Maize Production and Storage in Timor-Leste

A report on research conducted by the Department of Agronomy National University of Timor Lorosa'e (UNTL)

March 2006

UNTL

Oxfam

Written By: Acacio Guterres and Robert L. Williams

Cover Photo. Two maize cobs, one local, one an improved variety (Kalinga), after storage for 27 weeks after harvest using a traditional method of storage

Contents

Tables

Figures

Photographs

Images

Executive summary

Maize is the dominant cereal crop in the upland areas of Timor-Leste, with more than 80% of farmers growing some maize. Most rural communities in the upland areas rely on maize as their staple cereal crop, growing one crop a year during the wet season. Average maize yields in Timor-Leste are estimated to be approximately 1.5 tonnes per hectare (t/ha), which is barely enough to meet the calorie intake requirements of a farming family.

From 1961-2003, average East Timor maize yields have increased from 1.09 to 1.4 t/ha, a 27% yield increase. However, average world maize yields have increased by 130% and average maize yields in Indonesia has increased by 251% over the same period of time. Timor-Leste has missed out on the green revolution in maize yields seen in the rest of the world. The basis of the rapid rise in maize yield worldwide has been an equal combination of improved varieties (both open pollinated varieties and hybrids) and improvements in crop agronomy.

The majority of maize production in Timor-Leste is based on the use of traditional varieties, growing on steep hillsides, farmed by subsistence farming families. In these areas, maize is normally stored on the cob in the sheath, either hanging from a tree or above a kitchen.

Modern higher yielding maize varieties such as Arjuna and Kalinga have been introduced to Timor-Leste for approximately 20 years. These varieties have a yield potential of 6 t/ha and yield well above the local maize populations in variety evaluation trials. However, these varieties have had very little impact on most maize farmers in Timor-Leste.

The reasons for poor adoption of high yielding, modern maize varieties are complex. Farmers report problems with the modern varieties including the perception that the new varieties are susceptible to weevil attack during storage. This report details the results of participative research that was designed to enable better understanding of the issues of maize farming in Timor-Leste, record the experience of farming families using modern maize varieties and help inform stakeholders on the practices around maize production, storage and processing.

This participatory research worked with 18 farmer groups in 3 regions (Loes, Maubara and Remexio), testing a range of storage methods with local and introduced maize varieties, for 33 weeks after harvest. The storage of local maize varieties in traditional methods experienced very little weevil damage (1.5% of seeds damaged) whereas the modern varieties stored in the traditional manner suffered 45% loss due to weevil attack 30-33 weeks after harvesting.

Although weevil attack was very severe in the modern maize when stored in traditional methods, there was no weevil damage when the maize was stored in sealed airtight containers. There is therefore great potential to increase maize farming yield and sustainability by the combined use of modern varieties and airtight storage systems.

The key recommendation arising from this research is to combine the use of modern maize varieties with airtight storage as this can lift maize production, allowing farmers to grow a surplus of food. This recommendation is not theoretical, as farmers in a number of isolated parts of Timor-Leste have already obtained the benefit of enhanced levels of food security through the use of a combination of sealed grain storage and the use of modern varieties.

It is also recommended that high yield local maize varieties, such as one variety identified in this research, and modern open pollinated varieties be field tested with farmers in a variety of locations.

1. Introduction and background to the research

The maize plant

Maize was one of the first food plants taken up by farmers, approximately 7000-10,000 years ago in South America. The oldest evidence of maize as a human food comes from archaeological sites in Mexico; this maize is estimated to be 5,000 years old. Over time, maize has spread to many parts of the world.

The spread of maize around the world

It is generally believed that maize was domesticated in Mexico, because of the wide range of maize types there, including popcorn. It is believed that by about 1000 AD there was a process by which they retained the largest and most desirable cobs. In the highlands of central Mexico, farmers assemble for a religious fiesta at maize harvest time, and the farmer with the largest and best cobs is honoured.

Maize was grown throughout the North and South American continents prior to European arrival. It was grown from as far north as present day Canada to as far south as Chile. When Columbus returned to Spain in 1493, he probably carried some flint maize varieties from the Caribbean. This was the first maize to travel outside of the Americas. By the end of the 1500s, maize was grown widely in Italy, Spain and southern France. It was established as a food crop in South Asia by the mid 1500s and reached Japan in the 1580s. By the mid 1600s, it had become an established crop in Indonesia, the Philippines and Thailand.

As part of the spread of maize from Europe to Asia, it is likely that Portuguese traders brought maize varieties to Timor-Leste and Eastern Indonesia. The flint maize varieties commonly found in Timor-Leste today are very similar to those now found in the southern Philippines and in the Caribbean. This suggests that maize currently grown in Timor-Leste and the southern Philippines had a common source in the Caribbean. Hard seeded flint varieties were the first to travel around the world due to their superior storage quality.

How maize grows

A typical tropical maize plant is a tall leafy structure with a fibrous root system, with usually one stem and as many as 30 leaves. The top of the plant is a male inflorescence (tassel), which has a central spike and several lateral branches with male flowers. Each of these male flowers produces abundant pollen. One or more of the lateral branches of the leaf axil develops into a maize cob, which is well covered by husk leaves.

Maize is reproduced by seeds. When the seed is placed in moist soil, it absorbs water and begins to swell. Under warm conditions, the seed starts to germinate two to three days after planting. When germination starts, an emerging root and shoot break through the pericarp (the skin of the seed).

Maize seedlings are visible above the surface of the soil at a three leaf stage. At this time, the meristem (the place where new leaves are first formed) is below the ground. At the time the plant shows six expanded leaves, the meristem is above the ground, and the meristem starts to produce the first tissue that will become the male inflorescence. The plant then undergoes rapid leaf and stem expansion. During this time, the plant grows rapidly in height and the leaves expand, absorbing sunlight. The maize plant develops male and female flowers in different parts of the plant. These are the female inflorescence (the ear or cob) and the male inflorescence (tassel) at the top of the plant. Pollen is shed from the tassel for about a week, and can fertilise the silks (or stigmas) that emerge from the top of the ear.

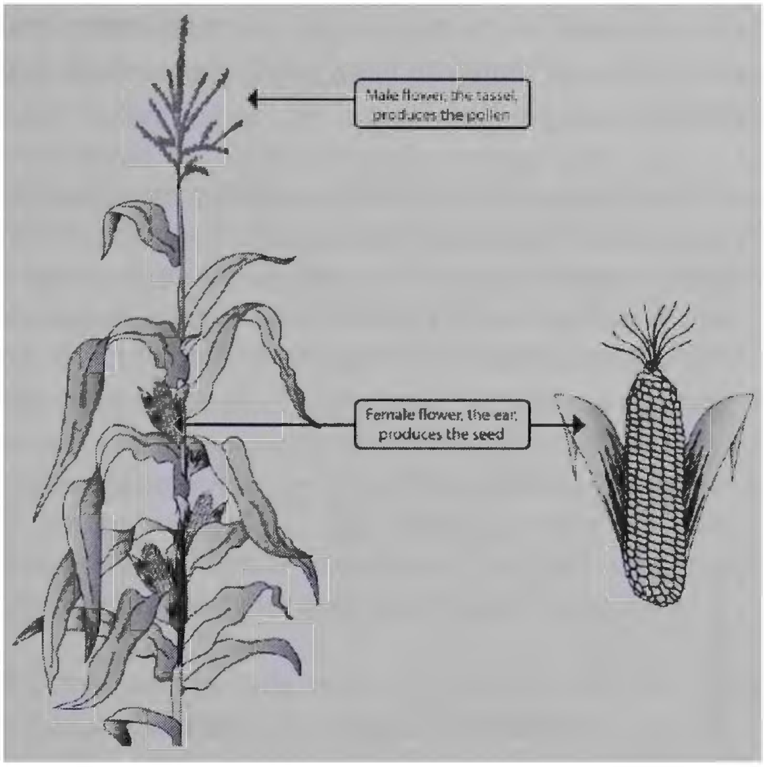


Image 1. The maize plant and its flowering parts

The development of the tassel generally occurs before the ear, and often pollen is shed prior to the silks emerging from the ear. The time difference between the start of pollen shedding and the emergence of the silks is called the Anthesis Silking Interval (ASI). Normally the ASI is approximately two days, but under stress conditions, can increase. Pollination occurs when pollen is trapped by the silks and transported to the developing ovules. Fertilisation results in seed which fills with starch and then dries down.

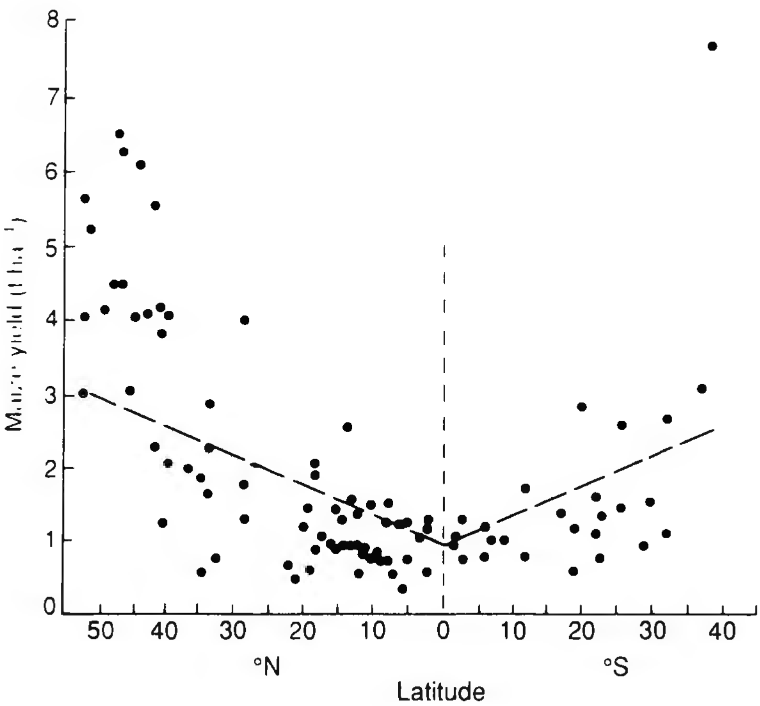


Figure 1. National average maize yields (1975-77) as a function of latitude as plotted by Evans (1996)

In the tropical regions, high day and night temperatures shorten the grain development and filling durations. The reduced duration of these stages reduces the time that the plant has to absorb sunlight and convert it into plant biomass and eventually seed. The high temperature therefore reduces the maximum yield that can be obtained in the tropics. By contrast, maize grown in temperate regions has a longer grain filling duration and therefore has a much higher maximum and average yield than in tropical areas (see Figure 1).

Maize has the advantage of being a tropical plant that utilises the C4 photosynthetic pathway. The C4 photosynthetic pathway is an efficient mechanism that has as the product of the first reaction a four carbon sugar. At higher temperatures, maize can therefore increase crop weight much faster than crops such as rice, which utilise the C3 pathway (see Figure 2). For this reason, with the same allocation of light and water, maize crops will outperform rice crops in terms of yield per hectare per day of growth.

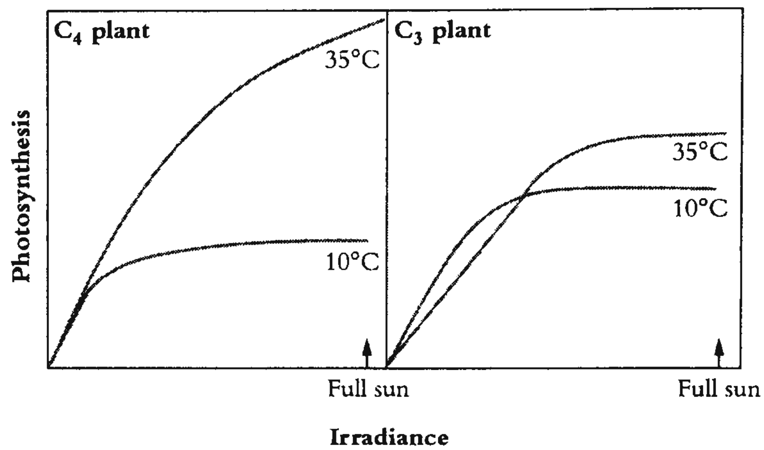


Figure 2. Generalized light response curves for leaf photosynthesis for C4 and C3 plants

Maize is an outbreeding species. More than 95% of the seeds are fertilised by pollen that comes from plants other than the mother plant. Each seed is genetically different from every other seed, because they have different sources of pollen fertilising the embryo, and seeds fertilised by the mother plant also produce genetically unique plants. Thus, the seeds on the one cob (i.e. the one mother plant) may all be different from each other. Both the pollen and the ovule carry genes from the mother and father plants to produce the genetic make up of the resulting seed. This is in direct contrast to rice, which is an inbreeding species. In inbreeding species, the mother plant also supplies the pollen for fertilisation. In inbreeding species like rice, it is therefore possible to have inbred lines that produce seed with the exact same genetic makeup as the parent.

Maize varieties can also be called populations, as each plant in that population is unique. Although the genetic make up of each individual is not conserved from one generation to the next, the general characteristics are maintained from generation to generation. As a result, a maize population that is tall and has white seed of hard/flint characteristics will produce a maize population that is tall and has white seed of hard/flint characteristics, even though all the individuals in the two populations are different.

Maize varieties

There are a range of characteristics used to distinguish maize varieties. Maize varieties can be distinguished in terms of characteristics such as grain colour, texture, composition, plant height, plant colour, resistance to stress (such as drought) and many other characteristics. Maize varieties can also be distinguished by their genetic composition, or genetic make up. The two most common types of genetic populations are open pollinated varieties (OPVs) and hybrid varieties. Timor-Leste has a wide mix of traditional and modern OPVs and a small number of hybrid maize varieties.

Open pollinated and hybrid varieties

An open pollinated variety (OPV) is a population of maize plants, which usually share a similar appearance. However, each individual in the population is genetically different from each other individual. OPVs are reproduced by random mating where there are a large number of plants together. Random mating amongst a large number of outbreeding individuals allows for all the genes in that population to be passed to the next generation in a similar frequency to the first population. As a result, OPVs can be maintained by farmers when grown in isolation as long as there are at least 30 plants together.

OPVs are improved by selecting those plants that have the desired characteristics and then crossing the selected plants to produce a new population that can then reproduce itself. For instance, to increase the height of a maize population, up to 2,000 individual plants are grown and only the 200 tallest plants are crossed among each other. The resulting seeds will have a gene frequency and plant characteristics similar to the original population, but they will have a higher frequency of genes for tallness and will therefore be taller than the original population.

Examples of OPVs in Timor-Leste include local populations such as Kakatua. Introduced OPVs that have been selected for high yield include Arjuna and Kalinga.

Hybrid varieties

More than 90% of commercial maize producers around the world utilise hybrid maize varieties. Hybrid varieties are the result of controlled crossing of two inbred parent populations resulting in the first cross generation (or F1) hybrid. Although maize does not naturally self pollinate, it is easy to develop inbred populations and inbred lines through simple interventions such as covering the silks at flowering time and controlling the pollen that fertilises the one plant. Once a large number of inbred populations are developed, they are crossed together in large numbers and the performance of the resulting F1 hybrid is recorded. In many cases, the F1 hybrid produces a much higher yield than the inbred lines, and also a much higher yield than the original open pollinated population. High yielding F1 hybrids are then further tested and released as commercial varieties.

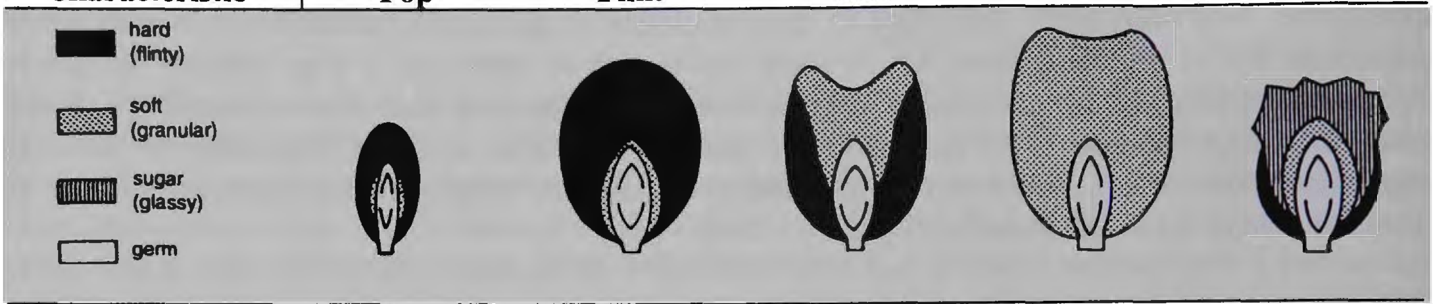
Hybrid maize varieties do not breed true from generation to generation. This means that when the seed from a F1 hybrid maize crop is grown again, the next generation will be very mixed, and quite different from the F1 hybrid crop. Examples of maize hybrid varieties available in Timor-Leste include Besi 1 and Besi 2. Seed of Indonesian sourced hybrid maize varieties is only sold in very small quantities in Timor-Leste.

Flint, dent and floury quality varieties

Maize has a tremendous variety of seed types. They can vary in colour, texture, composition, and size. The five most important maize types that are cultivated are pop, flint, dent, floury and sweet. The characteristics of these five grain types are shown in Table 1 below.

In flint maize, the entire outer portion of the seed is composed of "hard" starch, which does not easily form a paste with water. Flint maize makes good quality cornmeal (drymeal) and has a lower risk of spoilage than dent maize, as the hard seed absorbs less moisture. Flint grain is also more resistant to fungi and insect damage than dent types. Most flint maize types germinate better in cold wet soils and adapt better than other forms of maize in higher altitudes. Flint maize comes in many colours – white, yellow, red-blue or variable. Popcorn, a popular snack food around the world, is an extreme form of flint maize. It is not surprising therefore to find popcorn varieties in Timor-Leste, which is dominated by flint quality maize varieties.

Table 1. Main characteristics of the five principle kernel types of maize



Characteristic	Pop	Flint	Dent	Flour	Sweet
Form of starch	Hard	Mostly hard	Hard and soft	Soft	Glassy
Pericarp (outer skin)	Very thick	Thick	Medium	Stretched thin	Thick-medium
Crown appearance	Pointed or rounded	Rounded	Dented	Slightly dented	Wrinkled
Use	Confection	General	Livestock feed Industrial processing	Direct human use from hand-ground meal	Human consumption at milk stage

Source: Modified from Dowswell et al, 1996

Dent maize is the most widely grown type around the world. It accounts for 95% of the maize in the USA. In dent maize, the "hard" starch is confined to the sides of the seeds, while the "soft" starch amylose, forms the core and the cap. When the seed is dried, the amylose contracts, producing the characteristic dent on the top of the kernel. Dent maize can be yellow or white, but most of the commercially grown maize is yellow dent. Sweet corn is a form of dent corn that has an almost clear kernel when it is still young. The kernels become wrinkled when dry. The cobs are best eaten fresh. The only difference between sweet corn and other dent corn is that sweet corn has a gene that delays sugar from being converted into starch within the grain. This produces fully formed cobs with a low starch and high sugar content.

Floury maize is composed almost entirely of very soft starch that can be scratched by a thumbnail. It is mostly grown in the Andean highlands of South America and in the drier parts of the southwest United States. The people of the Andean highlands prefer floury maize because the seeds are easy to grind into flour. The authors are unaware of any floury types of maize being grown in Timor-Leste.

Maize varieties in Timor-Leste

All maize in Timor-Leste has been introduced from other countries, some a long time ago. Most of what is now regarded as local maize is flint quality maize, which may have been introduced 400 years ago. These varieties have small rounded seeds, made entirely of hard starch. Although the embryo is small, it germinates very quickly, especially in drought or high temperature stress. Short season maize (known as *batar lais*) grows quickly, usually reaching maturity in 60 days. This type of maize is often planted near the house; it is known to have a very low yield, but is the first cereal to be harvested during the wet season. Some farmers state that this is grown for the children to eat, but others say it is for all the family. Full season maize (normally known as *batar boot*) usually takes approximately 50-60 days from planting to flowering and 110-120 days from planting to harvest (Williams 2003).

A range of modern maize varieties have been introduced to Timor-Leste since the 1960s, and some continue to grow. During Portuguese times, a maize variety named *Angola* was introduced, and some farmers in Los Palos, Baucau and Maubara still grow corn varieties known as *Angola*. The authors have heard stories that the initial testing of a maize variety called *Angola* failed due to disease susceptibility, so it is unknown how the current corn populations called *Angola* represent the original introductions in the late 1960s or early 1970s. In Baucau, Angola is known to have good resistance to weevil attack.

More recently, during the 1980s, the Indonesian Department of Agriculture introduced a number of modern open pollinated varieties into Timor-Leste. Two of these varieties are Kalinga and Arjuna, which are semi dent maize varieties, and so are quite different from the local flint maize varieties that most East Timorese farmers grow. Kalinga and Arjuna were bred using modified mass selection techniques for resistance to Downy Mildew (a major disease) and for high yield. Arjuna was released in Indonesia in 1980, and Kalinga in 1985. Both have a yield potential of about 6 t/ha. Unfortunately, when Arjuna and Kalinga were first introduced into Timor-Leste, the packaging included the word "Hybrid". As a result, many East Timorese believe Kalinga and Arjuna are hybrid varieties (*hybrida*). In reality, Arjuna and Kalinga are not hybrids, but rather open pollinated varieties and breed true to type from year to year. Therefore they are an option for subsistence farmers who do not purchase seed each year. Kalinga is the standard variety grown by maize farmers in the Loes valley. More recently, experimental work has demonstrated newly introduced open pollinated varieties, such as Suwan 5 from Thailand, are producing higher yields than Arjuna and Kalinga (Ceniceros et. al. 2002).

Maize production

Maize is the most produced cereal worldwide and in Timor-Leste. Worldwide production has increased significantly in past last four decades, largely due to increased yields. In Timor-Leste, however, yields are generally low.

Worldwide production

The worldwide production of maize (640 million tonnes) is greater than that for rice and wheat, even though maize is grown on a smaller area of land than rice and wheat (see Table 2).

Table 2. Worldwide production, area and average yield of maize, rice and wheat

	Maize	Rice	Wheat
Area (millions of ha)	143	153	208
Yield (t/ha)	4.4	3.8	2.6
Production (millions of tonnes)	640	586	557

Source: FAOSTAT 2005

From 1961 to 2003, the global production of maize increased from 205 million tonnes to 640 million tonnes, a 212% increase. This increase in production was due to increases in both the area planted and higher yields per hectare. However, increases in yield were particularly significant. In the period from 1961 to 2003, yield per hectare increased from 1.94 to 4.46 t/ha, a 130% increase, while the area planted increased by only 36% (see Table 3 below).

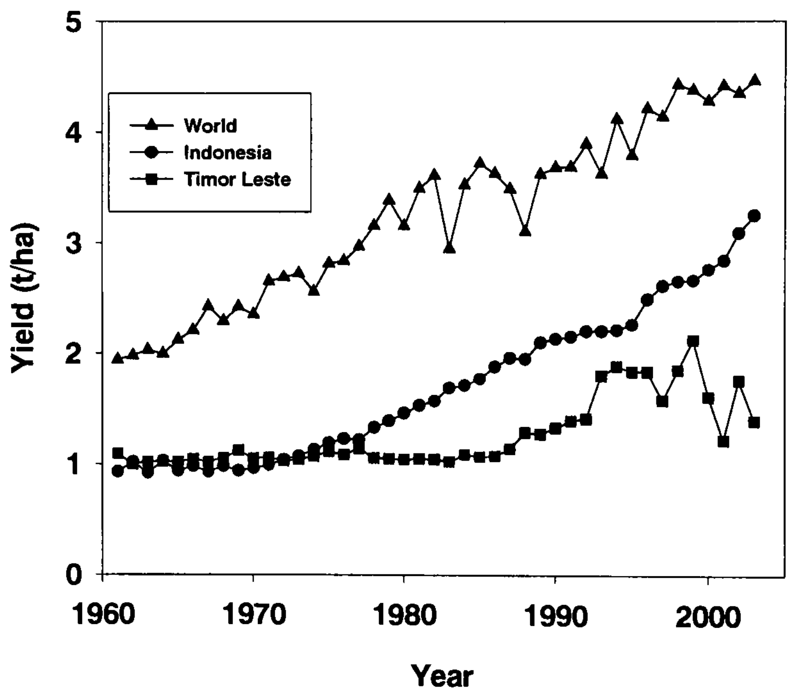
A large proportion of this increase in yields has been due to improved varieties made available to maize growers, adapted to each maize growing location. Improved varieties, both open pollinated and hybrid varieties, have been developed for most maize production locations. In addition to genetic gains, some of the increase in yield has been due to improvement of agronomic practices, especially fertilisation, and pest and weed control. The main usage of the increased maize production has been for intensive production of eggs and meat, initially in the developed world and more recently in developing nations including Indonesia.

Table 3. Maize production, area harvested and average yield for the world, Timor-Leste, and Indonesia for 1961 and 2003

	Production (million tonnes)	Harvested area (million hectares)	Yield (t/ha)
World 1961	205	105	1.94
World 2003	640	143	4.46
Percent increase from 1961-2003	212%	36%	130%
Indonesia 1961	2.28	2.46	0.93
Indonesia 2003	10.91	3.35	3.25
Percent increase from 1961-2003	378%	36%	251%
Timor-Leste 1961	0.018	0.016	1.094
Timor-Leste 2003	0.070	0.050	1.392
Percent increase from 1961-2003	301%	215%	27%

Source. FAOSTAT 2005

Figure 3 below illustrates changes in the annual production per hectare of maize globally and for Indonesia and Timor-Leste.



Source. FAOSTAT 2005

Figure 3. Average maize yield globally and for Indonesia and Timor-Leste from 1961-2003

Maize production in Indonesia

In Indonesia, the increase in maize production has been more rapid than world production, increasing by 378% in the period from 1961 to 2003. This has been due to average yield increasing by 251% and the area producing maize increasing by 36% (see Table 3). Most of the yield increase occurred from 1970 to 2003. During this time, maize production increased at an annual rate of 4.7% per year. This high production growth rate was mainly due to technological progress, with average yield increasing from 1.46 t/ha in 1980 to 2.13 t/ha in 1990 (a growth rate of 3.85%) while the area planted to maize only increased at a rate of 1.45%. Increased yields were achieved through the use of improved varieties (both open pollinated varieties and hybrids) which were released during that period (Swastika et al. 2004). However, the use of hybrid varieties is still fairly low, estimated to be 14% in 1998, up from 2% in 1990.

Maize production in Timor-Leste

Maize is the dominant cereal grown in the dry-land hills of Timor-Leste, and approximately 81% of Timor-Leste farmers grow some maize (ETTA, Suku Survey, 2001). There is no clear agricultural census data for the yield or production of maize in Timor-Leste, but there have been a number of estimates made as listed in Table 4 below. Estimated maize area per year ranges from 50,000 to 70,000 hectares. An FAO/WFP estimate of 50,400 hectares of maize in 2003 includes an allowance of 6,000 hectares of second crop maize, especially in the south of the island. Although the Suku Survey conducted in 2001 estimated the average maize yield to be only 0.57 t/ha, most other estimates of average yield have a narrow range of 1.3 to 1.5 t/ha. It is evident, however, that the yield varies significantly from place to place.

Table 4. Estimates of maize yield and production in Timor-Leste

Source	Estimated area	Estimated yield per hectare
ETTA Suku Survey 2001	70,000	0.57 t/ha
FAOSTAT 2005	50,000	1.4 t/ha
World Vision farm survey 2002/2003	Not available	1.5 t/ha

Photo 1. Much of the maize in Timor-Leste is grown by subsistence farmers on steep slopes

The World Vision maize farm yield survey was a random survey across 25 farms in two districts (Aileu and Bobonaro) in the 2002/2003 cropping season (Williams, 2003). This survey was of random locations in farmers fields. Prior to planting maize, a series of four plots 5m by 5m were marked out in farmer's fields. Fertiliser was applied to two of these plots and the remainder had no fertiliser applied. The crops were managed by the farmers, and the plots were treated the same as the rest of the field. At harvest time, the corn was harvested from these plots and the yield measured. Because the plots were marked out before planting, there was no bias in the yield estimates. The average yield with no fertiliser was 1.5 t/ha, but yields ranged from 0.3 to 3.2 t/ha.

The addition of 15 kg of nitrogen per hectare and 15 kg of phosphorus per hectare increased yields to 2.0 t/ha, a 30% increase.

As with the world's average maize production, Timor-Leste's production has increased substantially from 1960 to 2003 (see Table 3). Estimated production has quadrupled during this time (an increase of 301%), but unlike in Indonesia and the rest of the world, the production increase has mainly been due to a substantial increase in land area producing maize. From 1960 to 2003, the area under production has more than trebled (an increase of 215%), whereas the increase in yield per hectare has only increased by 27%. This yield improvement is much less than that observed in Indonesia and the rest of the world over the same period of time (FAOSTAT 2005).

There are a number of reasons why the rate of yield increase in Timor-Leste has lagged behind the world and the region. One significant reason is that the development of high yielding maize varieties in the world and Indonesia has concentrated on producing maize for animal feed, with farmers purchasing inputs such as seed and fertiliser and selling the maize to the animal feed industry. The lack of an animal feed industry in Timor-Leste has meant there has been little commercial opportunity to produce maize for sale. The result is that the vast majority of maize in Timor-Leste is produced and eaten on farm, with very little traded due to the lack of a market for significantly increased production. A second reason is that the varieties that have been developed have not been selected with small landholder subsistence farmers in mind. This has led to the release of maize varieties that are well suited to the animal feed industry, but not so well suited to subsistence farmers who consume their production directly. Small subsistence maize farmers require not just high yielding crops, but resulting grain and seed that can store well in local conditions, can be easily pounded and have a high percent of grain recovery.

Further increases in maize production in Timor-Leste are needed. At the current production level, most farming families do not produce enough corn to eat cereals for a full year, which contributes to a hungry season of two to five months duration prior to the harvest of the new maize crop. In Timor-Leste, most maize is multi-cropped with other plant species, including pumpkin, cassava, sweet potato and various types of peas and beans. After the maize is harvested, other crops not yet ready for harvest continue to grow on the same land and are harvested at a later date. These other crops are also an important part of rural livelihood systems.

At different times since the post-ballot violence of late 1999, the government, UN agencies and some NGOs have distributed maize seed varieties, such as Arjuna and Kalinga, which can yield two to three times the yield of most local varieties. However, there has been a very low level of adoption of such varieties in Timor-Leste. Only a small percentage of farming families who have been given high yielding seed have continued to grow these varieties. Their reasons for not using the high yielding seed varieties included poor seed storage, a bitter taste, and a general dislike for the grain for no stated reason.

In summary, Timor-Leste maize farmers have so far missed out on the benefits of the green revolution in maize varieties. The yield per hectare increases in Timor-Leste have been far less than seen in other maize producing countries, including neighbouring Indonesia. There is good scope therefore to increase maize yield on farm by capturing the benefits of the green revolution in a way that allows subsistence maize farmers to access the benefits.

Maize storage, processing and utilization

Numerous methods of storage and processing of maize are found around the world and in Timor-Leste. Effective storage is essential to maintain food and seed supplies between harvests. In Timor-

Leste, post harvest losses of maize have been identified as a significant threat to food security, with the FAO suggesting that post harvest losses are as high as 30% for maize and rice. Processing methods vary in Timor-Leste, depending on the varieties of maize, local traditions, and preferences. Most maize in Timor-Leste is consumed by the farmers who grow it; however, some is sold .

Maize storage requirements

As with any cereal, good storage of maize is important, as the seed is planted six to eight months after harvest and needs to be kept viable during that time. Good grain storage aims to minimise the loss of grain to spoilage. Grain storage does not improve the quality of the grain, it only slows down the deterioration. The objective of all grain storage structures is to protect against deterioration due to rain and moisture and to provide a barrier against insect and vertebrate predators. The main spoilage agents are rodents, mould growth, rotting of the seeds and weevil infestation.

Seed is a living organism, with a very slow respiration rate. Over time, seed will lose its ability to germinate. Seed will deteriorate faster in conditions of high moisture content, high temperatures and high humidity. Seed moisture content and temperature are the two most important factors influencing seed storability. Seed biological activity increases as seed moisture content and temperature increase. At the same time, the growth and reproduction of undesirable seed moulds and insects that can attack seeds are increased under higher moisture and temperature conditions.

Both temperature and moisture strongly interact to affect seed quality, although moisture is the most critical factor. The table below shows the effects of seed moisture, including mould growth in and around the seed, on viability. Mould growth is very dependent on seed moisture content. Seed moistures above 14% can give rise to fungal growth, unpleasant odours and rotting.

Table 5. Effect of grain moisture on seed physiology and the presence of abiotic stress factors

Seed moisture content (%)	Seed behaviour and stress occurrence
Above 45-60	Germination occurs
Above 18-20	Heating may occur
Above 14-20	Mould grows on and in the seed
Below 9-8	Little or no insect activity
Below 8-4	Sealed storage is safe.

Source: FAO (2000)

As seeds have the ability to take up or give off moisture, it is essential to store them in environments with low relative humidity. Many years ago a "rule of thumb" was proposed which stated that for proper seed storage the relative humidity (RH) percentage and the storage temperature in degrees Fahrenheit (F) should add up to no more than 100. Examples would include storage conditions of 50% RH and 50° F (10° C) or 60% RH and 40° F (4° C), etc. Such conditions would be quite suitable to maintain maize seed quality in storage for a period of one year or longer.

After harvest, maize is sun dried before storage. This drying reduces the grain moisture from approximately 30% to 14%. The cobs or grain are normally dried in the sun for two to three days. Farmers are able to tell when the grain is dry enough for storage by testing the hardness of the grain between their teeth.

Farmers are unable to reduce the temperature of their maize storage, but they can have some control on the RH by storing grain above a fireplace. There are many benefits of storing maize cobs above a fireplace, one of them being to lower the RH of the air around the corn. For a given absolute amount of water in a volume of air, if the air is heated, the relative humidity will drop. As a result, with corn stored above a fireplace, the RH of the air may be lower than the ambient air. This effect may be counteracted by the boiling of water on the fireplace. The author is unaware of any study looking at temperature and humidity in corn stored above a fireplace compared to the ambient air.

Preventing losses due to weevils and rodents

Preventing weevil and other insect attack is a major objective of long term storage of maize. Weevils found in stored maize in Timor-Leste are commonly called maize weevils (*Sitophilus Zeamais*). Under favourable temperatures, this weevil has a reproductive cycle of about 35 days, and can produce 200-300 offspring each cycle. Therefore, low levels of infestations can increase rapidly if left unchecked. Weevils can infest the maize prior to harvest, and there are clear differences between varieties regarding infestations in the field. Maize with exposed cobs are more prone to weevil infestation than varieties with a tight enclosed sheath at the very end of the cob. The sheath, if tight at the end of the cob, can help prevent weevil entry and infestation.

Weevil infestations can be suppressed by maintaining the maize at a low moisture content, a low oxygen content or through the use of pesticides. As Table 5 above shows, grain below 8-9 percent moisture content has little or no insect activity. This is because the ability of weevils to reproduce is reduced. Low oxygen content also reduces the ability of the weevils to reproduce. Low oxygen environments can be developed by storing grain in airtight containers, as the slow respiration of the grain itself can reduce the level of oxygen if no new oxygen enters the container. If there are weevils present the respiration of the weevils can also reduce the level of oxygen in an airtight container.

Preventing rodent attack of grain supplies is done by separating the rodents from the grain supplies. This is effectively accomplished by the use of methods such as storing grain in a rodent proof container or hanging the grain from a tree or the rafters of a house.

Maize storage methods in Timor-Leste

In Timor-Leste, a considerable variety of post-harvest storage systems can be found, depending on the agro-ecological zone and the customs of different ethno-linguistic groups. The choice of storage method is generally dependent on the location and available resources. The majority of corn is stored in the sheath, as the sheath is able to give protection to the cob inside by acting as a physical barrier to the invading weevils. The sheath can contain 10-20 leaves surrounding the cob. However, some varieties have sheaths that do not cover the tip of the corn cobs, allowing weevils easy access to the cob. Different varieties can have different levels of sheath protection and resultant weevil tolerance. When maize is stored in the sheath, it is normally stored in an elevated dry area to reduce rodent attack and minimise weevil damage.

Options for storage in the sheath in Timor-Leste consist of storing above a fireplace, hanging in a tree or storing in an elevated house (*bou leten*). In some locations, such as parts of Lautem district, maize is tied in bundles for storage. The tips of a number of cobs are tied together and then joined with long strips of bark, which is used like string. It is unknown whether tying the tips of the sheath together enhances weevil tolerance by reducing access points to the stored cob. When hanging from a tree, some of the outer leaves of the cob are pealed back and used to tie the cobs together around a central stick.

If the maize is shelled before storage, it may be stored in silos or second hand fuel drums (200 litres). There are a number of locations in Timor-Leste where farmers regularly store shelled maize in sealed drums. This includes most farmers in the alluvial Loes valley in Liquica district, farmers near Fatumaka Agricultural High School in Baucau district, villages in the subdistrict of Tilomar in

Covalima district, and farmers in parts of Lautem district. In each of these areas, farmers have combined the use of modern high yielding maize varieties with storing the grain in sealed 200 litre drums. Since 2002, the UN Food and Agriculture Organisation (FAO) has encouraged the use of grain silos for corn storage, and some communities now use these silos, which are made by local blacksmiths according to a design and with materials provided by the FAO.

Maize processing and cooking methods in Timor-Leste

Maize is normally harvested by hand at about 30% moisture content and requires considerable drying before storage. A range of options for drying are used through out Timor-Leste. In some places, the cobs are pre-dried in the field on a temporary drying line, before being carried to the house for storage.

If grain is shelled, it is either shelled by hand or placed in a woven poly bag and bashed with a stick. Grain that will be used as seed will always be shelled by hand, as the stick tends to damage a large number of the grains.

There is a range of processing and cooking methods of maize in Timor-Leste. Corn can be eaten as a snack when fresh. It can be roasted above a fireplace, and some varieties can be eaten as popcorn when popped in hot oil (*batar funan*). Farmers generally plant and keep seed of popcorn separate from the other varieties. Maize is most widely cooked as boiled maize (*batar daan*). Before maize is boiled, the maize seed is first pounded in a wooden vessel with a long wooden pole (*alu ho lesu*), shattering the grain and breaking the starch filled endosperm into grit, about the size of rice grains. The embryo and skin of the grain is shattered into fine powder-like material. This fine material (fines) is separated from the grit in a wide shallow dish, and the fines are fed to pigs or other animals, rather than being eaten. The grit is then washed and boiled for one to two hours over a wood fire, together with a mixture of beans and green leafy vegetables depending on availability.

A less common method of maize preparation is breaking the grain individually between two rocks (*batar tuku*) before cooking. The broken grain is then boiled with beans and leafy vegetables as for *batar daan*.

Photo 2. Women pounding maize in a tall wooden vessel with long sticks

Recent research (Williams and Guterres 2004) has documented differences between Arjuna and local maize regarding the effort required to pound the grain and the percent of fine material produced when the grains are pounded. Arjuna required more time and effort to pound and shatter the grain than did the local variety. In testing with three groups of rural families, pounding Arjuna took 60-100% longer to pound than the local variety, and therefore significantly increased the work of women. This was confirmed in the laboratory, where the force to shatter Arjuna seed was 45% higher than that required to shatter the local variety (a 20kg force for the local variety and 27 kg force for Arjuna). The pounding of Arjuna also produced more fine material. When 50g of Arjuna was pounded for 10 minutes, 37% of the original weight became fine material compared to 30% for the local varieties. In terms of taste, Arjuna was found to be a little sweeter than local varieties tested.

Photo 3. White maize after pounding, showing grit and fine material (the grit is eaten, and the fine material is generally fed to chickens and pigs)

Sale of maize in Timor-Leste

While some farmers produce surplus maize for sale, many do not. In relation to social constraints on maize production, Barnett et al (2003) have identified four reasons why many East Timorese farmers may pursue the low labour and low yield form of maize farming that they do: the poor access to markets (poor roads and high transport costs), which may make marketing surplus maize too expensive; the lack of diversification of agricultural production across the country, which means that if market access were better and people produced more maize to sell, the price would drop due to an oversupply; an inability or unwillingness to invest in inputs that would increase production; and rural to urban migration which reduces the labour available.

Market research on the sale of maize has been quite limited. A small survey by CARE International (2004) of rice farmers who also grow maize found that these farmers only marketed small amounts of maize, if any, and that most of them sold directly to neighbours, friends and relatives or to market vendors. Market vendors surveyed said that all maize that they traded was domestically produced (CARE International 2004).

Maize is sold in a number of forms in Timor-Leste. Fresh maize (30% moisture) is sold for roasting and eating as a snack food. Prices for fresh maize range from USD 10c to 20c for six maize cobs depending on the supply at the time. Fresh maize sold on cobs is still encased in the sheath. Dry maize on the cob is sold at various Dili and district markets at USD 10c for three cobs. Threshed whole maize is sold in markets by the tin. The tins are usually sweetened condensed milk tins (375ml) and contain just under 500g. The price of a tin of corn at the time of writing was 25c a tin. This is equivalent to 50c/kg or USD 500/t. As the world market price of maize over the last few years has been about USD 100/t, there is little export potential for maize from Timor-Leste.

Maize requirements in Timor-Leste

One aim of any food security program is to assist families and communities to improve access to sufficient healthy food so that they can concentrate their activities on other needs. As maize is the main cereal eaten by most people in Timor-Leste, efforts to increase the productivity and sustainability of maize production, especially in upland areas, are critical.

The draft national food security policy states that low agricultural production is one of the causes of food insecurity in Timor-Leste. This leads to a national food deficiency, resulting in a self-sufficiency ratio in staple food grains of two thirds. In order to meet the national staple food requirements, one third of the food grains required (60,000 tonnes) would have to be imported. This large deficit of staple foods is due to low yields, not only of maize, but also of rice and cassava, the dominant tuber crop in Timor-Leste (Draft National Food Security Policy for East Timor 2005).

Even if Timor-Leste were able to meet its food grain deficiencies through imports, subsistence farmers would generally not have purchasing power to be able to buy the imported food. Thus, it is necessary to consider the household level production requirements for subsistence farmers.

It is possible to roughly estimate the target yields of maize required for a household to achieve food security, as follows. The average minimum daily calorie requirement per person is 2,100 kilocalories, with 10-12% of total energy to come from protein and 17% from fat (SPHERE 2004). Approximately 60% of this requirement (1,260 kilocalories) should come from carbohydrates. In Timor-Leste, the percentage of calories obtained from carbohydrates is generally higher than 60%, perhaps as much as 80%, due to the low consumption of protein and fats. For the purposes of estimation of household production requirements of maize for subsistence farmers, we will use a figure of 1,680 kilocalories (80% of the average minimum requirement). This is not to suggest that farming families will not be able to obtain some of their carbohydrate requirements from other sources (rice, cassava, sweet potatoes, etc.), but simply to look at what household level production would be required if maize were the sole source of carbohydrates for a family.

Each gram of processed maize provides approximately four kilocalories. Thus, the average minimum daily requirement of maize per person is approximately 420 grams. According to the provisional results of the 2004 Census, the average household size is five people (4.7), a figure which does not vary greatly between districts, as the average in each district is between four and six people per household. On this basis, the average minimum daily requirement of processed maize per household is 2.1 kgs (2,100 g).

Due to processing of maize prior to cooking (removal of the embryo and outer skin of the seed), each kilogram of whole grain maize will reduce to approximately 700 grams of maize grit that is boiled and eaten. Thus the average minimum daily requirement of whole grain maize per household is approximately 3,000 grams (3 kg). The annual requirement per family is therefore approximately 1,095 kg.

The average land per household has been estimated to be around 0.8 hectares, and the seed requirement to plant 0.8 ha of maize is approximately 35 kg. Because of intermittent rain, farmers need to store enough seed for at least three plantings, so they need at least 105 kg of seed.

Therefore, the average production requirement per household is approximately 1,200 kg on 0.8 hectares of land, which requires a yield of 1.5 tonnes (1,500 kg) per hectare.

This minimum yield requirement of 1.5 t/ha is at the upper end of estimates of average maize yields in Timor-Leste (see Table 4 above). Note that this figure does not take into account post harvest loss and is based on an average sized household. In many cases, families would need to produce maize with a much higher yield to be able to meet their minimum carbohydrate requirements from maize and/or would need significant additional sources of carbohydrates. This highlights the need for improved maize yields and good storage.

2. Research objectives and methodology

To better understand maize production and storage in Timor-Leste, the National University of Timor Lorosa'e (UNTL), with funding support from Oxfam, undertook a research project in 2004.

Research objectives

The main objective of this UNTL research was to learn with farming families, through participatory methods, the ways that maize is included into farming households, especially how it is grown, stored, processed, and eaten. Specific objectives were:

- to identify the gender roles in maize production, storage and processing practices
- to describe the maize production and storage systems of farming families, especially as they relate to farm size, the volume and method of food and seed storage, the inter-cropping species grown, and the agroecological zone.
- to understand the perceptions of farmers regarding the maize varieties they are currently growing
- to describe the process of how farmers make choices about what maize varieties they will use and how and why they select the seeds that they do for planting in the following growing season
- to analyse and compare the storage, processing and eating qualities of local and modern maize varieties
- to record the experience of farming families with modern maize varieties, such as Kalinga and Arjuna
- to help inform stakeholders (including the government, UN agencies, donors, NGOs and communities) about attitudes and practices around maize production, storage and processing in Timor-Leste
- to enhance the capacity of UNTL and the agencies and farmers participating in the research to reflect on, analyse, record and describe the agricultural systems in Timor-Leste

Research team

The research team from UNTL included as senior investigators Sr Acacio da Costa Guterres and Mr Rob Williams. To conduct the research, they worked with farmer groups with and through local NGOs and with the assistance of two project staff who were recruited for the project. These project staff, Joni Anwar and Joscelina de Carvalho Gusmao, were both students who had completed their course work at UNTL, but had not yet graduated. They provided liaison between UNTL and the farmer groups and carried out laboratory work.

Research sites

The research project focused on maize growing regions of Timor-Leste in districts close to Dili. These sites were chosen to give a range of agro-ecological environments and maize production systems located on the north coast, within easy travel from Dili. The north coast was specifically targeted because of the long dry season during which corn must be stored. On the north coast, corn grows in the field for four to five months and is stored and consumed for the reminder of the year. The three regions where research took place were in Loes in Liquica district with most sites at 10-20m above sea level, the area around and inland from Maubara town in Liquica district with sites from approximately 200-700m elevation, and the area around Remexio town in Aileu district with sites at approximately 800m elevation.

Research methodology

The project involved desktop, fieldwork and laboratory research activities and a stakeholder workshop. The desktop research was a survey of current knowledge of maize production, storage and processing systems in Timor-Leste and similar maize systems elsewhere in the world through a review of existing literature.

For the fieldwork, UNTL staff worked with 18 farmer groups that had been previously established, some of which were being supported by local NGOs: seven groups supported by ETADEP in the Loes area, five groups supported by Rai Maran in the coastal hills around Maubara town, and six groups in Remexio. The field research started around harvest time at the end of the wet season and ended around the time of the planting of the next crop at the start of the next wet season. Project staff visited each field site once every three weeks (a total of 11 visits per location) for the duration of the field based part of the project.

During each field visit, the staff completed two tasks. The first task was a maize storage experiment, which went for 33 weeks, from 1 April to 16 November 2004. In this experiment, the staff worked with local farmers to track and record the storage qualities of local and modern maize varieties. One storage experiment was established at each site and included the local maize varieties and local storage methods. Prior to conducting the experiment, farmers were asked about the varieties that they grew the previous year and their method of storage. An experiment was then designed that included recently grown corn varieties and the normal method of storage.

Photo 4. Project staff with three types of maize storage – shelled maize in sacks and in sealed 5 litre jerrycans and cobs tied to store above a fireplace (one replicate of six treatments is shown)

The typical experiment consisted of six treatments, that is, two varieties stored using three different methods. Each variety/treatment combination was replicated twice. Thus, there were 12 experimental units at each site. Maize used for the experiment was purchased from farmers at the start of the experiment, and the farmers kept the stored maize away from rodent attack. Each lot of maize consisted of 50 cobs, equivalent to approximately 2 kg of grain. Identifying marks were made on the different maize varieties, so that they could be identified through the course of the project. All grain was clean and weevil free at the beginning of the experiment. The shelled maize was shelled by hand.

Across all sites, there were three traditional methods tested: hanging in a tree, storage above a fireplace, and storage in an elevated house. Maize stored using these traditional methods was stored in the sheath. Several groups used more recently introduced methods, all of which were examples of airtight storage, and these were also tested: storage in a second hand fuel drum (with a capacity of 200 litres), storage in a silo, and storage in sealed 10 inch-diameter water pipes. For storage in the sealed containers, the grain was first shelled. At each site, for comparison purposes, maize was also stored in a woven poly sack and in a sealed 5 litre plastic container. In both these cases, the maize was shelled. Table 6 shows the number of groups using each storage method for the experiments.

Table 6. Types of storage method and the number of groups using each method for the trials

Methods of Storage	Number of groups
Local methods used:	
Traditional methods	
Above a fireplace (in sheath)	7
Hanging in a tree (in the sheath)	6
In an elevated house (in the sheath)	1
More recently introduced methods (airtight storage)	
Sealed drum (200 litre, shelled)	3
Silo (shelled)	1
Sealed water pipes (10 inch diameter, shelled)	1
Methods used for comparison:	
Woven poly sack (shelled)	18
Sealed 5 litre plastic container (airtight, shelled)	18

The maize varieties tested included two of the most commonly grown modern varieties – Arjuna and Kalinga. There was also a selection of local maize varieties, which farmers identified as either full season maize (large cob, *batar boot*) or short season maize (quick corn, *batar lais*). It was expected that in each group, an experiment could be established that compared local maize varieties with a modern variety such as Kalinga or Arjuna, which had been distributed to farmers at planting time the year before. However, in practice this was not possible, as not all groups had more than one variety. Some had only local varieties and some had only modern varieties. Table 7 shows the number of groups that had each variety.

Table 7. Maize varieties and the number of groups with each variety

Variety	Number of groups
Kalinga	7
Arjuna	6
Full season	9
Short season	5

Every three weeks, UNTL staff returned to each field site. Together with the farmers, they checked the stored grains for any storage problems, and the farmers were asked to judge the suitability of the cobs for human or animal consumption. Farmers could see for themselves the immediate results of any weevil damage for the different combinations of storage method and variety. Observations were made with the farmers regarding moisture, moulds and weevils while the research staff collected a sample of maize from each experimental unit for laboratory testing at the UNTL campus at Hera. Each sample was approximately 100g (or two cobs). At the Hera laboratory, these samples were analysed for the percent of moisture and the percent of seeds with weevil damage. Weevil damage was measured by staff inspecting each grain in the sample and dividing the sample into clean seed and weevil damaged seed. The numbers and weight of the clean and eaten maize were measured. Moisture percent was measured by weighing the sample and then drying the sample in an 80°C oven for three days before reweighing. The difference between the two weights was a measure of the amount of water in the seed, and this was expressed as a percentage of the initial weight. During the course of the field research, the staff, along with the farmers, also did germination tests for seeds stored using the different methods.

Photo 5. A maize sample with approximately 50% of the grain damaged by weevils

The second task for the research staff during the field visits was to talk with the farmers about specific topics related to maize production and storage. To gather this information, staff used a semi-structured interview style with the farmers who were there at the time of the visit. The staff wrote notes after each farm visit to record their findings. Topics for discussion and action with the farmers included the following, though not all of these topics were covered at all sites:

- Discussion of maize storage practices by members of the group
- Assessing the volume of maize needing storage
- Ranking of factors reducing the yield of the maize crop just harvested
- Introduction to dry sealed storage of seeds and asking farmers about their expectations of what will happen to the seed in the sealed containers
- Recording the size of the holding used for the crop just harvested as reported by group members
- Physical measurement of some farms for size, slope and soil depth using a soil auger (this included showing the use of measuring tape and marking out 20m, 50m and 100m examples at the sites)
- Looking at the frequency of multi-cropping in maize fields and assessing the percentage of maize crops that have tuber and other crops inter-cropped in the same area

- Discussion of what is considered an appropriate balance in a multi-crop strategy and how house gardens are treated differently to fields that are further away
- Investigating what diet is eaten in which months
- Recording when the farmers harvest cassava and sweet potato for human or animal consumption
- Investigating the use of wild foods in the diet, especially yam bean (*sinkomás*) and bitter beans
- Investigation of who forages for wild foods, where they are collected, for how long each day, for how many days, and whether they are stored or eaten directly
- Investigating seed selection and planting strategies of farmers
- Investigating the effect of *adat* (including traditional law and local taboos) on production and storage
- Assessing the size of the holding for the crop to be planted as reported by group members
- Physical measurement of some farms
- Recording the percent of crop to be planted in newly opened areas and the percent to be planted in a repeat cropping cycle
- Identifying gender roles and *adat* roles in identifying farm areas and preparing the ground

After data was collected and analysed, initial results were presented at a stakeholder workshop held at UNTL on 26 November 2004. This workshop provided a forum for representatives from UNTL, the Ministry of Agriculture, Forestry and Fisheries (MAFF), UN agencies, donors, NGOs and farmer groups to discuss the research findings and help develop recommendations.

3. Results of the maize storage trials

The testing for weevil damage revealed some big differences between different storage methods and different types of maize. Weevil damage can have a big impact on food security, as maize cobs with more than 20% of the grain eaten by weevils are very unpalatable and are often discarded as pig food. The testing of water content, however, did not reveal any significant differences between sites nor between different methods of storage.

Weevil damage for the different storage methods

There were large differences between the different storage methods and different maize varieties regarding weevil damage during the testing period. In the sealed containers, no weevil damage was recorded at any of the experimental sites. This was true for all varieties and for all the different methods of storing the corn in an airtight container (see Table 8), even though the containers were opened each three weeks for seed sampling.

Table 8. Percent of grains eaten by weevils for the four methods of storing in a sealed container, averaged for all varieties of maize tested

Number of weeks of storage	Sealed 5 litre plastic container (threshed)	Silo (threshed)	Second hand fuel drum (200 litres) (threshed)	Sealed 10 inch diameter water pipe (threshed)
3	0	0	0	0
6	0	0	0	0
9	0	0	0	0
12	0	0	0	0
15	0	0	0	0
18	0	0	0	0
21	0	0	0	0
24	0	0	0	0
27	0	0	0	0
30	0	0	0	0
33	0	0	0	0

Table 9. Percent of grain eaten by weevils when stored in a sack and using three traditional methods, averaged for all varieties of maize tested

Number of weeks of storage	Woven poly sack (shelled)	Above a fireplace (in the sheath)	Hanging in a tree (in the sheath)	In an elevated house (in the sheath)
3	0	0	0	0
6	0	0.3	0	0
9	2.4	0.1	2.4	0
12	7.3	0	2.8	0
15	23.6	2.9	0	0.7
18	37.3	1.3	6.2	0
21	60.8	5.1	2.0	30.3
24	69.4	2.5	7.0	12.2
27	84.7	1.5	1.1	12.5
30	92.8	6.2	24.8	1.3
33	98.0	4.5	22.6	48.9
LSD p>0.05	6.0			

In contrast to storage in an airtight container, there was significant weevil damage to the grain stored using all the other methods. Storing shelled maize in a woven poly sack was the worst method. By 30 weeks after the start of the experiment, more than 90% of the seeds in sacks had been attacked by weevils. This was significantly worse than the three traditional means of storage tested. The best traditional method tested was storage in the sheath above a fireplace, followed by hanging in a tree and storage in an elevated house (see Table 9).

Weevil damage for different varieties of maize

Local and introduced maize varieties were damaged by weevils at a similar rate when stored in a sack. For this storage method, both types of maize were damaged quite quickly, with more than 50% of the seeds damaged by weevils after 21 weeks of storage. There were no statistically significant differences between the local and modern maize varieties regarding how fast they were attacked by weevils when stored in a sack (see Table 10).

Table 10. Percent of grain damaged by weevils for local and modern maize varieties when stored in a woven poly sack (threshed)

Number of weeks of storage	Local Varieties	Modern varieties
3	0.0	0.0
6	0.0	0.0
9	1.1	4.1
12	4	4.1
15	18	30.4
18	31.8	44.7
21	61.4	60.1
24	70.7	67.7
27	86.2	83.2
30	92.4	93.2
33	97.0	99.3

Table 11. Percent of grains damaged by weevils for local and modern varieties when stored using three traditional methods

Number of weeks of storage	Above a fireplace (in the sheath)		Hanging in a tree (in the sheath)		In an elevated house (in the sheath)	
	Local	Modern	Local	Modern	Local	Modern
3	0.0	0.0	0	0	0.0	0.0
6	0.0	1.3	0	0	0.0	0.0
9	0.0	0.4	3.1	1.4	0.0	0.0
12	0.0	0.2	1.8	4.1	0.0	0.0
15	2.0	6.5	0	0.1	0.0	1.3
18	1.0	2.3	5.1	7.7	0.0	0.0
21	6.4	0.0	0	4.6	0.0	60.5
24	2.6	1.7	10.0	2.3	0.0	24.3
27	1.7	0.6	2.0	0.0	16.7	8.4
30	2.8	20.0	5.3	50.7	1.0	1.6
33	0.0	22.0	0.0	48.9	0.0	97.8
LSD p<0.05	3.0					

Modern varieties were damaged quicker and more extensively by weevils than local maize types when stored on the cob using the three traditional methods (above a fireplace, in a tree and in an elevated house). The vast majority of samples of local varieties tested near the end of the trials showed very little weevil damage. By contrast, weevil damage to modern varieties was very significant by the end of the trials. For the last two samples (30 and 33 weeks after storage), averaged across the three traditional methods, local varieties suffered just 1.5% damage, whereas for the modern varieties, 40% of the grain was damaged by weevils (see Table 11).

Moisture content for different methods of storage

The measures of grain moisture content did not vary across the duration of the sampling. Only one maize sample was stored at moisture content above 12%. This was at one location in a sealed airtight container (water pipes). When sampling the maize at this site, the staff recognised fungal growth on the maize and a musty smell, indicating relatively high moisture content. This was the only observed case of fungal growth. All other samples were stored at low enough moisture for long term storage of maize seed. Grain moisture, averaged across the 11 samples collected for each treatment, is presented in Table 12.

Table 12. Average moisture content of grain stored using different storage methods

Methods of Storage	Moisture content (%)
Above a fireplace	10.2
Hanging in a tree	10.3
In an elevated house	10.5
Sealed drum (200 litre)	10.7
Silo	9.5
Sealed water pipes (10 inch diameter)	14.1
Woven poly sack	11.0
Sealed 5 litre plastic container (airtight)	11.7
LSD $p<0.05$	0.80

4. Maize production in three areas of Timor-Leste

The semi-structured discussions with farmers at the various fieldwork locations every three weeks provided qualitative data on maize production. The three areas where fieldwork was done – the lowland Loes area in Maubara subdistrict, more upland parts (200-700m elevation) of Maubara subdistrict, and upland areas in Remexio subdistrict (800m elevation) – had many similarities, but there were also considerable differences. In particular, differences were observed in the natural resources available to the communities, the level of technology used and the level of production.

The average farm size per family was approximately one hectare in each of the three areas, but production varied considerably. Most farmers at the lowland Loes sites reported a surplus of maize each year. They reported that they sell this surplus to purchase rice and other commodities. Farmers in more upland parts of Maubara also reported that they usually sell some maize. However, farmers in Remexio reported that they do not produce enough to sell corn. In terms of the natural resources, this is surprising, as farmers in Maubara and Remexio appear to have very similar natural conditions (steep hillsides with thin soils), but they end up with a different level of production. The semi-structured discussions enabled staff to investigate the methods of production and reasons for differences in production in the different locations.

Maize production at research sites in lowland Loes

The area known as Loes is in a mostly lowland part of Maubara subdistrict in Liquica district, located approximately 90 km west of Dili on the north coast. The research staff interacted with seven farmer groups in the sukus of Gugleur and Vatuboro, specifically with one farmer group in each of the aldeias of Loes Centro, Kaibai Alex, Kaibai Julio, Lebulugor, Trans, Tatamolobu and Wabitabo. These farmer groups were associated with the NGO ETADEP. Being on the main road west of Dili, the area has good access to transport and high visibility to passing traffic. A number of agencies work in the area, including ETADEP, FAO, YASONA, CBCJ, Caritas Dili, and LODA.

Photo 6. Loes farmer with grain silos used to store maize

Environment

The area is characterised by deep alluvial soils, which are relatively flat, and therefore can be easily cultivated by tractor. All of the sites were very similar except for Wabitabo, which is an upland site with thin soils and a more traditional way of farming than the other sites. This section of the report defines the Loes research sites as those farming in the flood plain area of the Loes river, with deep soils on a flat plain, at 10-20m elevation. As such, it excludes the Wabitabo site, which has more in common with the traditional farmers of upland Maubara and Remexio.

Method of maize production and adoption of technology

Farmers in Loes interviewed for this project are the closest example to a commercial cereal production the authors have seen in Timor-Leste. These farmers rent tractors for land cultivation and then sell the grain to buy rice, other food stuffs and other essentials. During the visits, there was a greater number and diversity of meat producing animals present than in other sites. Their domesticated animals included cows, buffalos, goats, ducks, geese, pigeons and chickens.

These farmers have a high level of production per hectare on permanent farms due to a range of factors. The climate and favourable soils combine to enable two crops of maize each year. As the authors are unaware of current or past rainfall data for this area, it is difficult to determine whether the second crop is possible due to extra rainfall in the area or due to the deep soils; however, it is more likely to be due to the deep soils, which can store water at depth. The first crop is sown with the first rains in November/December and harvested in March. The second crop can then be planted in March and harvested late in the dry season.

Tractors are used to plough the land twice before planting. The first pass is with a disc plough and the second is with a tyne plough and is called "grading" the land. This cultivation reduces the labour required for land clearing, especially in areas with a high incidence of blady grass (*du'ut manlain*, scientific name *Imperata cylindrica*) in the permanent farms. It is almost impossible for a family to control this blady grass over one hectare of land using just hand-held tools. Therefore, tractors are key to enabling this land to be productive.

Variety choice

All farmers interviewed reported using the modern maize variety Kalinga. When farmers were asked why they grew Kalinga, five of the six groups in Loes replied that it was because they had access to silos and sealable 200 litre petrol drums to store the grain. This clearly shows that these farmers are very aware of the need for good airtight storage of modern varieties such as Kalinga. The grain is threshed from the cobs before being stored in the drums.

Storage options

Farmers in Loes use sealed storage options for grain storage. The methods used include a variety of silos, second hand 200 litre fuel drums and sealed water and drainage pipes. They report that Kalinga can be stored for a considerable length of time in the silos and sealed drums. One farmer had a silo of maize (variety Kalinga) that had been stored for 14 months. The silo had been sealed with insulation tape at the top and bottom of the silo, which prevented oxygen and humidity from entering the silo. The silo had been opened infrequently in this time. When tested as part of the research, the seed was clean of weevils and had a germination test rate of more than 90%.

Mixed cropping

The maize fields of the farmers in Loes are monoculture of maize. This is quite different from the other two areas where research was done. The house gardens in Loes, however, are a mixed combination of many crop species. House gardens contain maize, pumpkin, long beans, sweet potato, cassava, peanuts and pigeon pea.

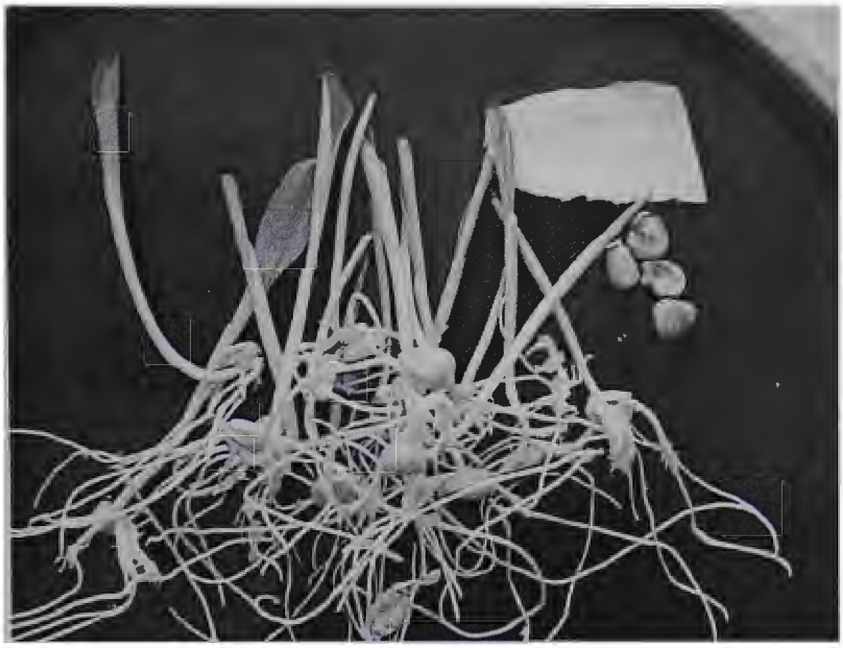


Photo 7. Germination of Seeds of Kalinga stored in silo for 14 months at Loes

Diet

The farmers reported that they eat corn twice a day, for lunch and dinner, and for breakfast eat bananas with either cassava or sweet potato. The average daily consumption of maize was four to five tins (375g sweetened condensed milk tins) of threshed maize (approx 2 kg) for a 10 person family; that is, approximately 200g per person per day. Although the groups in Loes were aware of wild foods and enjoyed eating them when family members brought them from the hills, these groups did not look for wild foods themselves.

Seed selection

These farmers select maize seed from the centre of large well-formed cobs. It is unclear whether the seeds for planting are kept separate from the maize that is sold or eaten by the families.

Gender roles

In Loes, there was a clear gender division of labour for some activities related to maize production, storage and use. Other activities could be done by both men and women. Men clear the ground prior to planting. Women have the main role in planting, but may be assisted by men. Women are the main harvesters, whereas the men arrange storage of the harvest. Preparing the corn for consumption and cooking is only done by women. Gender roles were similar across all three research areas, and are shown in Table 13 below.

Table 13. Gender roles identified across all 13 locations of the research

Activity	Gender roles
Clearing/cultivating the ground	men
Planting	women (may be assisted by men)
Weeding	women and men
Harvesting	women (may be assisted by men)
Storing	men
Threshing and selecting seed	women (may be assisted by men)
Pounding	women
Cooking	women
Selling surplus	women and men

Traditional beliefs and practices related to maize production

Farmers in Loes reported no *lulik* traditions in the process of farming maize. As most *lulik* activities are associated with opening new gardens, these may have been lost with the development of the permanent farms in Loes.

Maize production at research sites in the hills of coastal Maubara

There were five farmer groups involved in this research from the hills around Maubara town. Maubara town is in Maubara subdistrict in Liquica district and is approximately 50 kms west of Dili. All the groups were within 10 km of Maubara town, which is the subdistrict capital. There were two groups from the aldeia of Vatuguili, and one each from the aldeias of Baiquinulau, Darimina, and Kamela Ramut in the sukus of Maubaralisa, Vatu Vou and Vaviquinia. These five groups had been developed with assistance from the local NGO Rai Maran.

Environment

The research sites ranged in elevation from 200-700m above sea level, and the farmers who participated in the research live and farm on the north facing slopes of hills close to Maubara town. The soils in this area are derived from uplifted ancient river deltas. They are medium texture, but quite poor and thin, especially lacking in phosphorous. Although Maubara town has a low annual rainfall of 934mm, rainfall increases with altitude. For example, inland from Maubara town at altitude 460m, Boibau has an annual average rainfall of 1386mm. At 700m above sea level, there is often rain and fog in the wet season afternoons.

Method of maize production and adoption of technology

In this area, corn is produced in a slash and burn system. Food gardens are cleared of vegetation at the end of the dry season (August to October). The vegetation is cut, dried and burned in piles in the new gardens, and then a fence is built around the garden. There is no tillage on these farms. This area will be cropped for a number of years before being abandoned. The method of maize cultivation is very similar to that described by Metzner (1977).

It is often assumed that the reason for moving from one garden to open a new garden is due to soil fertility decline. However, during discussions with farmers, it became apparent that the increasing weed burden with each year of cropping is a major consideration regarding when to move gardens. The first year that non-grass vegetation is cleared for a food garden, there is very little weed burden. This is due to very few grass-weed seeds in the soil. However, very soon, weed seeds move onto the site and establish themselves, and increase in numbers. When talking to one farmer about this topic, he summarised it saying: "To clear new land is easier than weeding." He clearly linked the moving of food gardens to an increase of weeds.

With the exception of using maize varieties introduced in Portuguese times, there has been a very low level of adoption of technology in this area.

Variety choice

These farmer groups grow a wide range of maize varieties, which they group into two categories, short season maize (*batar lais*) and full season maize (*batar boot*). In these two categories, there were further distinctions. A variety called Gari was defined as *batar lais*, while varieties named as Ainar, Kolana, Angola and Arjuna were examples of full season varieties. Arjuna was grown in Kamela Ramut, which is the lowest altitude of the four group locations.

The three varieties Ainar, Kolana and Angola were believed to be local corn (*batar rain nain*), but had the appearance of modern maize. The grain of these three varieties were large seeds, with an apparent cap of soft starch on the seed on large cobs. The largest cob was of the variety Ainar, with a weight of 92g per cob, similar to that of Kalinga and Arjuna (see Table 14). It is likely that these three populations (Ainar, Angola and Kolana) were derived from modern varieties during the Portuguese era, have since been outcrossed with local maize populations, and have been kept distinct from local populations by the farmers when they have selected seed each year.

Table 14. Weight of grain per cob from a range of sources (mean weights are an average of 30 cobs at each site)

Source	Variety	Grain weight per cob (grams)
All areas	Arjuna	94
Loes	Kalinga	93
Vatuguili, Maubaralisa	Ainar	92
Baiquinulau, Maubaralisa	Angola	75
Darimina, Vatu Vou	Kolana	69
All areas	*Batar lais*	55

Farmers in the four groups around Maubara town knew of the modern maize varieties Arjuna and Kalinga, but did not grow them. Some farmers knew of the trials at Loes where the ACIAR funded "Seeds of Life" project had produced very high yields on the deep fertile soils in the Loes valley. These farmers suggested that those varieties were adapted to tractor cultivation and would not produce a good yield when grown on the hills, which were not cultivated. In addition, they were aware of the storage problem of these new varieties. In the previous season, FAO had distributed Arjuna seed to farmers in these groups. They reported that they used this seed to feed their chickens, and did not plant it.

Storage options

The groups in Vatuguili, Darimina and Baiquinulau reported that all farmers in their areas stored corn above a fireplace. Only for the group near the coast, in Kamela Ramut, was corn not stored above a fireplace. In this location, it is stored in an elevated house, with no additional drying facilities. This was possible near the coast due to a lesser incidence of rain and fog, resulting in a lower average relative humidity on the coastal plain.

Mixed cropping

Both the house gardens and the distant gardens are planted in a mixed manner to a wide range of species. The species mentioned by these groups include pumpkin, long beans, sweet potato, cassava, pigeon pea, velvet bean and arrowroot. Only peanuts were mentioned as being planted in a separate area, not mixed.

Diet

The farmers in these groups are traditional farmers who report that they are able to produce sufficient corn on these northern slopes to sell some for income. Some of the groups at higher elevations also have access to coffee plants and are able to sell and trade coffee as a source of income.

The farmers reported eating maize twice a day, for lunch and dinner, and eating a mixture of root crops and bananas for breakfast. The amount of corn eaten per person per day was defined as the number of cobs per person. Adults were said to consume three to four cobs per day, and children one to two cobs per day. On the basis of an average cob size of approximately 70g (taking into account the different varieties grown in the areas) then consumption is approximately 230g per day for an adult and 70-140g per day for a child.

The diet is enriched by a wide range of other crop species that are grown in the main food garden, as well as from the collection of wild foods which form a significant part of the diet. The foods identified by the farmer groups included bitter bean (*koto moruk*), wild yam (*kumbili*), elephant foot yam (*maek*), velvet bean (*lehe*) and yam bean (*sinkomás*). These are generally collected in July and August and eaten in conjunction with the dominant starch crops.

Photo 8. Maize storage in Maubara – kitchen with maize storage area above, accessable by ladder

Seed selection

Maize is stored in the sheath, and there is no separation of the cobs to be used for seed and cobs to be used for eating. At the end of the dry season, as the men prepare the fields, the women select cobs and seeds for planting. They only select large clean cobs for seed, and only the seeds in the middle of the cob are shelled for seed. These seeds are then stored in tins, as the farmers wait for the rain and a planting opportunity in October or November.

For these farmers, this seed selection stage is the stage at which the seeds of the different maize varieties are distinguished from each other. Varieties are therefore defined in terms of the size of cob and the visual appearance of the seed. As there is no variety selection in the field, there is no selection for characteristics such as plant height, cob height, number of cobs per plant, etc. Plants that produce a single large cob are used as mother plants for the next generation. One implication of this method of selection is that it is likely that the plants that are more competitive (that is, plants that are taller and shade out other plants) are the ones selected as the mother plants. This selection method may be good for developing populations that are weed competitive, but it may also lead to selecting tall thin-stemmed plants that are susceptible to wind damage.

Significantly, seed selection at the end of the dry season indicates that there is positive selection pressure for weevil resistance. As cobs that have been attacked by weevils are not used for seed in the next generation, there will be greater chance that weevil resistant genes will be passed on to the next generation. This selection may allow these farmers to improve the weevil tolerance of introduced varieties such as Angola, given sufficient generations.

Gender roles

The gender roles identified in the area around Maubara town are consistent with those in the Loes area. Weeding is a considerable burden on the families, and all able bodies people are required to assist in weeding.

Traditional beliefs and practices related to maize production

A number of *lulik* traditions were recorded, mainly associated with the opening of new gardens and harvest time. When opening a new garden, there is a requirement to ask traditional authorities to perform a *lulik* ceremony at the new site. The farmers said that the purpose was to feed the ground and ask permission of the local spirit to farm at that location. The ceremonies include spilling animal blood on the area, usually the blood of a pig or a goat. At harvest time there is also a *lulik* ceremony to start the harvest. There is strong tradition that the harvest cannot start prior to this ceremony being conducted. This ceremony includes the boiling and eating of eggs in the garden as well as spilling chicken blood. There is also a general tradition that one cannot enter another person's farm without their permission.

Maize production at research sites in Remexio

Six farmer groups from Remexio subdistrict in Aileu district were included in the field research. All six groups were within five kilometres of the subdistrict capital, Remexio. The groups were formed especially for this project. There was one group in each of the aldeias of Raimutin, Fahilebu kraik, Fahilebu leten, Aldeia 1, Aldeia 2 and Fahilebu Riliun, within walking distance of Remexio town.

Environment

In this area, the soils are very similar to those found in the Maubara hills (Cardoso e Garcia 1976), being medium textured. All groups were at a similar elevation (approx. 800m) and most had access to coffee production. This area has a significantly higher annual rainfall (2070mm) than the other two areas.

Method of maize production and adoption of technology

The method of maize production was similar to that in the Maubara hills, as was a low level of technology adoption.

Variety choice

Four of the six groups describe growing the modern varieties Kalinga and Arjuna as well as local full season and short season varieties. Seed of these modern varieties had recently been distributed by FAO and World Vision. Most of the groups reported using Kalinga and Arjuna, and some had experience of producing a very high yield from these varieties. However, they expressed difficulty storing the grain until the next dry season and had large post harvest losses. These groups were very interested in the seed storage aspect of the research project.

Storage options

Five of the six groups reported that they store corn by hanging it in trees in the sheath. One group reported that they store maize above a fireplace. Storing corn by hanging in a tree is a good method to reduce the rodent damage to the maize. Approximately 100-200 cobs in the sheath are tied onto wooden poles (approximately 1-1.5 m in length) and then the pole is hung from a tree about 3-5m above the ground. Only trees that are growing far away from other trees are chosen so that rodents cannot move from tree to tree. Sometimes, tin or another material is nailed to the tree as a barrier to prevent rodents climbing the tree. As in other locations, maize for seed and maize for consumption is stored together.

Mixed Cropping

A wide range of crops is grown with the maize in both the house gardens and the larger distant gardens. These crops include cassava, sweet potato, pigeon pea, pumpkin, long beans, taro, peanuts and bananas. Some house gardens also have fruit trees such as oranges and mangoes.

Diet

As in the other locations, breakfast is based on root crops and bananas, while corn is the main component of the other two meals of the day. People reported eating 250-280g of maize per day per person. Farmers in this area do not produce enough corn to eat corn throughout the year, and during the hungry season, which is usually from December to March, there is a great reliance on root crops. Root crops begin becoming more dominant in the diet in the period from June to August. The cassava roots can be harvested individually, without killing the plant. Wild foods similar to those collected in Maubara subdistrict are consumed when they are available.

Seed selection

Farmers in Remexio selected their seed using a very similar method to farmers in the Maubara hills.

Photo 9. Remexio farmer collecting a maize sample from his maize stored hanging in a mango tree

Gender roles

Gender roles were very similar to those in the other two areas.

Traditional beliefs and practices related to maize production

Lulik traditions were similar to those in the hills around Maubara town.

5. Conclusions and recommendations

The level of weevil damage to maize was very different for different storage methods and different maize varieties. Whereas there was no weevil damage in any sealed (airtight) containers, there were losses for all other methods of storage. Storage of shelled maize in a sack provided no protection, with virtually total loss by 33 weeks. Storage in the sheath above a fireplace, in a tree, or in an elevated house were in many cases quite effective methods of storage for local maize varieties, with some samples showing little weevil damage even at 33 weeks. However, these methods of storage were not effective for modern varieties, with very significant weevil damage in some samples by 15 weeks, and in all samples by 33 weeks. This is a very significant finding in relation to the promotion of high yield varieties of maize. Their use needs to be coupled with airtight methods of storage, lest the benefit of the higher yields be lost through post-harvest damage.

Regarding moisture content, all samples except one had been dried sufficiently to avoid fungal growth. This suggests that traditional methods of drying maize, approximately three days in the sunshine, is generally effective for all maize varieties used.

In the research sites, the adoption of technology for maize farming was very low, except in Loes, where tractors were used for land preparation.

All the farmers had clear reasons for choosing to grow the maize varieties that they did. Those who grew modern varieties, such as Arjuna and Kalinga, did so because they had access to airtight storage methods. Others knew of these modern high yield varieties, but chose not to use them because they were aware of the storage problems and were also unsure whether they would produce high yields on their hillside land. Doing field trials of these varieties in on farm trials and demonstrations plots would be a means for farmers to assess their potential for producing higher yields under local conditions.

The local varieties Ainar, Angola and Kolana apparently have been derived from modern varieties during the Portuguese era and outcrossed with local maize populations. These stored better than Kalinga and Arjuna when traditional storage methods were used, and in the case of Ainar, had comparable cob size. It would be useful to do field trials of high yield local varieties in different locations.

Mixed cropping was the norm in all locations except the Loes valley, and even there it was the norm for home gardens. A wide range of species were grown with maize, including pumpkin, long beans, sweet potato, cassava, taro, pigeonpea, velvet bean and arrowroot, and also some fruit trees.

In relation to maize consumption, it was evident that reported family consumption is lower than the minimum daily requirements of carbohydrates, even for farmers who reported selling some of their maize. Farmers involved in the research reported maize consumption of around 200-280 grams of processed maize per person per day for an adult and about half this for a child. Highest daily consumption was reported for Remexio (250-280 grams) and lowest for Loes (200grams). All these are lower than the minimum daily requirement of maize if it is the sole source of carbohydrates (300-420 grams). It should be noted, however, that in Loes, the diet is supplemented with purchased rice, resulting in a lower daily consumption of maize. It was not determined in this research whether those farmers in the hills of Maubara who reported selling "surplus" maize used the income to purchase other foods or to cover other family expenses.

Farmers selected seed from the middle of large, clean, well-formed cobs at the end of the dry season. This would favor weevil resistance and weed competitive plants (tall plants that produce a single, large cob). A disadvantage of this selection method may be that it results in selection for tall thin-stemmed plants susceptible to wind damage. This method would also select against more than one cob per plant.

The gender division of labour in relation to maize farming was the same in all the research locations and confirmed that women carry out most of the activities related to maize production (planting, weeding, harvesting, shelling selecting seed, pounding, cooking, and selling). The only roles specifically allocated to men were land preparation and storage. Men were generally involved in weeding and sale of maize and sometimes assisted with other activities (planting, harvesting, shelling and seed selection).

This results of the research lead to three main recommendations.

Combine use of modern open pollinated maize varieties with improved storage

To date, most East Timorese farmers have missed out on the benefits of the green revolution in maize production, which has seen average global yields per hectare more than double from 1961 to 2003. The use of high yield open pollinated varieties of maize is a sustainable and appropriate intervention to increase the food security of farming families in Timor-Leste. This will allow the farmers of Timor-Leste to participate in the global revolution in food production, without requiring annual inputs such as seed, fertilizer and pesticide. However, promotion of new varieties must include an awareness of what other characteristics, apart from yield, are important to farmers. This research has shown that two Indonesian bred varieties, Arjuna and Kalinga, are more susceptible to weevil attack than local varieties when stored using traditional methods. It is therefore essential that when these new varieties are supplied to farmers in Timor-Leste, the farmers are fully aware of the storage requirements and are given the opportunity to access airtight storage containers such as silos.

Collect and field test high yield local maize varieties

This project has identified distinct maize populations that are being conserved by farmers in the research locations. There are indications that some of these populations can produce a high yield with the hillside farming practices in Timor-Leste. These populations meet the criteria of subsistence farmers in terms of quality, taste and traditional storage requirements. It is recommended that these and other populations be collected in Timor-Leste and field tested for yield in a variety of locations.

Test modern open pollinated varieties on hillsides with farmers

Although the farmers in Remexio are experimenting with new maize varieties from various sources, farmers in Maubara believe that the high yielding varieties such as Kalinga and Arjuna will not produce a high yield on their steep hills. It is recommended that there be farmer field demonstrations and trials plots using high yield varieties in a range of locations.

Bibliography

Atwell B, Kriedemann P and Turnbull C. (1999). *Plants in action, adaptation in nature and performance in cultivation.* Macmillan Education Australia Pty Ltd.

Barnett, J, Dessai S, and Jones, R (2003). *Climate change in Timor-Leste: Science, impacts, policy and planning.* The University of Melbourne and CSIRO.

CARE International (2004). "Rice marketing survey report." Care International Timor-Leste. August 2004.

Ceniceros FG, Palmer B, Piggin C, San Valentin G, Tilman de sa Benevides F, and de Oliveira A (2003). "Challenges and opportunities for maize research in East Timor" in *Agriculture: new directions for a new nation East Timor (Timor-Leste).* (Eds. H da Costa, C Piggin, CJ da Cruz and JJ Fox), ACIAR Canberra 2003, pp. 72–78.

Cardoso and Garcia (1976). *Soils of East Timor.* Ministry of Agriculture Forestry and Fisheries.

Dowswell CR, Paliwal RL and Cantrell RP (1996). *Maize in the Third World.* Westview Press Inc.

East Timor Transitional Administration (ETTA), ADB, WB & UNDP (2001). *Poverty assessment Timor Lorosa'e, the survey of sukus in Timor Lorosa'e – summary of initial results and implications for poverty reduction.* (draft, August 2001).

Evans LT (1996). *Crop evolution, adaptation and yield.* Cambridge University Press.

FAO (2000). *Tropical maize: improvement and production.* FAO Rome.

FAOSTAT data (2005).

Ministry of Agriculture, Forestry and Fisheries (2005). *Draft food security policy for Timor-Leste.*

Metzner (1977). *Man and the environment in East Timor.* Australian National University

Narve R (1999). "The status of the East Timor agriculture sector 1999." Columbia University, Center for International Conflict Resolution.

Proctor DL (1994). "Grain storage techniques: evolution and trends in developing countries." *FAO Agricultural Services Bulletin* No. 109. Rome.

Republica Democratica De Timor-Leste (2004). "Sensus uma kain Timor-Leste" Provisional Results.

Sphere (2004). *The Sphere project: Humanitarian charter and minimum standards in disaster response.* The Sphere Project. Geneva.

Swastika DKS, Kasim F, Suhariyanto K, Sudana W, Hendayana R, Gerpacio RV, and Pingall PL (2004). *Maize in Indonesia: production systems, constraints and research priorities.* Mexico, D.F.: CIMMYT.

Williams RL and Gutterres (2004). "Selecting maize varieties for eating quality in East Timor." *Proceedings of the 4th International Crop Science Conference*, Brisbane 2004.

Williams RL (2003). "Increasing food security through fertiliser application." A final report written for World Vision East Timor.