



**LIFE Integrated Water Resources Management  
Task Order No. 802  
EPIQ II: Contract No. EPP-T-802-03-00013-00**

**Task 5: Environmental Services for Improving Water  
Quality Management**

**DESIGN AND COST ANALYSIS OF AGRICULTURE  
WASTES RECYCLING ALTERNATIVES FOR  
SINBO VILLAGE, GHARBIYA GOVERNORATE**

*Report No. 15*

**August 2005**

 **International Resources Group**

**In association with EPIQ II Consortium**

**Ministry of  
Water Resources and Irrigation**

**US Agency  
for International Development**

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## Acronyms and Abbreviations

AAU	Agricultural Administrative Unit
AED	Academy for Educational Development (a US-based entity providing USAID-funded assistance regarding environmental education and awareness)
APRP	Agricultural Policy Reform Program
BCWUA	Branch Canal Water User Association
BOD	Biological Oxygen Demand
C	Centigrade
CAD	Computer aided design
CD	Central Directorate
CDA	Community Development Association
CLAC	Central Lab for Agricultural Climate
CLEQM	Central Laboratory for Environmental Quality Monitoring (MWRI)
COD	Chemical oxygen demand
CTO	Cognizant Technical Officer (the USAID person responsible for supervising a technical assistance contractor)
CY	Calendar Year
DAI	Development Alternatives, Inc. (a Washington DC-based consulting firm working with IRG to implement the project)
EEAA	Egyptian Environmental Affairs Agency
EEPP	Egyptian Environmental Policy Program (a USAID-funded program aimed at achieving environmental policy reform)
EMP	Environmental Monitoring Plan
EPADP	Egyptian Public Authority for Drainage Projects (MWRI)
EPIQ	Environmental Policy and Institutional Strengthening Indefinite Quantity Contract
ET	Evapotranspiration
FC	Field Capacity
GB	Gigabyte
GIS	Geographic Information System
GOE	Government of Egypt
GPS	Global Positioning System
GW	Groundwater
GWS	Groundwater Sector
HD	(Aswan) High Dam
hp	Horsepower
IAS	Irrigation Advisory Service
IBRD	International Bank for Reconstruction and Development or World Bank
ID	Irrigation Department
IDS	Irrigation and Drainage System
IIIMP	Integrated Irrigation Improvement and Management Project

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IIP	Irrigation Improvement Project
IRG	International Resources Group (a Washington DC-based consulting firm that is prime contractor for the IWRMP)
IRMU	Integrated Water Management Unit
IRs	Intermediate Results
IRU	MWRI Institutional Reform Unit
IS	Information Systems
IT	Information Technology
IWMD	Integrated Water Management District
IWMU	Integrated Water Management Unit (A unit of MWRI)
IWRM	Integrated Water Resources Management
IWRMP	Integrated Water Resource Management Project
jpg, jpeg	Joint Photographic Expert Group (computing)
KB	Kilobyte
kg	Kilogram(s)
LAN	Local Area Network
LIFE	Livelihood and Income from the Environment (project)
LOE	Level of Effort
M&E	Monitoring and Evaluation
MALR	Ministry of Agriculture and Land Reclamation
MED	MWRI Mechanical & Electrical Department
mg/l	milligrams per liter
MIC	MWRI Ministry Information Center
MISD	Matching Irrigation Supply and Demand
MOE	Ministry of Education
MOH	Ministry of Health
MOU	Memorandum of Understanding
MSEA	Ministry of State for Environmental Affairs
MWH	Montgomery Watson Harza
MWRI	Ministry of Water Resources and Irrigation
NASA	(United States) National Aeronautics and Space Administration
NGO	Non-governmental Organization
NPK	nitrogen, phosphorus, and potassium (especially in chemical fertilizers)
NSCE	North South Consultants Exchange
NWRC	(MWRI) National Water Research Center
O&M	Operation and Maintenance
OJT	On-the-Job Training
PC	Personal Computer
pH	Potential of Hydrogen ions (measure of acidity or alkalinity)
PM&E	Performance Monitoring and Evaluation
ppm	Parts per Million
PWP	Permanent Wilting Point
RSC/WP	Red Sea Coastal/Water Project (short name for USAID-funded Red Sea Coastal and Improved Water Resource Management Project)
RWS	Relative Water Supply
SIRs	Sub-Intermediate Results
SOs	Strategic Objectives
SS	Suspended Solids

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STTA	Short-term Technical Assistance
SWERI	Soils, Water, and Environment Research Institute (MALR)
TA	Technical assistance
TDS	Total Dissolved Solids
TOR	Terms of Reference
TRG	Training Resources Group
TS	Transition State (chemical)
TSS	Total Suspended Solids
TWW	Treated Wastewater
UPS	Uninterruptible Power Supply Device
USAID	United States Agency for International Development
USB	Universal Serial Bus (computing)
WCU	MWRI Water Communication Unit
WDC	MWRI Central Water Distribution Center
WPRP	Water Resources Results Package
WQU	MWRI Water Quality Unit
WUA	Water User Association
WWTP	Wastewater Treatment Plant

## 1. Introduction

### Background

In 2003–04, Egypt’s dried crop residues following the harvests were estimated to be 3.4 million tons. The summer season produced 18.15 million tons/year, or 57 percent of the total. The balance—11.26 million tons/year, or 35 percent—was generated by the winter crop season. Pruning fruit trees produced the balance, or 1.42 million tons/year.

The amount and type of agricultural residues depend on a variety of factors:

- Purpose of crop cultivation
- Uses and consumption pattern of plants
- Growing season
- Agro-industrial methods
- Behavior of beneficiaries of plant and its residues.

Average crop residues are estimated to be between 1.13–3.05 tons/feddan for feed straw, 14.0 tons/feddan for greenhouse residues, and 3.0 tons/feddan for vegetable straw generated in the field.

Traditional uses of agricultural residues are:

- Animal feed—9.5 million tons/year, or 30 percent of total crop residues
- Compost—8.0 million tons/year, or 25 percent of total crop residues
- Fuel for primitive stoves or burned in the field—14 million tons/year, or 45 percent of total crop residues.

In many cases farmers leave residues on the banks of canals and drains where they may be dumped into the irrigation system, creating obstacles to water flow and endangering water quality.

The Ministry of Water Resources and Irrigation (MWRI) and the Livelihood and Income from the Environment–Integrated Water Resources Management Project (LIFE–IWRM) selected Sinbo village in Zifta, Gharbiya Governorate, as a pilot area to test feasibility of some alternatives for improving water flow and quality in Sinbo Canal.

## **Objective**

The main objective of this study was to investigate alternatives for disposing of agricultural waste and to design an alternative model for maximizing benefits from them.

Recycling of such residues is one suitable technology adapted in many countries. Recycling is the bioconversion of biomass into organic fertilizer, animal feed, non-traditional food, clean fuel, or chemical intermediate compounds. Recycling agricultural residues could reduce the impacts of drought and desertification, pesticides, and chemical fertilizers. The social, economic, and environmental benefits of recycling agricultural wastes include increases in both quantity and quality of crop yields and reducing the cost of agricultural production.

## **2. Agriculture Wastes Recycling Practices in Egypt**

Wastes produced due to agriculture activities are classified as:

- Crop residues
- Pruning residues from trees and date palms
- Weeds and water weeds harvested from rivers, canals, and drains
- Food processing wastes
- Animal droppings.

Residue from agricultural production make up 30–60 percent of the product that is used for human consumption and animal feed. An additional 30 percent is made up of wastes from humans and animals.

Traditional methods of using crop residues and cattle dung are of low efficiency and deprive agricultural lands of needed organic matter and plant nutrients. In addition, such methods are a constant hazard to human and animal health and represent a major source of environmental pollution.

This study looked at other ways to use agricultural waste, including:

- Composting
- Animal feed production
- Mushroom culture
- Biogas production.

### **Composting**

Compost is a mixture of crop residues and animal manure fermented together for a period under aerobic conditions. Compost is used for plant nutrition in organic agriculture and is the cornerstone of nutrient resources to conserve soil fertility.

Compost plays a variety of roles in soil fertility and productivity, including:

- Providing soils with needed humus to improve the soil's physical properties
- Decreasing water volume needed for irrigation by increasing the soil's capacity to hold water
- Building soil structure
- Increasing the capacity of the soil's molecules to exchange cations
- Adding elements required by plants to the soil.

With increasing availability of nutrients and improvement in the chemical and physical structure of the soil, crop production also increases.

The use of organic compost reduces pollution and consequently health problems with pathogens available in raw animal wastes. In the composting process, heat reaches 70°C (C) for a number of days, killing bacteria, protozoa, and weed seeds.

## **Animal Feed Production**

The direct use of agricultural residues as animal feed or as a component of such feeds is one of their oldest and most widespread methods of disposing of these residues. In rural Egypt, cellulose residues play an important part in animal production.

Agricultural residues are lower in value as feeds than those specifically processed for animal production. Residues are high in fiber low in protein, minerals, and vitamins.

Several methods for increasing feed intake and efficiency have been developed through physical, chemical and microbial treatments of the raw materials. Processes for increasing the digestibility of agriculture residues and availability of nutrition to the animal include:

- Physical treatment
  - Shredding dried crop residues and mixing them with green wastes or clover
  - Producing green fodder without soil.
- Biological treatment
  - Producing silage from fresh agriculture residues and/or such residues mixed with green wastes
  - Improving dried crop residues by use of white rot fungi to increase nutritional value
- Chemical treatment
  - Spraying or mixing agricultural residues with a urea solution
  - Injecting agricultural residues with anhydrous ammonia
  - Mixing agricultural residues with sugarcane molasses.

## **Mushroom Production**

Various agricultural residues—rice straw, wheat straw, peanut peels, and barley straw—can be used as substrates to grow mushroom for human consumption.

Different strains of mushroom cultures were tested for their efficiency in producing fruiting bodies of good quality. Average production of mushrooms on rice straw was 2.0 kilograms (kg) fruit bodies per one kg of moistened rice straw incubated for 40 days .

## **Biogas**

Small-scale anaerobic digestion and production of biogas is a widely used process. Historically, the reason behind developing biogas technology was the search for an alternative energy source; however, other environmental aspects and organic manure production have gained additional, often major, importance.

The biogas plant is designed to process animal manures and organic wastes to produce biogas and sludge and to control environmental pollution. The plant consists of two main parts: a digester (or a set of them) where the organic materials are organically processed; and the gasholder (or a set of them) where the biogas is collected and stored pending use.

Biomass energy has traditionally been used for cooking and baking, which was done in low-efficiency stoves or on open fires. In addition, removal of these nutrient-rich resources from the fields deprived the soil of much needed fertilizers and their replacement often means the use of chemicals.

Nevertheless, biogas technology has the potential to become interesting as a way to improve the energy release from agricultural residues, save plant nutrients, and improve health conditions and quality of life in the rural communities. Biogas technology provides:

- A clean and convenient fuel for cooking, lighting, and heating
- Electricity for irrigation pumps and other internal combustion engines
- Manure that is richer in nitrogen, phosphorus, and potassium (NPK); contains suitable amounts of micro-nutrients; acts as a growth regulator; and is more free of pathogens and parasites than traditional farmyard manures

In addition, crop stalks and straw—that are otherwise burned as fuel—are saved for use to make fodder and/or silage and produce compost.

### 3. Agriculture Wastes Production of Sinbo Village

To determine specific agricultural residues in Sinbo Village, a village-level questionnaire was designed and tested. A field survey was conducted to estimate amounts and availability of crop residues and animal wastes. The data was directly collected by personal interviews carried out by Community Development Association and Sinbo Information Bank staff with respect to the year 2003–04.

The questionnaire included four major topics:

1. Type of agriculture and cropping area
2. Type and amounts of crop residues during different cultivation seasons
3. Animal and poultry wastes produced
4. Amount and cost of chemical fertilizer consumed for cropping area.

The information gathered within the questionnaire was used to calculate the average production of crop residues and animal wastes, and the amount and cost of NPK fertilizers used. The data collected is presented below, and reveal the following about Sinbo Village:

- Total area under agriculture      1,680 feddans
- Yearly cropping area (as a result of multiple harvests) 3,416 feddans/year
- Total agricultural residues      3,696 ton/year dried material

Table 1 provides basic data about the village’s area, population, and agricultural background.

**Table 1      Sinbo Village Background**

Category	Data
Total area of village	1,708 feddans
Agriculture area of village	1,680 feddans
Agriculture area/Total area	98 percent
Total population of village	16,753
Number of families	3,347
Families working in agriculture	2,618
Families working in agriculture/total households	78 percent
Average agricultural land per family	0.64 feddan
Average agricultural land per person	0.10 feddan

Category	Data
Average family size	5

## Seasonal Agricultural Wastes

### Summer Season

The summer growing season contributes 82 percent of total agricultural residues during the production period from August through November.

**Table 2** Average Annual Cropping Area and Agricultural Residues, Summer Season

Crop	Cropping Area (Feddans)	Crop Residues per Year		Types of Waste
		Ton/Feddan	Ton/Total Area	
Cotton	435	1.8	783	Stalks
Maize	772	2.3	1,775	Stalks
Rice	144	2.2	316	Straw
Fodder	250	Green fodder is completely consumed		
Sugar cane	26	6.0	156	Bagasse
Total	1,627	—	3,030	—

### Nili Season

The Nili growing season contributes 12 percent of total agricultural residues during the production period of October and November.

**Table 3** Average Annual Cropping Area and Agricultural Residues, Nili Season and Fruit Gardens

Crop	Cropping Area (Feddans)	Crop Residues per Year		Types of Waste
		Ton/Feddan	Ton/Total Area	
Maize	150	2.3	435	Stalk
Citrus	47	2.5	117	Pruning
Grapes	13	2.4	31	Pruning
Guava	1	2.0	2	Pruning
Total	211	—	585	—

### Winter Season

The Winter growing season, lasting from March through May, contributes only 2 percent of total agricultural waste residue.

**Table 4 Average Annual Cropping Area and Agricultural Residues, Winter Season**

Crop	Cropping Area (Feddans)	Crop Residues per Year		Types of Waste
		Ton/Feddan	Ton/Total Area	
Wheat	586	3.0	1,758	Straw <sup>a</sup>
Fava bean	9	1.7	15	Straw
Clover/Alfalfa	948	Clover is completely consumed		
Onion	35	1.9	66	Straw
Total	1,578	—	81	—

<sup>a</sup> Wheat straw is used as dried fodder

### Wastes from Pruning Trees

Trees are pruned during January and February, and the prunings contribute 4 percent of total agricultural residues.

**Table 5 Type and Amount of Residues from Pruning Trees**

Type of Tree	Annual Tons Residue from Pruning
Citrus	117
Grapes	31
Guava	2
Total pruning wastes	150

The data showed that crop residues produced from August to November were estimated to be 3,465 tons, about 94 percent of the total crop residues in Sinbo Village. About 70–80 percent of the crop residues are suitable for recycling. Therefore, of the total produces residues (3,465 tons between August and November), about 2,600 tons could be recycled. Residues from tree pruning are largely used in various agricultural activities.

### Waste Produced by Farm Animals

Fifty percent of cattle droppings and 25 percent of droppings from other animals are agricultural waste.

**Table 6 Farm Animal Waste Produced, 2003–04**

Kind of Animal	Number	Rate		Available	
		Kg/h/d <sup>a</sup>	Ton/t/d <sup>b</sup>	Ton/t/d	Ton/t/y <sup>c</sup>
Buffalo	2,224	20.0	44.5	22.0	8,030
Cattle	1,924	15.0	28.8	14.0	5,110
Sheep	2,480	2.5	6.2	1.5	547

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Goats	1,754	2.0	3.5	0.8	292
Donkeys	2,040	10.0	20.4	5.0	182
Horses	50	10.0	0.5	0.1	36
Total	10,472	—	103	43	14,167

<sup>a</sup> Kg/h/d = Kg of dung/head/day

<sup>b</sup> Ton/t/d = Ton of dung/total number/day

<sup>c</sup> Ton/t/y = Ton of dung/total number/year

There are 13 poultry farms in Sinbo Village, each with a capacity of 5,000 chickens. Poultry manure is a marketable product and not classified as an agricultural waste.

**Table 7 Poultry Farm Waste Produced, 2003–04**

Bedding material	Sawdust/Shredded rice straw
Average production of poultry manure	13m <sup>3</sup> /rotation
Number of rotation per year	5
Total amount of poultry manure	845m <sup>3</sup> /year — 338 tons/year
Market price for poultry manure	LE20.0/m <sup>3</sup> — LE50.0/ton

## Fertilizer Use

**Table 8 Average Use of Nitrogen (N) Fertilizer by kg per Feddan, 2003–04**

Crop	Urea (46 percent N)	Ammonium Nitrate (33.5 percent N)	Ammonium Sulfate (20.6 percent N)	Total kg/ Feddan
Cotton	—	200	—	200
Maize	200	—	—	200
Rice	—	—	200	200
Wheat	—	300	—	300
Fava bean	—	200	—	200
Alfalfa	200	—	—	200
Sugar cane	200	—	—	200
Onions	—	250	—	250
Citrus	—	—	400	400
Grapes	200	—	—	200
Guava	200	—	—	200

**Table 9 Average Use of Phosphate (P) and Potassium (K) Fertilizers by kg per Feddan, 2003–04**

Crops	Super Phosphate (15 percent P2O5)	Potassium Sulfate (48 percent K2O)	Total kg/Feddan
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Cotton	200	50	250
Maize	—	—	—
Rice	100	—	100
Wheat	—	—	—
Fava bean	150	—	150
Alfalfa	—	—	—
Sugar cane	200	50	250
Onions	200	50	250
Citrus	400	100	500
Grapes	400	50	450
Guava	400	50	450

Based on consumption in 2003–04, Sinbo Village farms uses 561.3 tons of urea, ammonium nitrate, and ammonium sulfate chemical fertilizers annually, at a cost of L.E.400,800, as shown in table 10.

**Table 10 Total Amount and Value of Urea, Ammonium Nitrate and Ammonium Sulfate Chemical Fertilizers Consumed by Sinbo Village, 2003–04**

Crop	Cropping Area (Feddans)	Urea		Ammonium Nitrate		Ammonium Sulfate	
		Amount (Ton)	Value (LE1,000)	Amount (Ton)	Value (LE1,000)	Amount (Ton)	Value (LE1,000)
Cotton	435	—	—	87	59	—	—
Maize	922	184	140	—	—	—	—
Rice	144	—	—	—	—	28	19
Wheat	586	—	—	175	119	—	—
Fava bean	9	—	—	1.8	1.2	—	—
Alfalfa	250	50	38	—	—	—	—
Sugar cane	26	5	3.8	—	—	—	—
Onions	35	—	—	8.7	5.9	—	—
Citrus	47	—	—	—	—	18.8	12.7
Grapes	13	2.6	1.9	—	—	—	—
Guava	1	—	0.4	0.3	—	—	—
Clover/ Alfalfa	948	—	—	—	—	—	—
Total	3,416	242	184	272.5	185.1	46.8	31.7

Based on consumption in 2003–04, Sinbo Village farms uses 167.9 tons of super phosphate and potassium sulfate chemical fertilizers annually, at a cost of L.E.122,900, as shown in table 11.

**Table 11 Total Amount and Value of Super Phosphate and Potassium Sulfate Chemical Fertilizers Consumed by Sinbo Village, 2003–04**

Crop	Cropping Area (Feddans)	Super Phosphate		Potassium Sulfate	
		Amount (Ton)	Value (LE1,000)	Amount (Ton)	Value (LE1,000)
Cotton	435	87	38	21	45
Maize	922	—	—	—	—
Rice	144	14	6	—	—
Wheat	586	—	—	—	—
Fava bean	9	1.3	0.5	—	—
Alfalfa	250	—	—	—	—
Sugar cane	26	5	2.2	1.3	2.8
Onions	35	7	3	1.7	3.6
Citrus	47	18.8	8	4.7	10
Grapes	13	5	2.2	0.6	1.3
Guava	1	5	2.2	0.05	0.1
Clover/Alfalfa	948	—	—	—	—
Total	3,416	138.5	60.1	29.4	62.8

## **4. Proposed Model for Recycling Agricultural Wastes in Sinbo Village**

Using agriculture residues is being implemented in some areas in Egypt. Examples include composting, producing mushrooms, using residues as a feed source, fermenting alcohol, producing yeast, and using various residues in wood, brick, and handcraft products. Some technologies are currently in the pilot stage; others are applicable in rural communities.

This study will focus on the three main established technologies in Egypt which are compost production, animal feed production, and non-traditional food (mushrooms) production for Sinbo Village.

### **Compost Production**

#### **Economic Analysis**

Compost manure is used at 5 tons per feddan on previously worked land and 10 tons per feddan on reclaimed dessert land. Therefore, compost manure could be used to fertilize about 900 feddan per year of farm land in Sinbo Village, or about 450 feddan per year of new, reclaimed land.

The compost is added to agriculture land during soil preparation, before cultivation of summer crops (cotton, maize, rice, sugar cane, citrus, grapes) as a first crop of agriculture rotation. However, the residual effect of organic matter will continue for the second crop in the winter season (wheat, fava bean, fodder, clover). Therefore, the compost that could be produced by the Sinbo Village pilot project would fertilize 1,800 feddans per year in cropping area.

Sinbo Village farms consume 729.2 tons of NPK chemical fertilizer annually at a cost of LE523,700 per year. Nitrogen fertilizers make up 77 percent of the total consumed, or 561.3 tons/year, at a cost of about LE400,800. Phosphate and potassium fertilizers make up 19 and 4 percent of the total chemical fertilizers consumed, respectively—138.5 and 26.4 tons annually. The cost of these is about LE60,100 and LE62,800 each year.

If compost were substituted for 30–50 percent of the chemical fertilizers used, the use of nitrogen fertilizers would drop from 561.3 tons/year to 336.8 tons/year, and the cost from LE400,800/year to LE240,480/year. The use of super phosphate chemical fertilizers could decrease from 138.5 tons/year to 83.1 tons/year, and the cost from LE60,100 to LE36,060 annually. Use of potassium sulfate fertilizer could decrease

from 29.4 tons to 17.64 tons/year, and the cost decline from LE62,800 to LE37,680 per year.

In total, use of compost manure would decrease chemical fertilizer consumption from 729.2 tons/year to 437.54 tons/year. Total cash outlay for those fertilizers would decrease from LE523,700 to LE314,220 per year.

### **Producing Compost**

Compost is a mixture of crop residues and animal wastes fermented together for a period under aerobic conditions.

Sinbo Village produces about 3,465 tons of crop residues during peak growing season, August–November. Of that, an estimated 70–80 percent, or 2,600 tons, is suitable for composting.

The first step in composting would be shredding the crop wastes. This amount of wastes—2,600 tons—would average about 21 tons to shred per day during the 4 month period of August–November (or about 2 tons per hour over a 10-hour day).

The second step would be mixing 20 tons of crop residues with 20 tons of animal wastes per day to produce 25 tons per day of compost manure, or about 4,500 tons per year.

In order to produce good compost, the pile of compost should contain:

- Plant residues shredded into small bits to increase the surface area exposed to bacterial activity and other microorganisms
- Farmyard manure from cows or buffaloes as a source of cellulose decomposing microorganisms and as a source of nitrogen to all microorganisms
- Soil to regulate moisture inside the compost pile and capture elements released by plant decomposition
- A covering of soil to protect the pile from drying out

Water is sprayed on the compost pile as it is built and the pile is sprayed again on a weekly schedule. Excessive use of water will lead to anaerobic conditions and a loss of nutrients from the pile. Usually a moisture content between 50–60 percent (weight basis) is sufficient, reducing this to 30–40 percent at maturity.

Air inside the compost pile is very important, as all chemical and physical reactions taking place in the compost pile are aerobic. If conditions become anaerobic, transformation of beneficial ions into poisons will occur (e.g. conversion of nitrates into nitrites). Therefore, compost piles should be kept aerated by controlling moisture and mixing the piles as required.

## Equipment

1. Agricultural tractor (70–90 horsepower) provided with front loader for transportation, loading, and mixing the compost piles:	LE120,000–150,000
2. Farm trailer, capacity 4–5m <sup>3</sup> for transporting crop residues, farmyard manure, and compost:	LE15,000–17,000
3. Water pump, 3 horsepower to be used to moisten the compost piles:	LE3,000–5,000
4. Simple equipment, plastic, pipes, plastic sheets hand held equipment for mixing, moistening loading, etc.:	LE3,000
Total	LE141,000–175,000 (Average: LE158,000)

## Animal Feed Production

### Economic Analysis

This is a low cost alternative that can be undertaken at the household level.

### Producing Animal Feed

**Production of green fodder without soil**—This simple technology aims to produce green fodder without using soil. This helps to save agricultural areas for other purposes, as well as saving large amounts of irrigation water. Green fodder is produced in a soil-less medium through cultivation of barley seeds on rice or wheat straw, or on maize stalks. Each cycle lasts 10 days. The plants and supported material are homogenized. The product (plant seedlings supported on plant residues) has 12–14 percent protein and is used as animal feed.

**Green fodder silage from barley and farm wastes**—Barley seeds are cultivated on rice straw or wheat straw or on maize stalks for 10 days. Both the seedling and the supporting material are cut into 5kg units and sold in plastic bags. In order to enhance silage production, a suspension of lactic acid bacteria (*Lactobacillus plantarum* [10<sup>7</sup> cells/ml] and molasses [at a rate of 3 percent w/w]) are added to the seedlings and the straw, moisture is adjusted to 65 percent and the silage is bagged tightly. In order to follow this operation in laboratory experiments, 10 liter jars were used.

**Silage from barley and mushroom spent compost**—Silage can be produced by growing barley seed on the spent compost residue following mushroom cultivation. The spent material is used as the supporting medium. The crude protein, fiber, and the digestion index are increased in spent compost after barley germination.

### Equipment

Plastic dishes and or/agricultural residue dishes, barley seeds	LE300 per household
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## **Non-traditional Food (Mushroom) Production**

### **Economic Analysis**

This alternative use for agricultural residues is more expensive than the production of animal feed, but can also be undertaken at the household level.

### **Producing Non-traditional Food**

Agriculture residues can be used as culture medium on which to grow mushroom for human food. Three strains of mushroom cultures were tested for efficiency and produced fruiting bodies of good quality. These strains were *Plerurolus ostreatus*, *Pleurotus Florida*, and *Pleurotus sajorcajo*. The usual mushroom inoculate (spawns) is carried out by growing fungal mycelium on a medium containing wheat, barley, or sorghum as carriers.

Production of mushroom spawn should be under controlled sterile conditions. Plant residues (e.g., rice straw) are soaked and pasteurized, then temperature and relative humidity in the surrounding environment is adjusted. The mushroom spawn is introduced into the rice straw when temperature is between 20–25°Celsius and relative humidity is 65 percent.

After 3–4 weeks the plastic bags are opened and sprayed with water periodically. After another week, mushroom fruiting bodies can be harvested. Four to eight flushes (harvests) can be collected during 1–2 months. Fruiting bodies are collected, packed in polyethylene, and kept refrigerated.

### **Equipment**

Fifty liter container for sterilizing agriculture residues, table for air drying the residues, plastic bags, mushroom spawn: About LE500