AG:DP/OMA/87/011
Terminal Report

SOIL SURVEY AND LAND CLASSIFICATION PROJECT

OMAN

PROJECT FINDINGS AND RECOMMENDATIONS

UNITED NATIONS DEVELOPMENT PROGRAMME

FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS ROME, 1993

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Report prepared for
the Government of Oman
by
the Food and Agriculture Organization of the United Nations
acting as executing agency for
the United Nations Development Programme

UNITED NATIONS DEVELOPMENT PROGRAMME

FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS

Rome, 1993

The Food and Agriculture Organization is greatly indebted to all those who assisted in the implementation of the project by providing information, advice and facilities.

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LIST OF ABBREVIATIONS

ALES	-	Automated Land Evaluation System
GIS	-	Geographic Information System
MAF	-	Ministry of Agriculture and Fisheries
MWR	-	Ministry of Water Resources
PAMAP	-	Public Authority for Marketing Agricultural Produce

1. INTRODUCTION

1.1 PROJECT BACKGROUND

It is the policy of the Government of Oman to use part of its oil revenue to diversify the economic base and promote the conservation and sustainable use of the country's natural resources.

Only 20 years ago agriculture was the main contributor to the national income. Since the oil boom of the 1970s, agriculture has lost some of its economic importance, while still receiving considerable attention in order to promote economic diversification and for socio-cultural reasons.

More than half of Oman's agricultural land is in the Batinah and Salalah coastal plains. Excessive expansion of the cultivated area in the last 15 years has led to over-abstraction of ground water and salinization of soils and water.

Given the gravity and complexity of the situation, the Government requested UNDP assistance in order to collect data on land, water, crops and farming systems as well as conduct an irrigation subsidy programme.

1.2 OUTLINE OF OFFICIAL ARRANGEMENTS

The Project Document for project OMA/87/011 'Soil Survey and Land Classification Project' was signed in November 1988, with FAO designated as the executing agency and the Ministry of Agriculture and Fisheries (MAF) as the government implementing agency. The UNDP contribution was $US 3 711 038 and that of the Government was RO 476 023. The duration of the project was set at 36 months, and the objectives were limited to:

- preparing a general soil map of the country, at 1:250 000 scale (Soil Atlas);
- carrying out a detailed soil survey, at 1:20 000 scale, on 10 000 ha of desert land in five areas identified in previous consultants' surveys; and
- carrying out a detailed soil survey at 1:10 000 scale, on 20 000 ha in existing farmed areas.

In November 1989, the Project Document was revised in order to carry out multidisciplinary studies and provide technical support to an irrigation subsidy operation launched by the Ministry of Agriculture and Fisheries to encourage the use of modern irrigation systems by the farmers in the Batinah plain.

In December 1990, the Ministry of Agriculture and Fisheries requested the project to include irrigation design among its outputs without increasing expenditures or changing major outputs. As additional resources were needed, it was decided to reduce those inputs that could most easily be replaced by inputs in kind from Government agencies.

The duration of the horticulture and extension consultancy was reduced from 36 m/m to 12 m/m on the condition that the MAF staff would do most of the work in this field. One soil survey expert post was suppressed, and his duties were to be taken over by the team leader and the other soil survey expert.

Given the fact that a large amount of geo-coded data was accumulated by the project, it was also decided to include the preparation of a geographic information system (GIS) for the Salalah plain (approximately 4 000 ha) as a pilot area to demonstrate its usefulness.

Project operations were concluded on 4 November 1992.

1.3 OBJECTIVES OF THE PROJECT

The long-term objective of the project was to increase agricultural production through lateral expansion and intensification on existing farmland.

The immediate objectives of the project were to:

- survey soil resources in the country's virgin lands and determine their potential for agricultural use;
- provide information and policies for the intensification of agriculture in the Batinah (44 000 ha) and five other selected farmed areas (6 000 ha); and
- improve and rehabilitate agriculture in the Batinah plain through the introduction of appropriate irrigation systems, the adoption of more suitable cropping patterns, the establishment of an efficient agricultural extension service and the introduction of a functional subsidies scheme.

2. RESULTS AND CONCLUSIONS

2.1 ASSESSMENT OF THE POTENTIAL FOR LATERAL EXPANSION

2.1.1 General soil map (Atlas)

The general soil map (Atlas) was successfully completed as planned on 16 November 1990.

The Soil Atlas, at the scale of 1:250 000, is the first complete inventory of the soil resources of Oman. It identifies all sizeable areas of lands suitable for irrigated agricultural production. The main benefits of the Atlas are that it provides essential information on the national soil resource base for planning sustainable agricultural development, and identifies the most suitable areas where water resource exploitation for agricultural development can be concentrated, thus allowing the Government substantial savings.

A consolidated soil map, at 1:1 000 000 scale, was also compiled from the 1:250 000 scale general soil map. Both the 1:250 000 and 1:1 000 000 scale maps were digitized and stored in a geographic information system (GIS).

2.1.2 Detailed soil survey in virgin lands

It was initially planned that 10 000 ha would be mapped at 1:20 000 scale. However, the Ministry of Agriculture and Fisheries was unable to obtain confirmation from the Ministry of Water Resources on the availability of ground water in sufficient quantity and therefore chose not to carry out detailed soil surveys.

Instead, 9 000 ha, at 1:10 000 scale, were surveyed in the Batinah cultivated area. Because the scale is double, this survey represents the equivalent of a 36 000 ha survey at 1:20 000 scale. A minor soil survey, at 1:5 000 scale, was also carried out in the Al Ghabbi area (440 ha). The map was drawn and given to the Irrigation Department in 1989.

2.1.3 Conclusions

The Atlas has been successfully used in the Nejd and various other areas. It has proven its usefulness as a tool for national and regional planning. The Ministry of Agriculture and Fisheries has distributed it widely, especially to other Ministries, such as the Ministry of

Water Resources, which is an important user. Some foreign countries, including Iran, have also requested copies.

Now that the Atlas is digitized and stored in a geographical information system, it can be combined with any other theme, such as vegetation or geology.

2.2 ASSESSMENT OF THE POTENTIAL FOR INTENSIFICATION

2.2.1 Introduction

The physical conditions in the Batinah and Salalah plains will be presented first, followed by an analysis of plant and animal production to highlight the existing limitations in these fields. A section on land evaluation will focus on the physical and economic crop production potential of each study area. The farming systems section will analyse the socio-economic constraints. This will be followed by global conclusions and a diagnosis of the problems hampering sustainable agricultural development in the Batinah and Salalah plains.

2.2.1.1 Soils

The Project Document stated that 44 000 ha were to be mapped at 1:10 000 scale in the Batinah and 6 000 ha at the same scale in other areas. When the new aerial photography was taken by the project in 1990, it became clear that 44 000 ha would cover only 45% of the Batinah coastal strip, and that a gap would remain in south Batinah, between Suwayq and Masanaa. It was then decided to cover 4 200 ha in Salalah and 54 900 ha in south Batinah, leaving no gap.

Thus 9 100 ha of detailed soil survey were added to the initial objectives. The soil survey was initiated in November 1988 and completed in April 1992. Mapping was done at 1:10 000 scale, some 14 000 observations were made and 3 200 samples were collected from representative profiles for general chemical and physical analysis. In addition, 356 infiltration and permeability tests were concluded.

Ninety-nine major soil types, each divided in several phases, were identified in the study area and classified in both the American and the FAO soil classification systems. They were also given local series names. In view of the large number of soil phases, a special parametric system was conceived and used to describe them.

Soil data was compiled at the farm level, draft soil maps were digitized and soil information was stored in computer data bases in a geographic information system. A set of colour soil maps at the farm level were plotted with the GIS at 1:10 000 scale. Another set of 50 soil maps covering the entire study area, including the land between farms, was also prepared at 1:10 000 scale, with map legends based on consociations and complexes of phases of soil series. These maps were digitized, but there was not sufficient time to correlate the individual legends or groups of photographs for final publication. It is very important that this activity be carried out in the future, as these maps will be useful in case of relocation of farmers within the area.

Nearly all of the soils are very deep and have less than 2% slope. Topsoil is generally coarse-textured (sandy or coarse loamy in roughly 80% of the study area). The infiltration rate is moderately rapid to very rapid in approximately 60% of the area.

Approximately 30% of the soils are strongly affected by salinity, mostly due to the use of saline irrigation water and inadequate salt leaching.

General fertility is low and deficiencies are expected in several micro-nutrients, such as iron, manganese, zinc and copper.

2.2.1.2 Water resources

Since the oil boom and the start of the modernization of the country in the mid-1970s, there has been a rapid expansion of cultivated area. In the 1980s, an even quicker expansion of the irrigated area created a large deficit in aquifer recharge which was, and still is, partly compensated by sea water intrusion. Aquifers have become increasingly saline, causing severe crop damage.

No sustainable agricultural development is possible in the Batinah without restoring the ground water balance. Fortunately, unlike certain fossil aquifers, such as those in the Nejd, the Batinah benefits from natural ground water recharge. Therefore the degradation process can be reversed if the water balance is restored by increasing recharge and/or by reducing water consumption.

The programme of the Ministry of Agriculture and Fisheries for the construction of recharge dams aims at increasing water storage through artificial recharge. Although this programme is useful and should be continued, it is not sufficient to restore the water balance.

Reducing water consumption can be achieved by reducing irrigation losses through improved irrigation technology. However, although modern irrigation systems can save some water by reducing evaporation, their impact on the water balance in the situation of the Batinah is rather weak. As the irrigation water is drawn from below the farms, percolation losses, apart from a small percentage of storage above the water table, return to the aquifer. Therefore, reducing the irrigated area remains the most efficient and sustainable way to reduce water consumption.

The project has estimated the total crop area in the study area to be 14 400 ha 1/ and the global crop net water consumption to be 226 000 000 m^3 per year, as follows:

- fruit: 145 000 000 m^3;
- fodder: 62 000 000 m^3;
- vegetables: 19 000 000 m^3.

Using the consultancy work recently carried out for the Ministry of Agriculture and Fisheries as a reference, the ground water deficit in the study area was estimated to be at least 60 000 000 m^3/yr. Therefore, the reduction of net crop water by a volume of 60 000 000 m^3 should be a minimum target until better estimates of the deficit are obtained by hydrogeologists.

In order to be able to give specific cropping pattern recommendations to each farmer, an irrigation water quality survey was conducted on all of the farms in the study area. The information collected was used to determine the potential of each farm through the land evaluation exercise, to analyse and understand the present cropping pattern and to contribute to a better understanding of the geographic distribution of water quality in the plain.

According to the Project Document, 44 000 ha were to be mapped, with an average sampling density of one well for 12 ha (i.e., 3 667 wells). Actually 54 900 ha were mapped and 8 177 wells were visited. A number was assigned to each well and the depth to the water table (except in part of Suwayq) and the electrical conductivity was recorded. This information was entered in a computer data base, and then used to plot 50 salinity maps, at the farm level, at 1:10 000 scale, with a geographic information system. Water samples were also taken from 14 representative wells and analysed.

It was found that approximately 50% of the cultivated area in south Batinah is irrigated with relatively good water (<3 dS/m), whereas roughly 32% is irrigated with strongly saline water (more than 7 dS/m). It was also found that smaller farms tend to have more saline

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1/ Excluding abandoned crops and including 50% of the vegetable fallow.

water than large farms, as the larger farms, are generally more recent and developed near the highway where the aquifer is sweeter.

2.2.1.3 Land use

The land use survey covering 54 900 ha focused on agricultural land use. A comprehensive field survey was carried out at 1:10 000 scale, the draft maps were digitized and final colour maps (50 sheets) were plotted with a GIS. The land cover information stored in the GIS was used to analyse the present cropping pattern in the study area in order to determine the influence of water salinity and farm size on the present cropping pattern.

Three types of agricultural land use patterns, organized as successive bands running parallel to the coast of the Gulf of Oman, occur in the study area. Starting from the coast toward the Hajjar mountains, there are the date palm belt, the recently developed small farms and the large modern farms.

The date palm belt is a nearly continuous band of old date palm groves. Farms are generally less than five feddans in size and are strongly affected by salinity. Low quality date palm is the main crop and many farms are abandoned.

The recently developed small farms were mostly created during the 1980s in the framework of government land distribution programmes. Most of them are located between the date palm belt and the highway, although some of them are also located between the highway and the Hajjar mountains. A majority of farms in this area are between 5 and 15 feddans and are diversely affected by salinity. Alfalfa, date palm and lime are the main crops.

Most of the large farms are recently established private farms, with often a dual use as secondary residences for wealthy Omani households and as commercial farms. A few are purely commercial or Government and royal farms. Most of these farms are more than 20 feddans, use tube wells and grow a variety of crops, although some specialize in rhodes grass, vegetables or fruit. Salinity damage is more limited in this farm category.

Of the 54 900 ha covered by the land use survey, 26 280 ha are virgin lands while 28 620 ha are holdings used for agriculture or recreation or are fenced without being currently used. The latter includes 561.5 ha of intercropped area (i.e., crops grown under tree crops).

Table 1 presents global land use statistics for the study area. It is noteworthy that new farms starting operations at the time of the survey make up 1.9 % of the holdings, whereas land that is fenced but not presently used covers some 5 129 ha (17.9% of the total area). This land may turn into new farms in the future.

Table 2 shows that perennials comprise 81.2% of all crops. Fruits are the dominant crops with 59.3%, followed by fodder (21.9%) and vegetables (18.6%).

The land use survey has also shown that date palm is the first fruit, followed by lime and mango. With 87% of the fruit area, date palm is by far the dominant fruit on holdings smaller than five feddans. Approximately 20% of the area planted in date palm in south Batinah is already abandoned.

Table 3 shows that 81.6% of the holdings are less than ten feddans, 58.3% are less than five feddans and 37.5% are less than three feddans.

It was also found that 50% of the area under crops is irrigated with relatively good water (conductivity of 3 dS/m or less). This proportion is approximately 61% for vegetables and fodder but only 41% for fruit. The proportion of fruit in the cropping pattern increases with increases with increasing salinity at the expense of fodder and vegetables, while date palm tends to replace other fruit.

2.2.2 The Salalah plain

2.2.2.1 Soils

The soil survey was initiated in December 1990 and completed in July 1991. It covered an area of some 4 200 ha, of which roughly 3 544 ha were in holdings.

Thirty-eight soil types (phases of series) were identified in the study area, and soil data was compiled at the farm level. Soil maps were digitized and soil information was stored in computer data bases in a geographic information system. Colour maps were published with the GIS at 1:10 000 scale (eight sheets). Similarly a generalized soil map in one single sheet was prepared at 1:25 000 scale.

Deep to very deep soils cover approximately 85% of the study area, whereas moderately deep soils cover 9% and shallow and very shallow soils 4%. The slope is generally less than 2%. The slope is generally coarse loamy in approximately 60% of the study area, fine loamy in 7% and gravelly in 29%. Infiltration rate is generally low to moderately low. Available water-holding capacity is high or moderate in approximately 56% of the area. The average topsoil calcium carbonate content is 62% with a minimum of 45%. Gypsum is rare and its content is less than 15%.

Soil pH is generally mildly to moderately alkaline, and most soils are non-saline to slightly saline (83% of the study area). Fertility is low. The average topsoil cations exchange capacity, and calcium followed by magnesium, are the main cations saturating the soil exchange complex. Exchangeable potassium and available phosphorus contents are moderate. Organic matter is higher than in other areas, but remains low by international standards. The average organic carbon content in the topsoil is approximately 0.6%. Iron, manganese, zinc and copper are micronutrients that are commonly in short supply.

2.2.2.2 Water resources

The aquifers in the Salalah plain benefit from an important seasonal recharge during the summer monsoon (Kharif). However, excessive water withdrawals, due to the expansion of large farms growing rhodes grass, have caused a deficit in the water balance.

In 1991, the Salalah Water and Wastewater Master Plan, prepared by the consulting firm Dames and Moore International working for the Dhofar municipality, reached the conclusion that the ground water deficit is approximately 8 000 000 m^3/yr. The Master Plan proposed to:

- abandon the large fodder farms which might be shifted to the Nejd;
- inject the treated wastewater in the aquifer; and
- irrigate the coconut farm planned by the Ministry of Agriculture and Fisheries using treated wastewater.

These measures seemed adequate to compensate the deficit.

In order to be able to give specific cropping pattern recommendations to each farmer, an irrigation water salinity survey was carried out on all farms in the study areas, visiting a total of 796 wells. A number was assigned to each well, and depth to the water table, water salinity, total dissolved solids and water temperature were recorded. Seventeen representative wells were sampled for chemical analysis. The information collected was entered in a computer data base, and was then used to plot salinity maps at the farm level, at 1:10 000 scale (eight sheets), and a generalized map at 1:25 000 000 scale with the help of a geographic information system.

The survey showed that roughly one-third of the study area uses brackish water of electrical conductivity varying from 3 to 15 dS/m.

The situation varies with the district. In Awqadain district, all of the cultivated area is cultivated with brackish water, generally at more than 5 dS/m. In Salalah district, nearly

90% of the cultivated area is irrigated with water between 3 and 7 dS/m. Dahariz district has all types of salinity classes, whereas Hafa-Qarad district has almost 80% of its cultivated area irrigated with good water at less than 2 dS/m.

Water salinity also varies according to farm size. If farms smaller than ten feddans are considered separately, the situation is much worse than the global figures show. Only 36% of the area operated in farms of ten feddans or less is irrigated with good water, at less than 3 dS/m. Approximately 35% use brackish water, at 3 to 5 dS/m, and 28% use strongly saline, at more than 7 dS/m.

2.2.2.3 Land use

The land use survey was carried out in June and July 1991, providing information on areas under each major crop at the time of the survey. The field work was done at 1:5 000 scale, after which the draft maps were digitized and plotted at 1:25 000 scale with a geographic information system. The GIS was also use to statistically analyse the data.

The land use survey has shown that crops and fallow cover 75% and 7.6%, respectively. Therefore 82.6% of the study area is cultivated. The unused area inside the farms amounts to only 8.5%. These figures reflect the very high density of cultivation and dominance of perennial crops.

Farm buildings cover 4.6% of the area, whereas newly established farms, which are under development, cover 0.5%, and land that is fenced but not yet developed for cultivation (enclosures) covers 1.6%. There are five abandoned farms covering 0.1% of the area. Lawns and other ornamental plants cover 1.1% of the area. There are 291 feddans which are intercropped, representing 4.6% of the net cropped area.

The farms growing crops at the time of the survey were counted. The total number of 'active' farms in the study area was 796. Dahariz extension district had the highest number of farms (270), followed by Hala-Qarad (259), Salalah (163) and Awqadain (104).

The survey suggests that 90% of the farms are ten feddans , while larger farms (10% of all farms) operate 59% of the cultivated area.

On farms of ten feddans or smaller, fodder and banana occupy respectively 30.6% and 26.6% of the cropped area. Coconut and vegetable take the third and fourth places, with respectively 18.5% and 13.4%. Papaya and citrus represent respectively 2.9% and 1.1% of the total cropped area. Other fruit trees occupy 1.1%, and fallow 5.7%.

On farms larger than ten feddans, fodder and coconut occupy the first and second places, with respectively 58.1% and 13% of the cropped area. Banana and miscellaneous fruit trees and vegetables take the third, fourth and fifth places, with respectively 6.4%, 4.5% and 4.2%. Papaya, citrus and fallow represent respectively 1.5%, 0.8% and 5.7% of the total cropped area in this category.

Irrigation water salinity varies widely between farms and areas and is expected to strongly influence the cropping pattern. It has been possible, with the help of the geographic information system, to analyse the impact of water salinity on the cropping pattern on small farms.

Banana was found to be the dominant crop below a salinity of 5 dS/cm. It is a secondary crop in the 5 to 7 dS/m water salinity range and a marginal one from 7 to 10 dS/m. It disappears completely beyond 10 dS/m.

Papaya covers a significant area only below 3 dS/m, probably due to economic reasons. The slight increase of its share in the cropping pattern in the salinity class 7 to 10 dS/m is consistent with the fact that it resists salinity better than banana.

Citrus is significant only when salinity is less than 5 dS/m and virtually disappears beyond that.

The area share of coconut in the cropping pattern increases steadily with increasing water salinity levels, which is consistent with the higher resistance of this crop to salinity.

Fodder's (mostly rhodes and buffel grass) share of the cropped area increases clearly and rapidly with increasing salinity levels, as these crops are the most resistant to salinity. It was also found that elephant grass reaches a peak in the salinity range 5 to 7 dS/m then eventually decreases. This shows that elephant grass is less resistant to salinity than rhodes grass.

Vegetables occupy a nearly steady percentage (roughly 14% to 15%) of the area in the salinity range 3 to 7 dS/m, then decrease rapidly to approximately 1% beyond 10 dS/m. Fallow occupies roughly 3% to 5% of the crop area below 5 dS/m, then jumps to 8% to 10% in the 5 to 10 dS/m water salinity range. Beyond 10 dS/m, fallow occupies roughly 16.7% of the area. This shows that cultivation becomes increasingly unprofitable with increasing salinity levels.

2.2.3 Plant and animal production

2.2.3.1 Introduction

The project reviewed the technical aspects of crop and livestock production, and presented its conclusions in the 'Plant and Animal Production Report'. These conclusions are summarized in the following sections.

2.2.3.2 Plant protection

Climatic conditions in the Batinah and Salalah plains are favourable to the proliferation of many crop pests and diseases, resulting in heavy crop damage and yield losses.

Oman imports considerable quantities of agricultural produce. With these, a number of pests and diseases penetrates the country. An effective plant protection policy cannot be implemented without adequate quarantine services. Several weaknesses were found in the existing quarantine services.

There is a lack of specialized personnel, and, as there are no laboratory facilities, inspection is mostly visual. The list of prohibited pests is not updated, and some noxious weeds must be included. Post-entry quarantine services do not exist.

Although aimed at encouraging proper pest control, government subsidies on pesticides have resulted in misuse and overuse of chemicals. Given the wide occurrence of pests and diseases, the relatively low subsidized prices and the low educational level of the farmers, the latter tend to spray massively and preventively. This situation results in the pesticide resistance of pest populations, in hazard to citizens' health and to the environment, and in economic losses.

Most of the subsidized pesticides recently listed by the Ministry of Agriculture and Fisheries are of the broad-spectrum type. This results in the elimination not only of pests but also their predators, thus preventing natural biological control. There is no pesticide residue control laboratory in Oman. Therefore, toxic effects on humans, organisms other than pests and the environment are unknown.

Some large farms import pesticides directly, thus escaping control and possibly using harmful substances. The active ingredients content of imported pesticides is not checked locally, and there is thus no guaranty of efficacy. Pesticide residue control is not carried out on agricultural produce or in the environment.

There is a high and unexploited potential for successful biological control operations in the Salalah plain, as the region is isolated, climatic conditions are favourable, and variability in intercropped plants provides good habitat possibilities.

2.2.3.3 Fertilization

Most soils in Oman have a high lime content, a low capacity for holding nutrients and a relatively low fertility status. The high lime content induced severe micronutrient deficiencies that have been well documented in the study, especially in Salalah, through direct observation as well as soil and leaf analysis.

Smallholders use mostly manure and soil addition (called 'sahib' in Salalah) as a source of nutrients, and despite subsidies, NPK chemical fertilizers are used in small quantities in both the Salalah and Batinah plains. Manure contains some micronutrients and also increases the soil nutrient and water-holding capacity. However, there are a number of limitations associated with its use, including its high cost and propensity to propagate weeds and diseases.

2.2.3.4 Irrigation practices

The project reviewed the status of irrigation in south Batinah and Salalah. Traditional surface irrigation systems are currently the dominant systems of water distribution to crops. However, modern irrigation systems are eventually replacing them, with major government support.

Current irrigation practices are inefficient, and most farm owners and migrant workers who manage the farms have little or no knowledge of modern agriculture. The following limitations are associated with the use of traditional irrigation methods:

- low water-use efficiency;
- high labour requirement for managing and distributing water;
- weed growth along earthen channels and in basins;
- weed growth along earthern channels in the basins;
- uneven water distribution; and
- inability to fine-tune water applications through the frequent delivery of low volumes in order to maintain a soil moisture regime that is optimal for crop growth.

A number of government organizations are either directly or indirectly involved in irrigation within the study area. The Ministry of Agriculture and Fisheries is responsible for the evaluation and monitoring of water resources as well as the implementation of national policy on water extraction from wells. The municipalities are responsible for domestic water supply and for landscape irrigation. The coordination between these government organizations dealing with water is not presently sufficient.

Many companies are involved in the supply and installation of pumps and irrigation equipment. The industry is structured with a small number of manufacturers and importers of equipment and a relatively large number of local contractors. There are also two local manufacturers of PVC and polyethylene pipes.

A wide range of irrigation equipment is imported. It is of variable standard and some of it is of poor quality. Outside the MAF programmes in the agricultural sector there appears to be little recognition of equipment standards, with price often being the only criteria for selection.

Installation standards are highly variable, with the well established irrigation companies generally performing better than small, often part-time, contractors. The lack of skilled irrigation engineers and experienced plumbers is a limitation on the quality of the installations. The design capability of local companies in irrigation is limited, with relatively few engineers available. No qualified Omani irrigation engineers are currently working within the private sector.

2.2.3.5 <u>Animal production</u>

The development of animal production in Oman is hampered by many problems.

Imported animal products (such as meat, powered milk and other dairy products) are entering the country freely. The competition between local and imported animal products is usually in favour of imported products because they are cheaper. The high cost of imported raw animal feed ingredients (such as grains and soybeans) is responsible for higher local production costs.

Livestock is suffering from a shortage of roughage (energy) and minerals, particularly P and Mg, and diseases related to nutritional deficiencies, such as posterior paralysis resulting from Cu deficiency. The low fertility of livestock and its general bad performance might be partly due to trace mineral and vitamin deficiencies. The use of trace-mineralized salt blocks is not practices by all livestock owners.

The productivity of local dairy cattle is very low, owing to genetic characteristics. Cross-bred cattle give a milk production which is more than twice the production of local cattle.

Animals are not properly housed in well ventilated pens. The level of hygiene is low, and diseases such as pneumonia, rinderpest and rabies are reported to prevail in certain areas.

The marketing and handling of animal product is not functioning smoothly. Many animal products are available (particularly milk) in large quantities, but are not marketed because of the lack of collection, refrigeration and processing facilities. Livestock by-products, such as hides and skins, are not processed and marketed.

2.2.4 Land evaluation

2.2.4.1 Introduction

Land evaluation aims at identifying the potential for relevant alternative enterprises to improve productivity and sustainability. The evaluation of physical resources, mostly land and water, plays an important role in the process, and socio-economic opportunities and constraints must also be taken into account. In each study area (in the Batinah and Salalah plains) the land evaluation process consisted of the following four steps:

- the identification and description of alternative crop enterprises, including the determination of their land requirement and potential yields;
- the compilation of relevant soil and water characteristics at the farm level, and entering this information in computer-compatible form;
- the development of the Automated Land Evaluation System (ALES), a specialized computer software system capable of automatically determining the physical and economic suitability of each combination of soil and water quality; and
- the assessment of the physical and economic suitability of each land unit for each crop enterprise.

The land evaluation software (ALES) was developed by the project to estimate physical suitability, potential yield and potential profit (gross margin) for each farm and for most relevant crops.

The ALES software allows for changes in input or produce prices to be taken into account. It is a living land evaluation model that can be frequently updated and continue to serve, as opposed to a static one embodied in a simple report.

The following activities were carried out for each crop enterprise:

- information on crop calendars, recommended planting dates and varieties was collected;
- crop water requirements were calculated, using FAO's specialized software CROPWAT;
- fertilizer requirements were determined for each crop;
- pesticide requirements were estimated for each crop;
- requirements for planting material quantities and costs, and for labour and tractor services, were determined;
- achievable yields were estimated under each level of irrigation water salinity; and
- cost information was collected on all necessary inputs and produce selling prices, using the subsidized price for all subsidized inputs.

The land evaluation results, together with farming system and policy considerations, have formed the basis of the cropping pattern recommendations.

2.2.4.2 Results for the Batinah plain

Crop budgets were prepared for 15 vegetables, two fodder crops and seven fruits, and included the inputs necessary for optimal production. The following crops were evaluated:

- vegetables (cabbage, carrot, cauliflower, cucumber, eggplant, green bean, hot pepper, okra, onion, potato, squash, sweet melon, sweet pepper, tomato and watermelon);
- fruits (banana, chico (sapota), date palm, grapevine, guava, lime and mango): and
- fodder (alfalfa and rhodes grass).

Vegetables were evaluated (in ALES) under drip irrigation only, in order to reduce labour costs, and because the ground water situation was so bad that every opportunity to save water had to be taken. However, production costs for surface irrigated vegetables were also calculated for reference. Banana and grape were evaluated under drip, while date palm, chico, guava, lime and mango were evaluated under bubbler irrigation systems. Alfalfa was evaluated under improved basin irrigation and rhodes grass under sprinkler irrigation.

Potential gross margins were published for a wide range of crops for all of the soil phases comprising 75 ha or more of the cultivated area (60 soil phases of 18 series, covering a total area of 8 307 ha and 2 341 farms).

On farms having non-saline soils and water with E.C. below 3 dS/m, vegetables were found to be the most profitable crops, with fruits less profitable than vegetables but more than fodder. Mango, followed by lime and guava, are the most profitable fruits, and date palm is the least profitable. Of the fodder crops, which are less profitable, rhodes grass is more profitable than alfalfa, as there is a large market for it, it is more resistant to pests and diseases and it is generally grown on large farms the acreage of which compensates for lower per area gross margin.

On farms having non-saline soils and water with E.C. between 3 and 5 dS/m, cauliflower, tomato, squash, cucumber and sweet melon are the only profitable vegetables. Mango, guava, banana and grape are the most profitable fruits. Rhodes grass is less profitable than alfalfa.

On farms having non-saline soils and water with E.C. between 5 and 7 dS/m, cauliflower, squash, tomato, alfalfa and mango are the most profitable crops, although gross margin is low (250 to 450 Omani rials per feddan).

On farms having non-saline soils and water with E.C. higher that 7 dS/m, there are no profitable crops under modern irrigation systems, with the exception of date palm, which provides a very low income.

On farms having strongly saline soils and water with E.C. below 7 dS/m, no vegetables are profitable and fodder crops, firstly alfalfa, are the best crops to grow. Date palm gives a very low positive gross margin.

On farms having strongly saline soils and water with E.C. higher than 7 dS/m, only date palm gives a meager profit until an E.C. of 10 dS/m. Beyond this salinity no crop is profitable.

2.2.4.3 Results for the Salalah plain

Land evaluation was carried out for 14 vegetables, one grass, and six fruits. These were:

- fruits (banana, chico (sapota), coconut, grapevine, guava and papaya);
- fodder (rhodes grass); and
- vegetables (cabbage, carrot, cauliflower, cucumber, eggplant, green bean, hot pepper, okra, squash, sweet melon, sweet pepper, sweet potato, tomato and watermelon).

Vegetables were evaluated under surface irrigation and drip irrigation separately. Banana, papaya and grape were evaluated under drip, and coconut, chico and guava under bubbler irrigation systems. Rhodes grass was evaluated under improved surface irrigation and alternatively under sprinkler irrigation.

Potential yields, physical suitability and gross margins were calculated for four representative soil units covering 46% of the study area. The results showed that:

- vegetables are always the most profitable crops;
- among vegetables chilies are the most profitable when there is very good water, whereas squash, sweet potato and tomato are more profitable if water is saline;
- watermelon has a low profitability even with the best water and soil; and
- among perennial crops, guava, banana and sprinkler-irrigated rhodes grass are very close.

Evaluation results suggest that modern irrigation systems are nearly always profitable.

2.2.5 Farming systems

During the 1980s, the Government pursued a policy of expanding the area under cultivation by distributing land free of charge, and by supporting the establishment of new farms with an extensive package of subsidies in order to encourage new investments and to promote the use of modern techniques and inputs. The Government also protected the domestic market through a system of import licensing, improved agricultural services (extension, research, credit and marketing) and invested heavily in the country's infrastructure. As a result, the cultivated area has expanded and agricultural production has increased, although there is still much scope for improvement in productivity and sustainability.

Government policies of price support and subsidies to the livestock sector have induced changes in land-use. These policies have encouraged the expansion of area under grasses, both in south Batinah and Salalah, which have high water requirements, thus further deteriorating the aquifer water balance.

The social structure of Oman is undergoing a change from a closed tribal society to a commercialized household-centered one. The status of existing arable farming as a low payoff activity tends to make it an inferior option in the minds of farmers. The availability of economically superior alternatives in the non-farm sectors offers much higher and regular income as compared to farming. The aspirations of a majority of Omani people toward trading and administrative occupations tend to relegate agriculture to a side business to be managed by expatriate labour. This attitude is the main cause of the neglect of agriculture and the greatest constraint to its future development.

With a view to understanding the farm-household systems, field surveys were carried out in some 50 randomly selected sample households in each of the Batinah and Salalah plains (in March-April 1992 and July-August 1991, respectively). Survey results indicated that:

- small holdings (smaller than ten feddans) represent 90% of all farms;
- small holdings are more intensively cultivated than large farms;
- only a small minority of heads of households reported farming as their main occupation;
- the participation of family labour in agriculture is negligible and the work is mainly performed by expatriate labour;
- expatriate labourers are often involved in the management of the farms, thus rendering the decision-making process more complicated (They are also more interested in immediate profit and therefore little motivated for long-term investment and conservation of natural resources.);
- most of the expatriate labourers are young males from Bangladesh, India, Pakistan and Egypt;
- an average of RO 10 000 is invested in structures and buildings on sample farms, mostly for unproductive investments such as farmhouses, while investment in machinery and equipment is mostly for irrigation;
- as the type of assets acquired by farmers could not be financed by farm income, farming is supported by off-farm income;
- households keep animals mostly for their own consumption and to supply farmyard manure for crop production;
- the management of livestock has shifted from a family-based activity involving partial grazing outside the farm, to stall feeding by permanent labourers on the farms;
- gross margins for livestock are positive if the change in inventory is not accounted for, but if basic stock is to be maintained then all types of livestock records show negative gross margins;
- constraints to livestock development are in the fields of animal health, nutrition and management;

- efficient breeding management is not practiced, due to low economic returns and the lack of awareness of livestock holders;
- the distribution system, and facilities for marketing livestock and product processing, have not been well developed;
- the demand for animal products is far greater than the supply, resulting in imports of large numbers of cattle, goats and sheep; and
- there is no practice of using livestock by-products, such as hides, skins and hair.

Despite the dedicated efforts of the extension staff, it was found that extension services do not function properly for the following reasons:

- the extension centres mostly supply machine services and subsidized inputs, but do not provide the desired level of technical guidance, largely due to the lack of personnel to deliver such a large volume of services;
- there is no testing of research results in farmers' conditions to make the information directly usable by the extensionists to advise farmers;
- research and extension in Oman does not consider the farm as a whole but rather as a sum of individual plant and animal enterprises;
- there are no technological packages which take into account farm characteristics, such as farm size, farm age and cropping patterns;
- extension is not sufficiently directed to the labourer carrying out production activities, but rather to the farm owner; and
- extensionists are not available during weekends when absentee farmers are available.

Although it has achieved some good results, agricultural research suffers from several constraints, such as a general lack of resources in the areas of personnel, equipment and facility space.

As there are too few stations, they cannot be representative of the large variability in farmers' environmental conditions. The existing research stations are very large and therefore do not represent the ecology of the dominantly small farms.

Research programmes are not sufficiently oriented toward farmers' needs. No research has been conducted to identify vegetable varieties that are resistant to salinity, although salinity affects more than a third of the cultivated area. Tall grasses, banana, papaya, coconut and many vegetables have not received attention in proportion with their economic importance, whereas coffee and cereals have been studied in several trials.

Fertility trials on macronutrients do not cover all of the major crops, especially tree crops, and too little attention has been given to micronutrients.

Although inputs are generally in good supply, they are often inadequate. Certified seeds and chemicals are not all tested before being marketed. Many of the subsidized pesticides are not suitable for the control of some occurring severe pests and diseases.

Marketing of agricultural produce, particularly vegetables, is a major problem for farmers. In peak production periods, farmers are often obliged to sell their production at very low prices or throw it away. Storage facilities are inappropriate and losses are high. The Public Authority for Marketing Agricultural Produce (PAMAP) is trying to improve the situation, but faces problems of excess supply alternating with periods of shortage.

Although credit is available, farmers are not well informed about it, and there is often reluctance to take loans and mistrust of banking institutions. Credit institutions do not fully recover the amounts loaned to their clients. This leniency endangers their very existence as credit organizations.

2.2.6 Conclusions

Sustainable agricultural development in south Batinah and Salalah is hampered by two main obstacles: the lack of economic viability and the deterioration of the physical base, especially ground water. However, the deterioration of ground water resources, contrary to what is often thought, is not the cause of the problem but rather the result of an abrupt change in the socio-economic environment of agriculture.

Since the early 1970s, Oman has undergone two major inter-related changes: the modernization of the country and the advent of a petro-economy.

The modernization of the country started with the accession to the throne of His Majesty Sultan Qaboos, who introduced necessary changes to modernize the country's economy. Great achievements have been made in the country's infrastructure and administration, the health care system, and the educational system, including the establishment of the Sultan Qaboos University. However, the rapid pace of the development process over the last two decades has also caused inevitable socio-economic 'side-effects', as Omani citizens were required to adapt to massive changes.

The high pace of development could only be achieved by draining human resources form the rural areas and by foreign immigration, resulting in the onset of an agriculture without farmers and in urban dwellers who remain attached to rural areas. Most farms thus belong to part-time farmers who work in the administration or in the private sector but keep or acquire a farm for socio-cultural reasons. While the farm owners are busy with their off-farm professional activities, the farms are managed and operated by migrant workers.

There are many problems associated with the presence of a vast community of short-term migrant workers. Not only do they pose an economic problem, as they are not motivated by long-term investment, but their mere presence also poses socio-cultural integration problems.

The major engine of the changes has been oil wealth. Investment in agriculture has thus not been generated by internal processes but rather by external assistance from the oil sector.

The consequence has been that productive attitudes did not have to prevail within the farming community. Most farms are presently loss-making enterprises, subsisting only because of income generated by the oil sector. The farm owners are not fully committed to developing agriculture because their existence does not depend on it.

Facing massive and rapid changes generated from outside its production system, the rural community has adopted the passive behaviour of assisted people. Farm owners feel that the Government can and must continue to assist them.

The oil wealth in the early and mid-1980s and the availability of powerful diesel pumping sets prompted a strong popular pressure on the Government for land distribution. The massive land distribution schemes of the 1980s are the main cause of the uncontrolled expansion of the cultivated area and the resulting ground water deficit and degradation.

The ground water deficit must be eliminated as a prerequisite for the sustainable development of agriculture. Any strategy to remedy the present situation in the agricultural sector must make farming environmentally sustainable, economically viable and socially attractive.

It must be realized, however, that there is a basic dilemma in these requirements. If agriculture is made profitable and attractive, farmers will tend to increase the cultivated area rather than reduce it, hence increasing the water deficit. Therefore, adequate measures must be proposed to dissuade farmers from increasing the cultivated area.

The definition of new, more adapted cropping pattern orientations must be a major component of a remedial strategy. There is also a need to define a package of measures that would help increase productivity in the agricultural sector.

2.3 IRRIGATION SUBSIDY PROGRAMME

2.3.1 Introduction

The irrigation subsidy programme was introduced by the Government in order to encourage modern irrigation systems as a means of water conservation. Five million Omani rials were allocated for the Batinah coastal area and seven million Omani Rials for the rest of the country. This programme was implemented by the Ministry of Agriculture and Fisheries with the assistance of the project.

Irrigation design was added to the project's terms of reference in December 1990, as it became apparent that the private sector would have been unable to design adequate systems. However, this additional task drained resources from other project activities, causing delays in the soil survey and land use field work and the downgrading of extension work to a strict minimum. These delays in turn compressed the reporting period from the nine months initially planned in the Project Document to a mere four months, despite a two-month project extension.

2.3.2 Implementation of the irrigation subsidy programme

The irrigation subsidy programme faced many difficulties, among which the more important were initial technical and legal problems, problems of farm approvals and farm inspections, as well as problems with companies installing the systems and with farmers.

The initial stages of the subsidy programme were difficult because many parties were involved, namely the Ministry of Agriculture and Fisheries, the project staff, numerous irrigation companies and farmers.

It took several months to formulate technical standards and specifications that were accepted by all parties, and delicate legal and financial procedures had to be elaborated. Effective collaboration between the Directorate General of Irrigation Affairs, the MAF Legal Department and the project staff eventually overcame these problems.

Farmers were initially reluctant to join the subsidy programme because:

- previous systems installed by other programmes often proved to be unreliable;
- the cost of the proposed irrigation systems was higher than that of those previously installed by contractors, as the material and design specifications were much better; and

- they did not have money to pay their shares and were reluctant to take credit from banks.

A wide information campaign was carried out among farmers.

Project staff distributed some 10 000 letters on the farms and discussed the subsidy programmes with hundreds of farmers. Information seminars were also organized, with the contribution of the MAF Directorate General of Irrigation Affairs.

When the first systems were installed, visits were organized for groups of farmers to observe the systems in operation and hear the farm owners' comments. These visits were very successful, and the number of requests to join the subsidy programme eventually grew larger than the numbers required.

As most farm owners are absentee farmers, the project faced enormous difficulties in meeting them to collect their opinion on cropping pattern and other issues related to system design. Repeated visits consumed a great amount of time and disturbed other project activities.

As companies were often unable to mobilize resources to carry out the installation on schedule, the project had to train many staff members on installation procedures. Considerable delays occurred in the installation work.

Farmers often changed their minds regarding the cropping pattern, obliging the project to redesign the systems. Farmers also often refused to pay their share to the contractors who then interrupted the installation work.

Despite such difficulties, the irrigation subsidy programme succeeded in making remarkable achievements.

Modern irrigation systems were promoted among farmers in the Batinah. Standards and specifications were prepared stipulating all necessary details concerning the material, equipment and workmanship to be used for installations. Seven hundred fifty designs were completed (5 550 feddans), and 140 systems were redesigned to conform with the final specifications. By the end of June 1992, 120 installations had been completed.

Twelve graduates from the Sultan Qaboos University were trained in various aspects of irrigation. Although the time allocated for training was limited due to the priority which had to be given to systems design, the contribution of the trained engineers to the subsidy programme was considerable. Ten technicians were trained in field inspection and survey, and in the operation and maintenance of modern irrigation systems.

A team of project extensionists visited all farms where the installation of modern irrigation systems had been completed, and provided all of the necessary advice on operation and maintenance. Field visits proved to be very beneficial in training both the farmers and the labourers.

Seminars were organized in various parts of the Batinah coast, and farmers were informed of the benefits of the systems and of the subsidy programme as a whole. Informative leaflets were prepared and distributed to some 10 000 farmers throughout the Batinah.

Site engineers of the 15 companies executing the irrigation systems installation were trained in proper workmanship and installation standards as required by the specifications.

2.3.3 Conclusions

Although the irrigation subsidy programme has been successful, much remains to be done, in the areas of extension and irrigation scheduling. This programme has made great strides toward fulfilling it mission of convincing farmers of the usefulness of modern irrigation systems.

2.4 TRAINING

2.4.1 Introduction

Given the rapid deterioration of ground water resources in the Batinah, the project was conceived as direct support. Training, mostly on-the-job, was considered as an important by-product. The overload resulting from the inclusion of irrigation design in the project's work plan reduced the time available for training.

Despite the work overload, a considerable amount of training was provided, not only to counterparts but also to other MAF staff, staff of other ministries, university students and private contractors.

2.4.2 Training of counterparts

2.4.2.1 Formal training

As the project was initially involved only in soil survey and only two counterparts were available, two fellowships for soil science studies were included in the Project Document.

The National Project Director was sent to the United Kingdom where he completed a Master of Science degree. Another counterpart was sent to the Netherlands, where he completed a diploma course in soil survey.

2.4.2.2 In-service training

On-the-job training was provided in all disciplines that were practiced in the project. The degree of success was largely dependent on the educational level of the counterparts. Those who had graduated from the universities in the United Kingdom of the United States, or from Sultan Qaboos University, had a reasonably good understanding of English, and could benefit well from training. Those who had graduated from Arab or eastern European countries, however, faced major difficulties because they did not understand English. Owing to administrative and budgetary constraints, an English teacher could only be recruited seven months before the project ended.

Only inadequate counterparts were available for some disciplines, such as GIS and cartography. Moreover, many counterparts joined the project near its end and thus could not benefit from sufficient project training. Some disciplines, such as computerized land evaluation, were practiced only in the last few months of project operation because field work had to be finished before they could be started. There was thus no time to provide counterparts with adequate training in these disciplines. All counterparts received training in computer operation and photointerpretation. The following counterparts received additional on-the-job training in their areas of specialization:

- four soil surveyors, in soil mapping;
- twelve engineers, in irrigation;
- ten technicians, in irrigation, extension, land cover survey and farming systems survey;
- one soil chemist, in soil analysis;
- one horticultural engineer, in extension and crop husbandry;
- one agricultural engineer, in farming systems;

- one business and administration graduate, in finance and geographic information systems; and
- one secondary school leaver, in drafting film processing and digital camera operation.

Training was also provided for other ministry staff in photointerpretation and geographic information systems.

2.4.3 Training of non-MAF staff

2.4.3.1 Training of staff of other government agencies

Training in geographic information systems was provided for staff of the Ministry of Water Resources, the Ministry of Petroleum and Minerals, and the Planning Committee For The Southern Region.

Many visitors from these and other government agencies visited the project to learn about technical procedures and specialized software.

2.4.3.2 Training of university students

In 1989, the Sultan Qaboos University requested the Ministry of Agriculture and Fisheries to authorize project staff to organize seminars and field tours in soil survey and related subjects. Each January (1990, 1991 and 1992) the project organized a tour, crossing the entire country, for the students of the Soil and Water Department.

The soil types of Oman and their distribution were explained, and the students were able to practice soil mapping under the supervision of project staff.

Many visits were also organized to the project premises, where photointerpretation, GIS, land evaluation and map preparation and printing were explained to the students.

2.4.3.3 Training of irrigation works contractors

As explained in the section on the irrigation subsidy programme (Section 2.3), project staff had to train contractors in the installation of irrigation systems.

2.4.4 Conclusions

The project has provided considerable training to counterparts and to others. Training must be continued a few years more, until the number and the experience of the counterparts reaches a sufficient level.

2.5 INSTITUTION BUILDING

The project formed, strengthened, trained and fully equipped several units.

The soil survey unit received all of the required equipment, and a photointerpretation section and a cartography section were established and fully equipped.

An irrigation unit was created and fully equipped to carry out all design operations.

A farming systems section and an extension section were created and equipped. However, these units are not capable of sustaining activities and should be merged with other MAF departments.

A geographic information system was developed, and was the first of its kind to be introduced in the Ministry of Agriculture and Fisheries. It has played an important role in introducing this technology in Oman, and allowed the project to build computer data bases from which data could be easily retrieved and processed. Maps can now be periodically updated with minimum effort, which will be very useful in groundwater salinity and land use follow-up activities.

None of the above-mentioned units is presently capable of sustaining its activities or of retaining experienced staff, as most counterparts graduated only during the last two or three years. Therefore, training must be continued for a few years, during time which the contribution of foreign experts is still required.

2.6 SUPERVISION OF CONTRACTORS ON BEHALF OF THE MINISTRY OF AGRICULTURE AND FISHERIES

The project supervised the Nejd and Jabrine soil surveys conducted by consulting firms.

3. RECOMMENDATIONS

3.1 INTRODUCTION

The situation of agriculture in the Batinah and Salalah plains is serious but not desperate. The ground water deterioration process can be reversed if the proposed cropping patterns are adopted. This requires mostly a strong political will.

The sociological problems, particularly those caused by the use of foreign labourers and part time farming, will probably be more difficult to solve. Time will partly solve these sociological problems as the children of most part-time farmers form a new generation, born in town with no attachment in the rural areas. This will reduce part-time farming.

The Government objective of reversing the migration from the rural areas to urban settlements has little chance of being achieved. The difference in comfort between urban and rural areas is presently too great to permit a reversal of the rural exodus. Therefore, the foreign labour force will remain in Oman until a new generation of young Omanis, born in rural areas, is ready to take over. In order to convince young rural Omanis to remain in rural areas, they must be made more comfortable by pursuing a policy of village development.

The study has shown that there is scope for import substitution, especially for vegetables, which are imported in large quantities. The seasonal complementarity between Salalah and the Batinah should be exploited in order to supply the market throughout the year. Since the production of fodder and fruit cannot be substantially increased in the Batinah and Salalah plains, other areas should contribute to such production. The soil atlas prepared by the project, as well as recent ground water resource studies, have shown that the Nejd area has great potential for agricultural production.

For all crops, intensification can considerably increase the average crop yields which are far below potential.

The following sections present cropping pattern recommendations and a package of measures intended to develop agricultural productivity. With the major contributions from the MAF agricultural research staff, the project also prepared monographs on vegetables, alfalfa, rhodes grass, date palm, coconut, citrus, mango, banana and papaya.

3.2 CROPPING PATTERN

3.2.1 Batinah

3.2.1.1 Cropping pattern definition

The present cropping pattern in the Batinah is to a large extent a heritage of the past. A major part of the agricultural landscape of the coastal strip is dominated by old and marginal date palm groves that have lost their economic importance. Therefore the cropping pattern must be changed in order to reduce the global water consumption, ensure economic viability at the farmer level and preserve the role of the Batinah as the main provider of food to the population of Oman.

From the farmer's viewpoint, economic viability (i.e., profit) is the most important requirement of the cropping pattern. Increasing profit by increasing crop area is not possible, as sustainability requires a global reduction of the total crop area to save water. However, it is possible to increase the relative proportion of certain crops. Therefore the best way to increase profit is to grow crops that have a higher gross margin.

Crops should be selected in such a way that the global water consumption is compatible with the reduction of the water deficit by some 60 000 000 m^3/yr. This will help restore the aquifers' water balance and preserve the environment.

Vegetables are the most profitable crops with good soils and water. Fruits, especially date palm, are most often the least profitable crops.

Most date palm is grown on highly saline soils with very saline water in high humidity areas near the coast. In these conditions, most date production is of poor quality and much of it is fed to animals. More than 50% of the date palm is grown on farms smaller than five feddans. Many of these holdings are eventually abandoned because they are not economically viable. In these conditions, most holders have another source of income and the holding is mostly an economic burden. The date market is glutted and there is no hope of improvement. It is better to leave the market to the good dates produced in other areas in Oman.

The diet of Omanis has changed considerably during the last two decades, and although dates are still appreciated by the population, their relative importance has decreased. Vegetables, fruits and animal products form an ever increasing part of the modern Omanis' food. The cropping pattern should therefore take these evolutions into account in order to reach a high level of self-sufficiency in the produce required by the market.

The farming system study has shown that there is a strong and increasing national deficit in animal products, and therefore fodder should be encouraged. As feeding pure alfalfa to animals results in wastage of protein, rhodes grass cultivation should be encouraged at the expense of alfalfa.

Orchards involve heavy investments that are normally planned over 20 to 40 years, but the market is unpredictable on such a long term. Therefore, it is in the farmer's interest to be able to adapt his cropping pattern to the evolutions of the market by having less trees and more vegetables and fodder. As long as global water consumption is not increased, part of the fodder area could be changed to vegetables and vice versa. It is also in the nation's interest to give Omani agriculture more flexibility by reducing the relative share of trees in the cropping pattern.

Considering all of the above, it is recommended that:

- vegetables and fodder shares be increased at the expense of fruit, especially date palm; and
- the fruit area be reduced from 8 553 ha to 4 500 ha, and that vegetable and rhodes grass areas be moderately increased (The main reduction should be to the date palm area, which should be decreased from 5 073 ha to 2 000 ha. In addition, 653 ha of fruit trees in suitable areas should be converted to fodder or vegetables.).

The global decrease in crop area, which would be approximately 3 400 ha, can be achieved by:

- closing to farming some 2 000 ha of crop area, mostly date palm grown on strongly saline soils with water having a salinity higher than 7 dS/m; and
- closing to farming an additional crop area of some 1 400 ha of very small holdings, mostly palm groves, that are not viable due to small farm size or socio-economic reasons.

The reduction of the crop area, which would mainly affect the date palm belt, may be relatively easy to carry out, for a number of reasons.

The situation is so bad in the date palm belt that many farms are already abandoned. There are already 1 468 ha of abandoned crops, corresponding to some 2 100 ha of gross area 1/. Therefore, if adequate compensation is given to the farm owners of the date palm belt, they would probably accept easily in order to sell their farms. Compensation would accelerate a movement which is already underway. Most farms in the date palm belt are not economically viable because they are too small and have very saline water and soil. Most farm owners in the date palm belt are absentee farmers who have another source of income.

The detailed proposed changes in the cropping pattern are shown in Table 4. This represents the proposed global cropping pattern at the level of the area and not at the level of a particular farmer. For individual farmers, the procedures proposed in the land evaluation chapter of the 'Land Resources Report' and in Appendix 5 must be followed.

For the individual farmers, the following must be carried out by an MAF land evaluator:

- locate the farm on the soil and water quality maps, determine the land unit code and calculate the AWC;
- enter the land unit data with the ALES templates, for which the soil series data is available on diskette;
- run the evaluation for that particular land unit in ALES and determine the physical and economic suitability for each crop;
- rank the crops by physical suitability first, and then by economic suitability, and eliminate crops that are not suitable either physically or economically; and
- speak with the farmer to learn his preferences and advise him according to the evaluation results, and check if the proposed cropping pattern fulfils the conditions of the 'cropping pattern formula' (see Appendix 5).

If the proposed changes to the cropping pattern are achieved, fruits will occupy approximately 40% (reduced from 59%), alfalfa 13% (reduced from 14%), other fodder 17% (increased from 8%) and vegetable 30% (increased from 19%). These figures correspond to the areas that are actually under crops each year, and do not include the fallow on which there is no restriction. The total net yearly water consumption would become roughly 164 000 000 m^3, distributed as follows:

- fruit, 75 000 000 m^3;
- fodder, 65 000 000 m^3; and
- vegetable, 24 000 000 m^3.

1/ The gross area is the total area of the farm, including the net crop area, the fallow, the uncultivated land and the buildings. It was found in the land use survey that gross area = net area/0.7.

Therefore, the saving would be 226 000 000 - 164 000 000 = 62 000 000 m^3, which is approximately 27% of current consumption. This would bring the average net water consumption to 14 909 m^3/ha (6 262 m^3/feddan).

3.2.1.2 Implementation of the proposed cropping pattern

In order to successfully implement the proposed changes in the cropping pattern, a number of actions are recommended to the Government.

The Government should maintain a freeze on land distribution except for rare special cases.

The Government should buy back the 5 129 ha of land that is fenced but not yet farmed because it may turn into new farms. Although there is a ban on the drilling of new wells, at least part of this land may be put under cultivation, as many of these parcels already have a well. The owners of the parcels that do not have a well permit feel frustrated by the fact that they are prevented from using their parcels for the purpose for which they have acquired them (i.e., farming). Those who do not wish to sell their lands to the Government could keep them for non-agricultural uses.

Farmers should be prevented from eventually extending their farms into the adjoining land by preparing a cadastre through which all the farms should be registered. The preparation of this cadastre, perhaps by the Ministry of Housing, would be very useful for organizing and monitoring land use in the area.

The Government should buy back 4 900 ha (corresponding to 3 400 ha of net area) of farmland in the areas that are most affected by salinity and/or grow mostly date palm.

The very small minority of Omani smallholders, for whom farming is the main source of income and who themselves cultivate their land, should be relocated to new land parcels in suitable areas having good soil and good water. These new farms could be conveniently grouped and have a common water distribution network. This procedure should be very severely restricted to people who presently make agriculture their source of living and will continue to do so in the future.

The Government should buy back the 2 100 ha of abandoned farmland in order to prevent owners from restarting cultivation.

It should be ensured that the cropping pattern adopted on each farm fulfils the water-saving requirements. A formula and a special calculation procedure has been elaborated for this purpose (see the 'Summary of Conclusions and Recommendations Report'). An example of cropping pattern is presented in Appendix 5. As long as the farmer does not exceed the net water consumption allocated to him according to the formula, he should be allowed to select a cropping pattern that suits his particular conditions.

The control of net water consumption can be done either by installing a water meter in the well or by monitoring the cropping pattern. Although it is much quicker to check a water meter than measure crop areas, it is possible that some farmers, especially those who do not have a modern irrigation system, may use additional mobile pumps to irrigate.

If law enforcement is efficiently carried out, the cropping pattern is a much safer way to control water consumption. Random checks should be carried out an ongoing basis, and severe sanctions, to be defined by the Government, should be inflicted upon guilty farmers. Farmers found guilty could also be deprived of the right to receive services or inputs from the extension centres for several years.

3.2.1.3 Encouragement measures

In order to encourage farmers to enforce the new cropping pattern, the Government should:

- subsidize the removal of trees whenever they must be removed and, if possible, compensate farmers on a per tree basis;
- guarantee the marketing of vegetable production, through future trading (However, the Government should not offer marketing assistance for the vegetable area exceeding the recommended 30% of the total crop area. Otherwise the market would be glutted with excessive vegetable production and prices would crash.);
- give subsidies for irrigation systems only to those who follow the recommended cropping pattern; and
- give priority for inputs and services to farmers who implement the cropping pattern recommendations.

3.2.1.4 Compensation procedures

It has been proposed that the Government buy back the farms that should be closed to cultivation and those that are abandoned, as well as the land that is fenced but not yet cultivated. Decreasing purchase prices could be offered for these three categories of land. The owners of the land that is only fenced and not cultivated have generally acquired their parcels from the Government and have not yet invested in it. Those that have abandoned their farms are not investing in it anymore and therefore should receive less than those who are presently cultivating their land.

The actual purchase prices should be decided by the Government, but some likely figures are used here to estimate how much the Government may have to pay.

- active farms: RO 1 000 per feddan
- abandoned farms: RO 600 per feddan
- fenced land: RO 250 per feddan

Hence the total compensation amount may then be:

- active farms: 11 667 fed x 1 000 =	RO	11 667 000 000
- abandoned farms: 5 000 fed x 600 =	RO	3 000 000
- fenced land: 12 212 fed x 250 =	RO	3 053 000
Total		17 720 000

This amount may come to approximately RO 25 000 000, if other miscellaneous compensation, uprooting of trees and the organization of the operation itself (including the cadaster and visits to farmers) are counted.

It should be proposed to farmers to buy shares in Government-sponsored real estate companies, agro-industry, fishery companies, and oil and gas companies. This will allow the Government to avoid the immediate disbursement of large amounts of cash. It will also allow the farm owners to invest their money and keep receiving dividends instead of consuming it.

In any case, it is better for the Government to pay the above-mentioned amount rather than continue to subsidize agriculture in the Batinah and see its productive potential eventually destroyed.

The potential use of the purchased land must be defined. Some of this land, especially the fenced land, is comprised of scattered parcels that should simply be scrapped. However, especially in the date palm belt, continuous large tracts of land will be purchased. These tracts of land are in the lowest parts of the plain, where in the past surface runoff used to accumulate and infiltrate, thus recharging the aquifers.

It would be very useful if these conditions were recreated by concentrating surface runoff on these areas which would be left to the natural vegetation. This recharge with sweet water directly in front of the seashore would create an underground fresh water dam that would help combat sea water seepage. These areas might also become natural reserves and/or could be used for recreation and/or as touristic attractions. Given the very high density of partridges in the Batinah area, so numerous that they become a nuisance to crops, well managed touristic hunting could be organized without threatening these species.

3.2.2 Salalah

The water deficit in Salalah is small, and the removal of some of the large farms growing rhodes grass would probably suffice to restore the water balance. It is necessary, however, to change the cropping pattern in order to increase the economic viability of agriculture, by fitting to the land characteristics and growing crops that have a better economic potential.

It is recommended that the Salalah plain be developed for the exploitation of the existing market for vegetables. The potential for yield increases in vegetables is large, and a considerable expansion of the area under vegetables is feasible. This option has two advantages; the water requirements of vegetables are the lowest of all crops and vegetable production shows a high potential gross margin.

Although the ALES land evaluation programme, as developed by the project, evaluates each farm separately as the basis for cropping pattern recommendations for the individual farmer, there are also general cropping pattern recommendations, according to irrigation water salinity, as detailed below.

Below 3 dS/m, all crops can be grown profitably, but as vegetables are by far more profitable, especially since a 200% cropping intensity can be achieved, their share should be dramatically increased. The cropping pattern should tend toward 50% vegetable and 50% banana.

From 3 to 5 dS/m, several vegetables are still highly profitable. Banana and sprinkler-irrigated rhodes grass are close and still profitable. Coconut should be kept at no more than 20% of the area, whereas vegetable and banana may tend toward 30% each and rhodes grass 20%.

From 5 to 7 dS/m, rhodes grass should be the dominant crop, roughly 50%, whereas coconut and vegetables should not exceed 25% each. Squash, sweet potato and cauliflower are the best vegetables to grow.

From 7 to 10 dS/m, no agriculture is really profitable, although if the farmer applies fertilizer and other inputs he might maintain a very small positive margin with squash, sweet potato and rhodes grass.

Above 10 dS/m, no crop should be grown. This land could be used for urban development or other non-agricultural uses.

In order to recommend a cropping pattern to individual farmers, the following must be carried out by an MAF land evaluator:

- locate the farm on the soil and water quality maps and determine the land unit number;
- run the evaluation for that particular land unit in ALES and determine the physical and economic suitability for each crop;
- rank the crops by physical suitability first and then by economic suitability, and eliminate crops that are physically unsuitable; and
- speak with the farmer to learn his preference and advise him according to the evaluation results and to the general guidelines above.

The cropping pattern should never be imposed. It is far better to induce farmers to adopt it, particularly in Salalah where the water situation is not as dramatic as in the Batinah. In addition to extension activities, the following measures are recommended to encourage the farmers to adopt the proposed pattern:

- guarantee the marketing of vegetable production, through future trading;
- give subsidies for irrigation systems only to those who follow the recommended cropping pattern; and
- give priority for inputs and services to the farmers who implement the cropping pattern recommendations.

3.3 AGRICULTURAL RESEARCH

Although progress has been made in agricultural research, particularly in the Batinah, more investment is required.

The lack of resources (in the areas of personnel, equipment and facility space) should be addressed. The sites of the research stations are not sufficiently representative of farmers' environmental conditions. It is therefore recommended that research farms be established, of some ten feddans each, on representative sites in each of the Batinah and Salalah plains. These sites would allow researchers to extend their network trials in representative environmental conditions. The research farms should include automatic weather stations.

More research should be conducted to identify crop varieties resistant to salinity, as it severely affects more than one-third of the cultivated area. More research should also be devoted to investigations on early and late vegetable varieties in order to stretch the production season. Some research on greenhouses could also be initiated. A wider range of crops grown by farmers should be included in the trials, and perhaps less emphasis should be placed on coffee and cereals.

There is very little yield information available for tree crops, owing to the difficulty in preventing some labourers from eating the fruits before they are harvested and weighed. It is recommended that fruit plots be fenced and surveillance improved.

Every report on each crop research trial should start with a summary of the results achieved. The report should always include the salinity of the water with which the crop was irrigated and, if possible, the quantity of water it received, any special weather conditions, pest and disease attacks and pest control measures. The quantity of each type of pesticide used and the frequency of application should be mentioned.

Research on irrigation, with emphasis on modern irrigation systems, should be carried out by the Directorate General of Agricultural Research in coordination with the Directorate of Irrigation Affairs. The following topics must be included:

- crop water requirements;
- irrigation scheduling;
- microjet irrigation for orchards;
- mini-sprinkler systems with shoring angles in orchards in two or three locations in the country;
- the performance of various other emitters under local conditions; and
- salinity build-up in soils.

As labour in Oman is mostly a scarce and imported commodity, more research should be done on labour-saving technology. Fodder and fruit harvesting represent one area in which research could dramatically improve productivity. Research on the mechanization of farm operations should be given a high priority. For this type of research the proposed research farms would be ideal sites.

On-farm trials, in real farmers' conditions and with farmers' contributions, should be conducted in order to test packages with a whole farm approach. Every technology which has already been tested on the research farms could thus be tested, with the contribution of the extension services, in a whole farm context. The results of such research would then be fed back in the extension circuit.

Topics which should be tested in farmers' conditions include: seeds, optimal planting time, application of fertilizers including micronutrients, salinity resistance, integrated pest management, cultural practices, irrigation practices and post-harvest methods.

3.4 EXTENSION SERVICES

Owing to the lack of human resources and technological information in the extension services, extension staff have been obliged to focus largely on inputs delivery to farmers. More staff should be recruited and more facilities, particularly vehicles and petrol, should be made available to the extension services to enable them to carry out their primary duty, which is to educate farmers and introduce new technology.

The role of the private sector in providing tractor services to farmers should be increased. Even if the cost of these operations increases, the impact would be small on global production costs, but it would leave more time to extensionists to carry out their duties.

On-farm trials, conducted with the Directorate of Agricultural Research staff, should be the main source of technology to be introduced by the extensionists. Extension should adopt a whole farm approach instead of the present crop-based approach.

Ideally the target of extension should be the person who is carrying out production activities and not the farm owner. Thus the extension services should be addressed to the land owner as well as to his expatriate workers.

Whole farm analyses should be prepared for several selected farms. Individual constraints and potentials should be defined, and farm development plans prepared. Extensionists capable of communicating with migrant workers should be recruited, and training materials prepared in Arabic and other relevant languages. Training materials should cover technical aspects of cultivation as well as farm management issues, such as cost of production estimates, labour requirements, physical input requirements and time and way of allocation.

More plan protection staff should be recruited in the extension centres.

3.5 PLANT PROTECTION

Climatic conditions in the Batinah and Salalah plains are favourable to the proliferation of many crop pests and diseases, resulting in heavy crop damage and yield losses. It is therefore necessary to improve crop protection services in order to promote increased yields while preserving the environment and consumers' health.

A coherent national plant protection policy should be defined, and supported by adequate legislation. The national pesticide committee should commence activities as soon as possible, and the Royal Decree concerning the quarantine should be updated to take into consideration the new pest distribution. Environmental and citizens' protection against pesticide residues should also be considered in the legislation.

An institutional structure must be established for the national coordination of plant protection activities conducted by the six regional plant protection departments of the Ministry of Agriculture and Fisheries.

The quarantine services should be reorganized and strengthened, and training courses organized for quarantine officers. Adequate laboratory facilities should be established at organized at Muscat airport, as well as quarantine units on the highway linking Muscat to Salalah. The list of prohibited pests and diseases should be updated. An annual report should be published describing the activities of the quarantine services and presenting statistics (such as the number of samples controlled and the number of phytosanitary and condemnation certificates established).

Current subsidies lists should be re-examined in order to ensure the adequate representation of selective pesticides, non-toxic insecticidal substances, and other pest control materials safe and friendly to the environment. A central pesticide analysis laboratory should be established for quality control of imported pesticides. The efficacy and side effects of pesticides should be evaluated under local conditions, before their registration.

Two pesticide residue control laboratories should be established, one at Salalah and the other in the northern part of the country.

Monitoring and forecasting techniques required for tracking the population development of key pests should be developed. Economic thresholds and economic injury levels of key pest populations on major crops should be determined.

Priority should be given to natural biological control (through the conservation of natural enemies) and to other biological control methods. Insecticidal treatments should be applied only when needed, on the basis of monitoring information, in order to reduce the frequency of spraying. Alternative pest control methods should be used (including cultural practices, varietal resistance, sex-attractants, food-attractants, repellants, traps and other biotechnical materials) in preference to pesticides. Selectivity should be exercised in applied pesticide treatments, by carefully considering timing and spraying methods, and by choosing inherently selective pesticides whenever possible. Training programmes should be organized for the plant protection extension staff, the farmers and their labourers. Training courses should also be organized for the plant quarantine officers, in order to update their knowledge of plant quarantine problems and procedures.

There is a high potential for successful biological control operations in the Salalah plain, as the region is isolated, climatic conditions are favourable, and variability in intercropped plants provides good habitat possibilities. The Salalah plain may be useful as a natural reservoir of beneficial insect populations. These could be transported to the northern part of the country for inundative releases after the end of the summer period.

It is therefore recommended that the development of appropriate biological control operations for Oman be centred in the Salalah region.

One insectary should be established within the building recently constructed for the Biological Control Unit at the Agricultural Research Station at Salalah. Another insectary should be established for the Biological Control Laboratory at the Agricultural Research Centre at Rumais.

Classical biological control operations should be initiated by introducing promising exotic predatory and parasitic insects. Management of natural enemies should then be initiated by inundative releases of efficient predatory and parasitic insects and the conservation of native natural enemies.

3.6 FERTILIZATION

Crop-based fertilizer recommendations were made in the study and can be used safely until further research and soil testing are carried out. It is recommended that:

- manure be properly composed to germinate seeds before applying it to the soil;
- research be conducted to evaluate the real impact of organic fertilizers, as these are costly and the use of less organic fertilizer could substantially improve farmers' profits;
- fertility research include more trials involving micronutrients;

- fertigation (application of fertilizer through the irrigation system) be carried out in association with modern irrigation systems;
- the effect of water salinity on the efficiency of used fertilizers be studied;
- a survey be conducted on the nutritional problems of various crops in the area using soil testing, leaf analysis, visual symptoms and information on farming systems; and
- on-farm trials be organized with extension staff to verify the validity of recommendations and adjust them to the prevailing conditions.

It is also recommended that training be provided for extension staff in recognizing visual symptoms of nutrient deficiencies on various crops, the application of fertilizers, including micronutrient fertilizers, and soil and plant sampling for soil testing and leaf analysis.

This training can be organized by conducting a one to two week training course in the Batinah, focusing on practical field work, and by sending some of the extension agents for a one to two month training course.

3.7 IRRIGATION

Given the dominance in the study areas of coarse-textured soils, surface irrigation systems are inappropriate. Modern irrigation systems not only help reduce water consumption but also increase crop yields and reduce labour cost. Modern irrigation systems are also ideal for the application of fertilizers in solution (fertigation) to a wide range of crops. The advantages of this method of fertilizer application include:

- ease of application from a central or local injection point, reducing labour requirements;
- high uniformity of application, corresponding to system uniformity (more than 85% for drip);
- multiple split applications of small doses to improve plant response and efficiency of utilization; and
- timing of fertilizer application to match crop growth, such as iron chelate for micronutrient deficiencies.

The following modern irrigation systems are recommended for the specified crops:

- bubbler system, for citrus, date palm, mango, chico, pomegranate, guava, banana in small areas, grapevine in small areas and papaya in small areas;
- drip system, for all row vegetables, banana in large areas, grapevine in large areas, papaya in large areas, and wind-breaks;
- sprinkler system, for rhodes grass, elephant grass, other fodder, and leaf vegetables; and
- hydrants, for alfalfa and fodder in small areas.

Details of each recommended system are given in the irrigation report. However, it must be stressed that no automation has been recommended at this stage as it would be risky to jump directly from traditional surface irrigation systems to fully automatic modern systems.

Microjets (mini-sprinklers) are not recommended at this stage although they are potentially suitable for the irrigation of tree crops. They must be tested and evaluated under local conditions before a final decision to introduce them is made.

Two bubblers per tree are recommended for large canopy trees (such as date, citrus, mango and chico), whereas one bubbler per tree is recommended for small canopy trees (such as guava, grapevine, banana, papaya and pomegranate) and for young trees. In the latter case, the design of the network must be based on two bubblers per tree. The second bubbler would be attached when the trees reach the age of four to five years, as they would then require a better water distribution. Two bubblers per tree have the following advantages:

- better water distribution in the tree irrigation basin, hence the elimination of moisture stress and increase in yield;
- reduction of deep water percolation, hence a higher water use efficiency and energy savings; and
- facilitation of the conversion of traditional systems to modern localized irrigation systems.

These advantages largely offset the higher cost (roughly 15%) of the system, due to the oversizing of the laterals and the addition of one bubbler for each tree. Observations from installations with one and two bubblers per tree in the United Arab Emirates and Kuwait have shown the benefits of using the two bubblers for large canopy trees.

The cultivation of vegetables under drip irrigation year after year will result in salt accumulation and reduction of crop yield unless adequate leaching is done. Leaching of salts through the drip system is not effective, and no leaching occurs during the winter period as rainfall is erratic and quantitatively insignificant. It is recommended that portable sprinkler or mini-sprinkler systems be used for leaching at the end of the cropping season or before planting. They can be connected to the existing irrigation network.

Sprinkler systems are particularly suitable for fodder crops such as rhodes grass. It is recommended that permanent sprinkler systems be used with a buried PVC pipe network. Portable sprinkler systems, using aluminium pipes, should be used only where absolutely required because they hamper farm operations.

Irrigation by hydrants is recommended only for small areas of fodder, for alfalfa crop when the water quality is low (owing to high salinity) and in case of crop sensitivity to sprinkler irrigation.

The proper operation and maintenance of modern irrigation systems are essential to ensure adequate water supply to the crops to achieve high yields. It is therefore important that farmers and labourers in charge of irrigating farms are well trained and educated in the various components of the systems and know how to operate and maintain them.

Officers of the extension services of the Ministry of Agriculture and Fisheries should be trained in providing advice to farmers on the operation, maintenance and monitoring of irrigation systems.

As agriculture is the main water user in the area, the proper management of water resources is essential for agricultural development. Good coordination is therefore necessary between the Ministry of Agriculture and Fisheries, the Ministry of Water Resources and the municipalities.

Efforts should be made to develop a strong private sector with qualified Omani engineers, as this can play an important role in the development of modern irrigation in the country. The irrigation industry must adopt standards for design, equipment and installation in order to ensure that systems meet performance criteria. It is essential that companies be encouraged to recruit and train engineers to carry out system design and installation to a high standard. In close collaboration with the Directorate General of Irrigation Affairs, the project has prepared detailed standards and specifications for the design and installation of modern irrigation systems.

It is recommended that the eligibility requirements for the irrigation subsidy programme be amended to include farms smaller than five feddans, and include the water salinity level up to 7 dS/m, provided the cropping pattern is compatible with the physical land evaluation results and the water saving policy.

The Ministry of Agriculture and Fisheries does not have the appropriate staff for controlling and directing the subsidy programme throughout the country. It is recommended that an expert be appointed with good knowledge of the design and practice of modern irrigation systems. The expert will provide technical support for all matters concerning water use. The recruitment of additional staff, such as irrigation and electromechanical technicians and accountants, is also needed.

The national engineers and technicians need further training, either in Oman or abroad, in order to increase their capacity to cope with various technical issues. It is recommended that the Ministry of Agriculture and Fisheries recruit one expert to work with them for an additional two years.

3.8 ANIMAL PRODUCTION

Feed supply would be improved by increasing the production of irrigated forage and by using agricultural by-products.

In the Salalah plain, banana wastes, coconut by-products and fish sardines are available and could be processed into complete rations, supplying cheap roughage to livestock in the south. However, research is needed to enhance the nutritive value of these by-products. A feasibility study must also be conducted on the establishment of a processing plant for the by-products.

Animals should be fed according to their production. Mineral blocks must be supplied permanently to dairy and beef cattle in addition to the provision of clean water.

Livestock productivity should be increased by artificial insemination (cross-breeding), using proven dairy breeds such as Jersey or Frisian. Animals should be housed in well ventilated pens with adequate feeding and watering facilities. Vaccinations against infectious diseases must be practiced by all livestock owners in the mountains as well as in the Salalah plain.

The extension services should conduct on-farm research to demonstrate to the local people how to feed and manage their livestock. Livestock owners should be advised to keep only productive animals, and not overburden the carrying capacity of the pasture.

Some control mechanism must be established to limit the importation of animal products, particularly milk and beef. Incentives should no longer be given as feed, but rather through buying animals from the producers. Milk collection centres should be established in production areas.

Agro-industries involved in the processing of animal products, such as meat-processing industries and dairy plants, should be encouraged in the south. Industrial plants should also be established for drying and sterilizing sardines for animal feed.

Statistical data collection should be improved, particularly on the numbers of animals and the available quantities of animal feed and by-products.

3.9 MARKETING, CREDIT AND SUBSIDIES

3.9.1 Marketing

Omani agriculture should aim primarily at using its limited water resources to achieve a higher degree of food self-sufficiency. There is a shortage in animal products, fruit and seasonally in vegetables.

Although there is a huge potential for seasonal vegetable production, the local market cannot absorb it and export possibilities are unclear and unreliable. Vegetable production needs to be better distributed through the year. As Salalah can produce in the summer months (kharif), the MAF and PAMAP should exploit this complementarity between Salalah and the Batinah to achieve a more regular market supply in vegetables. Early- and late-producing vegetable varieties, as well as greenhouse production, should also be investigated through agricultural research.

The vegetable market should be regulated through future trading by the Public Authority for Marketing Agricultural Produce. Contracts should be made with farmers to supply vegetables in the framework of a calendar to avoid over-supply. The ALES land evaluation software can serve to determine a fair purchase price. When running ALES to determine fair prices, actual average yields should be used and not potential yields. Future trading is the best way to convince farmers to increase vegetable production.

PAMAP must therefore develop its capacity to forecast market demand and prices through better monitoring. Large farms should be requested to market their own production in order to avoid competition with small producers. These large farms can be assisted by PAMAP to find export outlets abroad.

Storage facilities should be improved. Feasibility studies should be conducted on multiple canning and processing factories which can process several types of fruit and vegetables. These may absorb excess production. Marketing should be developed for animal by-products, such as hides, skins and hairs.

3.9.2 Credit

Credit institutions should initially advise farmers on the economic feasibility of their planned investments. Once a credit is awarded, the bank must ensure that the money is not diverted for unproductive purposes such as houses. The bank should also recover the instalments as per contract.

3.9.3 Subsidies

The Government provides large subsidies for agricultural investment and inputs. These subsidies should be more carefully studied in the future, as they sometimes lead to results that are contrary to their objective. The abuse and misuse of pesticides, due to their low price, is a good example. In general, it would be better to subsidize purchase price rather than input price, in order to induce a wiser use of inputs and avoid wastage.

In Salalah, an irrigation subsidy programme can be initiated with excellent conditions, as all the necessary information is available.

3.10 FOLLOW-UP ACTIVITIES

The project has yielded an enormous amount of data as well as achieving its objectives. However, training and institution-building need to be continued. The data base and maps, which have all been conveniently put in digital format, need maintenance. Compared to the investments already made by the MAF, only a limited additional funding is required to complete and consolidate the work already achieved.

It is proposed that an extension of the project be agreed upon, with training and institution building as the main objectives. A limited amount of direct support is needed, however, as the Ministry of Agriculture and Fisheries does not dispose of sufficient numbers of experienced staff.

As the MAF has expressed its desire to continue the irrigation programme without assistance, it is recommended that training be provided in soil survey, land evaluation, land use mapping, cartography, geographic information systems, farming systems and laboratory techniques.

Activities should include assisting the Ministry of Agriculture and Fisheries to:

- establish practical procedures to apply the results of the first phase, especially in land evaluation and cropping patterns;
- complete the Batinah and Salalah (Taga) integrated studies; and
- conduct soil surveys in the Nejd area and other areas.

The Ministry of Agriculture and Fisheries should be advised on relevant issues.

Counterpart staff must take the lead in all direct support tasks in which the project staff participation would be aimed at providing technical know-how and training.

Depending on the staffing and the level of Government participation in kind, this follow-up project could cost RO 300 000 to RO 500 000.

Table 1

GLOBAL LAND USE IN THE STUDY AREA

Land Use	Area	
	Hectares	Percent
Active farmland	20 387	71.2
New farms (under development)	530	1.9
Abandoned farmland	2 473	8.6
Greenhouses and nurseries	26	0.1
Land fenced but not yet farmed	5 129	17.9
Parks and recreational land	75	0.3
Total	28 620	100.0

Table 2

CROPPING PATTERN ON ACTIVE FARMS IN THE STUDY AREA

Land Use		Area		
		Hectares	Percent of sub-total	Percent of grand total
Crops	Fruit	8 553	59.3	
	Fodder	3 167	21.9	
	Vegetable 1/	2 679	18.6	
	Other minor crops	34	0.2	
	Subtotal	14 433	100.0	70.8
Fallow	Vegetable fallow 1/	710	46.2	
	Fodder fallow	523	34.1	
	Other fallow	303	19.7	
	Subtotal	1 536	100.0	7.5
Farm buildings and gardens		694		3.4
Unused land inside farms		3 723		18.3
Grand total		20 386		100.0

1/ 50% of the vegetable fallow are also included because vegetables are seasonal crops.

Table 3

FARM-SIZE DISTRIBUTION IN THE STUDY AREA

Farm-size (feddans)	Number of farms	Cumulated percent	Total area			Average farm-size	
			Hectares	Feddans	Cumulated percent	Hectares	Feddans
< 3	3 604	37.5	2 549	6 068	9.0	0.7	1.7
3 to 5	2 000	58.3	3 261	7 764	20.5	1.6	3.9
5 to 10	2 238	81.6	6 853	16 316	44.6	3.1	7.3
10 to 20	1 288	95.1	7 287	17 351	70.3	5.7	13.5
20 to 50	390	99.1	4 611	10 978	86.5	11.8	28.1
50 to 100	69	99.8	1 957	4 659	93.4	28.4	67.5
> 100	16	100.0	1 870	4 453	100.0	116.9	278.3
All	9 605	100.0	28 388	67 591	100.0	3.0	7.0

Table 4

PROPOSED CHANGES TO THE CROPPING PATTERN IN SOUTH BATINAH

Crops		Present	Future	Increase	Decrease
Fruit	Date palm	5 073	2 000		3 073
	Lime	1 591	1 000		591
	Mango	918	700		218
	Other	971	700		271
	Subtotal	8 553	4 400		4 153
Fodder	Alfalfa	1 974	1 400		574
	Rhodes grass	981	1 600	709	
	Other	300	300		
	Subtotal	3 165	3 300	135	
Vegetables		3 679	3 300	621	
Global (rounded)		14 400	11 000		3 400

Appendix 1

PROJECT STAFF

Name	Function	Dates of Service Starting Date	Dates of Service Concluding Date
International			
A.G. Souirji	Team Leader	3 July 1988	30 Aug. 1992
A. Lepiece	Soil Survey Expert/ Party Leader	21 Jan. 1990	30 June 1992
S.E. Ahmed	Farming Systems Expert	4 March 1990	30 Sept. 1991
H.A. Dawoud	Soil Survey Expert/ Party Leader	12 April 1990	30 June 1991
R.S. Rout	Irrigation Expert	14 May 1990	3 May 1992
A. Al Hachim	Horticulturist	1 June 1990	31 Dec. 1991
L. Savvides	Irrigation Expert	29 March 1991	30 June 1992
F. Grita	Computer Programmer, Associate Professional Officer	28 Feb. 1990	29 June 1992
F. Pieltain	Soil Chemist, Associate Professional Officer	19 Oct. 1990	18 Oct. 1991
United Nations Volunteers			
M.K. Mahmood	Soil Surveyor	2 June 1988	30 Nov. 1992
J. Tejada	Soil Surveyor	19 June 1988	18 June 1992
P.S. Vijesuriya	Soil Surveyor	23 Jan. 1989	23 Jan. 1990
A. Wilson	Soil Surveyor	3 March 1989	2 March 1991
A. Louah	Soil Surveyor	8 March 1989	30 Nov. 1992
T.O. Mahmoud	Cartographer	20 April 1989	24 July 1992
F. Ghazal	Soil Surveyor	12 May 1989	30 Nov. 1992
M. Salem	Soil Surveyor	5 Feb. 1990	31 March 1992
J.P. Harvey	Cartographer	13 Feb. 1990	30 June 1992
J. Tejada	Photo Interpreter	17 Feb. 1990	17 Feb. 1992
M. Nur Ahmed	Soil Surveyor	1 March 1990	31 Aug. 1992
M. Melouk	Extension Engineer	2 March 1990	30 June 1992
P.S. Chhikara	Photo Interpreter	4 March 1990	30 June 1992
M. Ul-Islam	Finance and Administration	17 March 1990	7 July 1992
I.J. Al Rifai	Extension Engineer	13 April 1990	30 June 1992
M.M. Thein	Computer Programmer	29 April 1990	7 July 1992
M.A. Sekendar	Irrigation Engineer	12 May 1990	31 Aug. 1992

Name	Function	Dates of Service Starting Date		Concluding Date	
A. Butler	Soil Chemist	20 May	1990	31 Aug.	1991
S. Jahan	Soil Surveyor	20 May	1990	28 Aug.	1990
J. de Villers B.	Photo Interpreter	8 June	1990	30 June	1992
K.P. Ravindran	Extension Engineer	12 June	1990	30 June	1992
D.L. Bajracharya	Soil Chemist	16 July	1990	30 June	1992
A. Jamaa	Agricultural Economist	26 Sept.	1990	30 June	1992
G. Ben Saida	Soil Surveyor	20 Nov.	1990	30 June	1992
J. Cheng	Irrigation Engineer	20 Nov.	1990	30 June	1992
B. Menon	Extension Engineer	28 Nov.	1990	31 March	1991
A. Adil	Soil Chemist	31 Aug.	1991	30 June	1992

Locally recruited

R. Ratnam	Secretary	17 March	1990	30 June	1992
S.A. Subasinghe	Draftsman	31 March	1990	31 Aug.	1992
A.A. Muhammad	Soil Chemist	16 Nov.	1991	31 March	1992
N. Seguin	Data Entry	1 Dec.	1991	30 Sept.	1992
Lu Xiaoming	Soil Chemist	1 Jan.	1992	31 May	1992

National

A.B. Ahmed Taki	National Project Directc	1 July	1988	4 Nov.	1992
M. Al Alawi	Soil Party Leader	9 Oct.	1988	4 Nov.	1992
A. Al Qasmi	Agricultural Engineer	8 Jan.	1990	4 Nov.	1992
S.H. Al Sabahi	Agricultural Engineer	27 Jan.	1990	4 Nov.	1992
W. Ahyahyai	Administration Officer	13 Feb.	1990	4 Nov.	1992
S. Al Maameri	Irrigation Engineer	3 Nov.	1990	4 Nov.	1992
S. Al Kalbani	Irrigation Engineer	3 Nov.	1990	3 March	1992
S. Al Rijebi	Irrigation Engineer	3 Nov.	1990	3 March	1992
K. Al Naimi	Irrigation Engineer	3 Nov.	1990	3 March	1992
I.O. Al Jabri	Irrigation Engineer	3 Nov.	1990	4 Nov.	1992
M. Al Amri	Soil Engineer	3 Oct.	1991	4 Nov.	1992
J.R. Faraj	Soil Chemist	17 Oct.	1991	31 July	1992
S. Al Rijeibi	Irrigation Engineer	24 Nov.	1991	4 Nov.	1992
A. Al Haras	Irrigation Engineer	24 Nov.	1991	4 Nov.	1992
S. Al Aasi	Irrigation Engineer	24 Nov.	1991	3 July	1992
M. Al Oufi	Irrigation Engineer	24 Nov.	1991	25 June	1992
N. Al Bahrani	Irrigation Engineer	17 Dec.	1991	4 Nov.	1992
S. Al Alawi	Irrigation Engineer	21 Dec.	1991	25 June	1992
S. Al Rasbi	Soil Surveyor	1 March	1992	4 Nov.	1992
A. Al Saqri	Irrigation Engineer	20 March	1992	4 Nov.	1992
A.H.S. Al Shikeli	Technical Assistant	23 Dec.	1989	4 Nov.	1992
A.S.M. Al Miqbali	Technical Assistant	31 Jan.	1990	4 Nov.	1992
S.M.S. Al Ruwahi	Technical Assistant	5 Feb.	1990	4 Nov.	1992
Y.A.S. Al Rawahi	Technical Assistant	5 Feb.	1990	4 Nov.	1992
N.M.S. Al Tamimi	Technical Assistant	5 Feb.	1990	4 Nov.	1992

Name	Function	Dates of Service Starting Date		Dates of Service Concluding Date	
A.S.H. Al Hinai	Technical Assistant	11 Feb.	1990	4 Nov.	1992
S.A.S. Al Saifi	Technical Assistant	11 Feb.	1990	4 Nov.	1992
H.H. Al Fahidi	Technical Assistant	25 Feb.	1990	4 Nov.	1992
H. Al Rasbi	Technical Assistant	11 March	1990	4 Nov.	1992
N.K.R. Al Hatmi	Technical Assistant	10 Feb.	1992	4 Nov.	1992
S. Alawi	Draftsman	1 Jan.	1990	4 Nov.	1992
J. Al Afifi	Secretary	1 Feb.	1990	30 Nov.	1991
H. Al Sharji	Typist	1 Feb.	1990	30 Nov.	1991
K. Al Musafry	Driver	1 Feb.	1990	31 Aug.	1992
N. Al Ghafry	Driver	1 Feb.	1990	4 Nov.	1992
S. Al Busaidi	English Teacher	1 Dec.	1991	30 June	1992

Appendix 2

FELLOWSHIPS

Participants	Study	Place	Date
A.B. Ahmed Taki	MSc, Soil Science	University of Reading, UK	Sept. 1989- Sept. 1990
M.M.M. Al Alawi	Soil Survey	International Institute for Aerospace Survey and Earth Sciences, the Netherlands	Sept. 1991- Aug. 1992

Appendix 3

MAJOR ITEMS OF EQUIPMENT PROVIDED

Quantity	Item	Cost ($US)
1	Portable Ph meter	786
2	Portable EC meter	1 617
1	Printing machine, Diazo	2 906
2	Electronic balance	2 237
1	Drawing light table	1 628
1	Light table with study	781
2	Computer, laptop	1 172
4	Air conditioner	1 740
3	Air conditioner, Toshiba, split system	3 437
6	Air conditioner, Sanyo, window	3 562
1	Refrigerator	203
6	Computer, Hundai, model 286E	13 901
2	Computer, Hundai, model Super 286E	4 442
1	Camera, Sony, professional model CCD	1 796
2	Video cassette recorder, Sony	1 172
2	Television, Sony	973
1	Printer, Epson, model LQ 2550	1 523
6	Printer, Epson, model LQ 1050	5 078
1	Printer, Hewlett Packard	1901
1	Balance, electronic, model SC 300	508
2	Meter, Hach	1 615
1	Zoom transfer scope, horizontal stage	15 156
1	Zoom 95 stereo interpretation system	9 648
1	Digitizing area line meter, Planix	974
1	Filing cabinet, Elite, vertical model	820
2	Calculator, Casio	203
2	Camera, Pentax model K-1000	912
1	Lens, 28-80 mm SMCP-A	474
1	Lens, 70-200 mm SMCP-A	560
1	Lens, 100 m macro SMCP-A	482
1	Flash, AF 400 FTZ	404
1	Personal computer, AST, 2MB	8 854
4	Meter, Hach, model EC	3 438
1	Hi-fi equipment	1 720
1	Cassette recorder, Sony	215

Quantity	Item	Cost ($US)
1	Air conditioner, Toshiba, split system	1 458
1	Automatic vacuum extractor, 220 V	5 096
1	Ion selective meter	1 693
1	Electromagnetic sieve shaker, 220 V	2 075
1	Shaker, Universal, SM25	2 576
1	Balance, Mettler, model PJ 300	2 341
1	Balance, Kern, model 822-65	1 539
1	Water de-ionizer, Fistreem, model XR 100	2 196

Appendix 4

DOCUMENTS PREPARED BY THE PROJECT

A4.1 SMALL-SCALE SOIL SURVEY

General Soil Map of Oman, atlas of 59 maps at 1:250 000. A. Souirji, et. al., 1990.

A4.2 SALALAH INTEGRATED STUDY

Land Resources Report, with eight soil maps at 1:10 000, eight water salinity maps at 1:10 000, one soil map at 1:25 000, one water salinity map at 1:25 000, three computer land evaluation models (in ALES). A. Souirji, et. al., 1992.

Present Land Use Report, with eight land cover maps at 1:10 000 and one land cover map at 1:25 000. A. Souirji, J. Dorman-Tejada, B.P.S. Chhikara and J. de Villers, 1992.

Plant and Animal Production Report, Special Investigations. Compiled by A. Souirji, individual consultant reports listed under the 'Plant Protection' section. 1992.

Irrigation Report. R.S. Rout, 1992.

Farming Systems Report. J. Cools, S.E.S. Ahmed, et. al., 1992.

Summary of Conclusions and Recommendations Report. A. Souirji, 1992.

A4.3 BATINAH INTEGRATED STUDY

Land Resources Report, with 100 soil maps at 1:10 000, 50 water salinity maps at 1:10 000, three computer land evaluation models (in ALES). A. Souirji, et. al., 1992.

Present Land Use Report, with 50 land cover maps at 1:10 000. A. Souirji and B.P.S. Chhikara, 1992.

Crop Water Requirements Report, including a CROPWAT computer data base. A. Souriji, 1992.

Irrigation Report. L. Savvides, 1992.

Farming Systems Report. M.S. Rathore, 1992.

Summary of Conclusions and Recommendations Report. A. Souirji, 1992.

A4.4 HORTICULTURE MONOGRAPHS

Alfalfa And Rhodes Grass Production. A.W. Al Hachim and MAF research staff, 1991.

Banana Production. A.W. Al Hachim and MAF research staff, 1991.

Citrus Production. A.W. Al Hachim and MAF research staff, 1991.

Coconut Production. A.W. Al Hachim and MAF research staff, 1991.

Date Palm Production. A.W. Al Hachim and MAF research staff, 1991.

Mango Production. A.W. Al Hachim and MAF research staff, 1991.

Papaya Production. A.W. Al Hachim and MAF research staff, 1991.

Vegetable Production. A.W. Al Hachim and MAF research staff, 1991.

A4.5 PLANT PROTECTION

Plant Pathology in the Salalah Plain. M. Besri, 1992.

Integrated Biological Control in the Salalah Plain. P. Katsoyannos, 1992.

Weed Control in the Salalah Plain. A.R. Seghir, 1992.

A4.6 FERTILIZATION

Soil Fertility in the Salalah Plain. M. El Fouly, 1992.

A4.7 FARMING SYSTEMS

Monitoring and Continuing Evaluation System for Pilot Farms on the Batinah Coast. S.E.M. Ahmed, 1991. (Arabic.)

Farm Production and Resource Use in South Batinah (Barka/Rumais). S.E.M. Ahmed, 1990.

Physical and Financial Budgets And Efficiency Indicators Of Crop And Livestock Enterprises in South Batinah (Barka/Rumais). S.E.M. Ahmed, 1990.

A4.8 IRRIGATION

Standards And Specifications for Modern Irrigation Systems in Oman. R.S. Rout and L. Savvides, 1990, 1991.

Guidelines in the Supervision of the Installation of Modern Irrigation Systems. R.S. Rout and L. Savvides, 1991.

Operation And Maintenance of Modern Irrigation Systems. L. Savvides, 1991.

The Subsidy Programme in Modern Irrigation Systems in the Batinah Coastal Area. L. Savvides, 1992.

Lecture On Modern Irrigation. L. Savvides, 1992.

A4.9 SOIL LABORATORY

Methods of Soil Analysis. A. Butler and F. Pieltain.

A4.10 ADMINISTRATION AND FINANCE

Imprest Account Data Base Programme. M.M. Thein.

A4.11 TRAINING MANUALS

Principles of Agricultural Production Economics. S.E.M. Ahmed, 1991. (Arabic.)

Introductory Course in Agricultural Extension Education. A.W. Al Hachim, 1990. (Arabic.)

The Use of Hand Calculators in Hydraulics. J. Cheng and R.S. Rout, 1991.

Basic Hydraulics of the On-farm Pressurized Irrigation Systems. L. Savvides, 1991.

Irrigation Training Exercises. L. Savvides, 1991.

Computer Training Manual. M.M. Thein, 1991.

Training Programme in Cartography and Map Production. T.M. Osman and J.P. Harvey, 1990.

Appendix 5

EXAMPLE OF CALCULATION OF CROPPING PATTERN IN SOUTH BATINAH 1/

If a farmer has a total farm area of eight feddans, the cropping pattern formula is as follows:

$$T.\ (7\,122) + F_a\ .\ (8\,009) + F_0\ .\ (8\,450) + V.\ (3\,024) = \text{or} < \text{to } R_e\ .A\ .\ (6\,252)$$

with:

- T the tree area in feddans
- F_a the alfalfa area in feddans
- F_o the other fodder area in feddans
- V the vegetable area in feddans
- R_e the equivalent net crop area ratio
- A the total farm area in feddans

where:

A = 8 feddans
R_e = 0.65 taken from the table below

- less than 5 feddans	: 0.70
- 5 to 10 feddans	: 0.65
- 10 to 50 feddans	: 0.60
- 50 to 100 feddans	: 0.55
- more than 100 feddans	: 0.50

therefore:

$$W = R_e \times A \times (6\,262) = 0.65 \times 8 \times (6\,262) = 32\,562\ m^3$$

and:

$$T.\ (7\,122) + F_a.\ (8\,009) + F_o\ .\ (8\,450) + V.\ (3\,024) = \text{or} < 32\,562$$

1/ One feddan = 0.42 hectare.

As several combinations of individual crop areas can fulfil this equation, the farmer must be given recommendations according to the land evaluation results for his farm and express his preferences.

1) If a farmer has goats and sheep, for which he needs one feddan of alfalfa and 1.5 hectares of rhodes grass, and also wants to grow two feddans of vegetables; the only variable is therefore the tree area T.

$T. (7\ 122) + 1(8\ 009) + 1.5(8\ 450) + 2(3\ 024) = 32\ 562$

$T = (32\ 562 - 26\ 732)/7\ 122 = 0.82$ feddan

2) If the farmer wants to follow the recommended cropping pattern, which is 40% trees, 13% alfalfa, 17% other fodder and 30% vegetables, the outcome is:

$T + F_a + F_o + V = R_c.A = 0.65 \times 8 = 5.2$ feddans
$T = 0.40 \times 5.2 = 2.08$ feddan
$F_a = 0.13 \times 5.2 = 0.68$ feddan
$F_o = 0.17 \times 5.2 = 0.88$ feddan
$V = 0.30 \times 5.2 = 1.56$ feddan

b-2087/E/4.93/1/60