5.2 Water Resources and Irrigation

5.2.1 Present Water-Resources Development Situation

5.2.1.1 Water Use

(1) Water Supply (Domestic and Industrial Use)

In recent years, the water supply in Oman has increased rapidly, along with Oman's economic development. Traditionally, water supply sources have been aflaj and hand-dug wells. Nowadays, desalination stations play an important role in water supply in the capital area, while wells and aflaj are still the main water sources in Salalah and the rural areas. The total water supply volume, excluding that from aflaj and private wells, increased from 46.3 m.c.m. in 1986, to 53.9 m.c.m. in 1988. The average annual growth rate in this period was 7.9 %.

In the capital area, the quantity of water available from wells in 1976 was 1.95 m.c.m., but with the first installation of a water desalination plant in Ghubra in 1977 and subsequent expansions, water production increased substantially from 3.1 m.c.m. in 1977, to 31.8 m.c.m. in 1988. In northern Oman, including the capital area, total water production rose from 39.0 m.c.m. in 1986, to 45.7 m.c.m. in 1988. Of that, 87 % was consumed in the capital area in 1988. It is significant that the proportion of annual water supply from wells decreased from 50 % in 1985 to 30 % in 1988.

The water-supply records for each month and seasonal fluctuations of water supply in the capital area are shown in Table 5.2.1 and Figure 5.2.1. The water demand exceeds the annual average water supply in the summer (May - October) but is below it in the winter (December - March). The minimum water consumption per month in a year is about 70 % of that of the maximum per month. No remarkable fluctuations are observed.

In the Southern Region, water production increased from 2.0 m.c.m. in 1977, to 6.8 m.c.m. in 1985, and then to 8.0 m.c.m. in 1988. Wells dominated as water sources, except for a small desalination plant for

Table 5.2.1 Water-Supply Record for Each Month in Capital Area

(Unit: c.m./day)

Year / Month	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988
January	16,732	23,053	31,543	38,846	42,630	49,449	62,295	77,825	87,063	89,380
February	17,648	24,857	33,007	37,992	44,064	58,254	67,118	73,970	89,183	95,921
March	18,360	26,719	38,788	36,632	46,736	58,878	68,395	81,095	90,436	105,057
April	19,305	28,958	28,155	39,808	46,975	63,735	75,524	91,223	95,951	110,998
May	21,264	32,159	38,362	44,727	55,725	36,955	81,813	101,654	114,735	118,577
June	23,185	34,944	41,505	52,612	63,599	47,854	82,237	101,149	116,393	123,212
July	25,120	32,071	41,823	47,630	57,309	65,257	84,629	103,737	119,384	113,533
August	23,801	32,834	41,765	47,674	54,347	47,454	82,429	100,159	111,333	115,234
September	24,139	33,580	42,005	48,991	56,476	44,217	87,995	104,043	111,786	114,983
October	24,372	33,127	41,633	48,569	59,083	47,484	91,184	102,916	107,110	113,899
November	24,185	36,338	29,973	45,657	59,492	64,462	85,162	98,406	101,588	107,801
December	22,554	28,625	35,649	42,116	52,822	64,172	81,637	86,843	92,929	99,953
Annual average	21,722	30,605	37,017	44,271	53,271	54,014	79,202	93,585	103,158	109,046

Source: Statsitical Year Book 1985, 1989, Development Council

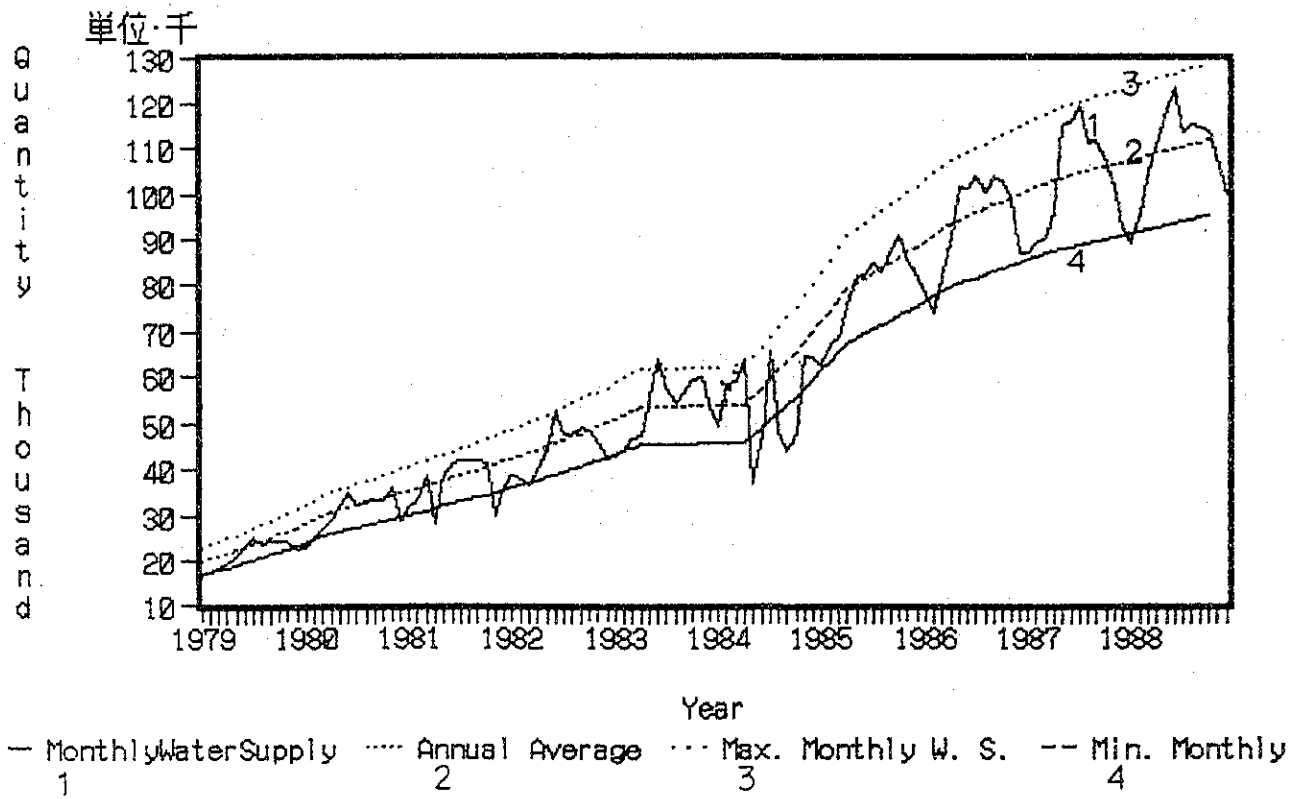


Figure 5.2.1 Seasonal Fluctuation of Water Supply in Capital Area

brackish water at Dhalqut.

(2) Agricultural Water Use

The amount of water used for agriculture is difficult to measure conclusively. A lot of estimates have been made by studies concerned with water resources development. In 1982, PAWR (the predecessor to the Ministry of Water Resources) estimated that 1,260 m.c.m. of water was used for agriculture. Figures of 0.065 m.c.m. a year per hectare (6,500 mm/year) and 0.032 m.c.m. a year per hectare (3,200 mm/year) were used in calculating water use for agricultural lands watered by aflaj and by wells, respectively. On the other hand, 380 m.c.m. per year for agricultural use, which is one-fourth of the former result, was estimated by Hydroconsult in 1985. Arthur D. Little International Inc. estimated total agricultural water demand in 1985 at 2,184 m.c.m., in which 395 m.c.m. per year was consumed for alfalfa production. These estimates do not take into account the potential for reuse of water.

In 1986, JICA reported that the annual average amount of water used from 1983 to 1984, in the Batinah coast area (about 10,000 ha) was approximately 233 m.c.m., most of which was consumed by irrigation. This was based on actual records taken from hydrological observation networks established by a technical cooperation scheme of the Japanese government. As a result of the survey, annual water use was estimated at 3,000 mm/year in mountainous areas and 2,258 mm/year in coastal areas.

The estimates for groundwater use vary widely. Given the uncertainties, agricultural water use on a regional basis was estimated in order to identify the general trends in Oman, taking into account the characteristics of cropping patterns, irrigation methods in each agricultural region, results of the above-mentioned JICA study and regional recharge dam study reports submitted by MacDonald in 1989, and data on cultivated areas from MAF.

As shown in Table 5.2.2, annual agricultural water use in 1985 and 1988 was estimated to be 1,132 m.c.m. and 1,295 m.c.m., respectively. The annual growth rate was 4.6 % and approximately 53 % of the total

Table 5.2.2 Annual Agricultural Water Use

Year / Region	Pattern	1985		1986		1987		1988	
		Cultivated Area (ha)	Water Use (thousand c.m./year)	Cultivated Area (ha)	Water Use (thousand c.m./year)	Cultivated Area (ha)	Water Use (thousand c.m./year)	Cultivated Area (ha)	Water Use (thousand c.m./year)
North Batinah	A	12,872	283,184	13,384	294,448	13,995	307,890	14,605	321,310
South Batinah	A	14,667	322,674	15,219	334,818	15,920	350,240	16,602	365,244
Sharqiya	C	7,490	179,760	7,829	187,896	8,215	197,160	8,615	206,760
Dakhliya(Wusta)	B	1,816	54,480	1,911	57,330	2,005	60,150	2,109	63,270
Dakhliya	B	4,804	144,120	5,071	152,130	5,329	159,870	5,619	168,570
Dhahira	C	4,850	116,400	5,085	122,040	5,338	128,112	5,603	134,472
Al Janubiya	C	1,303	31,272	1,359	32,616	1,424	34,176	1,488	35,712
Total		47,802	1,131,890	49,858	1,181,278	52,226	1,237,598	54,641	1,295,338

agricultural water was consumed in the Batinah Region. Agricultural operations account for more than 92 % of the water used in Oman.

Estimates of agricultural water use are as follows:

Pattern A: Annual consumption: 2,200 mm/year
Crops: tree crops like date palms, limes, mangoes, etc. alfalfa, vegetables, etc. grown in combination. Date palms are cultivated more than other major crops.
Water source: wells
Region: North Batinah, South Batinah

Pattern B: Annual consumption: 3,000 mm/year
Crops: tree crops like date palms, limes, mangoes, etc. alfalfa, vegetables, etc. grown in combination. The ratio of alfalfa to dates is higher than that in Pattern A.
Water source: aflaj
Region: Dakhliya (Interior, Wasta)

Pattern C: Annual consumption: 2,400 mm/year
Crops: tree crops like date palms, limes, mangoes, etc. alfalfa, vegetables, etc. grown in combination. Cropping pattern is between Pattern A and Pattern B.
Water source: wells
Region: Sharqiya, Dhahira, Al Janubiya

(3) Availability of Groundwater

Most of Oman is arid. Annual rainfall is about 130 mm, except for desert areas. Potential evaporation is quite high, around 2,000 mm/yr. Surface run-off flows out to sea quickly as mountains are not covered by vegetation and their surface soil layer is thin. Perennial rivers, therefore, do not exist. Water resources are basically equivalent to groundwater resources. Most of the surface flow from catchment areas in

the mountains percolates underground at the foot of the mountains.

It is important to estimate the availability of groundwater resources to assess the potential for agricultural development. As explained in section 5.2.1.1 (2), estimates of agricultural water use vary widely. In addition, uncertainty about groundwater-recharge rates and surface run-off rates makes it difficult to estimate available water resources accurately. Groundwater endowments, however, have been estimated in order to understand the recent general trend of groundwater availability in Oman. This was done using the results of past studies, and a medium year's rainfall. The result is 1,240 m.c.m/yr. However, agricultural operations require 1,309 m.c.m/yr. Water supply and agriculture combined require 1,323 m.c.m/yr (see Table 5.2.3).

These calculations indicate that there are few groundwater resources available for development. More effective water conservation methods are required in most areas before groundwater-resources development will be possible.

General trends of regional water balance are as follows:

(a) Batinah Region indicates serious overdrafting as seen in areas where salinization occurs.

(b) Dhahira Region is reasonably balanced.

(c) Dakhliya Region shows signs of overdrafting.

(d) Sharqiya Region might have additional available groundwater resources.

(e) Salalah Region reveals great disparity of available water resources, i.e. considerable additional water resources are available in some areas although salinization has already occurred in the central Salalah Plain.

These regional assessments are also depicted on maps, namely

Table 5.2.3 Regional Groundwater Balance

Region Number	Region Name	Catchment Area (km2)	Mean Annual Precipitation (mm)	Mean Annual Precipitation (MCM)	Runoff Rate (%)	Catchment Runoff (MCM)	Flood Loss (MCM)	Gr.Water Recharge (MCM)	Estimated Agri.Use (MCM)	Water Supply (MCM)	Gr.Water Balance (MCM)
1	N.Batinah	4,860	137	665.82	40.0	266.3	26.1	240.2	321.3	0.0	-81.1
2	S.Batinah	7,757	125	969.63	35.0	339.4	22.5	316.9	428.5	8.7	-120.3
3	Dhahira	7,143	135	964.31	20.0	192.9	56.3	136.6	134.5	0.6	1.5
4	Dakhliya	4,280	168	719.04	30.0	215.7	58.3	157.4	168.6	3.2	-14.4
5	Sharqiya	10,597	105	1,112.69	25.0	278.2	46.2	232.0	206.8	1.1	24.1
6	Musandam	693	255	176.72	20.0	35.3	5.3	30.0	13.4	0.2	16.4
7	Al Janubiya	3,655	156	570.18	25.0	142.5	15.8	126.7	35.7	0.0	91.0
Total		38,985	133	5,178.37	28.4	1,470.3	230.5	1,239.8	1,308.8	13.8	-82.8

'Regional Availability of Groundwater to Support Additional Agricultural Development in Oman' (scale: 1/500,000) drawn by MWR. These assessments are made on a regional basis. New water-resources development in catchment basins of individual wadi will be possible following a further, detailed water-balance study to be conducted by MWR. The results will be very useful in planning future water-resources development.

Circulating groundwater in shallow aquifers is considered above. Therefore, the quantity of groundwater in deep tertiary limestone aquifers is not included. One of the potential areas for agricultural development is Nejd, where non-renewable groundwater is widely available. The volume of fresh water able to be extracted economically and reliably is estimated to be 10 m.c.m/yr, although its total availability is estimated to be about 80,000 m.c.m. Fossil water has to be carefully developed from a long-term point of view because of its non-renewable nature.

Another potential area for groundwater-resources development is the deep aquifers in the tertiary limestone in northern Oman, especially on the Batinah coast. Detailed investigations have not yet been completed, so only the possibility for development potential can be indicated at this stage.

There is one exception to this process of groundwater development. No attempts can be made to utilize the brackish water (more than E.C. 6,000 micro mho/cm) which is underneath the desert areas. It is impossible to plant ordinary crops there due to the water's high salinity, so it will be necessary to select special, more tolerant species.

5.2.1.2 Water-Resources-Utilization System

The present situation and the constraints affecting aflaj, wells and recharge dams are described below.

(1) Aflaj

(a) Present Situation

The aflaj of Oman have provided communities with water for domestic and irrigation purposes for 1,500 - 2,000 years. They are the dominant, traditional means of obtaining water in all areas of northern Oman except for the Batinah coast. Many of them in operation at present are over a thousand years old, and some may even date back to the fifth century B.C. They are controlled by well established social and financial structures which have evolved from ancient times.

From the standpoint of spontaneous water management, which takes into account the seasonal fluctuations of water flow, falaj systems adapt themselves very well to the amount of water flow, especially in dry season. Water from a falaj is utilized for farm irrigation at the end of the system, where date palm trees are major crops and seasonal crops such as wheat, alfalfa etc. are cultivated around date palm trees in wet seasons. In dry seasons, however, seasonal crops are not cultivated and water is mostly allocated to the date palm trees which are traditionally so important to the Omani.

A falaj consists of a tunnel which taps groundwater and brings it the surface for distribution to crops and households. The sources of falaj water are classified as follows:

(i) natural springs from alluvial and fractured bedrock
(ii) perennial wadi flow
(iii) groundwater contained in wadi gravel (beneath both present-day and former wadi courses), and often fractured bedrock layers as well.

Each falaj system comprises three basic sections:

(i) water-collecting section;
(ii) water-conveyance section; and
(iii) water-distributing section;

Spring-fed aflaj are directly connected to a relatively long

conveyance section that is normally a lined-surface channel. As discharges from these sources are in some cases small, tanks are constructed at the end of the collection section to store the water until specified levels are obtained.

In a falaj utilizing perennial surface flows of a wadi, the flow is diverted into an open shallow channel either by building a low weir across part of the wadi or by a short collector gallery. Under local law it is an offense to bar the wadi flow completely in order to obtain irrigation water.

The third falaj resource, groundwater contained in the wadi gravel or fractured bedrock, is tapped by means of a series of underground channels that reach the water source from various directions. These falaj systems are often up to 30 m below the surface in the vicinity of the mother well and in some cases over 50 m below the surface at the mother well. They convey water through a closed channel under ground and an open channel to an oasis located several kilometers downstream. The underground section of the falaj comprises a rectangular tunnel whose width varies from 0.5 m to 1.0 m with heights of between 0.5 m and 2.0 m. Vertical access shafts are dug approximately every 20 meters for ventilation during excavation and for removal of debris. To maintain the underground water-collecting section and carry out major repairs, administrations and finances for aflaj are required. Although the total number of aflaj is unknown, it is estimated that there are more than 4,000. MAF lists names of around 2,000 aflaj and the locations of 300 aflaj are indicated on a map prepared by the Department of Surveys.

(b) Problems

In the past twenty years, Oman has achieved rapid economic growth and this has brought with it major socio-economic changes. Unfortunately, the traditional institution of the falaj systems has not really been able to keep up with these changes. The following problems have occurred in recent years.

(i) Shortage of maintenance funds

Income increases in rural communities have often led landholders who have insufficient water rights to irrigate the crops they wish to grow to establish private wells instead of using falaj water. The decrease in the number of participants has caused a shortage of funds, because the maintenance fund for a falaj depends on the lease of its water.

(ii) Lack of local labor

The creation of job opportunities in the cities has driven people of working age away from rural areas. Even though they come back, they usually do not work unless they are paid high wages. This lack of a labor force results in infrequent communal maintenance work on the aflaj.

In addition to these problems, aflaj face physical and institutional constraints as follows:

(i) Decline of groundwater table

Recent establishment of pumping wells has caused a decline of the groundwater table where falaj water is collected, so that its water flow is adversely affected.

(ii) Difficulty of flexible water management when introducing new crops

The traditional arrangement for water use in which water is distributed based on eight or sixteen day rotation intervals makes it difficult to grow highly valued vegetables such as watermelons, fruit, and spices on falaj land.

(iii) Water losses in falaj water distribution systems

Water losses in a falaj system are attributed primarily to un-lined, inefficient channels and water distribution which follows no sequence from one farm to the next. It is likely to be especially difficult to adjust the water rotation system without offending water-right holders, since water-rights are hereditary and personal property.

(iv) Inefficiency of mechanization on farm

The introduction of agricultural machinery into farming to fill the labor shortage is difficult because the small size of the farms prevents suitable mechanization.

(2) Wells

(a) Present Situation

There are two types of wells in the country. One is the hand-dug well which can be seen mainly in the coastal areas at Batinah and Salalah. This type of well may be older than the aflaj but was not the focus for agricultural purposes before the introduction of the diesel engine driven pump. This type of well is more than 1 m in diameter and is rarely more than 20 m deep, which makes it applicable mainly to the unconfined groundwater in shallow aquifers.

The other is a drilled well which supplies water to most of the drinking water supply systems. This type of well has been introduced to agriculture relatively recently, but it has spread rapidly, mainly on the Batinah coastal plain. This type of well is between 0.2 m to 0.3 m in diameter and usually about 50 m deep, but exceeds 100 m in some cases. It is intended mainly for unconfined groundwater but sometimes taps into semi-confined groundwater. It is drilled mainly by the rotary method.

Since wells are private property, no water management system is currently possible to prevent excessive pumping. The actual number of wells is not known for certain, although it is roughly estimated at 40,000, based on the number of pumps sold. Of these, 30,000 wells are the hand-dug type. However, the number of drilled wells is increasing.

(b) Problems

The following three items can be pointed out as major problems

in utilization of wells:

(i) Reduced function of old hand-dug wells

Since most of the hand-dug wells were constructed quite a long time ago, there are many wells where the well wall is severely damaged or the well has become shallow due to deposits at the bottom. MAF has extended a subsidy to rehabilitate these old wells under the Third Five-year Development Plan. Unfortunately, further support shall be required in the future.

(ii) Lowering of groundwater table

Lowering of the groundwater table is observed in various inland areas due to the proliferation of drilled wells. This has resulted in reducing the functionability of the existing aflaj and hand-dug wells, and of drilled wells themselves. As the reason is clearly over-pumping, it is important to take practical measures against this.

(iii) Sea-water intrusion

Over-pumping in the coastal plain does not reduce the groundwater table as rapidly as observed in inland areas, but instead induces sea-water intrusion. Considerable areas have already suffered from salinization and it is particularly serious in the vicinity of Barka on the Batinah coast and in Salalah.

(3) Recharge Dams

(a) Present Situation

In order to increase agricultural production, the government investigated the viability of artificial groundwater-recharge methods and proposed the construction of recharge dams in the Second Five-year Development Plan. In 1983, the construction of Al Khawd Dam commenced as a pilot project, and subsequently Hilti/Salahi Dam and Wadi Quriyat Dam were also begun. In parallel with these operations, a preliminary survey for a countrywide recharge-dam plan was

conducted. It identified 58 proposed recharge-dam sites, including the existing ones. Observing the effect of the three pilot projects, three recharge dams, i.e. Wadi Al Jizzi, Wadi Ghul and Wadi Tanuf have been completed under the Third Five-year Development Plan, and currently the final designs of four dams in the Barka/Rumais area have been prepared. One of them is now under construction. Three dams in other areas are under construction as well.

The existing recharge dams are the rockfill type in which a compacted sand core is covered with bulky stones. Important parts of the dam are protected with metallic gabion baskets or concrete facing. The highest dam is about 20 m. The crest length of some of the dams is as long as 9 km. The first three dams were located on the Batinah coast (two dams) and in Dakhliya (one dam) and constructed relatively far downstream of the respective wadi. The three dams constructed later were located on the Batinah coast (one dam), and in the Dakhliya (two dams). They were constructed relatively far upstream compared with the first dams. The dam being constructed on the Batinah coast is located downstream, like the first ones.

(b) Problems and Some Considerations

In planning the existing recharge dams, flood discharge from both the catchment area and the downstream aquifer were studied to the extent possible. However, since basic data, such as precipitation and river discharge were generally not fully available, it was rather difficult to estimate the dams' effectiveness beforehand. Accordingly, it is vital to analyze the observation records obtainable from the existing dams and to use the results in planning new projects. In order to analyze the effects of the recharge dam, the hydrological records observed before the construction of the dam are essential; unfortunately, studies were seldom conducted. Therefore, it is strongly recommended that such observations be performed prior to the construction of more dams.

Artificial recharge volume is often discussed as a means of

identifying the effect of a recharge dam. This evaluation factor may be sufficient to estimate the volume needed to supplement the deficiencies of the water balance in the coastal area where sea water intrudes. In order to determine the increase of the potential water resource in inland areas, however, other factors such as increased groundwater table must be considered. In any case, a considerable amount of data has been made available by the initially constructed dams. Therefore, these data must be analyzed and the results applied to the fullest possible extent to future projects.

Some of the existing dams have been constructed at locations relatively distant from the mountain foot. Basically, the choice of such locations shall be studied after results of that decision are obtained and evaluated. In general, the infiltration capacity is higher in areas closer to the mountain foot, which suggests that the farther upstream the recharge dam is the larger its effect will be.

5.2.2 Irrigation

5.2.2.1 Present Situation

(1) Irrigated Area

There are no statistics regarding the extent of irrigated area in the country except in the First Agricultural Census of 1978-79.

Table 5.2.4 shows the estimated area equipped with irrigation systems as compared to the total area irrigated by region. 65 % of the total area was supplied with irrigation systems; 26 % of the total irrigated area was irrigated by aflaj and 67 % by wells (see Table 5.2.5). At present it is roughly calculated by MAF that about 50 % of the area is irrigated by aflaj, and the remaining 50 % by wells.

(2) Irrigation System Efficiency

Several studies have been conducted with regard to irrigation system

Table 5.2.4 Estimated Area Equipped with Irrigation Systems

(Unit: ha)

Region	Total area	Area supplied with irrigation systems			Area not equipped with irrigation systems
		Total area	Irrigated	Not irrigated	
Batinah & Capital	46,126.08	25,400.10	21,121.98	4,278.12	20,725.98
Mussandam	1,120.46	1,120.46	903.98	216.48	0.00
Hajar Al Gharbi	2,623.72	2,623.28	1,892.00	731.28	0.44
Hajar Al Sharqiya	1,955.58	1,685.20	1,211.32	473.88	270.38
Jqh & Buraimi	1,312.52	1,312.52	795.30	517.22	0.00
Al Dahira	7,202.36	5,953.42	2,584.78	3,368.64	1,248.94
Oman Interior	14,494.92	8,045.84	4,341.26	3,704.58	6,449.08
Sharqiya & Gaal	5,817.68	5,769.06	3,866.06	1,903.00	48.62
Dhofar	2,706.66	2,486.88	1,594.78	892.10	219.78
Total	83,359.98	54,396.76	38,311.46	16,085.30	28,963.22

Source: First Agricultural Census, 1978-79

Table 5.2.5 Distribution of Irrigation Area by Irrigation Source by Region

(Unit: ha)

Region	Total area	Area irrigated by				More than 1 source
		Falaj	Well	Spring	Rain	
Batinah & Capital	21,112.96	2,935.46	17,697.24	72.16	198.88	209.22
Mussandam	1,324.84	0.00	1,252.68	0.00	40.92	31.24
Hajar Al Gharbi	1,901.02	1,627.56	104.50	3.30	1.10	164.56
Hajar Al Sharqiya	10,010.44	788.04	9,152.88	0.00	3.96	65.56
Jqh & Buraimi	785.30	581.24	132.66	11.44	0.00	69.96
Al Dahira	2,603.48	1,364.88	559.24	0.00	3.08	676.28
Oman Interior	4,337.52	2,244.44	1,010.46	1.54	0.00	1081.08
Sharqiya & Gaal	3,883.44	2,868.36	508.64	21.12	1.32	484.00
Dhofar	1,826.00	0.00	1,586.20	11.00	228.80	0.00
Total	47,795.00	12,409.98	32,004.50	120.56	478.06	2,781.90

Source: First Agricultural Census, 1978-79

Table 5.2.6 Irrigation System Efficiency

System	Irrigation Efficiency		
Traditional	45%	40%	30%
Traditional lined canals	65%	-	-
Piped supply and flood	70%	-	-
Modern sprinkler (pump)	75%	60%	60%
Drip/Trickle	85%	80%	85%

Source: Hydroconsult(1985), Arthur Little(1985), Atkins(1989)

efficiency. Generally speaking, traditional flood irrigation systems are unlikely to rise above an irrigation efficiency rate of 65 % and are more likely, given unlined canals and uneven basins, to drop to 30 - 45 %. The efficiencies of modern irrigation systems like sprinklers, and drip are 70 - 85 % (see Table 5.2.6).

The most common irrigation system in Oman is flood irrigation. This is the process of applying water at a point at the edge of a field, and allowing gravity and hydrostatic pressure to spread the flow across and down the field. Its irrigation efficiency, as mentioned above, varies from 30 % to 65 % (and from 30 % to 45 % if an unlined channel is used). The application efficiency of flood irrigation is, naturally, reduced by the over-irrigation which is necessary in order to adequately irrigate the least watered area, i.e. the farthest area from the intake of a field.

(3) Introduction of Modern Irrigation Systems

In order to rationalize agricultural water consumption, MAF has adopted financial subsidies and policies to encourage farmers to use modern irrigation systems and to teach them about the benefits and required water for each crop.

A Royal Decree regarding adopting modern irrigation systems in Batinah was issued on July 23rd, 1989 (Royal Decree 72/89). It decreed that MAF and MWR shall issue, under the authority of each ministry and subject to the approval of the ministers' cabinet, the necessary regulations and resolutions for the adoption of modern irrigation systems in the Batinah Region.

MAF is carrying out two detailed integrated studies in Batinah with regard to the introduction of modern irrigation. One is the "Study of a New Organization of Irrigation in Barka-Rumais Area in View of the Conservation of Water Resources and Optimization of Their Use" and the other is the "FAO/MAF Soil Survey Project". The primary objective of the former study is to draw some conclusions on the optimum organizational set-up for water resources control in the area in order to ensure the protection of land and groundwater against salinization. The principal

aim of the FAO/MAF study is to determine cropping policies from an economic perspective in Batinah. It also includes an analysis of the existing irrigation systems at farm level.

Modern irrigation systems such as bubbler, sprinkler, center pivot and trickle have been installed in some newly established modern farms and have achieved higher agricultural productivity. Small farmers, however, hardly ever use them. The main reasons for this are that farmers do not understand the importance of saving water, even though a Royal Decree was issued on the subject, nor do they have the capital or knowledge required to install the modern systems. Another constraint is the shortage of instructors to teach the correct water management methods to them. OBAF is financing instruction by private contractors for farmers. Extension services, however, from private contractors and extension officers are not sufficient to foster whole-hearted participation.

5.2.3 Administration for Water-Resources Development

5.2.3.1 Governmental Organizations Concerning Water-Resources Development

Ministries concerned with water-resources development and their responsibilities are as follows.

(1) Ministry of Water Resources

(a) To be responsible for the development and maintenance of water resources in the Sultanate.
(b) To propose general policies for the formulation of a long-term water plan in line with the socio-economic plan of the country and submit the same for government approval.

(2) Ministry of Agriculture and Fisheries

(a) To organize and manage agricultural water use.
(b) To supervise maintenance work on aflaj, wells and springs.
(c) To construct groundwater-recharge dams in order to provide

necessary water for agricultural development.

(d) To save farmland from erosion and damage due to flooding from nearby wadi by erecting suitable protection.

(e) To provide the statistics and survey data on aflaj, wells, springs and dams.

(3) Ministry of Electricity and Water

(a) To construct desalinization plants for the water supply in the Capital area and to control their operation and maintenance.

(b) To construct pump stations, storage tanks, and to expand the pipeline network in the Capital area.

(c) To expand water-distribution networks in major cities.

(d) To provide potable water to rural areas.

(4) Office of the Minister of State and Wali of Dhofar, Directorate General of Water Supply and Transport

(a) To construct pump stations, storage tanks, and to expand the pipeline network in Salalah.

(b) To expand water-distribution networks in major cities of Dhofar.

(5) Ministry of Defense

(a) To supply water to military bases.

5.2.3.2 Legislation and Regulation

The Sultanate depends heavily on groundwater resources, and these are obtained by means of wells and aflaj. Due to the scarcity of rainfall, the groundwater level in aquifers is subject to change. Considerable attention has been paid to conserving water resources by applying laws, regulations and issuing Royal Decrees.

MWR (formerly PAWR) has been responsible for issuing permits for the drilling of new wells, in accordance with rules concerning restricted areas and specifying distances from mother wells of aflaj.

A Royal Decree regarding water resources as a national wealth was issued in November, 1988 (Royal Decree No.82/88). It decreed that:

(1) The water resources of the Sultanate shall be considered as a national wealth. The government shall direct its utilization such that it serves agricultural and developmental plans. All the aquifers which exist at the time of this decree or those which appear later shall be considered as water storage in this sense, regardless of the owner of the land which is irrigated by the storage.

(2) The use of the water resources of the Sultanate shall follow rules which regulate its utilization in such a manner which does not affect the available amounts. Such regulations shall specify aquifers, areas which benefit from them, their passages and rules for their use and distribution.

(3) MWR and MAF shall coordinate with the office of the Deputy Chairman for Legal Affairs, in the preparation of the regulations for the execution of this decree.

MWR is preparing a national water resources master plan for sustainable development, management and conservation of the water resources of the Sultanate. This master plan will comprise the following components:

(1) Conceptual planning for mathematical modeling.
(2) Recommendations for new projects with suggested priority.
(3) Assessment of existing demand and projection of future demand.
(4) Identification of constraints on development.
(5) Identification of policy options for water resources management.
(6) Recommendation on legal framework.
(7) Proposal for institutional changes.

5.2.3.3 Coordination between MAF and MWR

Many studies have been carried out by MAF in the field of agricultural development. Studies of land resources and water resources are indispensable for agricultural development. Without proper water-resource studies, deliberate agricultural development plans cannot be worked out. Therefore, coordination with MWR is very important for MAF in expanding new farmland and ensuring the availability and suitability of water for irrigation in a nation-wide water-resources development and conservation framework.

5.2.4 Development Potential

5.2.4.1 View of Water Irrigation and Dams

On the whole, the potential for large-scale water-resource development is low in the Sultanate of Oman, although there are viable places for it in some regions. Therefore emphasis should be placed on improving water-use efficiency. In the meantime, action to augment the quantity of groundwater should be taken from a medium-term point of view. The following four subjects are important in planning irrigation and dam projects.

(1) Water conservation.
(2) Augmentation of available groundwater resources.
(3) Utilization of new water-resources.
(4) Establishment of a legal framework.

It will be most effective if these subjects are integrated.

5.2.4.2 Water Conservation

The hydrologic observation project on the Batinah coast, conducted by JICA, concluded that groundwater was overdrafted by 21 % more than the calculated water requirements that assumed 80 % irrigation efficiency. If 20 % of the annual agricultural water used, i.e. 1,295 M.C.M. as estimated

in section 5.2.1 is conserved, 259 M.C.M/yr should be available. If the conserved water was used, alfalfa could be planted in 8,600 ha or vegetables could be cultivated in 17,300 ha, assuming that water requirements of alfalfa and vegetables are 30,000 CM/ha/yr and 15,000 CM/ha/yr, respectively. Taking into account the fact that the total cultivated area in Oman was estimated to be 54,600 ha in 1988, it is obvious that water saving methods could create a great potential for new agricultural developments and water conservation. It will take, however, a long time to complete water saving programs since they need the understanding and cooperation of farmers who are, in general, conservative and do not pay much attention to optimizing water management. Modern irrigation will be easier to install in well irrigation systems than falaj systems, from social and institutional aspects.

(1) Installation of Modern Irrigation Systems

Flood irrigation is the most common irrigation method in Oman. Its irrigation efficiency is generally estimated to be 30 to 40 %. Efficiency could be doubled by introducing new irrigation methods such as bubbler, sprinkler and trickle i.e. up to 60 to 80 %. This would result in doubling available arable land with the same amount of water presently utilized for agriculture. At the same time, water balance deficits in overdrafted areas could be made up for by reducing groundwater discharge. New irrigation systems are, therefore, a promising solution on the Batinah coast, where sea-water intrusion occurs.

Modern irrigation systems save water and improve agricultural productivity by means of properly controlling the amounts of water used. Furthermore, manpower required for time-consuming water management is reduced. Organizing and managing the use of agricultural water are important duties for MAF, so emphasis should be placed on improving irrigation systems, which will play an important role in improving agricultural production and conserving water resources.

(2) Improvement of Irrigation Efficiency in Falaj Systems

(a) Constraints to Falaj System

Falaj systems are traditional, and therefore, well established irrigation systems unique to Oman. They consumed about 70 % of the total water used in 1982 (PAWR: Water Usage of the Sultanate of Oman). Their role should be considered carefully when water-saving programs are worked out.

Aflaj are well suited to closed, and self-sufficient societies so several problems, mentioned in section 5.2.1, arose in the relatively open society brought about by rapid economic growth. Maintenance problems in the transporting section and the collecting section can be resolved by the 'Maintenance and Repair of Aflaj Project', which is entirely subsidized by MAF. However, the resolution of physical and institutional problems in oases, which is crucial to improving irrigation efficiency, is mandated to local falaj organizations. It is likely that MAF will have to persuade farmers to adopt appropriate water-management systems, although each falaj organization ought to select one by itself. Modern irrigation should not be required to replace the falaj system. Ways of re-instating and utilizing the advantages of traditional falaj systems, and of rectifying their disadvantages, little by little should be considered. The following are difficulties to be solved.

(i) Improvement of distribution channels.
(ii) Effective usage of surplus water in wet seasons.
(iii) Rebuilding of efficient water-distribution systems in oases.

The first two subjects will not be difficult to resolve from a technical standpoint. The most difficult subject is the third one. It is impossible to introduce modern irrigation systems before traditional water-distribution systems are rebuilt.

(b) An Example of How to Improve the Efficiency of Water-Distribution Systems

An example of a present-day distribution system and an improved system is schematically shown in a simplified manner Figure 5.2.2.

The assumptions are as follows;

(i) Messrs. A,B,C,D, have their own fields (1,2), (3,4), (5,7,9), (6,8), respectively.

(ii) Water is distributed to each field in sequence from 1 to 9 through a complex network of earth channels.

The following pertain;

- One 'athar' is allocated to each field, but the price of each 'athar' is different.
- The sizes of the fields are almost the same
- Perennial crops are planted in the fields

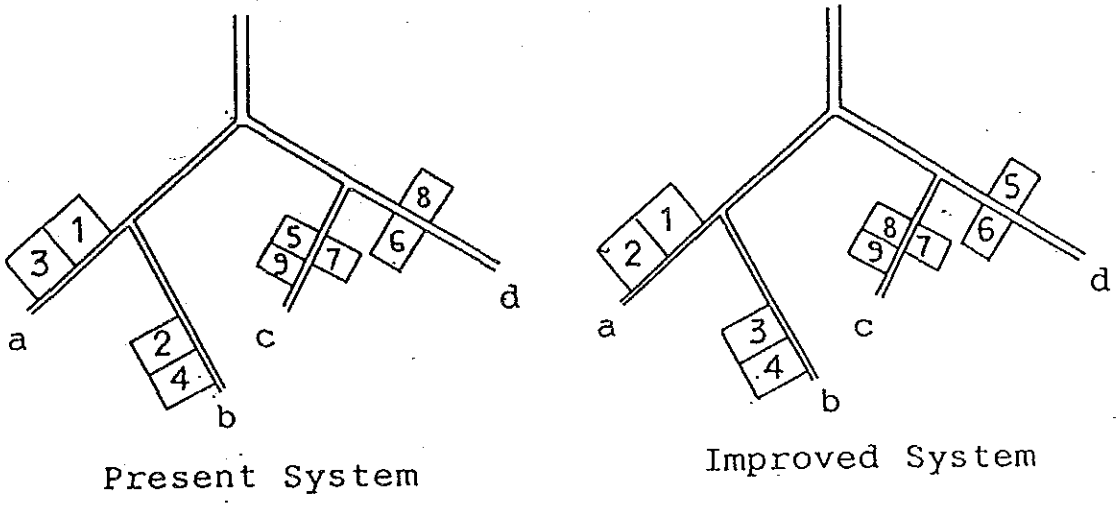


Figure 5.2.2 Schematic Diagram of Water Distribution System

(i) Case I: Land exchange between Mr. A and Mr. B

Mr. A distributes water to fields 1 and 2. Subsequently, Mr. B irrigates fields 3 and 4. Water, therefore, flows in channels a and b in turn and is lost in the earthen conveyance channel. The water, however, would be smoothly rotated and efficiently conveyed if Mr. A and Mr. B exchanged fields 2 and 3 with a settlement of the differences of land prices. The following are the primary procedures:

- Line distribution channels a and b, and improve intake facilities in order to preserve equal conditions when distributing water among the owners concerned.

- Estimate land prices of 2 and 3 on a fixed and fair basis.

- Settle the difference between prices. The land owner who has the less valuable land pays the balance to the other.

(ii) Case II: Water rights exchange between Mr. C and Mr. D

Mr. C has three 'athar' to irrigate fields 5, 7 and 9. The two 'athar' of Mr. D are allocated for fields 6 and 8. Water, therefore, goes into channels c and d in turn. Water losses increase during this rotation. An efficient system, however, would be established if the water rights of Mr. C were exchanged with those of Mr. D.

Main Procedures are as follows:

- Line distribution channels c and d, and improve intake facilities in order to preserve physically equal conditions among the owners concerned.

- Estimate the prices of water rights 5 and 8 on a fixed and fair scale.

- Settle the difference of prices. The owner who has cheaper water right pays the balance to the other.

The third case is a combination of Cases I and II. It will be very complicated and meticulous work if there are many water rights owners. In Japan, for example, a systematic and fair land exchange method has been established. However, this kind of program could not be accomplished without the understanding and cooperation of water right owners.

5.2.4.3 Augmentation of Groundwater

It extremely important to rationalize irrigation methods and to refrain from wasting water resources, and also to augment groundwater from a medium-term viewpoint. The combination of the following three subjects, taking into account regional situations, will have a profound effect on efforts to increase groundwater.

- Increase groundwater recharge.

- Store essential groundwater outflow.

- Rationalize groundwater-intake facilities.

(1) Groundwater Recharge

Recharge dams are the most common way of augmenting groundwater in Oman. The primary idea of a recharge dam is to dam surface run-off, which flows out to sea or into the desert, discharge it little by little according to the infiltration capacity downstream, and thus recharge groundwater. Six dams have already been constructed in both the Batinah coast and Interior by 1990. It will become even more important to connect the construction of recharge dams with recharged-water usage. One of the main objectives in constructing recharge dams is agricultural land development. It is, therefore, vital that implementation of agricultural

development projects such as modern irrigation projects, which help to improve agricultural production, be carefully planned within the limits of the replenished groundwater.

The dams which have been constructed were pilot projects to monitor recharge effects. MAF is monitoring and collecting hydrological data for the purpose of analyzing recharge effects and establishing proper maintenance and operation procedures.

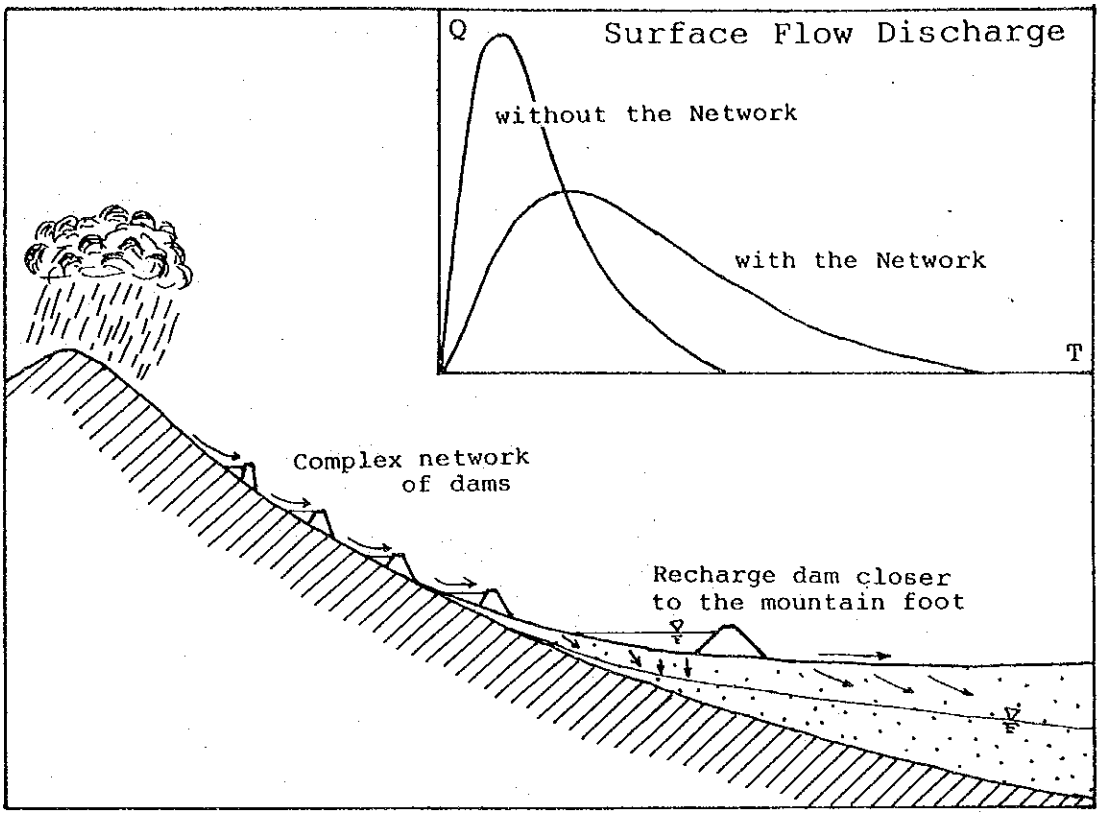
The special feature of recharge dams constructed to date is that in most cases they are downstream of the wadi and stores the entire peak discharge temporarily. Considering the importance of groundwater-recharge schemes, there is a need to study every kind of potential recharge techniques depending on the characteristics of each dam site.

An example of a possible method is the combined dam network as follows:

The special feature of the dam network is that it utilizes a group of small dams at the downstream of the wadi to combine functions of sediment run-off, groundwater recharge and flood control. The upstream dams would function mainly to control sediment run-off with storage function to steadily increase for dams downstream. Run-off would be stabilized by controlling peak discharge, and natural recharge capacity downstream would be maximized. (Figure 5.2.3)

Simple dam construction of gabions, etc. would be used with dam site and type to be determined according to run-off characteristics. Figure 5.2.3 shows some examples of dam types. Type A is constructed on solid basement. The other three types will be suitable for poor ground. When dam catchment becomes blocked with sediment, the dam will continue to function as an artificial aquifer. Another small dam would then be constructed either upstream or downstream.

(2) Storage of Essential Groundwater



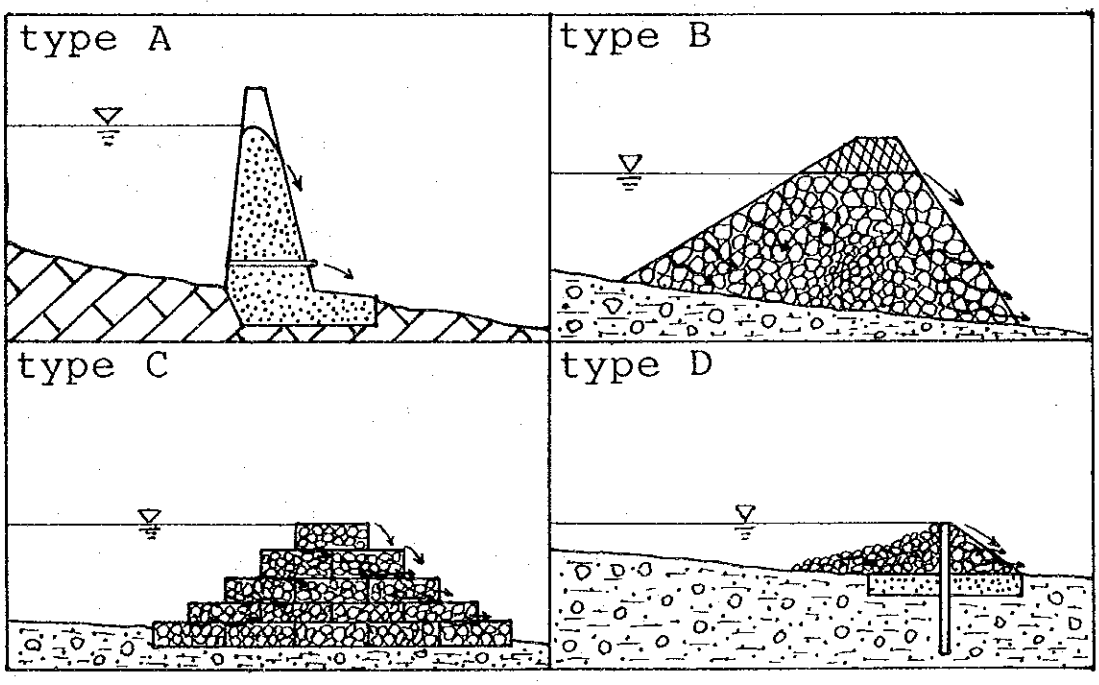


Figure 5.2.3 Combined Dam Network

Recharge dams are one of the methods by which to increase groundwater by making surface flow percolate into the ground. It is very beneficial for a groundwater-recharge method to store essential outflow to the sea or desert. Every year, even if there is no rain, large quantities of essential groundwater flow out to the sea and into the desert. Artificially recharged groundwater might also be escaping.

This essential outflow is allowed in the following cases;

- A thin and widespread aquifer, for which it is difficult for an ordinary pump to extract groundwater.

- Where it is necessary to allow a certain amount of essential groundwater outflow in order to protect against sea-water intrusion.

Taking these two points into account, if essential groundwater outflow can be avoided to the extent possible, considerably large amounts of water resources could be reserved.

A sub-surface dam (underground dam) is another effective method for retaining essential groundwater outflow. It can dam groundwater and store it behind a cut-off wall which extends down from near the ground surface to the basement, provided an appropriate underground valley fenced by an impermeable basement stratum is identified. By this method it is possible to create an artificial spring under certain conditions.

It can prevent sea-water intrusion along the coast as well. If the impermeable basement is so deep that construction of high sub-surface dams is not economical, then low sub-surface dams should be considered. These will also contribute to the reduction of sea-water intrusion. If they are used in combination with recharge dams, this will further increase their effect. Sub-surface dams, the bottoms of which, the cut-off walls, are sealed to the basement have already been constructed and made excellent use of in Japan.

In planning sub-surface dams, hydrogeological surveys play an

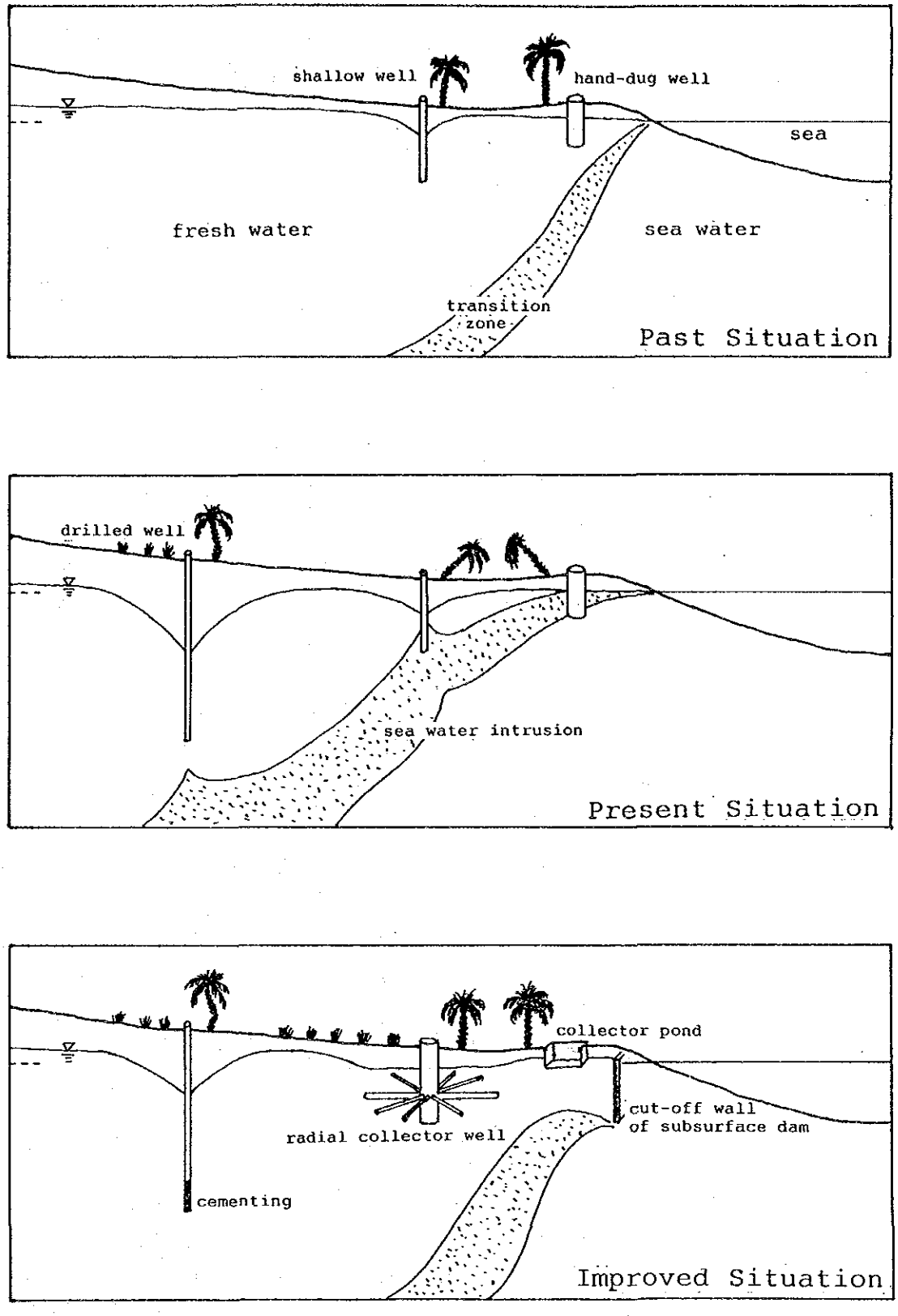


Figure 5.2.4 Effect of Subsurface Dam

extremely important role. First of all, test drillings are required in order to select an appropriate project site and identify aquifer constants, etc. Then, detailed data analysis and computer simulation in utilizing adequate hydrogeological data must be performed to ensure that the dam is designed properly.

Since there are a number of uncertainties with regard to implementing a sub-surface dam project in Oman, a survey to identify proper dam sites should be initiated. Subsequently, a pilot project to construct a sub-surface dam can be considered.

(3) Diversification of Well-Type

Hand-dug wells and drilled wells are common in Oman. As a result, the country is suffering from a decline of the groundwater table and salinization caused by overdrafting of groundwater. For the sake of water-resources conservation, the following three types of wells are considered more favorable.

- collector pond

- collector culvert

- radial collector well

The first type, because of its shallow depth and wide basement is preferable to hand-dug wells along the coast where deepening wells cause sea-water intrusion into the wells because the underground sea-water table is lowered. It is, however, necessary to take proper measures to prevent evaporation of surface water. This type is effective in collecting groundwater from permeable aquifers as well.

The second type is an application of the technique utilized in the collecting component of the falaj system. It is an alternative to hand-dug wells in wadis. The collector culvert is able to collect river bed water flowing under wadis.

The third type should be applied to drilled wells in overdrafted areas. It does not cause a drastic lowering of the groundwater table. Aflaj and hand-dug wells around it, therefore, will not be adversely affected.

Adoption of these three types of wells is a short-term solution as it only eases constraints occurring in limited areas. It should be understood that they will not contribute significantly to an improvement of the long-term groundwater balance. In addition, since drilling costs for these well-types are rather high compared with those of existing wells, individual users will probably not be able to install them. They should be utilized as public wells which serve several farms, and will probably require some sort of official assistance.

5.2.4.4 Utilization of New Water-Resources

It takes time from a study phase to realize agricultural production which utilizes groundwater reserved by recharge dams and sub-surface dams. Other new groundwater-resources-utilization techniques which yield more immediate results and therefore can be readily incorporated into regional development are also important.

There are some promising areas for new agricultural development using shallow aquifers. Examples are as follows:

- Wadi Dayqah (near Quriyat)
- Wadi Bani Khalid (near Al Kamil)
- Wadi Andam (near Mudaybi)
- Wadi Darbat (near Taqah, Salalah)

Optimum water-resources utilization methods in each wadi should be considered, taking into account their individual hydrogeological features. Some detailed agricultural development surveys in each wadi have already

been begun by MAF. A preliminary study on the Al Kamil area was conducted in 1983. However, because of the increase of groundwater use in the area after the study, a review is probably necessary. Feasibility studies on the Buraimi area and the L'Ajrid area have been completed. The former study concentrated on regional water balance. The latter requires a water balance analysis of the wadi as the next step.

At the same time, groundwater in deep aquifers, which has not been fully developed should be tapped by drilling deep wells. It is, however, not necessary to install pumps with high heads in comparison with the depths of the wells themselves since deep groundwater is mostly confined, and are sometimes artesian wells. As examples of this kind of new water-resources development, fossil-water developments in Nejd and the tapping of groundwater in the tertiary limestone which lies under the Batinah coast are promising. The information necessary for agricultural development in Nejd has been accumulated insufficient and development should proceed as quickly as possible. Further investigation, however, on the Batinah coast is necessary to identify precise potential for agricultural development.

It is necessary to conduct a proper study for the Batinah coast as early as possible, because of its important role in agricultural production.

5.2.4.5 Establishment of Legal Framework

The major reason for water resources constraints is inappropriate water use. Agricultural water use accounts for more than 90 % of total water consumption. Rationalization of water use must be adopted. H.M. Sultan Qaboos bin Said issued a Royal Decree in 1988 which stated that water resources are a national wealth. Since then, water-resources conservation has become an important subject: the permission of MWR is necessary to drill new wells, and drilling wells within 3.5 km of mother wells of aflaj is prohibited. Since the lowering of the groundwater table and sea-water intrusion result from over-pumping, the easiest measure to counter this is to regulate water pumping. MWR is studying the legal

framework required.

It is necessary for MWR to establish a conservation and development strategy for each drainage basin on the basis of deliberate water-balance control, i.e. to establish a groundwater control framework for each drainage basin taking long-term forecasts of water supply and demand into consideration as well as the physical characteristics and social conditions of agricultural communities. MAF is in a position to make the utmost effort to maintain and improve agricultural productivity. Under these circumstances, the most effective and important policy that MAF should take is to create an efficient water-conservation scheme on farms, and facilitate water-saving management and the installation of modern irrigation systems. Oman must save water in order to improve productivity.

Heightening farmer willingness to improve their irrigation systems will be most effective in trying to popularize water-saving irrigation. Certain incentives are necessary. One of them is the provision of subsidy. As a good example clearly showing the effect of subsidization, it can be cited that, after the commencement of a subsidy program for pumps, the installation of pumps increased drastically, and it declined sharply as well after the termination of the subsidy program.

Provision of subsidies which oblige farmers to save agricultural water and to install flow meters in order to report to extension officers their water consumption with kinds of crops cultivated, will contribute to the expansion of modern irrigation systems and the extension of water-management technology to farmers. It will be even more effective if such assistance is applied in those areas where the water balance is negative, and where wells are the main water source.

5.3 Cultivation

5.3.1 Progress of the Third Plan

MAF is carrying out a "Master Plan for the Development of Date Palm Cultivation" project, the progress rate of which indicates that it will be approximately 16 percent complete by the end of 1989. This project, in the sector of the cultivation, focuses on various activities such as a date palm survey, a cause of deterioration survey, introducing better-suited varieties and superior cultivation methods to each region (including reforestation, appropriate planting density, pollination, pest control, and intercropping), etc.

5.3.2 Cultivated Crops

(1) Characteristics of Cultivated Crops

The most common cultivated crop in the country is the date palm. It occupies approximately 45 percent of the entire cultivated area. The date palm is the traditional crop in northern Oman and constitutes an important part of the Omani diet. The second largest cultivated area is for alfalfa. The cultivation of alfalfa in southern Oman, where the livestock industry prevails, corresponds to only 4 percent of the entire cultivated area of alfalfa in the country. One of the typical cultivated crops which illustrates marked climatic differences between southern and northern Oman is the coconut palm. Three major crops - coconuts, bananas and alfalfa - occupy nearly 60 percent of the entire cultivated area in southern Oman. Although by far the most common cultivated crop in northern Oman is the date palm, there is actually a great variety of cultivated crops. The cultivated area of major crops is shown in Table 5.3.1.

(2) Kinds of Cultivated Crops

(a) Fruit Trees

Fruit trees occupy approximately 65 percent of the entire cultivated

Table 5.3.1 Acreage and Percentage of Area Cultivated for Each Major Crop

Crops		North Oman	Southern Region	Total	Rate of cultivated area(%)
1.	Vegetables	5903	137	6040	11.0
	Tomato	1189	23	1212	2.2
	Chili pepper	595	15	610	1.1
	Onion	552	8	560	1.0
	Garlic	150	0	150	0.3
	Okra	51	2	53	0.1
	Watermelon	1225	25	1250	2.3
	Sweet-melon	613	12	625	1.1
	Cabbage	740	30	770	1.4
	Cucumber	650	20	670	1.2
	Potato	138	2	140	0.3
2.	Field crops	9326	321	9647	17.7
	Wheat	468	0	468	0.9
	Alfalfa	8449	321	8770	16.1
	Tabacco	409	0	409	0.7
3.	Fruits	31657	646	32303	59.1
	Dates	24095	75	24170	44.2
	Limes	2378	22	2400	4.4
	Mango	3775	5	3780	6.9
	Banana	1409	216	1625	3.0
	Coconut	0	328	328	0.6
4.	Other crops	6267	384	6651	12.2
	Total	53153	1488	54641	100.0

Table 5.3.2 Crops Treated by the Ministry with Insecticides for Plant Protection

Crops	1986	1987	1988
Field crops(ha)	13123	11460	14326
Vegetable crops(ha)	50545	34122	32411
Fruit trees(Number)	2231618	1417981	1135159

crop area, and the area for date palms account for nearly 75 percent of all the fruit trees. The number of major varieties of date palms is about 10. The most important ones are Fardh, which is the most prevalent, Khalaseh, Khisaab, Barni, Khenize, Khalas, Madlouki, Mabsali, Hilali, etc. All of them are fruit type, and have a specific color and season for maturing. The areas cultivated for mangoes and limes are next to date palms in rank. It is believed that both of these are of Indian or Malayan origin and have been cultivated in Oman for many years. Mango varieties are Neelum, Baneshan, Mulgoa, etc. The lime is called Omani lime. It is a local variety and is used for juice the same way a lemon is. Dried limes are used for seasoning and spice.

Four crops - the three mentioned above and bananas - occupy nearly 93 percent of the area cultivated for fruit trees. Other major fruits are papayas, pomegranates, guavas, apples, quince, grapes, plums, apricots, walnuts, figs, and almonds.

Each fruit prevails in a specific region. Limes, for example, in inland areas; coconuts, bananas and papayas in Salalah; pomegranates, apples, walnuts and other temperate fruit in mountainous areas (Jabal Akhdar). On Royal Razat Farm, various kinds of tropical fruit, which are rarely found in the rest of the country, are cultivated or experimented with.

(b) Vegetables

Vegetables occupy slightly more than 15 percent of the entire cultivated area, and again various kinds are cultivated. Watermelons and tomatoes are remarkable for their cultivated area which corresponds to slightly more than 25 percent of the entire vegetable crop. Other major kinds are cabbage, cucumbers, sweet-melons, chili peppers, onions; although, the total cultivated areas for all seven of these vegetables is still only slightly more than 60 percent of the entire vegetable crop.

The major crops other than the above are garlic, potatoes, okra,

eggplants, squash, pumpkins, carrots, cauliflower, radishes, turnips, lettuce, spinach, leeks, beans, peas, etc. Potato production has recently been recommended in North and South Batinah where land and water resources are still available. The area cultivated for vegetables has increased by nearly 44 percent since 1983/84. On commercial farms such as the Oman Modern Farm, the Oman Sun Farm, etc. vegetables with higher market values are being enthusiastically cultivated.

Each kind of vegetable prevails in a more or less specific region, for example, okra in South Batinah, and onions and garlic in the Interior and Dhahira.

(c) Field Crops

Field crops are classified into upland crops and forage crops. Major upland crops are sorghum and wheat. In particular, the area cultivated for wheat has increased by 48 percent since 1983/84. The areas where wheat production has increased are mainly in the interior, particularly Nizwa, Bahla, Wadi Quriyat, Rustaq, etc., because of the available water and dry climate which is relatively appropriate for wheat cultivation.

Other than the above crops, barley, maize, cowpeas, chickpeas, etc., are cultivated. Barley and maize are also used as green fodder. Upland crops also prevail in specific regions, for example, wheat in the Interior, Dhahira and Sharqiya, and sorghum in northern Oman.

With regard to forage crops, alfalfa is by far the most-cultivated, occupying more than 80 percent the total area devoted to field crops, and cultivated on the most farms.

The production area has increased by as much as 40 percent since 1983/84. MAF recently recommended the production of Rhodes grass, which is superior to alfalfa in terms of drought and, salinity tolerance, and yield. The area cultivated for this grass is increasing, especially on commercial farms such as the Dhofar Cattle

Feed Company and the Oman Sun Farm.

(d) Industrial Crops

Industrial crops consist mainly of tobacco, sugar cane, and cotton. However, the area cultivated for these is still small. Tobacco prevails in North Batinah as frankincense does in the Southern Region. Coffee is being cultivated under experimental conditions on the plateau of the Southern Region.

(e) Flowers and Others

Roses are cultivated to produce rose water at Jabal Akhdar. Rasasi Farm & Gardens, Maabela Flora & Fauna, Al-Miskiry Trading & Constructing Co., and other commercial farms import and sell many kinds of ornamental plants such as croton, dracaena, caratea, and others. Royal Razat Farm produces vegetables mainly but also grows flowers, flowering trees, ornamental plants, succulent plants, etc., and has recently decided to cultivate orchids.

(3) Development Potential

Among those crops cultivated in the country are temperate vegetables, tropical fruit trees, flowers, and ornamental plants. They are deemed useful for the future development of agricultural management.

From the viewpoint of the short-term development, the major crops which will contribute to improving the farming economy in northern Oman will be tomatoes, watermelons, sweet-melons, cucumbers, squash, cabbage, cauliflower, potatoes, eggplants, onions, garlic, chili peppers, sweet peppers, okra, carrots, lettuce, beans, alfalfa, Rhodes grass, sorghum, cowpeas, etc. While in Southern Oman, in addition to the above, bananas, coconuts, papayas, sweet potatoes, etc. are also promising. Other major crops which, from a national point of view, can not be neglected, regardless of their present situation in the economy, are wheat, barley, date palms, limes and other citrus, mangoes, guava, etc.

Regarding seed production, there is further possibility on the Dhofar plateau of the Southern Region and Jabal Akhdar of northern Oman of producing potatoes and in the Interior, producing onions, carrots, chilly peppers, etc. Rain-fed cultivation will also be viable for sweet corn, upland rice, etc. In the mountainous area (Jabal Akhdar), in addition to the production of various temperate vegetables and temperate fruit trees during the off-crop season, vernalization will be feasible by temporarily planting strawberry seedlings in the summer for cultivation in the plain area. With respect to the utilization of brackish water and damaged land due to salt injury, the introduction of appropriate crops and the expansion of cultivatable land are worth examining, since there are various salt tolerant and drought tolerant crops such as coconuts, Rhodes grass, sisal, Burbank's spineless cactus (Opuntia ficus - indica), Atriplex, Salicornia, etc.

5.3.3 Cropping System

(1) Present Situation

(a) Northern Oman

The cropping pattern is generally monoculture on new large scale farms and commercial farms. However, on small-scale traditional farms, there are many cases where intercropping has been adopted to grow feed crops, etc. beneath and between the date palms. Crops of this kind are primarily barley, sorghum, alfalfa, etc.

Most of the one-season crops in the north of Oman are cultivated in the winter season which starts at the beginning of September and ends at the end of March, since that is when a little extra precipitation is available and the temperature stays relatively low. The farmers generally employ single cropping systems, a typical example of which is illustrated in Figure 5.3.1. As is clearly depicted in the figure, almost all crops are seeded from July to November and harvested from November to April the next year, except watermelons and sweet-melons which are generally seeded in January and February

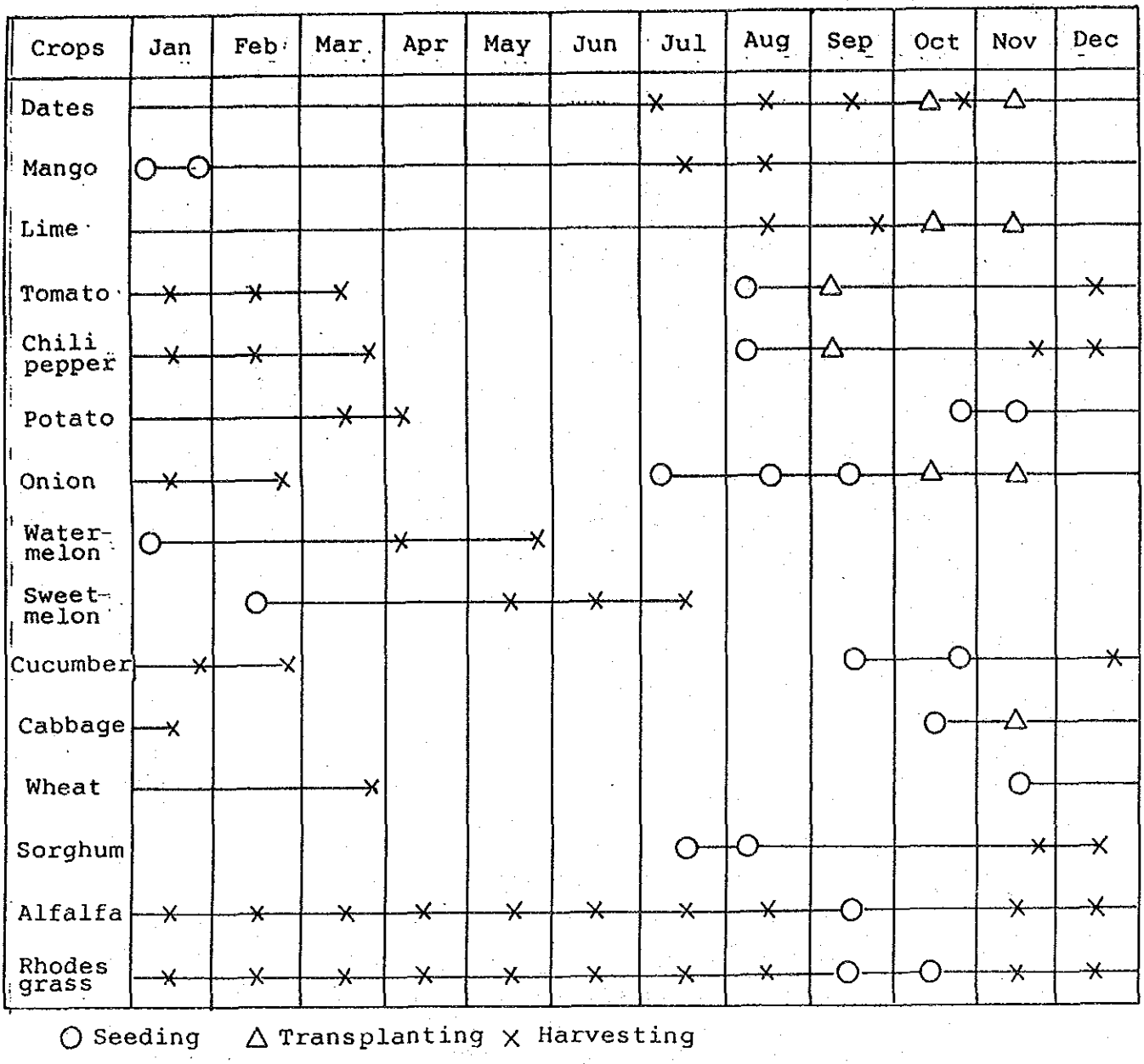


Figure 5.3.1 Example of Cropping Season of Major Crops in North Batinah Region

and are harvested from April to July.

Extremely high temperatures and the dry climate in summer which inhibit cropping can be cited as a reason for the single cropping system employed by farmers.

Nevertheless, some commercial farms such as the Oman Modern Farm, conduct double cropping with a cropping intensity of 150 percent. One such example is presented in Figure 5.3.2, wherein cabbage is cultivated as an autumn and winter crop, after spring and summer crops such as sweet-melons, watermelons and squash.

It seems there is no definite crop rotation pattern in the country; although, extension centers have prepared model patterns and endeavor to propagate them. One such model pattern is as shown in Figure 5.3.3. It aims to avoid continuous cropping of the same family of crops and to maintain soil fertility by introducing leguminous crops the year before planting a crop which requires high nourishment. In this example, vegetable and field crops are proposed separately in different rotation patterns. It is likely that the simultaneous combination of those in one rotation pattern will be considered as more preferable. This idea is also accepted by experts in the field.

(b) Southern Region

In the Salalah area of the Southern Region, the summer (from the middle of June to the middle of September) is the rainy season, affected by southwest monsoons. Annual average rainfall is between 140 - 370 mm, depending on the place. The maximum monthly average temperature is not extremely high during the hottest season (May to July), 29.9 degrees centigrade on the plain (at Razat Farm) and 24.7 degrees centigrade on the plateau of the Dhofar mountains (at Medinat Al-Haq). In the winter, the minimum monthly average temperature is relatively high, 20.9 degrees centigrade on the plain and 18.7 degrees centigrade on the plateau. This relatively moderate climate enables farmers in these areas to cultivate one season crop through the entire year, if irrigation water is available. Some even

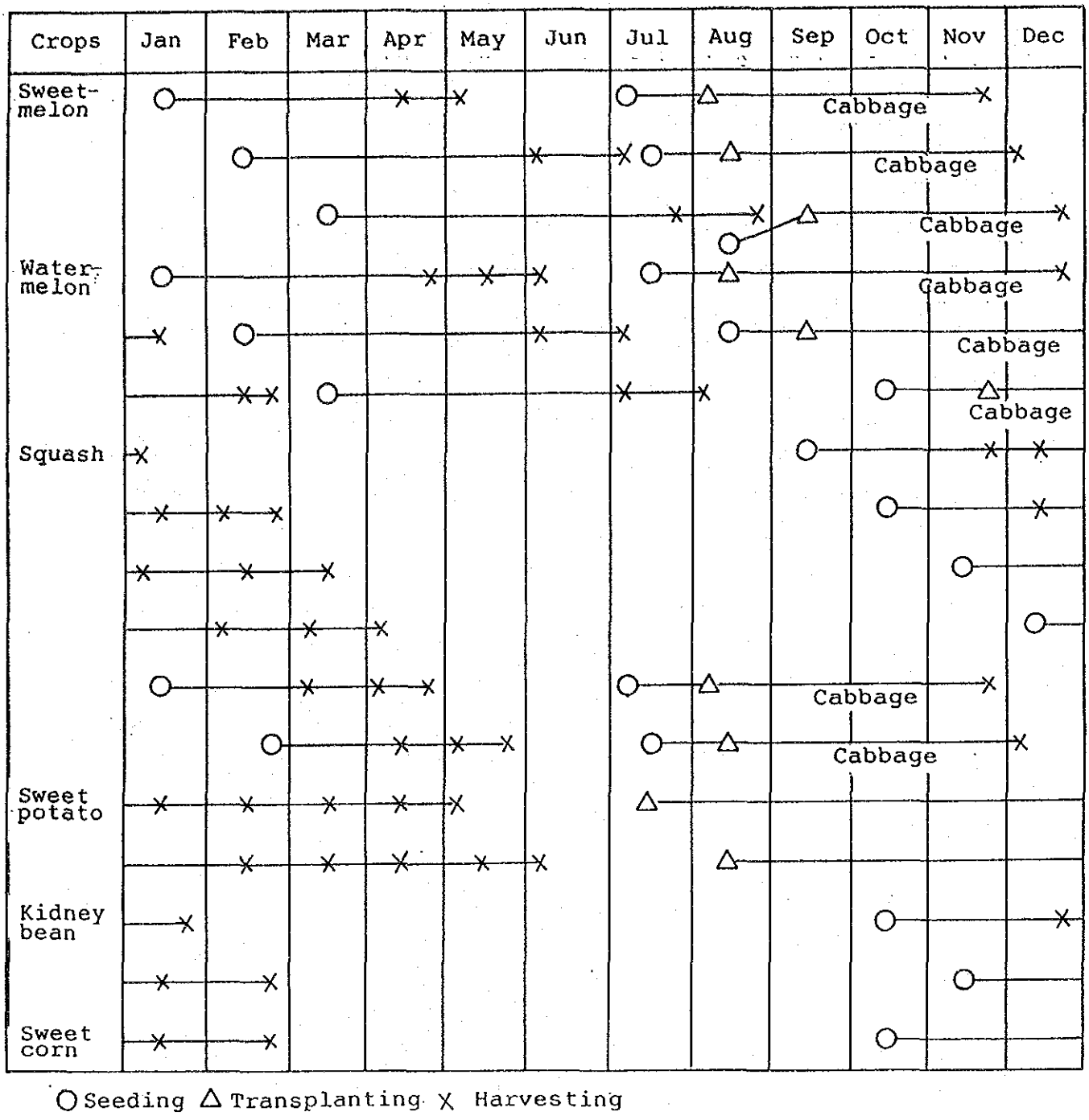


Figure 5.3.2 Example of Cropping Season in Double Croppings in the Oman Modern Farm

Field	No.	1st year	2nd year	3rd year
	1	Tomato, Potato, etc.	Watermelon, cucumber, etc.	Legume crop
	2	Watermelon, cucumber, etc.	Legume crop	Tomato, Potato, etc.
	3	Legume crop	Tomato, Potato, etc.	Watermelon, cucumber, etc.
	1	Wheat, Barley, etc.	Ground nut, Chick-pea, etc.	Maize, Sorghum, etc.
	2	Ground nut, Cow-pea, etc.	Sorghum, Maize, etc	Wheat, Barley, etc.

Figure 5.3.3 Example of Crop Rotation Patterns in Sharqiya Region

cultivate twice a year, particularly watermelons, sweet-melons, cucumbers and okra as depicted in Figure 5.3.4. Besides the crops above, Royal Razat Farm produces tomatoes, eggplants, chili peppers, carrots, cabbage, cauliflower, squash, etc. throughout the year. Another particular feature of the Southern Region is the fact that alfalfa has to be re-seeded every year unlike in the northern Oman where it can be cultivated semi-perennially. The reason for the deterioration of alfalfa in April or rainy season is unclear and this needs further study.

On the plateau, rain-fed cultivation of cow-pea, sorghum, local feed grass, etc. is conducted in the rainy season in the limited upland areas enclosed with stone fences. This type of cultivation may be the only exceptional case of the methods of water utilization in agriculture in Oman.

(2) Development Potential

With regard to cropping patterns, incremental production can be achieved through intercropping, mixed cropping, double cropping, and appropriate crop rotation. Intercropping and mixed cropping have been carried out traditionally in areas under and between coconut palms and date palms, but further promotion is still quite possible.

Double cropping has been carried out actively by the commercial farms, however, small farmers have not yet practiced it in most areas except Salalah, where only a few crops are double cropped. Large increases in double cropping are definitely possible, with a special focus on vegetables.

Crop rotation is essential to maintaining soil fertility, to prevent the prevalence of crop pests and to continue production of high quality crops. Guides for crop-rotation have been produced by the ministry but not actually practiced yet by farmers. It is advisable to systematically introduce a marigold, effective in controlling soil nematodes, and a crotalaria which is effective in suppressing soil nematoda population density and as a green manure. A rational crop-rotation system should be

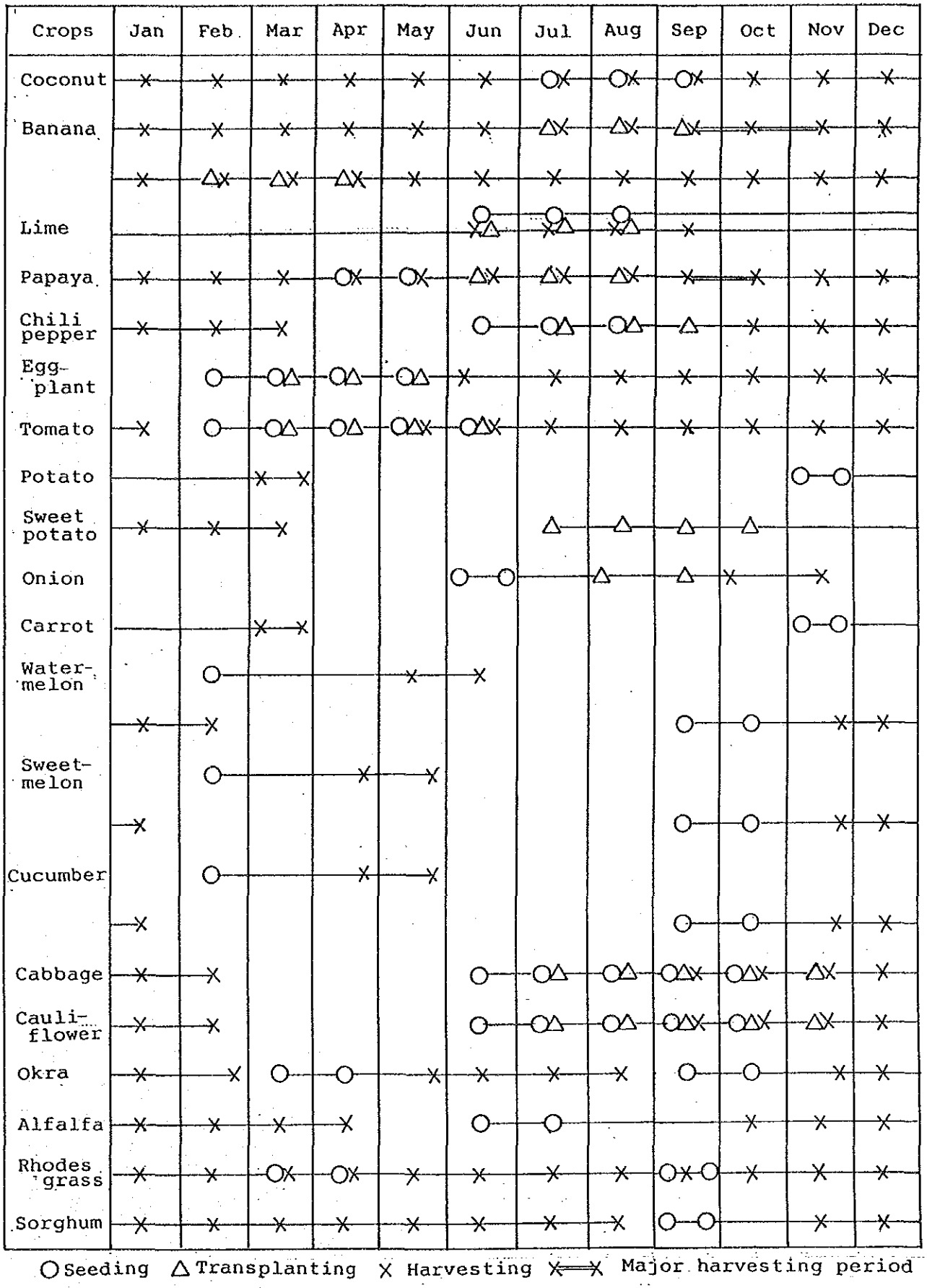


Figure 5.3.4 Example of Cropping Season of Major Crops in Southern Region

widely used, especially for vegetables and field crops.

5.3.4 Cultivation Methods

(1) Present Situation

In general, productivity and quality of crops vary considerably by varieties. MAF endeavors to introduce and distribute high quality, disease-tolerant, productive varieties which are fairly easy to cultivate, but the majority of fruit trees and field crops are still local varieties. In alfalfa fields, there are some plants which are noticeably less prone to developing disease symptoms among plants affected by a virus. This fact suggests the practicability of breeding disease-resistant strains in the future.

Plowing and land preparation -- except for very small areas -- are generally carried out by tractor. Threshing of wheat is also done by mechanical threshers, rarely by a combine. While fertilization, seeding, transplanting, weeding, harvesting, etc., are done manually. Since manual pollination of tall date palms has always required intensive labor, MAF has developed and is recommending the use of a pollen duster for such work. Required cultivation parameters and techniques for major crops are presented in manuals prepared by the extension centers.

Fertilization strongly influences crop production. MAF has prepared fertilization criteria and has been trying to promote them among farmers, however, application rates of fertilizers by farmers is still less than 50 percent of the amount recommended.

Some of the large farms and commercial farms carry out weeding by tractor or garden tractor with implements attached for intertillage and weeding; however, they still employ manual labor for weeding between plants. Small farms still employ intensive labor for all weeding. Herbicides have been used by commercial farms but not yet by the small farms.

(2) Development Potential

There are various ways of improving productivity through the introduction of quality varieties, adjustment of cropping time, improvement of cultivation type, use of new material, labor saving methods, etc. With respect to fruit trees and field crops, there are some areas where large areas are occupied by less productive varieties. In such cases, the introduction of a high-quality variety, recommended by MAF will definitely increase production.

Moreover, the adjustment of cropping time is a very effective method for alleviating losses through excessive production during an ordinary production period. Such adjustments will be rather easy in Salalah, but not in northern Oman. On the other hand, shading plants and shading nets would be useful. The major harvesting time in Salalah and the mountainous area (Jabal Akhdar) corresponds with the post-harvest period in northern Oman. Considering this seasonal difference, an annual crop supply would be possible if a suitable transportation system existed.

At present, cucumbers, tomatoes, etc. are cultivated without using a support stick. The expansion of vertical cultivation by use of such plant-supportive material will greatly contribute to efficient land use, easy pest control and higher quality and productivity. Although modern irrigation systems are being introduced by farmers, further expansion is required in order to increase water use efficiency.

Farmers' application quantity of fertilizer is estimated at as low as 50 percent or less in comparison with the fertilization criteria prepared by MAF. Taking soil and irrigation characteristics into account, the quantity and frequency of the fertilizer application should be increased in accordance with the criteria mentioned above.

On small farms, weeding is done manually and/or by machinery which carry out intertillage simultaneously. On the basis of studies and the clarification of the biology and ecology of weeds, the minimum amount of herbicide should be applied and the cost of labor considered.

Mechanized agriculture should also be promoted in order to save labor expenses and to improve profitability. Harvesting is carried out manually except on some of the commercial farms and large-scale new farms where mechanization has been started for feed crops, wheat, etc. Further mechanical operation should be adopted for plowing, land leveling, intertillage/weeding, pollination, pest control, etc.

5.3.5 Pest Control

(1) Present Situation

The white fly is common all over the country, especially in fields of alfalfa, tomatoes, chili peppers, eggplants, cucumbers, etc. Crops other than alfalfa suffer severe damage from virus diseases transmitted by this insect, in addition to injuries from its sucking of plant sap. Severe damage caused by these diseases has been observed. For example, a tomato field was completely destroyed by a virus. In most cases concerning chili peppers, production in the later harvesting season is greatly reduced by the same disease. Thus, the pest is one of the greatest factors in production reduction and the deterioration of crop quality. Other examples can also be cited: cucumbers damaged by leaf miners, cabbage by the diamond-back moth, date palms by the dubas bug, mangoes by the mango leaf gall midge, etc.

Pest control methods in Oman can be categorized into the chemical method which uses pesticide sprays and a biological method which uses natural enemies to destroy the pests. There are many sites where MAF has applied the aerial spray method by helicopter. The pest control teams of MAF carry out pesticide applications to 30,000 ha of vegetables and 14,000 ha of field crops, as shown in Table 5.3.2.

In case the application of agricultural chemicals with high toxicity to humans and animals is required, the extension staff carries out such pesticide spraying, while they advise the farmers to use safe chemicals with low toxicity levels. Chemicals with high residual toxicity, e.g. organic chlorides, and those which damage the environment, e.g. dusts, are

not applied.

Large farms and commercial farms utilize high-pressure sprayers for the application of agricultural chemicals. However, these sprayers are generally less efficient due to their single nozzle design. Moreover, it is observed that there are many cases where the efficiency of the spray is low due to abrasion of nozzles caused by prolonged operation or some other reason which results in larger spray drop and lower spray efficiency. Small farms use manually-operated sprayers.

Biological control methods utilizing natural enemies were adopted against some fruit insect pests and some of them are showing successful results. For instance, since 1987, chemical control has not been required at the citrus orchard in Salalah where the release of parasitic wasps (Encarcia) was begun in 1985, against the citrus blackfly. Following its successful application in Malaysia, the Baculo virus was introduced to control the Rhinoceros beetle on coconut palms in 1989. With regard to the introduction and release of parasites against the mango leaf gall midge, the suitability of Chrysonotomyia has already been confirmed. For caterpillar control on cabbage,etc., bio-chemicals like Thuricid HP are recommended for application since 1980. Regarding the white fly, since its appearance no natural enemy has been distributed in Oman; the introduction of a parasite like Encarcia formosa is now being considered by MAF.

(2) Development Potential

Even through pests are one of the largest problems facing quality and production, pest control is not sufficiently practiced. Further improvements must be extended to the selection of adequate pesticides, effective application timing and frequency, pest control implements, etc. Considering the preservation of bio-ecosystems and safety of the producer and the products, an integrated control needs to be maintained on the basis of an economic threshold needful for chemical control. There are some promising results and trials with respect to biological control of fruit insects. For example, biological suppression of the white fly population density will be examined further in order to protect such

important crops as vegetables, alfalfa, etc. from injury.

5.3.6 Salinity Problem

(1) Present Situation

In some of the coastal areas within about 3km of the sea, especially in North and South Batinah, saline accumulation is observed at the ground surface of irrigated areas because of an increase in salt concentration of ground water caused by recent saline water intrusions. Date palms are markedly affected as they get closer to the coast, and many of them have withered and died. Most such areas are abandoned, but there are some areas where farmers are trying to cultivate other crops instead of the date palm.

The JICA team conducted a survey of such areas about 0.5 km and 2 km from the coast in Barka. A farmer 0.5 km from the sea, where the result of an electric-conductivity test indicated about 6,000 to 12,000 micro mhos/cm, had cultivated alfalfa and barley by applying a flood irrigation method and large amounts of stable manure. In the first year, alfalfa grew without any damage. However, in the second year many of them died. The ratio of live crop was below 30 percent. Barley was also observed as growing less favorably.

A farmer at a field about 2 km from sea had initiated cultivation of field crops and various vegetables on a large scale where the result of the electric conductivity test indicated about 4,000 to 8,000 micro mhos/cm. Although marked saline accumulation was observed at the ground surface, various herbaceous crops such as alfalfa, barley, Rhodes grass, sorghum, tomatoes, eggplants, watermelons, sweet-melons, cucumbers, cabbage, carrots and others were growing without any damage. With regard to mangoes (a perennial crop), however, necrosis at the tops and peripheries of the leaves were observed. This was regarded as the result of saline accumulation. Dying leaves at the lower portions of date palms were also obvious.

Investigations related to the damage are being conducted by MAF and FAO. It is supposed that the reason why single season herbaceous crops do not suffer from salt injury is mainly due to their short growing period, which prevents the accumulated salt in the cell from causing plasmolysis. Of course, further investigation is necessary.

In areas 2 to 3 km from the seashore, there are many farmers who have initiated the cultivation of field crops and vegetables in fields where date palms died. Areas where saline accumulation is due to brackish water were observed even in inland areas such as Dhahira, Sharqiya, Nejd, etc.

(2) Development Potential

In order to cope with the saline problem observed along the coastal area of the North and South Batinah Regions, a comprehensive method composed of the combination of the following measures will be most effective in reducing the salinity of the water to within tolerable limits for crops.

(a) Application of irrigation methods which account for the leaching effect
(b) Introduction of crops with high tolerance
(c) Supply of larger amounts of organic fertilizer

Regarding the introduction of more tolerant crops, seasonal crops are generally cultivatable in areas with relatively low electrical conductivity. These methods will probably be effective in solving saline problems in brackish water areas in Sharqiya, Nejd and other places. Crop cultivation on the Batinah Coast where date palms have withered or deteriorated must be improved, and therefore, further intensive research is required.

Crop classification in terms of tolerability is indicated in the Manual of Cultivation Technique issued by MAF. According to this, date palms and coconut palms are classified as highly tolerant fruit crops and pomegranates, figs, olives, grapes and guava have medium tolerance levels.

5.3.7 New Materials and New Facilities in Use

(1) Present Situation

Shadow nets are used by commercial farms, etc. for the cultivation of flowers and ornamental plants. Greenhouses, as well as hydroponic facilities are employed by some of them. In these cases, management is reconciled to deficit operation due to excessive costs both in construction and operation. New technology using plastic film to provide such things as plastic-film houses, plastic-film tunnels and plastic-film mulching have not yet been introduced. Water-preservation material such as water absorptive polymers and porous ceramics have also not yet been adopted in Oman.

(2) Development Potential

Various plastic films with different characteristics which have been developed enable farmers to improve agricultural production. For instance, some plastic film is applicable for mulching for the purposes of longer preservation of soil moisture content, prevention of weed growth, soil temperature control (both increases and decreases are possible), increasing the quality of products, etc. For increased crop production in lower temperatures, plastic film can be used for tunnel-shaped and house-shaped greenhouses.

Again, water-preservation material such as water absorptive polymers and porous ceramics have been developed, and are ready for use in desert and arid areas. These materials increase the irrigation water supply, which enables farmers to minimize irrigation-related labor forces. Accordingly, further development potential can be seen in the utilization of these materials. More detailed information and experiments will be necessary.

5.3.8 Apiculture

In the Sultanate of Oman, an apiary has been created by rearing Apis

mellifera jamanifica introduced from Egypt and other countries and a domestic bee, Apis florea. Beekeeping has been conducted in a traditional method such that the bee nest is placed inside a hole made by hollowing out a date palm trunk which is then put under the branches of a garden tree or a house. Honey is collected by smashing the nests.

Honey in Oman is of high quality so its price is about three to four times higher than that of imported honey. Therefore, apiculture is a profitable supplement for farmers. The number of beekeeping farms, however, is not high and the practicing scale is small. Also, there are some problems: shortage of honey-production-plants, occurrence of American foul-broad and others.

MAF has put high priority on operating honey bee projects in the Five-year Development Plan for agricultural development from the first year. Under the project, three apiculture research centers were constructed in Rustaq, Nizwa and Salalah, and a modern apiary complete with a hive, nest materials, a smoothing tool, a centrifugal separator, etc. is being promoted, through distribution by experts and extension workers.

At present, however, research center stock, the number of experts, quality and number of extension workers, the budget, etc. are not sufficient and more support is needed in the future.

5.4 Farming

5.4.1 Progress of the Third Five-year Development Plan

The Third Five-year Development Plan has continued to conduct the agricultural situation survey: Annual Updates of Important Statistic Series Project (e.g. land in production, yields, production, prices, production costs), which was started in 1982.

This survey aims to examine the profitability of agricultural production through the above cited statistical analysis for specified crops cultivated by more than four farmers who are sampled every year by each of the five extension centers located in the major agricultural areas. From these data, figures which are necessary for an analysis of data obtained by the JICA team are arranged in Table 5.4.1. A census of agriculture and livestock for 1987/88 was not carried out, though it was proposed.

5.4.2 Farming Scale of Farmer

The total number of farmers in the country is about 83,000 and the average area of arable land per farm family is 1.0 ha (i.e. 0.6 ha of cropped area) as shown in Table 5.1.1.

The farming scale differs markedly depending on the region: namely about 1.6 ha in the region along the Batinah Coast and about 0.15 ha in Salalah in the Southern Region. In the Batinah Region and the Oman Interior Region, there is a considerable number of new farmers who have moved onto the uncultivated land. These new farmers manage relatively large-scale farms of about 4 to 10 ha.

5.4.3 Farming Types

Farming can be classified into three types: new farms at settlement;

Table 5.4.1 Average Production Cost, Yield, Sale Price and Production Profit of Major Crops in Oman

Crops	Production cost[1] (RO/ha)	Yield (Ton/ha)	Price[2] (RO/Ton)	Balance (RO/ha)	Note	Crops	Production cost[1] (RO/ha)	Yield (Ton/ha)	Price[2] (RO/Ton)	Balance (RO/ha)	Note
Watermelon	1,583	19.0	125	792		Wheat	536	1.5	256	−152	
Sweet-melon	1,528	13.1	290	2,271		Barley	560	1.9	250	−85	
Cucumber	1,147	14.9	202	1,862.8		Maize	1,500	△3.0	△200	△−900	Seed
Squash	1,100	15.8	140	1,112				42.8	50	640	Fodder
Tomato	1,537	22.2	146	1,704.2		Sorghum	1,250	53.3	50	1,415	Fodder
Chilli pepper	1,559	9.0	325	1,366				△2.0	△200	△−850	Seed
Eggplant	1,600	19.0	61	−441		Alfalfa	1,804	38.4[3]	60	500	
Potato	1,272	25.0	117	1,653		Rhodes grass	1,800	57.6[3]	50	1,080	
Sweet potato	1,400	23.8	150	2,170							
Sweet pepper		9.0				Sugarcane	1,600	40.0	175	5,400	
Cabbage	1,280	23.2	65	228		Tobacco	651	4.9	2,500	11,599	
Cauliflower	1,280	9.1	80	−552		Average	1,212.6	37.9	423.9	1,864.7	
Radish	1,050	23.0	100	1,250		Dates	2,033	4.1	150	−1,418	
Beet	1,050	14.3	150	1,095		Lime	1,609	10.8	120	−313	
Carrot	1,400	23.8	200	3,360		Sweet lime	1,610	11.0	150	40	
Lettuce	1,500	17.0	200	1,900		Lemon	1,609	15.0	150	641	
Onion	1,404	13.7	90	−171		Orange	1,610	11.0	175	315	
Leek	1,270	17.0	175	1,705		Mango	1,642	2.0	250	−1,142	
Garlic	1,302	8.0	550	3,098		Guava	1,600	8.3	140	−438	
Sweet corn	(1,350)	(10.0)	(147)	(120)							
Okra	1,499	13.2	255	1,867		Banana	1,790	13.6	100	386	
Beans	1,350	17.0	230	2,560		Coconut	1,476	16.8	150	1,044	
Cow-pea	1,305	15.0	150	945		Papaya	1,500	12.0	175	600	
Chick-pea	1,350	14.0	150	750		Grape	1,700	15.0	300	2,800	
Fababean	1,250	14.3	150	895							
Average	1,348.5	16.3	178.3	1,366.1		Average	1,652.6	10.9	174.5	228.6	

Notes: 1) Depreciation cost is not included in production cost.
2) Average Selling price of farmers during production season of each crop in 1988. ( ) These are figures in the Oman Modern Farm.
3) Semi-dried weight.

traditional farms; and commercial farms. After a discussion with persons concerned, the JICA team conducted a current farming condition survey on the typical farmers in the five major agricultural regions, i.e. eight new farms, four traditional farms and 1 commercial farm. The summary of the survey method and its results are described below and shown in Table 5.4.2.

Each sample farm was investigated by interviewing farmers and observing the following areas: general affairs (address of farm, name of owner, ages of farming members, etc.), production bases (total holding land area, total cultivated land area of each crop in the present cropping year, number of laborers, number and depth of wells, number and Hp of pumps and tractors, number of high-pressure and manual sprayers, number of agricultural vehicles, length of concrete canals for irrigation, etc.), livestock (number and ages of each livestock), infrastructures (number and size of storehouses, pump shed, livestock shed, fences, etc.), irrigation (quantity and quality of water, method and interval of irrigation, etc.), cropping system (cropping time, cropping pattern, crop rotation system, mixed or intercropping, etc.), cultivation method of each crop, production materials (amounts and prices of seeds and seedlings, fertilizers, pesticides, boxes, etc.), labor costs, operation costs of machinery, etc.

The farming profits in new farms and traditional farms were calculated by the following formula.

$$Npfi = (Mpi \times Myi \times Cai - Mci \times Cai)$$

Npfi : Net profit without depreciation for each sample farm (R.O.).
Mpi* : Mean selling price (R.O./ton) in Oman of each crop.
Myi* : Mean unit yield (ton/ha) in Oman of each crop.
Cai : Cultivated area (ha) of each crop on each sample farm.
Mci* : Mean unit production cost without depreciation (R.O./ha) in Oman of each crop.
* : These figures (1988) have been annually updated through a project called "Annual Updates of Important Statistic Series" by the Department of Agriculture and Statistics.

Table 5.4.2 Outline of an Economic Survey Conducted by JICA Team

Region	Number of farmers	Type of farmer	Size of farm (ha)	Net balance in farming for the past year (RO)*1
North Batinah	1	New	4.20	293.800
	2	New	4.20	4,671.410
	3	New	4.20	3,199.310
South Batinah	1	Traditional	0.63	-384.960
	2	Traditional	0.53	-165.510
	3*2	Traditional	14.70	3,591.990
Oman Interior	1	New	27.72	17,529.750
	2	New	6.30	3,552.544
Sharqiya	1	New	29.40	6,039.056
	2	New	8.40	3,555.958
Southern	1	New	1.89	1,220.370
	2	Traditional	1.89	1,679.600
Average		New	10.79	5,442.272
		Traditional	4.44	1,180.280

＊1 Net balances were calculated from unit values obtained by the Department of Agriculture and statistics (Table 5.4.1). Production costs do not include depreciation costs.

＊2 This farm has a character as a new farm.

The present farming conditions of each farm investigated by the JICA team are indicated in Annex Table 5.4.1 - 5.4.13. Farming size and profit of each farm investigated by the JICA team are indicated in Table 5.4.2.

(1) Farming of New Farms in Settlement

The average cultivated area, percentage of area cultivated for major crops, and profitability were investigated for eight farms, and are presented in Table 5.4.3. This table indicates that the average cultivated area is 6.15 ha, out of which about 52 percent is cultivated for vegetables, 25 percent for field crops, and 22 percent for fruit. The average net profit which excludes depreciation is about R.O. 5,300 for vegetables and R.O. 2,000 for field crops. However, fruit indicates a deficit operation of about R.O. 800. The overall net profit without depreciation is about R.O. 6,600 per farm family.

New farms in settlement can be characterized by the following:

(a) The capital and farming scale are large and there is high management vitality compared to traditional farms.
(b) The possession and utilization rate of agricultural machinery, such as tractors and high pressure sprayers, is high, but further mechanization is intended.
(c) The management rate, in agriculture exclusively, is high, and the employment rate of expatriates is also high.
(d) The cropping ratio of dates and coconuts is low, while that of crops with high profitability is high, but, there is still a lot of room for further improvement.
(e) Monoculture still prevails and intercropping is rare. Therefore, there is a high potential for future introduction of double cropping and intercropping systems.
(f) The irrigation areas developed by mechanically drilled wells are dominant, but aflaj are not used. So far, both water quality and quantity are adequate but are unpredictable.
(g) The intention to introduce new technology is high. However, the introduction rate of modern irrigation systems like sprinkler, drip or others is higher here than with traditional farmers, but is still

Table 5.4.3 Ratio of Areas Cultivated for Major Crops and Their Profitability for New Farmers

Crop		Average area cultivated (ha)	Average percentage of area cultivated (%)*	Average of net profit (RO)*
Vege-	Tomato	0.77	13.03	1,329.232
tables	Chilli pepper	0.23	5.38	315.888
	Watermelon	0.72	9.63	569.250
	Sweet-melon	0.34	5.74	760.785
	Cucumber	0.21	3.40	391.188
	Cabbage	0.16	2.15	36.195
	Carrot	0.13	1.56	432.600
	Onion	0.35	5.08	-58.995
	Eggplant	0.04	1.48	-17.640
	Others	0.31	4.79	1,612.130
	Total	3.26	52.47	5,370.633
Field crops	Alfalfa	1.10	14.49	551.250
	Rhodes grass	0.21	2.96	226.800
	Sorghum	0.11	1.68	148.575
	Wheat	0.08	1.95	-11.970
	Others	0.28	4.00	615.038
	Total	1.78	25.08	1,529.693
Fruits	Date palm	0.67	9.61	-946.515
	Coconut	0.02	0.98	23.490
	Lime	0.07	1.15	-20.736
	Lemon	0.07	1.78	46.473
	Mango	0.05	1.26	-61.383
	Banana	0.14	5.94	52.086
	Others	0.09	1.73	65.600
	Total	1.11	22.45	-840.985
Total		6.15	100.00	6,059.341

Note. *Net profits were calculated from unit values obtained by the Department of Agriculture and Statistics (Table 5. 4. 1).
Production costs do not include depreciation costs..
Average value of farmers investigated was calculated from the values obtained from each farmer.
Others : Potato, cauliflower, radish, lettuce, beet, garlic, barley, maize, sugarcane, cow-pea, papaya, sweet lime, and guava.

quite low. Therefore, there is a large potential for introducing such technology.

(h) Although farming profitability is high, there is considerable potential for improvement.

(2) Farming of Traditional Farms

For very long time, the area along the seashore of the Batinah Coast, in the mountainous areas, at the foot of the Oman Mountain range, and in the Salalah area and the Musandam area, agriculture has been conducted through the use of aflaj and hand-dug wells. Such agricultural methods have been defined as traditional farming.

With respect to the major cultivated crops of four farmers investigated by the JICA team, the average cultivated area (ratio) and its profitability are shown in Table 5.4.4. This table indicates that out of the average cultivated area (3.48 ha), about 53 percent is cultivated for fruit, 27 percent for field crops, and 20 percent for vegetables. The average net benefit which excludes depreciation is about R.O. 1,500 for vegetables, R.O. 1,000 for field crops, and fruit shows a deficit operation of R.O. 1,400. The average net profit without depreciation per farm family is about R.O. 1,200 which means a ratio of 1/5.5 to new farms in settlement.

However, using Table 5.1.1, the average cultivated area per farmer is considerably smaller than the figure indicated above. Therefore, the nationwide average productivity level is estimated to be even lower.

When date palms need replanting due to old age he declining productivity of the area where they grow, the date palm cultivation area is seldom changed to another crop because the traditional farmer has a strong attachment to date palm cultivation.

As a result, the proportion of unit profit (R.O./ha) to unit production cost (R.O./ha) for date palms is very low, just 0.3 obtained from R.O. 615/2,033. Accordingly, the low profitability of farming in the traditional manner is a result of the higher proportion of date palm

Table 5.4.4 Ratio of Areas Cultivated for Major Crops and Their Profitability for Traditional Farmers

Crop		Average area cultivated (ha)	Average percentage of area cultivated (%)*	Average of net profit (RO)*
Vege-	Tomato	0.03	0.28	51.126
tables	Chilli pepper	0.15	7.28	201.485
	Watermelon	0.32	3.75	253.440
	Sweet—melon	0.33	5.35	749.430
	Cucumber	0.03	0.28	55.884
	Cabbage	0.03	0.28	6.840
	Carrot	0.03	0.28	100.800
	Onion	0.03	0.68	-7.268
	Eggplant	0.03	0.28	-13.230
	Others	0.06	2.03	119.948
	Total	1.04	20.49	1,518.455
Field	Alfalfa	0.39	15.63	192.500
crops	Rhodes grass	0.21	1.95	226.800
	Sorghum	0.11	0.98	148.575
	Barley	0.04	8.18	-3.610
	Others	0	0	0
	Total	0.75	26.74	564.265
Fruits	Date palm	0.83	31.48	-1,176.940
	Coconut	0.05	2.23	46.980
	Lime	0.27	2.70	-83.728
	Mango	0.26	2.45	-299.775
	Banana	0.26	12.93	101.325
	Others	0.02	0.98	12.000
	Total	1.69	52.77	-1,400.138
Total		3.48	100.00	682.582

Note. *Net profits were calculated from unit values obtained by the Department of Agriculture and Statistics (Table 5. 4. 1).
Production costs do not include depreciation costs.
Average value of farmers investigated was calculated from the value obtained from each farmer.
Others : Papaya, sweet potato, leek and okra.
Net profit per hectare (ha) : Barley : —85. The other as well as table 5. 4. 1

cultivation.

On the other hand, the farmers who convert their crops from date palms to feed crops and vegetables are in the area located about 1 to 2 km from the seashore of South Batinah, where the problem of date palms withering due to salt injury is regarded as serious.

The following characteristics are generally observed about the traditional farmers:

(a) Both capital and farming scale are small with management vitality being low.
(b) Less agricultural machinery, such as tractors and high pressure sprayers, is owned but, there is a higher dependence upon mechanical operation provided by the extension centers.
(c) There is a heavy dependence on non-farm income and employment of expatriates is low.
(d) There is less profitability due to the high cropping ratio of the originally and naturally vegetated fruit trees, such as date palms and coconuts.
(e) Intercropping under and between date palms is practiced with barley and other feed crops, vegetables and small fruit trees (papaya, etc.) The ratio of such intercropping is about 20 percent in northern Oman and about 30 percent or more in Salalah.
(f) Groundwater irrigation by aflaj is common in the mountain and foothill areas, while along the Batinah Coast and Salalah hand-dug wells prevail. In addition, small farmers who practice rain-fed cultivation, are distributed on the plateau of the Southern Region.
(g) Management of agriculture is rather conservative and the farming techniques are still primitive. Therefore, there is considerable potential for improvement.
(h) The farming profitability is low and requires improvement. This is viable.

(3) Farming of Commercial Farms

Located mainly alongside National Highway Route No.1 of the North and

South Batinah Regions, and in Salalah, commercial farms number more than 100 and carry out large-scale agricultural production. Some of the commercial farms are Oman Sun Farm, Oman Modern Farm, Al Raja Farm, Dhofar Cattle Feed Company, and Royal Razat Farm.

The crops produced on these farms vary considerably: Rhodes grass and other feed crops, tomatoes and other vegetables, lemons and other fruit trees, flowers, flowering trees, ornamental plants, and others.

Both modern and mechanized irrigation are fully employed on these farms. Modern irrigation systems were introduced to use the groundwater obtained from the mechanically-drilled deep wells and springs (in Salalah). Heavy agricultural machinery is employed for plowing, land leveling, intertillage, weeding, and spraying of herbicides and pesticides. Such machinery is also used efficiently for harvesting and processing (drying) of such crops as feed crops. There are farms which utilize green house and hydroponic facilities as well.

The JICA team conducted a farm survey of Oman Modern Farm located next to National Highway Route No. 1 (Barka). The results of the survey and the analysis are presented in Table 5.4.5. As indicated in the Table, the farm cultivates 25 ha of vegetable fields and 15 ha of orchards, and produces agricultural products in 2.5 ha wide production facilities.

With respect to the vegetable production where the cropping intensity is raised to 150 percent by introducing double cropping, eight kinds of vegetables are cultivated throughout the year by drip irrigation systems and have a net profit which includes depreciation as high as about R.O. 3,240 (R.O. 80,877.650 / 25 ha = 3,235.106 R.O./ha) per ha, which corresponds to almost twice the productivity of the new farmer described previously (about 1,650 R.O./ha as the average net profit without depreciation). This high productivity is accomplished by means of comparatively high standards of management and cultivation techniques examined below.

(a) Introduction of high quality and high yielding varieties and an increase in cropped areas for profitable crops.

Table 5.4.5 Areas Cultivated for Major Crops, Facilitated by Modern Production Systems and Their Profitability in the Oman Modern Farm

Crop		Areas cultivated (ha)	Rate of areas cultivated (%)	Net profit (RO)
Vege-tables	Tomato	2.4	4.4	
	Cabbage	10.0	18.2	
	Cauliflower	1.5	2.7	
	Water melon	2.0	3.7	
	Sweet-melon	11.0	20.0	
	Squash	6.3	11.5	
	Sweet potato	2.7	4.9	
	Sweet corn	1.5	2.7	
	Total	37.4*1	68.1	80,877.650*4
Fruits	Date palm	1.0	1.8	
	Lime	3.0	5.5	
	Lemon	5.0	9.1	
	Orange	5.0	9.1	
	Mango	1.0	1.8	
	Total	15.0	27.3	1,281.000*5
Modern facili-ties	Greenhouse	1.5*2	2.7	-100,444.000*6
	Hydroponic facilities	1.0*3	1.8	-42,030.000*6
Total		54.9	100.0	-60,315.350

Note. * 1 Actual area : 25.0 ha.
Percentage of double cropping : $\frac{37.4-25.0}{25.0} \times 100 = 49.6\%$.

* 2 Pad and fan system produced cucumber, sweet pepper, tomato, etc.

* 3 Circulative hydroponic system produced lettuce.

* 4 , 6 Net profits were calculated from data obtained by the Oman Modern Farm itself. Depreciation costs have been taken into consideration.

* 5 Net profit was calculated from unit values obtained by the Department of Agriculture and statistics. Depreciation costs have not been taken into consideration.

(b) An increase in the efficiency of land use by double-cropping and better spacing between plants.
(c) Improvement of efficiency of irrigation water and fertilizers supplied by means of drip-irrigation systems.
(d) Increase weeding efficiency by effective application of herbicides.
(e) Enhancement of crop quality and yield by complete pest control.

However, in the orchard, fruit productivity of the commercial farms is as low as that of the small farms, while in greenhouses and hydroponic facilities, the financial balance indicates a deficit operation even though the management and cultivation make use of modern and high-standard technology. Judging from these facts, it is assumed that the commercial farm, which is not equipped with such modern facilities and only concentrates on highly profitable vegetables and field crops, may be able to manage at a high profit.

5.4.4 Cultivated Crops, Management Scale and Farming Profitability

All the above results, which have been analyzed by the JICA team on the basis of the contents of the agricultural situation survey (i.e. Annual Updates of Important Statistic Series), suggest that profitability varies considerably depending on the kind of crop. The difference in profitability can be clearly indicated by such relationships as: vegetable > field crop > fruit.

Furthermore, such profitability also differs in terms of the management scale. The relationship of the difference can also be indicated by large-scale > medium-scale > small-scale.

5.4.5 Development Potential

The development potential varies according to farm type. Their respective potentials are discussed below.

(1) New Farms in Settlement

Judging from the farm survey conducted by the JICA team, improvement potential in farming is regarded as significant. As was described, the selection of profitable kinds and varieties of cultivated crops, new cropping patterns, cultivation methods and other advances will raise the present farming level of the individual farmer toward that of the commercial farms.

(2) Traditional Farms

The scale of the traditional farm is generally small, and date palms and coconut palms are the major crops. Consequently, development potential is not very large. It can be provided by:

(a) effective use of land beneath both palms through the cultivation of beneficial crops such as feed crops and vegetables,
(b) increased productivity of feed crops and vegetables in the vicinity of palm gardens,
(c) reduction of water-loss by lining the irrigation canals with concrete, and
(d) more efficient water supply and distribution.

It is advisable to store water from aflaj in a reservoir tank, and then use it for irrigation. Such irrigation water makes it possible to increase the cultivated area of more profitable feed crops and vegetables.

(3) Commercial Farms

Commercial farms are equipped with modern facilities and employ modern cultivation techniques. Therefore, their productivity is quite high. However, they have still ample room for improvement, especially in the kinds and varieties of cultivated crops, cropping systems, cultivation methods, etc. In some of the commercial farms, excessive investment in facilities induces pressure on management due to the present economic circumstances.

In order to enhance nationwide self-sufficiency and to promote exports of competitive agricultural products, commercial type management is most effective. Nevertheless, it may be very risky for the private sector to participate directly in agricultural projects which require large initial investment. One reason is that price differences in terms of different product quality have not been clearly established yet. This is mainly due to the consumer's immature sense of value. In other words, the price of high quality products supplied by the commercial farm is not much different from that of lower quality products from the small farms. This is a major subject to be considered along with management improvement efforts to be made by the commercial farms themselves.

5.5 Agricultural Research

5.5.1 Present Situation

(1) Historical Background

Agricultural research in Oman was initiated some 18 years ago. The agricultural research center and stations were established one by one in selected areas such as Rumais, Salalah and Jemmah. And in addition, research farms in Sohar, Wadi Quriyat and Qairoon Herietti have been established. Since experiments and research conducted at the above facilities support agriculture in Oman, the government named 1988/89 "Agriculture Year" and has been promoting their expansion and influence. The government is also endeavoring to conduct agricultural research based on the latest information obtained from international research organizations.

(2) Research Organization

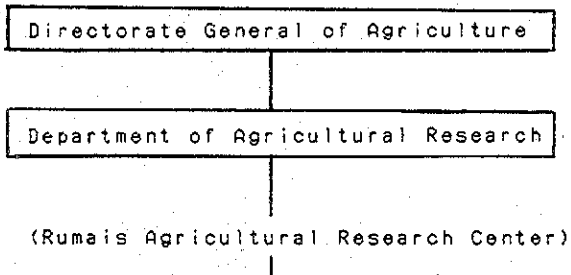
(a) Organization

The Agricultural Research Department at Rumais (Rumais Center) comes under the control of the Directorate General of Agriculture, while the Department of Agricultural Research at Salalah (Salalah Station) comes under the control of the Directorate General of Agriculture and Fisheries of the Southern Region and the Research Station in the Interior (Jimmah Station) comes under that of the Supervisory General of the Interior. The research in the Interior operates under a unified technical plan coming from the Headquarters at Rumais, while research in the Southern Region is operating independently. These centers and stations are outlined below, and their organization is as illustrated in Figure 5.5.1.

(i) Rumais Center

In the Rumais Center, there are 12 research units, several farm management and nursery units, an administration section, general services including work shops (machine and carpentry), and transport

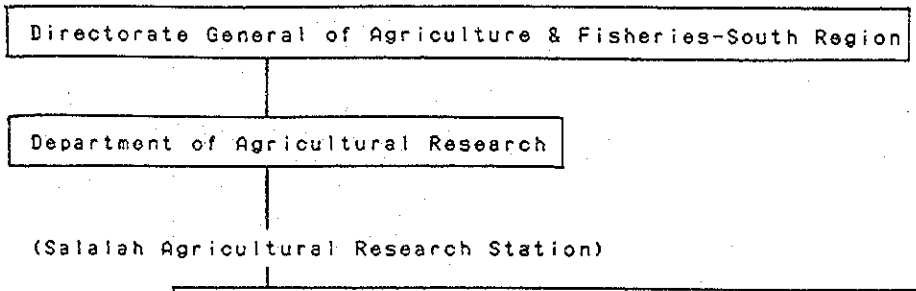
Figure 5.5.1 Organization of Agricultural Research



Section	Field Area	Number of Researchers		Number of Technitians		Number of Workers	Total	Total of Foreigners
		Total	Foreigner	Total	Foreigner			
1.Research Farm	73	0	0	2	0	70	72	0
(1)Research main farm	20	0	0	1	0	31	32	0
(2) Research farm 1	13	0	0	0	0	20	20	0
(3) Research farm 3	40	0	0	1	0	19	20	0
2. Fruit Nursery	92	1	1	3	1	52	56	2
(1) Rumais fruit nursery	35	0	0	2	0	26	28	0
(2) Sohar fruit nursery	15	0	0	0	0	6	6	0
(3) Barka date farm nursery	15	1	1	1	1	20	22	2
(4) Kamil date farm nursery	27	0	0	0	0	0	0	0
3 Forestry Nursery								
(1) Kamil forestry nursery	2	0	0	0	0	0	0	0
4. Forestry farm								
(1) Majees forestry farm	200	0	0	0	0	0	0	0
5. Research Unit		18	10	16	4	0	34	17
(1) Soil and water		2	2	5	0	0	7	2
(2) Plant physiology unit		1	0	0	0	0	1	1
(3) Entomology unit		1	1	1	0	0	2	1
(4) Plant pathology unit		1	1	1	1	0	2	2
(5) Vegetable unit		3	1	1	1	0	4	2
(6) Fruit unit		2	1	1	1	0	3	2
(7) Field crops unit		1	1	1	1	0	2	2
(8) Irrigation unit		3	2	0	0	0	3	2
(9) Tissue culture		1	0	0	0	0	1	1
(10) Biological control		1	1	1	0	0	2	1
(11) Honey bee		1	0	3	0	0	4	0
(12) Forestry		1	0	2	0	0	3	1
6. Administration							12	2
Total	367	19	11	21	5	122	162	19

explanatory notes:
These data are derived from Rumais Agricultural Research Center

Figure 5.5.1 Organization of Agricultural Research
(continued)



Section	Number of Researchers		Number of Technitians		Number of Workers	Total	Total of Foreigners
	Total	Foreigner	Total	Foreigner			
1.Research Farm	2	1	0	0	2	4	1
(1) Salalah research farm	1	0	0	0	0	1	0
(2) Qairooh Herietti research farm	1	1	0	0	2	3	1
2. Fruit Nursery	1	0	2	1	4	7	1
3. Forestry Nursery	0	0	0	0	0	0	0
4. Research Unit	8	5	15	6	34	57	11
(1) Soil and water	2	1	1	1	1	4	2
(2) Plant physiology unit	1	1	0	0	1	2	1
(3) Entomology unit	0	0	1	1	1	2	1
(4) Plant breeding unit	0	0	0	0	0	0	0
(5) Vegetable unit	1	1	1	0	1	3	1
(6) Fruit unit	1	1	2	1	7	10	2
(7) Field crops unit	0	0	1	1	1	2	1
(8) Honey bee	0	0	2	0	12	14	0
(9) Forestry and range unit	3	1	7	2	10	20	3
5. Administration						7	0
Total	11	6	17	7	40	75	13

explanatory notes:
These data are derived from the Department of Agriculture and Fisheries at Salalah

units. This center extends its services to 5 regions, i.e. South Batinah, North Batinah, Sharqiya, Musandam and Buraimi.

(ii) Interior Station

The Interior Station consists of a research farm (Wadi Quriyat Farm) and a research station at Jimmah (Jimmah Station). This farm and station cover 3 regions, i.e. Dhahira, Interior and Wasta.

(iii) Salalah Station

The Salalah Station consists of 9 research units, 2 research farms, one fruit nursery and one forestry nursery. This station only covers the Southern Region.

(b) Personnel

There are 30 researchers (of these, 17 are foreign) and 38 technicians (12 are foreigners) in the Rumais Center and the Salalah Station. Since only 13 researchers are Omanis, research activities depend largely on foreign researchers.

(3) Research Management

(a) Management System

The center and station are independent organizations, take charge of research for their respective regions, and are supervised by each Director General. Each center and station are able to find and research a subject which closely relates to its region or regions and apply it to agricultural policy and technical guidelines. In addition, they carry out nursery projects to promote the development of fruit and forestry.

(b) Long-Term Research Targets

Long-term targets are very important for agricultural research for the following reasons:

(i) In general, agricultural research requires a long period to obtain results. Individual research should be planned on the basis of the research targets and objectives in line with the agricultural

policy.

(ii)The researcher must be consistent throughout in order to maintain the target of the research.

Currently, study on A Framework for Research is being carried out at the Rumais Center towards establishment of long-term agricultural research targets.

(c) Planning and Evaluation of Research

The procedure for planning and evaluation at the Salalah Station is shown in items (i) to (iii).

(i) Planning

A program of research is created for each unit. Each researcher puts his program into a standard form in December for the next year's activities, which start in July and end in June. These programs are discussed by a technical committee in the department first, and then discussed with the agricultural department of the region. After that, they are submitted to the ministry where a higher committee discusses and approves research programs throughout the whole country.

(ii) Approvals

Approvals of research programs are given by the National Higher Technical Committee. These programs will be implemented during the July-June period.

(iii) Evaluations

A technical committee within the research department will review the research done, and after, approving it, will send it to be published in scientific journals. Also, the ministry brings in outside consultants to evaluate research projects.

(d) Annual Research Report

No annual report except the 1983 report has been published. Therefore, research activities, products and its accomplishments are not clear. The annual report is indispensable for planning future research programs as it is prepared on the basis of the evaluation

for the research results. Currently, the research results from 1989 are being prepared as an annual report for publication in 1990.

(e) Necessity of Continuous Research

When a foreign researcher's assignment finishes after 1 to 3 years, it takes one or two years to fill the vacancy. Often, if no applicant is available from the same field, the research is terminated.

(f) Selection of Research Subject

There are two kinds of agricultural research: one is development research which aims to resolve the problem in the field, the other is applied research to integrate the technology from advanced countries. In Oman, well-balanced employment of both of the above is necessary. Research subjects and their present stages, which are to be given high priority are as follows:

(i) Virus-Resistant Varieties

This research has commenced already. Since it is common to find vegetables destroyed completely in farmers' fields, further strengthening of this research is required.

(ii) Forecast of Pest Prevalence

Various types of research on pest control have been conducted and widely adopted. However, research to forecast pest damage has not been planned yet. Although this research requires a lot of time, its accomplishment will contribute greatly to production increases and cost reduction.

(iii) Modern Irrigation Method

Modern irrigation practice is of the highest priority in Oman. This has been applied in the research stations as well as in private farms in different regions, through the Oman Bank for Agriculture and Fisheries, but it has not become very popular yet. The research results for soil properties, irrigation efficiency, high salt content irrigation water, and salt accumulation need to be integrated into the extension services.

(iv) Quality Control and Processing Techniques for Crops

Since emphasis has been placed on production increase, the research on quality control and crop processing has not been conducted adequately. Therefore, better technology for variety improvement, cultivation management, storage and processing is required.

(v) Research on Agricultural Economics

Research on agricultural economics, particularly agricultural management, have not started yet. In order to target the growth of agriculture, research here is vital.

(vi) Research on Environmental Aspects

As part of the research on the environment, selection of the appropriate kinds of trees for reforestation has commenced.

(4) Accomplishment of Agricultural Research

(a) Rumais Center

The Rumais Center provides the thrust for agricultural research in Oman. The major subjects of research cover areas such as soil, irrigation, plant analysis, plant protection (nemetology, entomology, chemical control and biological control, pathology, virology, weed control), plant physiology and seed testing, and cultivation tests of vegetables and fruit. A research report was summarized and published in 1983. According to the report, the Rumais Center and the Interior Station published variety comparison tests for vegetables which included 52 subjects and covered 20 kinds of vegetables such as tomatoes, cabbage, onions, etc., and also conducted a fertilizer suitability test which included 9 subjects and 4 kinds. The report also covered the relationship between irrigation and tomato production, the cultivation of strawberries, a maturity test of pomegranates, a method for grafting mango and lime trees, plant nutrition, weed control, etc. The Interior Station is the center of

field crops research and if completed 56 projects including variety comparison tests for 7 varieties, cultivation tests for 11 crops and fertilizer tests for 3 different kinds. In particular, the development of a new wheat variety was highlighted. Researchers succeeded in developing high yield, high quality and disease tolerant varieties through breeding local and foreign varieties. These new varieties were named Wadi Quriyat 151 and 160 and have been available to the farmers since 1988.

(b) Salalah Station

The Salalah Station is the center of agricultural research in the Southern Region. The research activities in this station include variety tests, fertilizer tests, suitability-of-area tests, tests for disease tolerance, and cropping season tests for fruit, vegetables and field crops. The current major research topics are the identification of pathogenic organisms of crops in the Southern Region, virus-resistivity tests, identification of major harmful insects, fertilizer application tests for various crops, salt tolerant crop cultivation in the agricultural development area, etc. In the previously mentioned 1983 report, 49 subjects in total were reported including 14 variety comparison tests for vegetables like tomatoes, cabbage, etc., and 14 variety comparison and fertilizer tests for field crops including wheat, maize, etc. Regarding fruit, fertilizer tests for bananas, and variety tests for mangoes, etc. were also conducted.

(5) Linkage of Research and Extension

The long-term results obtained through the trials conducted at research stations provide the basis for established crop recommendations utilized by extension services. The recommendations are routed through subject matter specialists attached to each of the regions. Regular discussions are held between the research staff, extension subject matter specialists and extension engineers. These meetings help to formulate extension programs, and at the same time,

will highlight the problems faced by farmers for research consideration. In addition, the research staff provides specialized knowledge needed to implement development programs formulated by the ministry. This research work requires a great deal of time from the research staff. Agricultural research provides extension bulletins for use by extension services.

(6) Research Support System

(a) Research Information

Scientific publication plays a vital role in providing ideas for technology development. A researcher generally develops his research method based on the comparison of similar past research. The collection and study of foreign publications provides researchers with various types of information, most especially research which has been conducted under similar agricultural circumstances. Therefore, further efforts should be made to collect such foreign publications. Fortunately, the International Symposium on Agriculture & Fisheries Development in Oman was held at the Sultan Qaboos University from October 15 to 19, 1989. At this symposium, 131 subjects were reported, and of these, about 50 were research results for crops, soil, pests, etc. which gave great incentive to Omani research-related personnel.

(b) Technicians

In order to conduct the development research, two to three technicians are generally required per researcher. However, at present, the number available is far less than that.

(c) Research Facilities

The research facilities greatly influence the research accomplishments. In the Rumais Center, various research facilities are being upgraded. For instance, a research building has just been completed and modern equipment, such as microscopes and soil and

nutrient analysis equipment, has been recently introduced. Moreover, controlled environment greenhouses were completed quite recently. On the other hand, in the Salalah Station, each research unit is installed with research facilities, but, most of these need to be replaced, with the exception of the soil-and nutrient-analysis equipment.

5.5.2 Progress of the Third Plan

The following was proposed and approved for incorporation into the Third Five-year Development Plan:

(1) Agricultural research facilities at the Rumais Center
(2) Agricultural research facilities at the Salalah Station
(3) Agricultural research facilities at the Interior Station

The progress of the above facilities is summarized below:

(1) The Rumais Center

The office and research buildings were completed in December 1989. Currently, the installation of the research equipment is under way.

(2) The Salalah Station

Initially, the construction of the research substation, research farm, research unit and facilities were proposed, but, almost nothing has been started.

(3) The Interior Station

A new research facility is currently under construction, but is not expected to be completed during the Third Five-year Development Plan.

5.5.3 Development Potential

(1) Establishment of Research Management and Implementation

Research management is indispensable if the country is to implement research effectively. The purpose of research management is:

(a) to establish a suitable environment in which researchers can produce creative achievements efficiently,
(b) to clarify the demarcation of study fields and deepen each study along with given targets, and
(c) to formulate the targets of research and set priorities for implementation in line with fundamental policies of agriculture and agricultural development

The methods of research management are used:

(a) to improve research facilities' ability to provide a better environment for researchers
(b) to create the opportunity for periodical gatherings where researchers in the country can exchange information and schedule research plans in order to clarify current problems and future strategies
(c) to secure enough funds to continue research activities

Both the organizational aspect and systematized implementation are important, because the research concerning agriculture needs long-term efforts before targets are met. Thus, a new body which controls research activities relating to agriculture and livestock should be created in the headquarters of MAF in order to coordinate with other administrative departments.

(2) Introduction of Applied Research

At the stage to which the research of agricultural technology has progressed, the necessity for applied research has also increased. Applied research requires physical and chemical instruments with high degrees of accuracy, such as environment control facilities for verifying insect-generating processes. In order to transfer the achievements of research to the practical level, applied research should be introduced in

the near future.

(3) Education and Training of Agricultural Researchers

(a) University Graduates

Whether research succeeds or not depends on the capability, passion and accumulated knowledge of researchers. Oman established the Sultan Qaboos University in 1986 and the first students will graduate in 1990. The agricultural research institutes should definitely recruit those graduates. They should be trained to become leading researchers through post-graduate education and on-the-job training provided by senior Omani researchers or expatriate scientists. It will be beneficial for the researchers to be given the opportunity to do extension work in rural areas in order to acquire experience in the present agricultural situation. The exchange of personnel between research and extension centers is very important as it reflects the current problems in research and enhances the quality of the extension centers.

(b) Assistant Researcher

The graduates of the Agricultural Institute in Nizwa contribute enormously to agriculture and fisheries. These graduates should also be employed in research and assigned as assistant researchers, of which a shortage exists. If possible, assistant researchers should be trained and positioned in future as researchers. They should be assigned as extension experts through personnel exchanges so that their experience as assistant researchers may help farmers to learn new farming methods.

5.6 Extension Services

5.6.1 Present Situation

(1) Guidelines for Extension Services

The extension of agricultural techniques is essential for agricultural growth. Therefore, the government has endeavored to promote extension services for a long time, and in particular the theories behind the techniques. In order to provide practical extension services, MAF has established guidelines which focus on the following:

(a) Annual training to assist farmers in their farming practices
(b) Increase of agricultural production
(c) Reduction of costs of agricultural production
(d) Improvement of traditional farming practices
(e) Introduction of better agricultural management
(f) Securing high yields through modern irrigation methods and improvement of water management
(g) Linked activities between extension and research
(h) Intensive training programs for extension workers and farmers

The extension services are carried out in accordance with the target of the Yearly Action Program (which is also established by MAF) by summarizing the proposed targets of the Action Programs prepared and submitted by every extension center in the country.

The main target of the Action Program in 1989 was "Suitable Cropping in Suitable Land".

(2) Organizational Structure

In MAF, the Director of Agricultural Affairs and the Director General of Agriculture are responsible for extension services: one expatriate and one Omani specialist take charge of the services.

There are nine regional offices in the country and the 43 extension

centers belong to respective offices as shown in Table 5.6.1. For instance, in southern Oman, there are five extension centers which are supervised by the Director of the Agricultural Extension Services Section (Southern Region) who is located in Salalah.

With respect to the number of extension centers, seven have been set up in both the South Batinah and the Oman Interior Regions. These two regions have the largest number of extension centers. Three centers each are located in the Wasta and Buraimi Regions. This is the smallest number of extension centers in any region.

The area for which each extension center is responsible, varies from 700 to 2,400 ha. The distance between the centers is 25 to 30 km in the Batinah Coast and 20 to 40 km in the inland area. This distribution, as well as the area for which they are responsible, is regarded as appropriate.

Each regional office is assigned one extension supervisor and under his supervision extension officers provide the services in each extension center. At the same level as the extension supervisor, the subject matter specialist (SMS) provides technical guidance to the extension officers in regions concerned with specific technical fields.

However, there are as few as two SMSs for vegetables, one for fruit trees and two for field crops. Of these, one is stationed in the regional office in north Batinah, and two SMSs for both vegetables and field crops are stationed in Sharqiya and the Oman Interior.

More than half of these extension-concerned positions are occupied by expatriate experts: nine extension supervisors out of a total of 10, and all of the SMSs and 38 extension officers -- a total of 85 --are expatriate experts.

(3) Substances of Extension Services

As will be described, the extension services consist of general services for all farmers, programs focusing on encouraging specific

Table 5.6.1 NUMBER OF EXTENSION EXPERTS IN EACH EXTENSION CENTER

REGION		EXTENSION CENTER		EXTENSION			SUBJECT MATTER SPECIALISTS						PLANT PROTECTION		STATISTICS	
				SUPER-	OFFICER		VEGETABLE		FRUIT		FIELD CROPS		ENGI-	ASS-	SPRAY	STAT-	ENUM-
No.	NAME	* No.	NAME	VISOR	TOTAL	EXPAT-RIATE	TOTAL	EXPAT-RIATE	TOTAL	EXPAT-RIATE	TOTAL	EXPAT-RIATE	NEER	IST-ANT	TEAM	ISTI-CIAN	ERAT-OR
1	SOUTH BATINAH	1	SEEB & MUSCAT		2	1									5		1
		②	BARKA	1	2	1							1		7	1	2
		3	AL MASNA'AH		2	1									6		1
		4	A'SUWAIQ		1	1									2		
		5	A'RUSTAQ		1	1									4		1
		6	QURIYAT		2	0									4		2
		7	MASIRAH		0	0									0		
	TOTAL			1	10	5	0	0	0	0	0	0	1	0	28	1	7
2	NORTH BATINAH	1	AL KHABURAH		2	1									3		
		2	SAHAM		2	1									3		
		③	SOHAR	1	2	1			1	1			1		12	1	1
		4	LIWA		2	1									2		
		5	SHINAS		3	2									2		
		6	AL MURAYR		2	1									2		
	TOTAL			1	13	7	0	0	1	1	0	0	1	0	24	1	1
3	SHARQIA	①	IBRA	1	3	1	1	1			1	1	1		8	1	1
		2	DIMA TAYEEN		1	0									3		
		3	KAMIL & WAFI		2	1									4		2
		4	SUR		3	0									4		2
		5	SANAW		2	1									5		2
		6	SAMAD		3	1									2		1
	TOTAL			1	14	4	1	1	0	0	1	1	1	0	26	1	8
4	OMAN INTERIOR	1	BAHLA		3	1									6		1
		2	WADI QURIYAT		2	1									6		1
		③	NIZWA	1	3	0	1	1			1	1	1		7	1	1
		4	AL HAMRA		3	1									4		1
		5	MANAH		3	1									4		
		6	ADAM		4	1									4		
		7	JABAL AKHDAR		2	0									2		
	TOTAL			1	20	5	1	1	0	0	1	1	1	0	33	1	4
5	MUSTA	1	IZKI		3	1									2		1
		②	SAMAIL	1	1	1							1		3	0	1
		3	BIDBID		1	0									3		1
	TOTAL			1	5	2	0	0	0	0	0	0	1	0	8	0	3
6	DAHIRAH	1	DHANK		2	2									5		
		②	IBRI	2	3	1							1		6	1	0
		3	WADI AL AYN		3	1									1		
		4	YANQUL		2	1									4		
	TOTAL			2	10	5	0	0	0	0	0	0	1	0	16	1	0
7	BURAIMI	①	AL BURAIMI	1	1	1							1		2	1	0
		2	AL SANENA		1	1									0		
		3	MAHDHA		1	1									2		
	TOTAL			1	3	3	0	0	0	0	0	0	1	0	4	1	0
8	MUSANDAM	1	KHASAB		1	1									2	0	0
		②	DIBA AL BAYAH	1	3	3									2		
	TOTAL			1	4	4	0	0	0	0	0	0	0	0	4	0	0
9	SOUTH REGION	①	SALALAH	1	2	1							1	2	3	1	4
		2	TAQAH		1	0									0		
		3	DAHAREEZ		1	1									3		
		4	MUQADEEN		1	0									3		
		5	AL HAFA QARAD		1	1									3		
	TOTAL			1	6	3	0	0	0	0	0	0	1	2	12	1	4
	GRAND TOTAL		43	10	85	38	2	2	1	1	2	2	8	2	155	7	27

explanatory notes:
1) ○ of the column of No.* indicates the location of regional department of agriculture
2) These data are derived from the Department of Agricultural Affairs in MAF

farmers to whom particular attention must be paid, and others.

(a) General Services

(i) Periodical visit to farmers for guidance

On average, an extension officer visits 5 to 7 farmers, daily, and provides consultation on practical issues for each crop on their farms. However, only an average of 1.9 extension officers are located in each extension center, which means that each officer is compelled to give advice on all technical aspects.

(ii) Farmer's visit to the extension center to ask questions

In some cases, a farmer will visit the center directly, to ask questions. This type of farmer tackles agricultural management actively. Therefore, the officer can deal with the problem much more easily. This helps to increase the effectiveness of the extension centers. In this case, the staff of the research center sometimes assists the officer with technical advice.

(iii) Discussions among small groups of farmers

Each extension center schedules a field day and organizes farmers into small groups to provide extension services at the extension farm. The farmers discuss each others' problems concerning cultivating crops and the officer provides technical advice. In the meeting, realistic issues with which every farmer is familiar, are discussed. Farmers participate enthusiastically in the discussions and increase the effectiveness of the extension centers themselves. In addition, during this meeting, agricultural techniques are introduced using audio-visual equipment. Unfortunately, only one set of equipment is available in each regional office, therefore, it is difficult for all of the extension centers to use it.

(iv) Demonstration of farming techniques

Good varieties of crops and cultivation techniques recommended by the research center are actually demonstrated in the farmers' fields with the consent of farmers. There are about 20 such demonstration fields established by each extension center. The effectiveness of new varieties of vegetables, field crops, etc., and the comparison of the growth and yield of crops in terms of the different cultivation methods, are demonstrated in order to allow farmers to identify the advantages themselves.

(b) Extension Services to New Farmers

In addition, there is an extension program for 2,500 new farmers in the country which commenced in 1987. This program aims to encourage selected farmers who are expected to become leading farmers. The major objectives of this program are summarized below.

(i) To provide new farmers with guidance on the basis of the techniques taught by the Agricultural Research Center and to extend their effects to all other new farmers.
(ii) To instruct new farmers on the most appropriate use of agricultural input material, i.e. application of proper amount of seed, fertilizers, chemicals, etc.
(iii) To assist new farmers in reducing production costs by introducing new technology, such as modern irrigation methods.
(iv) To inform new farmers about suitable crop rotation patterns which match the soil on their farms.

In order to successfully achieve these objectives, the center selects new farmers who satisfy several conditions. They must be full-time farmers with the ability to purchase materials for the execution of block-rotation and the extension program, etc.

Thus, selected farms are recorded in a file with other management information about annual cropping area, location, etc.. In addition, the results of soil analysis, water quality analysis, etc., are recorded. These assist the extension center significantly.

(c) Seed Production Project

This project aims to produce seeds of field crops in the farmer's field. If the quality of the seeds produced is high, the government purchases them at a price higher than the market price. The major seeds used for this project are wheat, barley and maize, which are produced mainly in the Oman Interior Region.

The selection criteria for seed production farmers are:

(i) Soil of the farm suits production of the specific crop
(ii) The farmer has extensive experience in cultivating such crops
(iii) The farmer cooperates with extension services and readily accepts improved techniques.

Previously, a limited number of farmers participated in this project because they preferred to cultivate vegetables than cultivate field crops. However, the number of participants has recently increased because the government, namely the extension centers, have been putting more emphasis on field crop cultivation.

(d) Other Extension Services

In addition to technical guidance, the extension officers are engaged in administrative activities for the distribution of seeds, fertilizers and chemicals which are provided by the government. This administrative work includes the verification of the necessity of fertilizer for the crops cultivated by the farmers. Based on this verification, the farmers are able to obtain a government subsidy and free materials.

Also, each extension center organizes a spray team for plant protection and a tractor service team for plowing. For plant protection, the extension officer evaluates the necessity and instructs the team on what kinds of pesticides, etc. to use. In this case, there is free labor for the spray service and a government

subsidy covers 50 percent of the pesticide cost. With respect to the tractor services, the extension center provides the services at a cost of R.O. 1 per feddan, but the government has an additional subsidy of R.O. 5 per feddan.

(e) Publicity Services of the Extension Center

The Publicity Section, under the Directorate General of General Diwan Information, is in charge of publicity for each extension center. This includes the introduction of new technology developed by the research center, yearly targets of extension services, advice on current farming issues, etc.. Publicity is done by means of pamphlets, video tapes, and television and radio broadcasts. This service endeavors to increase the technical level of the farmers through broadcasting two times a month on TV and two times a week on radio.

(f) Training for Extension Officers

Training for the extension officers is being conducted eagerly. The training program, intended for all officers, is conducted three times a year. The first program is carried out at the research center, and is mainly for the introduction of new technology and recommended varieties of crops. The other two programs are carried out at the regional offices where a specialist from MAF is in charge as a lecturer. A training program intended for Omani officers is carried out at each regional office once every month. This program lasts two days: the extension methods for cultivation for vegetables, field crops, etc. is covered the first day, and field practice is covered the second day.

(4) Issues in Extension Services

(a) Shortage of Extension Officers

At present, the total number of extension officers is 85. The largest number of officers in one center is four, the smallest number

is one, and the average is 1.9. Assuming that the total number of farmers is 83,204 (refer to the Feasibility Study for the Establishment of a National Company for the Supply of Agricultural Inputs and Services, 1988), the number of farmers under the care of each extension officer is about 1,000. The number of farmers under one officer in the U.S., West Germany, and Japan is 190, 220 and 393, respectively. Compared to Japan, Omani extension officers are in charge of 2.5 times more farmers. Furthermore, there are 15 (33%) extension centers with only one officer. This means that when the officer conducts periodical visits to farmers, there is nobody in the extension center and nobody to respond to visiting farmers. This undoubtedly affects the farmers' confidence in the center.

(b) Shortage of Subject Matter Specialists

The SMS is responsible for training extension officers in agricultural techniques. However, they are too short in number. Considering the fact that most officers are currently forced to take charge of various fields of agricultural techniques, the role of the SMS, who provides advice to the officer, is extremely important. In particular, the SMSs for the cultivation management of dates, which are the major product of the country, and for irrigation, which is the most important policy that needs to be tackled, are extremely short in number.

(c) Publicity Services for the Improvement of Living Conditions in Rural Areas

The present publicity services focus on the improvement of agricultural techniques. These services shall continue in the future with hopes of informing farmers, in their own language, of new technology. Since the rural areas combine both production activities and family living, the improvement of living conditions there is closely related to the farmer's activities with respect to agricultural production. Therefore, the publicity services should aim to improve living conditions and to promote, in close coordination with improvement programs being carried out by other concerned

agencies, awareness in the fields of nutrition and hygiene.

(d) Training Opportunities for Extension Officers

Training the extension officers is essential and must definitely be continued. However, it should also be pointed out that technical knowledge is increased and accumulated through the daily activities of the extension services. Therefore, all necessary technical documents and data should be collected, sorted, filed and arranged so that the officers can educate themselves as well. This process is still poorly organized in some extension centers.

(5) Present Progress of the Third Plan

In connection with the extension services, the following were requested and approved in the Third Five-year Development Plan,

(a) Completion of the Development and Construction of 40 Agricultural Services Centers
(b) Information Facilities and Farmer Training
(c) Accommodations for Agricultural Extension Center Staff
(d) Performance Improvement in Agricultural Extension Centers

Among these items, the approval for the construction of extension centers was the greatest accomplishment. Construction of 40 extension centers project and also accommodation for extension center staff project started in the Second Five-year Development Plan and most of them were completed. The unfinished ones were completed in the Third Five-year Development Plan, and a total of 43 extension centers have been completed.

Although one set of publicity service equipment has been installed in each regional office, one set for each of the extension centers was initially proposed but they have not been supplied yet.

In addition, the requests for an increase in extension staff and the improvement of working conditions have been partially approved.

5.6.2 Development Potential of Extension Services

(1) Strengthening Personnel in Quantity and Quality

(a) Employment

Annually-programmed employment of university and college graduates will be required in order to supplement the shortage of personnel for extension services and to enhance personnel capacity. Since farmers are generally conservative, Omani guidance will probably be more persuasive than a foreigner's. Therefore, Omanization in the sector of the extension services sector is necessary.

(b) Training of Extension Officers

At present, extension officers are active in various fields and provide as many services as possible with the small number of personnel available. In future, however, more technical knowledge will be required because of the diversification of crops. Accordingly, the training of officers is essential and must continue with greater efforts. At the same time, training methods and office facilities should be improved in order to provide more effective and efficient services.

(2) Publicity Services

In parallel with the extension services, the improvement of the rural population's health, hygiene, and nutrition standards, etc. should be highlighted and carried out in close cooperation with other concerned ministries and agencies in order to raise living standards in rural areas and thereby to promote agriculture. Therefore, an executing and promoting body should be arranged, and well-organized.

(3) Enhancement of Farmer's Capabilities

The successful impact of the extension services depends largely on

the capabilities of the recipient, i.e. the farmer. Accordingly, the enhancement of the farmer's capacity for change ought to be tackled, as part of the nation's education in general. As the younger generations, who have finished their compulsory education, begin to participate in agriculture, their modernized sense is expected to emerge clearly, and carry agriculture from traditional and customary practices towards modernization and new management activities. The responsibilities of the extension services are expected to develop in line with such advances in farmers' capabilities and awareness.