JAPAN INTERNATIONAL COOPERATION AGENCY（JICA）

THE REPUBLIC OF DJIBOUTI

THE MASTER PLAN STUDY
FOR
SUSTAINABLE IRRIGATION AND FARMING
IN SOUTHERN DJIBOUTI

TECHNICAL MANUAL FOR ESTABLISHING IRRIGATED FARMLAND

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1. Introduction

1.1 Objectives of the manual

In Djibouti, irrigation is absolutely necessary for crop cultivation because annual rainfall is approximately 100mm. So far irrigation system has been established individually on a small scale at each farmland in Djibouti. In order to enhance the development of irrigated agriculture officially, appropriate irrigation system must be established to ensure sustainable irrigation and farming at each project site.

This manual defines general and basic technical contents relating to investigation, planning, implementation and operation & maintenance in establishing the irrigation system in Djibouti. In this sense, this manual is expected to be fully utilized as technical guideline by the engineers of Djibouti government and the donors who have charge of irrigation development project.

1.2 Flow of establishing the irrigated farmland

For the establishment of the irrigated farmland, one needs a set of process which consists of selection of the targeted area, site investigation, irrigation planning, design of the facilities, construction implementation and operation and maintenance of the facilities. The flow of the process is described as **Figure 1.2.1**.

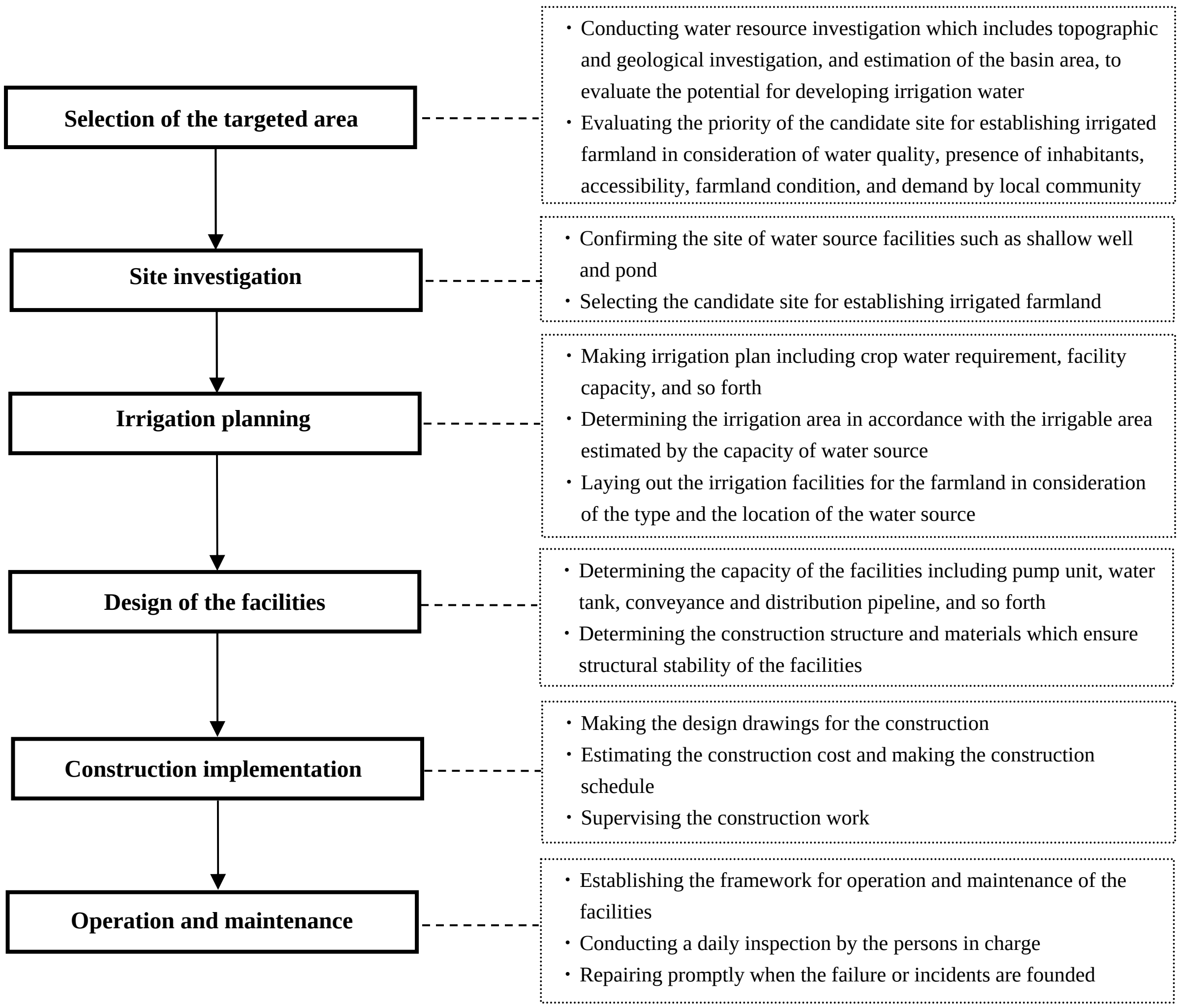


Figure1.2.1 Flow of establishing the irrigated farmland

2. Investigation

2.1 Investigation of water source

(1) Target water resource

Available water resources of Djibouti are classified into several categories such as surface flow water, shallow groundwater, underflow water, intermediate groundwater, and deep groundwater as shown in **Figure 2.1.1**. In this manual, three types of water resources 1) underflow water, 2) shallow groundwater, and 3) surface flow water is defined as the target water resources for irrigated agriculture. The general outline of such water resources is briefed in **Table 2.1.1.**

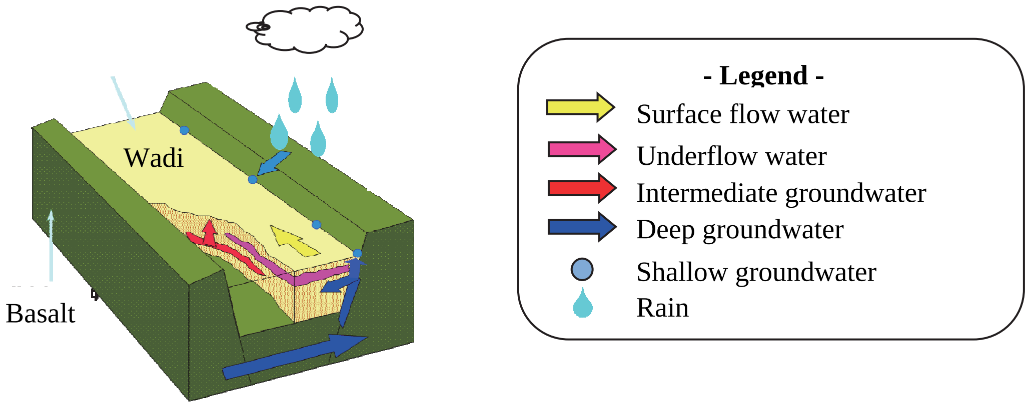


Figure 2.1.1 Conceptual diagram of water resources in Djibouti

Table 2.1.1 General outline of the target water resources for irrigated agriculture

Water source/ Facility	Photo	General outline
Underflow water/ Shallow well		· Underflow water exists under the wadi or the terrace along the wadi · High salinity concentration is reported near the sea and lake which are located at end of the wadi stream.
Shallow groundwater/ Shallow well		· Shallow groundwater is defined as the water extracted from the crack of the rock foundation or the fault fracture zone. · It also includes the extracted rainfall through the crack of the rock foundation. · Seasonal fluctuation of water table is relatively small, and water quality is generally good.
Surface flow water/ Pond or subsurface dam		· Runoff water is defined as the water which is stored into the pond or submergible dam during the floods. · As for water quality, it is mostly muddy, but can be utilized as irrigation water.

(2) Investigation methodology

Investigation of water source is divided into two parts, review of the collected information and field survey. As a first step of the review, the available information listed in **Table 2.1.2** should be collected and compiled in order to extract necessary information.

Table 2.1.2 Available information

Available information	Necessary information
Topographic map (Scale:1/200,000)	Geography, type of land-use, stream of the wadi, boundary of the basin, basin area, type and location of existing wells
Google Earth	Geography, type of land-use, location (latitude and longitude) and elevation of the farmland
Geological map	Geological classification
Location map of existing wells	Location of the existing wells
Meteorological and hydrological data	Rainfall, humidity, temperature, sunshine hour, and flood level
Others	Record on past water source development projects, and on planned water source development projects

Next, field survey should be conducted based on the result of the review stated above to evaluate the potential and accessibility of irrigation water sources. Consideration points for field survey are summarized as follows.

① Underflow water / Shallow well

Target water is the underflow water in the wadi and adjacent area. Flash floods sometimes flow down in the wadi. To avoid the damage caused by the floods, the shallow well must be placed at the stream bank or the terrace. In the case that the wadi has s-shaped stream, the point that the flood flow hits is not suitable as the candidate site of the shallow well.

② Shallow groundwater/ Shallow well

Target water is the shallow groundwater which flows out through the crack of rock foundation. Fault fracture zone is one of the critical indicators from the geological aspect. It is noted that the fault stops the water flow of the groundwater, and also fractured zone lets the groundwater out in the direction toward ground surface. In addition, excavation work is relatively easy at the fault facture zone because the rock foundation is generally soft due to rock decay. However, it is not easy to find the fault fracture zone of the rock foundation because it is covered with surface soil and/or sand gravel in most cases. Geological consideration is essential to find the fault fracture zone such as to figure out the lineament from geographical feature and to identify the fault from exposure of the rock. Observing white incrustation on the ground surface is another key point of geological reconnaissance. Spring water which has flown out through the fault fracture zone contains calcium carbonate in some cases. In addition, it is important to take advice from the patriarch who has good experience on this issue.

③ Surface flow water / Pond

As for the pond, not only evaporation from water surface but also underground seepage must be considered in the field survey. If pond foundation is permeable, it is difficult to keep up the impounding water. In this respect, the places that the pond foundation is coarse sand, gravel ground, or cracked rock ground, are not acceptable as the candidate site for the pond.

④ Surface flow water / Subsurface dam

Subsurface dam is another construction method to store surface flow water. The water is designed to be stored into the permeable sand gravel layer under the wadi by shutting off the underwater flow with impermeable materials. For the construction of subsurface dam, the wadi bed will be excavated partially or entirely to replace the sand gravel ground to impermeable materials. Meanwhile, it is recommended to select a site having rock ground at both banks to minimize the seepage from both banks. It is preferable to find a place where the wadi is narrow in width for the dam axis and also has wide flat area at the upstream from the viewpoint of water storage efficiency.

2.2 Selection of the project site

The project candidate sites are nominated based on the investigation result of water source. As a next step, the candidate sites are evaluated in terms of the priority for establishing irrigated farmland in consideration of the following conditions.

① Water quality

As for water quality for irrigation, salinity concentration is essential issue in Djibouti. The level of salinity concentration can be expressed by Electric Conductivity (EC). FAO indicates the water quality criteria on EC in the guideline published as “Water Quality for Agriculture” (FAO Irrigation and Drainage Paper 2). In this guideline, general indicator for irrigation water is shown by EC in **Table 2.2.1**.

Table 2.2.1 Water quality criteria for irrigation（EC）

Electric Conductivity(EC)		Criteria
0.7 ds/m and less	700 μs/cm and less	No restrictions
0.7～3.0 ds/m	700～3,000 μs/cm	Some usage restrictions
3.0 ds/m and more	3,000 μs/cm and more	Strictly restricted

Source: *Water Quality for Agriculture*, Table.1 Guideline for Interpretations of Water Quality for Irrigation (FAO Irrigation and Drainage Paper 29 Rev.1, Reprinted 1989, 1994)

② Presence of inhabitants

The main target group of the irrigated agriculture development is the semi-settled nomad family. Therefore, the available number of nomad families for farming is one of the essential elements to ensure the sustainability of irrigated agriculture. In this respect, the presence of schools is considered as one of the indicators because schools have been established in the villages where a certain number of inhabitants live. Another indicator is the presence of drinking water supply facility provided by a donor. Villages having such drinking water supply facility have a potential of increasing the number of inhabitants in the future.

③ Accessibility

To realize a sustainable farming in the developed irrigated farmland, it is absolutely necessary to get an income by selling agricultural products. In that context, the accessibility to local markets is considered an essential issue. Accessibility can be evaluated from the viewpoints of the distance between the irrigated farmland and the local markets and the road conditions.

④ Farmland conditions

Farmland conditions can be evaluated in terms of farmland area, flatness, and soil conditions. Since one well is expected to irrigate a farmland of one to two ha, a farmland bigger than that is necessary for irrigated agriculture development. A land with steep slope and irregularity has a disadvantage because land levelling is required as the preparation work for farmland development. A land containing big stones has also a disadvantage for farmland development.

⑤ Demand from local community

There are several existing farmlands where the irrigation system is not working due to flood damages. For such farmlands, the demand for rehabilitation is high from the local community. The first priority must be given to the rehabilitation of the damaged irrigation system.

2.3 Finalization of the location of the irrigated farmland

After the selection of the project site, the location of the irrigated farmland will be finalized at the site in consideration of the following points.

The place for the irrigated farmland is recommended;

1) To be an available area from the aspects of land ownership and status of current land use.
2) To have a sufficient elevation, protecting against the inundation during floods
3) To be close to the water source and also not too high in elevation compared with that source in order to minimize energy cost for pump operation.
4) To be flat and large in area, amounting to at least more than one to two ha
5) To be land having less stones and smaller ones in size.

3. Irrigation plan

3.1 Crop water requirement

Evapo-transpiration (ETo) is fundamental element for irrigation plan. ETo value is estimated with FAO Penman-Monteith equation by using meteorological data and location data. **Table 3.1.1** shows ETo value for Djibouti city.

Table 3.1.1 Evapo-transpiration ETo (mm/day)

Item	Unit	Jan	Feb	Mar	Apr	May	Jun	July	Aug	Sep	Oct	Nov	Dec
Temperature(mean)	°C	26	27	28	29	31	34	36	34	33	30	28	26
Temperature(max)	°C	29	29	31	32	34	38	41	39	36	33	31	28
Temperature(min)	°C	23	24	25	26	28	30	31	29	29	27	25	23
Wind speed (mean)	m/s	4.6	4.6	4.1	4.1	4.1	4.6	5.7	5.7	4.6	4.6	4.1	4.1
Relative humidity(mean)	%	69	71	73	74	70	53	43	44	60	65	67	71
Sun shine hours(mean)	hr	7.8	8.6	8.2	9.3	10.0	8.3	7.5	8.5	9.0	9.6	10.0	8.9
ETo	**mm/day**	**5.0**	**5.3**	**5.4**	**5.9**	**6.6**	**8.3**	**10.4**	**10.1**	**7.7**	**6.6**	**5.7**	**4.7**

Place: Djibouti city, Latitude: 11°33'N, Longitude: 43°09'E, Altitude: 13 m

Crop evapo-transpiration (ETcrop) is computed for each crop by multiplying evapo-transpiration (ETo) by crop coefficient (Kc).

$ETcrop = ETo \times Kc$

ETcrop: Crop evapo-transpiration (mm/day)

ETo: Evapo-transpiration (mm/day)

Kc: Crop coefficient (Source: *FAO Irrigation and Drainage Paper No. 56)*

Table 3.1.2 Crop coefficient (Kc) by crop types

Crop type	Kc by crop growing stages		
	Kc initial	Kc middle	Kc end
Vegetable	0.6	1.15	0.8
Fodder	0.4	0.95	0.9
Perennial fodder	0.7	0.65	0.7
Tree crop	0.9	0.9	0.9

Table 3.1.3 Crop evapo-transpiration (ETcrop) by crop types (mm/day)

Crop Type	Jan	Feb	Mar	Apr	May	Jun	July	Aug	Sep	Oct	Nov	Dec
Winter vegetable	5.7	5.2	4.4	-	-	-	-	-	4.6	4.6	5.7	5.4
Summer vegetable	-	-	3.2	3.8	6.4	9.5	11.7	9.5	-	-	-	-
Winter fodder	4.7	4.9	4.9	-	-	-	-	-	3.1	3.3	4.6	4.5
Summer fodder	-	-	2.2	2.6	5.1	7.9	9.8	8.4	-	-	-	-
Perennial fodder	4.5	4.8	4.9	5.3	5.9	7.5	9.4	9.1	6.9	5.9	5.1	4.2
Tree crops	3.5	3.7	3.8	4.1	4.6	5.8	7.3	7.1	5.4	4.6	4.0	3.3

Crop water requirement (CWR) is computed by dividing crop evapo-transpiration (ETcrop) by irrigation efficiency (Ei).

$CWR = ETcrop \div Ei$

CWR: Crop water requirement (mm/day)

ETcrop: Evapo-transpiration (mm/day)

Ei: Irrigation efficiency (mm/day)

Irrigation efficiency (Ei) consists of conveyance efficiency (Ec) and application efficiency (Ea). Conveyance efficiency (Ec) is specified by the condition of irrigation canal; earth lining=70%, concrete lining=80-90%, pipeline=90%. Meanwhile, application efficiency (Ea) is specified by irrigation method; surface irrigation=70%, sprinkler irrigation=80-90%, drip irrigation=95%.

Irrigation efficiency (Ei) of 60 % can be applied for the proposed irrigated farmland in Djibouti.

Irrigation efficiency (Ei)= Conveyance efficiency (Ec) × Application efficiency (Ea)

$=(0.8\sim0.9)\times0.7=0.56\sim0.63 \Rightarrow$ <u>Ei=0.6 (60%)</u>

Conveyance efficiency (Ec): 80～90% (concrete lining), 90% (pipeline)

Application efficiency (Ea): 70% (surface irrigation)

3.2 Irrigation water amount by farming models

The irrigated agriculture of Djibouti is classified into two categories: water source type and farming level.

There are seven farming models as shown in **Table 3.2.1**

Table 3.2.1 Classification of irrigated agriculture in Djibouti

Water source / Facility		Farming level / Farmers 'groups			
		Home-garden farmers' Group	Beginners farmers' Group	Self-sustained Farmers 'Group	Advanced farmers' Group
Groundwater	Shallow well	**SW-H**	**SW-B**	**SW-S**	**SW-A**
Surface water	Pond	**P-H**	**P-B**	**P-S**	-

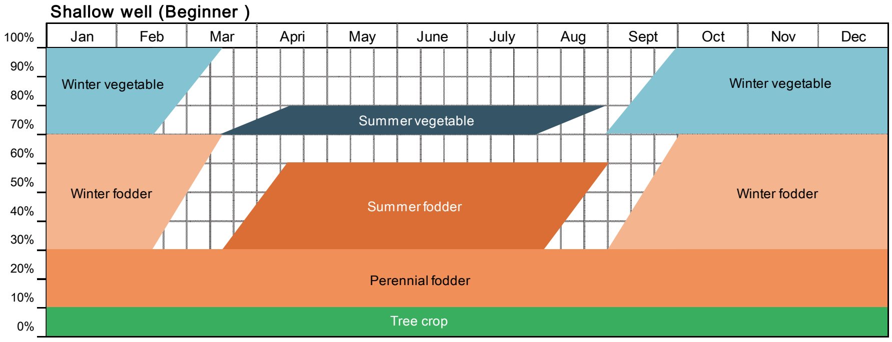
The same cropping pattern can be applied to home-garden farming and beginners farmers' group; therefore, five cropping patterns as shown in **Figure 3.2.1** are proposed for the irrigated agriculture of Djibouti.

Considering an irrigation efficiency of 60 %, irrigation water amount per ha is computed based on the farming models as shown in **Table 3.2.2**.

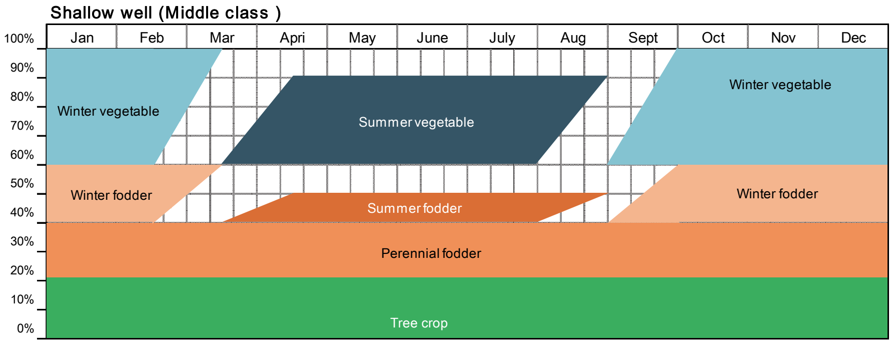
Table 3.2.2 Irrigation water amount based on farming model in Djibouti (m^3/ha)

Farming model	**Irrigation water amount (m^3/ha)**												
	Jan	Feb	Mar	Apr	May	Jun	July	Aug	Sep	Oct	Nov	Dec	**Total**
SW-H SW-B	2,431	2,131	947	1,306	1,914	2,694	3,363	2,279	1,726	2,163	2,492	2,288	**25,733**
SW-S	2,417	2,124	1,144	1,627	2,277	3,151	3,914	2,697	1,951	2,297	2,518	2,277	**28,393**
SW-A	2,465	2,137	1,142	1,627	2,277	3,151	3,914	2,697	1,996	2,363	2,575	2,324	**28,667**
P-H P-B	2,517	2,082	198	0	0	0	0	0	1,033	1,826	2,468	2,369	**12,494**
P-S	2,614	2,107	194	0	0	0	0	0	1,123	1,958	2,582	2,463	**13,041**

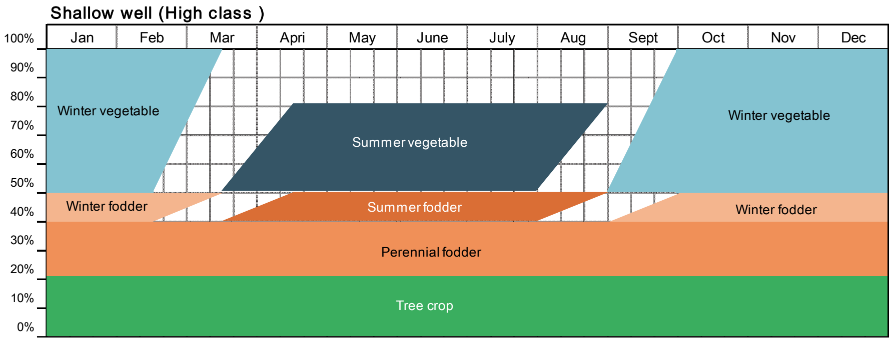
Farming Model (SW-H) (SW-B)



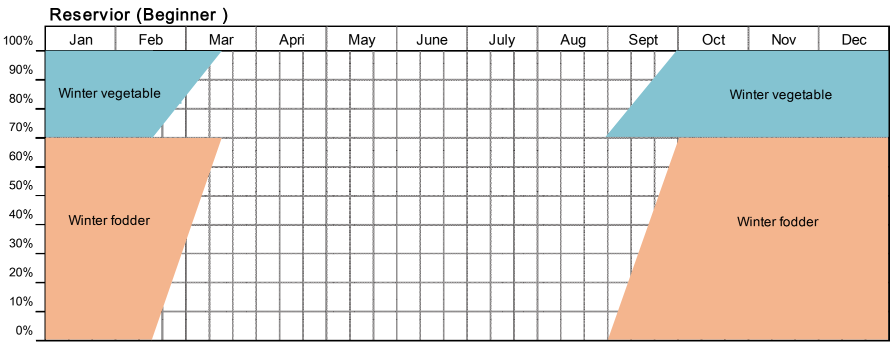
Farming Model (SW-M)



Farming Model (SW-H)



Farming Model (P-H) (P-B)



Farming Model (P-M)

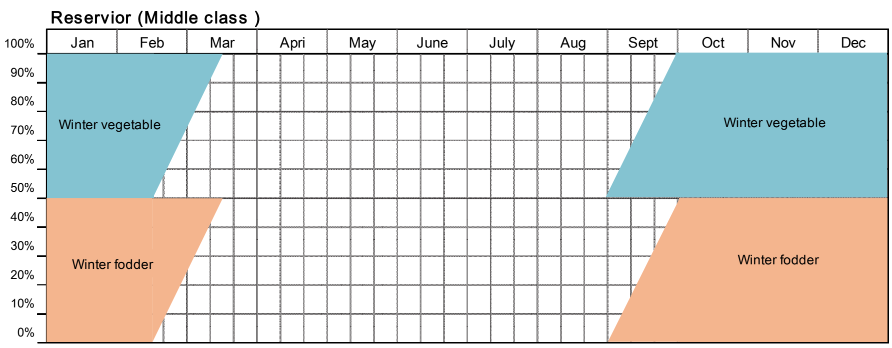
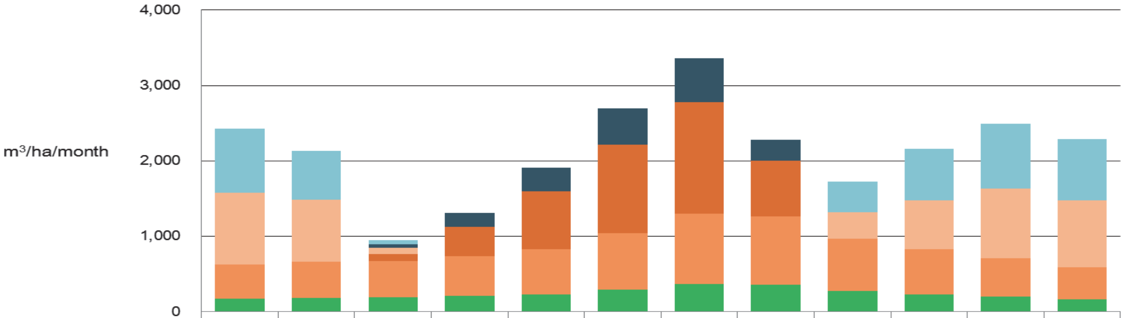


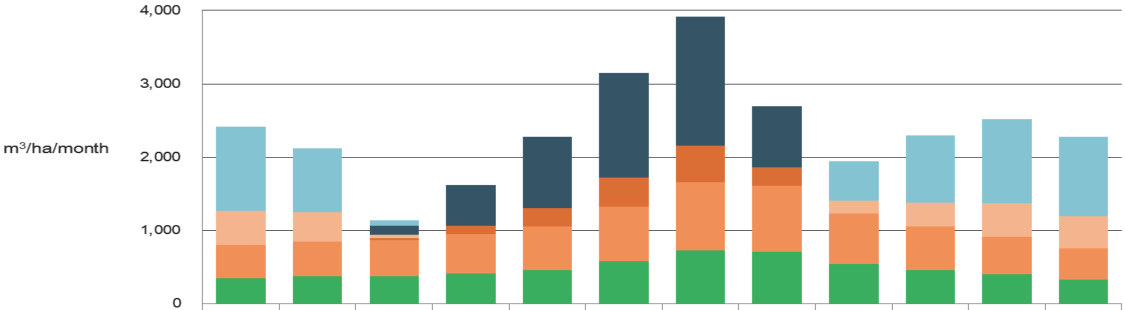
Figure 3.2.1 Proposed cropping pattern for each farming model

Farming model (SW-H, SW-B)



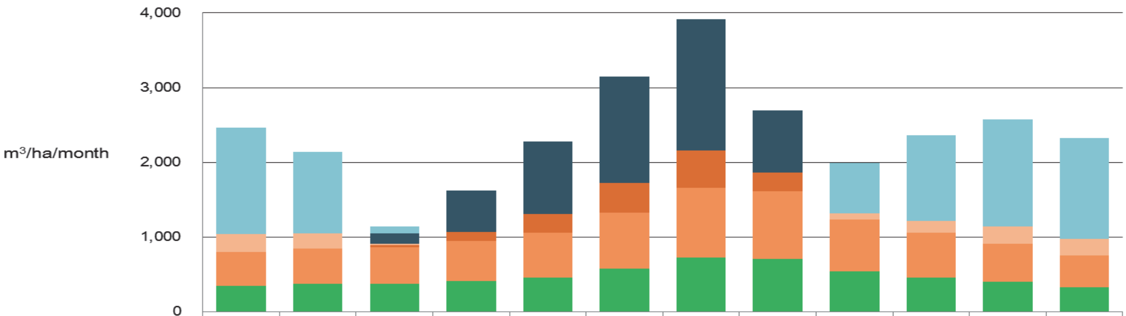
	Jan	Feb	Mar	Apr	May	Jun	July	Aug	Sep	Oct	Nov	Dec
Winter vegetable	857	651	56	0	0	0	0	0	404	686	860	809
Summer vegetable	0	0	45	185	322	476	586	278	0	0	0	0
Winter fodder	949	818	81	0	0	0	0	0	359	651	919	891
Summer fodder	0	0	90	384	767	1,180	1,477	738	0	0	0	0
Perennial fodder	450	477	486	531	594	747	936	909	693	594	513	423
Tree crops	175	186	189	207	231	291	364	354	270	231	200	165

Farming model (SW-S)



	Jan	Feb	Mar	Apr	May	Jun	July	Aug	Sep	Oct	Nov	Dec
Winter vegetable	1,142	867	74	0	0	0	0	0	539	915	1,147	1,079
Summer vegetable	0	0	135	556	965	1,429	1,758	835	0	0	0	0
Winter fodder	474	409	41	0	0	0	0	0	180	326	459	446
Summer fodder	0	0	30	128	256	393	492	246	0	0	0	0
Perennial fodder	450	477	486	531	594	747	936	909	693	594	513	423
Tree crops	350	371	378	413	462	581	728	707	539	462	399	329

Farming model (SW-A)

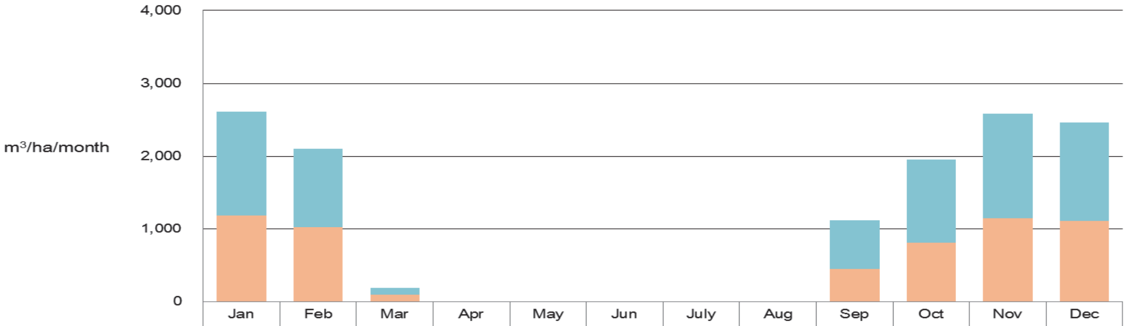


	Jan	Feb	Mar	Apr	May	Jun	July	Aug	Sep	Oct	Nov	Dec
Winter vegetable	1,428	1,084	93	0	0	0	0	0	674	1,144	1,434	1,349
Summer vegetable	0	0	135	556	965	1,429	1,758	835	0	0	0	0
Winter fodder	237	204	20	0	0	0	0	0	90	163	230	223
Summer fodder	0	0	30	128	256	393	492	246	0	0	0	0
Perennial fodder	450	477	486	531	594	747	936	909	693	594	513	423
Tree crops	350	371	378	413	462	581	728	707	539	462	399	329

Farming model (P-H, P-B)

	Jan	Feb	Mar	Apr	May	Jun	July	Aug	Sep	Oct	Nov	Dec
Winter vegetable	857	651	56	0	0	0	0	0	404	686	860	809
Summer vegetable	0	0	0	0	0	0	0	0	0	0	0	0
Winter fodder	1,661	1,431	142	0	0	0	0	0	629	1,140	1,608	1,560
Summer fodder	0	0	0	0	0	0	0	0	0	0	0	0
Perennial fodder	0	0	0	0	0	0	0	0	0	0	0	0
Tree crops	0	0	0	0	0	0	0	0	0	0	0	0

Farming model (P-S)



	Jan	Feb	Mar	Apr	May	Jun	July	Aug	Sep	Oct	Nov	Dec
Winter vegetable	1,428	1,084	93	0	0	0	0	0	674	1,144	1,434	1,349
Summer vegetable	0	0	0	0	0	0	0	0	0	0	0	0
Winter fodder	1,186	1,022	102	0	0	0	0	0	449	814	1,149	1,114
Summer fodder	0	0	0	0	0	0	0	0	0	0	0	0
Perennial fodder	0	0	0	0	0	0	0	0	0	0	0	0
Tree crops	0	0	0	0	0	0	0	0	0	0	0	0

Figure 3.2.2 Irrigation water amount based on crop type for each farming model

4. Development of water source facility

4.1 Shallow well

(1) Location selection of the shallow well

Shallow well is classified into two types according to the target water source in Djibouti. One is shallow well (type A): the target water source is the shallow groundwater which flows out through the crack of rock foundation or the fault fracture zone. The other type is shallow well (type B): the target water source is underflow water in the wadi. The location of each type of shallow well shall be selected in consideration of the following remarks.

<u>Shallow well (type A)</u>

1) Rock foundation of the basin area is basalt of Miocene, Superior Pliocene.
2) A crack or crushed zone caused by fault movement is observed on the periphery.
3) The basin area is estimated to be more than $10km^2$.
4) Existing shallow wells are found on the periphery.
5) Lower place compared with the periphery. (For example, near the wadi)

Shallow well (type B)

1) Water-bearing sandy layer is found in the wadi.
2) The basin area is estimated to be more than $10km^2$.
3) Existing shallow wells are found on the periphery.
4) Avoid a place that can be damaged by flood.

(2) Construction of the shallow well

As for the excavation of the shallow well, an excavation machine (backhoe) shall be used effectively for the soil layer of the ground surface (1 to 2m in depth) in the case of shallow well (type A), and for the whole soil layer in the case of shallow well (type B). Electric jackhammer is also helpful to excavate the rock layer below the soil layer in the case of shallow well (type A) to improve working efficiency and safety. For the operation of the electric jackhammer, a generator and fuel are required as power and energy source. After groundwater starts to flow out in the well as the excavation continues, this water needs to be drained out gradually using a pump for both cases of shallow wells. Meanwhile, the maximum depth of the shallow well is considered to be around 10 m when manpower is used for the excavation from the viewpoints of work efficiency and safety.

Manpower and materials necessary for the excavation work of the shallow well (type A) are listed below based on actual performance done in Hambokto.

Excavation work for soil layer

Manpower: one supervisor, one backhoe operator, and two workers

Materials: backhoe, drainage pump, pick, bar, shovel, ladder, bucket, pulley, and rope

Excavation work for rock layer

Manpower: one supervisor, one jackhammer operator, and three workers

Materials: jackhammer, generator, drainage pump, pick, bar, shovel, ladder, bucket, pulley, and rope

	
Excavation work for soil layer (backhoe)	Excavation work for rock layer (left: jackhammer, center: excavation work, right: drainage pump)

Figure 4.1.1 Excavation work of the shallow well

(3) Protection work of the shallow well

After confirming the well water amount and depth, a protection wall must be constructed to avoid soil falling at the portion of the excavated soil layer. The protection wall is widely built by heaping up stones with cement as shown in the photos below.

	
Case example in Afka-Arraba site	Case example in Hambokto site

Figure 4.1.2 Protection wall of the shallow well

In most cases, the shallow wells are built inside the wadi; therefore, special consideration must be taken against flood damages. In particular, the top of the well shall be covered with concrete to prevent the flood from flowing into the well, and also a guide wall shall be made in a triangular shape at the upstream edge of the well to make the flood flow smoothly. At the points where the flood flows with a high velocity, the side of the well may be washed away as shown in the photos (right and center). As a countermeasure, a protection work with gabion and concrete is recommended as shown in the photo on the right.

		
The side of the guide wall was washed away by the floods.		The side protection of the well was made with gabion and concrete.

Figure 4.1.3 Protection work of the shallow well

4.2 Pond

There are six ponds having a certain storage volume in southern Djibouti as shown below. The photos show that surface water that runs off during the flood is guided and stored into the pond with the dike. The two ponds of Kourtimalei and Doudou Bolole are in use for agriculture, but the other four ponds are in use for livestock exclusively.

		
Kourtimalei (Arta) N: 11° 18’9” E: 42° 40’54”	Doudou Bolole (Ali-Sabeih) N: 11° 12’24” E: 42° 38’32”	Gaggabodlei (Ali-Sabeih) N: 11° 13’35” E: 42° 41’2”

		
Gabla Oalan (Arta) N: 11° 15’56” E: 42° 33’41”	Guilanguelle (Arta) N: 11° 16’56” E: 42° 38’3”	Digri（Ali-Sabieh） N:11° 17’59” E:42° 51’30”’

Figure 4.2.1 Pond constructed in southern Djibouti

The following considerations shall be taken into account to select the candidate site of the pond.

1) The basin area shall be 30km^2 or more.
2) A site with less underground seepage shall be selected from a geological aspect.
3) To maximize the amount of inflow water through a proper arrangement of the dike.
4) To reduce the huge evaporation loss which is assumed to be around 3,000mm a year, the pond bed must be excavated so as to make a pocket to respond to the situation when the storage water amount becomes small.
5) To control soil sedimentation of the pond, building a filter zone made of gravels.
6) Closely supervise the works to ensure a proper compaction work of the dike.
7) The location of the spillway should be selected not to affect earth filling of the dike in consideration of geographical and geological viewpoints.

5. Development of the farmland

5.1 Land reclamation

If the selected farmland has less stones and flat, it is not necessary to carry out land reclamation. However, it is required when the selected farmland is stony or not flat. Heavy construction machines of the Department of Big Works under the Ministry of Agriculture are recommended to be used effectively to save the construction cost of the land reclamation. Flow of the land reclamation work is briefed as follows.

Cut and filling, and stone digging up by bulldozer

↓

Removal of the stones by manpower and loader

↓

Land levelling by grader

		
Cut and filling, and stone digging up by bulldozer	Removal of the stones by manpower and loader	Land levelling by grader

Figure 5.1.1　Flow of the land reclamation work

According to the result of the pilot project implementation, it was proved that land reclamation can be completed within two weeks for a stony farmland of around one ha by using heavy construction machines. Especially, cut and filling work must be sufficiently done by a bulldozer because levelling is essential to ensure uniform watering on the farmland.

5.2 Appurtenant facilities

To successfully manage the farming activity of the project, appurtenant facilities such as fence, gate, warehouse, and compost pit needs to be set in the farmland.

(1) Fence

Fence must be placed around the farmland to avoid livestock from entering into the farmland and also to protect against theft. Prickly plants, stone masonry, and net fence are available materials for making fences in Djibouti. Judging from the result of the pilot project, the fence needs at least 1.5m in height to avoid goats from entering the farmland. A lot of labor and time is needed to make a fence by stone masonry; therefore, net fence is recommended for the project site. Since small wild animals might enter through the bottom of the fence, concrete base must be placed all along the line of the net fence as shown in the photo below on the right.

		
Fence with prickly plants （for small scale farm）	Fence with stonemasonry (adopted by the advanced farmers)	Fence with net fence （farmlands developed by donors）

Figure 5.2.1　Types of fences

(2) Warehouse

A warehouse should be built near the farmland to store farm tools and necessary materials for the repair of the irrigation facilities. The size of the warehouse is determined according to the irrigated area and number of farm households. Within the pilot project, the warehouse was constructed with stones as shown in the photo below on the left.

(3) Compost pit

A compost pit should be built for the purpose of making organic manure. In the pilot project, two compost pits having 3 meters square and 1 meter high each were built to be co-managed by the 15 families. In reality, the co-management was difficult because the collected and consumed amount of livestock manure were different according to each family. Individual compost pit is recommended to solve the problem. The size of the compost pit shall be determined depending on each farmland area and the consumed amount of manure. In the case that small-scale farmers use the compost pit individually, a simple compost pit as shown in the photo below on the right is useful as well. **Table 5.2.1** shows the standard size of the compost pit.

Table 5.2.1 Standard size and number of compost pits according to the farmland area

Farmland area	Required amount of manure for one season	Size of the compost pit	Required number of the compost pit
0.025 ha	50~100 kg	1 m square and 1 m high	2 pits
0.25 ha	500~1,000 kg	2 m square and 1 m high	2 pits
1 ha	2,000~4,000 kg	3 m square and 1 m high	2 pits
2 ha	4,000~8,000 kg	3 m square and 1 m high	4 pits

Warehouse | Compost pit | Simple compost pit

Figure 5.1.3 Example of warehouse and compost pit

6. Development of pump unit and water conveyance & distribution facilities

6.1 Pump unit

Pump unit is necessary to convey irrigation water from the water source to the farmland. Three types of pump unit: foot pump, engine pump, and solar pump are available in Djibouti. Foot pump can be used for small scale farming; however, most farmers use engine pump.

Foot pump is recommendable for small scale farming because purchase price is low and operation cost is free. Meanwhile, in the case that the farmland area is larger than a few hundred square meters, engine pump shall be adopted instead of foot pump in term of workability. An engine pump is classified into gasoline pump and diesel pump based on the type of fuel. Gasoline pump is widely used because purchase price is cheaper than for diesel pump. In contrast, the price of gasoline is about 300 DJF per little, which is roughly double of the diesel price 210 DJF per little. In addition to that, gasoline is not available in the rural market. Therefore, diesel pump is recommended as engine pump in Djibouti.

So far, solar pump has been adopted for drinking water use in Djibouti. In recent years, it has been also adopted for irrigation purpose because solar energy has an advantage of free operation cost. If the initial cost is covered by the donors, solar pump is the best solution for farmers.

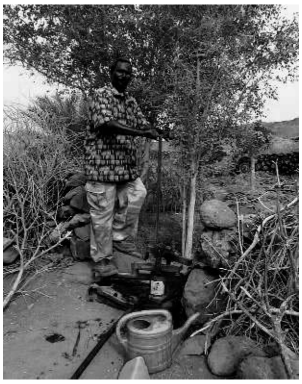
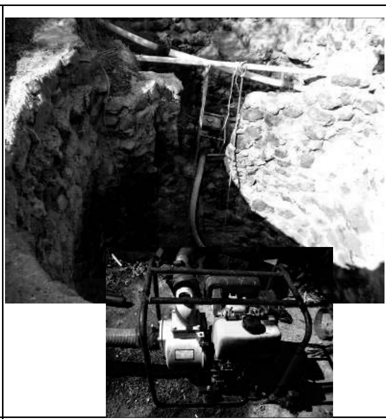
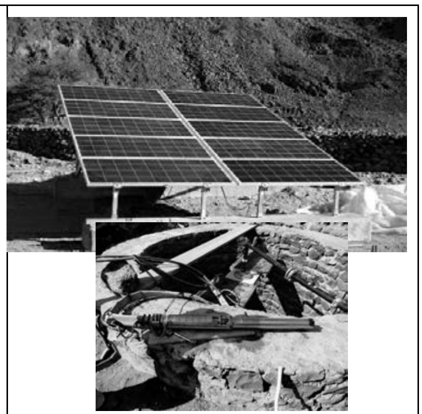
		
Foot pump	Engine pump	Solar pump

Figure 6.1.1 Classification of pump unit

6.2 Solar system

(1) Composition of solar system

The solar system for the pump unit consists of three main parts as follows.

Solar module: This is a number of panels which convert solar energy into electricity. The number of panel and power output of the panels are determined according to the required electric power.

Controller: It is the devise that controls pump operation, and indicates the status of operation such as on-off, generated electric power, unusual status of water level, and failure. In general, the controller is set up under the solar module.

Pump: It is the pump that is driven by solar energy. An electric drive submergible pump and and a centrifugal pump are applicable to the solar system.

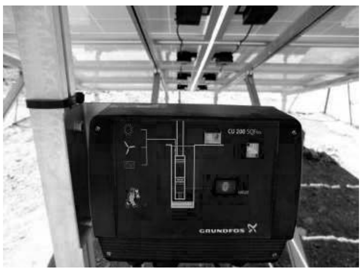
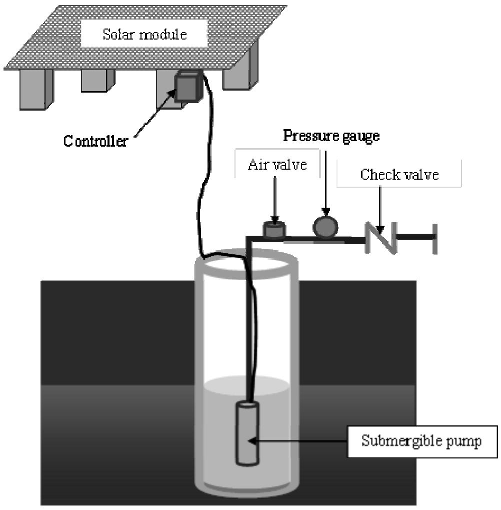
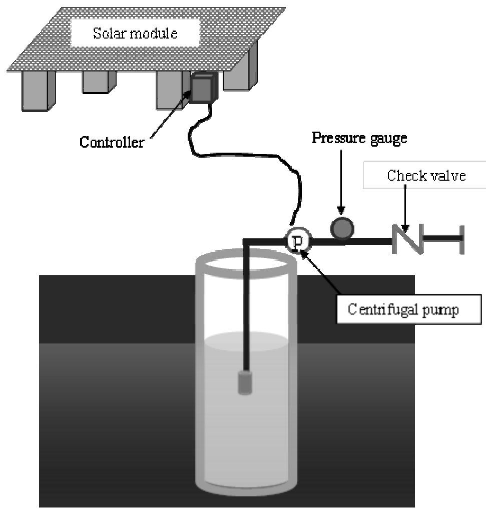
		
Solar module	Controller	Pump (submergible or centrifugal)

Figure 6.2.1 Composition of solar system

(2) Applicable pump for solar system

A solar system has been applied to the deep well for drinking water supply; therefore, a submergible pump has been normally used for the deep well. When the solar system is applied to the shallow well for irrigation purpose, either a submergible or a centrifugal pump can be used in accordance with the water level condition. If the water level is low, a submergible pump is recommended; instead, if the water level is high, a centrifugal pump is adoptable. The appropriate type of pump should be selected in consideration of the features described in **Table 6.2.1**.

Table 6.2.1 Comparison of solar pumps

Classification	Submergible pump	Centrifugal pump
Place where pump is set up	Under water	On the ground
Current	Direct current (DC) Energy use efficiency is higher than centrifugal pump because it can be used without converting DC to AC.	Alternative current (AC) Energy use efficiency is lower than submergible pump because one needs to convert DC to AC.
Water level condition	Applicable under the condition that water level is low. **(Submerged depth of about 1 m is required.)**	Not applicable under the condition that water level is too low (**Suction head must be less than 8 m.**)
Initial cost	More expensive	Cheaper
Repair and replacement	One needs to pull out the pump from the well in the case of repair or replacement. It takes time to replace because the specified pump must be ordered to the manufacture.	It is easy to replace because the pump is placed on the ground. Commercialized pump is available in the market.
Schematic diagram		

(3) Determination of the specification of solar pump

The specification of the solar pump is determined in accordance with the following procedure.

Calculation of irrigation water amount

Required irrigation water amount (m^3/day)

= Crop water requirement (mm/day) × Irrigation area (ha) × 10

Calculation of pump discharge

Pump discharge (m^3/hr) = Required irrigation water amount (m^3/day) ÷Irrigation hour (hr)

For the solar pump, available daily sunshine hour must be adopted as irrigation hour.

Available daily sunshine hour is estimated to be 6 to 8 hours in Djibouti.

Determination of pump diameter

Pump diameter (mm) = (4/ π ×Pump discharge (m^3/hr)÷3,600 / Velocity (m/s))$^{1/2}$×1,000

Velocity is generally assumed to be 2.5m/sec.

Calculation of total pump head

Total pump head (m) = Actual pump head (m)＋Pipeline loss (m)＋Allowance

Required electric power

Required electric power (kw)

= Pump discharge (m^3/hr)÷3,600×Total pump head (m)×9.8÷Pump efficiency

Pump efficiency = 0.5 - 0.6 (50 - 60%)

【Reference example】

Required irrigation water amount

= Crop water requirement 10 mm/day×Irrigation area 1.5 ha×10 = 150 m^3/day

Pump discharge = Required irrigation water amount 150m^3/day÷Irrigation hour 6hr =25 m^3/hr

Pump diameter = (4/ π ×Pump discharge 25m^3/hr÷3,600 / Velocity 2.5m/sec)$^{1/2}$×1,000 = 59 mm

→ 3 inch

Total pump head = Actual pump head 12m＋Pipeline loss 2.5m＋Allowance 0.5m = 15 m

Required electric power = Pump discharge 25m^3/hr÷3,600×15m×9.8÷0.5＝2.0 kw

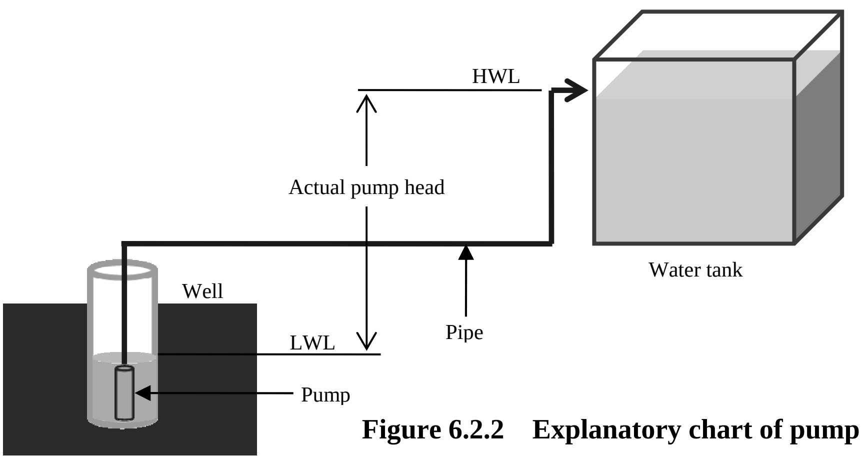


Figure 6.2.2 Explanatory chart of pump head

(4) Number of solar module

The required number of solar modules can be calculated by dividing the required electric power by the output power of one piece of solar module. Various power outputs for the solar module are available in the market.

【Reference example】

Required number of solar modules

= Required electric power 2.0 kw ÷ Output power 120w / piece = 16 pieces

(5) Pumping test of solar pump

After the installation of the solar pump, its performance must be verified by conducting a pumping test. In the pilot project, the solar pump was installed at the shallow well of Afka Arraba pilot farm. **Figure 6.2.3** shows the performance curve that was prepared based on the results of the pumping test of Afka Arrab, which shows the relation between generated electric power and pump discharge. As clearly shown in this graph, pump discharge is stipulated by generated electric power. Pump discharge is small when generated electric power is low, and pump discharge increases in accordance with the increase of the electric power. In this case, the pump discharge reaches nearly 7 m^3/hr when generated electric power is 1 kw.

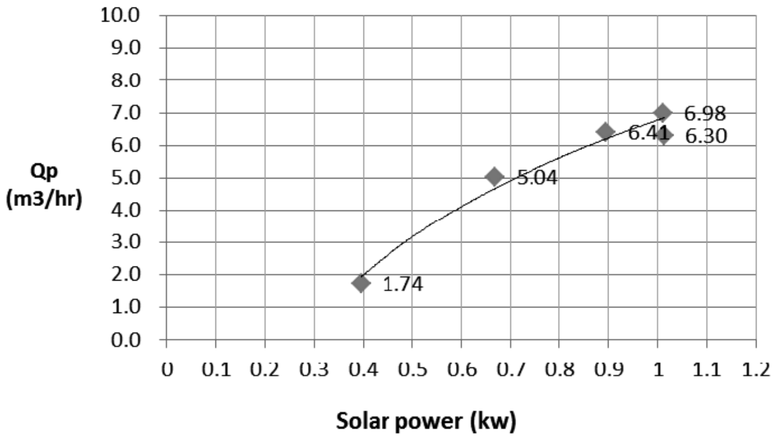


Figure 6.2.3 Performance curve of the solar pump (Reference example)

(6) Automatic operation of the solar pump

An automatic operation system is generally applied to the solar pump. The pump starts and stops automatically by detecting water level with the water level sensors that are installed in the well and the water tank in order to avoid the following situation.

<u>Empty operation caused by the drawdown of the water in the well</u>

When the water level goes down to ”Low-Water OFF” set up in the well, the pump stops automatically. After a moment, when water level goes up to the set water level, the pump starts again automatically. Meanwhile, the quiescent time from stop to start of the pump drive is set at five minutes to avoid the motor from damage due to frequent on-off drive.

<u>Overflow from the water tank</u>

The water level sensors such as the floating type and the electric pole type are installed in the water tank.

When the water level goes up to ”High-Water OFF” set up in the water tank, the pump stops automatically. Then, the pump starts again automatically when the water level goes down to the set water level. Instead of automatic operation, manual operation can also be used. In the case of manual operation, close monitoring for the water level is needed to avoid empty operation of the well and overflow from the storage tank.

6.3 Water conveyance & distribution facilities

(1) Classification of conveyance and distribution facilities

As shown in **Figure 6.3.1**, the part between water source and water tank is defined as conveyance facility, and the part between water tank and irrigated farmland is defined as distribution facility.

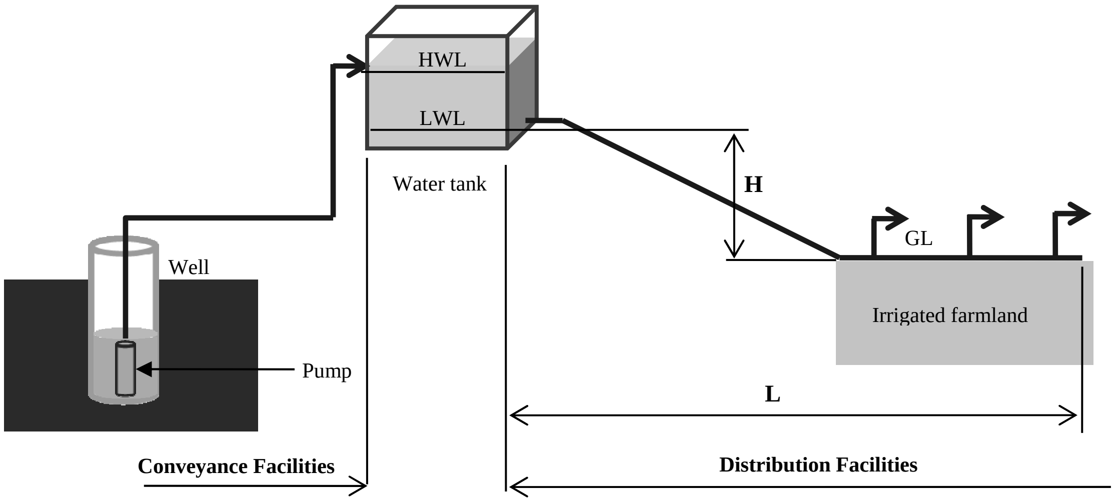


Figure 6.3.1 Classification of conveyance and distribution facilities

(2) Conveyance & distribution pipelines

Irrigation water is taken from the water source by the pump; therefore, a pipeline can be adopted as a conveyance facility. Meanwhile, both open canal and pipeline can be adopted as distribution facilities. Seepage and operation water loss is normally observed in the case of open canal; in that sense, pipeline is recommended as a distribution facility to improve water use efficiency.

Both steel and PVC pipes are available as pipeline material. A steel pipe is recommended in the case that the pipeline is installed on the ground; instead, a PVC pipe can be applied to the case where the pipeline is buried under the ground. A steel pipe is much more expensive than a PVC pipe, and also the machine tool used to making thread for small size steel pipe is unfamiliar in Djibouti. In contrast, a PVC pipe is easy to purchase at the market of Djibouti city, and has the following advantages: 1) price is cheaper, 2) light and easy to join, and 3) various fittings are available. Thus, a PVC pipe is recommended to be used as the material for conveyance and distribution pipelines. As shown in **Figure 6.3.2**, hot-dip galvanized steel pipe can be placed directly on the ground; instead, a PVC pipe must be buried with a sand bed to avoid the degradation due to sunlight and damage due to impact.

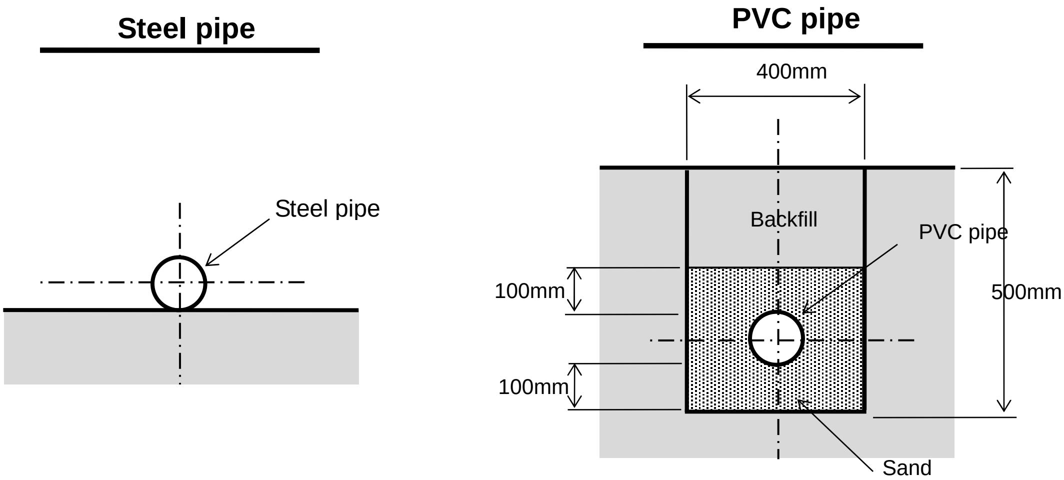


Figure 6.3.2 Standard section for the installation of steel and PVC pipes

(3) Diameter of the pipeline

Conveyance pipeline

The diameter of the conveyance pipeline can be calculated in accordance with the equation below. The velocity shall be set at less than 1.0 m/sec to restrain the friction loss in the pipe. **Table 6.3.1** shows a rough indication in selecting the diameter for the conveyance pipeline.

Diameter of the conveyance pipeline (mm)

$$= (4/\pi \times \text{Pump discharge } (m^3/hr) \div 3{,}600 \text{ / Velocity } (m/sec))^{1/2} \times 1{,}000$$

Table 6.3.1 Selection of the conveyance pipeline

Pump discharge	Pipe diameter	
0 - 7 m^3/hr	50 mm	2 inch
7 - 15 m^3/hr	75 mm	2.1/2 inch
15 - 22 m^3/hr	90 mm	3 inch
22 - 34 m^3/hr	110 mm	4 inch

Distribution pipe

The diameter of the distribution pipe must be selected to satisfy the requirement that the friction head loss of the distribution pipeline is kept within the range of the difference (H) between the water tank (LWL) and the irrigated farmland (GL) as indicated in the **Figure 6.3.1**. Friction head loss of the pipeline (h_f) can be computed by using Hazen Williams's formula below.

$$h_f = 1.1 \times 10.67 \cdot \frac{Q^{1.85}}{C^{1.85} \cdot D^{4.87}} \cdot L$$

H_f: Friction head loss in the pipeline (m)

Q: Discharge (m^3/sec)

D: Diameter of the distribution pipeline (m)

L: Pipe length (m)

C: Velocity efficiency, C=140 (PCV pipe)

【Reference example】Q=15 m^3/hr → 0.004 m^3/sec, D=75mm → 0.075m, L=200m, C=140

$$h_f = 1.1 \times 10.67 \times \frac{0.004^{1.85}}{140^{1.85} \times 0.075^{4.87}} \times 200 = 2.8m$$

(4) Water tank

Since the well and the pond have the function for water storage, the water tank itself does not need to have the function of water storage. The objective of the water tank is to give flexibility to the irrigation system by adjusting the conveyance time and the distribution time. In that respect, the water tank is designed to have the capacity of irrigation water demand for one day. In the case that crop water requirement is 10 mm/day, and irrigated farmland is 1.5 ha, the water tank needs a capacity of 150 m^3. The water tanks are generally constructed by using stones and cement in Djibouti as shown in the photos below. A cover is normally not placed on the water tank as shown in the photo on the left below; however, some water tanks have a concrete cover as shown in the photo on the right. Generally speaking, the cover is not necessary for irrigation water tank. Meanwhile, a drainage pipe must be installed at the bottom of the side wall in order to drain water from the water tank for cleaning and repair.

Water tank without cover

Water tank with cover

Figure 6.3.3 Example of water tank

7. On-farm irrigation facilities

7.1 Hydrants

Hydrants shall be installed to irrigate each farm plot. The photo on the right shows a hydrant installed in one of the pilot project farmland. This hydrant has two valves: one of standard size (2.1/2 inch) on the bottom and the other of small size (3/4 inch) on the top. For farmlands having a certain area, only standard size valves are normally used to distribute irrigation water to on-farm canals. Meanwhile, for small plots farmlands, small size valves are much more useful in terms of easy watering and effective water use.

Hydrant

Figure 7.1.1 Example of hydrants

7.2 On-farm canals

Canals that distribute irrigation water from the hydrants to each furrow is defined as on-farm canals. It is essential to make on-farm canals that have gentle and constant inclination to ensure uniform watering. To control seepage loss, the improvements of the on-farm canals have been carried out so far by farmers; for example, placing small stones on the base, or making concrete lining.

On-farm canal

Figure 7.2.1 Example of On-farm canals

7.3 Furrow irrigation

The main irrigation method practiced in Djibouti is surface irrigation; namely basin irrigation and furrow irrigation. Surface irrigation has an advantage in terms of initial cost and operation cost, which does not need any irrigation equipment and power source like the pressurized modern irrigation such as sprinkler irrigation and drip irrigation. Irrigation efficiency of surface irrigation is lower than that of pressurized modern irrigation; therefore, the following water saving manner shall be taken into consideration in applying surface irrigation.

Basin irrigation: smaller plots, and levelling of the plots
Furrow irrigation: shorter furrows and levelling of the furrows

Basin irrigation	Furrow irrigation

Figure 7.3.1 Surface irrigation in Djibouti

It is noted that basin irrigation has the disadvantages in terms of consolidation of cultivated soil, uneven watering, and increase of seepage loss. Comparing furrow irrigation to basin irrigation, furrow irrigation has the advantages in terms of soil condition for crop cultivation and water saving. In conclusion, furrow irrigation is much more recommendable surface irrigation method in Djibouti.

7.4 Drip irrigation

It is well known that drip irrigation is the best irrigation method for water saving. It is already proved by the actual performance in the arid area that the required irrigation water amount of drip irrigation is half or one third of that of surface irrigation. The water resources are limited in Djibouti; in that context, drip irrigation is a promising irrigation method. In reality, agribusiness firms and advanced farmers have adopted drip irrigation system in their farmland.

		
Damerdjog (Arta)	Doudou Bolele (Ali-Sabeih)	Afka-Arraba (Dikhil)

Figure 7.4.1 Case examples of drip irrigation system introduced in Djibouti

(1) Types of drip tubes

Two types of drip tubes, In-line type and On-line type as shown in the photo below are in use in Djibouti. Within the pilot project, discharges comparison test was conducted with the two types of drip tubes in the pilot farms. As a result, it was proved that On-line type drip tube works well even under low pressure. In addition, On-line type drip tube has another advantage of easy maintenance against clogging owning to its structural feature. On-line type is recommended as promising drip tube in Djibouti.

	
In-line drip tube	On-line drip tube

Figure 7.4.2 Drip tubes applied in Djibouti

(2) Selection of filters

Shallow wells will be the main water sources used for drip irrigation in the future in Djibouti. Water taken from a shallow well contains soil and other contaminants much more than that from a deep well; therefore, the installation of filters is essential to prevent drippers from clogging. Various types of filters are available as shown in **Table 7.4.1**. Appropriate filters must be selected in consideration of water quality and use.

Type	Sand filter	Cyclone filter	Screen filter	Disk filter
Water source	Reservoir, River	Reservoir, River, Well	Well	Well
Target impurity	Floating particle, Organic matter, Algae, Sand	Sand	Floating particle, Sand	Organic matter, Algae, Sand
Photo				

Table 7.4.1 Selection of screen type

In the case of Djibouti, screen filter is recommended in terms of water quality and maintenance work for cleaning.

		
Damerdjog (Arta)	Afka-Arraba (Dikhil)	Afka-Arraba (Dikhil)

Figure 7.4.3 Case examples of the screen filter installed in Djibouti

(3) Water management in drip irrigation

Frequent irrigation with one day or two days interval is recommended as on-farm irrigation method for drip irrigation in order to improve crop production. Required irrigation hours for drip irrigation can be computed with the following equation.

Irrigation hour (hr)＝Irrigation water amount at one time (mm) ÷ Irrigation intensity (mm/hr)

Irrigation intensity (mm/hr) = Discharge of the drippers per one meter (lit/hr) ÷ Wetting area (m^2)

【Calculation example】

In the case that the discharge of one dripper is 4 lit/hr., and the arrangement of drip tubes is assumed as shown in **Figure 7.4.4**, irrigation intensity is computed as follows. And then, irrigation hours for two days interval is estimated as shown in **Table 7.4.2**.

Irrigation intensity = (4 lit/hr×2.5) ÷ (1.0m×0.8m) ＝12.5mm/hr

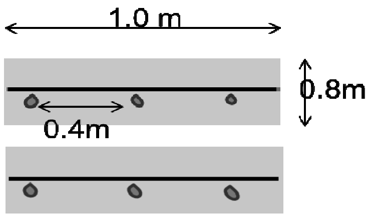


Figure 7.4.4 Arrangement of drip tubes

Table 7.4.2 Irrigation hours of drip irrigation by crop in Djibouti (hr)

Crop type	Jan	Feb	Mar	Apr	May	Jun	July	Aug	Sep	Oct	Nov	Dec
Winter vegetable	0.9	0.8	0.7	-	-	-	-	-	0.7	0.7	0.9	0.9
Summer vegetable	-	-	0.5	0.6	1.0	1.5	1.9	1.5	-	-	-	-
Winter fodder	0.8	0.8	0.8	-	-	-	-	-	0.5	0.5	0.7	0.7
Summer fodder	-	-	0.4	0.4	0.8	1.3	1.6	1.3	-	-	-	-
Perennial fodder	0.7	0.8	0.8	0.8	0.9	1.2	1.5	1.5	1.1	0.9	0.8	0.7
Tree crops	0.6	0.6	0.6	0.7	0.7	0.9	1.2	1.1	0.9	0.7	0.6	0.5

8. Operation and maintenance of irrigation facilities

8.1 Operation of irrigation facilities

(1) Intake from water source

Pump operation must be managed while monitoring the water level. The pump can be driven intermittently when the intake water level is low. Start and stop of the pump operation must be done manually by watching the water level of the source. In addition, water level of the tank must be monitored carefully. When the water level comes close to the top of the tank, the pump must be stopped immediatelly to avoid overflow from the tank.

On contrast, for the solar pump operation system, the automatic On-Off drive is normally programed in response to the water levels of the source and tank.

(2) Watering from hydrants

Rotation irrigation shall be applied at farm level; therefore, the opening and closing of the hydrants must be managed in order. If a number of hydrants are opened at the same time, water pressure in the pipeline is lost, resulting in the decrease of water discharge from the hydrants. For an irrigation farmland having several plots, the rotation of irrigation must be applied as follows; three times a week for summer vegetables cultivation, and twice a week for winter vegetables cultivation.

8.2 Maintenance of irrigation facilities

(1) Maintenance items

The maintenance for the irrigation facilities can be carried out on a daily and occasional basis. In case that the maintenance is undertaken as a joint work by the beneficiaries, the following rule would be recomended to be adopted. Daily maintenance work shall be conducted by one or two persons in charge, who are selected by the beneficiaries. Meanwhile, ocasional maintenance work shall be conducted collectivelly by the beneficiaries as necessary.

Table 8.2.1 Maintenance irrigation facilities

Items	Maintenance works
Daily maintenance	・Monitoring water level of the water source ・Monitoring water level of the water tank ・Monitoring operation condition of the pump ・Cleaning the surface of the solar module ・Monitoring the status of the pipeline (operational check, finding water leakage) ・Reading and recording water consumption with flow meter
Occasional maintenance	・Dredging sediment of the well and the pond ・Cleaning the water tank. ・Repairing the defect of the facilities

(2) Troubleshooting

In principle, the beneficiaries must deal with the failure of the irrigation facilities on their own. However, special defects such as troubles related to the electrical system may be difficult to fix by the beneficiaries. In such cases, repair must be given over to a professional company.

Table 8.2.2 troubleshooting of irrigation facilities

Items	Cause of the troubles	Remedy
Damage of the well	Flood	Repair with stones and cement
Leakage of the water tank	Occurrence of holes	Chip the leakage point, and then past the mortal on the inside wall
Leakage from the valve	Breakage of the valve	Replace the valve
Leakage from the pipeline	Breakage of the joint	Replace the joint
Breakage of the fence	Degradation of the materials	Repaint the fence or replace the net
Trouble of the engine pump	Degradation of the oil	Replace oil
	Breakage of parts	Replace the parts
Trouble of the solar system	Breakage of the module	Order the module to the professional company for replacement
	Defect of the electric system	Contact with the professional company for the repair of the defect

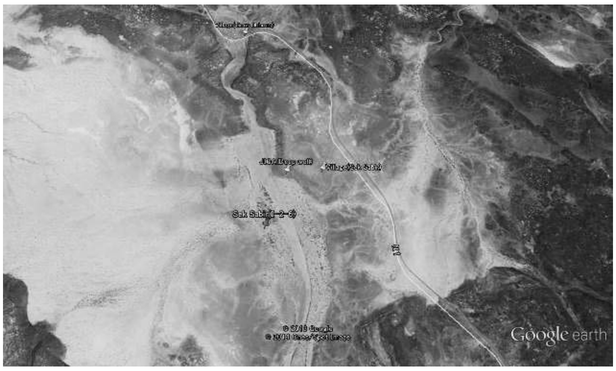
【Example】Outline of irrigation project site

Outline of irrigation project site: I-2-6 (Sek Sabir)

Basic information	
Site number	I-2-6
Site name	Sek Sabir
Region	Dikhil
Type of development	New settlement
Type of water source	Sub-surface water
Water source facility	Shallow well B
Catchment area	50km^2

Location	
Latitude	N: 11-15.8
Longitude	E: 42-13.6

Map



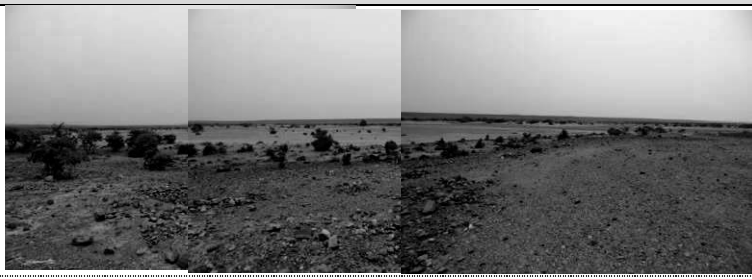
Evaluation

Score	① Availability of water source	3	15
	② Demand by local community	3	
	③ Accessibility	2	
	④ Farmland condition	2	
	⑤ Presence of inhabitants	3	
	⑥ Water quality	2	
Evaluation rank		A	

Overview

There is a village where a significant number of nomad families live. In 2012, deep well equipped with solar system was set as drinking and domestic water supply facility under the Japanese grant aid project.
This area is recognized as a potential site of agricultural development because it has several advantages as 1) fairly large basin area, 2) presence of a significant number of inhabitants, and 3) availability of sufficient water amount.

Site Photo



Panoramic landscape of the wadi

Drinking and domestic water supply facility constructed with the support of Japan.

Abandoned shallow well in the wadi

Remarks

MAEPE-RH (MINISTRY OF AGRICULTURE, WATER, FISHERIES, LIVESTOCK, AND MARINE RESOURCES)

JICA (JAPAN INTERNATIONAL COOPERATION AGENCY)

THE MASTER PLAN STUDY FOR SUSTAINABLE IRRIGATION AND FARMING IN SOUTHERN DJIBOUTI

The Manual for the Vegetable & Pasture Cultivation in Djibouti

December 2014





NTC International. Co., Ltd.

For the Farming Training of Nomad people in Djibouti

Preface

This manual is an achievement of JICA’s Technical Cooperation Project called “*The Master Plan Study for Sustainable Irrigation and Farming in Southern Djibouti”.*

This manual was created for agricultural extension workers and farming instructors who teach how to cultivate to nomads and former-nomads . It is expected that they will use this manual in On-farm instructions while consulting on it and/ or showing it to the targets.

Based on these concepts, this manual has many pictures as possible that readers can visually understand how to cultivate each product. Moreover, given the fact that this manual is created for agricultural beginners, cultivation techniques that are difficult to understand or unnecessary in terms of management of subsistence farming by nomad and former-nomad were omitted.

We would appreciate it if this cultivation manual could help Djibouti’s agricultural extension.

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RIDGE MAKING

In ridge making, the most important work is leveling of the ridges. Incomplete leveling will lead to ununiform growth of crops due to the difference of watering volume. You must be aware that ridge making by manpower will take a long time and huge labor, if a field has lots of small rocks.

1. Necessary Materials

Necessary materials in ridge making are scoops, hoes, rakes, and so on. In addition, pickaxes are also needed in many cases of tillage in Djibouti since the soil contains many large rocks. In particular, pickaxes are essential for exploitation of terrace surface of wadi to remove a bunch of buried rocks. Then, unicycles are also necessary to carry the removed rocks. Although every material is purchasable in Djibouti city, we recommend you to prepare stocks in advance since those farming tools will be broken if you use them so frequently.

Ridge making with scoops is possible if a farm is sandy and not including many small rocks.

Pickaxes are essential if a farm soil has a bunch of small rocks.

Rakes are to arrange ridges. In a farm of stiff soil, stocks are needed due to hard use of agricultural implements.

2. Soil Preparation

Soil preparation is prior to ridge making. Plow the farm with scoops, hoes, pickaxes, etc. and remove small rocks. If the farm has a slope, it should be leveled as much as possible. This makes leveling of ridges easy.

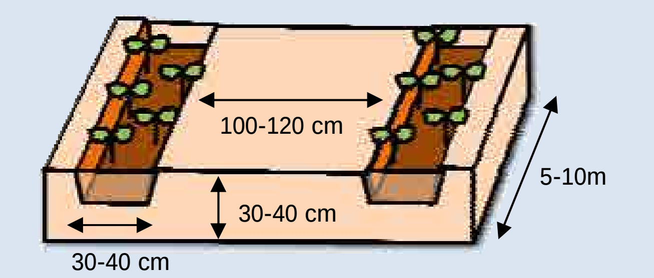
If a field has a slope, it should be leveled. This is, however, not essential because of the amount of labor needed.

Women can do the soil preparation. Promotion of women's participation is preferable.

3. Decision on ridge form

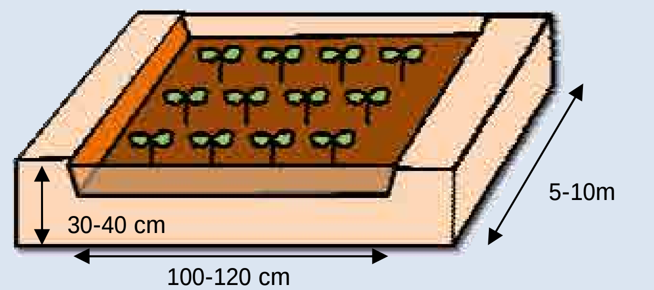
The way of ridge making should be appropriately adjusted in response to irrigation methods. Although the following figures show examples, you must properly decide it in accordance with the kinds of crops and soil.

Case 1. Furrow Irrigation



In furrow irrigation, ridge width is about 30-40cm. Whereas width among ridges should be changed according to products, 100-120cm is preferable for securing working spaces and spaces that can be rooted. The minimum depth of ridges is 30cm, and rocks must be carefully removed from plowed soils.
Kinds of Crops: Tomato, Red pepper, Sorghum, Maize, Melon, Watermelon, Okra, etc.

Case 2. Basin Irrigation



In basin irrigation, the length of a basin is about 100-120cm. As leveling of basins is more difficult than furrow irrigation, how to level should be instructed in cultivation instructions. It can be appropriate to teach furrow irrigation first to nomad with little experiences in agriculture because the leveling is easier. The minimum depth of ridges is 30cm, and rocks must be carefully removed from plowed soils.
Kinds of Crops: Onion

4. How to Make Ridges

Make ridges in accordance with the planned ridge from. It is convenient for instructions to prepare wood of a certain length necessary to regularly set ridges. Also, strings make it possible for even nomad to properly make straight ridges.

Even nomad with little agricultural experiences can properly make ridges by using wood of a certain length.

With strings, you can make straight ridges.

5. Leveling of Ridges

While leveling of ridges is a very important step, nomads with little agricultural experiences tend to undervalue its necessity. So, special attentions must be paid in cultivation instructions. Of several ways of leveling, the easiest one is to see whether ridges are leveled or not by using water poured before seeding. If there is a slope, soils on the higher side of a ridge should be transferred with scoops to the lower side.

Without proper leveling, crops ununiformly grow up.

Before seeding, see whether ridges are leveled by pouring water.

An innovative farmer’s ridges. Properly leveled.

COMPOST MAKING

In Djibouti, it is unrealistic for nomads to use chemical fertilizers since the obtaining them is quite difficult and expensive. Consequently, compost should be made of organics such as livestock dung like goats and sheeps. Here, a simple way of making compost using livestock's dung, which nomad tribes can practice.

1.Necessary Materials

Nomads can gather a certain amount of dung of goats and sheep. But, unicycles or sandbags for gathering and carrying them to compost pits should also be prepared. In making compost, a hose reaching to watering pots or water tanks is necessary since it uses a lot of water.

Sandbags enable you to stock livestock dung.

With unicycles, livestock dung and created compost are carried tofarms.

A huge volume of water is necessary for making compost.

2. Necessary Amount of Compost

Before making compost, the amount of compost for certain farming area should be estimated in advance. The following table shows approximate amount of manures for each area (hectare). As the quantity of livestock dung a household can gather is about 300-400kg per season, which can cover the minimum necessary amount of manures for an area of 0.2ha. But, a procurement cost for livestock dung will occur if the cultivation area is more than that. The following table shows the approximate amount of manures needed for particular farmland area. Be aware that more compost will be needed depending on the kinds of crops.

Minimum necessary quantity of compost (per season) for particular cultivation area

Cultivation area (ha)	Initial amount of compost (kg)	Additional amount of compost (kg)	Total(kg)
0.2	200	200	400
0.5	500	500	1,000
1.0	1,000	1,000	2,000
2.0	2,000	2,000	4,000

3. Period of Making Compost

At least, in Djibouti, 8 weeks is required to gather livestock dung and to actually create and use compost. So, compost making must be begun at least 2-3 months prior to seeding. In practice, as gathering livestock dung takes a long time, proper scheduling for compost making is essential.

4. How to make compost

The procedure of compost making is below:

① Put gathered livestock dung into compost pits

② While watering livestock dung with hoses and watering pots, stir them with shovels so that livestock dung as a whole get wet. Water volume must not exceed necessary amount for wetting them. Appropriate water amount is the extent that water does not trickle down when you strongly grasp livestock dung.

③ After stirring well livestock dung, they should be covered by blue sheets. Let this be as it is for 4 weeks.

④ Overturn livestock dung. If livestock dung are not fermented due to dryness, water and have them get wet.

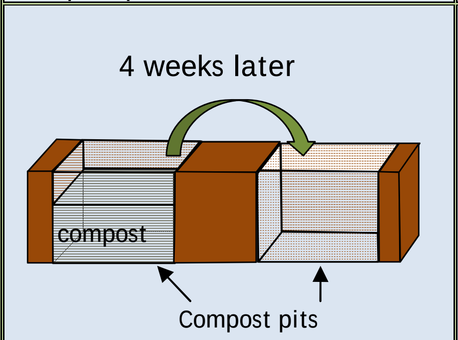
⑤ Check ferment heat and smell by touching livestock dung. If they are completely fermented, you recognize no heat and no smell. If there still are heat and smell, cover it again and wait for the complete ferment.

⑥ Keep covering with blue sheets. Use the compost as necessary.

1. Put gathered livestock dung into compost pits.

2. Stirring while watering them. Do not water too much

3. Cover livestock dung with blue sheets. Wait for 4 weeks.



4. 4 weeks later, overturn livestock dung and wait for further 4 weeks

5. Check ferment heat and smell by touching livestock dung.

6. Use compost as necessary.

5. How to Improve Quality of Compost

Although it is possible to make compost from only livestock dung of goats and sheep, effects of compost will be improved by mixing with charcoal and ashes of plants. Particularly, acquisition of ashes of plants is easy from ovens that nomads use. As they contain lots of potassium and calcium, it is recommendable to put them into livestock dung as much as possible. Regarding charcoal, as nomads often create it for the purpose of earning money, acquisition of it is also easy. Charcoal has not only lots of potassium, but many small holes that can increase soil's moisture and soil's holding power of nourishment. Proper amount of charcoal and ashes of plants is 2-3kg per 1 ton of livestock dung.

MORINGA & LUCENA CULTIVATION

Countermeasures against wind are crucial for crop production in Djibouti. Moringa and Lucena surrounding farms can mitigate dryness of fields and damages on crops. Moreover, not only they can be used as forage crops, but also fresh leaves of Moringa are used as human food. Here, how to cultivate Moringas and Lucenas is described.

1. Acquisition of Seeds

Acquisition of seeds is relatively easy since Moringas and Lucenas are popularly cultivated in Djibouti. Both often bear seeds in June and July. If you need a large bag of their seeds, this period is preferable for seed acquisition. Be aware that you should sow the seeds as soon as possible after acquisition because the germination rate of those seeds will be decreased as time goes.

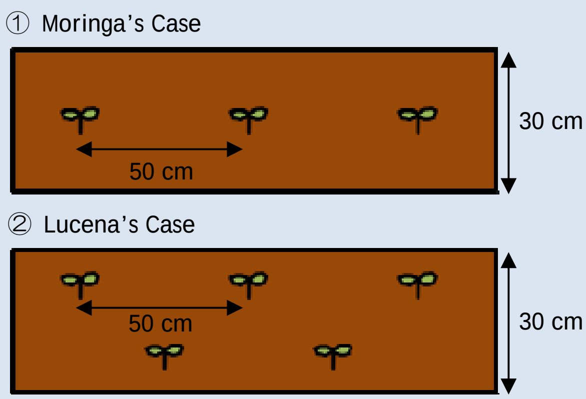
Moringa seeds

Pods holding Lucena seeds

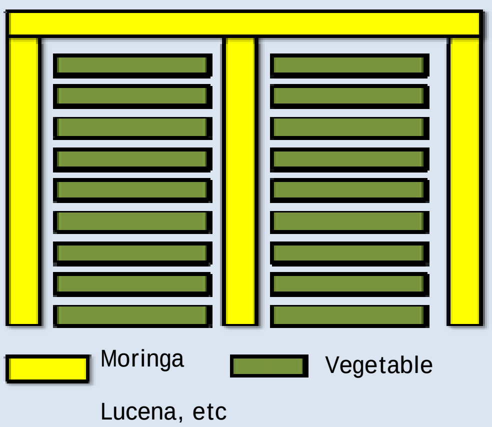
Lucena seeds

2. Cultivation Plan

October and November are best fit for sowing as temperature goes down in this period. One seed should ideally be sowed every 50cm on ridges of 30cm width. As the main purpose of Moringa and Lucena cultivation is to avoid wind, putting them around the ridges for tomatoes and onions, etc. is recommended.



Moringa seeds are on one line on a ridge because their trunks get thick in a year after sowing. Regarding Lucena seeds, they can be on a zigzag line because Lucena's trunk does not get thick that much.



The above is an examle of Moringa and Lucena cultivation. They should be laid to surround ridges for vegetables. Be aware that you must make a proper cultivation plan, while taking into consideration wind direction around the fields.

3. How to Cultivate

(1) Pretreatment of Seeds

Although sowing of Moringa and Lucena seeds without any processing is acceptable, pretreatment heightens germination rate and makes seeds sprout at once. Particularly in the case of Lucena, the germination rate of Lucena seeds dramatically decreases and a long time will be spent until germination without pretreatment.

Kind	How to do pretreatment of seeds
Moringa	Soak seeds in water in a bucket for half a day or a day.
Lucena	Soak seeds in hot water of 70℃ heated in a pot for 10 minutes.

(2) Sowing

Sow seeds after pretreatment while following the above cultivation plan. If there are lots of seeds, it is recommendable to sow about three seeds per sowing point and thin unnecessary sprouts out. Laying stones of 20cm wide around a sowing point enables sprouts to avoid vaporization of moisture and to protect from wind. The surrounding stones, however, can be a nest for grasshoppers. If you find the sprouts are bitten off, remove the stones.

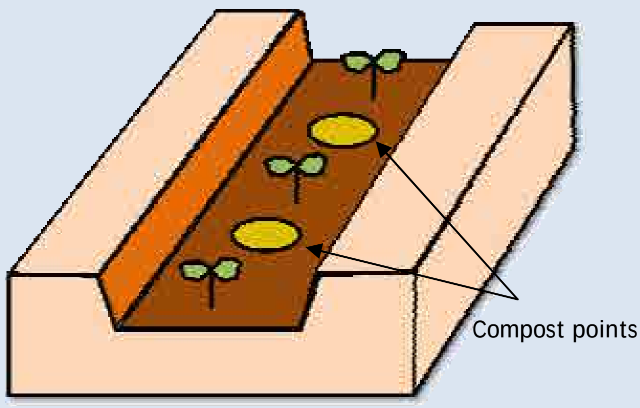
		
Sowing Moringa seeds. 2-3 seeds per sowing point.	Surrounding a Moringa sprout by stones to avoid sunshine and wind.	Sowing Lucena seeds. Secure proper spaces by a ruler.

(3) Cultivation Management

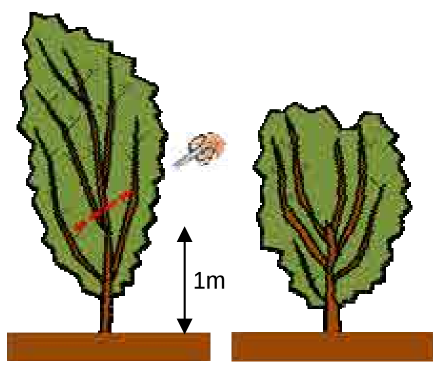
Pay attention to the following points in Moringa and Lucena cultivation:

[1] Sufficient water pouring is important for sound growth. Sprouts grow up to 2m high in a year with sufficient water pouring at least every other day.

[2] Compost can promote growth of Moringas and Lucenas. Their seeds themselves have nutrients in them, which is sufficient to secure their sprouts' initial growth. So, compost should be put among sprouts, not under them. In other words, use of compost in response to sprouts' growth is preferable. Initial amount of compost is about 200g and add if necessary.

	Where compost should be put in Moringa cultivation 
Cultivating Moringas and Lucenas along irrigation channels for vegetables eases water pouring and helps you secure sufficient amount of water.	Compost should be put among sprouts. Compost of 200g should be buried at the depth of 10-20cm.

[3] In the case of Moringa, it is recommended to cut Moringas back when they grow up to more than 2m high. Without cutting back, they can topple due to wind, so keeping their height about 2m is better. For this purpose, you had better cut the trunk off at the height of 1m and arrange the shape of the tree with branches.

		
Cut the trunk off at the height of 1m and grow branches.	An innovative farmer's Moringas. Tree height is about 2m	Moringas after cutting off. Back to trees with leaves in half a year.

Lucenas are hardly damaged by pest and insect. Moringas, in contrast, are vulnerable to damages by larvae of ticks and mosses, so proper countermeasures are needed. Basically, the most effective way is use of agrichemicals, but they are so expensive that it is difficult to get. Consequently, use of organic agrichemicals made of soaps and red peppers can be an option.

		
A moss larva that eats Moringa leaves.	Ticks flock to Moringas	Agrichemical perchasable in Djibouti. Expensive, effective.

TOMATO CULTIVATION

Tomato is one of the staple crops in Djibouti. Not just even agricultural beginners can relatively easily cultivate, but nomads highly get interested in it. So, tomato cultivation is indispensable in agricultural development for nomads. Here, the most fundamental points for the cultivation are described.

1. Acquisition of Seeds

You can get tomato seeds in these three ways in Djibouti:

① Buy them in Djibouti city

② Ask some innovative farmers and tomato farmers to sell and/ or share seeds

③ Get seeds distributed at Ambouli's agricultural office.

Regarding ①, one way is to buy seeds at stores in Djibouti city selling vegetable seeds, and the other way is to ask Al-gamil to import seeds. As both ways are expensive, only some innovative farmers can use them. ② and ③ are realistic ways of obtaining seeds for nomads. Regarding ③, Ambouli's agricultural office stocks vegetable seeds given by FAO, and staff of the office distributes them to cooperatives and individual farmers.

2. Cultivation Plan

(1) Cultivation Schedule

The following table is a tomato cultivation schedule. The seedling of tomato grows at the beginning of September when temperature goes down. The seedlings are transplanted in around October and harvested 2-3 months later. Tomato cultivation in summer season is very difficult due to too high temperature, suggesting that nomads that have neither agricultural experiences nor greenhouse facilities have difficulties in doing it. In contrast, as tomato cultivation in winter is popular, tomatoes' market price dramatically goes down in February and March, a season for tomato harvest. If you start tomato cultivation as soon as possible and accelerate a cultivation period, you can sell tomatoes at a relatively high market price.

Cultivation Schedule for tomatoes

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Raising Sprout									■■■			
Transplantation										■■■		
Harvest	■■■	■■■	■■■									

(2) Decision on Cultivation Area and Preparation of Seed Beds

Although the amount of sowing depends on planting density and ridge width, 60g per 10a is a standard. A seed bed of about 4m^2 is sufficient for 30g of seeds. In addition, mosquito nets to protect sprouts from insects and covers to avoid sunshine.

3. How to Cultivate

(1) Raising Sprout

Raising sprout is implemented in the following procedures. Be aware that the procedures assume to make a seed bed of 4m^2. The size of seed beds changes in response to cultivation area.

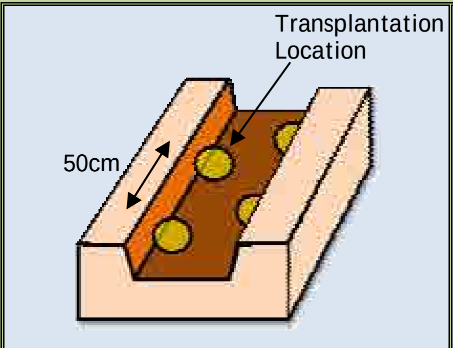
		
1) Plow the planned site for seed beds to the depth of 30cm, and remove large rocks.	2) Put compost of 6kg on bed soils and stir well.	3) Leveling seed beds with rakes, make gutters for sowing every 10 cm.
		
4) Put seeds on the gutters. Be careful to sow seeds evenly.	5) Cover seeds with soils, and softly compact them with hands.	6) Pour water, and cover whole seed beds with blue sheets or sandbags until germination which normally take 1-2 weeks.
		
7) After germination, prevent pest by mosquito nets, and avoid sunshine by date leaves.	8) Frequency of water pouring is once per 2 days. Don't water too much.	9) When sprouts grow up to 20cm high, transplant them.

(2) Transplantation of the seedling is done as follows:

① Location of transplantation: Spaces between seedling is 50cm and seedling should be put on a zigzag line. Try to secure proper spacing by using rulers.

② After digging holes of 20cm depth and 20-30cm wide at every transportation location, put compost of 200g and stir them well. If possible, pour water once and leave them for 3 days to adjust compost to soils.

③ Transplantation should be done after 4pm. Dig seedling up without cutting roots by scoops, transplant them to the farm. After that, compact transplanted parts by hands and feet so that soils adhere to roots.

		
Secure proper spaces among transplantation locations.	You can secure proper spaces with rulers to decide transplantation locations.	Transplantation is a light work women can do.

(3) Cultivation Management and Harvest

Pay attention to the following points

1) <u>Timing for Additional Compost</u>：When the first calyx appears, add 200g of compost among seedlings.

2) <u>Props Preparation</u>： It is difficult to get the props in Djibouti. Cultivation without them, however, will lead to damages to fruits and flowers due to wind and rocks, so it is recommended to substitute dead branches and unnecessary fabrics for connecting props if possible.

3) <u>Irrigation Frequency</u>： You should give water as frequently as possible, because in spite of the fact that it is winter cultivation in relatively cold atmosphere, Djibouti's soils tend to dry up soon due to strong sunshine. It is recommended to water once per 2 days in early morning or evening.

4) <u>Countermeasures against Insects & Pests</u>： As long as you do not use insecticide and pesticide, damages by biting of insects like larvae of mosses, aphids, and leaf miners are basically happened. If you can cultivate good seedlings on seed beds, damages from pests do not severely matter, so the initial cultivation is crucial. Regarding mosses, even organic agrichemicals made of hot peppers and soaps keep them away.

5) <u>Harvest</u>：If it is for self-consumption, harvest timing does not matter, but if it is for sale, you should harvest soon after you find a little red parts on fruits.

		
Use branches as attracting props.	Tobacco budworm eats tomatoes.	If it is for sale, tomatoes with a little red parts must be harvested.

ONION CULTIVATION

Like tomatoes, onions are popularly consumed the most in Djibouti. The fact that agricultural beginners can relatively easily cultivate onions is similar to tomatoes. Compared with other vegetables, onions are easy to stock, which is a positive point of onions. Fundamental ways of onion cultivation are explained here.

１. Cultivation Plan

(1) Cultivation Schedule

Cultivation of onions starts at the beginning of September when temperature goes down. They are transplanted in October, and harvested 4-5 months later. Cultivation in summer should be avoided because of high temperature.

Cultivation Schedule of Onions

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Raising Sprout									■■■			
Transplantation										■■■		
Harvest				■■■	■■■							

(2) Decision on Cultivation Area and Preparation of Seed Beds

Although the amount of sowing depends on planting density and ridge width, 60g per 10a is a standard. A seed bed of about $4m^2$ is sufficient for 30g of seeds. In addition, mosquito nets to protect sprouts from insects and covers to avoid sunshine.

２.How to Cultivate

(1) Raising Seedling

Raising Seedling is implemented in the following procedures. Be aware that the procedures assume to make a seed bed of $4m^2$. The size of seed beds changes in response to cultivation area.

1) Plow the field for seed beds to the depth of 30cm, and remove large rocks. Put the compost of 6kg on bed soils and stir well.

3) Leveling seed beds with rakes, make gutters for sowing every 10 cm.

4) Put seeds on the gutters. Be careful to evenly sow seeds. Cover seeds with soils, and softly compact them with hands.

		
6) Pour water, and cover whole seed beds with blue sheets or sandbags until germination, which will normally take 1-2 weeks.	7) After germination, prevent pest by mosquito nets, and avoid sunshine by date leaves.	When seedlings grow up to 20cm high, transplant them.

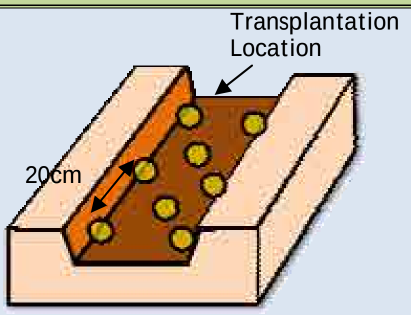
(2) Transplantation

1) Form of ridges: Whether furrow irrigation or basin irrigation, the former is suit for agricultural beginners because leveling of ridges is crucial.

2) Decision on transplantation Location: In the case of furrow irrigation, seedlings should be put on 3 lines with spaces of 20cm among them like below

3) Initial Compost：Put compost on all layers in proportion of 2t/ha.

4) Transplantation should be done after 4pm. Dig seedlings up without cutting roots by scoops, transplant them to a field. After that, compact transplanted parts by hands and feet so that soils adhere to roots.

		
Secure proper spaces among transplantation locations.	After initial compost, dig holes to the depth of 10cm and transplant sprouts.	Transplanting of the onion seedling

(3) Cultivation Management and Harvest

1) Timing for Additional Compost： A month later from planting, scatter the compost of 2t per hectare.

2) Watering Frequency： You should pour water as frequently as possible. It is recommended to pour water at least once per 2 days in early morning or evening.

3) Harvest：If it is for self-consumption, harvest timing does not matter.

OKRA CULTIVATION

Okra is a kind of easily cultivated crops in Djibouti as it is tolerant to heat. Nomads consume okras as ingredients of soups and sell the rest of them. As okra cultivation is easier than other products, okra is suitable for agricultural beginners to try for the first time. Basic procedures of okra cultivation are explained here.

1.Cultivation Plan

(1) Cultivation Schedule

The monthly average temperature of 20-30℃ is the best for growth, blossom, and bearing fruits of okras. As Djibouti's temperature is continuously high through a year, okra cultivation is promising through a year except for excessively hot seasons. Okras normally bloom in 35-60 days after germination, and you can harvest them about 1 week after the blossom.

CultivationSchedule of okras

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Sowing	■■■	■■■	■■■	■■■					■■■	■■■	■■■	■■■
Harvest	■■■	■■■	■■■	■■■	■■■	■■■	■■■					■■■

(2) Decision on Cultivation Area and Sowing Quantity

Although sowing quantity of okras depends on planting density and ridge width, 300-600g per 10a is a standard.

2.How to Cultivate

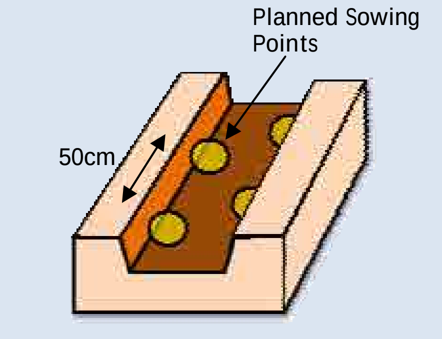
(1) Sowing

Sowing procedures are as follows.

1) Decide sowing points. Spacing among seedling is 50cm, and they should be laid on 1 straight line or 1 zigzag line. Try to secure proper spacing by using rulers.

2) After digging holes of 20cm depth and 20-30cm wide at every transportation location, put compost of 200g and stir them well. If possible, pour water once and leave them for 3 days to adjust compost to soils.

3) After compost, dig small holes of 1cm deep with your fingers on every sowing point. 2-3 seeds per hole are good. By the way, pretreatment for okra seeds (e.g. soaking them into water through a night) will improve okras' germination rate and help them germinate at once.

		
Secure proper spaces among planned sowing points.	Dig holes of 20-30cm deep on planned sowing points, and put compost.	After compost application, sow seeds. 2-3 seeds per 1 sowing point. Remove unnecessary sprouts later.

(3) Cultivation Management and Harvest

1) Removal： Of germinated sprouts, 1-2 sprouts are left and remove others, when sprouts have 4-5 leaves.

2) Timing for Additional Compost：When sprouts start blooming, put compost of 200g among them

3) Watering Frequency：You should water as frequently as possible, because in spite of the fact that it is winter cultivation in relatively cold atmosphere, Djibouti's soils tend to dry up soon due to strong sunshine. It is recommended to pour water once per 2 days in early morning or evening.

4) Countermeasures against Insects & Pests：As long as you do not use agrichemicals, damages by biting of insects like aphids and leaf miners are happened. What is worse, a sprout as a whole can be infected with viruses and this possibly spreads to a whole field. You have to remove every infected sprout soon after you find them.

5) Harvest：Harvest okras when the length of pots reached 7-10cm. After the harvest season, okras will get stiff and get unedible. So, everyday harvest in the harvest season is desirable as long as it is possible.

		
Okra sprouts before removal. Leaving 2 sprouts is acceptable if they receive enough nutrients.	Okras in the harvest season. As long as you can, you should harvest every day.	Okras after the harvest season. Pots are too big to eat.
		
Okra sprouts infected with viruses. Remove all of infected ones.	A tobacco budworm eats okras. Damages on young sprouts can lead to death of them.	Coccoideas eat okras. As they propagate at once, remove a whole sprout soon after you find them.

GLASS CULTIVATION

Grass cultivation in fields is important from a view point of securing feed for livestock especially in drought. Regarding sorghum and maize, as their seeds are purchasable in Djibouti's markets, cultivation of them is very easy. In contrast, it is difficult to get seeds of sudan grass and alfalfa. They just suit for some innovative farmers.

1.Cultivation Plan

(1) Cultivation Schedule

Basically, grass cultivation is possible through a year, but sowing in excessive hot seasons should be avoided. About 3 months later from sowing, sorghum and maize is harvested as grass. On the contrary, you can harvest alfalfa and sudan grass 4-6 times per a year. If you cultivate them on a virgin soil, you are expected to positively cultivate grass and arrange the soil. Besides, cultivation of legume grass that fixes nitrogen allows you to fertilize soils.

Staple Grass cultivated in Djibouti

Kinds of Grass	Annual/Perennnial	Frequency of Harvest per year	Seed Acquisition	Notes
Sorghum	Annual	3-4	Easy	Purchasable at markets
Maize	Annual	3-4	Easy	Purchasable at markets
Crotalaria	Annual	2-3	Difficult	Leguminosae
Sudan grass	Perennnial	4-6	Difficult	Distributed at Ambouli's agricultural office
Alfalfa	Perennnial	4-6	difficult	Leguminosae Distributed at Ambouli's agricultural office

(2) Decision on Cultivation Area and Sowing Quantity

Although sowing quantity depends on planting density and ridge width, standard quantity of sowing seeds per 10a is shown in the right table. In the cases of sorghum, maize, and crotalaria, spaces among sprouts are 20cm, and lay on 2-3 lines. Regarding sudan grass and alfalfa, paired-row seeding and laying seeds on 3 line are assumed.

Sowing Quantity of each Grass

Kinds of Grass	Sowing Quantity
Sorghum	3-6 kg/10a
Maize	3-6 kg/10a
Crotalaria	3-6 kg/10a
Sudan grass	4~8 kg/10a
Alfalfa	4~8 kg/10a

2.How to Cultivate

The following are an explanation of how to cultivate sorghum and sudan grass respectively. How to cultivate maize and crotalaria is the same as sorghum, and alfalfa is the same as sudan grass.

(1) Sorghum

In sorghum cultivation, put compost of 200kg per 10a into prepared ridges. After that, mixing it with soils and leave it for 3 days to adjust compost to soils.

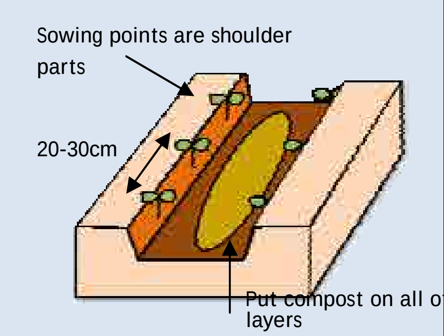
2) After compost, sow sorghum seeds every 20-30cm on 2-3 lines. Seeds should be put on shoulder parts of ridges, not center of them. The number of seeds per sowing point is 4-5. Pretreatment for sorghum seeds (e.g. soaking them into water through a night) will improve sorghum's germination rate and help them germinate at once.

3) You should pour water as frequently as possible, because in spite of the fact that it is winter cultivation in relatively cold atmosphere, Djibouti's soils tend to dry up soon due to strong sunshine. It is recommended to pour water once per 2 days in early morning or evening.

4) When the height of sorghum reached 15-20cm, remove unnecessary grass. Although in the cultivation of sorghum as grass, removal is not such important, leave only 2-3 sprouts per sowing point. In the case of maize, however, only 1 sprout is left because you need to harvest maize fruits.

5) When the height reached 40-50cm, check the color of leaves. If their green color is weakened, add compost. Additional compost of 200kg per 10a should be scattered on ridges.

6) As long as you do not use agrichemicals, sorghum will be affected by aphids and whiteflies. But, countermeasures against such pests do not matter as long as you cultivate sorghum as grass. If, however, smut happens, be aware not to feed them to livestock as infected sorghum is poisonous.

		
How to sow sorghum seeds. Sowing points are shoulder part of ridges.	With rulers, secure proper spacing for sowing	Smut happened in sorghum. Do not feed them to livestock because of poisons.

(2) Sudan grass

1) In cultivation of sudan grass, put compost of 200kg per 10a into prepared ridges. After that, mixing it with soils and leave it for 3 days to adjust compost to soils.

2) After the application of compost, do the paired-row seeding and lay seeds on 2-3 line on a ridge.

3) You should pour water as frequently as possible, because in spite of the fact that it is winter cultivation in relatively cold atmosphere, Djibouti's soils tend to dry up soon due to strong sunshine. It is recommended to pour water once per 2 days in early morning or evening.

4) When the height of sudan grass reached 1m, cut them at the height of 20cm and harvest them. After harvest, check the leaves' color and add compost if green color weakened.

5) As long as you do not use agrichemicals, sudan grass will be affected by aphids and whiteflies. But, countermeasures against such pests do not matter. If, however, smut happens, be aware not to feed them to livestock as infected sorghum is poisonous.

		
Put compost on ridges and stir with soils	Do the paired-row seeding	Harvest when the height reached 1m.

DATE CULTIVATION

Date cultivation is possible in even alkali soils which are often seen in dried areas because it is adjusted to Djibouti's atmosphere and has salinity tolerance. As market price of date fruits is high, it is a promising product. Increment of date production, however, needs high technology such as division of roots. So, in instruction for agricultural beginners, experts' support is crucial. Here, how to divide date roots is mainly explained.

１．Necessary Items

You need to prepare the following items in advance

- Date roots： The easiest way is division of roots from innovative farmers' or agri-business companies' date. Date has male and female, and both are essential for getting fruits. At least 1 male and 1 female must be prepared.
- Sandy soil：Often seen around wadi. The easiest way of finding it is to ask local people appropriate places to gather sandi soil.
- Clay：Like sandy soil, ask local people where to gather.
- Matured compost and immature compost：Prepare them in advance as a lot of them are necessary for transplantation of a date.

Transplantation of date needs a lot of sand, clay, and compost.

Compost, sand, and clay (from the left)

２．Preparation for Transplantation

(1) Decision on transplantation points

Decide transplantation points. In transplantation of several date, spacing of at least 10m is necessary. In selecting transportation locations, be aware of distance from buried irrigator PVC with the growth of date roots in mind. After selection of transportation locations, dig a hole of 100cm deep and 75 cm wide.

Prepare a hole of 100cm deep and 75cm wide.

(2) Picking of date

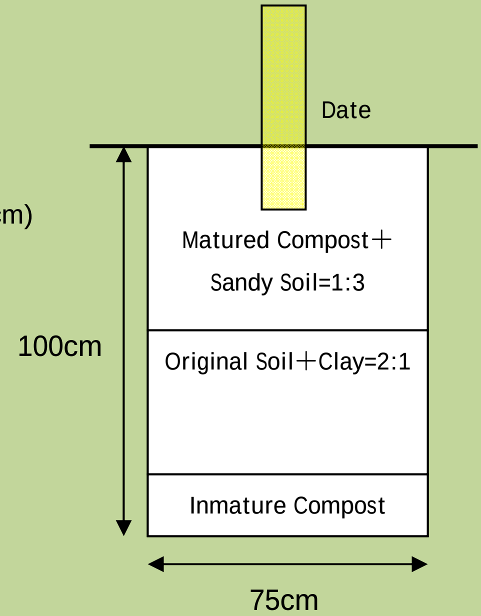
Pick date stock after selecting pickable ones. Ram a post between main stock and sub stock, and divide the sub one from the main one. Be careful not to damage the main one’s roots.

	
Picking of date stock. Not to damage the main stock.	Picked date

3. Transplantation

Transplantation should follow the following procedures

- Put immature compost at the bottom of a hole (about 15cm)
- Mix clay soil and original soil, and put it into the hole (about 40cm)
- Mix compost and sandy soil, and put it into the hole.
  After burying the hole, stir soils while pouring water,
  and leave it for 3 days
- Transplant date stock and pour water
  after compacting soils around the date stock.



	
Put sandy soil into transplantation point.	Transplanted date