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SANDY SOILS

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III.4 QUALITY OF WATER IN RELATION TO IRRIGATING SANDY SOILS

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SUMMARY

Irrigation water is becoming more and more scarce to meet the needs of agricultural expansion in the region and as a result the intensity of using lower quality water is increasing. Such water should not be deemed unfit for irrigation without careful consideration being given to all facts concerned. This paper briefly discusses these factors and cites some examples where saline water is being used in the region.

Criteria such as the total salt concentration, sodium percentage, residual sodium carbonate and boron are used in setting standards of water quality for irrigation. Due to the influence of soil, climate, crop and water management practices there is no simple water classification scheme applicable in all cases. On permeable soils such as the sandy ones and where rainfall distribution and intensity prevent salt accumulation, water of lower qualities could be tolerated.

Yields and quality of crops are usually impaired by salts from irrigation water. Certain ions have specific effects when they are abundant and others are toxic even when they are found in minute concentrations. Plants vary widely in their tolerance to salinity, but most of them are more sensitive during germination and emergence than in the later stages of growth. It is through proper soil, water and cultural practices that the harmful effects of salty water can be reduced. The paper cites the results of work carried out in Tunisia as an example.

Salinity can be controlled by providing the required leaching and an adequate drainage system. The leaching requirement, as affected by the kind of soil and the salt content of irrigation water, is low in the case of sandy soils and increases rapidly with the salinity of the water. The relation between leaching and drainage requirements must be observed for proper drainage design and economic use of water. The efficiency and timing of leaching are discussed. The use of salty water in sprinkler and drip irrigation methods, which are more suitable than the other methods for irrigating sandy soils, has proved to be successful when properly managed. Shortage as well as over supply of irrigation water may cause salinization as a result of thin spreading of irrigation water in the former case and water-logging in the latter.

Examples are given of the use of low quality groundwater to irrigate sandy soils in some countries of the region. Salt tolerant cereal crops, vegetables, alfalfa and date palms are being irrigated with water of 2 000 ppm or more in Bahrain, 2 400 to 6 000 ppm in Kuwait and 15 000 ppm in the Tagora area of the Libyan coastal plain. Soil reclamation and development projects in Saudi Arabia depend on groundwater of about 2 500 ppm for crop production. In the United Arab Emirates, forest plantations have been established on deep sandy soils, using drip irrigation with very saline groundwater of up to 10 000 ppm.

4.1 INTRODUCTION

In almost all countries in the Near East region, the provision of irrigation water is one of the most important factors for expansion of agricultural production. In some parts, with all available good quality water already being used, and with irrigation expansion approaching saturation point, the need to use saline waters is increasing. A study of the safe limits of salts in irrigation water and of the conditions under which saline water may best be used for irrigation is essential in order to utilize intelligently the resources of the arid region.

Saline irrigation water should not be deemed unfit for irrigation without careful consideration of all factors concerned. Permanent irrigated agriculture can be maintained using rather salty waters with proper management.

The concentration and composition of dissolved constituents in a water determine its suitability for irrigation use. Apart from the quality of irrigation water itself, the following factors are also involved: type of soil, climate, prevailing drainage conditions, methods of irrigation, land development and land preparation for irrigation and types of crop grown.

This paper discusses briefly the above factors and their interrelationship. Some aspects of the use of different levels of saline water in irrigating sandy soil in some countries of the region are also included.

4.2 STANDARDS FOR IRRIGATION WATER

Waters with conductivity below 750 micromhos/cm are satisfactory for irrigation insofar as salt content is concerned, although salt sensitive crops may be adversely affected by the use of irrigation water having conductivity values in the range of 250 to 750 micromhos/cm. Waters in the range of 750 to 2 250 micromhos/cm are widely used, and satisfactory crop growth is obtained under good management and favourable drainage conditions, but saline conditions will develop if leaching and drainage are inadequate. Use of water with conductivity values above 2 250 micromhos/cm is the exception and very few instances can be cited where such waters have been used successfully. Highly permeable soils, such as sandy ones, facilitate the task of obtaining a favourable salt balance in the soil, even with relatively saline irrigation water.

An irrigation water with a high sodium percentage $\frac{100\ Na}{Na + K + Ca + Mg}$

will, after a time, cause a soil with a large proportion of exchangeable sodium. The higher the cation exchange capacity of the soil, the greater the risk of alkalization and hence the deterioration of soil structure. It should be pointed out, however, that even on sandy soils with good drainage, waters with 85 percent sodium (expressed as a percentage of the total cations) or higher, are likely to make soils impermeable after prolonged use. With a higher total salt content, there is a flocculating action that tends to counterbalance the poor physical condition caused by a high sodium concentration in the water.

Residual sodium carbonate is another criterion for water quality and it is equal to the total carbonate and bicarbonate minus the total calcium and magnesium ions in milliequivalents per litre. Waters with residual sodium carbonates of 2.5 meq/l or more are considered unsuitable for irrigation, while those of 1.25 to 2.5 meq/l are classified as marginal and below 1.25 are considered as safe.

Boron is essential to plant growth and work on sand cultures has shown that many plants make normal growth with traces of boron (0.03 to 0.04 ppm) but that injury often occurs in cultures containing 1 ppm. Some crops, such as beans, are very sensitive to an excess of boron but others, like sugarbeet, will tolerate large quantities. However, water containing more than 2 ppm will usually cause trouble after a time.

The amount, intensity and distribution of rainfall plays an important role in the use of water for irrigation purposes. Heavy and intensive rain during winter reduces the amount of leaching water required during the irrigation season. This is very important for areas where the quality of available irrigation water is marginal and/or of short supply. Crops and cultural practices can be selected properly for effective utilization of precipitation stored as soil water. On the other hand, some crops become more sensitive to a given level of salinity during hot, dry weather than during cooler, more humid weather.

As mentioned before, because soil, crop, climate, drainage and soil management all influence the suitability of water for irrigation, no simple water classification scheme is applicable for all cases. Some writers have indicated that waters of 70% sodium are unsuitable under most conditions, yet on sandy soils in the Coachella Valley, California, waters of more than 80% sodium are used and the farmers are making a profit. Electrical conductivity of 2 250 micromhos/cm is considered as the upper limit for good production on most soils; however, good yields of alfalfa and some winter vegetables are obtained in the Arabian Gulf States with waters of a salinity content double or even triple the above level.

4.3 REACTION OF CROPS TO SALINITY

4.3.1 Effect on Yield and Quality of Crops

Studies on the effect of several moisture treatments and salinity levels indicate that plant growth is a function of total soil moisture stress, regardless of whether this stress arises primarily from salinity or moisture tension.

Salts generally decrease the yield and impair the quality of crops. Yields of tomatoes and pepper are reduced not only because of fewer fruits per plant, but also because of a marked decrease in fruit size. Conversely, salinity may increase the sugar content of some vegetables, especially carrots, but this gain in quality is more than offset by lowered yields. Cabbages from salty fields are generally more solid than those from non-saline fields, but again, lowered yields offset this favourable effect. Chloride fertilizers are generally believed to make potatoes less starchy and more watery; but on saline soils, high in chloride, the decreased water availability counteracts this effect so that the tubers produced are of normal starch content. Salinity accelerates the maturation of potatoes, although the tubers are smaller. In contrast, salinity delays the flowering and, therefore, the maturation of sweet corn (maize).

4.3.2 Water Composition and Plant Toxicity (Specific Ion Effects)

The quality of the irrigation water affects the mineral composition of the plants and this process of mineral uptake is intensified when water is applied by sprinkling, which is widely used for irrigating sandy soils. This can lead to a serious upset in the metabolism of the plant and to its intoxication which, no doubt, explains some failures observed in the case of sprinkling. It is also known that some ions are more toxic than others to certain crops. Excessive chloride ions are toxic to peaches and other stone fruits, pecan and avocados. Sulphate ions cause disturbances to the optimum cationic balance within the plant, as they limit the uptake of calcium and increase that of sodium and potassium.

Boron, although it is required for the nutrition of the plants in trace quantities, is toxic even at low concentrations (2 ppm or more). High concentrations of sodium not only cause adverse effects on soil structure and related properties, but also unbalanced uptake of nutrients.

4.3.3 Minimizing the Effect of Salinity

Most plants are more sensitive to salinity during the germination and emergence stage than in later stages of growth. Some crop species which are very salt tolerant during later stages of growth may be quite sensitive to salinity during germination, like sugarbeet.

Under field conditions, it is possible by modification of planting practices to minimize the tendency of salt to accumulate around the seeds and to improve the stand of crops that are sensitive to salt during germination. Planting on the side of the ridge, but well below the water line in the furrows, is one method to adopt. In Kuwait, since 1953 they have been producing vegetables rather successfully using brackish water with a salt content of 2 500 ppm but on deep, good permeable sandy soils. However, their practice is to produce the seedlings of vegetables, such as tomatoes, cauliflowers, cabbages, lettuce, beetroot, cucumbers, eggplants and pepper in pots made of organic material (jiffy pots) and to use sweet water (salt content less than 1 000 ppm). After 3 to 4 weeks and at 10 to 15 cm high, these seedlings are planted with the pots in the field. After that, they are irrigated with the brackish water (content mentioned above) until the crop is harvested.

4.3.4 Tolerance of Crops to Salinity

The U.S. Salinity Laboratory at Riverside, California, classified crops in three categories according to their tolerance to salinity: high, medium and low.

Comprehensive research work was carried out in Tunisia on irrigation with saline water (1962-1969). Various crops were grown from sowing to harvesting, utilizing four different water qualities (from 200 ppm to 4 000 ppm). Owing to the similarity of soil and climatic conditions between Tunisia and other north African countries, it is important to present the general conclusions of this work, which are that:

i. An agronomist can utilize the saline water available for irrigation in Tunisia, but must take greater precautions and accept lower yields than in normal cases. Higher salinity of the irrigation water results in a decrease in the yield. Salinity as it occurs in the irrigated areas of Tunisia is a surmountable barrier, but one cannot totally eliminate its unfavourable effect upon the vegetation. Compared to normal conditions, plants are more sensitive to suffocation, even temporarily, more frail during their critical periods and more exposed to lack of moisture supply during extreme weather conditions. Good preparation of the soil makes emergence less hazardous; but it should be realized that this is always a difficult stage. The salinity of the irrigation water affects mainly the summer crops, whereas the winter crops are strongly influenced by rainfall and the salinity of the soil in autumn.

ii. The effect of the quality of irrigation water on several agricultural crops under Tunisian conditions are now known; they can be summarized as follows:

   a. The quality of irrigation water has little influence on the yield of alfalfa as long as salinity stays below 4 000 ppm.

b. Fodder sorghum seems moderately salt tolerant. The decrease in yield as well as in the productivity per cubic metre of water was approximately 40% for an increase from 200 to 3 500 ppm in salinity.

c. In the case of maize, a yield decrease of 40 to 50% occurred when water salinity increased from 200 to 3 500 ppm.

d. With 300 mm of winter rainfall, the water salinity (3 000 ppm) had very little effect on ryegrass.

e. Berseem was found to be very sensitive to the quality of irrigation water. With the climate of Tunisia (450 mm of rainfall), the yield decrease becomes serious as soon as the water salinity exceeds 3 000 ppm. Given a rainfall of 250 to 300 mm, the salinity should not exceed 2 500 ppm, especially if it is necessary to irrigate after sowing.

f. With regard to barley, the quality of the irrigation water does not seem to have a pronounced effect on the yield as long as the salinity does not exceed 4 000 ppm.

g. Summer tomatoes appear to be sensitive to the quality of irrigation water. The use of saline water causes blossom end rot which diminishes the quantity of marketable fruit. The yield decrease was from 50 to 70% with an increase in salinity from 200 to 3 400 ppm. The wastage from blossom end rot decreased with temperature.

h. Broad beans seemed moderately salt tolerant. The yield decrease was 30 to 40% for a rise in irrigation water salinity from 200 to 3 200 ppm.

i. Early asparagus seemed to be very salt tolerant. The yield obtained (4 to 8 tons/ha) where the salinity of the irrigation water was 6 500 ppm was about the same as in areas irrigated with fresh water.

4.4 CONTROL OF SALINITY AND WATERLOGGING

4.4.1 Leaching Requirements

The amount of percolation required (or leaching requirement) which is governed by the salinity of irrigation water, evapotranspiration, local rainfall and the permissible level of salts in the soil solution, which is determined by the kinds of crops grown and the soil type, may be calculated by the following formula:

$$P = (ET - R) \frac{Ci}{fCsm - Ci}$$

where: P = Percolation or leaching requirement

ET = Evapotranspiration

R = Rainfall

Ci = Salinity of irrigation water

Csm = Salinity of soil solution at field capacity

f = Leaching efficiency. It denotes the ratio between the salt concentration of the water draining from a soil layer and the salt concentration of the soil solution in that layer. This coefficient varies with soil texture and is taken to be about 0.4 for heavy soils, 0.6 for medium textured and 0.8 for sandy soils.

The data in Table 1 show the leaching requirement for different levels of soil salinity. The salinity of irrigation water is assumed to be 0.5 mmhos/cm and that of drainage water (Csm) twice that of the soil saturation extract (Cex), i.e. Csm = 2 Cex.

Table 1

LEACHING REQUIREMENT (P)
AS % OF THE NET IRRIGATION REQUIREMENT (ET - R)

Leaching Efficiency (f)	Salinity (mmhos/cm) of the Soil Saturation Extract (Cex)			
	2	4	6	8
0.4 (for heavy clay soils)	45	19	12	8.4
0.6 (for medium loamy soils)	26	12	7	5.4
0.8 (for light sandy soils)	19	8	5.5	4.0

From Table 1 it can be noted that the leaching requirement increased sharply when the equilibrium of the soil salt content was set lower. It can also be observed from the table that the leaching requirement varies with the kind of soils and that it is low in the case of sandy soils as compared to heavier soils.

The effect of the quality of irrigation water on the leaching requirement is shown in Table 2, assuming a sandy soil with a leaching efficiency (f) of 0.80 and that the salinity of the drainage water is twice that of the soil saturation extract.

From Table 2 it will be seen that the leaching requirement increases rapidly with an increase in the salt content of the irrigation water. Theoretically speaking, certain levels of salinity could be obtained in the soil to suit different crops using relatively high saline irrigation water, provided that the water could flow through the soil without obstruction and that the natural drainage conditions and/or artificial drainage systems were capable of draining away the necessary leaching requirements. It is obvious that the level of salinity which could be maintained in the soil would always be higher than the salinity level in the irrigation water if no leaching was provided by rainfall.

Table 2 ANNUAL LEACHING REQUIREMENT (P) AS % OF THE NET IRRIGATION REQUIREMENT (ET - R)

Salinity of Irrigation Water mmhos/cm	Salinity (mmhos/cm) of the Soil Saturation Extract (Cex)					
	2	4	6	8	10	12
0.3	19	8	6	4	3	2
1.0	45	19	10	9	7	6
2.0	167	45	26	19	14	12
3.0	1 500	88	46	31	23	19
4.0	N.A. 1/	167	71	45	33	26
5.0	N.A.	357	109	64	45	29
7.0	N.A.	N.A.	270	120	78	58
10.0	N.A.	N.A.	N.A.	360	167	109

1/ N.A. = Not attainable.

4.4.2 Drainage Requirements

According to general experience, about 30-60% of the water applied to the field is usually lost, resulting in an irrigation efficiency varying from 70-40%. Hence field drainage must be able to discharge these losses if waterlogging is to be avoided. If the leaching requirement for salinity control proves to be less than the normal irrigation losses, then the latter and not the former should be used in calculating the required field drainage system. Seepage from outside, if it exists, should be added to this.

In cases where irrigation water of high salinity is used, the leaching requirement for salt balance will be much higher than the normal field irrigation losses. In such circumstances, drainage facilities should be able to handle the leaching requirement plus seepage from outside, if any. The Qatif Oasis Project in north-east Saudi Arabia could be mentioned as an example of this. The average salinity of irrigation water is about 3.5 mmhos/cm and with the assumption of a salt balance at a level of salinity in the drainage water at 5.5 mmhos/cm, the leaching requirement will amount to about 60% of the net irrigation requirement, i.e. the consumptive use of the crops. The estimated consumptive use during the peak demand period is about 8.0 mm/day. This means a leaching requirement of about 5.0 mm/day and a total gross irrigation requirement of 13.0 mm/day. Seepage from outside the area has to be added to the leaching requirement to obtain the required drainage runoff. The amount of seepage from outside the farm was found to vary from 7.0 to 0 mm/day, depending upon the distance from the farm boundary. If 4 mm/day is taken as an average figure for seepage, the drainage factor will amount to about 9 mm/day. This is equivalent to about 70% of the total gross irrigation requirement.

4.5 WATER MANAGEMENT TO ACHIEVE SALT BALANCE

4.5.1 Leaching Practices

Under saline conditions or in areas where a potential danger exists from salinization, as is the case in most of the irrigated projects of the Near East, criteria must be selected to determine the level to which salinity may be allowed to increase during the growing period. Especially where water is scarce or expensive, leaching practices should be designed to maximise crop production per unit volume of water applied for irrigation and leaching.

It has been shown that, except where the salt is concentrated at the bottom of the rooting zone, the greatest amount of water is conserved when the practice of periodic leaching is followed rather than maintaining a salt balance by a regular application of extra water. Moreover, better results are obtained by leaching the salts with alternate ponding and drainage than by continuous ponding, also considerably less water is needed. In the case of low infiltration rates, it is advisable wherever possible to postpone leaching until after cropping.

4.5.2 Irrigation Methods

In general, irrigation methods and practices which provide uniformity of application and downward movement of water through soils favour salinity control. Consequently, furrow irrigation must be practised with considerable care, particularly during the germination stage.

Fewer problems are encountered with basin and border irrigation. It has proved beneficial to rotate crops irrigated by furrows with crops irrigated by the border method. Land levelling and especially land maintenance are essential to both furrow and border irrigation. The basin method provides better control of the depths of water applied and greater uniformity in application than the border and furrow methods.

Sprinkler irrigation ensures a close control of the depth of water applied and, when properly used, results in uniform distribution. However, sprinkler irrigation with saline water can cause appreciable damage due to burning of the foliage and defoliation. In the Netherlands, the upper limit of the salt content of water used for sprinkler irrigation ranges from 1 000 to 1 500 ppm. Foliar absorption of salts can severely restrict the use of even good quality water for sprinkler irrigation of some fruit crops (citrus). Night sprinkling has proved advantageous in a number of cases; also, the moving of laterals with the main wind direction may result in better washing of the salts from the leaves. Work in Tunisia has shown that crops irrigated by sprinkling had higher sodium and calcium contents than those irrigated by surface irrigation. This greater sodium and calcium absorption by the leaves, as well as by the roots, together with a decreasing absorption of the potassium may lead to too early maturity, stunted growth and consequently, to a decline in yield.

Drip irrigation has provided good results even when using highly saline water owing to the low moisture tension level in the soil maintained throughout the growing season. Due to the continuous supply of water, the high salt concentration, which would have built up with conventional irrigation by the time the irrigation date approached, is avoided. However, with this method of irrigation, salts are concentrated in the soil surface and at the edges of the wetted area, but plant roots appear to be concentrated in the wetted area where the salt content is minimal. However, in the case of annual crops, after harvest, leaching is required to lower the salt content in the soil before sowing the new crop.

4.5.3 Water Supply

Inadequate water supply is causing soil salinity problems in many projects, for instance in West Pakistan and in the Euphrates Valley in Syria and Iraq, where farmers try to irrigate too much land in relation to the water supply. If the irrigation water is already of poor quality, soil salinization will develop very quickly. The use of tubewells in Pakistan, where good to medium quality underground water was mixed with the surface irrigation water, improved drainage conditions and there was more water available for leaching purposes.

Reducing the irrigated area and changing the cropping pattern by selecting crops which are drought tolerant, have a short growing period, grow at a certain time of the year when the evapotranspiration potential is low, or are more salt tolerant, would result in a lower irrigation demand.

On the other hand, over supply of irrigation water, which may occur in surface irrigation of sandy soils, is indirectly responsible for waterlogging problems and soil salinization. The lining of canals or the replacement of open channels by pipes significantly reduces seepage losses and consequently salinity and waterlogging.

4.6 EXAMPLES FROM THE REGION OF THE USE OF VARIOUS QUALITY WATERS TO IRRIGATE SANDY SOILS

4.6.1 Bahrain

The soils of Bahrain are relatively shallow sandy soils overlying bedrocks, which are affected by salinity and waterlogging. The water available for irrigation is from groundwater with a salt content of 2 000 ppm or more (3 mmhos/cm or more). Waterlogging is caused by excessive losses of irrigation water on these very permeable sandy soils and also by the drilling of artesian wells with no proper casing. Natural drainage conditions are also poor due to flat topography and low elevation of ground surface in relation to the surrounding sea level. The depth of the water-table varies from 30 to 150 cm below the ground surface.

A very limited range of crops is grown on a commercial scale because of the high salinity both in irrigation water and soils and because of waterlogging. Beside date palms, which occupy more than 65% of the cultivated area, winter vegetables and alfalfa are the most important crops raised in the islands. The crops are usually grown in small basins and the practice is to irrigate once every 3 or 4 days in winter and once every 1 or 2 days in the summer.

4.6.2 Kuwait

Interesting work on the development of irrigated agriculture is taking place both in the north of the country (Al Abdali area) and in the south (Al Wafrah area) on local saline underground water. In Al Abdali the salt content of the irrigation water varies from 2 000 to 6 000 ppm. The soils are shallow and sandy overlying gypsiferous soils. Tomatoes, onions, garlic and water melons are grown. Shifting cultivation is being practised as the soils become saline after one or two seasons of cultivation. Irrigation is carried out twice daily during the hot season. Groundwater is 20 m deep.

At Al Wafra, the irrigation water is even worse than at Al Abdali as the salt content varies from 4 000 to 8 000 ppm, but the soils are deep, very permeable sandy ones. Groundwater is 10 to 20 m deep. Alfalfa, tomatoes, carrots and leafy vegetable crops like celery, mint and spinach, are grown. Shifting cultivation is not practised. As in Al Abdali, small basins are used and irrigation is carried out twice a day in summer and once daily in winter.

On deep sandy soils at Al Jahra, just north of Kuwait, a farm is using local groundwater of about 10 000 ppm and producing leafy vegetables such as spinach, celery, malvacea and alfalfa.

4.6.3 Libyan Arab Republic

Very highly saline underground water with a salt content as high as 15 000 ppm is being used in the Tagora area on the coastal plain about 20 km east of Tripoli. Date palms, pomegranates, alfalfa, tobacco and winter vegetables, mainly tomatoes, are grown on deep very permeable sandy soils. The water-table is about 20 m deep. The local rainfall is about 350 mm which helps greatly in leaching the salts. However, salinity in the irrigation water is increasing because of the change from hand dug wells and manual lifting to deep drilled wells with mechanical lifting devices. The salinity in the soils is also increasing and a gradual deterioration is taking place in gardens that were once prosperous.

In the Kufrah area, deep in the desert in the south-east of the country, a very ambitious sheep production scheme is being developed. At present, about 1 300 ha is under forage and grain production, but it is proposed to expand this area to 10 000 ha. The soils are deep sandy soils, irrigated by sprinkling. However, the irrigation water is a fossil water with a very low salt content (less than 100 ppm), which is creating nutrient problems as several elements have to be added beside the usual three major elements, i.e. nitrogen, phosphorus and potassium.

4.6.4 Saudi Arabia

In the Qatif area on the east coast, light sandy soils with a high salt and gypsum content (up to 40% gypsum) have been reclaimed through leaching and drainage. The available water for irrigation is underground water with a salt content of about 3.5 mmhos/cm (2 500 ppm). High yields of vegetables such as tomatoes, cabbages, cauliflowers and onions are produced. Wheat, alfalfa and sugarbeet are also grown. Fifty tons of chicken manure/ha are required to start plant growth.

In the Al Hassa Oasis a total gross area of about 20 000 ha (about 10 000 ha is now under cultivation) is provided with irrigation and drainage systems. Irrigation water of 2.5 mmhos/cm (1 750 ppm) is being used. Date palms, food crops and alfalfa are grown with success. Citrus orchards have also been established, but not too successfully. Owing to an impermeable marly layer at 1 to 2 m depth below the good permeable top soil of loamy sand and sandy loam, waterlogging is a serious problem. The existing drains at 150 m spacing are not sufficient to control the salinity and water balances in the soils. Once the required drainage facilities are provided, successful agriculture could be maintained with the use of relatively saline irrigation water, as mentioned above.

4.6.5 United Arab Emirates

Very saline groundwater up to 17.0 mmhos/cm (more than 10 000 ppm) has been used to establish 700 ha of forest plantations on deep sandy soils with an undulating topography in Abu Dhabi State. Drip irrigation, the only practical method under the local conditions, is being used. After 3 years of establishment the trees of different species, such as tamarix, *Prosopis sp.*, casuarina, eucalyptus, acacia and *Zizyphus spina christi*, are doing rather well. However, some mortality has been observed recently at locations with groundwater of excessive salinity.

On the east coast in the Al Saaf area, groundwater with a salinity of 3 000 to 5 000 ppm (4.5 to 7.0 mmhos/cm) is being used for the production of winter vegetables, mainly tomatoes, on light to medium textured soils. However, the land has to be abandoned after 3 to 4 seasons of cultivation because of the accumulation of salts in the soil profile. No waterlogging problem exists in the area. Sometimes, after years of heavy rainfall, abandoned lands may be put under cultivation again due to the leaching of salts from the upper part of the soil profile.

4.6.6 Yemen Arab Republic

At Jumeisha Farm in Tihama area the problem is not salinity, but high temperature and high nitrogen content of the groundwater which is available for irrigation. The temperature of the irrigation water is about 30°C and the nitrogen content is 120 to 300 ppm of nitrate. Such a high nitrogen content is good for the production of fodder crops and leafy vegetables but it induces excessive vegetative growth in grains, fibre crops and oil seeds. The extent to which this high temperature of the irrigation water affects the crop yields needs to be investigated.

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