0.5353	-1.5081	0.4543	-0.197
Months of grain shortage	-0.2251**	-0.4286	-0.0288	-0.0828
Hours to nearest market	-0.358*	-0.7829	0.06148	-0.1317

*** Does not include 0 in the 90% Highest Posterior Density region**

**** Does not include 0 in the 95% Highest Posterior Density Region**

***** Does not include 0 in the 99% Highest Posterior Density Region**

The column titled "Marginal effect" in Table 3 shows the effect that a change in the variable of interest by one unit will have on the probability of adoption. Marginal effects are calculated using the joint posterior distribution of the estimated model and are calculated whilst holding all other variables constant at their mean values or at zero if they are a dummy variable. A mathematical expression for calculation of marginal effects is shown below (Greene, 2003):

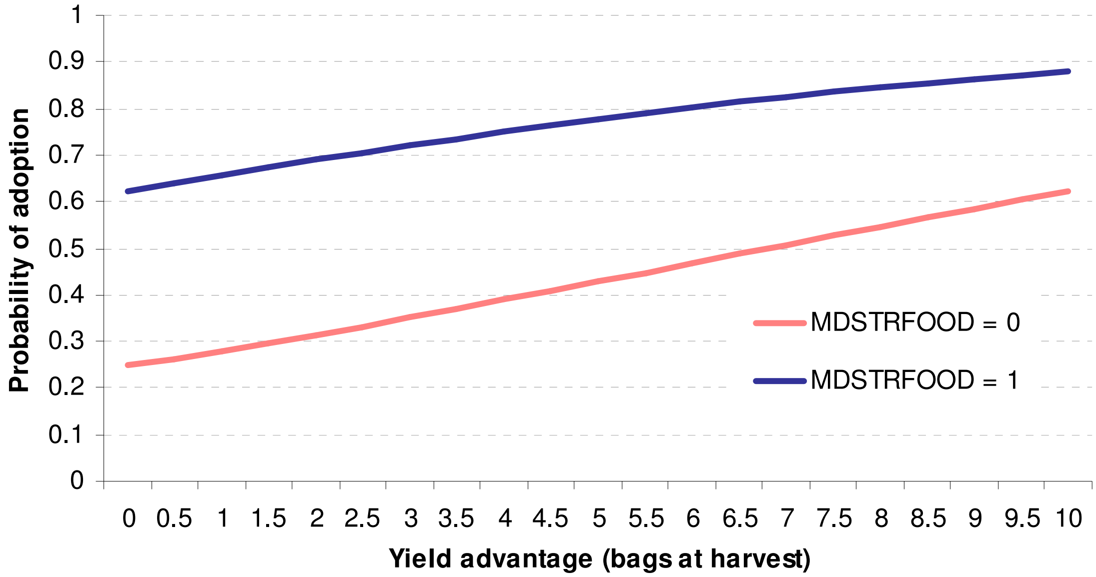
$$\partial P / \partial x_{ik} = f(x_i' \beta) * \beta_k$$

The presence of sealed storage for food increases the probability of adoption of the maize varieties by almost 39% according to the estimated model, *ceteris paribus*. The yield advantage of introduced varieties also has a significant positive effect whilst "Months of grain shortage" and "Hours to nearest market" both have significantly negative effects on the probability of adoption. The variable "storage disadvantage" has, unexpectedly, a positive sign for its associated coefficient. Observing the HPD for this variable however it can be seen that the associated distribution almost equally spans negative and positive values suggesting that it is not significant in predicting adoption behaviour for the three maize varieties. All other variables appear to be consistent with prior beliefs as to their effect on adoption but are not consistently different from zero at or above the 90% probability level and are thus not included in further analysis below.

Analysis of the posterior distribution of significant variables was undertaken to show the effect on the probability of adoption over the observed range for each of these variables. Probabilities were calculated for sequences of observations for "yield advantage", "months of shortage", and "distance to market" whilst holding all other variables constant at their mean values or at 0 for dummy variables. To test the impact of the presence of "modern storage for food", the range of probability scores for each of the variables tested below were calculated both for when "modern storage for food" was present (1 - depicted by blue/dark line) and when it was not present (depicted by pink/light line).

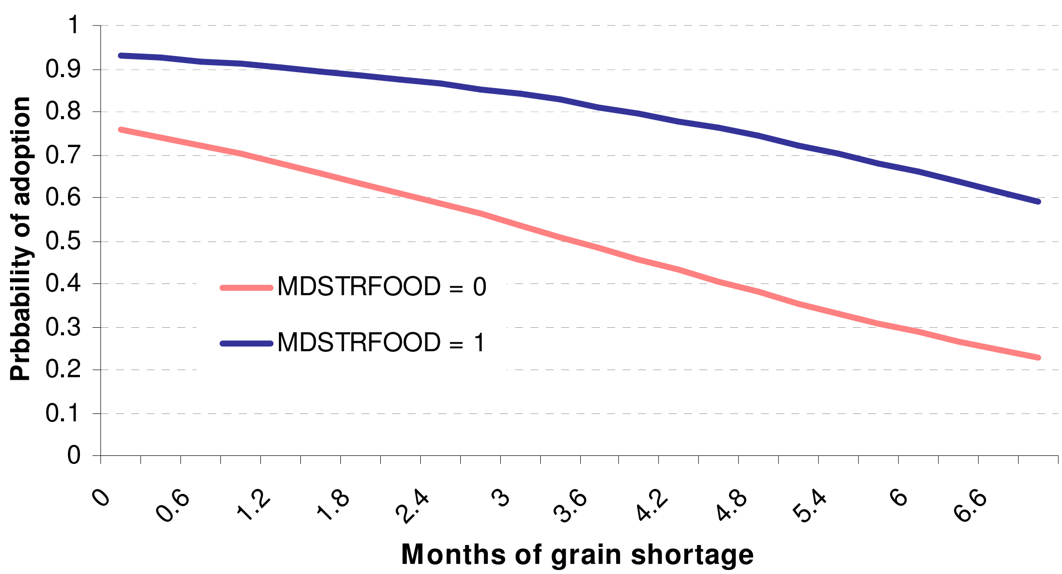
Figure 2 shows the effect of "Yield advantage" and "Sealed storage for food" on the probability of adoption of the introduced varieties. It can be seen that the presence of sealed storage for food grain stocks is likely to increase the probability of adoption of the introduced varieties for the entire range of reported yield advantages. A higher perceived yield advantage also leads to a higher probability of adoption of the introduced maize varieties.

Figure 2: Effect of "Yield advantage" and "Sealed storage for food" (MDSTRFOOD) on the probability of adoption



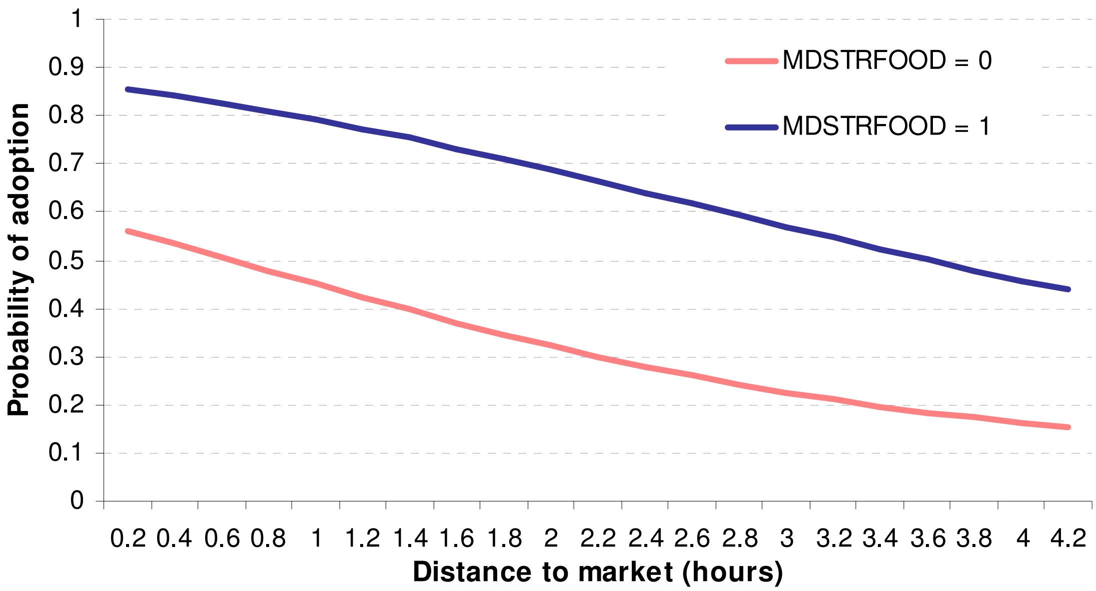
The period of time for which a respondent experienced grain shortage in the preceding season was a significant factor affecting the probability of adoption. Figure 3 shows how the period of grain shortage (months) and the presence of sealed storage for food affected the probability of adoption for respondents to the survey. The presence of sealed storage for food becomes increasingly important as the number of months of grain shortage increases. Based on the estimated model the increase in probability of adoption for farmers with sealed storage for food (versus those without) goes from 17% when no shortage of food is experienced to 36% when 7 months of shortage is experienced.

Figure 3: Effect of "Months of grain shortage" and "Sealed storage for food" (MDSTRFOOD) on the probability of adoption



The distance in hours to the nearest market was an important factor influencing the probability of adoption for survey respondents. Figure 4, below, shows the effect "Distance to the nearest market" (in hours) has on the probability of adoption with and without the presence of sealed storage for food.

Figure 4: Effect of "Hours to nearest market" and "Sealed storage for food" (MDSTRFOOD) on the probability of adoption

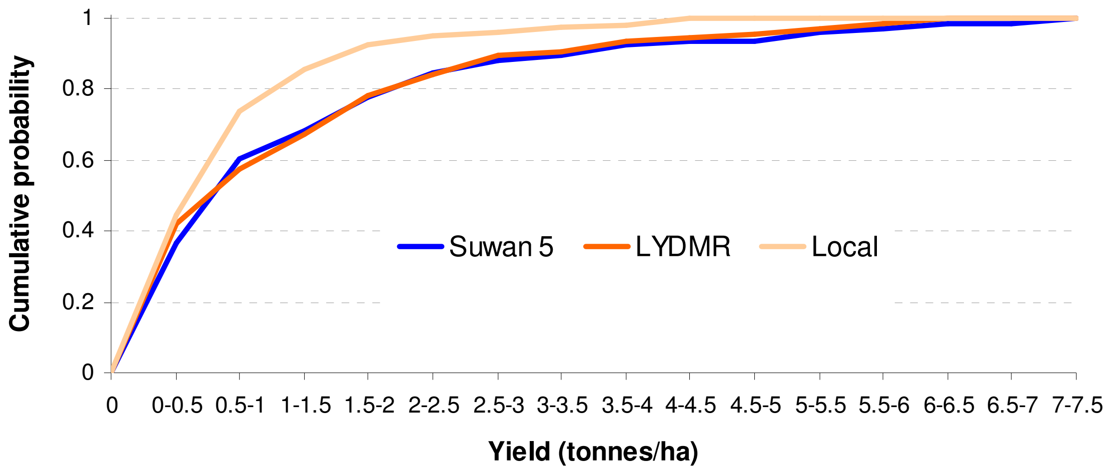


As distance to market approaches the upper end of the reported range of times (approximately four hours), the probability of adoption and when the farmer has no sealed storage for food, approaches 15%. At the same distance to market but with the presence of "sealed storage for food" the model suggests the probability of adoption remains above 40%.

3.2 Stochastic dominance

The assessment of gross yield (yield at harvest) for the local and introduced maize varieties is shown in Figure 5. It can be seen that the cumulative density distribution of the local variety is always to the left of those of the introduced varieties and thus is dominated by FSD. Neither of the introduced varieties dominates the other by FSD (or SSD).

Figure 5: Cumulative density distributions for gross yield of local and introduced (Suwan 5 and LYDMR) maize varieties



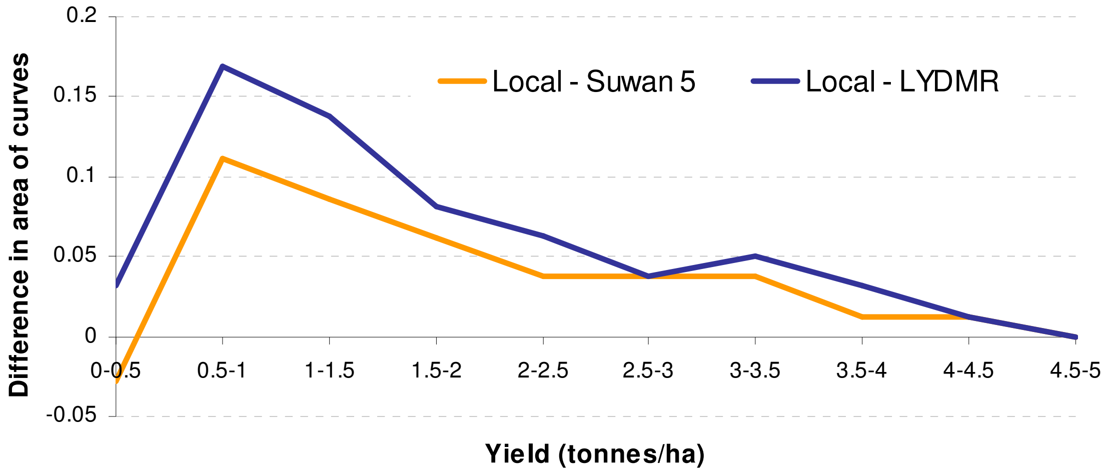
After correcting for the percentage of grains damaged by weevils over the storage season (using traditional, unsealed storage methods), the distributions are again assessed using FSD and SSD. Figure 6 shows the cumulative distribution of the difference in net yield between the introduced varieties and the local varieties. The "Local - LYDMR" distribution is always positive showing that the LYDMR variety dominates the Local varieties by FSD and thus also SSD.

Suwan 5 does not dominate the Local varieties by FSD (or vice versa) as it has more area under its distribution than Local for at least one point along the x axis. This violates the condition required for FSD that for all x, $F_{Local}(x) \geq F_{Suwan}\ 5(x)$. Further, since the point at which the distribution for Suwan 5 is less than Local at the origin, the cumulative density accumulated under Suwan 5 at all points on x is, at least once, greater than that of the cumulative density of Local evaluated at all points on x. In mathematical notation, the condition:

$$\int_{-\infty}^{Z} [F_B(x) - F_A(x)]\, dx \geq 0 \qquad (2)$$

does not hold so Suwan 5 does not dominate local varieties by SSD.

Figure 6: Distribution of the differences between net yield PDFs for the introduced varieties and the local variety



Note: Net yield is calculated as the gross yield data provided by Seeds of Life multiplied by the percentage of grain damaged by weevils (see Table 2, "Percentage grain with weevil damage").

4. Conclusions

The adoption of new technologies – even those with no explicit costs of adoption – depend on whether they are consistent with the objectives and preferences of those receiving the technology (Torkamani, 2005). This research has shown that both the institutional environment (market availability, food insecurity) and technology specific aspects (storage characteristics and yield differences) likely affected the adoption of introduced maize varieties in East Timor. This is despite a high level of effort given to extension of the new varieties by the Seeds of Life staff.

There currently exists a lack of integrated assessment in the research and selection of technologies as shown by Fox (2008). This gap in extension methodology requires the development of a simple and reliable method of *ex ante* technology assessment to be implemented (Claessans *et al*., 2009). Stochastic dominance methods present a potential technology appraisal framework to meet these needs due to their ease of implementation (with or without full information) and their orientation toward utility maximisation in a risky setting (Graves & Ringuest, 2009). Stochastic dominance can be used to simultaneously assess any number of technologies/projects and can incorporate information commonly gathered by research and extension scientists.

Stochastic dominance as applied in this paper was limited in that only yield considerations were included in the utility assessment – it represents the case of limited information. Although it is limited it was still able to show how new technologies are not necessarily utility maximising under certain conditions (i.e. the lack of sealed storage infrastructure). A more informative model would include more quantitative data such as processing losses for different varieties as well as, potentially, qualitative variables such as taste and drought tolerance. Qualitative factors could be included through the use of a model that prices hedonic factors such as a choice modelling exercise. One key advantage of these methods is that they align with currently accepted *ex post* assessment methods such as random utility models in that they assume individuals are utility maximisers.

The use of utility-maximisation consistent methods in the appraisal of new technologies for extension to farmers in developing countries is potentially most beneficial in how it can facilitate consideration of prospective adopters' utility frontier. Simple methods, such as stochastic dominance, can be shown to represent choice under some basic assumptions on utility maximisation (such as a person prefers more of a good than less). It is hoped that the use of these methods may contribute to a greater understanding of the choice framework of potential adopters, and that this choice framework may be based on a rational framework of utility maximisation.

The research presented in this paper was limited in a number of ways including the time to obtain a large sample, the availability of other data such as storage losses, asset (cow and buffalo) prices, relative preference for different traits of maize varieties, and others. Future research may incorporate such improvements as:

- The survey of the general subsistence-farming population to understand the initial decision in participating in the Seeds of Life programme.
- Increasing the sample size or including all Seeds of Life participants in a decision analysis survey.
- Applying the stochastic dominance procedures to the set of maize varieties tested before OFDTs.
- Obtaining a description of the observed distribution of storage losses to more accurately model these in a stochastic dominance assessment.
- Obtaining more information on other utility considerations such as taste preference and processing losses.
- Training relevant staff to undertake the assessments independently to examine whether it facilitates an understanding of household decision processes.

Given that people will adopt a new technology only if it is consistent with their objectives and preferences; research and extension of new technologies should actively try to understand the objectives and preferences of the target population. The requirement for a framework to integrate preferences can be realised through the implementation of stochastic dominance assessments during technology assessment and prior to extension or investment. Even without the utility trade-off information revealed from choice experiments, stochastic dominance assessment can provide an easily accessible joint assessment method to help agricultural research and extension scientists understand the full potential benefit/disbenefit of new technologies to their prospective adopters.

Acknowledgments

Dr. Rob Williams, Seeds of Life – For providing the opportunity to carry out this research with Seeds of Life, guidance in survey design and development and for providing an introduction to the people and country of East Timor. Rob kindly provided accommodation during two visits to East Timor which is greatly appreciated.

Seeds of Life – Seeds of Life financed a return flight from Darwin to East Timor in June 2007 following an initial visit in February. Acknowledgements are made to all of the staff of Seeds of Life for the hospitality provided and for providing invaluable help with survey design, testing and extension, and with the data entry.

Dr Rob Cramb, University of Queensland – For providing guidance during the write-up of the research for submission as an honours thesis in partial completion of the Bachelor of Natural Resource Economics (Honours) in 2007.

Dr Romy Greiner, River Consulting – For providing invaluable guidance and comments on a draft of this paper as well as the time to revisit this research for presentation at the Annual Conference of the Australian Agricultural and Resource Economics Society in Cairns 2009.

Trish Saunders, River Consulting – For the provision of editing services and comments on drafts of this paper.

References

ADB 2001. Timor Leste Suco Survey. Asian Development Bank, Manila.

Albert, J., 2008. LearnBayes. Package designed to be run in the R program. cran.r-project.org/web/packages/LearnBayes/index.html

Anderson, J., Dillon, J., and Hardaker, B. 1988. Agricultural Decision Analysis. The Iowa State University Press, Iowa.

Bolstad, W., 2004. Introduction to Bayesian Statistics. Wiley-IEEE, New Jersey.

Byerlee, D. and de Polanco, E. 1986. Farmers' Stepwise Adoption of Technological Packages: Evidence from the Mexican Altiplano. American Journal of Agricultural Economics, 68: 519-527.

Ceniceros, F., Palmer, B., Piggin, C., San Valentin, G., de sa Benevides, F. and De Oliveira, A. 2003. Challenges and opportunities for maize research in East Timor – results of variety identification during the 2000 and 2001 cropping seasons. In: Agriculture: New Directions for a New Nation - East Timor (Timor-Leste). da Costa, H., Piggin, C., da Cruz, C., and Fox, J.(eds). Australian Centre for International Agricultural Research, Canberra.

Claessans, L., Stoorvogel, J., and Antle, J. 2009. *Ex ante* assessment of dual-purpose sweet potato in the crop-livestock system of western Kenya: A minimum data approach. Agricultural Systems, 99: 13-22.

Colman, D. and Young, T. 1989. Principles of Agricultural Economics: Markets and prices in less developed countries. Cambridge University Press, Cambridge.

de sa Benevides, F. 2003. Cropping Systems in East Timor. In: Agriculture: New Directions for a New Nation - East Timor (Timor-Leste). da Costa, H., Piggin, C., da Cruz, C., and Fox, J.(eds). Australian Centre for International Agricultural Research, Canberra.

EIU 2006. Country Profile: East Timor. Economist Intelligence Unit, London

Feder, G., Just, R., and Zilberman, D. 1985. Adoption of Agricultural Innovations in Developing Countries: A Survey. Economic Development and Cultural Change, 33(2): 255-298.

Fox, J. 2003. Drawing from the past to prepare for the future: responding to the challenges of food security in East Timor. In: Agriculture: New Directions for a New Nation - East Timor (Timor-Leste). da Costa, H., Piggin, C., da Cruz, C., and Fox, J.(eds). Australian Centre for International Agricultural Research, Canberra.

Fox, S. 2008. Evaluating potential investments in new technologies: Balancing assessments of potential benefits with assessments of potential disbenefits, reliability and utilization. Critical Perspectives on Accounting, 19: 1197-1218.

Graves, S. and Ringuest, J. 2009. Probabilistic dominance criteria for comparing uncertain alternatives: A tutorial. Omega, 37: 346-357.

Greene, W. 2003. Econometric Analysis (5th ed.). Prentice Hall. New Jersey.

Griffiths, W., Carter Hill, R., and O'Donnell, C. 2006. A comparison of Bayesian and sampling theory inferences in a probit model, in Holt, M. and J.-P. Chavas (eds) *Essays in Honor of Stanley R. Johnson*. http://www.bepress.com/sjohnson/art12.

Koop, G. 2003. Bayesian Econometrics. Wiley. Chichester.

Lapar, M.L., Ehui, S., 2004. Factors affecting adoption of dual-purpose forages in the Philippine uplands. Agricultural Systems, 81:95-114.

McFadden, D. 1980. Econometric Models for Probabilistic Choice Among Products. The Journal of Business, 53(3): 13-29.

Neill, S. and Lee, D. 2001. Explaining the adoption and disadoption of sustainable agriculture: The case of cover crops in northern Honduras. Economic Development and Change, 49: 793-820.

NSD 2006. ATLAS: Timor-Leste census of population and housing 2004. National Statistics Directorate, Dili, East Timor.

Oxfam (2006). Maize Production and Storage in Timor-Leste. A report on research conducted by the Department of Agronomy National University of East Timor.

Piggin, C. and Palmer, B. 2003. An introduction to the ACIAR project 'Seeds of Life - East Timor'. In: Agriculture: New Directions for a New Nation - East Timor (Timor-Leste). da Costa, H., Piggin, C., da Cruz, C., and Fox, J.(eds). Australian Centre for International Agricultural Research, Canberra.

SoL 2006. Annual Research Report 2006: Seeds of Life. Seeds of Life, Dili.

Torkamani, J. 2005. Using a whole-farm modelling approach to assess prospective technologies under uncertainty. Agricultural Systems, 85: 138-154.

UNDP 2006. Human Development Reports: Timor-Leste. United Nations Development Programme. Accessed on: 21-11-2008.

UNWFP 2005. Food Insecurity and Vulnerability Analysis: Timor Leste. United Nations World Food Program, Timor Leste.

Viegas, E. 2003. Agricultural mechanization: managing technology change. In: Agriculture: New Directions for a New Nation - East Timor (Timor-Leste). da Costa, H., Piggin, C., da Cruz, C., and Fox, J.(eds). Australian Centre for International Agricultural Research, Canberra.

Appendix A: Survey

Name	Aldeia	Suco	Sub-district	District

1.)Educational attainment

	Husband	Wife	Single
Age			
Years of School			

2.) How many People live permanently in your home?

3.) What kind of animals do you own?

Type	Karau Timor(Cow)	Karau Vaka Buffalo	Kuda Horse	Bibi Goat	Fahi Pig	Manu Chicken	Asu Dog
Number							

4.) How do you involve others in your farming system

Familia (extended family)	
Troka Liman/ Servisu hamutuk (exchanging hands/ mutual labour exchange)	
Selu kole ho osan (paying with money)	
Selu ho animal (paying with assets	

5.)Have you sold any SoL varieties? YES / NO

if yes which ones have you sold?

LDMR (Sele)	Suwan 5	CIP 1 Hoharae 1	CIP 6 Hohorae 2	CIP 7 Hohorae 3	PT5 Utamua	GN11	PSB RC54 Nakroma

6.) Will you plant SoL varieties next season? YES / NO

7.) Which Sol varieties will you plant next season?

LDMR	Suwan 5	CIP 1	CIP 6	CIP 7	PT5	GN11	PSB RC54

Sele)		Hoharae 1	Hohorae 2	Hohorae 3	Utamua		Nakroma

8.) Which variety of Maize do you prefer out of

	LDMR (Sele)	Suwan 5	Arjuna	Kalinga	Local
Know about: Hatene					
Harkarak Kuda: Want to plant					
Gustu (taste)					
Duration of storage (Months storage)					

9.) Perceived yield difference- if local has 10 Bote how many for the other varieties?

	Local	Suwan 5	Arjuna	Kalinga	LDMR (sele)
Bote (bags)	**10**				

10.) Do you own the land that you farm on? YES / NO

If not then is it

Sharecropped	
Communal	
Church/mission	
Government	

11.) In which way do you store maize for food, for seed?

	AI Leten (tree)	Fire place	Ailin (pole elevation)	Umaoan (elevated grain	Bidon (44 gallon	Masa (plastic container)	Bamboo	Silo

				house	drum)			
Food								
Seed								

12.) Do men or women prepare the land? MEN / WOMEN / BOTH

13.) Do men or women select which varieties of maize are grown? MEN / WOMEN / BOTH

14.) Do any of the people in your household earn cash income?

How?	
Sell livestock	
Sell fresh produce	
Sell Coffee	
Sell handmade goods	
Sell to traders (eg copra, candle nut, cloves etc)	
Employment Servisu	
Bua (beetlenut)	

15.)Last year did you

Have enough maize to feed your family all year	
Have enough maize to share or sell	
Not have enough maize	

- in what month did you stop eating maize?

Apr 06	May 06	Jun 06	Jul 06	Aug 06	Sep 06	Oct 06	Nov 06	Dec 06	Jan 07	Feb 07	Mar 07

16.) How many hours walk away is the nearest market?