B5. Activity of the Hydrogeologist

B5.1. Activity of the Hydrogeologist

There were two major purposes for a hydrogeological work in this phase; one was a supplemental hydrogeological survey which could not completed during the phase 1 survey period, and another was an actual field hydrogeological investigation work newly added for a job of the hydrogeologist.

As a supplemental hydrogeological survey, a) supplemental data collection on ground-water, especially for water quality and aquifer properties, b) checking locations and photo-graphing the water resources of oases, and c) spot field reconnaissance surveys on physio-graphical and Geomorphological situations of several oases, were performed in parallel with the a field investigation work. The items of actual field investigation work were gypsum survey and in-situ permeability test. A part of data collection was conducted in Tunis but most of those works were carried out in the field through long survey tour.

Prior to the main survey tour for about seven weeks, a preliminary field inspection for only three nights four days, throughout the target four provinces however, was conducted to discuss with engineers in each CRDA on actual investigation works. All members of the Advisory Committee on the Study accompanied with the hydrogeologist, to inspect the sites directly and to discuss/interview with the personnel concerned.

The major survey tour to the south was performed for more than seven weeks, including two short interruptions to return to Tunis. Originally, the survey tour was planned out for total about five weeks with one interruption, on the hypothesis that the gypsum soil shall not be distributed in Gafsa Province. However, it was revealed that the gypsum soil distributes in some oases in Gafsa in the early stage, and the work schedule must be revised in rather wide range. The actual work progress, in comparison with the original work schedule, is shown as Fig. 5.1.1. As shown in the figure, the gypsum survey in Gafsa Province, together with the in-situ permeability tests, was planned out to do additionally after completion of all survey works in other three provinces. And further, it was modified again on 21st October to precede the survey in Gafsa than the one in Gabes because of record-breaking downpour in the south, especially at Gabes. They said it was more than 150mm of rainfall within four days since 16th October, nevertheless an annual rainfall in this area is around 200mm.

Through the said long survey tour for four provinces, total 78 hand auger borings in 11 oases to check the distribution of gypsum and 11 in-situ permeability tests at 7 oases were conducted, as well as the supplemental hydrogeological surveys in parallel. After return back to Tunis, the results of the field works were arranged and analyzed, and some of typical soil samples obtained through the auger boring were send to the laboratory of "Centre de Recherches du Genie Rural", MOA. Results of these surveys or investigations have been discussed in the previous chapters.

Fig. 5.1.1. Field Survey Schedule and Actual Progress on Hydrogeology Party

R.Kawasaki and Miss Rim Abdi

Date	Day	Appointment		Planed Work Schedule	Actual Progress	Target		Stay	
				as of 13th Sep.	6th Nov.	Sch.	Act.	Sch.	Act.
15-Sep	Fri.	12:00	CRDA Gafsa	Tunis to Gafsa, Meet with H-geologist	Meet with DG, Mahmoudi,Kadri.	Gafsa	Gafsa	Tozeur	Tozeur
16	Sat.		(H-geologist)	PT-1, Supplemental survey.	PT-1(S.Ouest) 2.0m int. by rain.	Gafsa	Gafsa	(H Oasis)	(H Oasis)
17	Sun.			Holiday	Holiday	Gafsa	Hol.		Tozeur
18	Mon.	15:00	CRDA Tozuer	PT-2, Shift to Tozeur. Meet with H g.	am. PT-2(O.Shili) 2 .5m int. by hard layer.	Gafsa	Gafsa		Tozeur
					pm. Meet with Mr. Bayoudhi,Chebbi,Moumni.	Tozeur	Tozeur		
19	Tue.		(D.G, H-g)	Gypsum survey in Tozeur (1)	Tz- Auger 2 holes (TZ-1,2), P.T 2 times.	Tozeur	Tozeur		Tozeur
20	Wed.			Gypsum survey in Tozeur (2)	Tz- Auger 4 holes (TZ-3,4,5,6)	Tozeur	Tozeur		Tozeur
21	Thu.			Gypsum survey in Tozeur (3)	Tz- Auger 4 holes (TZ-7,8,9,10)	Tozeur	Tozeur		Tozeur
22	Fri.			PT-1, PT-2.	Ds- Auger 4 holes (DS-1,2,3,4)	Tozeur	Tozeur		Tozeur
23	Sat.			Return to Tunis	Return to Tunis via. Kairouan.	Tz/Tu	Tz/Tu	Tunis	Tunis
24	Sun.			Holiday in Tunis	Holiday in Tunis	Tu	Tu		Tunis
25	Mon.			am. MOA, pm. Move to Tozeur	Team Meeting, p.m. Move to Tozeur.	Tu/Tz	Tu/Tz	Tozeur	Tozeur
26	Tue.	8:30	CRDA Tozeur (D.G)	Meet with D.G/H g, Hydrothermal Survey	Meet with D.G/H g, am. Geothermal survey.	Tozeur		(H Oasis)	Tozeur
					pm. Supplemental Hydrogeological Survey.		Tozeur		
27	Wed.			H thermal survey, move to Kebili	Ds- Auger 3 holes (DS-5,6,7), PT 1 (DS-5)	Tozeur		Kebili	Tozeur
					Casing installation 2 holes (DS-2, TZ-9).		Tozeur	(Oasis H)	
28	Thu.	8:30	CRDA Kebili (D.G/H g)	Courtesy call, Hydrothermal survey.	10.00 CRDA Kebili, courtesy D.G, Chief H.G	Kebili			
					pm. Hydrothermal survey.		Kebili		Kebili
29	Fri.			Hydrothermal survey.	Supplemental Hydrogeological survey	Kebili	Kebili		Kebili
30	Sat.			Gypsum survey. (0.5)	Supplemental Hydrogeological survey	Kebili	Kebili		Kebili
1-Oct	Sun.			Holiday in Kebili	Holiday in Kebili	Kebili	Kebili		Kebili
2	Mon.			Gypsum survey in Kebili (1.5)	am. Supplemental Hydrogeological survey,	Kebili			
					pm. Meet with CRDA, Meet with Soil Dep.		Kebili		Kebili
3	Tue.			Gypsum survey in Kebili (2.5)	Hand auger REA-1,2	Kebili	Kebili		Kebili
4	Wed.	10.00	CRDA Gabes	Meet with D.G/H g, Hydrothermal Survey	Hand auger REA-3,4,5	Kebili	Kebili		Kebili
5	Thu.		(D.G/H g)	Gypsum survey in Kebili (3.5)	Hand auger REA-6,7,8	Kebili	Kebili		Kebili
6	Fri.			Gypsum survey.(4)	Hand auger GT-1,2,3	Kebili	Kebili		Kebili
7	Sat.			Sup survey.	Hand auger GT-4,5,6, Casing Install (GT-5)	Kebili	Kebili		Kebili
8	Sun.			Holiday in Kebili	Hand auger GT-7, P.T-1, Casing Installation	Kebili	Kebili		Kebili
9	Mon.			Gypsum survey in Kebili (5)	Hand auger MN-1,2,3	Kebili	Kebili		Kebili
10	Tue.			Gypsum survey in Kebili (6)	Hand auger MN-4,5,6,7	Kebili	Kebili		Kebili
11	Wed.			PT-1, PT-2.	Hand auger RM-1,2,3	Kebili	Kebili		Kebili
12	Thu.	10.00	CRDA Gabes	Meet with H g, Supplemental Survey	Hand auger RM-4,5,6, Supple. Survey.	Gabes	Kebili	Gabes	Kebili
13	Fri.		(H g)	Gypsum survey (0.5)	Kebili-Gabes-Tunis	Gabes	Kb/Tu	(H Chems)	Tunis
14	Sat.			Gypsum survey (1.0)	MOA, DGRF, others.	Gabes	Tunis		Tunis
15	Sun.			Holiday in Gabes	am. Team Meeting, pm. Tunis->Gabes	Gabes	Tu/Gb		Gabes
16	Mon.			Gypsum survey in Gabes.(2)	CRDA Gabes, Supple H.G-Survey.	Gabes	Gabes		Gabes
17	Tue.			Gypsum survey in Gabes.(3)	CRDA Gabes,Meet Discuss with Soil Dep.	Gabes	Gabes		Gabes
18	Wed.			Gypsum survey in Gabes.(4)	Hand auger GB-1,2,7.	Gabes	Gabes		Gabes
19	Thu.			Sup survey, PT-1.	Arrangement of the data because of rain.	Gabes	Gabes		Gabes
20	Fri.			PT-2.	Arrangement of the data because of rain.	Gabes	Gabes		Gabes
21	Sat.			Return to Tunis	Arrangement of the data, Change the schedule.	Tunis	Gabes	Tunis	Gabes
22	Sun.				Remove to Tozeur		Gb/Gf		Tozeur
23	Mon.				CRDA Gafsa, Supple H.G-Survey.		Gafsa		Tozeur
24	Tue.				CRDA Gafsa, Hand auger SO-1,2,3		Gafsa		Tozeur
25	Wed.				Hand auger SO-4,5,6, pm.CRDA Tozeur		Gafsa		Tozeur
26	Thu.				Hand auger OS-1,2,3		Gafsa		Tozeur
27	Fri.				Hand auger OS-4,5,6, PT-1,2.		Gafsa		Tozeur
28	Sat.				CRDA Tozeur/Gafsa, remove to Gabes		Gafsa		Gabes
29	Sun.				Field inspection on extreme south (Tataouine)		Ex South		Gabes
30	Mon.				CRDA Gabes, Hand auger GB-6,5,4,3. PT		Gafsa		Gabes
31	Tue.				Hand auger MT-1,3,6.		Gafsa		Gabes
1-Nov.	Wed.				Hand auger MT-2,4,5,7.		Gafsa		Gabes
2	Thu.				Hand auger AO-1,6,5.		Gafsa		Gabes
3	Fri.				Hand auger AO-2,3,4,7. PT		Gafsa		Gabes
4	Sat.				CRDA Gabes, Return to Tunis.		-		Tunis

B5.2. Personnel List

Major personnel with whom the Hydrogeologist has been cooperated, assisted, discussed, and got a useful suggestion are listed below (besides the counterpart staff of MOA).

a) Tunis

Mr. Mohamed PACHA	Director General DGRE, MOA
Mr. Mamou AHMED	Director des Eaux Souterrines DGRE, MOA
Mr. Zouhaier CHAABOUNI	Soil Department CRGR, MOA

b) Gafsa Province

Mr. Znazen SALAH	Director General CRDA Gafsa
Mr. Mahmoudi ABDELAZIZ	Director, Irrigation Dep. CRDA Gafsa
Mr. Kadri RIDHA	Irrigation Dep. CRDA Gafsa
Mr. Mohamed MERAI	Director, Soil Dep. CRDA Gafsa
Mr. Abdelkarim MARRAKCHI	Hydrogeologist CRDA Gafsa
Mr. Abdelhafidh BELARBI	Director, Irrigation Dep. (Phase-1) CRDA Gafsa

c) Tozeur Province

Mr. Hamza MEKKI	Director General CRDA Tozeur
Mr. Yagoubi MABROUK	Director, Irrigation Dep. CRDA Tozeur
Mr. Mohamed CHEBBI	Director, D.E.S CRDA Tozeur
Mr. Mohamed BAYOUDHI	Director, D.T.V CRDA Tozeur
Mr. Lahmadi MOUMNI	Hydrogeologist CRDA Tozeur
Mr. Chebbi AHMED	Hydrogeology Dep. CRDA Tozeur
Mrs. Chehla BOUAJIL	Soil dep. CRDA Tozeur
Mr. Sadek EL OUEDRNI	Director General Hotel Oasis Dar Tozeur / Kebili
Mr. Brahm ABIDI	Hydrogeologist (Phase-1) CRDA Tozeur

d) Kebili Province

Mr. Ridha B. ABDALLH	Director General CRDA Kebili
Mr. Mohamed GRIRA	Director, Soil Dep.

	CRDA Kebili
Mr. Plani SAID	Soil Dep. CRDA Kebili
Mr. Khalile BAHNI	Chief Hydrogeologist CRDA Kebili
Mr. Hlaini AISA	Hydrogeologist CRDA Kebili
Mr. Ben H. ABDALLAH	Hydrogeology dep. CRDA Kebili
Mr. Hadji MOSBAH	Director, Irrigation Dep. CRD Kebili

e) Gabes Province

Mr. Chtioui HAMDI	Director general CRDA Gabes
Mr.Adel SAIED	Director, Soil Dep. CRDA Gabes
Mr. Ghrairi RACHID	Soil Dep. CRDA Gabes
Mr. Ben MARZOUK	Hydrogeologist CRDA Gabes
Mr. Ghoudi RIDHA	Hydrogeology Dep. CRDA Gabes
Mr. Abbes BECHIR	Soil Dep. CRDA Gabes
Mr. Mohamed L. TOUMIA	Director General (Phase-1) CRDA Gabes
Mr. Rahali MOHAMED	Hydrogeology dep. CRDA Gabes

f) Sfax Province

Mr. Hamed B. DHIA	Professor, Dep. of Geology SFAX UNIV.

B5.3. List of Data/information collected

From MOA
- ACTUALISATION DE L'ETUDE DES RESSOURCES EN EAU DU SAHARA SEPTENTRIONAL (ERSS) UNESCO, 1972
- RECHARGE CHARACTERISTICS AND GROUNDWATER QUALITY OF THE GRAND ERG ORIENTALE BASIN (Interim Report) British Geological Survey, 1995

From Office National des Mines
- CATALOGUE DES PUBLICATIONS 1992-1993
- NOTES DES SERVICE GEOLOGIQUE
  - No.48. The geological setting of Oued El Akarit and the palaeoclimate significance of gypsum soil, Southern Tinisia.
  - No.53. Lexique stratigraphique de la Tunisie. Premiere partie.
  - No.57. Geochimie des eaux thermo-minerales de la Tunisie, and others.
- MONOGRAPHIES REGIONALES
  - 3. Les grands problemes d'hydrogeologie en Tunisie.
- CARTES GEOLOGIQUES A 1/500 000.
- CARTES GEOLOGIQUES DE LA TUNISIE A 1/100 000.
  - No.59, 60, 65, 66, 67, 71, 72, 73, 74, 75, 79, 81, 82, 83, 90, 91, 92
- CARTES GEOLOGIQUES DE LA TUNISIE A 1/50 000.
  - No. 50, 51, 52, 53
- CARTE SISMOTECHTONIQUE DE LA TUNISIE 1/1000 000.

From DGRE
- annuaire de l'exploitation des nappes profondes
  - 1974 ~ 1994
- Reseau National de Surveillance piezometrique de Tunisie
  - 1991 ~1994
- Annuaire piezometrique de Tunisie
  - 1991 ~ 1993
- EVOLUTION DE LA PIEZOMETRIE ET DE LA SALINITE DE LA NAPPE DU COMPLEXE TERMINAL DANS LA NEFZAOUA A.MAMOU & B.B.BACCAR, 1994
- RESEAU HYDROGRAPHIQUE 1/1000 000.
- CARTE DES RESSOURCES EN EAU DE LA TUNISIE 1/500 000.
- ACTUALISATION DE L'ETUDE DES RESSOURCES EN EAU DU SAHARA SEPTENTRIONAL (UNDP)
- evaluation of water resources (Mamou)

From SFAX UNIV.
- Les Provinces Geothermiques en Tunisie.
- Application of Chemical Geothermometers to some Tunisian Hot Springs.
- Tunisian Geothermal Data from Oil Wells.
- Thermal Regime and Hydrodynamics in Tunisia and Algeria.
- Shallow Geothermal Studies in Tunisia: Comparison with deep subsurface information.

From each CRDA
- Major well lists
- Chemical Analysis Data

B6. Recommendations

(1) Groundwater development on phreatic aquifers is already fallen into over-development, there is no space to further development. The total exploitation from the phreatic aquifers must be reduced, or any counter-measures for overdevelopment, such as an artificial recharging or a construction of underground dam, must be taken as soon as possible.
(2) As an exception on the phreatic aquifers, aquifers in Tamerza region are still keeping a balance between recharge and discharge including artificial groundwater use, however, further development on the aquifer is not recommendable.
(3) Developments on deep aquifers, represented by C.T. and C.I., are said still within their resources potential because of their hugeness. However, total exploitation from C.T. is already reached its limit in average, and beyond the limit at Kebili. No more groundwater development on C.T. shall be done.
(4) C.I. has still some spare for further development from the study on the desk, however, it has very closed relation with C.T. as a leaky aquifer complex and the overdevelopment on C.T. influences to the aquifer immediately. Thereby, the development on C.I. also must not be done any more, at least until the day when recharging system of C.T. and C.I. has been more clearly studied.
(5) For the Project, water resources facilities must be just as they were, but to construct monitoring wells for both shallow and deep aquifers is recommendable, because the further detail groundwater resources potential study is quite important in the South, and for the study the data on exact groundwater hydrograph are just essential.
(6) In parallel with the construction of monitoring wells, devices to measure the pumping rate of tube wells shall be improved or newly settled, to grasp an accurate exploitation of each well, each oasis, each province, and each aquifer.

ANNEX - C

GEOTHERMAL WATER

ANNEX - C

GEOTHERMAL WATER

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ANNEX - C

GEOTHERMAL WATER

LIST OF FIGURES

C.1 GENERAL

Field work on the cooling facilities constructed to cool the C.I. formation geothermal water was carried out in the governorates of Tozeur, Kebili and Gabes.

There are four types of cooling facilities; (1) cooling tower type, (2) cascade type, (3) spiral type and (4) lattice type. Of these, the principal type is cooling tower. In some oases, combination system of greenhouses with pond is used for cooling.

Number of cooling facilities is 18 for cooling tower type (Tozeur: 3, Kebili: 10, Gabes: 5), 4 for cascade type (Kebili: 4), 1 for spiral type (Gabes: 1) and 2 for lattice type (Gabes: 2).

Data and informations collected at the cooling sites are listed as follows.

(1) Structure of cooling facilities,
(2) Operating conditions of cooling facilities,
(3) Water temperature at the inlet and the outlet of cooling facilities,
(4) Configuration of the scale deposits,
(5) Confirmation of scale materials of hydrochloric acid (HCl),
(6) Present management on the scaling problem,
(7) Corrosion of materials, and
(8) Problems on operation and maintenance.

Based on the data and information as listed above, arrangement of the problems was made so as to examine the problems and to work out improvement plans.

C.2 PRESENT STATUS OF COOLING FACILITIES

The cooling tower type is principally used as the facilities for cooling the geothermal water produced from C.I. formation in Tozeur, Kebili and Gabes governorates. Other types such as cascade, spiral and lattice are less effective in cooling.

C.2.1 Cooling Tower Type

Including one cooling tower which is now under construction (Bechima in Gabes), there are 18 cooling towers. Their basic structure is the same.

Geothermal water from C.I. formation is transported from production well onto the platform (about 13 m high from ground level) of cooling tower through a pipe. As the well head pressure is high enough, (around 20 bars) the geothermal water can be conveyed by itself. The geothermal water falls into inside the cooling tower through the small holes made in the platform of tower.

Inside the cooling tower, falling water collides with wooden obstacles and is accelerated in cooling by evaporation. A fan with an electric motor of 20 - 30 kW is set up on the cooling tower for ventilation.

Cooled water flows out from a water pool of the tower, and is conveyed to the oases through pipelines and/or open canals. An average flow rate of the geothermal water is about 50 l/sec, however, that of large cooling tower at Bechima oasis (Gabes) is 100 l/sec.

In the period of this field work (September 26 to October 5, 1995), fans were in operation at only two cooling towers (Steftimi and Menchia, Kebili). At El Hamma (Tozeur), because of insufficient well head pressure, the geothermal water was not conveyed up to the platform, but was directly conveyed into the water pool. The cooling towers of Oum El Farth and Douz (Kebili) were not in operation. Thus, the geothermal water was cooled by natural ventilation at eleven cooling towers.

The ventilation by the fan can effectually cool the geothermal water from about 70℃ to lower than 35℃ (Steftimi and Menchia, Kebili). Without fan operation, temperature of cooled waters ranges from 51℃ to 44℃.

Discontinuous operation of the fan is to save electric power cost. In some cases at Gabes cooling towers, fans are not always operated through out the year, but limited only summer season. In an another case at Bouabdallah in Kebili, as the cooled C.I. water is subsequently mixed with shallow cold water, wide range cooling is not necessary.

Another problem of the cooling tower is scale deposition. A large quantity of scale is deposited in the cooling towers and conveyance pipelines.

The cleaning work of the scale necessitates not only man power, time and cost, but is also dangerous especially inside the cooling tower. Results of site testing using hydrochloric acid indicates that the scales are mainly composed of carbonate. Scale deposition occurs in the process of escape of CO_2 gas dissolved in the C.I. geothermal water by depression of production water (20 bars to atmospheric pressure). Thus, the scale does not deposit inside the pipe from the production well to the cooling tower.

Though the interval of cleaning work is different from site to site, wooden obstacles are usually replaced once six months and pipes are cleaned or replaced once 1 - 3 years. Scales deposited inside the pipes are removed by high pressure water jet. The water jet cleaning machine (price : 30,000 DT), owned by CRDA of Kebili, can be pulled by car and convenient to transport. So that, this machine can be used for cleaning work at the cooling facilities located in Tozeur and Gabes. Though the speed of cleaning work depends on the state of scale (hardness and thickness), usual cleaning rate at Kebili is 200 m/day, at Tozeur, 50 m/day, and at Gabes, 500 - 600 m/day, respectively. At some oases (Jemna at Kebili and Ben Ghilouf at Gabes), open canals are used for conveyance of cooled water. Open canals are more convenient than pipelines to remove scale.

C.2.2 Cascade Type

Although, four units of cooling facilities of the cascade type exist in Kebili, those of Douz oasis are incomplete. The cooling facilities of Ras El Ain consist of

four terraces. This cascade system cools the low pressure geothermal water transported from broken casing of the production well from 64℃ to 52℃. Cooled water flows through winding stream-like open canal around the irrigation area, then arrives at a pond. The water temperature at the pond is 46℃.

Cooling facilities of Mansoura and Saidane, very similar each other, consist of three terraces and a water pool. In order to extend the capacity, three units of cooling facilities are combined at Mansoura. The capacity of each unit is 20 l/sec. In usual operation, the geothermal water is cooled from 60℃ to 50℃. Cooled water is conveyed to the irrigation area after subsequent mixing with shallow ground water.

The cooling system of Saidane with single unit cools the geothermal water from 52℃ to 44℃. The geothermal water flows into the top of cascade through a many small holes (Ø 2 cm) made on a steel pipe of 10 cm in outer diameter. This steel pipe has been corroded.

All the scales found around the cascade type cooling facilities are carbonates. At Mansoura, cleaning work has been carried out 8 months after the beginning of operation. Even though using the water jet machine, 10 days and 5 - 6 persons were required for this work. At Saidane, transport pipe (15 cm inner diameter) of cooled water is completely plugged in 3-year operation.

C.2.3 Spiral Type

Only one cooling system of this type exists at Chenchou oasis in Gabes. The geothermal water is induced in the center of concrete spiral-shape canal through a steel pipe (Ø 15 cm). The geothermal water is cooled from 54℃ to 40℃ (45 l/sec). Scale deposition is not remarkable.

C.2.4 Lattice Type

As this type is very old, only two units of cooling facilities are operated at Khebayet (Gabes). Cooling facilities of Glib Dokhane (Gabes) is not used at present.

Geothermal water falls down from the top of the facilities of about 3 m high to the concrete lattice, and is cooled from 65℃ to 50℃. A large amount of scale deposits on the surface of the lattice.

C.2.5 Corrosion

As the C.I. geothermal water is saline, steel used at the cooling facilities has been easily corroded.

At the site of cooling tower, a lot of corroded equipment such as steel pipe, doors, stairs and motors was observed.

Almost all the electric motors, very important equipment in cooling towers, are installed outside the exhaust chimney. However at the cooling towers of Ben Ghilouf (two towers) and Glib Dokhane, motors are installed inside the exhaust chimney. It is better to set the motor outside the exhaust chimney from the standpoint of anticorrosion.

At Oum El Farth (Kebili), steel pipe located nearby the well head is corroded at a part of just below the ground level. So that geothermal water leaks out due to increase of the flow rate of production water.

These phenomena suggest the disadvantage of laying the steel pipe under the salty ground. Therefore, steel pipe should be used only on the ground. It is better to use concrete pipe instead of steel pipe for the transportation of the geothermal water. Painting and piping works should be done carefully to protect the surface of steel pipe.

C.3 RECOMMENDATION FOR IMPROVEMENT OF COOLING FACILITIES

C.3.1 Scale Deposition

One of the most serious problem is occurrence of scale deposited in cooling facilities and irrigation pipelines. The scale is mainly composed of carbonate produced from C.I. geothermal water in the process of its passage.

The carbonate scale deposits on the surface of wooden obstacles and breaks them by their own weight. Irrigation pipes are plugged by carbonate scale. So that, periodical cleaning and replacement of wooden obstacles and pipes are being carried out. These operations increase maintenance cost of the cooling facilities.

The water cooled by the cooling facilities is oversaturated with calcite ($CaCO_3$). Therefore, without a chemical treatment, as applied at some Japanese geothermal power plants, carbonate scale deposits from the water.

Direct mixing of C.I. geothermal water with shallow cold water makes the mixture undersaturation, and is effective to prevent the scale deposition. This method is applied at some oases.

Simplification of cleaning operation will be able to reduce cleaning cost. Some ideas are listed as follows.

(1) remove the wooden obstacles set inside the cooling tower
(2) use open canals instead of pipe lines
(3) provide a deposition pool
(4) install obstacles in open canal and / or deposition pool

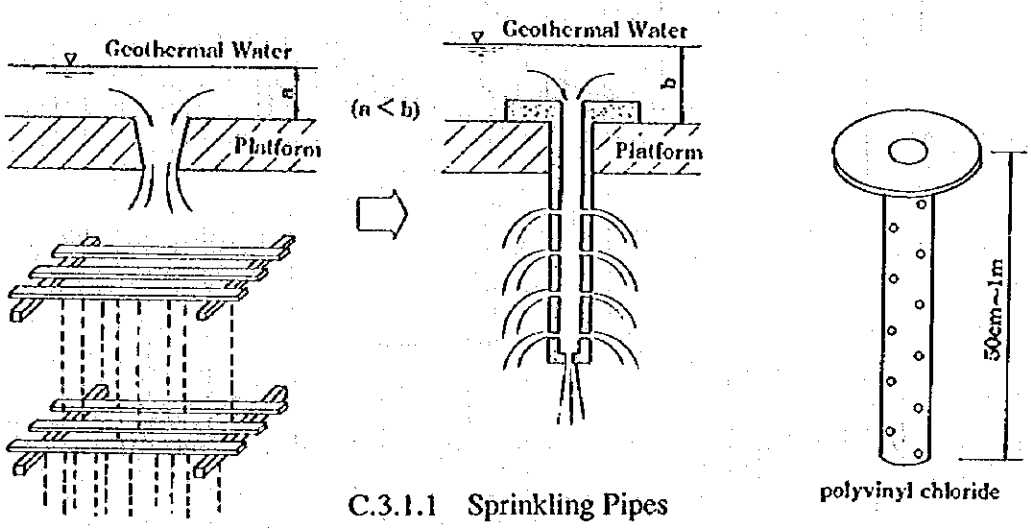
Detail of each idea is written as follows.

C.3.1.1 Remove the wooden obstacles

Wooden obstacles are originally provided inside the cooling tower to prolong the contact time of water drops with air. If water drops become more fine, it is possible to get sufficient cooling effect without wooden obstacles.

As the well head pressure of C.I. production well is as high as approx. 20 bars, it is possible to set sprinkling pipes at the ceiling as an inlet of the geothermal water. Compressed geothermal water becomes fine drop through a sprinkler.

Another simple method to make fine water drops is to use pipes with a lot of small holes. Water drops will become more fine by inserting these pipes into holes of platform as illustrated as shown in Fig. C.3.1.1.



C.3.1.1 Sprinkling Pipes

C.3.1.2 Use open canals instead of pipeline

As the cleaning work of open canal is comparatively easy, it is recommended to adopt open canal except for steep transport line. Even if pipe is used at steep section of the transport line, subsequent open canal set at flat section will be effective to accelerate the scale deposition. Therefore, amount of scale of downstream can be reduced.

Combination of open canals and cascades can be applied for steep section, and is also effective to accelerate the scale deposition.

C.3.1.3 Install a deposition pool

As the C.I. production well has high head pressure, most of the cooling facilities are constructed at elevated places. So that, a pump is not necessary to be installed to transport the cooled water, even though water pool is additionally provided between the cooling facilities and the distribution canals as shown in Fig. C.3.1.2.

Cooled water from a cooling tower falls into the deposition pool, then additional cooling and CO_2-loss will be accelerated. This system is basically composed of cooling tower, cascade and water pool.

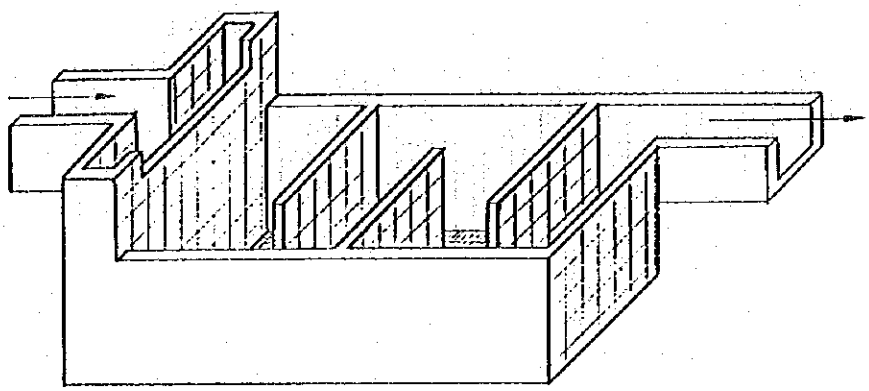


Fig. C.3.1.2 Deposition Pool

C.3.1.4 Install obstacles in open canal and/or deposition pool

Installation of the obstacles in the path of cooled water, which is oversaturated with calcite, aims to accelerate the growth of scales on their surface. Periodical replacement of obstacles makes cleaning work simple. Coarse meshes made of palm leaves can be used as obstacles.

C.3.2 Improvement of The Present Facilities for Effectual Cooling

From the standpoint of effectual cooling, some comments on possible improvement of the present cooling towers are described as follows.

(1) Insert short pipes, which have multiple fine holes, into inside the cooling tower through holes of the platform. This method is the same that explained in (1) above, and is aimed to improve a cooling effect by an evaporation of fine water drop.

(2) Change the inlet nozzle from present single hole to multiple holes or slits. In addition to this change, inlet nozzle or slit would be elevated to higher position.

(3) Attach radiator fins on the surface of inlet steel pipe line. However if steel pipe line is not so long, cooling effect by radiation could not be expected.

C.3.3 Plans for Future Stage

C.3.3.1 Prevention system against the calcite scale deposition

As the C.I. geothermal water is originally saturated with calcite, it becomes oversaturated at the cooling facilities due to CO_2-loss. Without chemical treatment as applied at geothermal power plants, calcite scale inevitably deposits from this cooled geothermal water.

At the Mori geothermal power plant in Japan, addition of sodium polyacrylate solution ([- CH_2 · CH(CO· ONa) -]$_n$: 10 - 15 ppm in geothermal water) is effective to prevent the calcite scale deposition. This chemical treatment can be applied to the cooling facilities for irrigation. However, field testing is necessary to estimate the operation cost. Although sodium polyacrylate is halmless to human health, the influence to plants should be tested. An advanced organic chemical industry is also necessary to produce high molecular organic chemicals such as polyacrylic acid. If the sodium polyacrylate solution is added to the C.I. geothermal water of 50 l/sec to get a concentration of 5 ppm (half concentration of the Mori geothermal power plant), cost of the chemicals will be about 60,000 DT/year. Except for the geothermal power generation, this high cost may create a new serious problem for the operation.

As sodium polyphosphate ($Na_{n+2} P_n O_{3n+1}$) is unstable at high temperature (>200℃), this chemical is not used as a scale inhibitor at the geothermal power plant. However, the result of laboratory experiments suggests that the sodium polyphosphate has a possibility of prevention against the calcium carbonate scale deposition.

If the effect of sodium polyphosphate is checked by field test at the site of cooling facilities, it is recommended to use this chemical as a scale inhibitor which may be more inexpensive than sodium polyacrylate in Tunisia where chemical industry relative to phosphorous compound is developed.

C.3.3.2 Cooling facilities in needless of electricity

(1) Natural ventilation cooling tower

The cooling towers operated in the oases are planned to get effectual cooling by the operation of fan. However, because of expensive power rate, fans of many cooling towers are not operated to save the cost of electric power.

A natural ventilation cooling tower is able to cool the C.I. geothermal water without electric power. In case of the Matsukawa geothermal power plant in Japan, the cooling tower of this type (44.6 m in height and 46.7 m in basement diameter) is used to cool thermal water of 5,000 t/h from 48℃ to 25℃. The C.I. geothermal water can be sprinkled by its own pressure. Flow rate of the C.I. geothermal water cooled by present cooling towers ranges from 50 to 100 l/sec (180 to 360 t/h). So that, the size of a natural ventilation cooling tower for the oasis is not necessary as large as that of the Matsukawa geothermal power plant.

(2) Combination of fountain and pond

As the well head pressure of C.I. production well is high, it is possible to spout the geothermal water high. Dispersed water is effectually cooled by evaporation in the air. There are basically two methods for the arrangement of fountain. The first one is single (or 2 ~ 3 inlets) inlet set in the centre of a pond. The second one is multiple inlet. Concerning this cooling system, higher spout is better for effectual cooling, however, large pond is necessary due to scattering of water caused by wind. Therefore, the second one is profitable. The cooling system of the second one is applied at one of the geothermal power plants in the U.S.A.

ANNEX - D

SOILS

ANNEX - D
SOILS

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D.1 GENERAL

For clarifying the chemical and physical characteristics of soils of Oases, the semi-detail soil survey was carried out in the middle of May 1995. Supplementary soil survey for confirming distribution of gypsum layer and impervious soil layer was also carried out in late September to early October, 1995.

Soil observation and profile description were carried out in soil pits (about 150 cm depth). Soil were dug at twenty sites (5 sites in each governorate) and soil profiles were taken according to "Guide line for Soil Profile Description" (FAO). At the same time, soil samples were collected for laboratory test.

Soil analysis aims at a clarification of the physical and chemical properties of soil of the study area. The soil samples were sent to the laboratory of Ecole Nationale d'Ingenieurs de Sfax (ENIS). The soil samples were analyzed with the respect to the following test items:

(1) Physical analysis
- Particle analysis

(2) Chemical analysis
- pH value
- Electric conductivity (EC)
- Cation exchangeable capacity (CEC)
- Exchangeable cation (Ca, Mg, Na and K)
- Organic substance (or total carbon)
- Total nitrogen (total N)
- Water soluble anion (SO_4, Cl)

Soil profile description, physical property and chemical characteristics of soils are presented in Tables D.1 and D.2.

D. 2 LOCATION AND TOPOGRAPHY

The study area is located in a range between 250 km and 390 km south of Tunis, the capital of the Republic of Tunisia. It extends from Gafsa town to ES Sabria town with a length of approximately 140 km in the north-south direction, and from Gulf of Gabes to the border with Algeria with a length of 260 km in the east-west direction. It covers a part of Governorates of Gafsa, Tozeur, Kebili and Gabes with respective area of 7,360 km^2, 6,159 km^2, 22,454 km^2, 7,505 km^2 totaling 43,478 km^2. It lies at the north latitude 33° 20' to 34°40' and the east longitude 7°40' to 10°30'.

The territory of Tunisia is roughly classified into three morphological zones, Atlantic Tunisia, Eastern Tunisia and Saharan Platform. The study area occupies the north margin of Saharan Platform.

The study area in Gafsa is located in an undulating basin at an elevation ranging from 220 m to 400 m. The basin is surrounded by mountains such as Mt. Sidi Aich (1,029 m high) and Mt. Es Souinia (679 m high) on the north. Mt. Biada (1,163 m high) on the east, and Mt. Asker (608 m high) and Mt. Morra (510 m high) on the south. The basin is dipping gently to the southwest where Chott El Gharsa is located. Several wadis originated from these mountains flow down to the directions of south and west. They join Oued(wadi, O.) El Melah and flow into Chott El Gharsa which is 17 m below the sea level. Its major tributaries flowing down in the study area are O. El Kebin, O.Sidi Aich and O. El Melah.

The four Oases in Gafsa Sud and Ksar Delegation are located at the centre and the lowest part of Gafsa basin. The former is located in the west of Oasis Baiech at an elevation between 250 m and 260 m, whereas the latter is located in the east of O. Baiech at an elevation between 250 m and 270 m, respectively. The Oasis in Guettar Delegation is located approximately 14 km east of Gafsa town. It is surrounded by hilly areas and Chott El Guettar in the north, and hence it is dipping towards south at an elevation ranging from 220 m and 270 m. The two Oases in Metlaoui Delegation are located 30 km and 60 km southwest of Gafsa town. They are located south of the hilly area, and hence slope of the area is rather steep at an elevation ranging between 230 m and 280 m. The Oasis in Redeyef Delegation are located outside of Gafsa basin and near the border with Algeria. Elevation of the area is 100 m.

The study area in Tozeur stretches northeast-southwest along National road No. 3, and located at an elevation ranging from 10 m to 150 m. The area is bounded by Mt. Morra on the north, by Chott El Jerid on the east and south, and by Chott El Gharsa and border with Algeria on the west. It is dipping to the both east and west with rather steep slope toward to two greatest Chotts. It is noted that most of the wells for Oases are located in the margin of these two Chotts and the border.

The ten Oases in Tozeur Delegation are located mostly east and south of Tozeur town and stretches in the direction of Chott El Jerid. The area located at an elevation between 40 m and 80 m, is dipping toward the east and the south. The five Oases in Nefta Delegation are situated south of Nefta town and north of Chott El Jerid. The slope of the area is toward the south at an elevation ranging from 30 m to 80 m. The seven Oases in Degache Delegation are located surrounding Degache town, in the northeast and the south east, separately. The Oases located in the former area at an elevation ranging from 10 m to 50 m slope down to Chott El Gharsa, whereas the latter at an elevation between 20 m and 50 m slope down to Chott El Jerid. The Oases in Hazoua and other four Oases in Tamerza Delegation are situated near the border with Algeria.

The study area in Kebili is bounded by Chott El Fejaj on the north, Mt. Tebaga (496 m high) on the east, dunes of the Great Erg on the south, and complicated lake shore of Chott El Jerid on the west. It is characterized by a very flat topography with an elevation ranging from 40 m to 80 m. Most of Oases in this Governorate are located along National Roads No. 103, 206 and 210. Great number of wadis originated from Mt. Tebaga flow down to the respective directions of north and south. They change their courses towards the west and finally flow down to Chott El Jerid.

The 14 Oases in Souk Lahad delegation are situated in the area jutted out into Chott El Jerid. The area is divided into two by National road No. 16. The Oases located on the north of the road slope down to the north and those located on the south of the road slope down to the south. The elevation of the Oases located in the Delegation ranges between 30 m and 50 m. The 12 Oases in Kebili Nord Delegation are concentrated in the north of Chott Kebili (east of Chott Jerid), and dipping towards the south. The elevation of these Oases ranges from 30 m to 50 m. The 18 Oases in Kebili Sud Delegation are scattered in the east of Chott Kebili. The land slope down to the west with an

elevation of 30 m to 50 m. The 13 Oases in Douz Delegation are situated along National Road No. 202. The land is flat with minor relief. The elevation of these Oases is between 30 m and 50 m. The ten Oases in Faouar Delegation are scattered along the lake shore of Chott El Jerid. The land is also flat with minor undulation and elevation of these is between 30 m and 50 m.

The study area in Gabes is bounded by Mt. Es Stah (318 m high), Mt. El Haid Oudi (259 m high), Mt. Zemlet El Beida (160 m high), etc. in the north, Gulf of Gabes in the east, Mt. Bateun Kradre (370 m high), Mt Saikra (302 m high), etc. on the south, and Chott El Fejaj in the west. It is characterized by an undulating topography with an elevation varying between 10 m and 150 m. Most of Oases are located along National Road No. 1, No. 15, No. 16 and No. 107. The watershed in the area is formed in the north-south direction through Mt. Zemel El Baida - Hamma town - Mt. Saikra, and hence the area is divided into two, the east area and the west area. The former is influenced by the sea, whereas the latter by Chott El Fejaj.

The watershed of Gabes Governorate is formed in the north-south direction through Mt. Zemel El Baida-Hamma town - Mt. Saikra. There are five Oases in Gabes Est Delegation, five Oases in Gabes Ouest, five Oases in Ghannouch, three Oases in Metouia, and 17 Oases in Mareth, totalling 35 Oases, all of them facing to Gulf of Gabes, on one hand. Therefore, they are characterized by a gentle slope with minor relieves towards the Gulf. Elevation of these Oases ranges from 10 m to 100 m. On the other hand, the 11 Oases in El Hamma Delegation and two Oases in Matamata Delegation, totaling 13 Oases are located facing to Chott El Fejaj. They are characterized by rather undulating topography, and at an elevation ranging from 40 m to 120 m. The land slopes down towards the west, where Chott El Fejaj is situated.

D.3 PHYSIOGRAPHY

The study area of Gafsa is in undulating basin with an elevation of 200 to 400 m. The area is physiographically classified into piedmont plain. It is coalescing colluvial and alluvial fans of wadis. The basin is dipping to the southeast where Chott El Gharsa is located, with a rather steep slope. The ground water table is rather deep compared with those of other Governorates.

The materials covers piedmont plain are the weathered reddish brown particles. Coarse textured soil is observed in all the basin area. The coarse texture of soil is observed in the surface, however, calcic sandy-lime, calcic sandy-loam and calcic loam texture are observed with an increase of the depth of soil. Impervious soil layer is observed at the depth of lower than 5 m from soil surface in almost all the Oases.

The study area of Tozeur is in undulating basin with an elevation of 40 to 150 m. The area is physiographically classified into piedmont plain. It is coalescing colluvial and alluvial fans of wadis and lacustrine deposit of lake. The basin is dipping to the east and west with rather steep slope towards the Chotts.

The material covers piedmont plain and lacustrine plain are the weathered reddish brown particles. Coarse textured soil is observed in all the basin area. The coarse texture of soil is observed in the surface, however, calcic sandy-lime, calcic sandy-loam and calcic loam texture are observed with an increase of the depth of soil. Water impermeable soil layer is observed at the depth of lower than 3 m from soil surface in the most of Oases. In some of Oases, the water impermeable soil layer is distributed at 2.5 to 3 m from soil surface. Hydromorphic soil is observed in some area. As the plain extended along the Chott are flat topography and relatively shallow water table, there is sometimes observed imperfect drain.

The study area of Kebili is in undulating basin with an elevation of 40 to 80 m. The area is physiographycally classified into piedmont and lacustrine plain. It is coalescing colluvial and alluvial fans of wadis and lacustrine deposit of lake. The basin is dipping to the Chotts with a gentle slope.

The material covers piedmont plain and lacustrine plain are the weathered reddish brown particles. Coarse textured soil is observed in all the basin area. The coarse texture of soil is observed in the surface, however, calcic sandy-lime, calcic sandy-loam and calcic loam texture are observed with an increase of the depth of soil. Water impermeable soil layer is observed at the depth of lower than 3 m from soil surface in the most of Oases. In some of Oases, the water impermeable soil layer is distributed at 2.5 to 3 m from soil surface. Hydromorphic soil is observed in some area. As the plain extended along the Chott are flat topography and relatively shallow water table, there is sometimes observed imperfect drain.

The study area of Gabes is in undulating basin with an elevation of 30 to 150 m. The area is physiographycally classified into piedmont plain. It is coalescing colluvial and alluvial fans of wadis and lacustrine deposit of lake. The basin is dipping to the Gulf of Gabes with a gentle slope.

The material covers piedmont plain and lacustrine plain are the weathered reddish brown particles. Coarse textured soil is observed in all the basin area. The coarse texture of soil is observed in the surface, however, calcic sandy-lime , calcic sandy-loam and calcic loam texture are observed with an increase of the depth of soil. Impervious soil layer is observed at the depth of lower than 3 m from soil surface in all the Oases. In some of Oases, the impervious soil layer is distributed at 2.5 to 3 m from soil surface. Hydromorphic soil is observed in some area. As the plain extended along the Chott are flat topography and relatively shallow water able, there is sometimes observed ill-drained area.

D.4 SOIL CLASSIFICATION

Soil in the project area is reddish brown weathered coarse textured soil. On the basis of field survey and soil profile description, major part of soils in the study area are classified into Xerosols (X), and sub-classified into Calxic Xerosols (Xk) and Gypsic Xerosols (Xs). These two soil unit is mixed.

(1) Calxic Xerosols :
Calxic Xerosols are Xerosols having a pallid A layer and calxic layer within 100 cm from soil surface.

(2) Gypsic Xerosols :
Gypsic Xerosols are Xerosols having a pallid A layer and gypsic layer within 100 cm from soil surface.

D.5 PHYSICAL PROPERTIES

D.5.1 Soil Texture

Soil texture influences a number of other properties of soil , such as water holding capacity, permeability, infiltration rate, erodibility, root

penetration and soil fertility. Soil texture is classified into soil textural classes based on United States Departmemt of Agriculture (USDA) system.

Soils	Texture	Class
Sandy Soils :	Coarse texture	S and LS
Loamy Soils :	Moderate coarse texture	SL
	Medium textured	L, SiL and Si
	Moderate fine textured	CL, SCL and SiCL
Clayey Soils :	Fine textured	C, SC and SiC

As seen in Table D.1, coarse to moderate coarse textured soils are observed in the larger part of the study area especially in Gafsa and Tozeur, however, in the Oasis in Gabes and Kebili vary from coarse to medium. In almost all of soils of Oases, clay content is very low. The soil texture is mainly governed by the silt content.

Soil depth is described according to the following classes.

Effective Soil Depth Class	Depth (cm)
Very shallow	< 30
Shallow	30 - 60
Fairly deep	60 - 90
Deep	90 <

As seen in Table D.1, the depth of soil of almost all Oases is deep, only in a part of Oasis de Gabes, Atilet and Limaoua, relatively shallow profile soil is observed.

D.5.2 Topography

Topography is described according to the following.

Complex slope (%)	Class
0 - 2	Flat to very gentle (G)
2 - 5	Gently undulating (G)
5 - 8	Undulating (U)
8 - 16	Rolling (R)
16 - 30	Hilly (H)
30 <	Hilly

Topography of all the Oases is classified into flat to very gentle.

D.5.3 Drainage

Drainage of water refers to the rapidity and extent of the removal of water from the soil surface especially by surface runoff and flow through the

soil. On the basis of the observation, relative soil drainage classes are described below.

(1) Very poorly drained :
Water is removed from the soil so slowly that the water table remains at or on the surface for the greater part of the time. Soils usually occupy level or depressed sites and frequently ponded.

(2) Poorly drained :
Water is removed so slowly that the soil remains wet for a greater part of time. The water table is commonly at or near the surface during a considerable part of the year.

(3) Imperfectly or somewhat poorly drained:
Water is removed from the soil slowly enough to keep it wet for significant but not all of the time. Imperfectly drained soils commonly have a semi-pervious layer within the profile.

(4) Moderate well drained :
Water is removed from the soil somewhat slowly, so that the profile is wet for a small but significant of the time. Moderate well drain soils commonly have a semi-pervious layer within of immediately beneath the solemn.

(5)Well drained :
Water is removed from the soil readily but not rapidly. Well drained soils are commonly intermediate texture.

(6) Somewhat excessively well drained :
Water is removed from the soil is rapidly. Many of them have little horizon differentiation and are sandy and very porous.

(7) Excessively drained :
Water is removed from the soils very rapidly. Shallow soils on slopes may be excessive drained.

In all the Oases, drainage capability is excessively to somewhat excessively. Here is no problems for drainage of surface water. Permeability of soil in the Oases are also rapid to very rapid. These phenomena can be explained by soil texture. However, in some Oases where impervious soil layer exists at 2.5 m under soil surface or Oases with hydromorphic soil, ill drained area is observed, although surface area of ill drained area is limited.

D.6 SOIL CHEMICAL PROPERTY

D.6.1 Acidity

Soil reaction, which is expressed by the negative logarithm of hydrogen ion activity in soil - water suspension, was determined in the laboratory. The pH value also shows the relationship between soil acidity and electric conductivity (EC). The pH value of 8.5 or more usually occur in the soils in which presumably alkaline earth carbonates or much more sodium ion are present. Soil acidity is described by the following classes according to soil pH value.

Class	pH-H_2O
Extremely acid	< 4.5
Strongly acid	4.5 - 5.5
Slightly acid	5.6 - 6.5
Neutral	6.6 - 7.3
Moderately alkaline	7.4 - 8.4
Strongly alkaline	8.5 - 9.0
Very strongly alkaline	9.0 <

Soil pH value of Oases ranges from 8.0 to 9.3, a larger part of soil is classified into moderately alkaline with few exceptions. Soil pH value of Tamerza Oasis shows 9.3 and it is classified into very strongly alkaline.

D.6.2 Soil Salinity

Soil salinity is described according to following classes corresponding to electric conductivity (EC) value:

Salinity class	EC ($mS \cdot m^{-1}$)
None-saline	< 400
Slightly saline	400 - 800
Moderately saline	800 - 1600
Strongly saline	1600 <

The EC value of soils ranges 15 to 520 $mS \cdot m^{-1}$. Higher EC value is noted in Atilet, Oum El Ferth, Mansoura and Oued Shili. The larger part of soils are classified into non- saline soil. Only the soils of Atilet and Oum El Ferth are classified into slightly saline soil. The EC value of irrigation water is acceptable in almost all the Oases, only relatively high value in Oum El Ferth, Chenchou and Oued Shili as shown in Table D 3. In the case of soil salinity being more than 400 $mS \cdot m^{-1}$, drainage is necessary for keeping the soil good

condition. Therefore, there will be expected no salinity problem in future, when the reasonable irrigation and drainage practice will be employed.

D.6.3 Soil Sodicity

Soil sodicity is described according to the following classes corresponding to Exchangeable Sodium Percentage (ESP, ESP is given as a value of exchangeable Na divided by total exchangeable cations). Soils more than 6 % of saturation with exchangeable sodium in some horizons within 100 cm of the surface are identified as soils with sodic phase (FAO/UNESCO, 1974).

Sodicity Class	ESP
Non-sodic	0--5
Slightly sodic	6--10
Moderately sodic	11--15
Strongly sodic	15 <

Soil sodicity ranges from 2.9 to 12.2. The almost all of Oases is classified into non sodic and slightly sodic. Only Oued Shili and Oum El Ferth are classified into moderately sodic. In spite of relatively high content of exchangeable sodium, ESP is relatively low. One reason of relatively low sodicity of soils in the Oases can be explained by high content of exchangeable calcium in the soils. Since the CEC values of soils in the Oases is very low and the quality of irrigation water is acceptable, it cannot be expected an increase of ESP and exchangeable sodium of soils in future by continuing irrigation agriculture. As the content of exchangeable cation is high, however, it can be induced salts injury by accumulation of salts in the soil surface, when a reasonable irrigation and drainage practice cannot be employed. In the view point of quality of irrigation water and ESP of soil, it required more elaborate irrigation and drainage management in Oued Shili and Oum El Ferth.

D.6.4 Cation Exchangeable Capacity (CEC)

CEC is one of index of soil fertility, such as a fertilizer holding capacity. It is largely governed by clay minerals. Since the clay content of soils of Oases is very low, high CEC value can not be expected. CEC value ranges from 0.1 to 2.2 and is extremely low and there is no difference in CEC among the Oases. Under these condition, an elaborate fertilizer management is

required and organic fertilizer is more effective compared with inorganic fertilizer.

D.6.5 Total Nitrogen and Organic Matter

Total nitrogen content and organic matter content are also indices of soil fertility. Total nitrogen content is very low and ranges from trace to 0.16 %. In the soil with relatively high content, C/N ratio is very high and calculated as about 30. Very low amount of amount of nitrogen supply from soil can be expected. Fortunately, nitrate content in irrigation water is very high as shown in Table D.3, a large amount of nitrogen is supplied by irrigation water.

Total organic matter content ranged from 0.6 to 6.62 %, and a big difference in organic matter content among the Oases. In the traditional Oases, there is a big difference in organic matter content among the Oases. On the other hand, in the newly developed Oases there is no big difference in organic matter content which is very low. From agronomic point of view, in the newly developed Oases, it is recommended to increase soil fertility by cropping leguminous perennial fodder crops.

D.7 RECOMMENDATION FOR SOIL MANAGEMENT

Physical and chemical properties of Oases is presented above. At present, these soils can be estimated suitable to marginal suitable soils for tree crops and field crops which have been cultivated in the area. For tree crops such as date palm and olive, the soils of almost all of the Oasis can be estimated suitable. It cannot be expected to be salinity problem and to become sodic soil by continuing irrigation agriculture, when the reasonable irrigation and drainage practice would be employed.

However, there is a problem, salts accumulation in soil surface. Since the content of exchangeable cation is very high in all the oases and evapotranspiration rate is very high in summer season, it can be supposed salts accumulation in soil surface by movement of soil water and evaporation of the water. It is necessary to decrease the amount of stagnant water in soil profile by drainage practice. The yield would decrease, when a large amount of salt is accumulated in soil surface. Therefore drainage is necessary for Oases where salts is easily accumulate in soil surface in Tozeur, Kebili and Gabes.

As the clay content of soil is very low and CEC value is also very low in all the Oases, nutrient holding capacity of soil is very low. Therefore, organic fertilizer is more effective. Some of Oases are very poor organic matter and low amount of nitrogen supply from soil is expected. It is important to increase soil fertility by cropping leguminous perennial fodder crops.

Table D.1 Soil Physical characteristics

Code No	Name of Oasis	Depth of Horizon	Boundary of Horizon	Form of Boundary	Colour Wet	Colour Dry	Texture	Particle size Clay	Particle size Silt	Particle size Sand	Structure Grade	Structure Type	Structure Size	Consistence Wet	Consistence Moist	Consistence Dry	Remarks
		(cm)						(%)	(%)	(%)							
GF- 1	Kasba	0--100<	na.	na.	2.5Y 3/1	2.5Y 5/2	SL	4	24	72	na.	na.	na.	ns,np	lo	lo	
GF- 2	Sud Ouest	0--100<	na.	na.	5YR 5/3	5YR 8/2	SL	14	20	66	na.	na.	na.	ns,np	lo	lo	
GF- 4	Lala	0--100<	na.	na.	7.5YR 4/2	7.5 YR 5/2	LS	1	16	83	na.	na.	na.	ns,np	lo	lo	
GF- 6	Oued Shili	0--100<	na.	na.	10YR 6/6	10YR 8/3	LS	2	16	82	na.	na.	na.	ns,np	lo	lo	
GF- 8	Segdoud	0--100<	na.	na.	10YR 6/6	5YR 7/3	SL	2	28	70	na.	na.	na.	ns,np	lo	lo	
TZ- 1	Tozeur	0--100<	na.	na.	2.5Y 3/2	2.5Y 6/2	SL	3	26	71	na.	na.	na.	ns,np	lo	lo	
TZ- 11	Nefta	0--100<	na.	na.	2.5Y 3/3	2.5Y 5/3	LS	1	11	88	na.	na.	na.	ns,np	lo	lo	
TZ- 15	Draa Sud	0--100<	na.	na.	10YR 7/4	2.5Y 8/3	SL	1	31	68	na.	na.	na.	ns,np	lo	lo	
TZ- 21	Cedada	0--100<	na.	na.	10YR 5/3	2.5Y 8/3	LS	2	24	74	na.	na.	na.	ns,np	lo	lo	
TZ- 26	Tamerza	0--100<	na.	na.	2.5Y 8/3	2.5Y 5/2	S	0	7	93	na.	na.	na.	ns,np	lo	lo	Natural spring
KB- 1	Bechiri	0--150<	na.	na.	10YR 7/3	2.5Y 7/3	SL	3	47	50	na.	na.	na.	ns,np	lo	lo	
KB- 17	Mansoura	0--150<	na.	na.	10YR 4/2	2.5Y 6/2	SL	3	23	74	na.	na.	na.	ns,np	lo	lo	
KB- 24	Oum El Ferth	0--150<	na.	na.	7.5YR 6/6	7.5YR 7/4	L	3	53	44	na.	na.	na.	ns,np	lo	lo	
KB- 44	Atilet	0--40	na.	na.	10YR 7/6	10YR 8/4	Si	1	82	17	na.	na.	na.	ns,np	lo	lo	
		40--150<			10YR 7/6			Calcareous soil									
KB- 60	Faoura 1	0--150<	na.	na.	7.5YR 6/4	10YR 8/4	Si	2	91	7	na.	na.	na.	ns,np	lo	lo	
GB- 6	Gabes	0--45	s	s	7.5YR 4/4	10YR 7/3	L	10	45	45	na.	na.	na.	ns,np	lo	lo	
		45--150<			10YR 3/3			Calcareous soil									
GB- 7	Limaoua 1	0--45	a	s	7.5YR 6/6	7.5YR 7/4	SL	1	37	62	na.	na.	na.	ns,np	lo	lo	Hydromorphic
		45--150<			10YR 7/6			Gypsum									
GB- 19	Chenchou 1	0--150<	na.	na.	2.5YR 3/4	5YR 7/4	SiL	5	50	45	na.	na.	na.	ns,np	lo	lo	
GB- 30	Arram	0--150<	na.	na.	5YR 6/8	5YR 8/3	Si	6	72	22	na.	na.	na.	ns,np	lo	lo	
GB- 42	Kettana 3	0--150<	na.	na.	5YR 5/6	5YR 8/3	SL	2	37	61	na.	na.	na.	ns,np	lo	lo	

Source: Determined by JICA study team

Table D.2 Soil Chemical Characteristics

Code No	Name of Oasis	pH	EC	Organic Matter	Total N	CEC	Exchangeable Canon Ca	Exchangeable Canon Mg	Exchangeable Canon Na	Exchangeable Canon K	Water Soluble SO4	Water Soluble Cl	ESP
			(mS/m)	(%)	(%)	(me/100g)	(meq/100g)	(meq/100g)	(meq/100g)	(meq/100g)	(meq/100g)	(meq/100g)	(%)
GF- 1	Kasba	8.8	80	5.64	0.13	1.2	29.5	4.3	2.3	0.6	2.2	2.5	6.3
GF- 2	Sud Ouest	8.1	22	3.52	0.06	2.3	49.0	7.4	2.7	1.2	5.6	3.8	4.5
GF- 4	Lala	8.1	22	4.00	0.05	1.2	32.0	13.6	2.7	2.7	1.5	0.9	5.3
GF- 6	Oued Shili	8.4	350	0.78	0.01	0.5	42.5	5.4	6.8	0.9	52.1	12.1	12.2
GF- 8	Segdoud	8.3	225	1.64	0.06	1.3	49.0	7.4	4.6	1.2	5.6	3.8	7.4
TZ- 1	Tozeur	8.2	280	5.34	0.16	1.4	43.0	7.4	3.4	1.4	80.6	1.1	6.2
TZ- 11	Nefta	8.2	88	0.60	0.03	0.6	34.4	3.3	1.3	0.5	7.7	1.1	3.3
TZ- 15	Draa Sud	8.9	25	0.64	ND	0.3	24.2	2.4	1.9	0.6	18.1	5.1	6.5
TZ- 21	Cedada	8.7	85	1.20	0.10	0.1	48.0	6.7	3.7	1.3	1.5	3.0	6.2
TZ- 26	Tamerza	9.3	60	0.04	ND	0.2	39.0	4.3	1.2	0.6	0.8	1.0	2.7
KB- 1	Bechiri	8.0	220	1.68	0.08	0.9	35.0	1.6	2.1	0.2	212.5	4.8	5.4
KB- 17	Mansoura	8.3	360	6.62	0.13	1.6	33.7	4.6	4.2	0.9	53.7	5.6	9.7
KB- 24	Oum El Ferth	8.4	460	1.26	0.06	0.6	34.0	4.6	4.8	1.0	11.2	0.4	10.8
KB- 44	Atilet	8.6	520	1.78	ND	0.6	33.2	4.4	3.8	1.2	125.0	14.1	8.9
KB- 60	Faoura 1	8.2	85	0.70	0.03	1.7	23.5	5.3	0.9	1.7	18.2	0.7	2.9
GB- 6	Gabes	8.3	240	2.42	0.01	0.5	53.0	7.1	3.3	1.3	22.5	2.2	5.1
GB- 7	Limaoua 1	8.5	245	3.24	0.04	0.9	47.0	7.4	4.2	1.1	3.5	2.9	7.0
GB- 19	Chenchou 1	8.4	65	3.16	0.06	1.2	46.0	6.6	4.7	1.0	1.1	1.5	8.1
GB- 30	Arram	8.9	14	1.30	0.04	0.9	48.0	5.0	3.6	1.4	0.7	1.5	6.2
GB- 42	Kettana 3	8.3	59	2.12	0.06	1.5	45.0	7.1	4.7	1.2	1.1	1.5	8.1

Source: Determined by JICA study team

Table D.3 Chemical Characteristics of Irrigation Water

No Code	Name of Oasis	pH	EC	Salinity	Ca	Mg	Na	K	NH4
			(mS/m)	(mg/l)	(me/l)	(me/l)	(me/l)	(me/l)	(mg/l)
GF- 1	Kasba	7.0	170	1.20	10.6	14.0	7.7	0.6	<2
GF- 2	Sud Ouest	7.8	170	1.20	7.0	8.4	8.0	0.6	<2
GF- 4	Lala	7.3	180	1.30	10.0	11.4	7.7	0.6	<2
GF- 6	Oued Shili	7.4	480	3.20	10.1	12.3	35.0	0.7	<2
GF- 8	Segdoud	7.5	460	3.36	8.6	10.0	37.4	0.7	<2
TZ- 1	Tozeur	7.6	240	1.60	5.5	8.1	14.0	0.6	<2
TZ- 11	Nefta	7.6	340	2.32	8.4	12.6	15.6	0.7	<2
TZ- 15	Draa Sud	7.7	290	2.00	6.1	7.0	16.5	0.9	<2
TZ- 21	Cedada	8.3	300	2.10	7.4	5.4	14.7	2.7	<2
TZ- 26	Tamerza	7.8	130	0.90	4.0	4.0	7.0	0.8	<2
KB- 1	Bechiri	7.7	200	1.40	5.1	3.6	11.0	0.8	<2
KB- 17	Mansoura	8.1	330	2.30	7.0	7.7	19.6	1.3	<2
KB- 24	Oum El Ferth	7.4	570	4.00	11.4	5.9	45.5	1.1	<2
KB- 44	Atilet	7.7	370	2.60	6.6	8.4	23.3	0.7	<2
KB- 60	Faoura 1	7.6	220	1.50	5.3	6.0	12.5	0.6	<2
GB- 6	Gabes	7.5	330	2.31	11.3	23.9	16.0	1.2	<2
GB- 7	Limaou 1	7.3	350	2.45	5.9	10.1	19.8	0.4	<2
GB- 19	Chenchou 1	7.2	520	3.50	8.7	8.6	25.4	1.4	<2
GB- 30	Arram	7.2	320	2.30	6.8	10.3	17.5	0.4	<2
GB- 42	Kettana 3	7.4	320	2.30	6.2	10.3	17.2	0.9	<2

Code No	Name of Oasis	Fe	Mn	Si	Cl	SO4	HCO3	NO3
		(mg/l)	(mg/l)	(mg/l)	(me/l)	(me/l)	(me/l)	(me/l)
GF- 1	Kasba	tr	tr		5.1	8.1	3.6	0.3
GF- 2	Sud Ouest	tr	tr		3.9	7.7	3.3	0.3
GF- 4	Lala	tr	tr		5.0	7.9	2.4	0.2
GF- 6	Oued Shili	0.08	tr	4.5	22.3	15.9	2.0	0.2
GF- 8	Segdoud	0.14	tr	4.5	17.5	18.7	2.0	1.5
TZ- 1	Tozeur	0.03	tr	4.0	12.7	9.0	1.2	0.3
TZ- 11	Nefta	0.08	tr	4.0	14.4	11.2	1.2	0.2
TZ- 15	Draa Sud	0.04	tr	4.4	14.6	7.1	1.7	0.3
TZ- 21	Cedada	0.18	0.10	10.9	11.4	9.0	1.7	
TZ- 26	Tamerza	0.04	tr	4.2	2.2	4.6	2.8	0.3
KB- 1	Bechiri	0.07	tr	3.5	10.2	3.7	2.0	0.3
KB- 17	Mansoura	0.16	0.01	6.3	20.3	7.4	1.7	0.3
KB- 24	Oum El Ferth	0.59	0.10	5.5	26.2	18.4	1.8	
KB- 44	Atilet	0.11	tr	4.2	26.2	5.4	1.2	0.6
KB- 60	Faoura 1	0.03	tr	5.0	13.8	4.3	1.8	0.6
GB- 6	Gabes	tr	tr		17.6	10.6	2.2	0.3
GB- 7	Limaou 1	tr	tr	3.8	14.6	9.8	2.4	
GB- 19	Chenchou 1	tr	tr	7.7	21.3	11.1	2.4	
GB- 30	Arram	tr	tr	4.1	14.1	9.9	2.5	
GB- 42	Kettana 3	tr	tr	3.9	14.1	9.9	2.5	0.4

Source : Determined by JICA Study team

ANNEX - E

AGRICULTURE
AND
AGRICULTURAL ECONOMY

ANNEX - E
AGRICULTURE AND AGRICULTURAL ECONOMY

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E.1 INTRODUCTION

The present studies on agriculture, agro-economy and agricultural supporting system so far carried out are mainly the following field investigation and data collection in and around the Study area :

(1) collection of data and information on present agricultural production including land use, planted and harvested area, present cropping pattern, crop yield and production, current market flows and prices of agricultural commodities, etc.,

(2) farm survey for collecting more practical information on land use, cultural practices, farm inputs and farming expenses, and

(3) collection of data on existing agricultural support systems including agricultural extension, research, credit, farm inputs supplies and farmers' cooperatives.

The data and information were mainly obtained from the central and local government authorities concerned such as Direction Générale du Genié Rural (DGGR), Direction Générale du Production Végétale (DGPV) of Ministere de l'Agriculture, Institute National de lu Statistique, Comminissariat Regional au Développement Agicole (CRDA Gafsa, Tozeur, Gafsa and Gabes), Cellule Territorials Vulgarisation (CTV) offices, Celle de Rayonnement Agricols (CRA) offices, Institute National de Recherches Agronomiques de Tunisie (INRAT), Société Tunisienne des Marchés de Gros (SOTUMAG), Coopérative Regionale de Service Agricole (CRSA), Groupement Interprofessionnel des Dattes (GID) office and Société Tunisienne d'Engrais Chimiques (STEC).

In parallel with such data collection, an extensivé field investigation was made over about 30 Oases of the Study area. The interview survey by questionnaire was made to 17 CTVs and 54 CRAs in 4 Governorates (Gafsa, Tozeur, Kebili and Gabes). On the basis of the overall results of field investigation and preliminary results of data analysis, the farmer's interview was made on 58 representative farm households so as to confirm the data and information so far collected and also to obtain more practical and reliable information on farm economy. Based on the results of above mentioned study, agricultural development plan is being formulated.

E.2 BACKGROUND OF THE PROJECT

E.2.1 National Economy

Tunisia has a relatively diverse economy with important agriculture, energy, manufacturing and services sectors. Agricultural product is exported, although the country remains dependent on substantial food imports. Tunisia is an important producer of phosphate rock, and processes some of its output into phosphoric acid and fertilizers.

Gross Domestic Product (GDP) at current factor cost in 1993 was TD. 12,936 million (US$ 12,900 million). Per capita GDP at factor cost was TD. 1,735 (US$ 1,730). Agriculture sector in Tunisia occupied around 18.3 % of GDP in 1992/93 and held 26 % of labour force in 1992. Shares of GDP in industry and service sectors were 31.6 % and 50.1 %, respectively. There was no significant change in the sectional GDP distribution during the last 5 years. Annual growth rates of GDP and per capita GDP during 1992-1993 are estimated at 2.6 % and 0.6 %, respectively.

GDP and growth rates of respective sectors are summarized as follows :

Sector	GDP in 1993	Share	Real Growth Rate (1992 - 1993)
	(TD. Million)	(%)	(%)
Agriculture	2,372	18.3	
Industry	4,088	31.6	
Services	6,476	50.1	
GDP	12,936	100.0	2.6
(Per Capita GDP)	(TD.1,735)	-	0.6

Note : * ; Gross Domestic Product at current prices

Olive oil, fish, shellfish and fruit have been the main agricultural products for export. The share of these exports during the period from 1989 to 1993 was around 10 - 14 % to the total export. Olive oil and fruit exports account for 4.7 % and 1.6 % of the total amount in 1993. Major imported foods are milk, sugar, vegetable oil and cereals which account for 5.0 % of the total import in 1993. The wide fluctuation in cereals imports reflects domestic crop production. The low level of cereals imports in 1991 was attributable to the excellent harvest in the year.

E.2.2 Eighth Development Plan

The Eighth Development Plan (the VIIIth Plan) has been implemented since 1992, and 1996 is the last year of the Plan. Annual growth targets for the VIIIth Plan were set at 6.0 % in GDP and 4.1 % in per capita income during the plan period based on the strong expansion in manufacturing industry (8.7 %) and tourism (22.3%). These target could not be achieved in the period of the Seventh Development Plan i.e. actual growth rates were 4.2 % in GDP and 2.1 % in per capita income.

The primary objective of the VIIIth Plan in agriculture sector is set at the achievement of the food security through self-sufficiency in wheat, barley and meat, and improved needs coverage in dairy products (70 %) and sugar (16 %) by 1996, as well as the development of exports of agricultural and food products.

The agriculture sector will be restructured, including a re-organization of the public sector, the strengthening of the private-sector roles, the enhancement of agricultural research and extension programs, the adoption of a policy of price incentives, agrarian reform, and the promotion on investment.

The research and extension activities will be focused on productivity of crops evolving high production technology and its quick transfer to the farmers. Closer linkages will be established between the agriculture and irrigation departments. Concerted efforts will be made to improve the operational efficiency of the irrigation infrastructure and promote conjunctive use of water along with other inputs in order to rapidly increase crop production. Major emphasis will be laid on increasing the yield of crops and improving the productivity of livestock, fisheries and forestry sub-sectors. Based on the above agricultural development strategy, annual growth rate of major crop production targets at 1.8 % at 1990. Following shows a growth trends of major crop production.

Items	Target
1. Cereal farming*	-13.8 %/year
2. Tree farming	4.5 %/ year
3. Vegetable farming	4.2 %/ year
4. Livestock activities	5.3 %/ year
5. Fisheries	10.7 %/ year

(*) ; This decrease is due to the exceptionally high production in 1991, the base year for the VIIIth Plan.

E.2.3. Agriculture in Tunisia

(1) Agricultural Economy

Agricultural production now occupies much smaller proportion of GDP than at the time of independence. From 56 % in 1960, it had fallen to 20 % by 1972. Since 1980 agriculture has typically contributed about 16 - 17 % to GDP, falling back to 13 - 14 % in drought years (1983, 1986, 1988, 1989) and rising to 20 % after the record harvest of 1991. The government regards the increase of agricultural production as one of its most important economic objectives in order to reduce import of foods, increase export earnings and halt internal migration from the countryside into the town.

The wide annual variation in agricultural production is largely the result of Tunisia's irregular rainfall pattern. Thus is an erratic with respect to both the timing and the amount of rain. Annual rainfall in the north is 500 mm at average while in the south it is less than 200 mm. Yet rainfed farming predominates; about 4.8 million ha, or around 30 % of the country's area of 15.6 million ha, is arable, but out of this only 250,000 ha is irrigated. Over one-third of the total cultivated area is devoted to cereals, mostly wheat. Another third of arable land is planted with around 55 million olive trees, which make Tunisia one of the largest producers and exporters of olive oil in the world. However, the country was left with large stocks of unsold olive oil following bumper harvests in 1990-93, after which the government hoped to encourage olive growers to replace old olive trees with other fruit trees or crops. Other important crops are dates, citrus, sugar beet and vegetables. Cultivation in the south concentrates on dates .

In recent years, a sharp fluctuations in agricultural production, have been seen, particularly in cereals, which are cultivated almost entirely under rainfed. The 1988 harvest of 290,000 tons of wheat and barley was 85 % down on the previous year, whereas the 1991 cereal harvest was the largest on record

and 1992 saw a bumper olive crop. 1993 was an exceptional high yield year for citrus and dates.

The major crop production during 1989 - 1993 are estimated as below :

(Unit '000 tons)

Crops	1988/89	1989/90	1990/91	1991/92	1992/1993
Wheat	420	1,122	1,786	1,584	1,412
Barley	215	511	765	611	501
Olive oil	54	130	165	280	135
Citrus fruit	260	237	226	185	281
Tomatoes	440	530	580	550	420
Melons	250	450	350	380	330
Peppers	110	175	180	190	180
Potatoes	180	217	220	218	200
Grapes	55	40	55	50	60
Dates	75	81	75	75	86
Sugar beet	229	289	210	291	246

Source : Country Profile, Tunisia, 1994-95, The Economist Intelligence Unit

Poor rains in the autumn, winter and spring of 1993/94, followed by high summer temperature, have devastated the 1993/94 cereal crop. Four years of favorable good rainfall, invited bumper harvests of cereals at 1.6 million tons in 1989/90, 2.5 million tons in 1990/91, 2.2 million tons in 1991/92 and 1.9 million tons in 1992/93, however, the 1993/94 cereal crop is forecast at only 800,000 tons. Autumn in 1993 was very dry, and spring rains which might have saved the harvest were disappointed. April and May in 1994 were unusually dry, and with the exception of the south-east rains were well below average everywhere. Some reservoirs received only 25 % of the water in 1992/93, and irrigation water was rationed. The date palm for 1993/94 season was, however, the best for several years. Total production weighed in at 86,000 tons, including some 52,000 tons of the choicest variety, large and juicy "Deglet-Ennour". Olive oil production in the 1991/92 season was 63 % higher than in 1990/91 at an estimated 280,000 tons. This, however, is less welcome since olive stocks were already high, despite rising sales both at home and abroad.

(2) Land use

The surface area of the Republic of Tunisia is 15.6 million ha, 8.6 million ha or 55 % of total area is used for agricultural purpose. The present land use is shown in Table E.2.3.1 and summarized below.

(Unit : '000 ha)

Governorate	Total Land	Agricultural Land					
		Arable Land			Forest	Others	Total
		Cultivated	Fallow	Sub-total			
Gafsa	736	115	116	231	1	259	491
Tozeur	516	8	6	14	0	311	325
Kebili	2,245	13	17	30	2	290	322
Gabes	751	75	83	158	1	34	543
Sub-total	4,248	221	222	433	4	1244	1681
North	2,867	1509	316	1825	467	336	2,629
Centre	4,318	1980	503	2483	176	1,083	3,741
South	8,372	352	153	505	6	1,684	2,915
Tunisia	15,557	3841	972	4813	649	3,103	8,565

Source: Resultats de l'enquête sur la suivi de la campagne agricole 1993/94

The area of agricultural land occupies 8.6 million ha or 55 % of total land. The area of arable land is 4.8 million ha or 31 % of total land and 56 % of agricultural land. About 3.8 million ha or 44 % of agricultural land is forest, grazing land, farm road and so on. One million ha of arable land or 20 % of arable land is now remained fallow condition. These uncultivated land including fallow land is mainly used for grazing. The area ratio of agricultural land to total area is the highest in North District and lowest in South District. The area ratio of cultivated land to total arable land is also very low in south District compared with North and Centre Districts.

The land use pattern varies among the Districts. The area ratio of agricultural land to total area is about 90 % in North and Centre Districts, however, about 30 % in South District. The area ratio of arable land to total area ranges 66 to 69 % in North and Centre Districts, however, that in South Districts is only 23 %. The area ratio of cultivated land to arable land is lower in South District than in North and Centre Districts.

The total area of study area, the Governorates of Gafsa, Tozeur, Kebili and Gabes, is around 4.3 million ha. About 1.7 million ha or 40 % of total area is used for agricultural purpose. The area of arable land is 433 thousand ha and it occupies 26 % of agricultural land. A half of arable land is kept as fallow condition. There is a big difference in the surface area of arable land among the Governorates. The area of arable land is much larger in Gafsa and Gabes than in Tozeur and Kebili. The area ratio of arable land to agricultural land is also higher in Gafsa and Gabes than in Tozeur and Kebili. However, there is no big difference in the area ratio of cultivated land to arable land among the Governorates. The area ratio of cultivated land to arable land is approximately 50 % in all the four Governorates.

From above mentioned facts, land use pattern of the four Governorates is classified into two. One is relatively intensive land use type in Gafsa and Gabes, and the other is non-intensive land use type in Tozeur and Kebili. The different land use pattern in the two areas reflect the difference in climate between the two areas. In Gafsa and Gabes, the amount of precipitation is larger than in Tozeur and Kebili, the mean temperature of summer season is lower than in Tozeur and Kebili. The less precipitation and high summer temperature is not preferable for agriculture, especially in the dry area.

(3) Agricultural Production

Planted area of major crops

The cultivated land and planted area of Tunisia in 1993/94 is 3.8 million ha and 4.1 million ha, respectively as shown in Table B.2.3.2, and the cropping intensity (C.I.) can be calculated as 1.07. The planted area of major crops is summarized below.

(Unit : '000 ha)

Governorate	Cereal	Fodder	Legume	Vegetable	Arbor	Industrial	Other	Total	C.I.
Gafsa	18.5	24.8	2.0	2.2	73.0			115.1	1.05
Tozeur		0.3		0.4	7.7			8.4	1.09
Kebili		4.2		3.0	12.9			20.1	1.56
Gabes	12.5	3.8	0.5	5.4	74.6	0.8	0.6	98.2	1.31
Sub-total	31.0	33.1	2.5	11.0	168.2	0.8	0.6	247.2	1.17
North	849.5	207.4	91.3	77.4	284.7	18.8	6.2	1,535.3	1.02
Centre	559.9	109.3	10.5	65.8	1,390.6	0.5	2.1	2,138.8	1.08
South	96.1	9.1	4.4	10.3	307.3	0.9	0.9	428.9	1.22
Tunisia	1,505.5	325.8	106.2	153.5	1,982.6	20.2	9.0	4,103.0	1.07

Source: Resultats de l'enquete sur la suivi de la campagne agricole 1993/94

The planted area of South District is much smaller than North and Centre Districts. The area of arboriculture (tree crop and fruit tree cultivation) is the largest and occupies approximately 2 million ha or 48 % of total cultivated area, followed by cereal crops cultivation, 1.5 million ha or 37 % of total. The planted area of other crops such as vegetables, fodder crops and industrial crops is limited.

The cropping pattern varies by District. In North District cereal crop cultivation is dominant, followed by arboriculture and fodder crop cultivation. Cereal crop area occupies more than three times of arboriculture area. In Centre and South Districts, arboriculture is dominant, arboriculture area occupies 70 % and 87 % of cultivated land in Centre and South District, respectively. In South District, the area of field crop cultivation is very limited,

it occupies only 34 % of cultivated land. Cropping intensity of North, Centre and South District is 1.02, 1.08 and 1.22, respectively. Cropping intensity is the highest in South District. In Tozeur, Kebili and Gabes, since the arboriculture area is almost same as the total cultivated area, almost all of the field crop are inter cropped with trees.

Major cereal crops is wheat and barley and planted area of other cereals is very limited. Major cereal area is North and followed by Centre Districts, planted area of cereals in South District is very limited. In the Study area, cereal crops is cultivated in Gafsa and Gabes, and cereal crop area in Tozeur and Kebili is negligible.

Major fodder crops are annual grasses, lucerne, green barley, green oat, maize and cactus. Major fodder crop area is also North District followed by Centre District, and planted area of fodder crops in South District is very limited. Larger part of cereals and fodder crops are cultivated under rainfed condition. The planted area of cereals and fodder crops is shown below.

(Unit : '000 ha)

	Cereal Crops						Fodder Crops		
Governorate	Wheat	Barley	Triticale	Oat	Others	Total	Ann.	Perennial	Total
Gafsa	12.5	6.0				18.5	5.6	19.2	24.8
Tozeur							2.0	2.2	4.2
Kebili							0.0	0.3	0.3
Gabes	3.1	9.5				12.6	0.9	2.9	3.8
Sub-total	15.6	15.5				31.1	8.5	24.6	33.1
North	632.7	189.1	8.8	14.8	4.1	849.5	175.3	32.0	207.3
Centre	302.1	250.7	0.0	5.1	2.0	559.9	22.1	87.2	109.3
South	13.6	82.5				96.1	3.5	5.6	9.1
Tunisia	948.4	522.3	8.8	19.9	6.1	1,505.5	200.9	124.8	325.7

Source: Resultats de l'enquete sur la suivi de la campagne agricole 1993/94

Date palms is cultivated only in South District. In Tozeur and Kebili, since planted area of date palm is same as the cultivated area, other crops are planted under date palm. Main olive area is Centre District, it is equivalent to 70 % of total olive area . Planted area of tree crops and fruit trees are shown below.

(Unit : '000ha)

Governorate	Date Palm	Olive	Fruit Tree					
			Apple	Apricot	Almond	Pomegranate	Others	Total
Gafsa		43.4		0.2	9.8		19.6	29.6
Tozeur	7.7							
Kebili	12.9						5.0	5.0
Gabes	6.1	48.3	2.1	0.2	8.9	2.1	7.0	20.3
Sub-total	26.7	91.7	2.1	0.4	18.7	2.1	31.6	54.8
North		182.5	10.5	1.6	9.7	5.5	74.9	102.2
Centre		1,052.5	11.7	8.1	242.1	5.0	71.2	338.1
South	34.5	232.3	3.9	0.7	13.8	2.3	19.9	40.6
Tunisia	34.5	1,467.3	26.1	10.4	265.6	2.8	166.0	480.9

Source: Resultats de l'enquete sur la suivi de la campagne agricole 1993/94

Main vegetable area is North and Centre Districts and vegetable area in South District is very limited. In the Study area, 11,000 ha is used for vegetable cultivation, 2,200 ha for Gafsa, 400 ha for Tozeur, 3,000 ha for Kebili and 5,400 ha for Gabes, respectively. Major vegetables are onion, melon, pepper and tomato. The planted area of vegetables are shown below.

(Unit : '000 ha)

Governorate	Tomato	Pepper	Potato	Artichoke	Onion	Beans	Melons	Others	Total
Gafsa	0.39	0.27	0.05		0.16		0.48	0.85	2.20
Tozeur	0.04	0.09	0.01		0.05		0.09	0.10	0.38
Kebili	0.05	0.03			0.15	0.08	0.11	2.58	3.00
Gabes	0.15	0.36	0.01		0.89	0.16	1.52	2.29	5.38
Sub-total	0.63	0.75	0.07		1.25	0.24	2.20	5.82	10.96
North	19.19	7.55	15.73	2.19	3.51	7.07	8.30	13.87	77.41
Centre	5.24	10.53	2.13		4.74	3.65	21.01	18.54	65.84
South	0.31	0.61	0.04		1.40	0.36	2.10	5.44	10.26
Tunisia	24.74	18.69	17.90	2.19	9.65	11.08	31.41	37.85	153.51

Source: Resultats de l'enquete sur la suivi de la campagne agricole 1993/94

Production of major crops

The production of cereals of Tunisia is 634,3000 tons in 1993/94 and it largely varies year by year. The major cereals area is North District, 82 % of cereals is produced in North District, and only 5 % in South District. The production of cereals in the Study area is 3,500 tons in 1993 and most of it is produced in Gabes and very limited amount in Gafsa. Main cereal is wheat followed by barley.Cereal production by Governorate is shown below.

(Unit : '000tons)

Governorate	Wheat (hard)	Wheat (soft)	Barley	Triticale	Total
Gafsa	na	na	na	na	na
Tozeur	0.0	0.0	0.0	0.0	0.0
Kebili	0.0	0.0	0.0	0.0	0.0
Gabes	0.9	0.2	2.4	0.0	3.5
Sub-total	0.9	0.2	2.4	0.0	3.5
North	3,89.9	60.2	65.4	6.7	522.2
Centre	42.8	6.0	34.6	0.0	83.4
South	3.5	0.2	25.0	0.0	28.7
Tunisia	436.2	66.4	125.0	6.7	634.3

Source: Resultats de l'enquete sur la suivi de la campagne agricole 1993/94

The amount of production of date palm in Tunisia is 90,000 tons in 1994 and its yearly fluctuation is very small. Most of it is produced in South District, especially in the Study area. The production of date palm is the largest in Kebili and it occupies about 50 % of total production and followed by Tozeur and Gabes. There is no official data on date palm production in Gafsa, however, it is estimated few thousand tons by CRDA Gafsa. The amount of olive production in 1994 is 700,000 tons and it largely varies year by year.

The production of vegetables of Tunisia is 1.7 million tons in 1993/94 The major vegetable area is North and Centre District, 95 % of vegetables is produced in North and Centre District, and only 5 % in South District. The production of vegetables in the four Governorates is 84,500 tons in 1993 and most of it is produced in Gabes and Kebili, very limited amount in Gafsa and Tozeur. Vegetable production by Governorate is shown below.

(Unit : '000 tons)

Governorate	Tomato	Pepper	Potato	Onion	Beans	Melons	Others	Total
Gafsa	0.2	2.1	0.5	0.6		1.7	0.9	6.0
Tozeur	0.5	0.4	0.1	0.4		0.9		2.3
Kebili	1.6	0.4		1.8	0.7	1.9	14.6	21.0
Gabes	6.0	6.0	0.1	29.4		18.7		55.2
Sub-total	8.3	8.9	0.7	32.2	0.7	18.2	15.5	84.5
North	465.8	60.1	199.3	60.7	1.4	121.7	56.6	965.6
Centre	126.0	100.3	30.2	127.1	20.7	182.5	75.5	662.3
South	9.6	9.2	0.3	35.3	0.9	22.0	18.1	95.5
Tunisia	601.4	169.6	229.7	223.1	23.0	326.2	150.2	1,723.4

Source: Resultats de l'enquete sur la suivi de la campagne agricole 1993/94

E.3 PRESENT CONDITION OF THE STUDY AREA

E.3.1 General Condition

The Study area is located in a range between 250 km and 390 km south of Tunis, the Capital of the Republic of Tunisia. It extend from Gafsa city to Es Sabria city with length of approximately 140 km in the north-south direction, and from Gulf of Gabes to the border with Algeria with length of 260 km in the east-west direction. It covers a part of Governorates of Gafsa, Tozeur, Kebili and Gabes with respective of 7,360 km^2, 5,159 km^2, 22,454 km^2, 7,505 km^2 and totaling 42,478 km^2.

The territory of Tunisia, which extends from north to south is roughly classified into three morphological zones as The Atlantic Tunisia, The Eastern Tunisia and The Saharan Platform. The Study area, which consists of four Governorates, occupies the north margin of the Saharan Platform.

The Study area is located in the South Region or semi-arid zone with an annual rainfall of less than 200 mm . Annual mean temperature of Tozeur and Kebili is higher than 20 °C which is attributed to the very hot months of June to August because of inland nature of climate, whereas that of Gafsa and Gabes show rather low temperature less than 20 °C due to favorable location of Gafsa (located in the northern area) and Gabes (located near the sea). On the contrary, relative humidity at Tozeur and Kebili is lower than that of Gafsa and Gabes. It is thought to be the fact that the former two station are situated inland where very dry spell lasts long during the summer, and that the latter two stations located in the north and seashore where dry spell is rather short. Likewise, there is a distinct difference in rainfall pattern. For instance, records of the two meteorological stations of Tozeur and Kebili indicate that the annual rainfalls are as little as 86.9 mm and 73.6 mm, respectively. In contrast with the above, annual amount of rainfall in Gafsa and Gabes is more than two times, the former station recorded 174.3 mm, and latter, 212.8 mm. Eventually, such differences in the climatological characteristics are reflected on the evaporation. Annual mean evaporation of Tozeur and Kebili is as high as 7.2 mm and 8.4 mm per day, while of Gafsa and Gabes is 6.6 mm and 5.5 mm per day, respectively.

As discussed in the above, the Study area can be classified into two sub-areas, in term of meteorology, nonetheless it is located in the South Region as categorized nationwide. Governorates of Tozeur and Kebili are classified as

hot and dry inland, whereas those of Gafsa and Gabes are classified as temperate and rather humid with some rainfalls.

E.3.2 Administrative Division

Local government bodies in Tunisia comprise 23 governorates (Governorate), 254 districts (Délégation) and 2,044 villages (Imada) in 1994. Administratively Study area comprises 4 provinces covering 30 districts and 220 villages as of May 1994. Administrative divisions of the Study area and in and around 153 Oasis area are summarized as follows :

Item	Gafsa Governorate	Tozeur Governorate	Kebili Governorate	Gabes Governorate	Total
No. of Délégation (district)	11 (5)	5 (5)	5 (5)	9 (7)	30 (22)
No. of Imada (village)	74 (38)	36 (36)	40 (40)	72 (60)	222(174)

Source : Instituti National de la Statistique, Mai 1994
Remarks : ( ) ; related districts and villages of 153 Oases

E.3.3 Land and Population

The population and household number in and around the Study area are estimated at around 840,200 (which accounts for 9.6 % of the national population) and 148,700, respectively, with an average family size of 5.6. Population density was 6 persons per km^2 in Kebili Governorate, which is very low compared to 57 persons per km^2 of Tunisia average. Population in the Study area and around 153 Oases area are shown in Tables E.3.3.1, E.3.3.2 and E.3.3.3 and summarized as follows :

Item		Gafsa Governorate	Tozeur Governorate	Kebili Governorate	Gabes Governorate	Total
Study Area :						
Population, 1994	(Person)	307,513	89,055	131,914	311,713	840,195
Household No.	(No.)	54,330	16,590	21,316	56,431	148,667
Family Size	(per H.H.)	5.66	5.37	6.19	5.52	5.65
Total Area	(Km^2)	7,360	6,159	22,454	7,505	43,478
Population Density	(per km^2)	41.8	14.5	5.9	41.5	19.3
Population Growth	(%)	2.7	2.7	3.3	2.6	2.8
153 Oases Area :						
Population, 1994	(Person)	194,697	89,055	131,914	282,896	698,562
Household No.	(No.)	35,189	16,590	21,316	51,318	124,413
Family Size	(per H.H.)	5.53	5.37	6.19	5.51	5.61

Source : Instituti National de la Statistique, Mai 1994

Number of the farmer's household in the Study area is estimated about 39,600 or 32 % of total household.

E.3.4 Land Holding Size

The average farmland size of 153 Oases are estimated 0.38 ha and ranged between 0.11 ha and 5.13 ha. The farmland size of new Oasis is equalized distribution from 0.5 to 4.0 ha. The details are shown in Table E.3.4.1, and summarized as below.

Items	No of Oasis	Total Area	below 0.5 ha	0.6 - 1.0 ha	1.0 - 3.0 ha	above 3.0 ha	Total Farmers	Average Farmland
Gafsa Governorate :		(ha)						(ha/farmer)
- New Oasis	2	273	141	80	110	187	518	0.53
- Traditional Oasis	6	3,194	1,673	2,510	604	311	5,098	0.63
Sub-total	8	3,467	1,814	2,590	714	498	5,616	0.62
			(32%)	(46%)	(13%)	(9%)		
Tozeur Governorate :								
- New Oasis	6	1,163	0	7	728	0	735	1.58
- Traditional Oasis	24	4,459	3,598	1,013	1,508	206	6,325	0.70
Sub-total	30	5,622	3,598	1,020	2,236	206	7,060	0.80
			(51%)	(14%)	(32%)	(3%)		
Kebili Governorate :								
- New Oasis	10	809	106	816	124	0	1,046	0.77
- Traditional Oasis	57	6,404	27,542	2,225	426	16	30,209	0.21
Sub-total	67	7,213	27,648	3,041	550	16	31,255	0.23
			(88%)	(10%)	(2%)			
Gabes Governorate :								
- New Oasis	6	428	86	94	150	22	352	1.22
- Traditional Oasis	42	6,705	14,279	2,308	861	109	17,557	0.38
Sub-total	48	7,133	14,365	2,402	1,011	131	17,909	0.40
			(80%)	(13%)	(6%)	(1%)		
Total 153 Oasis Area :								
- New Oasis	24	2,673	333	997	1,112	209	2,651	1.01
- Traditional Oasis	129	20,762	47,092	8,056	3,399	642	59,189	0.35
Grand Total	153	23,435	47,425	9,053	4,511	851	61,840	0.38
			(77%)	(15%)	(7%)	(1%)		

Sources : Gafsa, Tozeur, Kebili and Gabes CRDA

E.3.5 Land Use and Cropping Pattern

The gross area of 153 Oases is 26,005 ha and net irrigated area is 23,435 ha or 90% of gross area as shown below. Non agricultural is used for farm road, canals and farm management building.

(Unit : ha)

Item	Gafsa Governorate	Tozeur Governorate	Kebili Governorate	Gabes Governorate	Total
Gross Area	3,852	6,105	8,014	8,084	26,005
Net Irrigation Area	4,467	5,622	7,213	7,133	23,435
(ratio)	90%	92%	90%	88%	90%

Source : Gafsa, Tozeur, Kebili and Gabes CRDA

The irrigated area of the Study area which includes 153 Oases in Gafsa, Tozeur, Kebili and Gabes is 23,435 ha. Total planted area in 1993/94 is

34,680 ha and cropping intensity can be computed 1.48. The planted area of major crops by Oasis is shown in Table E.3.5.1 and summarized below:

(Unit : ha)

Item	Gafsa Governorate	Tozeur Governorate	Kebili Governorate	Gabes Governorate	Total
Total Area :	3,467	5,622	7,213	7,133	23,435
Arboriculture	3,432	5,622	7,213	7,133	23,400
Vegetables	1,041	568	2,067	1,485	5,161
Fodder crops	886	311	2,850	1,620	5,667
Industrial crops	0	0	0	452	452
Total Planted Area :	5,359	6,501	12,130	10,690	34,680
Cropping Intensity	1.55	1.16	1.68	1.50	1.48

Source: Resultas de l'enquete sur le suive de la campagne agricole 1993/94

In all the Governorate, since arboriculture area is the same as cropped area, other crops are inter cropped with trees and cropping intensity is mainly affected by the planted area of field crops (vegetables, fodder crops and industrial crops). Vegetables and fodder crops occupies 25 to 40 % of cultivated area in each Governorate, except Tozeur. In Tozeur, the area ratio of vegetables and fodder crops to the total cultivated area is less than 10 %. The cropping intensity is the lowest in Tozeur at 1.16 and there is found no big difference in the cropping intensity among the three Governorates. Industrial crops are cultivated only in Gabes.

There is two types of Oasis categorized by start of implementation, so called newly developed Oasis (New Oasis) and Traditional Oasis, and some difference in cropping pattern between the two types of Oasis. The planted area of major crops by Oasis type is shown below:

(Unit : ha)

Item	New Oasis	Traditional Oasis	Total
Total Area :	2,801	20,634	23,435
Arboriculture	2,777	20,623	23,400
Vegetables	554	4,607	5,161
Fodder crops	536	5,131	5,667
Industrial crops	6	446	452
Total Planted Area :	3,873	30,807	34,680
Cropping Intensity	1.38	1.49	1.48

Source: Resultas de l'enquete sur le suive de la campagne agricole 1993/94

There is a some difference in the cropping pattern. Arboriculture occupies the major part of agriculture both in New and Traditional Oases. However the cropping intensity is much higher for traditional Oasis than for new Oasis. This means that the area ratio of planted area of vegetables and

fodder crops to total is higher for Traditional Oasis than for New Oasis and more effective land use in Traditional Oasis.

The planted area of tree crops and the number of tree crops by Oasis is shown in Table E.3.5.2 and Table E.3.5.3, and the ratio of the number of each tree crops to that of total trees are summarized below.

(Unit : %)

Item	Gafsa Governorate	Tozeur Governorate	Kebili Governorate	Gabes Governorate	New Oasis	Traditional Oasis
Date Palm	17	78	80	29	63	53
Olive	55	3	3	10	3	14
Fruit Trees	28	19	17	61	34	33
Plant Density (trees/ha) :						
Date palm	165	217	178	137	114	196
All trees	245	248	200	213	131	237

Source: Resultas de l'enquete sur le suive de la campagne agricole 1993/94, Gafsa, Tozeur, Kebili and Gabes CRDA

In Tozeur and Kebili, date palm is the main tree crops, and the number of olive tree is very low. In Gafsa, olive is the major tree crops. Olive is mainly cultivated in Gafsa and the ratio of the number of olive to total trees is very low in other three Governorates. In Gabes, fruit trees are the major tree crops. There is a big difference in the plant density of trees between New Oases and Traditional Oases. It is much higher in Traditional Oases than in New Oases.

From the view point of cropping pattern, type of agriculture of each Governorate can be very roughly grouped into four (4) types: the first is Tozeur and Kebili where date palm is dominant, the second is traditional Oases in Gafsa where olive is dominant and the third is Gabes where fruit trees are dominant crop and the fourth is field crops (Vegetables, Fodder crops and Industrial crops) dominant which is observed in Gabes. By considering the number of trees of each arbors, plant density of arbors and planted area of field crops, Oases are finally categorized into 13 types. The concept of categorization is shown below.

Type	Date Palm	Olive	Fruit Trees	Annual Crops
O - 1	+, ++	++++	+, ++	*
O - 2	+, ++	++++	+, ++	**
D - 1	++++	+	+	*
D - 2	++++	+	++	*
D - 3	++++	+	+	**
D - 4	++++	+	++	**
F - 1	++	+, ++	++++	*
F - 2	++	+, ++	++++	*
DF-1	+++	+, ++	++	*
DF-2	+++	+, ++	++	**
FD-1	++	+, ++	+++	*
FD-2	++	+, ++	+++	**
A	Small*	Small*	Small*	****

Remarks :

++++ : Predominant ; No of trees is more than 70 % of total
+++ : Leading ; No of trees is more than 50 % of total
++ : Small ; No of trees is less than 50 % of total
+ : Very small ; No of trees is less than 20 % of total
**** : Predominant ; Large area is used for field crop production
** : Relatively large ; Planted area of field crops occupies more than 20% of total
* : Small ; Planted area of field crops occupies less than 20% of total
Small* : Plant density of all trees is less than 90 trunks per hectare

The Oasis type categorized by cropping pattern is shown in Table E.3.5.4 and summarized below:

Type	Gafsa Governorate	Tozeur Governorate	Kebili Governorate	Gabes Governorate	Total
O - 2	3			2	5
D - 1	2 (1)	6	1		9 (1)
D - 2		8			8
D - 3			36 (3)		36 (3)
D- 4	1 (1)	1	19 (5)		21 (6)
F - 1				7	7
F - 2				13	13
DF-1		12 (6)			12 (6)
DF-2	2	3	10 (2)	5	20 (2)
FD-1				5 (4)	5 (4)
FD-2			1	12 (1)	13 (1)
A				4 (1)	4 (1)

Source : JICA study team estimation based on CRDA data.
Remark : Numerals in parenthesis shows New Oasis

The Oases in Gafsa are categorized 3 types. One is olive dominant type which are situated around Gafsa town, the second one is date palm dominant type which are located near the boundary of Tozeur and the third is date-fruit type. Almost all of Oases in Tozeur belongs to the date dominant or date

leading type, and only in four Oases, the planted area of field crops is more than 20 % of total cultivated area. It is observed some difference in Oasis type between traditional and new Oases. In New Oases, the ratio of number of fruit trees to that of total trees is higher for New Oasis than for traditional Oasis.

In Kebili, almost all of Oases belongs to the date dominant or date leading type, only one Oasis is fruit tree leading type, and the planted area of field crops is more than 20% of total cultivated land in all the Oases except one Oasis. There is no difference in Oasis type between Traditional and New Oasis.

In Gabes, there is no date dominant type Oasis. A larger part of Oases is fruit tree dominant or fruit tree leading type. Two Oases are olive dominant type and five are date leading type. The field crop dominant type Oases are five and found only in Gabes.

E.3.6 Farming Practice and Farm Input

There is many crops in the Study area. Since the precipitation is very low in the Study area, as already mentioned, crop cultivation is carried out under irrigated condition. So called basin irrigation method is employed in the area. To increase the efficiency of irrigation water for crop production, inter cropping method is employed. This cultural practice is one type of agroforestry or so called two or three layer crop cultivation.

Three types of crop is cultivated under typical three layer crop cultivation, date palm at top, fruit trees under date palm and field crop at lowest layer. In such case, the yield of fruit trees is affected by the population of date palm and that of field crops is also affected date palm and fruit trees. At present, a typical three layer crop cultivation is rarely observed. Three layer crop cultivation is observed only limited Traditional Oasis and very difficult to find in the New Oasis. Since a new date palm variety which has short trunk is planted in New Oases, it is very difficult to plant fruit trees under date palm. In New Oases fruit trees are planted between date palm row.

There is a big difference in arboriculture between Traditional and New Oasis, and among the Governorates. In Traditional Oases, arbors are planted randomly and plant density is very high compared with New Oasis. On the other hand, in New Oasis arbors are planted regularly. The plant density of

date is much higher for Tozeur and Kebili than for Gafsa and Gabes. In Tozeur and Kebili, planted area of a new recommended date palm variety, Delglat Ennour, is increased in both Traditional and New Oases, especially in New Oases a larger part of newly planted date palm is new variety. In Tozeur, the ratio of number of trees of Delglat Ennour to total number of date palm is 94 % for New Oasis and 46 % for Traditional Oasis, respectively. The major fruit tree in Gafsa is apricot, and in Gabes is pomegranate. In the Oases, apricot pomegranate, fig, apple, pear, peach, grape and almond are planted.

Irrigation interval varies by the crop. Irrigation interval for tree crops ranges 20 days to 30 days and 7 to 14 days for field crops. Achievement of irrigation water widely varies from 20 % to 70 %. This means amount of irrigation water can be assumed to be one of the limiting factor crop yield.

Present amount of farm inputs and labour requirement are presented in Table E 3.6.1. All the cultural practice is carried out by manpower. Since inter cropping method is employed and field size is very small, it is very difficult to mechanize cultural practice, especially in Traditional Oasis. Therefore, a large number of manpower is required for land preparation, weeding, water management and harvesting.

Since some kinds of crops in the same field, herbicides cannot be used. As the soil is very poor in CEC, organic fertilizer is more effective compared with inorganic fertilizer (chemical fertilizer), and split application of chemical fertilizer is recommended. The climate is dry and mixed cropping practice is employed, damage by fungal disease is generally very low in normal year. Only damage of date fruit affected by fungus after rainfall is observed at harvesting time. Protection of date fruit from damage by fungal disease is done by fungicides application and covering the fruits bunch by plastic film.

A larger part of vegetable varieties cropped in the area is improved fixed variety which are imported from advanced countries. Only in limited area and green house, in which vegetables is cultivated during the period from October to April or early May by using geothermal water, F1 hybrid variety is used. In the area, many kind of vegetables are cultivated. Carrot turnip, onion, kidney bean are cropped as winter vegetables, and tomato, pepper, melons, beans and etc. are cropped as summer vegetables. Lucerne, barley, oat and maize are cultivated as fodder crops. Tobacco and henna for the industrial crops are cultivated only Gabes.

Main cropping season of annual crops (vegetables and annual fodder crops) is shown in Table E 3.6.2. Winter crop season starts at beginning of September with two to two and half month staggering period, and ends three and half to six month after seeding. Summer crop season starts at beginning of April with two to two and half month staggering period, and ends three and half to four month after seeding. Calendar of cultural practice of arbors is also shown in Table 3.6.2. Protection of fruit bunch of date palm is carried out one to one and half month before harvest. When symptom of disease and insect is found, disease and insect control is carried out.

E.3.7 Crop Yield and Production

The yield of major crops in the Study area by Oasis is shown in Table E 3.7.1 and summarized below.

Item	Gafsa Governorate	Tozeur Governorate	Kebili Governorate	Gabes Governorate	Ave-rage	New Oasis	Traditional Oasis
Date Palm	7.3	5.8	5.7	5.9	5.2	6.0	5.9
Olive	8.0	2.7	4.6	4.0	4.1	6.2	6.1
Fruits	10.8	2.5	2.6	9.8	6.0	9.1	8.7
Winter Vegeta.	23.5	12.5	12.8	28.1	16.1	19.4	19.1
Summer Vege.	18.0	9.6	10.1	15.2	12.1	13.6	13.4
Fodder Crop	59.3	77.6	50.1	59.4	56.4	56.4	54.9
Industrial Crop				1.5	1.5	1.5	1.5

Source: Resultas de l'enquete sur le suive de la campagne agricole 1993/94, 1992/93
Gafsa, Tozeur, Kebili and Gabes CRDA

It is found a difference in the yield of major crops among the governorates and among Oases even in the same governorate. There is no big difference in the date palm yield among the four governorate and between traditional and new Oases. The yield of date palm is slightly higher for Traditional Oasis than for New Oasis and higher Gafsa than for other three governorate. The yield of olive is the highest in Gafsa and lowest in Tozeur, and there is a big difference in the yield between Gafsa and Tozeur. Very low yield of fruit tree is found in Tozeur and Kebili. These value is only less than one third of that of Gafsa and Gabes. One of the reason of low yield of fruit tree in Tozeur and Kebili is unfavorable light condition. In Tozeur and Kebili, all the fruit trees are planted under palm tree and the plant density of palm trees are very high, especially in Traditional Oases, and they can receive less amount of solar energy compared with Gafsa and Gabes where the plant density of palm trees are very low.

The yield of vegetables is also low in Tozeur and Kebili, about 50 % to 60% of those of Gafsa and Gabes. On the other hand, the yield of fodder crops is higher in Tozeur than in other three governorates. There is no big difference in the fodder crop yield among three governorates.

At present, irrigation water supply for crops is much less than water requirement of crops, it ranges from only 20 % to 70 % of water requirement. Therefore, water supply can be assumed to be one of the limiting factor for crop production. There is found a definite relationship between date palm yield and the achievement of water supply (the ratio of effective water supply to water requirement of crop) in traditional Oases in Tozeur. The yield of date palm is presented by exponential function ($y = 2.4\ x^{0.25}$,where y: yield. x: achievement of water supply) or quadratic function ($y = a + bx + cx^2$, where a, b and c: constant) of achievement of water. (Fig. E.3.7.1) There is no available information on the relation ship between water supply and crop yield. However, there is many information on the relationship between the crop yield and some limiting factors, such as amount of solar radiation, amount of nitrogen application, amount of phosphorus application under phosphorus deficiency soil. These articles shows that there is a definite relationship between crop yield and limiting factors and crop yield can be presented by quadratic function or exponential function of limiting factors. (Fig. 3.7.2)

Matsushima (1953, 1969) shows that there is a definite relationship between the grain yield of paddy plant and the amount of solar radiation during the most sensitive period and grain yield is presented by quadratic function of amount of solar radiation .

Koyama et al (1973) shows that grain yield of paddy plant grown under phosphorus deficient soil is presented as a quadratic function of the amount of phosphate fertilizer application. Many report studied by International Rice Research Institute (IRRI) reported that there is a definite relation ship between grain yield of paddy plant and amount of nitrogen fertilizer application.

It was recently found that grain yield of paddy plant is presented by quadratic function of amount of total fertilizer application in Indonesia (1994).

Jacob and Uexkuell (1963), Sanchez (1976) and Wazir and Effendi (1963) showed that there is definite relationship between maize yield and nitrogen application (quadratic function).

These information support the relationship between yield of date palm and amount of water supply. The yield of date palm increases exponentially with an increase of water supply. And it can be easily estimated that crop yield in the area increases with an increase of water supply.

The present production of major crops by Oasis is shown in Table E 3.7.2 and summarized below :

(Unit : tons)

Item	Gafsa Governorate	Tozeur Governorate	Kebili Governorate	Gabes Governorate	Total	New Oasis	Traditional Oasis
Date Palm	5,958	29,329	37,289	18,470	91,046	10,907	80,139
Olive	17,854	480	898	6,879	26,111	950	25,161
Fruits	4,584	1,006	1,295	24,412	31,297	2,718	28,579
Winter Vegetab.	11,763	3,833	16,083	24,275	55,954	5,658	50,296
Summer Vegr.	9,779	2,514	8,120	9,435	29,848	2,584	27,264
Fodder Crop	47,531	24,143	142,936	96,203	310,813	30,240	280,573
Industrial Crop				662	662	9	653

Source: Resultas de l'enquete sur le suive de la campagne agricole 1993/94, 1992/93
Gafsa, Tozeur, Kebili and Gabes CRDA

Main date palm area is Kebili. followed by Tozeur and Gabes, production of date in Gafsa is smaller than former three governorates. Both in Traditional and New Oases in Tozeur and Kebili, date production occupies more than 90 % of total production of tree crop production. There is no big difference in crop production pattern between Traditional and New Oases in Tozeur and Kebili.

Olive production is the highest in Gafsa followed by Gabes and that of Tozeur and Kebili is negligible, olive production in Gafsa is more than 70 % of olive production in the Study area. In Gafsa, there is a big difference in crop production pattern between Traditional and New Oases. In New Oases, date palm production is major and olive and fruits production is very low.

The main fruit area is Gabes and Oases in Gabes is more than 80 % of fruits production in the Study area. Especially in new Oases in Gabes, fruits production occupies 70 % of total tree crop production.

Vegetable production is the highest in Gabes and fodder crop is the highest in Kebili. The amount of production of vegetables and fodder crop in Tozeur is particularly low.

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E.3.8 Livestock Production

Animal husbandry is also one of the main line in agricultural activities in Tunisia and the Study area. Animal population by Oasis in the Study areas shown in Table E 3.8.1 and summarized below :

(Unit : head)

Item	Gafsa Governorate	Tozeur Governorate	Kebili Governorate	Gabes Governorate	Total
Cattle	1,870	776	99	3,671	6,416
Sheep	84,000	34,172	60,600	18,030	196,802
Goat	14,500	25,800	50,500	32,060	122,410
Camel	740	500	7,600		8,840
Equine	2,950				2,950

In the Study area, sheep is the most important animal, followed by goat. In Gafsa, the number of sheep is much larger than goat, on the other hand, in Gabes the number of goat is much larger than sheep. In Tozeur and Kebili, there is no big difference in the number between sheep and goat. The cattle population is higher in Gafsa and Gabes than in Tozeur and Kebili. There is no available information on the livestock production. However, it can be

estimated that the value of livestock production is much less than that of agricultural production referring animal population.

In the area, since a larger part of livestock is ruminant animal, it is required a large amount of crude feed. Since the productivity of grass in grazing land is very low, especially in summer, a large amount of fodder crop production is required in Oases.

E.3.9 Marketing System and Prices

Agricultural products in the Study area are sold mainly through the traders and wholesale agencies to the Wholesale Market, Tunis, Gabes and other Governorates. The Central Wholesale Market (Societe Tunisienne des Marches de Gros, SOTUMAG) located in Tunis is the country's largest market. There is no wholesale market in Gafsa, Tozeur and Kebili Governorates. Other marketed agricultural products are sold through the open or weekly (Souks) market system. Therefore, data collection and analysis of marketing and prices in the Study area is conducted on the Agricultural Statistic office, CRDA.

Date palm for export which is produced by farmers and collected by traders or commission agents is temporarily stored in cold storage in Tozeur which is managed by the Groupement Interprofessionel des Dattes (GID) office and delivered for Tunis to exports. Most of olive is taken to olive oil mills through traders or mill agencies. Some of fruits are generally purchased from producers on a standing crop basis by pre-harvest contractors who are responsible for harvesting the crop and for all aspects of primary marketing. It is understood that some products in the Study area with substantial areas of fruits sell their standing crops in a similar manner to pre-harvest contractors.

At the market, the agricultural products pass into the hands of a commission agents. The commission agent is a key figure in the marketing system for fruits and vegetables. The agent trades in products on behalf of the producers (farmers) on a commission basis. The commission agent has a fixed place of business in the market from which he negotiates sales of vegetables to middlemen / wholesalers in the market. In some cases the commission agents also function as the wholesaler. The middleman / wholesaler pays a fee to the Market Committee. It is reported that there is a considerable degree of price collusion between the commission agent and the middleman / wholesaler in

both negotiated sales and a action. The commission agent charges a fee which is generally fixed at 11 % for fruits and 12 % for vegetables of the price received, and summarized as below ;

Items	Fruits	Vegetables
1. SOTUMAG tax	2 %	2 %
2. Commission fee	5 %	5 %
3. Delivery service charge	3 %	3 %
4. Special fund of stabilization of price	1 %	1 %
5. Special (GIL) tax		1 %
Total	11 %	12 %

GID : Groupment Interprofessional des Legumes

The government has already created conductive environment for marketing of major crops. Support prices for cereal crops (wheat, maize, etc.), tree crops (date palm, olive) and others are fixed by the government with a view to provide economic incentives to farmers. The support prices are reviewed annually keeping in view factors such as cost of production, domestic demand, import and export parity prices, supply and stock position, comparative advantage of crops. Average market and farmgate prices of major crops at the Study area (Tozeur, Kebili and Gabes) from January 1994 to September 1995 are shown Table E.3.9.1 (1) to (3), E.3.9.2. The price for fruits and vegetables are increased at beginning and end of harvesting period. The wholesale market prices of major crops at the Central Wholesale Market (SOTUMAG) located in Tunis are shown in the Table E.3.9.3 (1) to (2).

Based on the farm economic survey, farmgate price for agricultural products and farm inputs in the Study area are estimated in Tables E.3.9.4 and E.3.9.5. The farmgate prices of major crops are in a range between 80 to 88 % of market price , and summarized as below ;

(Unit : D./kg)

Crops	Market Price	Farmgate Price	Crops	Market Price	Farmgate Price
Date Palm	1.274	1.025	Turnip	0.236	0.201
Olive	0.463	0.400	Onion	0.218	0.186
Pomegranate	0.342	0.287	Kindney Bean	0.435	0.370
Apricots	0.587	0.385	Pepper	1.026	0.874
Fig	0.458	0.385	Tomato	0.364	0.310
Henna	2,160	1.900	Luceme	0.062	0.053

E.3.10 Crop Production Value

Present crop budget per ha are estimated based on above farmgate prices, labour and farm inputs requirement, and present yield. Present crop

production value in the Study area is estimated based on the farmgate prices as of September in 1995. The total gross and net crop production value are D. 160,4 million and D. 122,9 million. The details at are shown in Tables E.3.10.1 (1) to (4), E.3.10.2, E.3.10.3 and E.3.10.4 and summarized as follows ;

Crops	Crop Production (tons)	Gross Prod. Value (D., '000)	Production Cost (D., '000)	Net Prod. Value (D., '000)
Arboriculture :		113,980	22,060	91,920
Date Palm	91,050	93,320	15,120	78,200
Olive	26,100	10,440	3,360	7,080
Pomegranate	23,150	6,640	2,310	4,330
Apricot	4,100	2,020	400	1,620
Fig./others	4,050	1,560	870	690
Winter Vegetables :		11,830	4,810	7,020
Turnip/ Carrot	23,760	4,780	1,820	2,960
Onion	26,440	4,920	2,190	2,730
Kidney Bean	5,760	2,130	800	1,330
Summer Vegetables :		16,880	4,160	12,720
Pepper	13,540	11,830	2,870	8,960
Tomato	16,310	5,050	1,290	3,760
Fodder Crops :				
Luceme	310,810	16,470	5,880	10,590
Industrial Crops :				
Henna	310,810	1,220	570	650
Total		160,380	37,480	122,900

Remarks : Prod. ; Production

E.3.11 Farm Economy

In farmland in the Oases, date palm, olive and fruits trees such as pomegranate, apricot, grape and fig, etc. are planted, and under or between tree crops, vegetables, fodder crops and industrial crops are inter cropped. Farmers in the Study area get their income mainly from farming activities particularly from the date, olive and fruit production, partly supplemented by sales of vegetables and fodder, as animal husbandry is not a mainline of agriculture in the Study area and the income from the sales of livestock is very limited.

In order to grasp economic activities of farmer in the Study area, the farm economic survey was carried out for 18 farm households in 8 Pilot Oasis area selected by random sampling method. According to the results of farm economy survey, the food expenses are most important in the living expenses. The annual family living expenses is estimated based on the average size family of each delegation. The preliminary farm budget of the typical size farmer in 8

Oasis area are estimated as shown in Table E.3.11.1 (1 - 4), and summarized as below.

Items	Kasba	Oued Shili	Tozeur	Draa Sud	Mansoura	Oasis de Atilet	Gabes	Limaoura 1 et 2
Farm Land : (ha)	1.06	3.11	1.38	1.98	0.25	0.75	0.29	1.25
Gross Income : (D.)								
- Farm Income	7,848	13,410	9,471	9,421	1,640	4,652	1,991	7,453
- Off-farm Income	0	0	0	0	2,500	1,000	2,000	0
Sub-total	7,848	13,410	9,471	9,421	4,140	5,652	3,991	7,453
Number of Family :	5.33	5.47	5.27	5.27	5.65	6.17	5.48	5.48
Gross Outgoing : (D.)								
- Production Cost	1,843	2,393	1,757	2,297	410	1,648	473	2,286
- Living Expenses	3,059	3,140	3,024	3,024	3,244	3,542	3,145	3,145
Sub-total	4,902	5,533	4,781	5,321	3,654	5,190	3,618	5,431
Net Reserve: (D.)	2,956	7,877	4,690	4,100	486	462	373	2,022

Source : Farm economic survey by JICA Study team, 1995

E.3.12 Farmers' Organization

Farm inputs supplies, storing and marketing of farm products are primarily made through the establishment of cooperatives which have been promoted by the Government through the CRDA office in each Governorate. In spite of government efforts, however, the cooperative activity has not been well developed mainly because of poor in management and shortage of operational fund. In order to improve such stagnant condition of cooperative activity, establishment of Coopératives de Services Agricoles (CSA) has been promoted with the Tunisian Cooperative Status under supervision by Ministere de l'Agriculture.

In the Study area of 4 provinces, 17 CSAs have been organized so far. The total number of CSA members is preliminary estimated about 3,730, and summarized as follow;

Items	Gafsa Governorate	Tozeur Governorate	Kebili Governorate	Gabes Governorate
No. of CSA	1	0	4	12
Number of members	257	0	1,125	2,347

Sources : Gafsa, Tozeur, Kebili and Gabes CRDA

E.3.13 Agricultural Support Services

In order to promote and accelerate the agricultural extension activities, the Agricultural Extension Service Program has been launched in Tunisia. In the Central Government, the Agence de la Vulgarisation et la Formation

Agricoles (AVFA) was established as one of the extra-ministerial bureaus under the Ministry of Agriculture. At the same time, in the governorate level, the establishment of the Division de la Vulgarisation et de la Promotion de la Production Agricole in CRDA has been promoted with the provision of functions of adaptation tests of new recommended agricultural techniques recommended by research institutions and in-services training for field extension workers. In the Délégation and Imada level, Cellules Territorialles de Vulgarisation (CTV) offices and Cellules de Rayonnement Agricol (CRA) offices have been established as a base camp for extension of education activities with functions of preparation of extension program, dissemination of agricultural information and training for leading farmers at the local level

Present staffing of the extension service work for 153 Oases area is estimated at 16 for CTV and 60 for CRA. In Gabes, 3 Oases (Ain Zrig, Zrig Dakhlania and Limaoua 1 et 2) are not exist CRA office/building and staff. The details are shown in Table 3.13.1, and summarized as follows ;

Items	Gafsa CRDA	Tozeur CRDA	Kebili CRDA	Gabes CRDA	Total
Study Area : :					
CTV office	7	3	5	5	20
- Chef of CTV	6	3	5	5	19
CRA office	32	17	21	34	104
- Chef of CRA	25	18	21	14	78
153 Oases Area :					
CTV office	3	3	5	5	16
- Chef of CTV	3	3	5	5	16
CRA office	7	17	21	15	60
- Chef of CRA	7	18	21	14	60

Sources : Annuaire des Vulgarisateurs, Mars 1994
Gafsa, Tozeur, Kebili and Gabes CRDA

E.4 BASIC CONCEPT FOR THE PROJECT DEVELOPMENT

E.4.1 Agricultural constraints

Some constraints are observed concerning on water shortage originated from water supply system. And accumulation of salts in soil surface is observed in some places because of inadequate drainage system.

Since the lateral canal from secondary canal is earth ditch, a large amount of water leaks away from the canal and distribution of water to the field is very uneven. In addition, the large amount of manpower is required for on farm ditch preparation and for water management.

(1) In some Oases, irrigation interval is too long to cultivate vegetables, and cropping intensity becomes low.
(2) In some of Oases, because of undulating land surface, some areas which are relatively high and very far from the hydrant, cannot receive irrigation water. In addition to this, accumulation of salts in soil surface is observed in some places because of inadequate drainage system and shortage of washing water. In these area, cultivation of annual crops is difficult, tree crop is damaged. In serious case, a farm land sometimes becomes abandoned because of these problem.
(3) As regarding to cultural practice, no mechanization is employed for cultivation of annual crops, especially in traditional Oases, because trees are planted at random and plant density is too high.

E.4.2 Agricultural Development Concept

To solve the constraint above mentioned, agricultural plan should be formulated taking into account the following concepts:

(1) Proper irrigation water supply and drainage of excess water would be necessary for increasing crop production, keeping soil fertility and preventing salinaization of soil.

(2) Proper cultural practice would be necessary to introduce improved cultural practice for increasing yield under proper irrigation being employed.

(3) Crops would be selected taking into consideration of land suitability, knowledge level of farmers, marketing and benefit and so on.

(4) Arboriculture occuples major part of agriculture, and almost of arbors are full production stage, therefore, no new arbor would not be introduced. Concerning on field crops cultivation, by considering land suitability, farmer's knowledge on cultural practice and marketing, no new crop would not be introduced.