MINISTRY OF LANDS, AGRICULTURE, FISHERIES, WATER AND RURAL RESETTLEMENT

Farm Mechanization and Irrigation Developemnt Handbook For Farmers

Year 2021

Contents

Farm Mechanization

This refers to use of any mechanical input for farm operations through the use of machinery, implements, equipment and tools to increase work output and labour productivity.

The Three Power Sources for Farm Mechanisation

- Manual/hand
- Animal draught
- Motorised/mechanical

Manual Power

- Use of tools and implements powered by human muscle and are the simplest and most basic level of farm mechanization.

Tools used

- Hoes, wheelbarrows,picks, axes, machetes, knapsack sprayers, rakes, shovels, spades, and sickle.
- **Farmer category:** small-scale
- **Recommended area:** Less than 5 ha
- **Labour hours/day**: 8

Field operations, work rates and gross power consumed

Human operations	Work rates	Gross power consumed (W)
Digging (conventional hoeing)		300-500
Digging (Basin digging)	500 holes/day	500-550
Ridging	240+ hr/ha	400-1000
Planting (1-row hand planting)	64 hr/ha	200-300
Weeding	184 hr/ha	370
Spraying (knapsack)	5 hr/ha	250-350
Fertilizer application	64 hr/ha	200-300
Harvesting (maize)	128 hr/ha	300-350
Shelling (maize)	100 kg/day/person	330
Carrying 20 kg (head)	15-20 kg/adult person/trip	250
Cutting a tree		600
Shovelling		530

Note: The maximum sustainable power output by human being is approximately 75 Watts (about 0.5 hp for a few minutes). Power generated depends on: age, weight, health and condition, type of work, sex, training, nutrition and weather conditions.

Transportation

Type	Optimum work load (kg x km)
Head loading	(20-30) x 3
Hand pushed wheelbarrow	(50-70) x 5

Hand pushed/pulled cart (2 persons)	(300-400) x 2

Repair and maintenance of hand tools

- Tools require minimum replacement for a period of 3 years.
- Regular sharpening of tools is required.

Draught Animal Power

Power output depends on: breed, weight, sex, training, nutrition, health condition.

Animal	Mass/Weight (kg)	Travel speed (km/h)	Output power (kW)
Donkey	150-200	3	0.25
Cow	300-500	2.5	0.3
Ox	350-600	3.5	0.4

- **Farmer category**: Small and medium scale.
- **Recommendedarea:** 5-20 ha.
- **Working capacity**: 6 hr/day (with at least a rest period after every hours).

Field operations and work rates

Operations	Work rates
Ripping	5hr/ha
Ploughing (standard 1-furrow plough)	10-12 hr/ha or 0.5 ha/day
Harrowing	4-6 hrs/ha
Ridging	9 hr/ha
Planting (1-row planter)	0.8-1.0 ha/day or 6 hrs/day
Weeding (cultivator)	6 hr/ha or 0.8-1.2 ha/day

Transportation

Type	Optimum work load (kg x km)
Scotch carts	(500-1000) x 8

Harnessing Systems

Cattle harnessing

- Use double neck yokes.
- Plough yoke length**:** 150 cm.
- Cart yoke length: 170 cm.
- Cultivator yoke length: 240.

Donkey harnessing

- Use breast band harness.
- Avoid harnessing donkeys using the cattle double neck yoke.
- Avoid spanning donkeys with an ox or cow in a span.

Trek chain length

- Smaller oxen or cow (less than 350 kg): **2.5m.**
- Large oxen (over 350 kg)**: 3m.**

Repair and maintenance of animal drawn implements

Daily maintenance
- Check all wearing parts.
- Remove soil from the implement while in the field.
- Tighten all loose nuts and bolts.
- Wash and oil the implement if it is not to be used for the next few days.
- Store under dry conditions in a shed.

Seasonal Maintenance
- Strip the implement completely.
- Check all parts for wear.
- Obtain replacement and spare parts as appropriate.
- Clean all parts, oil or paint them if necessary.
- Re-assemble the implement.
- Store the implement in a dry shed.

Essential spares for animal drawn plough
- 1-2 shares as these last for 2 ha
- 1 wheel
- 1 king bolt (flat head)
- 1 bolt for attaching the plough beam to the frog (round head)
- 1 axle and axle nuts as these last for 10 ha

Desirable spares
- 1 landside (expected to last for 15 ha)
- 1 mould board (expected to last for 40 ha)

General tips
- Keep samples of old parts for checking that a new part is the same as the old one.
- Old parts can be kept for repair by a local blacksmith.

Management of draught animals
- Balanced nutrition (adequate feed and water) (See Livestock Section).

Animal welfare:
- Injury free, disease free, work and rest system, matching implements with power source.
- If cows are used for breeding purposes also, break and rest them at 7 months pregnancy to avoid abortions.
- Do not ill-treat animals (e.g. severe whipping stoning or using dangerous objects.

Motorised/Mechanical Power

Implements and machinery can be categorised as tractor driven or self propelled.

Tractor Power

Tractor classification/ category

Tractor size	Power output (kW)
Small	Up to 40
Medium	40-60
Large	More than 60

Farmer category: Medium to Large scale

Choice of tractor size to purchase depends on farm size. As a guide a small tractor (30 kW) is justified for a 15-25 ha land holding, a medium tractor (50 to 60kW) is justified for a 25-40 ha land holding and 40-100 ha are required to justify the investment in a larger tractor (+ 60 kW).

Tractor powered Implements: power rating, output rates and fuel requirement

Implements include those for tillage and land preparation, fertilizer application and planting, weed and pest control and crop and forage harvesting.

Tillage and Land Preparation Implements

Ploughs

Plough Type	Tractor power kW	Work Rate (hr/ ha)	Required fuel (L / ha)
Mounted			
2 disc	35	3	32
3 disc	50	2	25
4 disc	75	1	20
Trailed			
5 disc	90	0.8	17
6 disc	100	0.6	15
Reversible			
2 disc	35	3	32
3 disc	45	2	25

Rippers

Ripper Type	Required power(kW)	Work Rate (hr/ha)	Required Fuel (L / ha)
2 tine	45-60	1	3
3 tine	60-80	1	13
5 tine	75	1	20
7 tine	90-100	1	22

Spring Tines

Type	Required power(kW)	Work Rate (hr/ha)	Required Fuel (L/ha)
11 tine chisel	110	1	16
9 tine chisel	50	1	11

Disc harrows

Type of Disc Harrow	Required Power (kW)	Work Rate (hr/ha)	Required fuel (L/ha)
Light mounted			
2.9m	50	1	6
Mounted offset			
1.60m	40	2	6
1.83m	45	1.6	6
2.10m	50	1.4	7
2.29m	60	1.3	8
Trailed (single acting)			
5.48 m	100	0.5	15
Trailed offset			
2.06m	56	1.5	6
2.30m	65	1.3	7
Rome Type			
2.30m	90	1.3	13
2.60m	100	1.2	15

Ridgers

Type	Required Power (kW)	Work Rate (hr/ha)	Required fuel (L/ha)
2 Disc Ridger	50	2	8
2 Tine Ridger	50	2	8
2 Row Re-Ridger	50	1	5

Note: Ridgers can also be used for fertilizer application, fumigation and hole digging as a single operation in tobacco planting.

Fertilizer Application and Planting Implements

Fertilizer Applicators

Type of Applicator	Required Power (kW)	Work Rate (hr / ha)	Required fuel(L / ha)
Vicon Spreader	55	0.2	1
Broadcast Spreader	55	0.3	2
Box Type Spreader	40	1	3

Planters

Type of Planter	Required Power (kW)	Work Rate (hr / ha)	Required fuel (L / ha)	Operational Labour
2- Row (Maize)	55	2	5	Driver + 3
4 – Row (Maize)	55	1	4	Driver + 4
4 – Row (groundnuts)	55	1	5	Driver + 4
6- Row (Maize)	65	0.30	5	Driver + 6
Seed Drill (Soya)	55	1	9	Driver + 1
Box type spreader (wheat)	55	1	3	Driver + 1

Roller	55	0.4	2	Driver + 1

Note: Planters can also be used for lime and fertilizer application.

Crop Weeding Implements

Type	Required Power (kW)	Work Rate (hr / ha)	Required fuel (L / ha)
9 Tine Spring Cultivator	40	1	11
12 Tine Spring Cultivator	45	0.8	16
2 Row Gang Tiller	40	1.2	10
3 Row Gang Tiller	45	1	9
4 Row Gang Tiller	50	0.9	11
6 Row Gang Tiller	60	0.8	14

Weed, Pest and Disease Control Chemical Sprayers

Type	Required Power (kW)	Work Rate (hr/ha)	Required fuel (L/ha)
7 metre Boom Sprayer	50	0.4	2
12 metre Boom Sprayer	50	0.3	1
Spinning disc LV Sprayer	50	0.2	1
Knapsack Sprayer	Manual	3	nil

Crop and Forage Harvesting Implements

Type	Required Power (kW)	Work Rate(hr/ha)	Required fuel (L/ha)
Combine Trailed (Soyabean and Wheat)	60	2	8
Combine Trailed (Single-row Maize)	55	3	17
Combine (Self Propelled 4-metre width) Wheat / Soyabean,	90	1	14
Maize	90	1	15
Maize Sheller	35	75 * 50 Kg Bags /hr	4.5 L/hr
Rotary Forage Mower	45	1	4

Miscellaneous Farm Operations

Type of Operation	Required Power (kW)	Work Rate (hr/ha)	Fuel Required (L / ha)
Contour construction			
New contours	60		3
Maintenance	60		2
Hammer milling	60		Un-husked, 25mm screen, 1200kg/hr, fuel use 6.9 l/hr
Dam scooping	70		Levelling ant heaps, fuel use 5.5 l/hr
Pot holing	55	1	9
Land planning	70	0.5	4
Front-end loader (0.8m)	60		Gravel from stoke pile, fuel use 4l/hr
Baling (Square, straw, 8.5kg, 72cm long, 48 cm wide, 32 cm high, fuel use 0.02l/bale)	60	2	7
Tractor + trailer	60		On farm, drying trailers, fuel use 4.6l/hr

Source: *Adapted from Agricultural Research Trust Summer Report 1997*

Field Operations, speed and field efficiencies

Operation	Speed (km/h)	Field efficiency (%)
Ploughing	3-6	75-90
Discing	4-10	75-90
Ripping	3-6	80-95
Tining	3-9	75-85
Rolling	8-10	60-85
Planting	7-8	50-60
Drilling	5-8	60-80
Fertilizing	7-8	60-70
Spraying	4-8	55-65
Slashing	4-7	80-90
Harvesting (combine)	3-5	65-80
Harvesting (trailed)	3-5	55-70
Pot holing	4-5	50-60
Land planning	5-8	70-80
Ridging	3-8	65-80
Baling	3-7	65-80

A Comparison of Fuel consumption by Tillage Systems

Operation	Fuel Consumption by Tillage Type		
	Conventional	Reduced Tillage	Minimum Tillage
Ripping	0	20	0
Ploughing	30	0	0
Discing	17	17	0
Planting	6	6	6
Total	53	43	6

Estimated average tractor on farm fuel consumption

kW	L/h	kW	L/h	kW	L/h
20	2.5	60	6.9	100	11.3
25	3.0	65	7.4	105	11.8
30	3.6	70	8.0	110	12.4
35	4.0	75	8.5	115	12.9
40	4.7	70	9.0	120	13.5
45	5.2	85	9.6	125	14.0
50	5.8	90	10.2	130	14.6
55	6.3	95	10.7	140	15.7

Estimated working life (years) for tractors, engines and electric motors

	Annual working hours					
Machinery/equipment	500	750	1000	1500	2000	2500
Tractors	12+	12	10	7	6	5
Stationery engines	12+	12+	12+	12	12	12

Electric motors	12+	12	12	12	12	12

Source: *Farm management Pocketbook 34th Edition (2004) Imperial College London*

Economic and wear out life of machinery and equipment

Item	Economic life (years)	Wear out life (hrs)
Tractor	10	10 000
Combine harvester	10	2 000
Disc plough	15	2 500
Disc harrow	15	2 500
Planter-drill	15	1 200
Precision planter	15	1 200
Baler	10	2 000
Fertiliser spreader	8	1 200
Boom sprayer	10	1 500
Mower	10	2 000

Useful Formulas for use in estimating farm Machinery operations

Machine output in hectares per hour: $= \frac{W \times S \times 0.75}{10}$

Where:

W = operative width of equipment
S = speed in km per hour
Efficiency factor = 0.75

Transport

Fuel consumption in litres/ tonne / kilometre

Flat land	0.05
Undulating land	0.10
Hilly land	0.15

Fertilizer spreader calibration

- Calibration is done using collecting trays or bags.
- Collected fertilizer per min = (Fertilizer application rate (kg/ha) x working width (m) x speed (km/h)] ÷600.

Agricultural Spraying

Basis

i. Power required to operate a pump = $\frac{\text{Output (litres/ min)} \times \text{pressure (kPa)}}{600 \times e}$

Where **e** is the efficiency of the pump expressed as a decimal, and 600 is a constant.

ii. The volume of an impeller- pump varies with the speed of rotation, but any major speed change will alter its efficiency.

iii. The pressure- head delivered by an impeller- pump varies with the speed of rotation. Power required to drive it varies with the speed of rotation.

Field formulae

- For full coverage: Litres /ha = $\frac{\text{600 x litres /minute (one nozzle)}}{\text{Km/h x nozzle spacing (m)}}$

- For row crop: litres /ha = $\frac{\text{600 x litre/min(one nozzle) x no. of nozzles}}{\text{Km/h x band width (m)}}$

- For band spraying: litres/ha= $\frac{\text{600 x litres/minute (min one nozzle)}}{\text{Km/ha x band width (m)}}$

- For a nozzle Litres/min= $\frac{\text{litres/ha x km/ha x nozzle spacing (m)}}{600}$

- When purchasing a new pump to cope with maximum spray demand

Output volume litres/min= $\frac{\text{km/h x spray width (m) x litres/ha}}{600}$

Plus 25% for pump wear and by pass

When calibrating the sprayer

1. $\frac{\text{3.6 x distance travelled(m)}}{\text{Km/h= time (seconds}}$ or $\frac{\text{0.06 x distance travelled(m)}}{\text{time (minutes)}}$

2. Application volume: Litres/ ha= $\frac{\text{litres used x 10 000}}{\text{Boom length (m) x distance (m)}}$

3. Area covered by tank: ha= $\frac{\text{Tank Capacity (Litres) x row width (m)}}{\text{Application rate x band spray width (m)}}$

4. Speed change new spray rate: km/h= $\frac{\text{Current speed x present output (l/ha)}}{\text{New output (litres/ha)}}$

Mixing and filling

Even with most vigorous agitation system chemicals must be carefully and properly mixed before adding to the carrier. This is particularly important with wettable powders that must be first mixed to a creamy consistency. Failure to properly mix the chemicals leads to settling in the tank resulting in over concentration and clogging of sprayer nozzles.

- Wear protective clothing where required.
- Measure correct amount accurately.
- Powders must be weighed accurately.
- Liquids must be measured accurately.
- Calibrate sprayers and check output.
- Read and apply safety precautions noted on the chemical pack.

Calculations for mixing chemicals

- To determine the quantity of formulation (X) required applying the recommended amount of active ingredient per hectare (A) with a formulation containing (B) percentage active ingredient.

$$\frac{A \times 100}{B} = X$$

Example: apply 0.25 kg active ingredient/ha of 5% carbofuran granules.

$$\frac{0.25 \times 100}{5} = 5\text{kg granules /ha}$$

- To determine the quantity of active ingredient (Y) required mixing with unknown quantity of diluents (Q) to obtain a given concentration of spray.

$$Y = \frac{Q \times \%\text{ concentration required}}{\%\text{ concentration of active ingredient}}$$

Example**: -** Mix 100 litres of 0.5%active ingredient, using a 50% wettable powder

$$\frac{100 \times 0.5}{50} = 1\text{kg of wettable powder}$$

Calculations for determining sprayer outputs

$$A = \frac{600\,NF}{WS}$$

N = number of nozzles (18)
F = output of each nozzle (1.30l/min)
W= the width in metre covered in one pass (9m)
S= tractor's speed in km/hr (speed can be calculated)
A= rate of application in litres per hectare (95)

The figures in brackets are arbitrary chosen for use in the examples below.

1. $A = \frac{600 \times N \times F}{W \times S}$ $\quad \frac{600 \times 18 \times 1.3}{9 \times 8} = 195$ l/ha

2. $S = \frac{600 \times N \times F}{W \times A}$ $\quad \frac{600 \times 18 \times 1.3}{9 \times 195} = 8$ km/hr

3 $F = \frac{S \times W \times A}{600 \times N}$ $\quad \frac{8 \times 9 \times 195}{600 \times 18} = 1.3$ litres/nozzle

4. $N = \frac{S \times W \times A}{600 \times F}$ $\quad \frac{8 \times 9 \times 195}{600 \times 1.3} = 18$ nozzles

5 Hectare per tank $= \frac{\text{tank capacity} \times W \times S}{600 \times N \times T}$ $\quad \frac{500 \times 9 \times 8}{600 \times 18 \times 1.3} = 2.56$ ha

Or $\frac{\text{Tank load (litres)}}{\text{Application rate}} = \frac{500}{195} = 2.56$ ha

Calibration formulae for boom sprayers

- Calibration is done using collecting buckets placed under the nozzles.

Boom sprayer
For the whole **boom**:

- Calibration rate (l/min) = (Spray rate x working width (m) x ground speed (km/h) ÷ 600.
- For each nozzle: Calibration rate (l/min) per nozzle = Calibration rate (l/min) (boom) ÷ Number of nozzles.

Methods of spraying

- In order to achieve maximum effectiveness from your chemicals choose the correct type implement and methods to use depending on size of job.

Equipment and Recommended Use

Recommended machine	Recommended chemical application
Low pressure boom sprayers	Herbicides only
High pressure boom sprayers	Herbicides applications at low pressures. Fungicides applications at high pressures
High pressure low volume mist blowers	Insecticides and fungicides applications
Ultra low volume (ULV) hand operated sprayers	Herbicides and insecticide sprayers

Different spraying methods and application

Method	Possible use	Disadvantages	Advantages
Knapsack hand operated	- Nursery -Recently established coffee -In field	.	Cheap
Knapsack motorised mist blower	Nursery In field	Efficiency very dependent on operator, heavy on maintenance.	Suited to steep slopes and close spacing.
Tractor drawn mist blower	In field	Requires access down every row by tractor and sprayer.	Very efficient low labour requirement.
Tractor drawn sprayer with hand lances	In field	Efficiency dependent on operator, increase labour requirement.	Can be used for close spacing and steep slopes when using long hoses.
Fixed point pumping	In field	Efficiency dependent on operator, increased labour requirement.	Can be used for close spacing and steep slopes. Can use electricity or stationary motor in place of tractor.
Hand held ULV	In field	Efficiency dependent on operator.	Very efficient Can be used for close spacing and steep slopes.

Sprayer fault finding Table

Fault	Cause	Remedy
No spray comes out when switched	Faulty pump, nozzles assembled incorrectly, outlet at bottom of tank blocked, filter on suction side of pump completely choked.	New pump required, re assemble correctly see manufacture's handbook, disconnect outlet pipe and clear, dismantle, clean and re assemble.
Sprayer sprays for a short time only	Air inlet tank blocked, filter on suction side of pump blocking rapidly.	Clean vent hole, or tank may collapse, dismantle, clean and re assemble. If persistent clean out tank before refilling.
Spray is uneven across the spray bar	Some nozzle filters or tips are becoming blocked. Nozzle tips are not all of the same size. Nozzle tips may be worn. Nozzles at each end have a lower output.	Remove clean and refit correctly. Check the number of each tip and change any wrong tips. Replace any worn tips with new ones. Check output. Check pressure at end of bar by replacing end nozzle with pressure gauge. If pressure is lower at the end of bar, pump out is too low for the nozzles. Fit smaller tips or change pump if worn.
Pressure gauge reading going up spraying volume from nozzles decreasing	Nozzle filters blocking up gradually. Gauge may be strained.	Dismantle, clean and refit, check if pressure has returned to normal. Check that gauge returns to zero when spray is turned off. If not replace with a new gauge.
Pressure gauge reading falling	Filter on suction side of pump blocking up. Nozzles may be worn, pump may be worn, pressure too low, spray fans or cones very narrow.	Dismantle clean filter and refit. Replace tips with new ones of the same nominal size, a new pump may be required, check that the pressure is within the pressure range recommended for the sprayer , use smaller tips if necessary.
Course forming in the spray tank at the top of the liquid	Fault agitation, too vigorous agitation during filling.	If there is a return pipe above the level of the tank liquid this needs extending to the bottom of the tank or fill sprayer more carefully.
Very fine foam in the liquid in the tank	Air leak into the system between the tank and the pump or in the pump itself.	Locate and repair the leak.
Spay fans or cones streaky when viewed against a dark background	Nozzle partly blocked by minute hairs or flakes. Nozzle clean- probably faulty or worn tip.	Remove tip and clean. Refit correctly and test. Replace cap with a new one of same size and make test.

Fault	Cause	Remedy
Mist blowers V belts breaking after a few hours running, jumping the pulley grooves	Pillow block bearing bolds have worked loose, putting shafts out of alignment. Blower assembly frame bolts have worked loose, putting blower assembly out of line. Main fan pulleys on main drive have moved out of alignment. V belts too loose. Pulley worn.	Tighten bolts. Re align blower assembly frame and tighten bolts. Loosen taper lock grub screws and realign main pulley with fan pulley. Tighten V belts by adjusting the bolt at the top of frame. 1cm (½'' maximum) for tension. Replace pulley.
Pump not achieving correct pressure on V belts breaking or pressure fluctuating	Defective pump diaphragms. Loose V belts. Pump pulleys out of alignment. Insufficient liquid in tank.	Replace diaphragms. Tighten V belts. Loosen taper lock grub screws and realign pulleys. Re align pump by adjusting bolts. Fill tank.

Repairs and Maintenance

Tractors

- Tractor maintenance should be done as specified in the Tractor Operators Manual supplied by the manufacturer as follows:
  - Daily/Every 10 tractor hours
  - After running in at 50 hours
  - Every month

Implements

Daily maintenance

- Check and tighten bolts and nuts.
- Grease all greasing points.
- Clean implements after work.
- Equipment will last longer if cleaned and working surfaces are greased prior to storage.

Combine harvesters
Self-propelled or trailed

- Maintenance should be done as specified in the Operators Manual supplied by the manufacturer.

Safety on General Use Of Agricultural Machinery, Implements And Tools

Safety when using tractors

- Transmission system must be in good order.
- Steering mechanisms must be in good working order.
- Brakes must function properly.
- PTO shaft at the rear of the tractor must be guarded at all times.
- Children are not allowed to operate farm machinery.
- No passengers are allowed to ride on a tractor if it is not equipped with seating for two options.
- Riding on the drawbar or mudguard of a tractor or on attached equipment s not allowed.
- Avoid towing from a high hitch point, at the rear of the tractor to avoid overturning of the tractor.
- Avoid carrying drums or containers on tractor lifting arms.
- Hitch trailers according to the manufacturers instructions.
- Avoid using a tractor without lights at night.
- Wear ear protective device and protective clothing.

Safety when using combines

- Avoid driving the combine for long distances on main roads.
- Never unclog any part of the machine while it is running.

Safety when using farm implements

- PTO shafts must be operated with the guard properly secured.
- Guards should be fitted according to the manufacturers' requirement.
- Open shafting, sprockets, chains, pulleys, belts, and gears must be properly guarded.
- Machines fitted with cutter-bars must have a rigid guard over the fingers of the bar when the cutter-bar is not in use to avoid injury.

Safety when handling spray chemical

- Make sure that you read and follow instructions given by the manufacturer of the chemical.
- Wear protective clothing (wear rubber gloves when handling the chemical and a face mask when spraying).
- Wash hands and face thoroughly before eating and drinking.
- Avoid smoking when working.
- Keep out of the spray drift.
- Do not spray in windy conditions.
- Avoid spraying on grazing pastures.
- Containers that have been used for spray chemical should be properly disposed of.

First aid on the farm

- A first aid box must be kept on a farm.
- A fire extinguisher must always available.

Farm Structures

Farm Structures
Common farm structures:
- Greenhouses
- Grain storage structures
- Machinery and implement sheds
- Fuel and chemical stores
- Fertilizer Stores
- Farm workshops
- Tobacco barns
- Tobacco grading sheds
- Animal housing
- Grain dryers
- Mushroom housing
- Fruit and vegetable dryers

For specifications, design plans and bills of quantities contact the Institute of Agricultural Engineering-Farm Structures Branch and or private commercial companies.

Greenhouses
Types include:
- Closed greenhouses
- Saw tooth/Colombian
- Quonset/Tunnel greenhouse
- Shade houses

Grain storage structures
Size and type of depend on:
- Volume of crop
- Storage requirements for the crop
- Cost
- Form in which the crop is stored

Storage systems include:
- Solid-wall bins and silos for bulk storage
- Brick-walled silo
- Reinforced concrete silos
- Steel bins
- Bag storage

Important points to note are:
    - Keep store clean
    - Prevent moisture
    - Control insects and rodents
    - Keep store cool

Machinery and Implement Sheds
Points to note include:

- Narrow open-side shed.
- A well drained, raised earth or gravel floor is adequate.
- Sides can be partly or wholly enclosed.
- High enough to accommodate the highest machine.
- A smooth, level floor makes it easier to attach and detach tractor-mounted equipment or to move other machines.
- Space required is determined by measuring machines and implements to be stored.
- Must be secure to protect equipment from theft and vandalism.
- Shed must be dry.

Fuel and Chemical Storage structures
- Flammable products (cellulose thinner- petrol, kerosene, diesel should be stored in a separate building at least 15m from other buildings.
- Store must be well ventilated.
- Washing facilities should be available nearby for immediate use.
- Keep fire extinguishers ready.

Fertilizers Storage structures:-
- Bags must not be punctured.
- Storage conditions should be dry.
- Place bags on a raised platform.
- Roof must not leak or use watertight cover.
- Fertilizers are corrosive to metals and should not be stored close to machinery or tools.

Farm Workshops
- Must accommodate the largest machine that may need repair.
- Entrance must be wide and high enough for the largest equipment to be accommodated.
- Means of lifting and supporting heavy loads is needed.
- Electric lighting and electrical service for power tools.
- A water supply for both convenience and safety.
- One or more fire extinguishers of a type suitable for fuel fires.
- Two or three buckets of dry sand are a possible substitute or supplement for a fire extinguisher.
- Storage cabinets for tools, supplies and spare parts.
- Lockable sturdy doors for security.
- A workbench with vice.
- Ample window openings for light.

Tobacco Barns

Barns can be classified as below:

System	Characteristics
Conventional	Tall barn, with or without recirculation fan Long low, with or without recirculation fan
Down draught	Down draught tall barn Down draught long low
Billy barn	Billy tall barn Billy long barn

Bulk curers	Modro
Continuous System	Cascade/Chongololo Tunnel system
Low cost	Round barn

The following furnace types are available:

- Wood fired slot furnace
- Fire bar, (uses both fire wood and coal cobbles)
- Red mile plate. (Uses coal)
- Automatic stoker fan. (Uses coal)

Barn Capacities

The nominal imperial equivalents of metric barn sizes are given below.

Metres	Feet
3.6 x 3.6	12 x 12
3.6 x 5	12 x 16
5 x 5	16 x 16
5 x 6	16 x 20
6 x 6	20 x 20
6 x 10	20 x 32
6 x 12	20 x 40

Hectares per barn per season: 7-day turn-around.

Barn (m)	Tier	Strings	Reaping interval, days				
			3	4	5	6	7
3.6 x 3.6	3	125	0.15	0.20	0.25	0.30	0.35
	4	160	0.19	0.26	0.32	0.39	0.45
	5	205	0.25	0.33	0.41	0.50	0.58
3.6 x 5	3	165	0.20	0.27	0.33	0.40	0.47
	4	215	0.26	0.35	0.44	0.52	0.61
	5	270	0.33	0.44	0.55	0.66	0.77
	6	325	0.39	0.53	0.66	0.79	0.92

Barn (m)	Tier	Strings	Reaping interval, days				
			3	4	5	6	7
5 x 5	3	210	0.26	0.34	0.43	0.51	0.60
	4	280	0.34	0.45	0.57	0.68	0.79
	5	350	0.43	0.57	0.71	0.85	0.99
	6	420	0.51	0.68	0.85	1.02	1.19
	7	495	0.60	0.80	1.00	1.20	1.40
	8	560	0.68	0.91	1.13	1.36	1.59
5 x 6	4	350	0.43	0.57	0.71	0.85	0.99
	5	440	0.53	0.71	0.89	1.07	1.25
	6	525	0.64	0.85	1.06	1.28	1.49
	7	615	0.75	1.00	1.24	1.49	1.74
	8	700	0.85	1.13	1.42	1.77	1.98
6 x 6	4	455	0.55	0.74	0.92	1.11	1.29
	5	565	0.69	0.91	1.14	1.37	1.60
	6	680	0.83	1.10	1.38	1.65	1.93
	7	790	0.96	1.28	1.60	1.92	2.24
	8	905	1.10	1.47	1.83	2.20	2.56

6 x 10	4	720	0.87	1.17	1.46	1.75	2.04
	5	905	1.10	1.47	1.83	2.20	2.56
	6	1080	1.31	1.75	2.19	2.62	3.06
6 x 12	4	900	1.09	1.46	1.82	2.19	2.55
	5	1130	1.37	1.83	2.29	2.74	3.20
	6	1350	1.64	2.19	2.73	3.28	3.83

The table assumes:

- Reaping rate is two leaves/plant/reaping.
- Plant population is 15 000 plants/ha.
- Tying rate is 85 leaves/string/stick.
- String/stick spacing is 27 cm.
- If any of your measurements differ very much from these, use the formula to calculate your own requirements.

The formula used to calculate the tables is: $\frac{s \times l \times r}{p \times n \times t}$ = hectares/barn

Where: s = no. of strings/barn
l = no. of leaves/string
r = reaping interval, days
p = plants/hectare
n = no. of leaves/plant/reaping
t = barn turn round time, days.

Construction specification:

Designs and specifications can be obtained from the farm structures branch at Institute of Agricultural engineering, Tobacco Research Board, and other private companies**.**

Animal Housing (pigs, poultry, goats, sheep)

Cattle housing

Resting area for cows:

- Paved shade, or
- Deep bedding in an open sided barn, or
- Free-stalls in an open sided barn

Exercise yard (paved or unpaved)

- Paved feed area
  - Fence line feed trough (shaded or not shaded), or
  - Self feeding from a silage clamp

Milking centre

- Milking shed or parlour, and
- Collecting yard, and
- Dairy including milking store, and
- Motor room

Types of milking parlours

- Abreast parlour
- Tandem parlour
- Walk-through parlour
- Herringbone parlour
-

Bull pen with a service stall

Calving pen

Calf accommodation

Young stock accommodation (yard with paved shade and feed area)
Bulk feed store (hay and silage)
Concentrate feed store

Veterinary facilities

- Diversion pen with Artificial insemination stalls, and
- Isolation pen
- Cattle dip tank
- Cattle spray race

Poultry housing

- Brooder systems
- Housing systems for chickens
- Semi-intensive
- Deep litter
- Slatted or wire floor
- Combination of slatted floor and deep litter
- Cage and battery

Recommended Minimum Floor, Feed and Water Space (chicks and pullets)

Growth Stage (weeks)	Floor Space Stocking density		Feeder Space		Watering Space (birds/ m^2)
	Low (birds/m^2)	High (birds/m^2)	Trough (birds/ m^2)	Tube (birds/ m^2)	
1-4	15-20	25-30	40	40	150
5-10	8-11	12-15	15-20	25	75
11-15	5-6	7-8	9-10	12	50
16 +	3-4	5-7	7-8	10	40

Layer Housing Systems and Stocking Rate

- Two systems can be identified.

Semi-intensive system

Type	Floor Space Stocking density	
House-run	Low (birds/m^2)	High(birds/m^2)
House	3	4-5
Run	0.04-0.08	0.10-0.13
Straw-yard		
House	3	4-5
Yard	1.5	2.5
Fold system	2	2

Intensive Systems

Type	Floor Space Stocking density	
	Low (birds/m^2)	High(birds/m^2)
Deep litter floor	3-4	5-7
Wire floor	7-8	9-10

Combination floor	5-6	7-8

Pig Housing

- Types of pens
  - Farrowing/suckling pen
  - Boar pen
  - Gestating sow pens
  - Weaner pen (up to 25Kg or 12 weeks)
  - Growing pen (up to 40Kg or 17 weeks)
  - Finishing pen

Dimensions and Area of Various Types of Pig Pens

Type of pen		**Units**	**Stocking Density**	
			Medium	**High**
Farrowing / suckling pen	Resting area, if weaner pens are not used	M^2	7.5	6.0
	Resting area, if weaner pens are used	M^2	6.0	5.0
	Manure alley width	M	1.5	1.3
	Farrowing pen	M^2	4.5	4.0
	Piglet creep	M^2	1.5	1.0
Boar pen	Pen with yard			
	Resting area shaded	M^2	5	4.5
	Yard area paved	M^2	10	0.8
	Pen without yard	M^2	8	7
Gestating sow pens	Loose in groups of 5-10 sows			
	Resting area shaded	M^2	1.5	1.1
	Yard area paved	M^2	3.0	2.5
	Feeding stalls, depth x width	M	1.8 x 0.55	1.7 x 0.5
	Confined in individual stalls			
	Length x width of stalls		2.1 x 0.65	2.0 x 0.60
Weaner pen (up to 25Kg or 12 weeks)	Resting area excluding trough	M^2 / pig	0.30	0.25
	Manure alley width	M	1.0	1.0
Growing pen	Resting area excluding trough	M^2 / pig	0.45	0.40
	Manure alley width	M	1.1	1.1
Finishing pen (resting area excluding trough)	For porkers	M^2 / pig	0.60	0.50
	For baconer	M^2 / pig	0.75	0.60
	For heavy hog	M^2 / pig	0.85	0.70

Sheep and Goat Housing

General; housing requirements:

- Yards
- Sun shade
- Dipping tanks

Floor and Trough Space Intensive Sheep/Goats Production (Live Weight)

Growth Stage	Weight (kg)	Floor space (m^2/animal)			Trough space (m/animal)
		Solid Floor	Slatted Floor	Open Yard	
Ewe/Doe	35	0.8	0.7	2	0.35
Ewe/Doe	50	1.1	0.9	2.5	0.40
Ewe/Doe	70	1.4	1.1	3	0.45
Lamb/Kid		0.4-0.5	0.3-0.4	-	0.25-0.30
Ram/Buck		3.0	2.5	-	0.5

Key
- Slats shall be 70-100mm wide, 25-30mm thick and laid with 25mm spaces;
- Individual lambing pens should be 1.5-2.2m^2 depending on the weight of the ewe and number of lambs expected;
- A feed trough should be 0.3-0.4m deep front to back and have a 0.5-0.6m high front wall facing the feed alley.

Grain Drying
Type
- Natural drying;
- Artificial drying.

Natural Drying: include:
- Drying in the field;
- Drying in shallow layers and exposed to sun and wind on a surface;
- Drying in or on a structure which has open sides that permit air movement through the bulk.

Artificial drying
May be characterised by the depth or thickness of grain being dried:
- Deep layer driers;
- Shallow layer driers;
- In sack driers.

Dryer Specifications

Drying system	Dryer Type	Specifications
Deep layer	Beds, bins, silo	Depth of grain 30 cm-350 cm
Shallow layer	Batch	(1-2) wide; (2-4) long; (150-300 mm) deep
	Continuous-flow	(100-150 mm) deep
Sacks	Platform driers	A plenum chamber with a wire mesh open top with supporting means for 2-3 layers of sacks
	Stack system	Perforated plenum tunnel base for stack fitted with a fan to distribute the air uniformly

Mushroom Housing

Types

- Greenhouses
- Sheds
- Old farm buildings

Construction specification

- Building should be enclosed, well ventilated.
- Cement floor.
- Concrete roof is preferable to corrugated metal roofing.

Fruit and Vegetable Dryers

Type

- Solar box dryer

Specifications: Frame of timber material covered by greenhouse plastic, double tray and detachable legs

Dimensions: Length (2-2.5 m), width (1 m) height (1m)

Horticultural Handling Facilities

- Washing facilities.

The consumer should routinely wash products before use.

- Sorting and grading sheds:
- Cold rooms
- Pack houses
- Transport

Toilets

Type:

- Blair toilet
    - Construction specification: (0.9m Diameter x 5m Depth)

Note: A pit of 0.9m diameter and 5m depth lasts for about 5 years if used by a family of 6 persons.

Earth Dams

Earth Work Volumes and Basin Capacity

- Volume of earth works (V) = $0.216\ H \times Lc\ (2C + H \times S)\ M^3$
- Basin Capacity (Q) = $\frac{(Ls \times T \times D)}{6}\ M^3$

Where: C = Crest width (m)
D = Maximum water depth (m)
H = Maximum height wall (m)
Lc = Length of wall along crest including spillway (m)
Ls = Length of wall at full supply level (m)
V = Volume (m^3)
Q = Capacity (m^3)
S = Sum of upstream and downstream slopes of embankment

T = Throw back (m)

Values of maximum probable flood (mpf) M^3/S

Area (km^2)	X 1	X 10	X 100	X 1000	X 10000
1.0	55	222	953	3600	12000
1.1	58	236	1 010	3790	12000
1.2	60	250	1060	3980	13500
1.3	63	264	1120	4160	14000
1.4	65	277	1170	4330	14600
1.5	68	289	1220	4500	15100
1.6	70	302	1260	4660	15600
1.7	73	314	1310	4810	16100
1.8	75	326	1350	4960	16600
1.9	78	337	1400	5110	17000
2.0	80	348	1440	5250	17500
2.2	85	371	1520	5530	18300
2.4	89	392	1600	5800	19200
2.6	94	412	1680	6050	19900
2.8	98	432	1750	6290	20700
3.0	102	452	1820	6530	21400
3.2	106	471	1890	6760	22100
3.4	111	489	1960	6980	22800
3.6	115	507	2030	7190	23500
3.8	119	524	2090	7190	24100
4.0	122	542	2150	7400	24700
4.2	126	559	2210	7600	25300
4.4	130	975	2270	7810	25900
4.6	134	592	2330	8000	26500
4.8	138	608	2390	8190	27100
5.0	141	623	2440	8370	27600
5.5	140	661	2580	8560	29000
6.0	159	698	2710	8990	30200
6.5	168	733	2830	9410	31500
7.0	176	767	2950	9810	32600
7.5	184	800	3070	10200	33700
8.0	192	833	3180	10600	34800
8.5	200	864	3290	10900	35900
9.0	207	894	3400	11300	36900
9.5	215	924	3500	11600	37900

Maximum Probable Flood (MPF) Return period factor

Return period (years)	Factor	Return period (years)	Factor
10	0.115	750	0.558
25	0.192	1000	0.637
50	0.263	2000	0.742
100	0.340	2500	0.766

250	0.449	5000	0.855
500	0.541	10000	1.000

MPF = Maximum Probable Flood
Peak Flood = MPF x factor of a chosen return period

Recommended slopes for small, zoned, earth fill dams on stable foundations

Type	Purpose	Subject to (1) Rapid drawdown	Shell material Classification (2)	Core material (3)	U/S	D/S
Zoned with minimum core	Any	Not critical (4)	Rockfill, Gw Gp , Sw or Sp	GC, SC, SM, CL, ML , CH, or MH	2:1	2:1
Zoned with maximum core	Detention or Storage	No	Rockfill, Gw, Gp , Sw or Sp	GC, GM, SC, SM , CL, ML, CH, MH	2:1 2.5:1 2.5:1 3:1	2:1 2:1 2.5:1 3:1
Zoned with maximum core	Storage	Yes	Rock fill, Gw, Gp, Sw, or Sp	GC, GM, SC, SM, CL, ML, CH, MH	2.5:1 2.5:1 3:1 3.5:1	2.5:1 2.5:1 3:1 3.5:1

Recommended slopes small, homogeneous, earth fill dams on stable foundations

Type	Purpose	Subject to (1) Rapid drawdown	Soil (2) Classification	U/S	D/S
Homogeneous or modified Homogeneous	Storage or Detention	No	GW, GP, SW, SP, GC, GM, SC	Previous not suitable	
			SM. CL, ML. CH, MH	2.5:1 3:1 3.5:1	2:1 2.5:1 2.5:1
Modified Homogeneous	Storage	Yes	GW, GP, SW, SP, GC, GM , SC	Previous not suitable	
			SM. CL , ML, CH, MH	3;1 4:1 3,5:1	2:1 2.5:1 2.5:1

Note:

1. Draw down rates 150mm or more per day following prolonged storage at high reservoir levels;
2. OL and OH soils are not recommended for major portions of homogeneous earth fill dams. Pt soils are unstable;
3. OL and OH soils are not recommended for major cores of the earth fill dams. Pt soils are unsuitable;

4. Rapid draw down will not affect the upstream slope of a zoned dam which has a large upstream previous shell.

Key to abbreviations

GW well graded gravel	GP poorly graded gravel
GM silty gravels	GC clay gravels
SW well graded sands	SP poorly graded sands
SM silty sands	SC clayey sands
OL organic silts and silty clays	MH inorganic silts or elastic silts
CH inorganic clays of high plasticity	OH organic clays of high plasticity
PE peat and highly organic soils U/S	upstream slope
D/S down stream slope	

Vegetation indicators of possible earth materials for borrow sites

Latin Name	Common Name	Soils
Brachystegia spiciformis Julbernadia globiflora	Msasa Munondo	Well-drained paraferralitics and fersiallitics
Acacia albid Hyphaene apiculatum Combretum crinita	White-thorn Vegetable ivory	Alluvial siallitics Sand siallitic soils Siallitic or sodic, Soils if stunted
Guibourtia coresperna Baikiae plurijuga Azelia guanzesis Terminlia guanxzensis Preaea sericea Parinari abyssinica Syzgium guineense Colephosphermum mopane Acacia xanthophloea Eriosem engleranum Uapaca kirkiana	Zimbabwean mahogany Zimbabwean teak Pod mahogany Yellow wood Protea Muhacha Waterberry, hute Mopane Fever-tree Blue-bush Mohobohobo	Sands (Kalahari) Sands (Kalahari) Sands Sands Sands Temporarily wet soils Temporarily wet soils Permanently wet sands Sodic soils Sodic soils Poorly drained, Lateritic soils, Shallow, well drained lateric soils

Post-Harvest and Agro Processing

Post-Harvest Management

Processes from the moment the desired plant part is detached from the parent plant until it gets to the final consumer. Management steps differ with type of crop and stage of harvest. The categories of the desired or harvested products are non-perishable, semi perishables and the highly perishables.

Cereals

Cereals are a good example of non-perishable food products and maize will be used for purposes of illustration

Types of Losses

Quality – changes in colour, reduction in nutritional value, contamination with toxins
Quantity – occur due to spillage, damage by pests-reduction in weight

Harvesting

How to prepare before the harvest

Check that the equipment needed for the harvest and postharvest activities is available and in good repair. Decide where important activities will take place (allocate drying and threshing areas), and Ensure there is sufficient storage space for the crop. Clean grain stores and sacks thoroughly so that the residues of the old harvest are not mixed with the new crop

Harvest crop at physiological maturity to prevent in-field losses physiologically mature maize crop is identified by; yellowing and drying up of most of the leaves and husks turning papery, maize grains acquire a glossy surface, the grain is too hard and uncomfortable to chew when it is roasted, maize cobs begin to hang downwards on the stalk, (drooping), the silk completely dries up and turns black in colour and moisture content is between 35-40% of the total grain weight.

Crop	MC %	Characteristics
Sorghum	25-35	Black layer formation Grains can rub out of the head with slight force Plants are still green at maturity
Finger millet	>25	Leaves turn yellow
Pearl millet	>25	Heads change from greenish to greyish Leaves turn yellowish
Ground nuts	>35	Development of brown discolouration on the inside of pods Seed coat in mature kernel : 1. Starts drying out 2. Not easily rubbed off by hand 3.Has a papery texture 4.Has developed the colour expected of that variety In immature kernels the seed coat is thick, fleshy, rubs off easily and has a pale colour Leaves turn brown
Beans/cowpeas	35-55	The pods have just turned yellow

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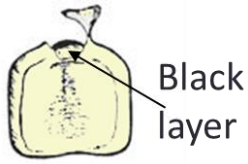
Black layer test method

Randomly collect ten maize cobs from a one hectare size of land. Shell ten maize grains from the centre of each maize cob. The total number of grains from ten cobs should be one hundred. Thoroughly mix the grains. Select a sub sample of ten grains randomly and peel the tip-caps backwards. Observe each exposed tip-cap. When more than 50% of the peeled maize grain has black or dark brown colour, the maize crop is mature and ready for harvesting



What to look out for at harvesting

Cobs should not come into contact with the ground to avoid termite attack, cob rots or soiling. Picking up all scattered cobs and heaping them together before loading. Separating damaged or diseased cobs from the normal ones to avoid pest attack, cross-contamination of fungal diseases (moulds).

Transportation
Transport the harvest to the next stage of post-harvest chain as soon as possible. Transport can be by head-load, wheel barrow, bicycle , tractor, ox or donkey drawn carts. Make sure the crop is transported in clean and dry containers that do not allow the crop to spill out or fall off. Avoid over loading.

Drying-moisture content determination
Drying is the reduction of levels of moisture content to safe storage levels. This can be done before or after shelling depending on the preferences of the farmer, harvesting method used and available drying facilities.
Grain is dried to prevent: Germination, Respiration, Microorganisms, Insect infestation, and to increase storage life

Factors affecting drying
Temperature, Wind and ventilation/airflow, Moisture-humidity/weather conditions

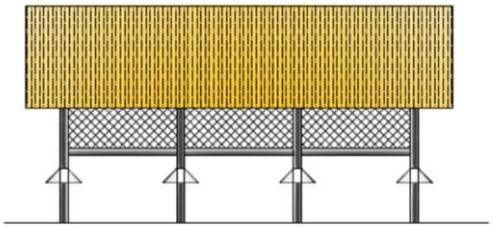
Factors for control of losses in stores
Drying systems
There are 2 drying systems the natural and artificial. The systems to use is determined by the farm cropping systems and the yield. The natural drying systems takes advantage of the natural solar radiation and the ambient temperatures. Examples of natural drying methods are sun drying, crib drying and solar dryers. Artificial drying of grains is commonly accomplished by forcing air through the bulk grain at different temperatures: ambient/natural temperature, near-ambient temperature, high temperature drying, and dryer aeration. Examples are continuous flow dryers, re-circulating batch dryers, batch dryers.

Crib

- A crib is a household structure constructed for the purpose of drying unshelled grains and they come traditionally in mainly two different shapes the conical and regular shape. Traditionally smallholders in Zimbabwe use flat rock surfaces to dry grain or they use unventilated (air flow restricted) cribs (made of grass and or stover) without roofs to protect from rain of direct sun. Farmers dry maize from April/May until August/September. The traditional methods of drying lead to losses. An improved cribs can dry maize cobs from physiological maturity moisture contented (35%) down to safe storage moisture content (15%) in 45-55 days depending on weather conditions. The width of an improved crib should be not more than 1.5m, the height of the crib is 1.7m from the platform floor while the length is unlimited to hold the entire yield. The sections of the crib can be extended.
- The long side of the crib must face the prevailing wind direction. The walls can be made of wire mesh or sticks (poles). For sufficient ventilation there must be at least 50% space openings in the wall area.
- The roof must be of thatch or corrugated sheets to protect the crop from dew, rain, sun and birds. The roof must have adequate overhang. Raising the crib 1m above ground prevents domestic animals from causing losses. Rat guards should be fitted on all supporting poles at about 0.6-1m above ground level to prevent entry by rodents. Supporting poles must be treated against termites. The improved crib enables quick drying of cobs. Dried cobs must be removed from the crib then shelled and stored.
- Characteristics of an improved crib
    - Roofed to avoid scotching &/ cracking of grain
    - Roof with adequate overhang to protect from rain

- Should have approximately 50% openings in the walls for maximum ventilation
- Made of either wire mesh and poles or poles of various sizes. Only-Treated poles offer durability
- Fitted with rat guards

Capacity
Cribs can be made to hold any amount of unshelled grain as long as the critical specifications are adhered to.



These are dependent on the amount of unshelled cobs to be dried. The recommended crib widths for different weather conditions are indicated below:

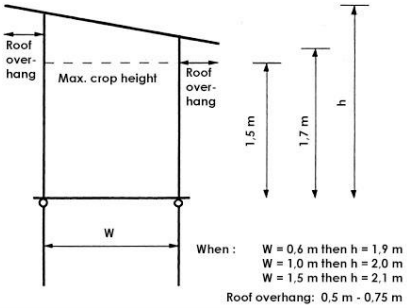
Mean daily relative humidity	**Recommended crib width (m)**
> 80%	**0.6**
75 – 80%	**1.0**
65 – 75%	**1.5**
< 55%	**2.0**

In Zimbabwe, the relative humudity during the drying period, is 65-75%. Therefore farmers can use the 1.5m wide crib. The length can now be calculated depending on the volume of maize to be dried as follows:
Estimate the final yield of the maize crop and then calculate backwards to determine the volume of the dehusked unshelled maize to be dried. Say the yield is estimated at 3tonnes;

$1m^3$ of dehusked cobs at 30%mc =500kg, this translates to 300kg shelled grain at 14%mc
Therefore: 3000/300 x 500 = 5000kg

Volume of dehusked maize =5000/500 = $10m^3$

The height of the structure from the platform and depth of loading are indicated below:



Hence from the example above the length of the crib can be calculated as follows:
$10m^3 = 1.5 \times 1.5 \times L$
$10m^3/2.25m^3 = L$
L=4.5m

Summary of crib specifications:

- Height of platform from ground should always be at least 1m
- Roof overhang should be between 50-75cm
- Pitch angle 45^o for gabled roof and
- Rat guards at least 0.6m from the ground
- Depth of pillar poles at least 0.5m
- At least 50% of walls should be opened

Materials

- Main posts-treated gum poles of diameter not less than 120mm
- Beams- treated gum poles of diameter range of 100- 120mm
- Rafters- treated gum poles of diameter range of 80-100mm
- Purlins- treated gum poles of diameter range of 75-80mm
- Wall supporters- treated gum poles of diameter range of 50-75mm
- Floor sticks- treated gum poles of diameter range of 50-75mm/pig mesh wire
- Wall sticks- treated gum poles of diameter range of 50-75mm/pig mesh wire
- Roof-grass or roofing sheets
- Rat guards-galvanised metal sheets or old tin cans
- Optional material: ¾ stones, cement, river sand

How to know when grain is dry enough

There is need to know when grain is dry enough for safe storage. This is at ≤13% moisture content. This can be done by:
Biting or pinching it, or by the sound it makes when pouring or rattling it. Dry grain is harder so experienced farmers can tell the difference. Using the 'salt' method. Asking someone who has access to a moisture meter.

Slat test method

Place a handful of maize and a teaspoon of dry salt in a glass or clear plastic bottle and shake for about one-and-a-half minutes. Leave this for about 5 minutes to settle down shake again and observe. When the salt clings to the walls of the bottle or glass, it means the moisture content is above 15% and the maize require further drying.

Shelling or threshing

Threshing or shelling separates the grain from the seed heads, panicles, cobs or pods.It is important to minimize grain damage during threshing. Avoid grain damage by avoiding techniques that crush or damage grain, not threshing grain that is too moist (soft) or too brittle (dry), threshing most types of grain when their moisture content is at 14-16%. Shelling /threshing methods available are manual and mechanical methods. Yield and availability of resources determines which method is employed by each farmer. Mechanical methods can be engine powered, electrical, tractor driven or human driven. Manual methods require maize to be dehusked and mechanical may or may not require the maize to be dehusked depending on the type of the machine.

An example of a diesel engine powered maize sheller

Cleaning

Cleaning grain can substantially improve its quality and hence its grade and price. Cleaning removes foreign matter such as stones, plant material from harvesting such as husks, pods, broken grain and dust produced during threshing. It also removes insect damaged and mouldy grains. This can also be done manually by winnowing, hand picking and using sieves or screens to remove heavier impurities or mechanically.

Motorised winnower

Grading

Quality of grain determined by end use.

Factors considered include; moisture content , percentage of impurities (extraneous matter), chipped, broken, defective (colour diseased, shriveled, stains), unthreshed, test density (A B C D) among others.

An example of a grading table:

Grade	A	B	C	D
Extraneous Matter (%)	0.5	0.75	1.0	4.0
Defective (%)	0.6	12	17	22
Mc (%)	12.5	12.5	12.5	12.5
Test Density (Kg/Hl)	70.0	68.0	66	-
Trash (%)	0.1	0.1	0.25	0.3
Broken/Chipped (%)	0.8	-	-	-

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Grain treatment
Insect pest control on-farm is needed when:
Grain is being stored for more than 3 months and it is not in an hermetic store

Types of insect pest control suggested for on-farm storage:

- Admixture of insecticidal dust with loose grain
- Admixture of insecticidal dust with cobs, seed head, pods etc.
- Solarisation (heat treatment) of a thin layer of grain
- Phosphine fumigation of sealed stores (only recommended when supervised by a certified fumigator)

Insecticide dusts are recommended for use by smallholder farmers because they:

- contain a low concentration of insecticide, making them safer to handle than more concentrated formulations
- are ready to use
- are supplied in small packets so dosage calculations are easier
- don't need elaborate safety precautions, but farmers should -
- Avoid breathing in the dust, e.g. could tie a cloth over the mouth
- Wash hands after completing the job
- Not reuse any pesticide containers

Storage
Storage is the process of ensuring that grain is kept in a safe place for later use between subsequent harvest seasons. It is important to keep enough grain on farm to feed the family until the next harvest. Purchase of grain some months after harvest can be very expensive, so money is saved by keeping enough in store. Good storage facilities are needed to protect the grain for household consumption


Steps to Successful Insect Management in Farm-stored Grains

What to Do Before Harvest

Sanitation

Thoroughly clean all grain residues from storage and handling facilities. Clean all residues from areas around the stores and feed storage areas. Remove all grain residues from combines, trucks, and augers. Clean grain debris from fans and other grain handling equipment. The residues will be the main sources of insect infestations for farm stored grain. This is a very important part of a good grain management program and can prevent many stored grain insect problems.

Residual surface sprays to storage facilities

After all debris and grain residues have been removed, a residual insecticide can applied in and outside side the stores and wherever residues have been removed. Spray all surfaces until wet prior to storing or handling grain. Use a course spray and insecticides are most effective if temperatures are 16^{o}C or higher. For optimal insect control, labeled products should be applied to these areas 6-8 weeks prior to handling grain. If sprayed within a few days of use the performance of the insecticides may be reduced.

Storage methods

These are divided into bulk and bag storage. There is a further distinction into hermatic storage and non-hermetic storage.The planned storage period may affect the choice of store type. Typically, grain is stored either –Short-term (e.g. <3 months) before transport to market or Collection Point of the Farmers' Organisation, for household consumption, or Medium to long-term (3-12 months) where farmers keep it for sale until prices are more favourable or for household consumption.

In bag storage there are two options the open weave bags (polypropylene, jute, sisal) and the sealed bags. The open weave bags are vulnerable to insect entry and the prevailing moisture conditions. The sealed bags are Hermetic (air-tight) and isolated from external moisture conditions.

In bulk storage there are many options among which are bins, silos, drums and bulk bags. Some options are insect-proof, but not air-tight and others are both isolating from external moisture conditions.

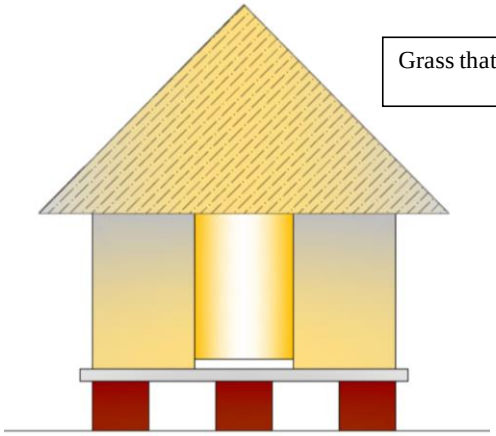
Improved brick granary

This is a household bulk storage structure which adopts its design from the traditional pole and mud granary. The main difference from the traditional structure is the use of better materials which offer durability and better protection against agents of grain losses. The improved brick granary was developed by the Institute of Agricultural Engineering. The granary has brick walls, 3 compartments with lockable doors, ceiling and thatched roof. It is built on a concrete platform that sits on brick pillars and has a lockable main door. A sheet metal plate can be nailed to the bottom part of the door to prevent entry of rodents.

The roof has adequate overhang to protect the walls of the granary from sun and driving rain thus keeping the structure cool and dry. The grain is fire proofed by the concrete slabs placed on top of the compartments.

Both the outside and inside walls of the granary are smoothly plastered with a layer of anthill soil followed by a layer of cow dung to seal off cracks or crevices that may harbour insects.

The capacity of the structure is 3.2 tonnes. The capacity can be expanded according to need.



Specifications

- The granary is made of well burnt farm bricks
- Pillars and walls made of bricks
- Platform and ceiling are made of concrete
- The storage bins have to be plastered with ant hill soil to a thickness of not less than 1mm on the wall and 20mm on the floor.
- It is thatched

Brick pillars

Materials

- Farm bricks
- 19mm stones
- River sand
- Pit sand
- Cement (specs. 32.5 strength)
- Reinforcement wire
- Thatch grass
- Thatching twine
- Nails
- Tying wire
- Screws
- 3m x 50-75mm treated poles
- Plained wood
- Hinges
- Hasp and staple

Maintenance

- The area around the granary should be free of trees and tall grass
- The granary should be kept clean
- No residual grain should remain in the granary from previous season

- The free space on top of ceiling or below the structure is not storage space and should remain free
- After each emptying of the bins the walls have to be plastered with a slurry mixture of cow dung and anthill soil to cover all cracks

Metal silos

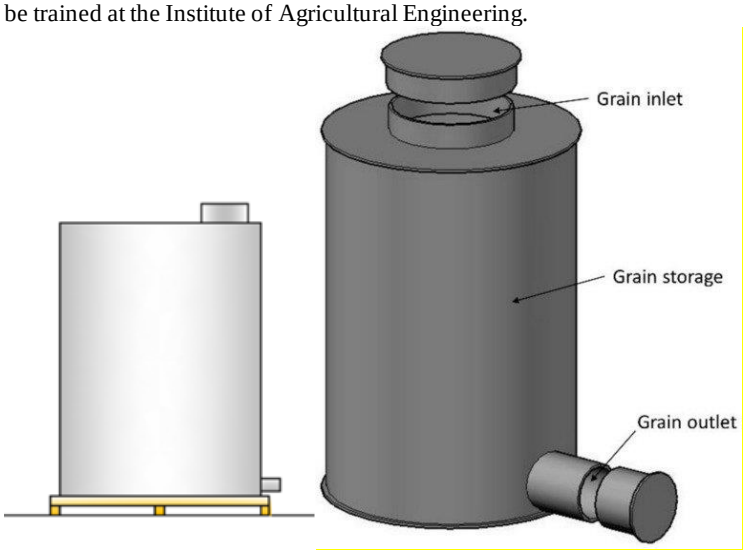
A metal silo is a cylindrical bulk grain storage structure, constructed from standard galvanized iron sheets and is hermetic (airtight) thus it kills any insect pests that may be present in the stored grain. The capacities of metal silos currently being made in Zimbabwe range from less than 0.5 to 6tonnes.

The metal silo must always be placed indoors or under a secure shed to prevent from sun and rain. It should be placed on a wooden platform (pallet) 15 to 20cm above ground level/ floor.

A metal silo has a loading inlet at the top and an offloading outlet at the bottom. It is made airtight by tying a rubber band at both openings after closing with lids: no air goes in or out. The rubber band is a strip of old tube from either a bicycle tyre tube of motor vehicle tyre tube.

If properly constructed to the standard specifications with good workmanship, a metal silo can last up to 25 years or more if properly handled. The metal silo is delivered/ supplied with a matching wooden platform and the strips of rubber bands.

In order to standardise the specifications and quality of metal silos, tinsmiths must be trained by experienced and specialised technical staff. In Zimbabwe it is recommended that tinsmiths be trained at the Institute of Agricultural Engineering.



Specifications

- Should be protected from rain and direct sun
- Should be designed to have a height of no more than 1.8m for easy loading
- Should be soldered at the seams
- Should be secured with rubber bands at the lids to create a micro environment
- Must be placed on a flat wooden platform
- Small size silos up to 1.5 ton are made from 0.5mm thick sheets and 2ton and above are made of 0.8mm thick sheets


Shed construction

Silo Maintenance And Use

- Should be placed on a wooden pallet to avoid contact with the ground
- Should be placed under a shade / indoors to protect from sun and rain
- Silo should not be in contact with the walls
- All seams and soldered joints should be painted with silver paint
- It should be kept sitting flat on the pallet
- When the grain level is low it should be scooped out, do not tilt the silo
- When loading do not lean on the silo. Use a bucket to load the silo
- Do not store or place things on top of the silo
- Once loaded tie the outlet with rubber band light the candle and place on top of the grain to deplete the oxygen in the silo, close and tie the inlet with a rubber band.
- Inspect the grain at regular intervals to check for insect damage.
- When the silo is completely empty it should be cleaned inside and outside, a person can crawl inside and wipe the inside with a dry cloth and remove all the dirt
- The area immediately surrounding the silo must be clean
- Any rust that might appear over the years should be cleaned off with sand paper and painted with anticorrosive silver paint
- In case of silo damage a trained artisan must be called in to repair the silo.

Practices to minimise post harvest losses

Post-production stage	**Recommended action**
Appropriateness of varieties	❖ Grow varieties that are less susceptible to insect/ bird attack; or spoilage by rainfall.
Harvesting	❖ Harvesting crop at physiological maturity to prevent in-field losses. ❖ Use appropriate harvesting methods to avoid scattering and mechanical damage. ❖ Do not leave the crop in the field or stacked any longer than necessary.
Transport	❖ Use recommended transport system to ferry crop to the homestead.
Drying	❖ Dry the crop on a prepared surface or in a well

	ventilated drying structure. ❖ This is done to avoid moisture uptake, crop contamination with dirt, protect crop against pests and adverse weather. ❖ Remove the cobs from the cribs when adequately dry.
Threshing/ Shelling	❖ Thresh the grain promptly when it reaches the appropriate moisture levels to avoid mechanical damage
Cleaning	❖ Clean the grain immediately after threshing. ❖ Remove extraneous matter, insect infested or damaged grain.
Treating	❖ Treat the grain with suitable chemical/ substance using recommended application rates. ❖ Use a recommended chemical that has not expired. ❖ Follow instructions on the chemical label carefully and take safety precautions. ❖ All threshed grain must be treated to avoid cross-infestation.
Storage	❖ Clean the storage structure and ensure it is dry before treating and loading the grain. ❖ The store must keep the grain dry, cool and protected from all grain pests. ❖ An improved storage structure with recommended design features will keep grain safely. ❖ Maintain the storage structure regularly.
Storage management	❖ Keep the area around the homestead clean. ❖ Repair and clean the storage structure before the new crop is harvested. ❖ Do not store old grain and new grain together in the same storage structure. ❖ Inspect the grain in the store regularly to check for the need to repair the store, re-treat grain or clean the store. ❖ An improved storage structure with design features will keep grain safely. Inspect and maintain the storage structure regularly by repairing damages to the store.

Storage pests

Divided into two classes the primary pests and the secondary pests.

- Primary pests feed on whole, undamaged, healthy grain
- Weevils, grain borers, Angoumois grain moth
- Secondary pests can only attack broken grain, grain damaged by primary pests or processed products(flour)
- Flour beetles

Management of storage pests

Cultural

- Early Harvesting, Drying, Careful Shelling To Avoid Grain Damage, Hygiene In Storage

Host Plant Resistance

- Tolerant Varieties

Chemical

- Grain Protectants, Fumigants

Horticulture

Products divided into semi perishable and highly perishable, with some generally requiring cold chain handling.

Characteristics of horticultural crops

- High moisture content of between 70 – 95%
- Large unit size
- High to very high respiration rate
  Heat production is high
- Soft texture and can be easily bruised
- Perishable hence natural shelf life is usually a few days to some months
- Losses usually caused by rotting (bacteria and fungi)
- Losses are higher compared to cereals

Factors related to Post Harvest Losses in Horticulture

- Maturity at time of harvest
- Storage arrangements both on and off farm structures
- Market channels
- Handling
- Temperature and Humidity
- Pests

Handling

Soft texture means that the products can be bruised easily hence require to be handled gently to avoid breaking and bruising. Bruised product becomes unsaleable to most people though in terms of nutritional status there seem to be no effect.

Careful handling and digging of tubers reduce post-harvest loses. There is also need to minimise number of times a commodity is handled to reduce mechanical damage

Temperature and Humidity

Cooling horticultural products reduces rate of physiological change thereby increasing storage life. Growth of fungi and bacteria is also reduced.

Cooling is the foundation of quality preservation.

High humidity retards wilting and maintains the product in good shape. Most horticultural products thrives well in an environment of humidity as high as 90%

Pests

Major causes of losses after harvesting are some fungi and bacteria pathogens. Rodents and viruses are of lesser significance after harvesting. Fungi and bacteria cause loss in both quality and quantity.

They also cause decline in shelf life, contamination of product by mycotoxins and also accelerated ripening.

Maturity
Maturity at time of harvesting is an important factor in keeping quality of products. Products that are harvested in an immature state tend to shrivel during storage and prone to storage disorders.
If the product is picked too mature the skin tends to be fibrous and breaks too easily.

Transport Losses
Transport losses usually are caused by;

- Use of unsuitable containers
- Overloading of mixed fruits and vegetables. Sometimes people even ride on top of the consignment
- Irresponsible driving
- Lack of feeder roads leading to highways or collection centres
- Rough roads
- Heat accumulation or lack of ventilation within transport vehicles
- Virtual absence of refrigerated trucks

Storage
Storage of fruits and vegetables prolongs their usefulness; checks market gluts, provides wider selection and may also increase financial gain to the producer
Adequate storage reduces subsequent losses but not pre-storage losses.
Adequate storage involves proper regulation of temperature, humidity, air circulation, proper stacking pattern, regular inspection and prompt produce disposal.
Feasibility of the construction of cold storage facilities and interest among farmers to use the cold stores depend upon economics parameters.

N.B: Some specific information is found under each crop in the production section of this manual or can be obtained from the horticulture section of Agritex department or the post-harvest section of the department of agricultural mechanisation.

Irrigation

Definition: is the artificial application of water to the soil to meet crop water requirements.

Irrigation Types

- Gardens, generally less than 0.1ha in area.
- Individual Schemes.
- Communal/ shared infrastructure schemes.

Irrigation Methods and Systems

Irrigation methods	System
Surface irrigation	• Furrow irrigation • Border irrigation • Basin irrigation
Overhead irrigation	• Sprinkler (conventional, rain gun, drag hose, micro sprinklers) • Centre pivot & linier moves • Side rolls
Localized irrigation	• Conventional drip irrigation • Drip kits
Manual irrigation	• Bucket system • Drip kits/drum kit • Hose system.

Centre pivot irroigation

Furrow irrigation

Drip irrigatiopn

Sprinkler irrigation

Choice of irrigation system

- Select a system of irrigation that suits particular circumstances of the farm were irrigation is to be practiced. Each irrigation system has advantages and limitations and will suitable better in some cases than in others.

System choice depends on;

- Slope of the land,
- Texture of the soils and their ability to absorb and hold water,
- Availability and quality of water,
- Crops to be grown,
- Aptitude of the farmer and his available capital, labour and management capacity,
- Size and shape of land to be irrigated,
- Available power or energy source.

Steps in Irrigation Development

1. Assess availability, quantity and quality of water resources. As a general rule in Zimbabwe the amount of water required per hectare per year is: for surface irrigation systems,18 000 m^3, for sprinkler 12 000 m^3 and for localized systems 8 000 m^3,
2. Conduct socio economic surveys and analysis to assess practicality and economic viability of proposed project,
3. Conduct soil surveys: depth and quality of soil to determine irritability and choice of irrigation system type,
4. Conduct Environmental Impact Assessments (EIAs) covering issues like drainage, pollution, health and diseases,
5. Conduct topographical surveys; determine irrigation type and general design parameters,
6. Prepare designs including field layouts, water delivery infrastructure structures, cropping programmes, crop water requirements, irrigation cycles and drainage patterns),
7. Construction,
8. Testing and commissioning.

Points to Note

- Commercial farmers can approach irrigation firms for designs, bill of quantities and quotation,
- Small Scale farmers are usually assisted by the Department of Irrigation for designs. Funding is by government and donors,
- For long- term sustainability in communally shared infrastructure schemes, the process of irrigation planning, designing and development is done by an irrigation expert with farmer participation.

Irrigation System Components

Water sources

Include dams, rivers, boreholes, springs and wells. Water use for irrigation is governed by the Zimbabwe Water Act whose salient features for irrigation include:-

- ownership of all water surface and or ground is vested in the state;
- Except for primary purposes, any exploitation of water resources requires specific authority from the state given for a given specific economic period;
- development of water resources should be implemented on an environmentally sustainable basis;

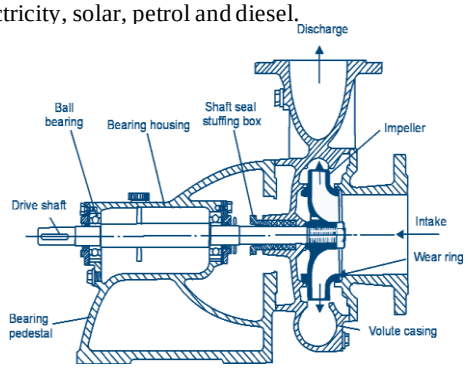
- water is priced based on the user pays and polluter pays principle and differs according to the different interest groups in the water sector;

Pumping units

- Most common types are; centrifugal pumps, submersible pumps, manual operated pumps e.g. treadle pumps, bush pumps, rope and washer.
- Preventive maintenance of the pumping system is essential during the irrigation season. The following checks and inspections are recommended for most engine or electric motor driven pumps; Noise, Vibration, Leakage, Temperatures of bearings and windings, fuel / power consumption, Capacity and output (water discharge and dynamic head), Ventilation screens, clean where necessary, Oil pressure, Oil, lubrication, change oil where necessary
- The long-term operation of the irrigation installation depends upon simple maintenance carried out by the farmer. The periodic servicing of pumping plants and the repair of special devices (filters, injector, etc.) should be carried out by trained maintenance and repair personnel.

Centrifugal Pumps

- Pump water from surface water sources. Most common power sources for these pumps are electricity, solar, petrol and diesel.



Cross-section of a centrifugal pump (Source: Miller, 1991 in FAO, 2001)

Basic data

- Maximum suction Head;
  - Below 1000m above sea level (asl): 3.5- 4.0 m
  - Above 1000m (asl): 3.0- 3.5 m
- Inlet of suction pipe should be 500mm below the water surface, or four times the diameter of the pipe whichever is the greater.
- A non return valve must be fitted at pump outlet.

Submersible pumps (diffuser/turbine pumps)

- Usually installed to lift water from deep wells, pools, dams, and boreholes. Pump may be driven by an electric motor, a solar powered motor, wind driven or a diesel engine on the surface with a long vertical shaft or by a submerged electric motor inside a waterproof casing.

Treadle pumps

- Pump water manually from surface water bodies, usually up to depth of six meters

Pump Selection

- Select a pump with an efficiency rating of not less than 60% using the manufacturer's performance curves.
- In the case of small pumps with a capacity of less than 8 l/s a lower efficiency figure may be accepted.

Energy sources

Most common sources for irrigation are:-

- Electricity (electric motors used as prime movers).
- Diesel/ petrol (engines used as prime movers).
- Gravity (usually no pumping is required when used).
- Manual power (used on manual pumps such as treadle pumps).
- Renewable energy sources like solar and wind.

Diesel powered pump

Power requirement

- For engineers to establish the power requirements of your pumping units they need to know the total discharge or flow of water and the total pressure required to move the water.

Pump malfunctions, causes and remedies (troubleshooting)

Symptoms	Causes	Corrections
Failure to pump	1. Pump not properly primed 2. Speed too low or high 3. Not enough head to open check valve/non return valve 4. Air leak 5. Plugged section 6. Excessive suction lift 7. Excessive suction lift	1. Prime pump correctly 2. Check speed, check calculations, consult with manufacturer 3. Check speed, check calculations, consult with manufacturer 4. Check and rework suction line 5. Unplug section 6. Check NPSH and consult manufacturer 7. Check NPSH and consult manufacturer
Rapid wear of coupling cushion	1. Misalignment 2. Bent shaft	1. Align 2. Replace
Reduced performance	1. Air pockets or small air in 2. suction line 3. Obstructed suction line or impeller 4. Insufficiently submerged suction pipe 5. Excessively worn impeller or wear ring 6. Excessive suction lift 7. Wrong rotation direction	1. Locate and correct 2. Remove obstruction 3. Extend suction line to deeper water to the extent that NPSH allows you or excavate and deepen the area where the suction basket is located 4. Replace impeller and/or wear ring 5. Calculate NPSH, consult with manufacturer 6. Ask contractor to rectify
Driver overloaded	1. Speed higher than planned 2. Water too muddy 3. Too large an impeller diameter 4. Low voltage 5. Stress in pipe connection to pump 6. Packing too tight	1. Reduce speed 2. Raise suction 3. Trim impeller 4. Consult power authority 5. Support piping properly 6. Loosen packing gland nuts

Symptoms	Causes	Corrections
Excessive noise	1. 21. Misalignment 2. 22. Excessive suction lift 3. 23. Clogged impeller 4. 24. Worn bearings 5. 25. Impeller screw loose 6. 26. Cavitation 7. 27. Wrong rotation direction	1. Align all rotating parts 2. Check NPSH, consult with manufacturer 3. Dislodge obstruction 4. Replace bearings 5. Replace 6. Check NPSH, correct suction piping 7. Ask contractor to rectify
Premature bearings failure	1. Worn wear ring 2. Misalignment 3. Suction or discharge pipe not properly supported	1. Replace 2. Align all rotating parts 3. Correct support 4. Replace shaft

	4. Bent shaft	
Electric Motor Failure	1. High or low voltage 2. High electric surge 3. Poor electric connection 4. Overloads 5. Bearing failure 6. Cooling vent plugged 7. Moisture or water in motor	1. Check voltage and consult power authority 2. Monitor voltage and consult power authority 3. Turn power off, clean and check connections 4. Amperage, should not exceed full load 5. Change motor bearing 6. 37. Install proper screen 7. 38. Send for blow-dry and protect from environment

Source: *FAO, 2001*

Sprinkler irrigation water delivery and application equipment

- Equipment required includes main pipe lines, secondary pipe lines hydrants, laterals, risers and sprinklers.

Sprinkler operating pressures and application rates

- Pressure is measured in kilopascals, 100 kilopascals= 1bar= 10m head
- Recommended precipitation rates:
  - 6mm/h for heavy textured soils or fine grained soils.
  - 8mm/h for medium textured or medium grained soils.
  - 10mm/h for light textured or course grained soils.

Guide to nozzle pressures

Nozzle size (mm)	Pressure (kPa)	Pressure (metres)
3.0 – 5.0	250 - 350	25 – 35
5.0 – 6.5	300 - 400	30 – 40
6.5 – 9.5	350 - 500	35 -50

Open flow / surface systems water delivery and application equipment

- Infrastructure required include water delivery canals diversion structures (weirs, diversion boxes, stilling boxes,) field canals, siphons, check plates, furrows, basins, beds and border strips.

Surface irrigation layouts

Parameter	Border strips	Corrugations	Contour flooding	Ridge and furrow
Dimensions	Width: 3-20m Length: 50-200m Border ridges 500-700 mm wide 250mm high	Furrows±150mm wide x 100mm deep. Centre 0.4-1m depending on soil and crop Length run=50-150m	Furrows±450mm wide x ±150mm deep Width between furrows 10-15m	Ridges 50-150mm deep Maximum length run Light soils 100m Heavy soils 200m
Gradients	Light soils 1:100-200 Heavy 1: 300-600 Cross slope: level between border ridges	Maximum 1:50 Minimum 1:250	Furrow gradients of ± 1: 200- 1:300	Light soils 1:100-300 Heavy1:300-600

Stream flow	Varies according to width and gradient. Approx 7 litres/s for 1m width/ 100m length	Initial run: 1-2l/s then cut back to 0.5 l/s or less	7-30 litres /s	±7 litres/s. Alternate rows during rains
Advantages	Row and broadcast Large stream with minimum labour. Best on flat land with low permeability	Row and broadcast crops. Slopes up to 2%. Depth of irrigation easily controlled	Slope in excess	Summer supplementary row crops. Wide variety of slopes. Little skill required. Layout easily changed
Limitation	14 litres/ s flow minimum	Minimum slope 1:250. Furrows±150mm Require skilled labour. Levelling will be necessary	Inefficient	1-labourer ±3 streams. Large labour force. Unsuitable for broadcast
General	Easily adaptable to peasant farming and ox drawn machinery	50mm siphon tubes start and then 25mm tubes for trickle over full length of run. $L = \frac{l/s \times 3\,600}{\text{Spacing (m)} \times \text{length}}$	Furrow dammed with plastic bags	Land levelling need not to be as accurate as for corrugations

Micro Irrigation systemswater delivery and application equipment

- Include pressurized drip systems and Drip kits: Water delivery and application equipment required includes drum/tank for drip kits, filtration system, fertigation system (optional), water delivery pipes, lateral pipes and emitters.

Manual irrigation water delivery and application equipment

- Bucket system. Required equipment: bucket),
- Drip kit. Required equipment: drum/ tank, buckets or manual pump e.g. treadle pump, filter, laterals emitters, fittings,
- Hose pipe system. Required equipment: manual pump and raised tank, hose pipe and fittings.

Note: Manual systems can be effectively used to irrigate up to 0.25 hectares.

Other irrigation related facilities.

- Depending on circumstances on the ground the following may be required: night storage reservoirs, booster pumping systems, roads, toilets, fencing, sheds, storage facilities, cold rooms, soil conservation and drainage structures.

Drainage

- Crop yields can be reduced (drastically sometimes) due to water logging and salinization of irrigated land,

- Water logging may also cause human health problems, particularly malaria, because of ponded water,
- Two important causes of water logging and salinization are: (a) excessive application of irrigation water; and (b) lack of adequate drainage.

Irrigation Management

- Proper management of irrigation infrastructure, water, labour, and crop production is important for sustainability of the system,
- For communal or shared infrastructure schemes to achieve effective irrigation management, an irrigation management committee should be in place with a constitution and bylaws agreed to by all members and endorsed by the local authority.

Typical information to be contained in a communal scheme constitution

- Name of Scheme;
- Address of scheme / location of scheme;
- Membership: number of farmers, inheritance and termination procedures;
- Committee term of office, choice and roles office bearers, type of committees;
- Meetings: Who should attend, frequency and types;
- Scheme funds -sources , security, uses, signatories, subscriptions;
- Cropping programmes and marketing;
- Operating time (days, hours, times);
- Security and maintenance, auditing of assets;
- Disciplinary issues (theft, misuse of funds, warnings, penalties);
- Dissolution of group (distribution of assets);
- Amendments of constitution and by-laws;
- List of members (by names).

Care and Maintenance

- Operation, care and maintenance is according to manufacturer's guidelines.

Some irrigation system components and issues that need attention

Component	Maintenance and care
Laterals.	Aluminium pipes should not be dragged along the ground to avoid damage, and soil entering the pipes. Always carry pipes horizontally, never up-end them, there could be overhead power cables around.
Buried pipelines.	Regular Inspections should be carried out for leaking sections, flattened or bend sections and exposed sections which are vulnerable to fires, traffic, weather elements and vandals.
Rubber seals, rings and hooks	• Sealing rings are made of rubber and should be inspected each season for any damages. Damage is evident from leakages. These rings have a lifespan of about two years and need to be replaced accordingly. • At end of season, remove rubber from coupler, brush in clean water, dry and store in a box away from light in a cool place. • When replacing seals, make sure that the ring seats evenly around the inside of the coupler and that no debris is trapped.

Drag hose, hose and riser assembly.	Care should also be taken to ensure that these components are not damaged during field cultural practices like tillage operations. At times perforations or cuts occur during these operations, regular inspections should be done to detect these. Another item that requires replacement is the rubber flap of the riser assembly which, depending on quality, can last about five years. The same holds true for the garden tap rubber or leather seal.

Component	**Maintenance and care**
Laterals	• Portable pipes are usually damaged through rough handling. They are very expensive and hence should be treated with care. • Move them with care. Do not throw them. • Do not walk or drive over them. Use pipe bridges to cross the pipeline, • If stored in open (aluminium pipes), make one end slightly higher to drain off water • Repair small dents before they get big. • At end of season store under cover if possible, above ground on wood or steel racks, where they are fully supported to avoid permanent sagging which results in leakages during irrigation especially in poly pipes(HDPE). • PVC pipes should be stored in a shed where they are protected from direct sunlight. • Sunlight damages the pipes and significantly reduces their lifespan, • If there is needed, poly pipes used as main line (not laterals), should be rolled up carefully to avoid damaging the pipes.
Sprinklers.	• The following ensures proper functioning of sprinkler irrigation system: • correct operating pressure and correct sprinkler layout(correct lateral and sprinkler spacing), • keeping sprinkler risers up-right, • nozzles should be replaced at least every two years (four seasons).Worn out nozzles should be replaced in order to maintain the correct flow and distribution of water from the sprinklers, • The tension of the sprinkler spring and the wear of some of the plastic seals also require attention as this may cause sprinkler malfunction, • Sprinklers should be taken to the supplier for an overall check-up every four to 5 years, • Regular inspections of sprinkler heads helps to identify malfunctioning sprinkler heads.
Hydrants.	• Rubber seals should be regularly inspected for leakages; worn out rubber seals should be replaced.

Gate/Isolation valves.	• Always open and close valve slowly to avoid damage of the pipe system and pumps from water hammer. • At end of season, check valve stems and seating pads for pitting or damage, replace where necessary • Do not seal valve tightly when not in use to avoid rubber sticking to the seat. Open them to have a small gap that won't allow rodents to enter. • Isolation valves, when unused for long periods, get stuck to the opening position and cannot be closed any more for the purpose of isolating for example areas where a pipe burst would have occurred. It is therefore necessary that once a month all isolation valves are checked by opening and closing. They should also be regularly lubricated.
Canals, night storage dams etc.	• Require regular inspections and maintenance in order to identify and remedy leakages and seepages, silting, vegetation growth etc.
Pumping units.	• The following needs attention, gland packing, oil, bearings, shafts and alignment. Pump motor should also not be exposed to water splashes. The pump house should also be well ventilated and adequate drainage should be in place to ensure no ponding in the pump house. Leaking pump joints or seals should be attended.

Component	**Maintenance and care**
Electrical wires/Cables	Regular inspections are required to identify naked or exposed wires, loose connections sagging wires, tree interference with cables or LT lines, etc.
Suction system	Attention should be given and maintenance should be carried out on foot valves, suction baskets, silt in suction chambers/ sump, etc). Trash screens should be clean and properly placed. Regularly inspect foot or check valves to ensure that they are operating properly. Suction pipe inlet should also be inspected regularly to ensure that it is submerged adequately to prevent entrance of air into the pipeline and eddying.
Filters	They can easily be blocked , so clean/ back flash them regularly or according to manufacturer recommendations

Effects of poor operation, care and maintenance

- Proper operation, care and maintenance of equipment ensures that equipment lasts and unexpected breakdowns usually during critical crop growth stages are minimized or avoided;
- Leaks can result in water logging in some places in the field; crops in such areas are usually over irrigated resulting in nutrients and fertilizers being leached. This leads to yield reduction;
- Leakages and blockages (due to e.g. silt and vegetation) can result in poor system performance such as reduction in the delivered water which implies reduced amounts of water reaching the crops hence crops can suffer from moisture stress which results in reduced yields;
- Vegetation, water logging and marshy conditions encourage the proliferation of disease causing organisms such as mosquitoes and snails. Hence out breaks of diseases such as malaria and bilhazia may occur;

- System breakdowns usually at critical crop growth stages are likely to happen due to lack of maintenance. The breakdowns are usually expensive and time consuming to repair. Total crop failure may occur as a result of this.

Irrigation Scheduling

Practical methods of determining when to irrigate

By 'feel'

- Suitable for small to medium scale farmers
- Equipment: Auger Method: Extract soil samples at each 300mm depth of root zone.

Guide for determining when to irrigate by 'feel' of soil

Available moisture	**Feel and appearance of the following soils**			**Action required**
	Sand, loamy sand and sand loam (light)	Very fine sand loam and sand clay loam (medium)	Clay loam and clays (heavy)	
0%	Dry, loose, flows through fingers	Powdery, sometimes slightly crusted, but easily broken into powdery condition.	Hard baked cracked, difficulty to break down into powdery condition.	Irrigate now. Soil to dry and should have been irrigated a few days ago.
50% or less	Appears to be dry, will not form a ball with pressure	Rather crumby, but will hold together with pressure.	Somewhat pliable, will ball under pressure.	Irrigate. Before the field is covered some spots will be too dry.
50-75%	Tends to ball under pressure but seldom will hold together when bounced in the hand.	Forms a ball, somewhat plastic, will stick slightly with pressure.	Forms a ball, will ribbon out between thumb and forefinger, has slick feeling.	Irrigate today or tomorrow. Otherwise last areas for irrigation will be too dry.
75-100%	Forms a weak ball, breaks easily when bounced in the hand, will not stick	Forms ball, very pliable, sticks readily.	Easily ribbons out between thumb and forefinger, has a slick feeling.	Soil moisture ok. Check again in 2 or 3 days.
100%	Upon squeezing no free water appears on the soil but wet line of ball appear on hand. Soil will stick to thumb when rolled between thumb and forefinger.			Soil very wet. Check again in 5 or 6 days.

Scheduling by means of evaporation pans

- Suitable for medium to large scale farmers.
- Fill pan to 50mm from rim and refill when approximately 50mm has evaporated.

Read daily;
Data required

- Moisture extraction depth (D) Moisture extraction table below
- Available moisture percentage (S) Available moisture table below
- Correlation factor (G) Correlation factor table below
- Evaporation Rate (pan not in situ) (R) Evaporation rate table below

Calculate as follows:

- Moisture requirement (at 50 percent depletion) = D x S/2
- Daily consumptive use by crop = R x G
- Frequency of application = 0.5D / RG
- Moisture requirement allowing for inefficiency = 0.5DSx1/e
- Reasonable efficiencies (e): for surface irrigation 0.60-0.70. For sprinkler irrigation 0.75-0.85.

Moisture extraction depths (D)

Crop	Moisture extraction depths (mm)
Vegetables	300
Potatoes	500-600
Maize	600-800
Field beans	600
Sorghum	600-800
Wheat	600-900
Soya beans	600-800
Fruit trees	800
Tobacco	900
Cotton	900
Groundnuts	900
Lucerne	1200

Available moisture (S)

Textural Class	Available moisture as percentage	Available moisture (mm^3 / mm)
Coarse sand	4-7	0.04-0.07
Fine sand	6-10	0.06-0.10
Fine loamy sand	10-13	0.10-0.13
Coarse sandy loam	12-15	0.12-0.15

Sandy Clay Loam		
Clay loam	10-22	0.10-0.22
Silty clay loam		
Clay loam	12-17.5	0.13-0.175
Sandy Clay		
Clay		
Heavy black clay	17-23.5	0.17-0.235

Pan Correlation factors at different growth stages (G)

Crop growth Stage	Pan correlation factor (Et/Eo ratios)
Emergency to early growth	0.3-0.5)
Vegetative growth	0.5-1.0
Flowering	1.0-0.8
Wet fruit	0.8-0.6
Dry fruit	0.6-0.0

Evaporation Data (Mm) Mean Daily Figures (Screened Class 'A' Pans) (R) +/- 10 years

Place	Jul	Ag	Sep	Oct	No	De	Jan	Feb	Mar	Apr	Ma	Jun
Beitbridge	3.7	4.8	6.9	8.3	7.7	7.9	8.6	7.3	6.8	5.4	4.1	3.3
Buffalo Range	3.3	4.4	6.4	7.6	7.5	6.9	6.6	5.7	5.4	4.5	3.6	3.3
Bulawayo	3.9	5.2	7.0	8.0	6.3	5.9	6.0	5.4	5.4	4.8	4.1	3.6
Chipinge	3.0	4.0	5.8	6.5	6.0	5.3	5.2	4.7	4.4	3.8	3.3	2.9
Chirundu	4.4	5.9	8.1	9.6	7.4	5.3	5.0	4.7	5.0	4.6	4.0	3.7
Chisumbanje	3.7	4.9	7.2	8.3	8.0	7.1	6.5	5.9	5.4	5.1	4.0	3.5
Dutchman's Pool	3.5	4.8	6.3	7.3	6.1	5.8	5.7	5.4	5.6	5.0	3.9	3.4
Kadoma	4.5	5.9	8.0	9.2	6.7	6.0	5.7	4.9	5.3	5.1	4.5	4.1
Gokwe	4.5	5.8	7.8	8.8	6.5	5.7	5.2	4.9	5.5	5.3	4.8	4.2
Grand Reef	3.8	5.1	7.6	8.6	7.3	6.1	5.7	5.1	5.2	4.7	3.8	3.2
Henderson	3.8	5.0	6.7	8.0	6.3	5.4	5.0	4.7	4.9	4.5	3.8	3.5
Nyanga	2.9	4.0	5.5	6.3	4.8	3.9	3.8	3.6	3.8	3.4	3.0	2.7
Karoi	4.1	5.2	7.4	8.4	6.3	4.8	4.2	4.2	4.3	4.3	3.9	3.6
Kutsaga	4.3	5.5	7.4	8.7	6.5	5.6	5.5	5.1	5.5	5.0	4.3	3.8
Lupane	3.6	4.7	6.8	7.7	6.2	5.5	5.4	5.1	5.1	4.8	4.0	3.3
Makoholi	3.7	4.8	6.8	8.3	6.8	6.2	5.9	5.5	4.8	4.5	4.0	3.4
Marondera	3.5	4.6	6.4	7.3	5.6	5.1	4.9	4.9	4.8	4.3	3.8	3.4
Matopos	3.8	4.9	6.9	8.0	6.7	6.1	5.8	5.3	5.2	4.7	3.9	3.4
Mt Darwin	3.9	5.1	6.8	8.3	7.1	5.7	5.0	4.2	4.3	4.1	3.7	3.4
Nyamandlovu	4.6	6.0	8.1	8.6	7.4	6.4	5.8	5.4	5.6	5.2	4.6	4.2
Nyanyadzi	3.8	4.9	6.9	8.2	7.3	6.8	6.4	6.1	6.3	5.3	4.3	3.5
Sabi Valley	3.5	4.6	6.6	7.8	7.5	6.8	6.5	5.8	5.4	5.1	3.9	3.2
Gwanda	3.6	4.8	6.7	8.0	7.0	6.8	6.6	5.8	5.6	4.7	4.0	3.3

Approximate Irrigation Intervals Based On Prevailing Weather Conditions.

Crop	Early Stage (days)		Vegetative		Mid to Late	
	Cool Dry	Hot Dry	Cool Dry	Hot Dry	Cool Dry	Hot Dry
Pepper	3	2-3	4-5	3-4	3-4	3
Cabbage	4-5	4-5	7-8	5	7	4

Onion	3	2-3	4-5	3-4	3-4	3
Rape	4-5	3-4	6-7	4-5	3-4	3
Tomato	4-5	4-5	6-7	5	7	4
Carrot	3	2-3	4-5	3-4	7	5-7
Butternut	3	2-3	4-5	3-4	3-4	3
Irish Potato	3	2-3	4-5	3-4	3-4	3
Green Maize		5-7		5-7		4-6
Peas	4-5	4-5	7-8	5	7	4

Note: To estimate the actual depth of irrigation, hence irrigation set time, more information is required on soil data, crop data and rainfall. With experience, farmers can estimate the set time at each stage.

Critical Moisture Growth Stages of Common Irrigation Crops

CROP	**CRITICAL PERIOD**
Sugar Beans	Flowering and pod filling
Cucumber	Flowering and fruit development
Cabbage	Head enlargement and ripening
Onion	Rapid bulb expansion
Peas	Start of flowering and pod development
Green Beans	Flower set and pod development
Irish Potato	Tuber initiation and ripening
Pepper	Fruit setting
Rape	Vegetative
Tomato	Flowering and Harvest
Maize	Flowering to grain filling
Wheat	Planting and Flowering to grain filling

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