Post-Harvest Grain Losses in On-Farm and Cooperative Stores

A Case Study of Maridi and Yambio Counties, Western Equatoria, Southern Sudan

by
Anne Itto and Lawrence Wongo

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Implemented under the USDA/RSSA with USAID/AFR/SD
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Foreword

The U.S. Agency of International Development, Office of Foreign Disaster Assistance (USAID/OFDA) funded agricultural recovery programs which led to major crop surpluses in the 1990s being produced in Western Equatoria, Southern Sudan. These activities are also viewed as a successful relief to development transition program. However, while surpluses were being produced, poor infrastructure and lack of external and internal commercial markets led to increased on-farm crop losses.

In an effort to understand the magnitude of crop losses and to train farmers to implement improved on-farm storage techniques, this study was implemented. Not only will this analysis assist in increased food security in Southern Sudan, it will also assist in the transition to longer term development programs that are just beginning.

Funding for this activity has been provided by OFDA's Sudan program to support mitigation activities. It is implemented through the USAID/USDA RSSA, contract number AOT-R-00-95-00085-00. Editorial assistance has been provided by Amiee Henderson.

We appreciate the continued support by OFDA staff both in Washington and in Nairobi to these mitigation activities.

Brian D'Silva
U.S.Agency for International Development
Sudan Task Force
Washington, D.C.

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Without the financial assistance and vision provided by USAID and, in particular, Dr. Brian D' Silva this project would not have been possible. Finally, our acknowledgements would not be complete if we failed to mention the participating farmers and the Farmers Associations of both Yambio and Maridi counties, who willingly allowed us to examine their storage structures and grain samples for the pilot study and in providing vital information through the questionnaires. Without the cooperation and excellent support of these individuals and many others who we might not have mentioned here, this report would not have come to fruition.

Executive Summary

The post-harvest grain loss study in Maridi and Yambio counties, Western Equatoria, Southern Sudan was carried out from March to November 2001 in order to determine the extent of grain loss and the factors causing it in these surplus producing areas. The study areas have experienced a shift in recent years from subsistence to commercial production as a result of agriculture recovery and local grain purchasing programs funded, in part, by USAID/OFDA. The study found that the resulting shift in post-harvest practices has, in some cases, led to unnecessarily high levels of grain losses. In conclusion, the study makes recommendations for next steps in curbing grain losses in these areas.

OBJECTIVES OF STUDY

- Identification of local storage structures and practices;
- Assessment of post-harvest grain losses at farm-level, in co-operative and grain traders' stores, and during handling;
- Determination of major post-harvest grain loss factors; and
- Recommendation of a post-harvest loss reduction and quality enhancing strategy for seed and food grain, as well as increasing local food reserves and markets.

METHODOLOGY

- Collection of information on post-harvest grain storage losses and practices from a randomly selected sample of farmers.
- Collection of grain samples and laboratory quality determination.

RESULTS OF STUDY

Storage Structures and Practices

- Traditional grain storage structures, systems and practices in Maridi and Yambio counties have not changed despite years of non-governmental organization (NGO) involvement and records of grain surplus.
- The average on-farm storage capacity in Maridi and Yambio ranges from 2.0 to 4.0 MT.
- Very few farmers' cooperatives and grain traders have permanent grain storage structures. The few storage structures belonging to cooperatives and traders are often small and in very poor condition (leaking roofs, cracked walls, etc.).
- Labor demand for storage construction, drying, shelling and cleaning of grain is very high and often competes with other agriculture production activities.
- Farmers' understanding of the science behind local grain storage practices such as grain drying and use of rat guards is limited.
- Improved grain storage technology, called *grainpro,* has been introduced to some farmers in Yambio. While they appreciate and believe that *grainpro* is superior to the traditional stores, they also regard it as expensive and difficult to access.
- Both Maridi and Yambio farmers lack mechanisms for introducing and promoting improved agriculture production and processing technology and production inputs, including technical services.

Acreage and Quantities of Grain Stored

- As compared to 2000, the total area under cultivation in the 2001 production season decreased in Yambio and increased in Maridi.

- There was a significant reduction in number of farmers cultivating maize in Yambio in 2001.
- There is a significant move of farmers in Marid and Yambio from cereals to production of other crops – most notably, groundnuts.
- The on-farm stores in Maridi and Yambio are currently being utilized at their maximum capacity.

Grain Condition and Storage Losses

- Percentage weight loss in on-farm and cooperative stores in Maridi and Yambio, during the period of the study were 0 to 4.2 percent, although many farmers claimed to have lost their entire first season crop in previous years.
- Insects and rodents are considered a very serious problem to stored grain in both Maridi and Yambio.
- The germination rate of grain taken from farmers' stores during the study ranged from 59 to 100 percent for all grain.
- Grain moisture levels increased steadily from about 10 percent at the beginning of March 2001 to approximately 17 percent in August 2001, a level that is favorable for the development and growth of storage fungi, such as *Aspergillus* ssp.
- There was medium level infestation of sorghum and maize grain by *Sitophilus* ssp.

Farmers' Response to Grain Marketing Problems

- There are traders involved in buying grain from Yambio and Maridi for markets in Rumbek, Yei, Congo and Uganda.
- Farmers and local grain traders in Maridi and Yambio have insufficient data and information for business decision-making.

STUDY CONCLUSIONS

- There is insufficient storage capacity at on-farm, cooperative and grain traders' levels in both counties.
- Farmers in Maridi and Yambio identified insects and rodents as the leading causes of post-harvest grain losses.
- Grain moisture content is also considered serious, but farmers referred to it as a problem of grain drying, especially during the rainy season.
- There is need to promote good storage practices as well as a technology that minimizes grain drying and storage problems.
- The percentage weight loss (0 to 4.2 percent), germination rate (59 to 100 percent), and moisture content (10 to 17 percent) of grain samples from on-farm stores are at levels, which though highly variable, need to be addressed immediately.

RECOMMENDATIONS

- A stakeholders' workshop to disseminate the results of this study;
- Develop a package for introduction and adoption of improved farm-level post-harvest technology, especially for grain storage, drying, handling and processing;
- Develop a strategy for increasing local grain reserves and improving access to markets; and
- Conduct post-harvest loss studies in Bahr el Ghazal and Upper Nile.

Farmer Charles Migido, right, is standing next to his newly constructed traditional Zande granary for storage of household food. The store, with a capacity of 1.5 to 2.0 MT, is raised 1.25 meters from the ground on four wooden legs, each with a mud-guard made of clay. (Maridi County)

Farmer Lino Edward, left, shows his crop of maize stored in plactic sacks kept on the floor of his kitchen due to lack of adequate storage facility. (Yambio County)

Mrs. Lino Edwards, right, is inspecting maize grain that is being sun-dried to reduce insect infestation.

Charles Migido and his wife, left, thresh their sorghum crop in their courtyard using sticks.

A sample of grain, left, from the Yambio Farmers' Association store showing mold and frass.

Research assistant Regina Wasuk, right, shows maize grain reduced to dust by heavy insect infestation.

Research assistant Philip Kotiote, above, weighs a sample of grain to determine moisture content.

Glossary of Abbreviations and Acronyms

CPD	Converted Percentage Damage
CW	Count and Weigh
Fd.	Feddans
MT	Metric tons
MOU	Memorandum of Understanding
NGO	Non-governmental Organization
OFDA	Office of Foreign Disaster Assistance
OLS	Operation Lifeline Sudan
SACB	Strategic Analysis and Capacity Building Activity in Agriculture and Natural Resources Management
SVW	Standard Volume Weigh
TGM	Thousand-Grain Mass
WV	World Vision

Chapter 1
Background

INTRODUCTION

It is often assumed that post-harvest losses occurring in traditional storage systems are very low or negligible, particularly when traditional varieties of crops are stored for a short period. This assumption, however, seems to hold true only during periods of peace, where communities are not forced to abandon some of their more effective traditional storage systems. This movement away from traditional practices exposes food reserves to theft, looting or destruction. A good example is the situation that developed in northern Bahr el Ghazal during the years of the civil war. Muraheleen and government militiamen repeatedly attacked, killed, and looted food, animals and other belongings from villages. A severe sense of insecurity caused communities to abandon traditional storage systems and begin storing grain in baskets and jute bags, often placed on the floor of their bedrooms and underground pits. Storing seed and food grains in this manner provides easy access to insects, rodents and moisture, leading to high levels of loss. In Aweil West, especially in Nyamlel and Marial Bi, there was a serious outbreak of rats in the1999-2000 production season, which was linked to the shift in storage practices plus a combination of other factors, including relief food distribution.

In areas experiencing relative peace, such as Western Equatoria and parts of Bahr el Ghazal, a different set of factors contribute to local storage problems. Farmers, through agriculture recovery and local grain purchasing programs funded by USAID/OFDA, produced huge quantities of grain surpluses during the 1998 to 2000 production seasons. The average farmer in these areas cultivates 3 to 5 feddans (fd.) of maize and sorghum, often of improved varieties from East Africa, while large-scale farmers cultivate 50 to 100 feddans of maize and sorghum, producing 50 to 100 MT of grain.

A number of problems have been associated with the shift from subsistence production using traditional crop varieties stored in traditional storage systems to producing huge quantities of improved crop varieties for cash. The first and most serious of these problems is the production of improved varieties of crops such as maize (Katumani, Longe 1) and sorghum (Serena and Sekedo) by local farmers for the relief market without the introduction of appropriate production, processing and storage technology. It is an established fact that improved sorghum and maize varieties, in general, experience serious insect infestation problems within two to three months of storage when kept under traditional storage systems. In Western Equatoria, this period has been reduced even further as improved crop varieties are harvested in the months of July and August when relative humidity is high and there is insufficient sunshine to dry grain.

Traditional storage structures in Maridi and Yambio evolved for family subsistence, and to hold food reserves and seed grain for one or two seasons. The average capacity of traditional storage holds one to three metric tons and, at most, five. Because of this, farmers often begin to experience serious problems with storage capacity when surpluses exceed three to five MT. Under such a situation, farmers are forced to store food and seed grain in grass thatched shades, living rooms, kitchens, courtyards and commercial buildings, where storage conditions are often poor and grain is exposed to high levels of moisture, insect infestation and rodents.

Poor storage conditions at farm-level and cooperative stores caused many problems, especially for large-scale farmers, who incurred heavy losses in Yambio and Tambura counties during the 2000-2001 production season. In fact, by May 2000, due to poor post-harvest practices, most farmers had lost their entire first season crop, which represented approximately 40 percent of the year's total production of cereals as well as years of investment in agricultural business.

Another important, but often ignored factor, is the consequence of the shift of responsibility for grain storage from women to men. It is very important to note that in the traditional setting women are responsible for storing grain and are more familiar with safe grain storage practices. They conduct inspections of the stored food regularly for signs of infestation by insects and rodents and, in doing so, avoid heavy losses from occurring. On the other hand, in large-scale farming storage becomes a business and men assume more responsibility. Unfortunately, very often, these male farmers and traders have inadequate knowledge and skills for managing storage problems, leading to quality being compromised for volume and quantity. This is very evident in the levels of loss experienced in the stores of large-scale farmers and traders in Yambio, Tambura and Maridi.

Finally, surplus grain production, especially in Western Equatoria, has often been wrongly equated with food security. Access to and availability of food is critical to food security and is guaranteed through, among other things, increased production, markets, storage, and household incomes. The low relief market demand for cereals in Maridi, Yambio and Tambura counties, especially after the closure of the local grain purchasing program induced reduction of maize and sorghum production and increased efforts by many farmers to diversify. Food insecurity can result in the interim period while farmers are shifting crops in response to market demands. In the case of Maridi and Yambio, many farmers did successfully shift to groundnuts, soybeans and other crops, which have high market demand in Uganda.

FRAMEWORK OF THE POST-HARVEST LOSS ASSESSMENT STUDY

Goal

The goal of the post-harvest grain loss assessment in Maridi and Yambio counties was to gain a better understanding of the key factors affecting the household as well as community food reserves, and ultimately, the food security situation in the area. The areas of focus included examining the local post-harvest grain storage and handling practices, type of crops grown, common storage problems, as well as their impact on the local volume and quality of seed and food grain. The findings of this study will be used in developing strategies for reducing post-harvest losses, increasing the quantity and quality of seed and food grain at on-farm and cooperative stores so that the grain is capable of meeting the quality requirements of regional and international markets.

Objectives

The specific objectives of the study were to:

- identify the local grain storage structures and handling practices in Maridi and Yambio counties;
- determine post-harvest grain losses in on-farm, cooperative and trader stores as well as during handling in Maridi and Yambio counties;
- identify key post-harvest grain loss factors;
- develop a strategy for reducing post-harvest grain losses as well as improving the quality of seed and food grains stored in on-farm, cooperative and trader stores and during handling.

Output

In addition to this assessment report, the post-harvest grain loss activity funded through USAID/OFDA will result in:

- A series of workshops for disseminating the results of the post-harvest grain loss assessment report;
- A strategy for reduction of post-harvest grain losses improving the quality of grain in farm, cooperative stores and during handling;
- A package for improving local grain storage and handling practices, and technology.

Chapter 2
Methodology

The post-harvest loss assessment study commenced in both Maridi and Yambio counties at the end of February 2001 and officially concluded at the end of November 2001. The research team leaders, Drs. Anne Itto and Lawrence Wongo, made regular visits to the field to monitor the progress of work by the research assistants. The four research assistants, Regina Wasuk, Kutiote Philip, Tartisio Wandu and Lilian Janee, were employed in February 2001 and their main responsibilities were to collect information and samples of grain from farmers and conduct testing for moisture, weight loss, purity, germination and infestation levels. They received training on proper application and use of laboratory equipment, identification of causes and symptoms of damage to grain and why this is important. The training was reinforced during visits by the researchers, who provided reading materials on grain losses and loss factors prepared by Itto and Wongo.

AREA COVERED

The post-harvest loss assessment study covered Maridi and Yambio counties in Western Equatoria, South Sudan. These counties have been selected for the study, because of the high agriculture production potential and reported surpluses, as well as the bartering and local grain purchasing program that was implemented by various agencies from 1997 to 2000.

SAMPLING PHASES

The post-harvest loss assessment exercise was divided into two phases that corresponded with the two local production seasons – March to July and August to November, with harvests in August and again between November and February. Phase I of the study extended from March to June, while Phase II extended from September to December 2001. Phase I covered sampling of grain stock from the 2000 production season. Phase II started in September and ended in November. Quantities of stored grain in farmer stores started to decline in the second sampling and by the third collection most farmers did not have much stored grain or refused to give permission for sampling, claiming that what they had was only enough for food and seeds for the next planning.

METHODS OF COLLECTING DATA

The first part of this study involved interviews and discussions with stakeholders, which included county authorities, the County Agriculture Department, extension agents, chiefs, elders and farmers. This stage was followed by a process of developing procedures and defining roles and responsibilities for all participants in the research.

The preliminary stages of planning and preparation was followed by selection of farmers to participate in the study using the random sampling method from a list prepared by extension workers and the Farmers Associations in Maridi and Yambio counties. Eighteen farmers were selected from each county and were first visited by a team comprising of Drs. Itto and Wongo, the research assistants, payam extension agents and the Chief of the area. However, because the research assistants in Maridi were unable to visit farmers from Moruka, Kozi and Landiili Payams due their distances from Maridi town, only 12 farmers were included in the Maridi samples. Therefore, there were a total of 30 farmers included in the final study.

The first component of the study was the administration of questionnaires to farmers aimed at generation of information on local grain storage systems, structures, practices and problems. The information collected was compiled, analyzed and interpreted by the two researchers.

The second component of the study involved collection of grain samples from farmers. These samples were brought back to one of the basic grain quality laboratories established in the Department of Agriculture buildings in Maridi and Yambio. In the laboratory, the grain samples were subjected to a series of tests to determine the percentage moisture content, percentage germination, percentage weight loss and insect infestation levels.

PROCEDURE FOR GRAIN QUALITY ANALYSIS

Three different grain loss assessment methods were examined before selection of the most appropriate for the operating environment in southern Sudan. These were:

1. Standard Volume Weight (SVW) Method, which depends on the determination of a baseline (reference) standard volume weight of grain. This method is the most accurate, but was rejected on the basis of its dependence on high-tech equipment and laboratory conditions that were inaccessible to the researchers.

2. Thousand Grain Mass (TGM) Method, which involves the determination of a baseline/reference. TGM is also accurate, but was rejected on the basis of the requirement of a more elaborate laboratory facility and space. It also requires the presence of experienced research assistants, who are currently difficult to get in southern Sudan.

3. Converted Percentage Damage (CPD) Method, which involves counting the number of damaged grain in a sample. This method determines the percentage damage and then converts it into weight loss by means of a conversion factor. It was rejected, because it required determination of a conversion factor or a conversion table for each type of grain on each occasion and, therefore, is cumbersome to use.

4. Gravimetric (Count and Weight) Method, which involves obtaining of a grain sample (about 1 kg) from the store, dividing the sample into equal portions to obtain a sub-sample of 250 gm, separating the damaged grain from the undamaged and weighting each portion. The percentage weight loss is calculated using the formula given below. This method was used in the study, because it does not need a baseline and is suitable for use in the field.

$$\text{Weight loss \%} = \frac{\text{Und - DNu}}{\text{U(Nd + Nu)}} \times 100$$

Where:

U = weight of undamaged grains

D = weight of damaged grains

Nd = number of damaged grains

Nu = number of undamaged grains

Chapter 3

Constraints and Opportunities

OPERATIONAL ENVIRONMENT

Like any other project, the post-harvest grain loss assessment project experienced some constraints, which have had some bearing on the final product of this project. The first of these hurdles was the fact that the two researchers had other commitments and as a result did not spend as much time in the field as they would have wished to. This reduced the time for contact with the research assistants as well as for coaching and training them. This also caused delays in decisions and interruptions in activity schedules.

Another very important constraint that affected the progress at the beginning of the study was the experiences and skills levels of the four research assistants who were selected through local interviews. However, rigorous coaching and training paid off well as, by the second phase of the study, all four had acquired sufficient practical skills required to handle the questionnaire and laboratory equipment without any assistance. This improved their confidence and accuracy in managing the equipment and quality of records kept.

Last, but very important, is the weak institutional capacities of the local agriculture department, which limited the support they could offer to the research assistants. This, however, did not limit their enthusiasm and willingness to assist the four research assistants in every way possible.

Practical problems resulting from the above issues included:

- Some minor errors in questionnaire administration in Phase I.
- Errors in reading and calculating grain moisture content.
- Inadequate working space.
- Diminishing sample size due to farmers' unwillingness to give larger samples when their stores were low.

LOGISTICAL BOTTLENECKS

Delivery of research equipment, materials and research personnel to the project site and to villages where farmers are located was a big challenge. Field visits by the two researchers were frequently delayed due to OLS flight constraints and to the lack of vehicle access. Very often the four research assistants traveled by bicycle in the rain or had to spend nights with farmers, extension agents, or the Chief in the villages. Also, farmers in distant areas – Kozi, Moruko and Landiili in Maridi County and Nadiangere and parts of Nzara payams in Yambio County – were inaccessible.

FARMERS' ATTITUDES

Farmers in Maridi and Yambio have been exposed to NGO activities, including assessments, for many years. While most assessments are short and focused on identification of community needs (resulting in external assistance to the communities), the post-harvest lost assessment focused on traditional grain storage practices and problems associated with them, without the promise of direct future assistance. This situation created some problems as the farmers expected to receive immediate benefits from the study.

It also proved to be difficult to take samples of seeds and food grain from individual farmers during the entire 10 months. At the beginning, some farmers were very excited to talk about their grain storage systems and problems, but later they became wary as they did not see any immediate benefit. Towards the end of the research, some farmers in Yambio started to de-

mand payment for the samples of grain collected from their stores.

OPPORTUNITIES

This study took advantage of opportunities that presented themselves in the relatively stable and peaceful environment of Western Equatoria. Other beneficial conditions that supported the successful implementation of the study included:

- CRS field bases and facilities were used for storage of research materials and for maintaining good communication between research assistants and researchers.
- The commitment of local agriculture extension agents, authorities and chiefs contributed immensely to the successful completion of the study.
- Relative peace and an economy that is recovering motivates communities to invest in the future.
- Two researchers with extensive experience and familiarity with the Western Equatoria operating environment.

Chapter 4
Study Results

The results of the study are described in the sections below on storage structures, local grain storage practices, grain production, quantity of grain stored, storage losses and problems, and laboratory analysis of grain.

STORAGE STRUCTURES

Types and Materials Used

Nearly all the stores visited in Maridi and Yambio during the study were traditional thatched-roof, mud-walled granaries with earthen floors. In Maridi, 8 out of the 11 granaries had mud walls, 1 had brick walls and another had open walls. All the traditional granaries were raised on four wooden stands, at least one meter above the ground. The study further showed that 58 percent and 79 percent of granaries in Maridi and Yambio counties, respectively, had rat guards, while 16 percent to 22 percent of the granaries had leaking roofs or damaged walls.

The majority of farmers in Maridi and Yambio kept their maize and sorghum grain for household use on the head, on raised platforms, until April and May when the first rains start. Yet a few others used the space in their kitchen, bedrooms or under granaries as temporary storages. From here grain is threshed and moved into granaries, where it is kept in baskets, tins, empty drums or jute bags until required.

Two of the farmers, who were also contract farmers during the World Vision (WV) local grain purchasing program, had one-ton capacity *grainpro* cocoons. One of the cocoons was still in a very good condition, while the second one was damaged by rats. A third farmer, who was a member of a farmers' cooperative, talked about different capacities of grain cocoons (5, 10, 50 and 100 MT) offered by WV under the same program. These larger cocoons, however, did not materialize as WV terminated its program in Yambio. The farmers interviewed believed in the superiority of the *grainpro* cocoons over the traditional granary, but complained about their cost and inaccessibility.

Age of Grain Stores

Although the age of farmers' stores in the area of study ranged from under a year to 25 years, most of them were 3 to 4 years old. Only two stores in the study area were older than 25 years and both were made of brick walls and metal roofs, likely being used as a shop before and during the civil war.

Capacity of Grain Stores

The capacity of on-farm and cooperative grain stores in the area of study ranged from under a metric ton (owned by a widow) to over 30 metric tons (owned by large-scale farmers), the median was 2 and 5 metric tons. It is important to note that the storage capacity indicated above is the only available storage facility for each household or cooperative group. In the case of household storage, this space is used for food and cash crops as well as for keeping processed or cooked food for the household's daily consumption.

Cost of Storage Construction

Estimating the cost of construction and labor for on-farm stores in Maridi and Yambio was very difficult due to the marked differences in the local economic situation as well as the period over which stores were constructed. This equation was further complicated by the ever-changing exchange rate for the Sudanese Pound and Ugandan Shilling against the dollar. A large-scale farmer in Yambio estimated the cost of constructing a 100 MT capacity store (permanent building), to be approximately US $6,000. The farmer also estimated that this store could last for over 30 years, if not destroyed by war. What remains true, however, is that farmers spend time and labor (one to five days) and money constructing or repairing these storage structures. The decision to repair or construct a new

store is often based on cost-benefit analysis or opportunity cost on the part of farmers.

LOCAL GRAIN STORAGE PRACTICES

Post-harvest activities in Maridi and Yambio counties include harvesting, transporting of crops from the field, drying, threshing, cleaning and packaging. Just as grain is prepared for storage, the storage place has also got to be prepared to receive the clean dry grain. This includes collection or purchasing of construction materials, such as grass, reeds, ropes and fibers, and actual construction of the store. Table 1 shows the roles and responsibilities of each member of the household, including children, in grain storage.

In both Maridi and Yambio counties, the tools, equipment and methods used for post-harvest activities are manual and slow. These include tools for harvesting, threshing, shelling and processing of crops, such as maize, sorghum and groundnuts.

GRAIN PRODUCTION

Area Under Crop Production

Table 2 shows the area under crop production by farmers participating in the study in the 1999 and 2000 seasons. Between these two years, there was a marked decline in total area under crop cultivation in Yambio, while an increase was observed for Maridi. Less maize was cultivated in both Yambio and Maridi, while the area planted with sorghum in Yambio decreased and increased slightly in Maridi. On the other hand, both counties experienced increased groundnuts production.

Percentage of Farmers in Maridi and Yambio Growing Key Food Crops

Table 3 shows the percentage of farmers who cultivated some of the common food/cash crops in the 1999 and 2000 production seasons. In order to minimize risk, there appeared to be a trend among farmers to shift from cereal grain production in 1999 to more diverse crops in the 2000 growing season.

Table 1. Household Division of Labor for Post-Harvest Grain Storage Activities

Activity	Household Members		
	Men	Women	Children
Preparation of grain for storage			
Harvesting***	Help	Responsible	Help
Transportation	Help	Responsible	Help
Drying ***	Help	Responsible	Help
Threshing ***	Help	Responsible	Help
Cleaning and sorting of grain	Help	Responsible	Help
Packaging	Help	Responsible	Help
Preparing storage for receiving grain			
Cutting grass	—	Responsible	—
Fetching poles, ropes, reeds and mud for walls	Responsible	Help	Help
Construction	Responsible	Help with water carrying	Help
Final smearing of walls and floor with fine mud	—	Women	—
Cleaning and custody of grain store	Responsible when the grain is for market	Responsible when the grain is for household use	—

*** Women are assisted by hired labor in the case of medium to large-scale farmers

Table 2. Total Number of Feddans Under Cultivation (in Feddans*)

Crop Type	Yambio**		Maridi	
	1999	2000	1999	2000
Maize	45.0	33.0	17.25	9.0
Sorghum	43.0	21.25	119.75	135.0
Beans /cowpeas	41.75	13.0	3.5	7.25
Groundnuts	27.5	54.5	8.0	17.5
Total	180.5	145.0	159.66	183.0

* feddans is a unit area equal to 4200 square meters
** the number of farmers who participated in the study were 18 and 12 in Yambio and Maridi, respectively

QUANTITIES OF GRAIN STORED IN ON-FARM AND COOPERATIVE STORES

Table 4 shows the quantity of grain found in on-farm and cooperative stores in Maridi and Yambio counties in March 2001. Table 5 shows the quantity of grain found in the stores of farmers in Maridi from September to November 2001.

The grain found in store in March 2001 was all carry over stock from the 2000 growing season. Fifty-nine metric tons of maize, 5.3 MT of sorghum 2.2 MT of beans/cowpeas and 4.0 MT of groundnuts were found in farmers stores in Yambio, while Maridi farmers had 1.6 MT of maize, 20.3 MT of sorghum, 1.0 MT of beans/cowpeas and 1.1 MT of groundnuts. The study also showed that in March 2001, Yambio County had an overall total of 71.3 MT of grain in store, about three times as much as Maridi.

High relative humidity in July, August, September and October in both Maridi and Yambio counties resulted in higher moisture contents of grain. In order to gain a better understanding of the dynamics of moisture content and other quality factors, the sampling of grain was extended to cover the period from August to November and this is referred to as Phase II sampling. The quantities of grain in on-farm and cooperative stores in Maridi, during Phase II sampling are presented in Table 5.

Generally, the quantities of maize and groundnuts found in storage in the Phase II sampling was low (0.3 and 0.07 MT) compared to quantities in the same stores (1.68 and 1.12 MT) in March 2001. Many farmers associated this with poor yield, especially for groundnuts. Farmers were not sure what disease caused the loses. From the description of the disease symptoms, groundnut rosette may have been the cause. Except for farmers 002 (cooperative group), 003 and 006 (large scale-farmers), the rest of the farmers in Maridi claimed to have used all of the first season harvest of maize and groundnuts as food and seeds for second season planting.

STORAGE LOSSES AND PROBLEMS

Farmers' Assessment of Losses and Problems

During the study local farmers were given the opportunity to identify common post-harvest loss problems

Table 3. Percentage of Farmers in the Study Growing Some of the Common Crops in the 1999 and 2000 Production Season

Crop Type	Yambio		Maridi	
	1999	2000	1999	2000
Maize	61	72	58	66
Sorghum	38	61	58	83
Beans/cowpeas	50	50	25	75
Groundnuts	61	72	33	66

Table 4. Quantity of Grain Found in 30 On-Farm and Cooperative Stores in March 2001 (MT)			
Season Produced	**Grain**	**Yambio**	**Maridi**
Most second season	Maize	59.730	1.685
All second season	Sorghum	5.357	20.385
All second season	Beans/Cowpeas	2.240	1.065
Most first season	Groundnuts	4.099	1.125
Total		**71.3**	**29.42**
Average		**3.96**	**2.02**

and agents as well as to assess losses occurring to grain during storage. Insects and rodents were at the top of the list in both Maridi and Yambio, while moisture was referred to indirectly as a problem of grain drying. Most farmers in the area of study considered storage losses caused by insects and rodents to maize and sorghum as serious, while they regarded losses in beans and groundnuts as negligible. The categorization of storage losses in beans as negligible did not match the visual assessment of losses by storage experts.

Visual Observation of Storage Losses

Most of the on-farm stores had old, infested grain stored next to new, clean grain. This practice exposes new grain to insect infestation very early during the storage period. In addition, most farmers do not conduct general cleaning in their stores before receiving a new crop. Insect infestation, exist holes, frass, dead insect bodies were observed in grain that was stored for barely two months. A few of the stores had off-color grain and no sprouting was observed. These observations suggests that the store had moisture related problems, which are often caused by leaking granary roofs, cracked walls or – in modern storages – moisture migration due to temperature variations.

Another general observation made was that on-farm (individual household) stores were better kept than cooperative or grain traders' stores. This is very evident when looking at the grain color, shine and wholeness of kernel. Laboratory results for grain moisture content, weight loss, germination and insect infestation further support this visual observation.

Table 5. Quantities of Grain Stored in On-Farm and Cooperative Stores in Maridi from September to November 2001						
Farmer Code	**Maize (MT)**			**Shelled groundnuts (MT)**		
No.	**Aug-Sept**	**Sept-Oct**	**Nov-Dec**	**Aug-Sept**	**Sept-Oct**	**Nov-Dec**
002*	1.350	1.800	1.800	0.020	0.00	0.000
003*	0.180	0.180	0.180	0.400	0.400	0.160
005	0.180	0.090	0.015	0.006	0.002	0.000
006*	0.540	0.030	0.015	0.048	0.048	0.008
007	0.135	0.000	0.000	0.048	0.048	0.024
008	0.270	0.135	0.060	0.048	0.144**	0.120
009	0.180	0.030	0.000	0.024	0.000	0.000
010	0.135	0.360	0.030	0.120	0.072	0.008
011	0.090	0.045	0.005	0.024	0.000	0.000
012	0.030	0.015	0.004	0.024	0.000	0.000
Total	3.090	2.685	2.109	0.762	0.714	0.176
Average	0.309	0.268	0.211	0.076	0.071	0.018

* Large-scale and cooperative farmers' stores

** More harvest of groundnuts from the field

LABORATORY ANALYSIS OF GRAIN

The variables considered in the monitoring of grain condition in on-farm and cooperative stores include weight loss, moisture content, percent foreign materials, viability and the number of insects per gram of grain. These have been presented in Table 6 for the period from March to June, and Table 7 for September to November 2001.

Percentage Moisture Content

The moisture content of grain samples taken from on-farm and cooperative stores in Maridi ranged from 9.0 to 14.0 percent for maize, 8.0 to 12.2 percent for Sorghum and 7.0 to 12.2 percent for groundnuts (any moisture level lower than 12 percent is acceptable). Increases in percentage of moisture content were small but steady for all grain types between March and June. The highest increase in moisture content during this same period was in maize (2 percent) followed by sorghum (1.8 percent) and groundnuts (1 percent). The moisture data for Yambio was rejected when it was discovered that the moisture meter gave faulty readings due to low battery.

In August, some samples of maize, sorghum and groundnuts were taken from the local market in Yambio and the Yambio Farmers' Association store, and subjected to a moisture test. The test results showed that the moisture content of groundnuts taken from the local market and Farmers' Association stores were 12.4 and 14.4 percent, respectively, while, the moisture content for maize samples taken from the Farmers' Association store and the local market were 16.8 to 17.8 percent, respectively. These extremely high moisture contents could cause grain condition to deteriorate very rapidly, especially under the temperature and relative humidity conditions in Western Equatoria.

The percentage moisture content of maize and groundnut samples taken from farmers' stores in both Yambio and Maridi, during the months of August to November was very high for both grains. In Maridi, these ranged from 11.8 to 16.0 percent for maize and 11.0 to 13.3 percent for groundnuts, while in Yambio the range was from 12.0 to 14.8 percent for maize and from 10.9 to 12.8 percent for groundnuts, respectively. These moisture contents are not only high, but well above the limit considered safe for long-term storage of both maize and groundnuts.

Foreign Materials

The percentage of foreign material in grain was relatively low for all grains. It is important to note that in cases where grain was sampled on the head, cob or unshelled, threshing was done in the laboratory by the research assistants. It is possible that some bias was introduced as a result of the research assistants' threshing the grain themselves rather than farmers.

Weight Loss

Percentage weight loss of samples of grain from stores in Maridi County ranged from 0 to 3.6 percent for maize, 0 to 4.2 percent for sorghum and 0 to 1.7 percent for groundnuts for the period between March and June 2001. The percentage weight loss of maize found in stores during September to November 2001 is shown in Table 7. Weight loss in maize stored from September to November were lower than for maize samples taken from the same stores in March 2001, while there was generally lower weight loss in Maridi than in Yambio stores. A positive correlation was observed between weight loss and duration of storage, insect infestation and germinability. On the other hand, weight loss in groundnuts was negligible throughout the sampling period, in both Maridi and Yambio counties.

Germination

The germination rate of grain differed from one grain type to another and over the sampling period. The germination rate for maize, sorghum and groundnuts ranged from 63 to 100 percent, 69 to 99 percent and 85 to 99 percent, respectively. There was, however, no significant correlation between germination rate and storage period during the Phase I sampling (Table 6).

Phase II sampling is shown in Table 7. Over these three months, the germination rate for maize grain and groundnuts in Maridi were from 48 to 99 percent and 83 to 100 percent, respectively, while they were 68 to 100 percent for both maize and groundnuts in

Yambio. The lowest germination rates for maize were reported in the stores of the large-scale farmers — farmers 006 (57 percent), and 008 (48 percent) in Maridi, and Farmers YG3 (68 percent) and YN2 (68 percent) in Yambio. There was also a positive correlation between germination rate, storage duration of grain and insect infestation levels.

Levels of Insect Infestation

Some insects, mainly weevils, were separated from samples of maize and sorghum grain, but no insect manifestation was found in groundnut samples. The level of insect infestation was estimated in terms of number of insects per gram of grain. The average for both Yambio and Maridi were 0.001 to 0.045 insects/gm for maize and 0.06 to 0.37 insects/gm for sorghum, with a significant increase in sorghum infestation from March to June.

In Phase II, the level of infestation increased steadily in Maridi (0.005 insects/gm in September to 0.13 insects/gm in November 2001) and Yambio (0.05 insect/gm in September to 0.28 insects/gm in November 2001) counties and, in general, infestation levels were higher in Yambio farmers stores than Maridi. As is to be expected, the same farmers who had grain with the lowest germination rates are the ones who had the highest infestation levels. These are Farmers 006 and 008 in Maridi and YG2, YG3, YN1 and YN2 in Yambio.

Table 6. Condition of Grain in Maridi County Farmers' Stores (March to June 2001)

Crop	Date	% moisture		% foreign materials		% weight loss		% germination		# of insects per gram of grain
		Range	Avg.	Range	Avg.	Range	Avg.	Range	Avg.	
Maize										
	March-April	9.0-15.0	11.6	0-0.6	0.06	0.0-3.6	0.92	63-97	88.25	0.001
	April-May-	10.6-14.0	12.1	0-1.2	0.2	0-0.9	0.38	81-100	95	0.045
	May-June	12.3-13.0	12.6	0	—	—	0.15	—	100	0.001
Sorghum										
	March-April	8.0-12.8	9.58	0-2.8	0.46	0-2.4	0.69	69-95	86.5	0.06
	April-May	9.6-11.9	10.63	0-0.7	0.23	0-4.2	0.87	59-99	83.9	0.09
	May-June	9.6-12.2	10.09	0-1.4	0.48	0-2.1	0.89	77-99	88.2	3.07
Groundnuts										
	March-April	7.0-11.6	9.7	0-0.4	0.17	0-1.2	0.72	89-100	96.3	0
	April-May	8.0-12.9	10.2	0-0.3	0.09	0-1.7	0.66	88-100	94.3	0
	May-June	10.2-12.12	11.5	0-0.1	0.02	0-0.9	0.28	85-99	92.7	0

Table 7. Condition of maize grain taken from farmers' stores in Maridi County (September to November 2001)						
Sampling Period and Avg. RH	**Farmer Code No.**	**% Moisture Content**	**% Foreign Matter**	**% Weight Loss**	**% Germination**	**# of insects per gram of grain**
September	002	15.0	0.0	0.0	97.3	0.005
RH: 79.3 %	003	13.9	0.0	0.1	96.0	0
	005	15.8	0.0	0.2	100	0
	006	13.9	1.6	2.6	88.0	0.025
	007	13.6	0.0	1.1	99.0	0.015
	008	12.9	0.2	1.1	84.0	0.007
	009	13.9	0.0	0.1	99.0	0
	010	13.8	0.0	0.3	79.0	0
	011	16.0	0.0	0.0	95.0	0
	012	13.0	0.0	0.0	97.3	0
	Average	**14.18**	**0.18**	**0.6**	**93.4**	**.005**
October	002	14.0	0.6	1.5	92	0.005
RH: 69.2%	003	14.7	0	0.4	—	0
	005	13.9	0	0	99	0
	006	13.9	0	0.3	99	0
	007	—	—	—	—	—
	008	12.0	0.2	1.8	69	0.045
	009	14.1	0	0.5	95	0
	010	12.9	0	2.7	91	0
	011	13.9	0	0.1	99	0
	012	11.8	0	1.0	96	0
	Average	**14.7**	**0.08**	**0.91**	**93**	**0.005**
November	002	14.0	0	0.8	95	0.005
RH: 60.0%	003	12.8	0	0.5	97	0
	005	14.8	0.4	0.7	97	0
	006	14.9	3.3	1.5	57	0.025
	007	13.0	0	0	99	0
	008	15.9	0.2	6.7	48	0.02
	009	—	—	—	—	—
	010	12.9	0	2.7	91	0
	011	14.0	0	2.0	84	0.010
	012	14.0	0	2.2	93	0.055
	Average	**14.03**	**0.4**	**1.9**	**84.5**	**0.013**

— Store could not be accessed due to absence of farmer

Table 8. Condition of Groundnuts in Maridi County Farmers' Stores (September to November 2001)					
Sampling Period and Aver. RH	**Farmer Code No.**	**% Moisture Content**	**% Foreign Matter**	**% Weight Loss**	**% Germination**
September	002	13.2	0	0.2	92
RH: 79.3%	003	11.9	0	0	99
	005	13.0	0	0.3	100
	006	13.3	0	0.2	99
	007	11.3	0	0	99
	008	11.9	4.2	0	97
	009	11.9	0	0.5	95
	010	12.3	0	0.9	96
	011	12.2	0	0.4	91
	012	11.0	0	0	83
	Average	**12.1**	**0.42**	**0.25**	**95.1**
October	002	—*	—	—	—
RH: 69.2%	003	13.3	0	0.3	93
	005	12.0	0	0	100
	006	13.9	0	0.1	100
	007	11.4	0	1.9	97
	008	12.0	0	1.7	100
	009	—	—	—	—
	010	12.8	0	0.9	100
	011	—	—	—	—
	012	—	—	—	—
	Average	**12.5**	**0**	**0.81**	**96.6**
November	002	—	—	—	—
RH: 60.0%	003	12.4	0	0.5	97
	005	11.9	0	0.5	93
	006	12.9	0	0.5	95
	007	13.0	0	0	99
	008	12.4	0	0.2	99
	009	—	—	—	—
	010	12.6	0	1.1	85
	011	—	—	—	—
	012	—	—	—	—
	Average	**12.5**	**0.0**	**0.45**	**94.6**

* — Farmers did not have groundnuts

Table 9. Condition of Maize Grain Kept in On-Farm and Cooperatives Stores in Yambio County (September to November 2001)						
Sampling Period and Aver RH	**Farmer Code No.**	**% Moisture Content**	**% Foreign Matter**	**% Weight Loss**	**% Germination**	**# of insects per gram of grain**
September	YG1	—	—	—	—	—
RH: 75.0%	YG2	13.9	0	1.3	80.0**	0.06
	YG3	13.8	0.7	1.3	68.0**	0.04
	YR3	14.7	0.9	16.0	72.0	0
	YNZ1	—	—	—	—	—
	YNZ2	12.1	0.8	0.3	88.0**	0.01
	YNZ3	12.8	0.9	0.4	84.0**	0.15
	YB2	13.7	1.0	2.0	72.0	0
	YYI	14.7	0.04	0.1	88.0**	0.045
	YY2	14.8	0.60	0.4	84.0**	0.0175
	Average	**13.8**	**0.6**	**2.72**	**79.5**	**0.06**
October	YG1	—	—	—	—	—
RH: 74.0%	YG2	—	—	—	—	—
	YG3	—	—	—	—	—
	YNZ1	13.2	1.0	1.0	72.0**	0
	YNZ2	12.2	0.09	1.0	68.0**	0.077
	YNZ3	13.4	0.1	1.3	80.0**	0.025
	YB3	12.0	0.5	0.02	92.0**	0.915
	Average	**12.7**	**0.42**	**0.83**	**78.0**	**0.25**
November	YG1	—	—	—	—	—
RH: 59%	YG2	—	—	—	—	—
	YG3	—	—	—	—	—
	YNZ1	13.3	0.6	3.0	84.0**	0.075
	YNZ2	13.4	1.0	2.0	80.0**	0.05
	YNZ3	14.0	1.0	1.0	100.0*	0
	YB1	13.0	0.5	0.1	100.0*	0
	YB2	12.0	1.0	1.0	100.0*	0
	YB3	13.0	0.07	1.0	100.0*	0
	YYI	11.3	0.7	4.0	100.0*	0
	YY2	12.0	0.3	0.1	100.0*	0
	YS1	11.8	1.0	1.0	92.0	0
	YS2	12.8	1.0	0.35	96.0	0
	Average	**12.6**	**.71**	**1.35**	**95.2**	**.0625**

***** Second season grain harvested in November 2001

****** Corresponds to high insect infestation rate and relatively low percent germination

— Farmers absent or refused to grant permission for taking samples of grain from their stores, during Phase II of the study

Table 10. Condition of Groundnuts in Yambio County Farmers' Stores (September to November 2001)					
Sampling Period and Aver. RH	**Farmer Code No.**	**% Moisture Content**	**% Foreign Matter**	**% Weight Loss**	**% Germination**
September	YG1	11.3	0	4.0	84.0
RH: 75.0%	YG2	11.9	0.2	4.0	92.0
	YG3	11.0	0	1.2	68.0
	YR1	11.3	0.5	1.0	100
	YR2	11.7	0.1	2.0	88.0
	YR3	11.8	0.9	9.0	84.0
	YN1	12.4	0.1	4.0	96.0
	YN2	11.9	1.0	9.0	88.0
	YB2	11.9	1.0	5.0	84.0
	YB3	11.8	0.1	5.1	80.0
	YB3	12.6	0.4	6.0	92.0
	Average	**11.85**	**0.3**	**4.5**	**85.8**
October	YG1	11.0	1.0	3.0	84.0
RH: 74.0%	YG2	12.4	0	6.0	100.0
	YG3	11.7	0.03	1.0	96.0
	YR1	11.7	1.0	11.0	96.0
	YB1	12.6	3.2	2.0	96.0
	YB2	12.1	7.0	7.0	100.0
	YB3	11.5	8.0	8.0	100.0
	YY1	11.6	3.0	3.0	68.0
	YY2	11.5	3.0	3.0	68.0
	Average	**11.7**	**2.6**	**3.9**	**90.0**
November	YG1	10.9	0.05	4.0	96.0
RH: 59.0%	YB1	—	0.05	4.0	96.0
	YB2	—	0.04	0.02	88.0
	YB3	—	0.02	4.0	72.0
	Average	**10.9**	**0.04**	**3.0**	**88.0**

Chapter 5
Analysis of Results

GRAIN SAMPLING

It is important to note that access to farmers as well as their attitudes, especially during Phase II of the study, greatly influenced the process of sampling. Farmers (especially those in Yambio) were at times absent during the visits of the research assistants, or sometimes did not grant permission for samples to be collected from their stores. In addition, despite repeated explanation of the purpose of the results of the study and the long-term benefits to farmers, many still demanded to be paid.

In Yambio County, at the start of Phase II sampling, hardly any samples were collected, but collection increased with the arrival of the second season crop harvest in November. On the other hand, Maridi did not have any serious problems with sampling. Only one farmer officially refused to participate in Phase II of the study, reducing the sample size to 10. He argued that, by the time the results of the study were acted upon, he would have lost tons of grain.

STORAGE STRUCTURES

Storage Types

The effectiveness of storage structures in any farming community is related to the availability and affordability of construction materials as well as the appropriateness of the technology and its efficiency. As reported earlier, the materials used for construction of stores in Yambio and Maridi are all obtained locally, except in the few cases where stores are constructed out of imported materials such as cement and galvanized zinc sheets.

The traditional granaries with grass thatched roofs are commonly used in Maridi and Yambio counties and do not last very long since the roofs require replacement every two to three years. Maintenance of storage structures cost farmers money and time. When forced to choose between maintaining stores or harvesting, farmers tend to give priority to harvesting of first season crops, land preparation and second season planting. Although the percentage of stores found to have leaking roofs or cracked walls was relatively low (16 to 22 percent), the amount of deterioration that could result, especially during the rainy season, could be significant.

Again, most farmers in Maridi and Yambio (58-79 percent) use rat guards as a physical barrier against rats gaining access to their stores. However, the principles of how they work seems to be ill understood, as many farmers leave poles and other objects leaning on the granary, or convert the area under the granary into a kitchen. Either way, the principles of creating a barrier is compromised and rats easily find their way to the store using these objects. If farmers did not use the space under the store as a kitchen and frequently open their stores to remove food, the rat guards would work better.

In addition to the granaries, farmers in the area under study use smaller containers such as baskets, earthen pots, plastic containers, empty drums, jute bags and woven grass lined with leaves. Most of these smaller storage containers are placed in the granary, living room, or kitchen for both short and long-term storage.

On the other hand, large-scale farmers and grain traders often resort to using other storage structures, leaving their traditional granaries for household grain. Open courtyards in the homestead, plastic sheets, grass held in position by poles, and empty shop buildings are often used by farmers and grain traders to hold grain for one to several months. Very often, these structures are not well secured from rains, ground moisture, direct heat from the sun, not to mention pests and other destructive domestic animals, such as, chicken, goats and cattle. These careless storage practices have often resulted in grain and monetary losses.

Finally, in Yambio, two farmers who were contracted by WV use grain cocoons for keeping maize and soybean seeds. One of these cocoons had been damaged by rats and was not in use. The farmers who had these cocoons believe in the superiority of the technology to the traditional granaries. They, however, complained that it was expensive and could not be accessed by local farmers.

Storage Capacities

The average on-farm and cooperative storage capacity ranged from under 1 MT to more than 30 metric tons, while the median capacity was 2 MT for Yambio and 4 to 5 MT for Maridi. If the expected average yield for maize and sorghum is approximately 500 to 1000 kg per feddan, a farmer who has five feddans of maize is expected to harvest 2.5 to 5 MT, which is already above the average on-farm storage capacity in the area of study. The situation of storage capacity gets worse with size of farm. Farmer 006 (Charles Migido), a large-scale farmer in Maridi, has the worst storage condition, the highest weight loss, the lowest germination percent and the highest levels of infestation in his store.

In reality, there are very few stores with capacities of five metric tons and above in the two counties. The typical household store is very small and can only hold food for one or possibly two production seasons. This situation causes food security in these two counties to be in a very delicate balance. Events such a crop failure or influxes of internally displaced people or returnees can result in a localized emergency with insufficient grain reserves to support increases in food demand.

There is no doubt, therefore, that on-farm storage capacity is an important factor in determining an individual household's food reserve, though actual availability and access depend on many other variables such as net production, land, labor, capital, knowledge, technology social/production relations, food supply in the market, wages, incomes, and assets. Adequate storage capacity at farm and community levels plays a key role in ensuring sustainable food security and well-functioning grain markets.

It is disturbing to note the lack of attention post-harvest and grain storage systems have received under the various food security and agriculture rehabilitation programs funded by donors and implemented by NGOs in the study area. In areas like southern Sudan, which has depended heavily on emergency food relief for many years while at the same time experiencing relative peace in agricultural surplus-producing areas, one would have expected a shift away from reliance on external food relief to an approach that focuses instead on developing local capacities for production, storage and marketing of food and seed grains. Those programs that did attempt to make this shift were primarily concerned with the quantity of grain that could be purchased locally rather than with the training and capacity building of local agricultural producers to efficiently produce, store, and market their commodities.

POST-HARVEST PRACTICES

Post-harvest practices in Maridi and Yambio counties include harvesting, transportation of grain from the field to homes, drying, threshing, shelling, cleaning and packaging. In Yambio and Maridi, all these tasks are performed manually and mainly by the members of the household with occasional assistance from paid farm hands. For example, it takes 10 to 14 days to dry a crop of maize from one feddan and, for each of these days, one or two members of the household removes the maize from the granary and lays it out to dry. Threshing and cleaning of sorghum harvested from one feddan takes one woman two to three days. Manual shelling of one sack (six tins) of groundnuts takes one person two to three working days to complete and yields just 20 kg of clean groundnuts. The issue here is that these post-harvest activities tie down farmers (particularly women), while at the same time other farming activities require their labor. To reduce labor requirements, some producers may put the first season crops of maize and sorghum into storage before their moisture content levels are low enough. Another invisible yet worrying problem is the deterioration of the nutritional quality and possible fungal infection of grain that results from high moisture content of grain.

Local grain loss reduction practices

The traditional storage structures, systems and practices, used by farmers in Yambio and Maridi have evolved over many generations to keep grain cool, dry and safe from pest attacks. Despite adaptations, moisture and pests often find their way to the stored grain, so farmers have to ensure good grain conditions and quality through sun-drying, smoking or admixing with ashes and plant materials.

An observation made during the study raised questions about farmers' understanding of why they carry out certain storage practices. For example, a progressive farmer in Yambio was found drying over two metric tons of infested grain in his courtyards, next to the granary from which the infested grain was removed, and where he keeps his new stocks of grain. The principle reason for sun drying infested grain is to kill immature insects and drive away the adults, hence, reducing infestation level. If this is done next to the granary, the eggs may be killed but the adult insects can walk right back to the store and infest new grain. Other farmers also leave insects and infested grain next to clean grain after cleaning. Similarly, this infested grain will serve as a source of infestation for new grain. Farmers are either not aware of the need to burn or bury infested grain or are too busy to prevent further infestation.

QUANTITY OF GRAIN IN STORAGE

While this study acknowledges possible errors resulting from farmers' inability to accurately estimate their field sizes and yields, there is concern that the quantities of grain found in on-farm stores do not represent total production. Take for example the total quantities of sorghum, beans/cowpeas and groundnuts and compare this with the acreage and then storage capacity. It is probable that apart from the quantities of grain consumed by the household, some grain is disposed of through other means. How, where and what volume, is the question posed by this study

The assumption that grain produced in Maridi and Yambio counties enters local and cross-boarder markets was confirmed through interviews with local farmers and traders. They believe that a substantial yet undetermined volume of grain trade is taking place with the neighboring counties of Yei and Rumbek and across the border with Uganda and the Democratic Republic of Congo (DRC). To confirm this, during one of the visits to the local market in Yambio town in August 2001, five traders, two from Rumbek, one from Yei and two from Yambio, were found purchasing maize, cassava and groundnuts. They estimated that they purchased up to 5.0 MT of grain and cassava flour every week. These items of produce were bagged and transported on trucks to markets in Bahr el Ghazal, Congo and Uganda. One of the grain dealers showed the research team 20 MT of mainly cassava and groundnuts already purchased and stored in one of the shop buildings.

Therefore, the figures obtained for quantities of grain found in on-farm and cooperative stores during this pilot study could only serve as demonstration for the existence of a very dynamic movement of grain in on-farm and cooperative stores as well as markets. To get accurate information and data on local grain reserves and movements, detailed records of production, markets, uses and users (primary and secondary) need to be factored into the equation.

COST OF STORAGE

The cost of grain storage should include the actual cost of construction as well as the cost of storage maintenance and grain handling. In the case of Yambio and Maridi, the actual cost of constructing a traditional grain storage structure is relatively low, and this is complimented by low grain losses experienced during short-term storage. However, this efficiency begins to decline for grain quantities larger than one to five metric tons. The cost, especially resulting from storage and farm production labor (drying, threshing and shelling, land clearance) is quite high. This is an area that needs cost-focused research to determine the most efficient way to minimize losses and improve the food security situation as well as maximize farmer profits.

STORAGE CONDITIONS

Although the initial condition of grain (including moisture content, cracks, toughness, and composition) is very important, the conditions prevailing in a store also affect the period for which grain can be stored safely. These conditions include temperature, relative humidity and accessibility to storage pests such as insects and rodents. For instance, temperature conditions between 29 and 32 °C and relative humidity (RH) of 60 to 80 percent are considered ideal for the growth and development of most molds and insects. These temperature and RH regimes were found to prevail in most stores in Yambio and Maridi, especially in the period between June and November — coinciding with the harvest and storage of first season crop.

The concern is that the conditions prevailing in most local stores in Maridi and Yambio, especially during the rains, are within the range that equilibrate with grain to produce an environment favorable for the development and growth of storage fungi, such as, *Aspergelus halophilicus* (R.H. 65-70 percent), *A. glaucus* (R.H. 70-75 percent), *A. candidus* (R.H. 75-80 percent), *A. flavus* (R.H. 80-85 percent) and some *Penicilium* spp. (R.H. 80-85). Unfortunately, these fungi, occurring under certain temperature and moisture conditions, have been associated with the production of toxic compounds, which are of serious public health concerns. Regrettably, due to lack of appropriate laboratory facilities, the identification of storage fungi on grain samples was not carried out in this study, although it deserves immediate attention.

CONDITION OF STORED GRAIN

A strong correlation was found between the condition of the stored grain, an individual farmer's storage conditions and post-harvest grain handling practices. Generally, the condition of the stored grain deteriorated over time, and it was faster in grain with higher moisture content and higher levels of insect infestation.

During the study, the percentage moisture contents of maize and groundnuts were quite high, (averaging 14 percent in Maridi and 13 percent in Yambio), particularly during the months of September, October, and November. High grain moisture contents, such as these, which are well above the accepted level for safe storage (12 percent and below), could trigger a chain of biochemical reactions, including the development and growth of storage fungi and production of toxic materials.

On the other hand, the percentage weight losses of grain remained relatively low (under 5 percent) for grain in most farmers stores, in both Maridi and Yambio, except in the case of maize grain for farmer YR3, which was as high as 16 percent. However, these levels of weight loss should not be taken lightly, because the loss assessment method used (Gravimetrix) is not very sensitive to low level infestation and the grain had only been in storage for three months.

The worst storage conditions were found in the stores of five large-scale farmers — farmers 006 and 008 in Maridi and farmers YG3, YNZ2 and YY1 in Yambio. All five had grain in storage with a relatively high percentage grain weight loss, low germination percent (below 90 percent) and high insect infestation levels for maize. Just as there were farmers who had grain in notably poor storage condition there were some farmers whose stores were equally notably well kept and this was reflected in the condition of their grain after three months of storage. Farmer 003 (Morris Garwan) in Maridi did not have any insect infestation throughout the sampling period, and the germination rate of maize grain from his store remained well above 95 percent.

SIGNIFICANCE OF LOSSES

Grain losses and deterioration start to be noticed very early during storage. By the third month, the percentage weight loss becomes significant. Take for example the percentage weight losses for maize stored by farmer Charles Migido from September to November. The estimated average loss for maize grain during the three months of storage was approximately 1.4 percent. Charles Migido is a large-scale farmer who produced

over 50 MT of grain a year. 1.4 percent of 50 metric tons of grain is equivalent to 700 Kg. In this situation, what kind of losses could one expect after six or twelve months of storage?

On the international market, there are grain grades and grain requirements to be met. For example in the U.S., the criteria for grading grain is based on the weight loss, moisture content, broken grain and percentage of fragments that enter through a 12/64 inch round sieve. Using the U.S.' grading system, farmer Charles Migido's grain may not even qualify for Grade 3 or 4.

Chapter 6:
Conclusion and Recommendations

CONCLUSION

This study has successfully identified post-harvest practices, storage structures, systems and problems in Maridi and Yambio counties. It has also shed light on the impact of agriculture rehabilitation and local grain purchasing programs implemented in previous years. There is concern that these programs have not placed local farmers in the center of their design. Too much emphasis has been placed in solving local food security problems through external efforts characterized by relief food, tools and seeds, and occasionally technical advice through the training of extension agents. There is a great deal of focus on food security and surpluses, but not on markets, storage, technology and indigenous capacities. Others even have assumed that since there are "surpluses," farmers must be doing profitable farming. There is, therefore, need to pay closer attention to farm-level systems and their efficiency in order to achieve greater success in agriculture and food security programs.

The following is a summary of concerns and key issues identified in the study:

1. The on-farm grain storage systems, structures and capacity in Maridi and Yambio have not changed despite reports of grain surpluses and years of local grain purchasing programs and other agriculture rehabilitation activities.

2. On-farm storage structures, though made from local materials that are easily accessible and affordable, require frequent repair work and may not offer the right set of conditions required for storing large quantities of grain.

3. Labor demand for performing post-harvest activities is very high. Harvesting, transportation of produce, drying (especially during the rains), threshing (maize, rice and groundnuts), cleaning and packaging is done manually using traditional methods that are often slow, time-consuming and inefficient. In order to minimize work, many farmers, particularly in July and August, store their grain prematurely when the moisture content is very high.

4. Post-harvest activities in Maridi and Yambio are undertaken by all members of the household (men, women and children) — each having very specific roles and responsibilities.

5. There is evidence that significant grain trade occurs locally in Maridi and Yambio, between neighboring counties, and across the border with Uganda and Congo. There is need to direct further investigation into the area of local grain trade and markets and to propose how this could be supported.

6. The serious grain-marketing problem experienced by farmers in Yambio and Maridi has caused significant reduction in total acreage under cultivation, especially maize and sorghum. However, some farmers have taken steps to solve this problem by diversifying their crops to include groundnuts and soybeans (primarily) because of Ugandan market demand. There is, however, no organized initiative aimed at improving grain markets or providing the technology and finances required for successful diversification.

7. There is significant grain loss, in both quantity and quality, occurring at on-farm and in cooperative stores. This has caused frustration and anger, particularly for medium and large-scale farmers, as they lose considerable amounts of grain (and cash) each year.

8. Deterioration of grain starts quite early during storage and is caused mainly by insects and rodents. Deterioration due to high moisture content is much more difficult to assess.

9. Mechanisms are lacking for the provision of technical and financial inputs to farmers to promote and ensure a higher technology adoption rate to maximize farmers' benefits from agribusiness.

RECOMMENDATIONS

A food secure household is defined as one that has access to enough food for individual members to lead a healthy life. At the community level, food security is the assured availability of food during a given period for individual households to draw on to meet their minimum requirements. It is critical to recognize that food insecurity hinges as much on as lack of purchasing power and entitlement as on variable supply. Sustainable local and regional food security, therefore, involves strengthening the resource base to increase the productivity of both small and large-scale farmers. Production support needs to target the storage and marketing capacities of individual farmers so that they not only meet their own requirements, but also supply the requirements of other food deficit households.

Below is a brief summary of recommendations based on the understanding of what food security is, as well as farmers' concerns, problems and key issues identified during this study.

Farmers' Concerns

- Low market demand for local produce;
- Grain damage by insect and rodents;
- Problems of drying grain due to high farm labor demand during the harvest of the first season crop; and
- Insufficient support (technical and financial) to agriculture, production, storage and marketing activities.

Problems

- Insufficient grain storage capacity;
- Inability to assess and value grain loss in monetary terms;
- Lack of awareness and access to improved post-harvest and storage practices and technology;
- Insufficient knowledge and understanding of farming as a business; and
- Insufficient capacity and poor condition of on-farm and cooperative level storages.

Key Issues

- The understanding of the concept of food security by the various stakeholders, especially donors and agencies involved in agriculture and food security programs
- Mechanisms to promote and support the adoption of improved grain storage practices and technology for farmers and grain traders in the context of southern Sudan
- Coordination and sharing of ideas and information on post-harvest technology among all stakeholders: farmers, traders, development agencies and experts
- Improving markets for agricultural produce and supplying production and marketing inputs

PROPOSED ACTIONS

1. Hold a stakeholders workshop to disseminate the results of the study and develop a strategy to deal with the issues identified.

A workshop should be held in Yambio or Maridi to disseminate the study results and to get feedback from stakeholders including farmers, local authorities and agriculture technicians as well as agencies implementing programs in the area. A second workshop at the SACB Agriculture Working Group level should be convened to resolve how some of the recommendations from this report and the stakeholders meeting can be adopted by agencies and used in policy formulation.

2. Establish a networking and coordination mechanism.

A network of farmers, traders, technical, and financial services institutions involved in food security and agriculture programs should be created with the purpose of collecting and circulating useful information related to storage practices, technology, and access to credit. This report will be disseminated widely to begin the information sharing process and the network could be established through the stakeholders' meeting proposed above.

3. Implement a plan for improving local farmers', cooperative and grain traders' capacity to produce, store and market high quality grain. Below are the main areas to be included in the plan:
    a. Safe grain storage practices campaign:
        i. Train laboratory technicians to work in community-based seed quality laboratories.
        ii. Teach farmers and all involved in post-harvest grain handling and storage safe grain storage practices.
        iii. Provide affordable and accessible grain quality testing, certification and advisory services for farmers at cost.
        iv. Introduction of grain grades and market quality requirements
    b. Promotion of improved on-farm grain storage, handling and processing technology
        i. Test, select and promote improved on-farm grain storage, drying, handling and processing technology.
        ii. Support 10 selected individual and cooperative farmers in Maridi and Yambio to test improved grain storage structures as well as grain driers, grain shellers and any other technology that reduces cost, time and effort.
        iii. Introduce the idea of an inventory grain marketing system.
4. Extension of post-harvest loss assessment study to Bahr el Ghazal and Upper Nile.

Undertake a post-harvest grain loss assessment in Bahr el Ghazal, where the introduction of ox-plough technology has resulted in increased production of grain. Another study in an area that has experienced extreme insecurity and loss of grain due to enemy looting, such as northern Bahr el Ghazal or Upper Nile, should also be included in Phase III to determine the impact of insecurity on local grain storage practices.

Details on all of the actions proposed will be provided after this report is discussed with stakeholders and the Agriculture Working Group.

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Appendix A

Post-Harvest Loss Questionnaires

Form I(a): Pilot Post-Harvest Loss Assessment

1. Description of storage structure

Ref. #: _____ Date: _____

Farmer's name: _____ Village: _____

Storage type: _____ Chief: _____

Grain type: _____ Age: _____

Capacity: _____

2. Storage structure

Roof/lid: (1) grass-thatched (2) palm- thatched (3) plastic cover (4) metal

Walls : (1) burnt bricks (2) Woven basket (3) Mud (4) crib (5) open wall

Floor: (1) concrete (2) earth (3) woven basket (4) wooden

Platform: (1) yes (2) no How high? (3) 0.5 m (4) 1.0 m (5) over 1.0 m

3. General condition of storage

(1) leaking roof (2) damaged walls (3) rat guards (4) no rat guards

(1) Very good (2) good (3) fairly good (5) poor

4. Cost of structure

How old is the structure? _____

Cost of labor: _____

Cost of materials _____

5. Maintenance

How frequently do you repair grain storage areas?

Roof: (1) every year (2) every 2 years By whom? (3) man (4) woman

Walls: (1) every year (2) every 2 years By whom? (3) man (4) woman

Rat guards: (1) every year (2) every 2 years By whom? (3) man (4) woman

Form I(b): Production

Acreage and grain stored

Crop type	Acreage			Grain stored
	1999	2000	2001	Quantity kg/tins
( ) maize	_____	_____	_____	_____
( ) Sorghum	_____	_____	_____	_____
( ) Finger millet	_____	_____	_____	_____
( ) Beans/cowpeas	_____	_____	_____	_____
( ) Groundnuts	_____	_____	_____	_____
( ) Others	_____	_____	_____	_____

Farmer's assessment of loss: (ask female members of the household whenever possible)

Maize (1) very serious (2) serious (3) negligible

Sorghum (1) very serious (2) serious (3) negligible

Finger millet (1) very serious (2) serious (3) negligible

Beans (1) very serious (2) serious (3) negligible

Groundnuts (1) very serious (2) serious (3) negligible

Causes of loss: (1) Insects (2) Rats (3) Molds (4) Birds

Pest control measures:

(1) sun-drying

(2) removal of infested grain from store and destroying it

(3) Admixing with as and other plant materials

(4) Smoking

(5) others (specify)

Grain stored

Variety: _____ _____ _____ _____ _____ _____

Date harvested _____ _____ _____ _____ _____ _____

# of days drying _____ _____ _____ _____ _____ _____

Grain condition (evidence of damage)

( ) insects ( ) rats ( ) moisture/molds ( ) birds

Moisture content: (i)_____ (ii)_____ (iii)_____ Average _____

Form II: **Determination of Loss During Storage**

Ref. # _____ Date:_____

Farmer's name: _____ Village_____

Storage type: _____ Chief: _____

Grain type: _____ Variety: _____

Total Weight of grain in storage: _____

Wt. Of Sample: _____

Wt. Of foreign matter: _____

percent foreign matter: _____

Insects Present

Species	Adults	Larvae	Pupae

% Moisture content (i) _____ (ii) _____ (iii) _____ Average _____

# of damaged (i) _____ (ii) _____ (iii) _____ Average _____

# of undamaged (i) _____ (ii) _____ (iii) _____ Average _____

Wt. of damaged (i) _____ (ii) _____ (iii) _____ Average _____

Wt. of undamaged (i) _____ (ii) _____ (iii) _____ Average _____

% weight loss: _____

Germination Test Data

Total # of seeds

# of germinated seeds: (i)_____(ii) _____ (iii) _____ Average _____

# of non-germinated seeds: (i) _____ (ii) _____ (iii) _____ Average _____

% germination: _____

Remarks:_____

Signature of analyst: _____

Date: _____

Form III: Post-harvest loss assessment: data compilation sheet

Serial	Grain	Date	% moisture	% foreign	% weight loss	% germination	# of insects

Preparing grain sample for testing

1. Remove foreign matter and dust from the 1000g sample collected from farmers' store, and weigh the foreign materials collected.
2. Separate insects from the foreign matter and place them in a vial containing alcohol. Then separate insects into adult, larvae and pupae.
3. Determine the moisture content of the clean grain sample
4. Divide the clean sample of grain into four sub-samples
5. Determine the germination percent of the grain sample suing the standard testing method.
6. Count 500 kernels of grain and separate damaged from undamaged grain
7. Count the damaged and undamaged grain and determine the weight of each
8. Determine percent weight loss using the formula provided in the gravimetric grain loss assessment method.

Gravimetric Loss Assessment

Procedure

1. Divide The 1000g (1 Kg) grain into four sub-samples
2. Take one sub-sample and separate the grain into damaged and undamaged
3. Count the number of damaged and undamaged grain and weigh each lot.
4. Calculate weight loss using the formula below:

U = weight of the undamaged grain

D = weight og the damaged grain

Nu = number of undamaged grain

Nd = weigh of the damaged grain

$$\% \text{ weight loss} = \frac{UNd - DNu}{U(Nd + Nu)} \times 100$$

NB: A serial number will be assigned to each sample:

First letter from left stand for county

The second and third letter represent payam

PM stands for payam of Maridi,

PB for Mambe,

PI for Ibba,

PL for Landiili,

PK for Kozi and

PW for Morukwa)

The letters will be accompanied three digit number, representing farmers; farmer 001, 002, 003 ——— 020.

Form IV. Field size and quantity of grain during the second production season

1. Description of storage structure

Ref. # _____ Date:_____

Farmer's name: _____ Village_____

Storage type: _____ Chief: _____

Grain type: _____ Age _____

Capacity: _____

2. Quantities of crop stored in bags/ tins/Kg

Maize ————————

Sorghum ————————

Groundnuts ————————

Beans ————————

Cowpeas ————————

3. Acreage of crop cultivated in the second production season (July-August) in feddans (fd)

Maize ————————

Sorghum (local) ————

Sorghum (serena/sekedo) ————————

Groundnuts (local)————————

Groundnuts (red beauty) ————————

Beans ————————

Cowpeas ————————

Simsim————————

Kerkedeh————————

Cassava ————————

Others ————————

_____

4. General storage condition

a. (1) leaking roof (2) damaged walls (3) rat guards (4) no rat guards (5) damage sign

b. overall assessment : (1) Very good (2) good (3) fairly good (5) poor

Form V: Farmers' storage structure and condition

Data compilation sheet

		Reference number											
Storage structure													
Roof	2.1												
Walls	2.2												
Floor	2.3												
Platform	2.4												
Storage Condition													
	3.1												
	3.2												
Cost of construction													
How old	4.1												
Cost of labor	4.2												
Cost of materials	4.3												
Capacity	4.4												
Maintenance													
Roof	5.1												
Walls	5.2												
Rat guard	5.3												

Form VI: Acreage and Grain Quantity Stored

Data compilation sheet

	Reference numbers															
Crop type (Acreage in 2000)																
Maize																
Sorghum																
Finger millet																
Beans/cowpeas																
Groundnuts																
Others																
Grain stored (kg)/tins																
Maize																
Sorghum																
Finger millet																
Beans/cowpeas																
Groundnuts																
Others																
Causes of loss																
Insects																
Rats																
Molds																

Form VII: Local Pest Control Measures

Data compilation sheet

Reference numbers											
Pest Control											
Sun-dry											
Disposal of infested grain											
Admixing with dust Or plant materials											
Smoking											
Others											
Farmers' Assessment of Loss											
Maize											
Sorghum											
Finger millet											
Beans/cowpeas											
Groundnuts											
Others											
Grain Condition											
Insects											
Rats											
Moisture/mold											
Birds											

Name: _____

Weekly Planner:

Month:_____ Year: ____

Week	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
1							
2							
3							
4							
5							

Form VIII: Farmers' Assessment of Storage Problem and Date of Storage

Reference numbers											
Assessment of storage problems											
Maize											
Sorghum											
Finger millet											
Beans/cowpeas											
Groundnuts											
Others											
Storage date											
Maize											
Sorghum serena											
Local											
Finger millet											
Cowpeas											
Groundnuts											
Soya beans											

Appendix B
Training Research Assistants

To increase the Research assistants general knowledge and understanding about grain, post-harvest loss factors, conditions that favors their activities, loss levels and their impact on both food and economic security at various levels of need. Secondly, to enable them observe and monitor loss and grain conditions in farmers' stores

Objectives

1. Improve Research assistants understanding about post-harvest grain losses, loss agents and conditions favoring their development
2. Improve accuracy in information and sample collection as well as laboratory determination of grain condition.
3. Develop and apply an efficient method for information compilation and storage

Expected Results

The information and data on post-harvest gathered by Research assistants are accurate and dependable

Training Methodology

1. Presentation of background information and materials on post-harvest loss factors, levels and assessment
2. Review of the questionnaire and laboratory procedures, followed by trainees trip to the local markets and farmers' stores for laboratory analysis.

Duration of Training: Three days

Day One: Presentation of information and materials on grain and post-harvest problems in general

Day Two: Continuation of presentation in the morning session, and review of the questionnaires and laboratory procedures in the after noon sessions

Day Three: Planning and preparation of post-harvest loss assessment activities from August to December 2001.

Training Outline and Notes

Introduction

- Seeds of cereals and legumes constitute the raw material of most of our food, animal feed and stimulating drinks such as beers and spirits.
- The seeds and their products such as flour are subjected to damage by insects, fungi, mites and rodents both before and after harvest.
- Insects and rodents do not only cause loss by directly consuming grain, but contaminate grain by way of their parts such as excreta, hairs, other body parts and introducing undesirable fungi, odors and flavors.
- The presence of insect/fungal parts and undesirable odors, flavors and toxic materials are used in grading of grain. Lower-grade is either rejected or receives lower prices in the international grain market.
- Both quantitative and qualitative losses translate into loss of food and economic loss to farmers, which will affect the farmer's physical, social and economic well-being.
- To maximize farmers' benefits, increase local and regional food reserves and minimize food insecurity it is very important to understand the grain, post-harvest storage structures and practices, loss factors and conditions favoring their activities.

Grains

Grain is a living organism that breathes in oxygen and gives out carbon-dioxide, and will grow under certain moisture, temperature and atmospheric conditions of oxygen and carbon-dioxide.

The cereal grain is a one-seeded fruit in which the fruit coat is adherent to the seed.

The fruit has a stigmata at one end, while the pericarp consists of four layers, the epidermis, hypodermis, cross cells and tube cells. The remaining tissues of the grain are the seed coat (testa), endosperm and germ.

The aleurone is rich in proteins, fat and minerals, the pericarp is are high in cellulose, hemicellulose and minerals, while the endosperm consists of largely storage grain surrounded by protein.

The germ consists of the plumule and radicle, connected by the mesocotyl. The scutellum is an organ of food storage for the embyo, while the outer layer of the scutellum is secretory or serves as an organ of absorption.

The structure and composition are important factors in determining the susceptibility and damage to grain during processing

Changes in texture and structure during drying of cereals are important in minimizing breakage during handling. For instance, broken corn is more susceptible to insect attack than whole kernels. In addition, broken kernels produce more dust, creating many problems in handling and condition

Chemical changes and nutritional losses in food grain during storage

The respiratory activity of grain continues after harvest and during storage.

It is accelerated by moisture content, relative humidity and temperature, although oxygen supply, history and condition of grain, storage and biological factors (insects and molds) also can have significant influence.

The respiratory rate of dry grain is low until it reaches above 14 percent. From this level there is a gradual increase in respiration rate until a critical level that coincides with the germination and growth of certain molds**.**

Carbohydrates

A and b-amylase in sprouting grain attack the starches and convert them into maltase and dextrose. At higher moisture content levels fermentation may occur with the production of alcohol or acetic acid resulting in the characteristic sour odor, loss in dry weight and nutritive value.

No indication of loss of protein but there is evidence that the quality of the protein is greatly altered by long storage. Study results also suggest that long storage under certain storage conditions might alter the amounts of Lysine

Fats and fatty acids

Not serious in grain but causes serious problem in milled grain

Minerals and Vitamins

Little change in minerals in grain stored under sound conditions

There is evidence that the small quantities of carotene in some cereals are unstable and are lost during storage.

Insects

Insects are living organisms which have adapted to live under different moisture, temperature, gaseous and other environmental conditions. They are found everywhere; in soil, under the soil, in plant and animal tissues, hot springs, in seas and fresh water, with unique structural adaptation of the moth parts, wings, legs and the body.

Insect feed on plants during the growing stages of plant and continues to feed on plants parts and particularly grain during storage.

The insects attacking grain during storage are referred to as storage insects. They are grouped into primary and secondary or external and internal feeders on the basis of feed on whole grain and where the immature stages feed and develop, respectively.

Primary stored product insects

Sitophylus oryzae

Sitotroga celeallela

Trogoderma granarium

Rhyzopertha dominica

Secondary stored-product insects

Tribolium spp.

Lasioderma serricorne

Plodia interpunctella

Conditions affecting the development of insects during storage

- Temperature (29-32 °C or 85-90 °F)
- Atmospheric humidity (60-80 percent)
- Grain moisture content
- Size of grain, physical properties, composition and nutritive value also influence insect infestation of grain.

The damage and losses caused by insects during grain storage

Loss would mean: weight difference of food materials before and after a specific post-harvest activity. This is despite the fact that food materials can undergo losses in quantity and food value due to various operational factors, while damage represents the physical-mechanical spoilage of food grain.

Storage pests are known to cause visible and hidden physico-chemical damage in food grain. This often is observed as damaged grain, dust, frass, insect fragments and metabolites, rancidity, loss of viability and mold growth.

Quality losses caused by insects include:

- Nitrogen and amino acid content—— loss
- Loss of essential amino acids reported——loss
- Carbohydrates—reducing sugar increase
- Fats—broken down into fatty acids
- Significant losses in thiamine
- Riboflavin —loss
- Loss in energy and nutritional value depend on the variety of the food materials, composition of food, and the feeding habit of the insect.

Fungi and molds

Fungi are filamentous micro-organisms whose long thin and often microscopic body grow in a substrate. Because it lacks chlorophyll it cannot make its own food and therefore takes it from the media it grows in. Fungi produce spores (seeds), which are microscopic and can be transferred around by air and movement of insects.

Molds are important grain problems because they are hard to see and in addition, they also grow very rapidly and produce toxic materials. The growth of fungi in any food materials results in consumers' rejection and reduction in grain quality. Thus the presence of mold in grain can cause economic loss and serious public health problem.

Presence of fungi in grain is observed as:

- Loss in weight
- Loss in viability
- Discoloration
- Change in biochemical properties of the grain
- Production of toxins

Fungi are classified as field and storage fungi

Field fungi

Invade grain kernels while grain are still developing or after seed maturity but before harvest at the stage the moisture content is very high. (at equilibrium with 90 percent r.h.) and dies rapidly at 70 percent r.h.

Examples are:

Alternaria

Fusarium

Helminthesporia

Cladosporia

Storage fungi

The spores enter with grain kernel at the time of storage and does well under r.h. of 65-90 percent, e.g., *Aspergillu*s spp. and *Penicillium* spp.

Equilibrium moisture contents of common grain seeds and feed and species of fungi				
Relative Humidity	**Starchy Cereals**	**Soya**	**Sunflower and G.nuts**	**Fungi**
65-70	13-14	12-13	5-6	*Aspergilus halophilicus*
70-75	14-15	13-14	6-7	*A. glaucus and restrictus*
75-80	14.5-16.0	14-15	7-8	*A. candidus and ochraseus*
80-85	16-18	15-17	8-10	*A. flavus, Penicilium*
85-90	18-20	17-19	10-12	*Penicilium* spp.

Lower limit of moisture content percent needed for growth of major storage fungi			
Fungi	**Cereals**	**Soya**	**Sunflower and G.nuts**
A. restrictus	14-14.5	12- 12.5	8.5-9.0
A. candidus	14.5-15	12.5-13	9-9.5
A. ochraceus	15.5-15	14.5-15	9-9.5
A. flavus	17- 18	18-18.5	10-10.5
Penicilium	16.5-20.0	17.0-20.0	10-15.0

Factors affecting the invasion of stored grain by fungi

- Moisture content (13-18 percent).
- Temperature (30-32 °C) optimum.
- Oxygen, carbon dioxide tension.
- Inherent grain structure.
- History of grain (e.g. harvesting and threshing, dust, injury by insects etc)
- Storage practices.

Sources of fungal infection

- Air
- Organic mater in the soil
- Damaged by insects etc
- Delayed drying of grain
- Storage structures and conditions

Grain Grades and Grade Requirements

High quality is essential for many of the uses of grain (seeds, food, malting and feed). For industrial processing into oil, starch and syrup high quality is also important. For this reason grain for commercial purposes are sampled, quality analyzed and rated according certain specifications. Lower grade grain fetches very low price in the commercial market.

Grain Grading Criteria in the U.S.

- Weight per unit volume
- Moisture content
- Broken grain kernel
- Percent of corn fragments that pass through a 12/64" round hole sieve

Grades of Sorghum				
Grade	**Minimum Test Weight**	**Moisture %**	**% Broken Grain and Foreign Materials**	**% Damaged Grain**
1	57	13	2	0.2
2	55	14	5	0.5
3	53	15	10	1.0
4	51	18	15	3.0

Appendix 3

Participating Farmers from Yambio County

Farmer Code No.	Name of Farmer	Payam
YY1	Henry Bernado	Yambio
YY2	Pasquel Enosa	
YY3	Cerilo Udak	
YN1	Franco Kamanda	Nzara
YN1	Joseph Daudau	
YN2	Lino Kuk	
YR1	Leopardo Magianga	Rangu
YR2	Edward Yotoma	
YR3	Simone Khamis	
YB1	John Yoasa	Bangusu
YB2	Aquila Daniel	
YB3	Samuel Gidamu	
YS1	Gordon Husea	Sakure
YS2	Lino Edward	
YS3	Simone Philip	
YG1	Ramad Sagino	Gangura
YG2	Yesaya Daga	
YG3	Oliver Timoteo	

Appendix 4

Participating Farmers from Maridi County

Farmer Code No.	Name of Farmer	Payam
002	Justin Koko	Maridi
003	MorisGarwan	
008	Luka Sanada	
009	Edward Kabara	
006	Charles Juma Migido	Ibba
007	Aquila Frangi	
010	Richard Magboro	
005	Elizai Lotole	Mambe
011	Thomas Khemis	
012	Richard Mardulu	