3 2027

Distr.: LIMITED

ECA/TNG/MULPOC/ICE/XIII/10
December 1996

Original : ENGLISH

UNITED NATIONS

ECONOMIC COMMISSION FOR AFRICA

REGIONAL OFFICE FOR NORTH AFRICA
OF THE ECONOMIC COMMISSION FOR AFRICA
(MULPOC)

Thirteenth Meeting of the Intergovernmental
Committee of Experts

Tangier, Morocco,
01 - 04 April 1997

PRE-FEASIBILITY STUDY ON EXTENSION OF SMALL IRRIGATION SCHEMES IN THE NORTH AFRICAN SUB-REGION

TABLE OF CONTENTS

Page No.

PRE-FEASIBILITY STUDY ON EXTENSION OF SMALL-SCALE IRRIGATION SCHEMES IN THE NORTH AFRICA SUB-REGION

I. BACKGROUND, OBJECTIVES AND METHODS

Background

1. Historically, water management has not been easy in the sub-region. Three climate inter-linked factors have had a direct influence on it. The first is the aridity that affects all countries of the sub-region. It is impressing to think that about ninety percent of the area of the Maghrebine countries receive less than 100 mm rainfall per year that is poorly distributed [1]. The second is the huge evaporation from open water reservoirs. For example, annual losses due to canal evaporation reach 2 cubic km in Egypt. Another factor is drought. All countries have since centuries been affected by recurrent and heavy droughts. This has negatively affected the water stocks capacity and lessened the agricultural output. All these factors have led to desertification and risks of land degradation.

2. At the present, the sub-region faces one important dilemma. On the one hand, there is growing demand for irrigated land and therefore for water supply. On the other, this resource is scarce. In order to solve the dilemma countries of the sub-region have been striving to optimize water utilization basically through the adoption of innovative water saving systems. But, despite these efforts there is still a long way to run to achieve such a goal. Extension of the scientific and technological irrigation techniques can contribute to disseminate the knowledge on irrigation efficiency and therefore to popularize their utilization.

3. By far, conventional irrigated agriculture offers the best opportunity for water saving. Water gains can be used for other purposes, including irrigation of new areas. The Moroccan case is quite illustrative. In that country, irrigation that presently accounts for 85% of total water consumption (0.9 million ha), is estimated to be 77 % by the year 2020 [2]. Sudan, in which large irrigation schemes still prevail, also has good opportunities for improving water efficiency. For example, simple water works such as water canals lining and cleaning, and replacement of open water distribution canals with close conduits could improve water savings and therefore agricultural returns in that country. In the western North African countries, water saving potentials appear to be equally promising because of the availability of technological, institutional and manpower capacities.

---

1 UN ECA Green Belts Rehabilitation Report, Addis Ababa, 1993, pag. 2.

2 The World Bank, Kingdom of Morocco, Water Sector Review, June 1995, page iii.

4. As conventional irrigation became neither cheap nor efficient in most countries, Governments and farmers started some decades ago by adopting new and more efficient methods of irrigation. Sprinkler was one of them. Later, by the end of the 60's, a real change occurred with the irruption of micro-irrigation technologies. For example in Morocco there were only 5 ha of greenhouse micro-irrigated in 1974. The figure is today considerably higher. In Egypt the expansion of micro-irrigated areas has also been important. Thus, in 1995, they covered about 15,600 ha, having had a growth of 14% during 1985-95. In Tunisia the areas under micro-irrigation schemes represent 3% of the total irrigated area, whereas that of sprinkler is 20%. In Libya sprinkler irrigation boomed in the 70's. The other countries of the sub-region witnessed similar progress. This means that farmers have clearly opted in the sub-region for the utilization of efficient irrigation methods that in addition yield significant economic returns.

5. Today, governments and farmers in the sub-region have at least two important irrigation challenges. One is to maximize the potential that the small scale irrigation technologies, mainly sprinkler and drip ones offer. The other is the opening up of markets and opportunities to the agricultural foods. But, how to achieve such objectives? First of all, by ensuring the flow of essential information and resources from the public and research authorities to farmers, to enable them to update their technical capabilities. Secondly by improving marketing and commercialization. The establishment of a market strategic framework is also considered essential. Without a commercialization strategy framework , both the long and short-term benefits from intensive irrigation might be at stake. More important, by co-ordinating both strategies the sector could be ideally managed both in space and time.

Objectives of the study

6. In order to cast some light on technical and policy aspects of small irrigation schemes in the sub-region , the main objectives of the study are:

- To analyze the information on status of sub-regional irrigation;
- To focus on the importance and opportunities of sprinkler and micro-irrigation systems;
- To identify solutions for minimizing disadvantages;
- To highlight and analyze critical environmental problems linked to the use of chemicals (chemigation) and of fertilizers (fertigation) for sprinkler and micro-irrigation technologies; and
- To suggest measures for expanding drip/sprinkler irrigation in the sub-region.

Methods and definitions

7. The method followed in preparing this document consists first in the analysis of the global situation of irrigation in the sub-region, but focusing on such analysis in three groups of countries namely , the Eastern, Central and Western ones. In analyzing sprinkler and micro-irrigation systems, emphasis has been given to the study of their advantages and limitations, state of development and research needed. The environmental status of chemigation and fertigation is reviewed in chapter four. Chapter five suggests three modalities of action that may invigorate the expansion of small scale irrigation technologies. Finally, the paper, to facilitate its reading and understanding, incorporates addendum A, which analyses some of the salient technical irrigation problems facing the countries of the sub-region. With the purpose of improving its clarity a set of annexes are also included.

8. This document has been prepared with: (i) the information available in the UN ECA (MULPOC) library; (ii) documents received from the Land and Water Development Division, GAL, FAO, Rome; (iii) data from international statistics and specialized books ; (iv) answers only from Morocco and Tunisia to a questionnaire prepared by the MULPOC; (v) technological support from TRAGSATEC , a Spanish Governmental firm specialized on irrigation and agricultural development and (vi) a field visit carried out by the CENTER , a permanent Irrigation Training and Research institution located in Madrid (Spain). It also incorporates relevant comments from the Agriculture Division of ECA(Addis Ababa).

9. The following definitions and equivalences have been used throughout this document:

Irrigated land:	Areas purposely provided with water, including land flooded by river water for crop production or pasture improvement, whether irrigated several times or only once each year.
Micro-irrigation:	Drip/trickle irrigation techniques.
Small-scale :	(i) Micro-irrigation within and outside of greenhouses, whatever the type of construction, systems of irrigation adopted and size of nurseries and (ii) those irrigated by aspersion for the production of fruits , cereals, fodder and cash crops in areas of about 5 ha. (See Addendum).
Sprinkler irrigation:	Aspersion , either with stationary or mobile sprinklers.
Surface irrigation:	Furrow, border, and flooded irrigation.
Spate irrigation:	Land with no irrigation control.

II. AREA UNDER IRRIGATION AND ITS POTENTIAL

Global analysis

10. In the sub-region the area in which there is some control on irrigation is estimated at 7.5 million ha. More important yet is its sub-regional irrigation potential, that including part of the already irrigated area, is estimated at about 13 million ha. The highest potential in physical terms appears to be in the Sudan and in Egypt. In general there is a direct correlation between the area under irrigation and water availability in each zone. This is particularly true for the countries crossed by the Nile(Egypt and Sudan) in which surface water is very abundant. In Libya and Tunisia a combination of surface and underground water is utilized for irrigation. Meanwhile, the Western countries with an estimated irrigation area of 2.4 million ha occupy an intermediate position.

11. The following table shows the actual and potential irrigation area in the sub-region. Nevertheless, for the correct interpretation of data the following clarifications are necessary. The first, is that the "present area" covers the area in which some type of irrigation control already exists. With regards its "potential " it includes land that is already under irrigation.

TABLE I	Present and Potential Irrigation Area in the Sub-region (000 ha)			
Country	Present Area	Potential	Increment %	Present/potential area %
Algeria (1991)	445	730	64	61
Egypt (1993)	3,246	4,434	36	73
Libya (1990)	470	750	60	63
Morocco(1989)	1,093	1,653	51	66
Sudan (1995)	1,900	4,842	155	39
Tunisia (1991)	355	563	59	63

<u>Source</u>: Irrigation in Africa in Figures, Water Reports 7, FAO, Rome 1995 and MULPOC calculations.

Eastern countries (Egypt and Sudan)

12. Both, the actual and the potential areas for irrigation are fairly extended in this zone and by large, Egypt and the Sudan are the most privileged. Together, they share about 66% (about 5.1 million ha) of the total irrigated area of the sub-region and 36% of all Africa's irrigated land. Another feature is their strong dependency on external surface water. The Nile constitute their main source of water supply. After the construction of the High Dam lake, and based on the average Nile's water flow during 1900-1959, presently it supplies with 18 cubic km per year to Sudan and with 55.5 cubic km to Egypt.

13. According to available data, in Egypt surface irrigation covers 87%, sprinkler 9.6% and only 3.2% is under micro-irrigation. An index of water's valuating policy in the country is the banning of surface irrigation in the newly reclaimed areas. Egypt intends to reclaim 1.2 million ha by the year 2000. If only sprinkler irrigation were utilized (600 m^3 per ha and six doses each year), it is estimated that extra 4.3 cubic km of water(or 9.5 % of the current volume of water consumed by the agriculture) would likely be necessary for their irrigation. On the other hand as water pumping will be necessary to reach the new areas, the marginal costs of water transportation per cubic metre will be higher than through the open canals. The comparative advantage of drip/trickle irrigation techniques on water consumption can clearly contribute to lessen the transportation costs and therefore to make profitable the irrigated agriculture in the arid zones.

14. A limiting factor for the future agricultural development is their large external water supply dependence. The Blue and White Nile are the backbone of irrigation in Egypt and Sudan respectively. The total water supply, including groundwater, amounts to 271 cubic km. per year. Of this amount, about 30% goes to agriculture. The total amount of global renewable water, in both countries , is about 82 % of the annual global water resources of the sub-region. As both countries are extremely sensitive to the effects of outside drought, mainly those originated in Ethiopia and Uganda, preparedness for water savings in critical times must constitute a basic policy element. In this context improving Nile's upstream watershed management can reduce the risks of water supply to the irrigated lowlands in both countries.

15. The irrigation potential of the two countries is still high. It is estimated at 9.2 million ha for the two countries. Assuming that in the future 4.1 million ha of new land would have to be irrigated with sprinkler systems , and using 60 mm per ha and watering (six times), the extra volume of water required would be 14.8 cubic km. The figure would represent 24.5 % of the total water used for agriculture in both countries in 1993. As the figure is impressive and in order to reduce future water supply risks, countries should work together to plan adequately the use of water.

Central countries (Libya and Tunisia)

16. Both, the irrigated area and the origin of water, differ substantially from those of the previous region. Water is less abundant . In these countries, there is full or partial irrigation control only in about 0.8 million ha, or almost 11% of all North Africa countries , that is 7.5 million ha. In Libya, where underground water is frequently used, the annual consumption by the agricultural sector is estimated at 4 million cubic km. It means 87% of the total country's water supply. The abuse of underground water extraction is leading the country to its exhaustion and also to its replacement by salted water of the previous potable stocks. This constitutes now a problem which affects many aquifers in the country. This is rooted on their reduced recharge capacity, estimated at only 1 million cubic km per year. Hence, the strong dependency on de-salination and deeper water utilization. A policy oriented towards their re-charge and to make more rational the use of water could avoid long term water shortages and may lessen environmental problems.

17. Despite the fact that surface irrigation is predominant in Tunisia, the specific water consumption is almost 11% lower than in Libya (7682 cubic metres/ha and year). Perhaps such a difference may be attributed to the nature of the Libyan soils, which are predominantly sandy. Like in Libya, almost 87% of the total water withdrawn goes to the agriculture in Tunisia. Another feature of the country is that about 50% of the irrigated land uses underground water. Private farmers obtain water from wells with less than 50 m depth. Currently over-exploiting is most severe in the Bizerte, Cap Bon, Kairouan and Sidi Bouzid provinces. A positive step of the government was the enforcement of a water saving policy, in 1995. One of its objectives will the reduction of surface irrigation as much as possible. It is estimated that its maximum ceiling may be 50%(today 77%). Other objectives of the Tunisian water policy are: the recharge of aquifers and the integrated surface water management.

18. In Tunisia, the current irrigation modalities are: surface irrigation 77%, sprinkler 20% and micro-irrigation 3%. In Libya, it seems that micro-irrigation is not yet important. On the contrary, sprinkler irrigation techniques are quite well spread out and known. In principle, it seems that Libya could save important volume of irrigation water by adopting the most appropriated drip/trickle techniques. The performance of these techniques in sandy soils is also high.

19. Globally, the irrigation potential in the two countries is not excessive. It might be only a percentage of 1.2 million ha. As usual, the main limiting factor will be water availability and its cost. Among the factors that may increase costs are: the distance to water sources, topography and type of soils , water quality and the type of constructions required for its transportation, storage, treatment and its distribution.

Western countries (Algeria and Morocco)

20. Together, the two countries have presently about 1.3 million ha of irrigated land, being twice the area irrigated in Morocco than in Algeria. Thus, in Morocco the large irrigation schemes occupy 0.5 million ha and the small ones 0.4 million ha. They provide employment to 1.6 million people. Both the area under irrigation in the two countries represents about 20% of the total irrigated land in the region. This figure is very similar to the percentage of country/subregion population, 22.9%. Both countries benefit from water accumulated in the Atlas. It constitutes the most important source of renewable water for them. Out of the 44,3 cubic km generated within the two countries, 12.9 cubic km are utilized for the agricultural sector. Surface irrigation is practiced in both countries, being 90% in Morocco. In the country sprinkler represents 9.4% and micro-irrigation about 0.6%.

21. Despite the important stock of underground water in Algeria, estimated at 3.5 billion m^3 expected by the year 2000 [3], it is believed that the expansion of irrigated areas may be more problematic in this country than in Morocco. In the latter, it is estimated that the full potential irrigation can be 1.6 million ha. Presently 1.26 million ha are irrigated. In Algeria, considering the present volume of water, 8.1 cubic km/year, it is estimated that only 0.7 million ha of new land might be irrigated in the future. Presently, 0.6 million ha of irrigated land have some kind of water control.

---

[3] United Nations, Ground Water in North and West Africa; Natural Resources/Water Series No. 18, New York 1988.

III. PRESENT SITUATION AND POTENTIAL OF SPRINKLER AND MICRO-IRRIGATION IN THE SUB-REGION

1. Sprinkler irrigation system

Advantages and limitations

22. The main advantage of sprinkler irrigation consists in its low water requirements, compared with surface irrigation. Water efficiency, in terms of the percentage of water consumed and supplied to the plant is about 50-75%. In surface irrigation this is much lower, 12-34%. Roughly, sprinkler irrigation may consume about half the volume of water than traditional surface irrigation. Other advantages of the system, of interest for the sub-region are:

- High water application efficiency and no need of soil levelling,
- Adaptability to any type of soils, and in particular to those with high permeability,
- Permits mechanization of some agricultural works,
- Reduces losses of fertilizers by percolation,
- Facilitates chemigation (chemigation is the application of chemicals into the irrigation water flows),
- Technology easy to assimilate and cheap to maintain.

23. Its main limitation is equipment costs. These are particularly higher if the network is stationary and considerably less if mobile or semi-mobile. The cost of irrigation installation varies considerably from one country to another. For example, in Algeria the average cost for sprinkler irrigation development ,in large schemes, is about $ US 15000 per ha [4]. In Egypt, the costs are of US $ 3200 and US $ 1300 per ha for stationary and mobile equipment respectively. In Tunisia, the average of communal intensive irrigation costs fluctuate between US $ 6,000 and 7,000 per ha. The costs for the medium scale sprinkler irrigation schemes are estimated higher. In Spain, the costs of equipment for full medium scheme sprinkler irrigation are estimated at US $ 4000. Governments must understand that a policy oriented to reduce tariffs and duties of sprinkler irrigation equipment imports such as tubes for primary, secondary and third water distribution, water pumps, sprinklers, and other material could be an important stimulus to farmers to buy the new irrigation techniques.

24. Maintenance costs vary mainly with the size of the area. Some countries report to spend about 2% of their total irrigation equipment costs in maintenance. Energy costs, in form of electricity or petrol can be important, particularly if water has to be pumped, as in Egypt's newly reclaimed areas. In this exercise, data were not available to compare these costs.

---

[4] Irrigation in Africa in Figures, FAO Water Reports 7, pag. 50

State of development and research needed

25. Table number two shows that about 0.8 million ha are irrigated by sprinkler in the sub-region. But the figure may be quite higher. Some reports estimate that the area under sprinkler irrigation might be over one million ha. This technique is commonly used in the sub-region for grain, fodder and fruit production. Nevertheless, if the current food policy encouraging farmers to produce dairy products is observed, in the short run, an important expansion of irrigated cereals and fodder areas could be expected. Libya is one of the countries in which grain's policy oriented goes in this direction. The country seeks self-sufficiency in grains [5] by irrigating 180,000 ha in the Great Man Made River area (GMR), a project that in addition would reinforce Libya's its whole food security. In Morocco and Algeria, countries which largely depend on cereal imports , sprinkler irrigation could equally play an important role to increase food security and lessen grain's imports dependency.

26. In Egypt, 100% of cereals production is ensured by sprinkler irrigation. Wheat, rice , fodder, sugar cane and maize are other crops in which sprinkler irrigation is successfully applied, in the sub-region. In Morocco 21,000 ha (of medium size) of wheat are equipped with sprinkler systems, basically pivot ones. In Tunisia, sprinkler irrigation is practiced in about 50 % of the area cover by cereals, in the North. An index of its efficiency is measured by the wheat yields obtained during the 1995/96 harvest, 3, 800 kg/ha. Tunisia's more ambitious long therm goals for wheat sprinkler irrigated are 5,500 kg/ha. For their achievement two factors will be decisive: (i) improve water management within the irrigated plot and (ii) ameliorate the use of the production inputs, through selective extension.

27. The following table depicts sprinkler irrigated area in five countries of the sub-region.

TABLE II	Sprinkler Irrigation Area in the North Africa Sub-Region, (ha)				
Countries	1989	1990	1991	1992	1993
Algeria				40,000	
Egypt					117,000
Libya		470,000(e)			
Morocco	103,000				
Sudan	-	-	-	-	-
Tunisia*				38,000	

(e) Estimated * in Tunisia 57, 000 ha of cereals were sprinkler irrigated in 1996.
Source: FAO Country Profiles, 1996.

5 The Economist Intelligence Unit, Country Profile, 1994-1995, page 17

28. Although the selection of the sprinkler equipment may be a problem, specially for the small farmers, the energy cost may be one of most decisive factors in its selection. Obviously, in countries in which the cost of the kilowatt/hour is cheap the selection of appropriate irrigation sprinkler technology is an easy exercise. Whenever possible the utilization of a medium irrigation water pressure e.g. 1.5-2.5 kg/cm^2 seems the most convenient. A 60 m radius plot, or about one ha can be irrigated using revolving sprinklers [6] at 4.5 kg/cm^2. The utilization of other types of sprinklers like sectoral, perforated and swinging tubes may lessen the electricity/fuel bills. This is an aspect that must be spread throughout all potential irrigators. Therefore, Governments should strive to help farmers to familiarize with the most cost/efficient sprinkler techniques , showing them the pros and cons of these techniques. A practical manner to reach such as objective is through publishing simple, easy to read and free of cost pocket books and panflets.

29. Among the issues in which research is necessary are the following:

- Selection and distribution of sprinklers adapted to different type of crops and soils (irrigation efficiency increases when the drop's size is appropriated)
- Design, construction and maintenance of sprinkler equipment adapted to the local conditions and plot dimensions;
- Sprinkler irrigation and energy consumption;
- Sprinkler irrigation and chemigation and;
- Sprinkler irrigation, salinity and recycled water.

2. <u>Micro-irrigation system</u>

Advantages and limitations

30. This study focusses on drip/trickle irrigation techniques . Micro-jet and cerco-jet techniques are only mentioned in this study. The main advantage of drip/trickle techniques consists in its high water application efficiency. It fluctuates between 75 and 90%. In other words, the plant consumes almost the totality of water supplied. In addition, the soil can keep a critical minimum level of moisture , but sufficient to allow the plant to grow normally. Another advantage of the micro-irrigation techniques is the reduction of transportation and distribution water losses. When distribution is made by a pressured network they are almost nil. Moreover, water losses due to percolation and surface run-off practically do not existent.

31. Other advantages of drip/trickle irrigation techniques are:

---

6 Ministerio de Agricultura, Pesca y Alimentacion. Curso Elemental de Riego,Madrid 1990, pag.160

- Increase production, productivity and product's quality;

- Important savings from water, fertilizers and manpower bills;

- Possibility of utilization of water with high salts content (salt content >2 gr/l impedes plants' growth);

- No need for drainage network and plots levelling;

- Facilitate chemigation. (It is a good technique for distribution of nematicides, insecticides for soil insects , some herbicides and soil fumigants);

- Within greenhouses drip/trickle irrigation production is more uniform and higher than in open air due to the combined effects of efficient utilization of water and constant temperature.

32. There are two main limitations. The first relates to costs. In Egypt, for example the average cost for irrigation development is about US $ 1600/ha. In this country workers average wages in the agricultural sector was US $ 338.4 in 1992[7]. Acquiring such irrigation equipment and the associated know-how is therefore a major constraint on peasant farmers. In Morocco, the cost of new equipment may fluctuate between US $ 4651 and 11,600. Rehabilitation costs are comprised between US $ 1.163 and 5, 814. In Tunisia that costs move around US $ 3,000-5,000 per ha. Another drawback is the insufficiency of skilled manpower to keep functioning the entire irrigation network. Frequent manpower training gaps are in the areas of irrigation automatic control, greenhouse management ,water salinity monitoring and diseases and fungi prevention and control.

33. Other common constraints are: (i) in the arid zones , where rains are scarce and soil's salts washing is poor, the continued use of salted water can ruin agricultural soils and (ii) the obstruction of the finest capillary can cause damages to the water tubes and in the end to the plant. Another misconception is that drip irrigation always is a panacea. Certainly, farmers may adopt this system only if they are reasonably sure they can sell their added output for a profit. In other words prices have to be sufficiently attractive to induce farmers to initiate such activity. But, in general they are usually low and variable. For example in Morocco tomato prices fluctuate between 35-100 Dh per box[8]. This suggests that when a drip irrigated project is identified, in addition to preparing a good technical analysis, the evaluation of its economic return is essential.

---

7 National Bank of Egypt, Economic Bulletin, Vol XXXXVIII, No. 3, pages 72 and 79, 1995, Cairo.

8 Le Monde Agricole et la Pêche Maritime, Juillet/Aout 1996, Num 105, pag 4.

State of development and research needed

34. The area covered by drip/trickle irrigation, either within or outside greenhouses, is difficult to estimate because of the large number of farmers that participate in this activity. For example, in Egypt more than 95% of landowners hold less than 2 ha each[9]. Despite this difficulty it is estimated that the total drip irrigated area in the sub-region cover some 114,000 ha, with Egypt at the top, with 83,000 ha. In Algeria, Libya and Sudan these techniques are less utilized, although neither the climate nor the soils are usually limiting factors for their expansion. In the remaining countries ,namely Egypt, Morocco and Tunisia, drip irrigation has known a quick expansion, specially during the last two decades. The main reason behind such a success has been its good economic returns. In addition, it has helped create employment and therefore stabilize rural migration in many areas of the subregion. In Tunisia, one of the regions in which drip irrigation has really contributed to improve the living standards of farmers is the Sahel. Keeping in mind these advantages it would not be surprising to see a rapid expansion of this technique to areas in which the traditional agriculture has been hindered by ecological reasons, and basically for the poor conditions of soils and water salinity.

35. Drip/trickle irrigation outside greenhouses is used to irrigate mainly fruit trees, including banana, date palm and other industrial fruits. The main greenhouse vegetable crops are vegetables, and flowers. But, there has recently been a move to cultivate medicinal and aromatic plants, because of their high prices and the good quality of their extracts. But, to be able to compete with traditional markets suppliers, potential entrepreneurs need to be conversant not only with farming technicalities but mostly with market characteristics. Equally important for them is, to know about transportation and storage facilities, costs, and also about quality standards.

36. In Algeria, drip greenhouse irrigation started in 1969, in the North of the country. Today it is concentrated in two areas, namely Sakra and Sahara. In total the actual area under drip irrigation occupies about 1080 ha, of which 68% is cultivated in the Sakra region [10]. The favorable climatic conditions of that zone, with not frosts together with the high agricultural yields, encouraged farmers to adopt this type of irrigation. On the contrary, in the South, due to the ecological and other problems there has been a regression in the cultivated area.

37. Nevertheless, drip irrigation techniques could significantly improve food supply in Algeria, particularly in the most arid zones. These areas, where salinity is high and agricultural soils are usually poor, are where drip irrigation can most contribute the most to food security. Moreover, it can be of interest to potential entrepreneurs due to its high yields and to the possibility of having three or more harvests per year. Economic returns can be even higher through improving diversification. Currently, tomato is the main product cultivated in

---

[9] Egypt Country Profile, FAO, Rome, 1996.

[10] Report on Greenhouse Agriculture in Sahara, Algerie, Institut Technique pour le development d'Agricuelture en Desert du Sahara, AOAD, Rabat 17-19 June 1996, page 2.

greenhouses. Peppers, either bitter or sweet varieties occupy a second position. A point of special importance to ensure productivity and product's quality in the South lies on the control of temperatures in the greenhouses. This calls for a highly specialized greenhouse design. conservation and management, particularly in areas such as refrigeration, heating, ventilation, quality, and of water distribution and control fields.

38. In Egypt ,out of the 83,000 ha which are under drip irrigation, the highest area in the sub-region, it is estimated that 15,600 ha are using greenhouse/tunnel irrigation techniques. The activity has been expanded very quickly, being today 98 [11] times higher than ten years ago. Nevertheless, the figure is low compared with other countries within the region. Actually, it only represents 2.6 m^2 per inhabitant, while in Morocco, a country that has less water, the figure is around 3.4 m^2 per person.

39. Productivity has also increased in Egypt. For example, pepper's often yielded 11 kg/m^2 while in Spain it does not exceeds 7.5 kg/m^2. But, diversification has not parallely grown. Thus, tomato and strawberry are the main vegetables cultivated under drip greenhouse irrigation. The country has few greenhouse areas to produce for example quince, banana, grapes and even flowers. A successful case of diversification was that of dehydrated onions. It makes possible a permanent utilization of such product. Dehydrated onions exports, valued at L.E (1 US $= 3.39 Egyptian pound end 1994) 40.4 million in 1994, show the benefits that diversification processing of a single product has for the country. On the other hand and as water is abundant in the Nile's river banks, and climate is adequate, investment opportunities for new products appear quite promising. Equally important may be the production of out-of-season vegetables for foreign markets and the utilization of quality labels.

40. In Morocco, drip irrigation started about 30 years ago in Agadir in 1974. Today such technique is practiced in about 7, 210 ha of greenhouses and in other 30,000 ha with no protection. In 1993/94 , the area exploited within greenhouse was: tomato 2540 ha; green pepper 200 ha; greens 1030 ha; banana 3100 ha and flowers 340 ha. The breakdown of total drip irrigation in Morocco is as follows: Wheat, 23.3 %: olive tree, 24.6% barley 10.9 %;vegetables 8.7 % and maiz 6.8%. In the country there are 1.500 small scale irrigation schemes. The zones of Souss /Massa and the Oualidia are by far the biggest areas covered by drip irrigation. But, despite the moderate water consumption with drip irrigation, the expansion of this system may be threatened in the future not only in terms of water availability but in terms of its quality. The 1995's draught evidenced the significance of the first factor. Salinity also is an important limiting factors for this agriculture in all arid zones of the country.

---

11 Greenhouse Agriculture in the Arab Countries, Importance and Perspectives. Arab Organization for Agriculture Development. AOAD. National Meeting of Arab countries, Rabat 17-19 June 1996.

41. Despite these bottlenecks, drip irrigation has to be seen as a practical tool to contribute to meet Morocco's long-term irrigation policy goals aiming at reducing dependency on rainfed agriculture. But, due to the increasing technical complexity inherent of micro-irrigation technologies their extension to farmers is vital. Generally, they have difficulties to reach the sources of extension. More and better services and means will have to be provided to them. Transportation and commercialization are also weak points. The recent step taken by the European Union, (EU), to helping farmers commercialize agricultural products should be analyzed by Governments and eventually be imitated. Short term objectives should bear mostly on quality improvement and to a lesser extent on diversification.

42. Likewise, in Tunisia drip irrigation area has progressed very fast during the last two decades. It rose from 11 ha in 1976 to 1,191 ha in 1995. The present average is 1.3 m^2 per inhabitant, a figure fairly low if compared with the above two countries. Nevertheless, the availability of soils, particularly in the South, in which protected drip irrigation only cover 14% of the country, may lead to the expansion of this activity. Presently, the area of drip irrigated greenhouses, which is mainly located in the Sahel, is 865 ha and 43,750 tons their annual output. The fact that only 3,070 greenhouses of the 18,925 actually being exploited are equipped with drip/trickle systems envisages good expectations for the activity. The of utilization of thermal water in the South e.g. in Kebili, Gabes, and Tozeur for greenhouse heating, 80 ha, is another comparative advantage of the country. Plans for expansion of the area up to 300 ha seems quite promising too.

43. Drip and trickle irrigation under plastic tunnels has also raised very fast in Tunisia, reaching today about 2,300 ha. The bulk of such exploitation is located in the coastal areas. Usually, farmers use tunnels of 1 m length by 0.5 m width covered by plastic of 100 micron thickness. The low cost of this structure and the other irrigation components of these mini greenhouses together with their high yield constitutes good incentives for the expansion of this irrigated agriculture. Apparently, they have more economic advantages than the traditional plastic and timber made greenhouse's structures.

44. A summary of inter-related research issues on drip irrigation and greenhouse management in the countries of the sub-region is:

Technical and managerial

(i) **Water salinity control.** It is recommended that drip/trickle irrigation should not be initiated if the total salts dissolved into water is higher than 1 g per liter. An easy way to determine the total salts in the water is through the following formula TS=Ec*k (TS=total salts in g/l; Ec=electrical conductivity at 25 grades centigrade and K=0.64).According to the type of crop drip irrigation, micro-jet and cerco jet must be selected.

(ii) **Greenhouse design, management automatization and of irrigation.** It is known that a correct greenhouse design and its correct location can improve energy savings and increase their lifetime. Their heating and refrigeration efficiency can be significantly increased if constructed in the wind prevailing direction. Likewise, their thermal performance can be improved by choosing the plastic's appropriate color, thickness and quality. It is estimated that the right location and dimensions, the maintenance costs may be reduced by about 30-50%. Excessive temperature needs to be controlled to avoid diseases in the plants. A practical way to ameliorate greenhouse ventilation and humidity control, is to reduce their size. Modules of about 180 m^2 (30 m*6 m), seem to be the most appropriated. Automatization of irrigation has not yet reached the desirable ceiling.

(iii) **Treatment of soils against nemathods.** Prior to the establishment of an irrigated greenhouse/tunnel area, it is recommended to carry out a soil analysis to determine whether there is infestation by nemathods and other parasites, or no. In many countries the detection of such problem usually occurs only after the greenhouse exploitation has started. One established, crops rotation can be an essential tool the successful control of the soil parasites. This practice is unequally observed in the sub-region. Solar U.V. rays can be used for soil sterilization, avoiding at as far as possible the utilization of chemicals.

(iv) **Plants diseases, pest and wed control.** It is known that intensive greenhouse cultivation favors the development of plant diseases and pests. For many farmers, their identification and control is not easy. Moreover, the proliferation of insecticides, herbicides, bactericides and so on add more complexity to farmers on how to use them. Generally, they do not have sufficient knowledge on their full advantages and inconvenients, including their handling, distribution and their optimal doses. Confronted with these problems farmers tend to utilize those products with which they are more familiar, losing opportunities to use other, that are more efficient and less harmful for the environment.

Environmental

(i) **Utilization, storage and destruction of insecticides, fungicides, fertilizers and other chemicals.** Excessive doses, poor observance of the storage and handling instructions provided by the manufacturers of chemicals may have a negative impact first on the workers and also on the soil and specially on its flora and micro-fauna. The environment can also be affected.

(ii) **Pollution of underground water and its re-utilization.** Excessive doses of fertilizers and chemicals in general increase underground water pollution. Before initiating any fertigation plan, it is necessary to determine at least the pH, electrical conductivity, the relation C/N (carbon/nitrogen) and a detailed analysis of soil. This makes it possible to better select the appropriate fertilizers and the optimum doses. Drip irrigation, if the frequency and quantity of water required, can reduce salinity, and therefore foster the re-utilization of subterranean one.

(iii) **Plastic recycling.** This is an unresolved problem in most countries of the region. Moreover, anti-ultraviolet, AUV, and infrared IR, greenhouse plastics are only slowly being introduced. Plastics burning has a tremendous environmental impact, and would have to be prohibited. If imported, and recycling is not possible in the country, the utilization of grinding and packing machinery to facilitate old plastic exports for recycling, is recommended.

(iv) **Waste water recycling.** This is an area no too much explored and that offers good opportunities for most of the countries of the sub-region. The waste waters originated in the small rural and urban nucleus, that basically contains organic products, can re-cycled and used for drip and sprinkler irrigation. The technology and its know how for its treatment is already available.

Economic and commercial

(i) **Improvement of the quality, appearance and calibre.** The three factors are decisive for successful vegetables commercialization. Quality starts by the selection of high-tech seeds, HTS. Color, size and shape are directly related to quality. For example by adding potassium (K), the red colour of tomato improves significantly. On the contrary, high temperatures cause its decoloration. Apart from seed quality, irrigation and nutrient supply have great influence on global quality. In the sub-region quality must be a short term goal.

(ii) **Diversification and new markets.** Diversification is fairly limited. New varieties would have to be developed and introduced into the local and external markets, for example the EU. All countries of the sub-region have comparative advantages on climate and price to meet the selective demand of the EU markets, particularly in winter and autumn. For example raspberry and other very tasty berries, flowers and small ornamental shrubs, are very coveted in Europe. The production of medicinal and aromatic plants under greenhouse also has a potential insufficiently exploited.

(iii) **Development of indigenous germ plasm.** The local germ plasm is insufficiently exploited. Globally, there is a high dependency on imported seeds. The research centres should work jointly with the associations of farmers and producers for the development of seed banks, and to ensure and improve the quality and price of the local species.

(iv) **Improvement of commercialization channels.** The fact that greenhouse production is often spread out does not facilitates commercialization of its products. Governments, should back the formation of co-operatives of farmers, aimed at improving the structures of storage, transportation and distribution of vegetal crops. Particular attention is required to ensure good refrigeration networks capacity from the producer to at least the wholesaler.

IV. FERTIGATION/CHEMIGATION AND ENVIRONMENT

Definitions, advantages and disadvantages

45. Fertigation is a technique through which the fertilizers dissolved into water are conveyed to crops. Although written reports on fertigation appeared in 1958, the technique was known and utilized earlier in the Near East countries. In the sub-region it started early in the 60s. Advances on irrigation systems and chemical injection equipment, have resulted in a significant expansion of such technique to most countries in the sub-region. Moreover, the great development and utilization of chemicals for agriculture came with "chemigation". Today, sprinkler and drip irrigation techniques permit to incorporate almost all kinds of agricultural chemicals e.g. fertilizers, herbicides, insecticides, and fungicides to soil.

46. Among the advantages of chemigation and fertigation the following are the most important:

(i) **Increase crops' yields and produce plants of better quality.** In addition they reduce soil compaction and lessens damage to crops, particularly compared with mechanical or manual fertilization;

(ii) **Reduce application costs.** Because chemicals are better utilized by plants and also because there are less losses due to percolation. (Some studies show that when chemigation is used two or three times per year, significant economical savings can be obtained);

(iii) **Elasticity in application timing.** It can be performed at any time and mechanically made. Therefore, there is not dependency on weather conditions, manpower and time for application and:

(iv) **Reduce health risks to worker .** Operators have no direct contact with chemicals during their distribution.

47. The main disadvantages by order of decreasing importance, of chemigation/fertigation

techniques in the subregion are:

(i) **High equipment costs.** In the developed countries both the costs of the injection system and the blackflow prevention systems may range between US $ 2, 000 and US $ 13,000[12]. Assuming an average customs tariff of 50% the full cost of that equipment in the sub-region might be between US$ 3,000 and US $ 19,500. In both cases the figures are high.

(ii) **Insufficient skilled manpower.** A good chemigator needs not only to have a good agricultural background, including a basic knowledge on agricultural chemistry, but basically on the principles that make the equipment working and safe. Calibration is another area of importance to make chemigation more effective.

(iii) **Possible pollution of underground water.** Depending on the type of irrigation and of soils the chemicals can, by infiltration, reach deeper water layers and pollute them. If fertilizer doses are high, and irrigation doses and their frequency are not adequate there are conditions to increase underground water pollution.

Present Situation in the Sub-region

48. In the sub-region fertigation started first. In Egypt it was used in the beginning to fertilize horticultural crops within greenhouses. Later, due to its many advantages, fertigation was used to grow irrigated vegetables crops such as melon, tomato and cucumber. Nowadays, not only fertigation but even chemigation, despite the management difficulties that they pose, are inching forward in the country. In Morocco, fertigation has also progressed very fast. It began in 1975 by using only nitrogen and today it is used in about 5,000 ha, about 50 % of the total greenhouse drip/trickle irrigated Morocco's area. The main difficulties encountered by the farmers in this country are connected with the correct utilization of equipment and chemicals. Like in Egypt, chemigation/fertigation extension is mostly provided by companies selling agricultural equipment and chemicals.

49. In Tunisia, the first experience with fertigation started in areas of citrus trees and with drip irrigation. In 1980, fertigation was practiced in only 25 ha. Today that area is over 4000 ha. Lessons from the past have permitted to apply fertigation not only to fruit trees but also to irrigated greenhouses . The use of geothermal water, from the South of the country, makes necessary a careful monitoring of its salts concentration, specially those of, Ca and Na.

50. Chemigation is also practiced in many countries of the sub-region. But, as it often

---

[12] Fertigation/Chemigation, Advantages in Irrigation, Fertigation and Chemigation; E. Dale Threadgill, AGL/MISC/189/91,FAO, Rome (Italy), 1991.

includes, it is difficult to make an evaluation of the areas in which it is practiced. Probably, its spreading follows some parallelism with the improvements on drip/trickle irrigation systems. But this a mere hypothesis. What are well known are the problems that farmers are facing on chemigation. The following are frequently mentioned:

- poor information on the state of art of chemigation/irrigation technologies and their costs;

- insufficient information on the effects of fertigation on salinity and on suitable fertilizers concentration for various types of crops requirements and their distribution during the crop cycle;

- high costs of soluble and liquid fertilizers and other chemicals;

- insufficient expertise on the whole system management, including the observance of security measures and;

- poor knowledge of chemicals toxiticy and of the precautions for their safe storage, handling and destruction.

Fertigation/chemigation and environment

51. One effect of excessive fertigation is soil salinity. The latter can be even higher if salts concentration in water is high. This applies equally both to sprinkler and drip irrigated lands. In the end, and depending on soil permeability and on the amount of water utilized, salts and other chemicals may migrate to deeper layers. There, underground water pollution may increase. When sprinkler irrigation is used and water extracted from wells, special care is needed to monitor salts concentration.

52. For environmental and economic reasons, the precise calculation of water/fertilizers doses is essential. In this context, the analysis of the soil C/N capacity and inter-actions and inhibitions among fertilizers, have to be known. If nitrogen is in excess in the soil there is a tendency to produce exuberant, but tender plants. Moreover it delays flowering and makes plants sensitive to diseases and pests. Phosphorus is necessary for the roots and flowers formation and growth as well as to ensure fruits ripening. Potassium contributes to the roots growth and to the production of good quality fruits. But, an excess of that element, apart from increasing salinity, may impede the plant to absorb the required quantity of calcium and magnesium.

53. The following are practical guidelines to minimize the environmental impact of fertilizers, specially on water.

(i) Start fertilizing after irrigation and make sure that irrigation continues once the fertilizer has been exhausted. It permits the washing of filters, tubes, injectors and in general of all equipment used for fertigation.

(ii) Do not mix directly N, P, and K fertilizers.

(iii) It is better to use lower than higher doses of fertilizers. Do not overpass 0.5 g of fertilizer per litre of water.

Indicatively, if the pH of the soil is alkaline (pH > 7.5) fertilizers with acid reaction as nitrogen in ammonium form are recommended. The clay soils need more phosphorus, and less nitrogen than the light and sandy ones.

54. Chemigation, can produce not only water but also air pollution. The very varied type of chemicals, and their potential damage to environment require a careful knowledge of their composition and utilization. Chemigation may provoke chemical's volatilization and increase local air pollution. Moreover, some chemicals can alter the composition of natural fauna and micro-fauna and also soil's texture. But, perhaps the effect of chemicals backlflow may be the main environmental problem of chemigation. It can affect not only the area in which the irrigation equipment is located but also the irrigation water supply network. On the other hand, plants and their tissues also can store chemicals. Some of them may remain long time not only in the soils but also in the tissues of plants. Operators, that do not observe safety regulations may be exposed to the risks of chemicals, particularly those working with sprinkler irrigation. Drip/trickle irrigation and chemigation operators are much less exposed to pollutants.

55. But, chemigation has its positive environmental side. The efficiency of the system results in a net reduction of chemicals consumption and therefore in less environmental contamination. A second advantage is linked to the minor leaching of chemicals from the root's area to the deeper layers. This is an important advantage because it permits the full utilization of the chemicals by the plants and obviously reduces the environmental damage.

V. CONCLUSIONS AND PROPOSALS FOR ACTION

Main conclusions

56. Based on the analysis of the information of the previous chapters, the following conclusions arise:

(i) All countries of the sub-region are aware of the advantages that sprinkler and drip irrigation have to improve water conservation and agricultural production. The comparative advantage that sprinkler irrigation has, in terms of water utilization and production, over surface irrigation, which is presently practiced over 6.6 million ha, 84% of the total irrigated area in the sub-region, must be the self-drive oriented engine for its progressive introduction. Moreover, sprinkler irrigation could be even more attractive when water's subsidies are removed. Despite all these advantages the rhythm of introduction of these technologies seems to be low.

(ii) Countries also recognize the important economic and social returns that could be obtained by modernizing some of the existing drip and sprinkler irrigated areas. But, small farmers often can not buy or replace equipment because they do not have sufficient resources and the required information on appropriate technology, its costs and maintenance. Lack or insufficient extension seems to be at the roots of the problem.

(iii) The size of small farms that prevail in some countries of the sub-region e.g. 2.0 in Egypt and 5 ha in Morocco has its positive side. When water is available the small private plots offer good opportunities for drip/tickle irrigation. On the contrary, the sprinkler system would be appropriate for areas that are at least two or three times higher than the average in Morocco, that is about 10-15 ha. (See Annexes III and IV).

(iv) With the exception of statal or parastatal irrigation schemes, in which investment has not posed special problems in the past, the initiative for the introduction of efficient irrigation techniques, basically drip and micro-irrigation ones, seems to be more a private activity, and better developed in those groups of farmers that have access to the technology, credit and markets facilities. This approach keeps some parallelism with the development of irrigated agriculture in the South East of Spain (Almeria), where the small farmers took the initiative in 1965 to develop a more intensive and high productive and irrigated agriculture. Today the area of irrigated protected agriculture in the country occupies about 300,000 ha of which 12,000 ha are found in Almeria.

(vi) The strong dependence on foreign technology constitutes an advantage and at the same time a bottleneck for farmers. The main advantage is that equipment, selected seeds, fertilizers, chemicals, plastics and their know how can be obtained when needed. Their high costs and in some way the reluctancy of countries to develop their own technologies are important inconvenients. On the other hand, as information on local and external markets, prices and storage facilities usually is not well known by farmers they have the tendency to produce a limited set of products. This neither induce diversification nor stimulates agrarian research.

(vii) Despite the technological support of foreign firms to farmers there are still many technological gaps in the sub-region. Among them are: (i) design, maintenance and management of small scale sprinkler irrigated zones; (ii) design, conservation and management of greenhouses; (iii) automatization of irrigation; (iv) use of saline and urban recycled water for micro-irrigation; (v) control and combat of diseases and pests and (vi) utilization of chemicals with minimum environmental impact.

(viii) There is unutilized and often overlapped research capacity in most of the countries on irrigation issues. A comparative advantage of the research centres seems to lie in the fields of diseases, pests, and fungi identification and control; efficient combat of soil's nemathods and salinity monitoring. On the contrary, important gaps are on proven and high quality seeds , new varieties and chemigation.

(ix) There is still room for developing extension on drip and sprinkler irrigation in all countries of the sub-region. Traditional farmers still have to convinced that shifting from traditional to more efficient methods of irrigation is a good investment opportunity. Current extension gaps are not only technological but economical and environmental ones. To be efficient, extension basically has to be practical and spacial oriented;

(x) It is belived that due to the increasing complexity of the new irrigation techniques the curricula and syllabus of some agricultural training institutions might not respond to the needs of the countries.

Proposals for further action

57. In order to tackle the problems identified in this study the three following domains : (i) technological; (ii) financial and (iii) training and extension in principle would be addressed in order to stimulate and disseminate both sprinkler and drip irrigation technologies at small scale in the sub-region.

(i) Technological

58. Narrow down the technological gap by incorporating the drip/sprinkler irrigation technologies and their know-how to the conditions of each country. Depending on the situation that prevails in each country or groups of countries, a three phases sub-regional programme might be initiated in order to: (i) identify the irrigation technological gaps on sprinkler and drip irrigation and to facilitate the access to the future investors to design and produce such technology; (ii) stimulate the progressive production of equipment adapted to the conditions of each country and (iii) formulate a sub-regional programme to spread the knowledge of such irrigation technologies and that of the new ones. The whole programme should focus on equipment and machinery standardization and specialization by differentiating three basic groups of products:

- drippers, sprinklers, pipelines of PE and PVC and films of plastic;
- water filters e.g. of sand, mesh and metallic ones, and fertigation tanks and;
- valves of pressure and flow, hygrometers and other instruments of precision.

Approaches:

- Use the information available in the countries and in the specialized Agricultural Research Centres and Universities of the sub-region and that from United Nations Organizations e.g. UNIDO, ECA, MULPOC and FAO to evaluate the irrigation technological gaps in each country and in the sub-region;

- Make an evaluation of the capabilities of the existing research and production centres in the sub-region to produce, at competitive prices, the equipment necessary to offset the gaps identified above. Countries specialization and standardization should be objectives to be strongly pursued; and

- Establish a sub-regional permanent information cell , with the collaboration of research centres and producers on equipment data bank and irrigation novelties in the sub-region. This permanent network would provide information about the new irrigation equipment its advantages and inconvenients, prices, maintenance and other information of interest to farmers.

(ii) Financial assistance

59. Provide financial assistance to small and young farmers, agricultural associations, and co-operatives at least in the three following areas: (i) project identification and formulation; (ii) implementation and (iii) machinery and equipment procurement.

Approaches

- Price irrigation engineering consultings, agricultural development banks and even some specialized government agriculture offices for helping farmers for drafting high quality techno-economical and environmental irrigation project documents;

- Reduce import taxes and customs levies as well as other barriers on irrigation equipment and know-how to allow small farmers and potential entrepreneurs to have access to such commodities at almost international prices;

- Reduce farmer's fiscal pressure proportionally to the investment made by them on irrigation

- Offer economical advantages and facilities to firms specializing in irrigation equipment installing, maintenance and development; and

- Stimulate banks and financial institutions to concede attractive loans at low interests as well as grants to the small farmers, and in particular to those shifting from surface to new irrigation techniques. The Tunisia case is quite illustrative. In this country subventions for small scale irrigated agriculture may reach a maximum of 25 % of the total investment.

(iii) Training and Extension

60. These areas have an extreme importance for the expansion of the new drip/sprinkler irrigation technologies in the sub-region. Up to date training is considered a pre-requisite for any successful extension programme to be undertaken in the sub-region. Moreover, training of trainees is also vital in the sub-region. Therefore, in order to establish and maintain the required level of training within the countries, it is thought that a three sub-regional training MASTER phases programme on irrigation systems may be necessary. It might be composed of a: (i) long term course for advanced engineers; (ii) medium term for technical engineers and (iii) short training course for irrigation planners and programmers.

61. These training courses should be carried out in the most specialized irrigation centres available, either within or outside of the region. Training should mainly be field oriented. This is why in selecting the potential training centers on irrigation, those with a balanced syllabus and a field programme of work should be chosen. An important training complement could be the participation of students in field research programmes.

Approaches

- Select a sub-regional agricultural training center with sufficient background on new irrigation methods and with facilities to update the training capability city of the three groups of people mentioned in paragraph 60. Essential for its selection it would be: (i) experience on irrigation in arid zones and (ii) field premises for conducted practical irrigation experiments.

- If such a Center does not exist in the sub-region, explore other centers outside that may meet the training demands identified above. A key point for its selection would be the possibility to have access to fellowships, travel and other advantages.

- In case of the above approach, try to set up a permanent irrigation training cell linked to the programme of national prestigious Research or University Centres. They might be the core for establishing of a future permanent center on modern irrigation techniques in the sub-region.

- Stimulate the preparation of Doctoral Theses and PhD cadres on small scale irrigation and environmental sound technologies.

62. Extension is also a cornerstone for the successful dissemination of new technologies. In general, as extension is neither easy nor cheap and in order to be more efficient it is thought that the extension programmes should be conducted on a sectorial bases and in some cases be individually oriented. As the establishment of an efficient extension network needs time and resources it is thought that there are two relatively economic ways for its spreading, namely: (i) to distribute among farmers very didactic publications on irrigation techniques, fertilizes and greenhouse management and (ii) to set up a permanent sub-regional irrigation techniques center.

Approaches

- Make a study on modern irrigation extension publications available in the countries of the sub-region and select those that could be of interest for the sub-region as a whole;

- Translate into Arabic those that may be the most relevant for extension;

- Launch a campaign for the distribution of these publications. It is suggested that farmers be provided, free of charge, with extension leaflets and pamphlets, whereas the price of books and specialized irrigation publications should cover their main publishing costs;

- Set up a permanent demonstration irrigation technologies centre, (ITC) perhaps with the assistance of countries that have acquired sufficient experience in this area. Its cost, location, size, activities and other features should be determined on the bases of the priorities and needs on irrigation of the countries of the sub-region.

- As an alternative, utilize the infrastructure already available in the agricultural institutions in some country in order to set up a cheaper demonstration and research irrigation technologies center.

63. The permanent center apart from showing the advantages of the new irrigation technologies could significantly increase the practical knowledge of farmers by showing them the results of applied research programmes e.g. diseases, pests and fungi identification, fight and monitoring; greenhouse design, and management; salinity control; and on selected seeds. Finally, the ITC would permit farmers to improve their knowledge on fertigation and chemigation technologies. In addition it could serve as an demonstration center for waste water recycling technologies, for water from the small urban nucleus, and in the end to stimulate irrigation at small scale in the countries of the sub-region.

ADDENDUM

ADDENDUM

RELEVANT SUBREGIONAL TOPICS ON SPRINKLER/DRIP IRRIGATION MANAGEMENT

A.1 This addendum intends to cast some light on some problems identified in the sub-region in the previous chapters. These are : (i) water quality monitoring; (ii) plant's water requirements, watering doses and intervals of distribution; (iii) selection and distribution of sprinklers and (iv) guidelines for an efficient drip irrigation system management.

Water quality monitoring

A.2 Water salinity constitutes a critical problem in most arid climates and its monitoring is essential. Insufficiency of water in the arid and semi-arid climates favors formation of salts in irrigated soils. In this context, apart from monitoring the total salt's content in the water the control of Na^+ concentration in water is also important. It is known that when its concentration moves reaches 0.2-0.3 gr/littre the plant's toxicity increases. In addition, it can degrade the soil structure. On the contrary, the presence of other ions like potassium may be beneficial. For example the amount of potassium incorporated into a soil through irrigation water containing 0.0312 gr/litre of such ion, when the soil is irrigated six times with 800 m^3 /ha amounts to 149,7 kilograms of ion K^+ per hectare. This is a figure of some significance, particularly to determine the effective doses of fertilizers. With no adequate doses, both the irrigated plants and soils may suffer from excessive water salinity ,excess of sodium, and even from excess of Ca^{++}. In the long term it may make soils unsuitable for agriculture. Water temperature and suspended solids have less influence on water quality.

A.3 For water quality control purposes it is suggested that the following two indexes be used : (i) Sodium Exchange Rate (SER, as %) to evaluate the sodium that can be incorporated to a plant and (ii) the "Sodium Adsortion Rate" SAR, a rate that measures the soil degradation caused by sodium. The index relates Sodium with Calcium and Magnesium concentrations. Annex I contains a set of indexes for water quality control for irrigation.

Use water for irrigation only if:

- SAR concentration is comprised between 0-26;
- When SAR varies between 0-10 SAR water can be used with no restrictions;
- If SAR is comprised between 11-18,(average alkalinity), then take precautions in the clay soils;
- When SAR ranges between 18-26 (high alkalinity) it is only recommended for light soils and those containing abundant organic matter and having a good drainage.

Other suggestions are: (i) do not use water containing ion chlorine > 0.5 g/l ; (ii) do not use water in which ion sodium concentration is higher than 0.3 g/l and do not use sprinkler irrigation if the Electrical Conductivity, (EC), of water is superior to 2,000 microhm/cm.

A.4 The following table shows per ha tomato production, in function of the (EC), for both drip and sprinkler irrigation.

TABLE IV	Tomato's Productivity (t/ha)		
EC (microhm/cm)	3600	3000	1200
Sprinkler irrigation	27.1	34.9	69.4
Drip irrigation	70.8	58.2	71.7

Source: J. Medina San Juan, Riego por Goteo, Teoria y Practica, Ediciones Mundi Prensa, Madrid 1979.

Plant's water requirements, watering doses and intervals of distribution

A.5 When water's quality is not a limiting factor, two basic aspects require special study, namely: (i) the calculation of the plant's water needs and (ii) irrigation programming. The accurate calculation of the crop's water balance is a pre-requisite for achieving good irrigation results and also for an optimal dimensioning of equipment and facilities (e.g. water tanks, water pumps and the whole set of pipelines and channels). The most common formula for calculating the total crop's water needs is the following:

$$ET = ET_0 * K_c \quad [1]$$

ET (mm/day), represents the total water needs, or the evapotranspiration of a particular type of crop;

ET_0 (mm/day) is the evapotranspiration of a reference crop, usually an area covered by green grass, having 8-15 cm height and with sufficient water to ensure its permanent growth.

K_c or crop coefficient. It varies with the type of crop and also with the vegetative period (e.g. for carrot in its phase of maximum growth K_m is 0.75)

A.6 When data are not available to calculate ET_0, the following table can be used for a rough evaluation in the arid and semi-arid climates.

TABLE III	APPROXIMATE VALUES OF EVAPOTRANSPIRATION ET_0 (mm/day)			
Climate	Annual Precipitation	Daily Average Temperature, °C		
	mm	< 15 °C	15-25 °C	> 25 °C
Arid	100-400	4-6	7-8	9-10
Semi-arid	400-600	4-5	6-7	8-9

Source: Ministerio de Agricultura, Pesca y Alimentacion, Curso Elemental de Riego, Madrid 1990

A.7 For an accurate calculation of water requirements for a particular crop, it is necessary to know evapotranspiration, ET_0 ,with precision and also the duration of the plant's vegetative period. The latter is essential to make a precise calculation of the crop cultivation coefficient K_c. For example, the water needs for a carrot crop, growing in arid climate, during its maximum growth period (30-35 days) may run between 6.75 and 7.5 mm per day. The same type of crop would need 6-6.75 mm per day in a semi-arid climate. The great number of species, mostly imported, growing on different climatic conditions , should incite Governments to give more impetus to research programmes aimed at producing crop's coefficient tables by species and ecological zones. As data on (ET) values are often not available in the sub-region those given in Annex II can tentatively be used. The table also illustrates crop's sensibility to drought.

A.8. Once irrigation requirements, that is "crop needs minus effective precipitation" have been calculated, irrigation has to be programmed. Farmers have to know the volume of water to be used, watering timing and its duration. Although irrigation needs may have been calculated in detail for a particular crop, if extra precipitation takes place, then, watering has to be modified. The same may occur with drought. The construction of a irrigation table as the following is recommended to determine the daily/monthly water requirements of a crop.

TABLE IV	Water Irrigation Requirements Calculations (mm)			
Months	October	November	December	Total
Water needs, mm per month	100	80	60	240
Effective precipitation P_e mm/month	55	39	26	120
Monthly (mm) watering requirements	45	41	34	120
Daily volume mm	45/31=1.4	41/30=1.4	34/31=1.1	1.3

P_e =0.8P-25 for P> 75 mm/month [2]
P_e =0.6p-10 for P<75 mm/month [3]
Source: UN ECA Tangier MULPOC

A.9 Irrigation doses must be calculated accurately, because the volume of water that a soil can store is limited. If water is added in excess, it will be lost by gravity. This does not usually happens with drip irrigation, because only a small volume of soil is damped. Contrarily, transpiration under greenhouse can be much higher for drip/trickle irrigation. Once the theoretical doses of watering have been calculated, the "practical ones" needs to be evaluated. For this evaluation be sure the right efficiency rate is used (see point 30). The selection of a precise rate may result in important water savings. Its importance is shown in the example of the following table.

TABLE V	Water Savings and Irrigation Efficiency Rates (m^3 /hectare)					
Irrigation system	T.D.	Practical Doses at Different Rates				
	m^3/ha	65 %	75%	85%	90%	Maximum differences
Sprinkler	500	500/0.65=769	500/0.75=667	500/0.85=588	n.a.	181
Drip/trickle	250	n.a.	250/0.75=333	250/0.85=294	250/0.90=278	55

Source: UN ECA Tangier MULPOC; T.D. = Theoretical doses ; n.a.- not applicable

A.10 When irrigation is not computerized, the selection of the right irrigation interval and its duration is of utmost importance. In the case of sprinkler irrigation at small scale it there may not be significant constraints in terms of manpower costs, as probably the main and secondary water pipes are fixed. For greenhouse drip irrigation, the situation may be similar. The problem usually consists in respecting the intervals and to obtaining the maximum advantages of the climate. The formula for determining the watering interval is :

Interval (days)= Theoretical doses (mm)/ Maximum (ET) in mm/day [4]

Selection and distribution of sprinklers

A.11 Sprinkler's water flow, their radius and spraying capacity have great influence in the selection of the ideal sprinkler. For small scale sprinkler irrigation, that is covering 5-10 ha, revolving sprinklers, sectoral, and in some cases fixed ones preferably working at 1.0-1.5 k/cm^2 are appropriated. Revolving irrigation is recommended for vegetables crops and fruit trees when they are irrigated under crown. Each of them can irrigate an area of about 100 m^2. Maize, barley, and shorgum are among the crops that can be irrigated at medium pressure rates. Micro-jet and cerco-jet is recommended for greenhouse irrigation, because water spraying efficiency is very high and consequently the damage to the soil is practically nil.

A.12 The formula for determining the water flow for a crop is the following: $P=Q_a/S$ |5|; being P (precipitation in mm/hour); Q_a the sprinkler flow in l./hour and S the effective irrigation surface.

A.13 For example, for a set of sprinklers with a water flow of 1500 mm per hour, placed at 12*20 m, the precipitation in mm per hour is calculated as follows:

$$P\ (\text{mm/hour}) = 1500\ \text{mm}/240\ \text{m}^2 = 6.25\ \text{litres per hour and m}^2 \quad |6|$$

Generally, the water flow of the most common sprinklers vary between 1000 -3000 litres per hour.

A.14 Concerning small scale sprinkler's distribution outside of greenhouses, the most common type of water distribution network consists in a main water pipe that follows the maximum slope and a set of side pipes that follow the earth's contour. Annex III shows the layout of a wheat irrigation scheme, 6.74 ha which are irrigated with a mobile hose irrigation set. The scheme uses 39 sprinklers, placed at 12*12 m, and yields US $ 664 per ha. Another example of maize sprinkler irrigation is given in Annex IV. Calculated at Spanish costs and prices, it reveals that 5.18 ha of irrigated maize may yield a net benefit of US $ 855 (DH 36,000 annually). In Central Tunisia (Kairouan), the net benefit, for irrigated wheat, varies between US $ 200 and 2,000 per ha.

Guidelines for an efficient drip irrigation system management

A.15 The performance of a drip irrigation system depends basically on the following three factors: (i) water filtration efficiency ; (ii) quality and distribution of the emitters (e.g. drippers, nozzles, microjets and small micro-sprinklers) and (iii) maintenance of the working and security equipment.

(i) Water Filtration Efficiency

A.16 In order to ensure efficient water filtration for drip irrigation, the following steps are recommended:

- Use adequate filters . For example use mesh filters for water from non exhausted wells and sand filters for water from other sources.(Sand's filters are available with 14, 35 and up to 100 m^3 /hour capacity). The suspended solids need pre-filtration;

- Clean the system periodically, and follow as far as possible the instructions manual. Control the pressure of outlet filter's water frequently. This is a good index to determine if filters are working properly and their yield;

- Install two sand filters, instead of one. It will help improve and facilitate filtration, the cleaning and maintenance of the system and they will ensure that there are no interruptions on planned irrigation;

- If there is fertigation equipment is advisable to make a regular control of the working conditions of the security filter. Normally, it is located between the fertigation tank and the irrigation pipe;

- Eliminate unfiltered algae, using for example sodium chloride.

(ii) Quality and distribution of drippers

A.17 Emitters have to be selected depending on the type of soil and crop. Their quality has to be adequate to withstand climate and location changes, including storage and distribution impacts that take place during the irrigation phases. But, the main characteristic must be water supply and distribution regularity. It is convenient to review the state of functioning periodically analyzing if deviations of water flow are acceptable or not. The following dripper equation can be used for calculating the dripper flow

$$F = K_d * P^e \quad |7|$$

Kd is a constant characteristic of each dripper ;P is the working pressure of the dripper and (e) relates to pressure and water flow of a certain dripper.

A.18 The distribution of drippers has to be adapted to the characteristics of each crop. Annex V shows a common layout of a greenhouse microjet irrigation scheme, for melon and tomato production. It shows that in Spain one hectare of that crop may produce a net benefit of US $ 21,967 per ha. Annex VI shows that the economic yield per hectare of an irrigated citrus plot in the same country, at 5*5 spacing, may be US $ 2899. In Morocco, sprinkler irrigation could triplicate the annual revenue, up to an estimated US $ 1,400. In Tunisia, Sahel region, it varies between US $ 4,200 and 10,700 per ha.

(iii) Maintenance of the working and security equipment.

A.19 Of all control mechanisms of an integrated drip irrigation system, those related to measurements of water pressure and flow regulation deserve especial control and care. The good performance of the whole system depends basically on their good maintenance. The fact that such control is usually mechanized or computerized facilitates their control and adjustment. Nozzles, drippers, micro-sprinklers and sprinkler maintenance is very simple. Many of them can be cleaned by simple to and for movements. For sprinklers the replacement of the spring and the axe is recommended every 5-10 years. Both are considered its weaker points and need special control. Nozzle's average lifespan is five years.

A.20 Manometers have to be installed in the most critical parts of the irrigation network, e.g. at the head water unit and also at the entry of the irrigated plot. They are instruments that permit to know when filters have to be cleaned, to carry out fertigation in an efficient manner and also to detect potential mechanical breakdown. The correct functioning of the whole flow and water volume instruments must be assured throughout all the irrigation network.

A.21 Concerning pipelines, their maintenance is fairly easy. Generally, the secondary and tertiary pipes as well as those carrying drippers are made with polyethylene, PE. The primary ones are composed of PVC. During their transportation and deployment, folding and external pressure must be avoided. If metallic pipes are used they must be protected against dents. Fibre-cement pipes rarely require maintenance. For eventual and small cracks the broken piece can be glued with epoxy resins. In Spain the UKE-53131 and 53142 indicates the basic requirements of an irrigation PE pipeline.

A.22 Needless to emphasize the importance of a proper maintenance of the water pumping equipment. The electrical, petrol or gas engines need to be revised and repaired periodically. Likewise, water pumps and pipelines leaks have to be controlled and avoided.

ANNEXES

QUALITY IRRIGATION INDEXES

Water Utilization	EC microhoms	SER(m.e.q/l)	SAR(m.e.q/l	Iron	Hardness
Good quality	1,172	60	4	0.5	<22
Average	1172/3135	0.75/2	4/8	0.5/1	22/54
Not to be used	3,125	70	8	2	54

Source: Jose E. Grau, Apuntes sobre riego localizado, Servicio de Extension Agraria, Ministerio de Agricultura, Pesca y Alimentacion. Madrid 1986.

ESTIMATED WATER NEEDS (ET) FOR SELECTED CROPS AND THEIR RESISTANCE TO DROUGHT

Type of crop	Cubic Metres per Hectare	Drought Resistance
Cotton	800 - 1600	low-medium
Rice	450 - 700	low
Oats	450 - 650	low-medium
Peanut	500 - 700	low-medium
Sugar cane	1500 - 2500	high
Barley	450 - 650	low-medium
Onion	350 - 550	medium-high
Citrus	900 - 1200	low-medium
Cabbage	350 - 500	medium-high
Sunflower	600 - 1000	low-medium
Pea	350 - 500	medium-high
Beans	300 - 500	medium-high
Maize	500 - 800	medium-high
Melon	400 - 600	medium-high
Potato	500 - 700	high
Pepper	600 - 900	medium-high
Banana	1200 - 2200	high
Sorghum	450 - 650	low
Tomato	400 - 800	medium-high
Wheat	450 - 650	low-medium

Source: Ministerio de Agricultura, Pesca y Alimentacion. Curso Elemental de Riego, Madrid 1990.

ANNEX III

WHEAT IRRIGATION SCHEME (6,74 ha)

FLEXIBLE SPRINKLER HOSE IRRIGATION SET

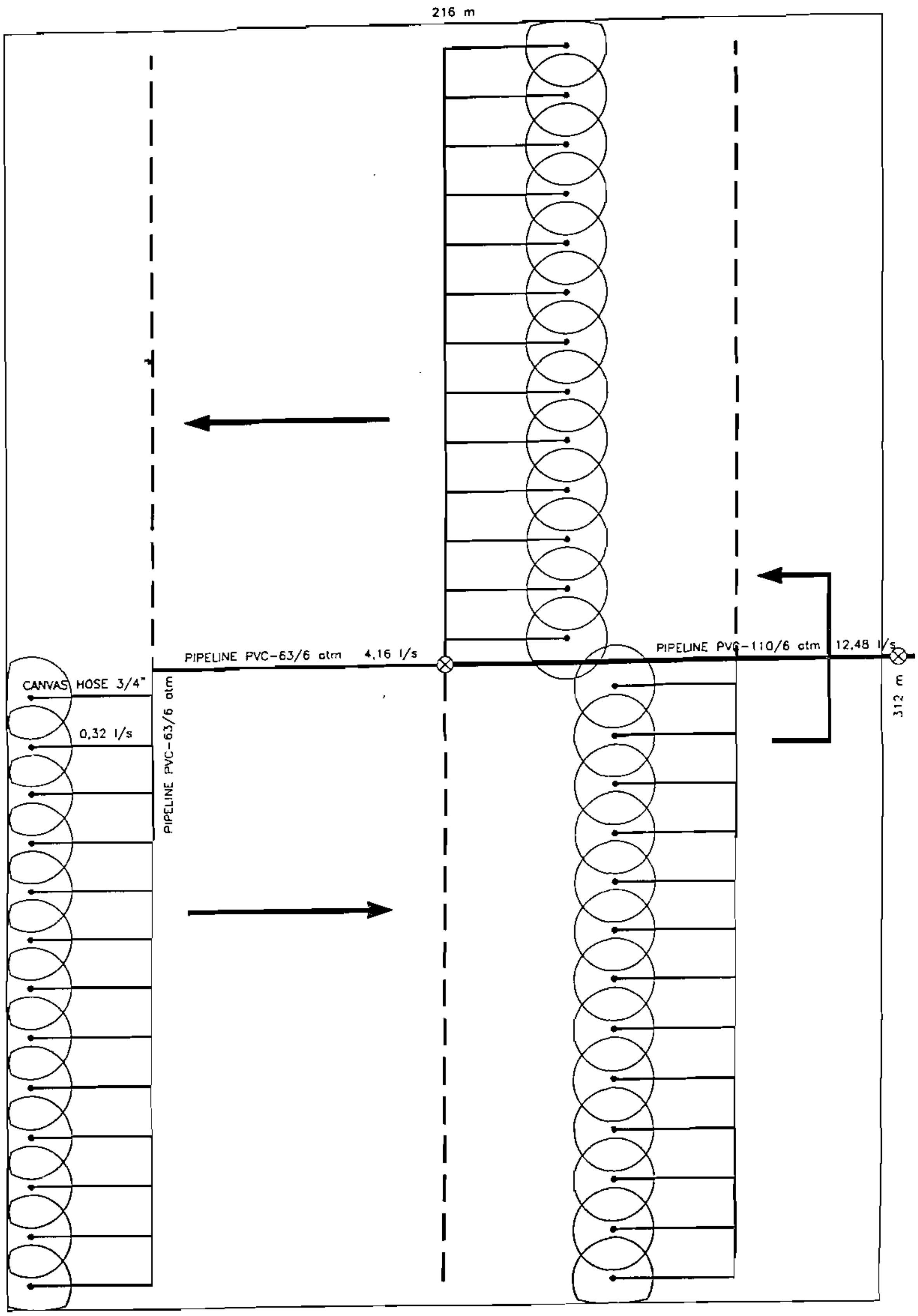
SPRINKLERS DISTANCE = 12 m x 12 m

WATER HEAD FLOW / SPRINKLER = 1152 l/hour

NUMBER OF SPRINKLERS WORKING = 39

NUMBER OF WATERINGS = 3 PER YEAR

NET BENEFIT PER ha = 664 US $



ANNEX IV

MAIZ IRRIGATION SCHEME (5,18 ha)

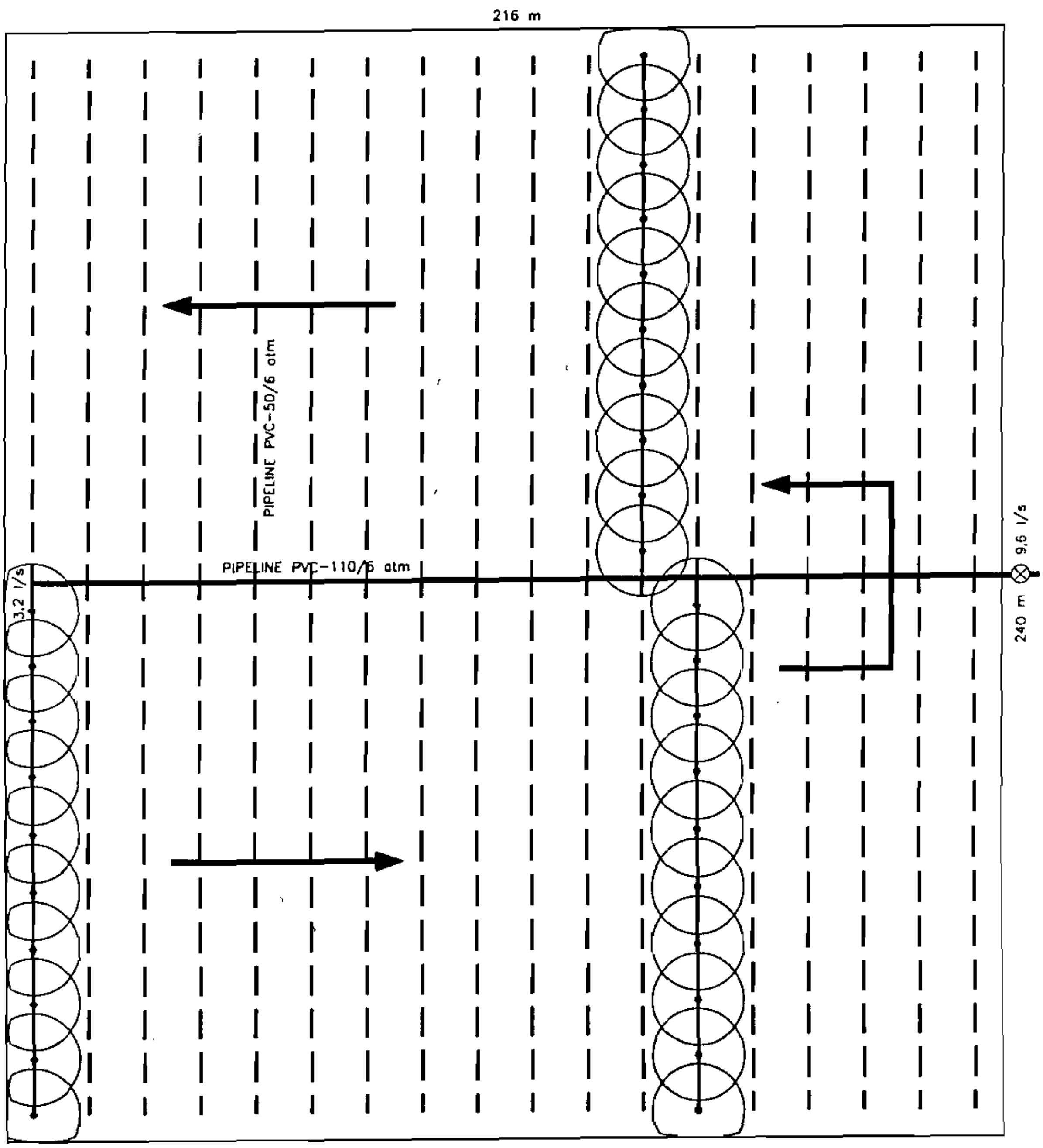
SPRINKLERS DISTANCE = 12 m x 12 m

WATER HEAD FLOW / SPRINKLER = 1152 l/hour

NUMBER OF SPRINKLERS WORKING = 30

NUMBER OF WATERINGS = 12 PER YEAR

NET BENEFIT PER ha = 855 US $



ANNEX V

GREENHOUSE CULTIVATION SCHEME (0,2 ha)

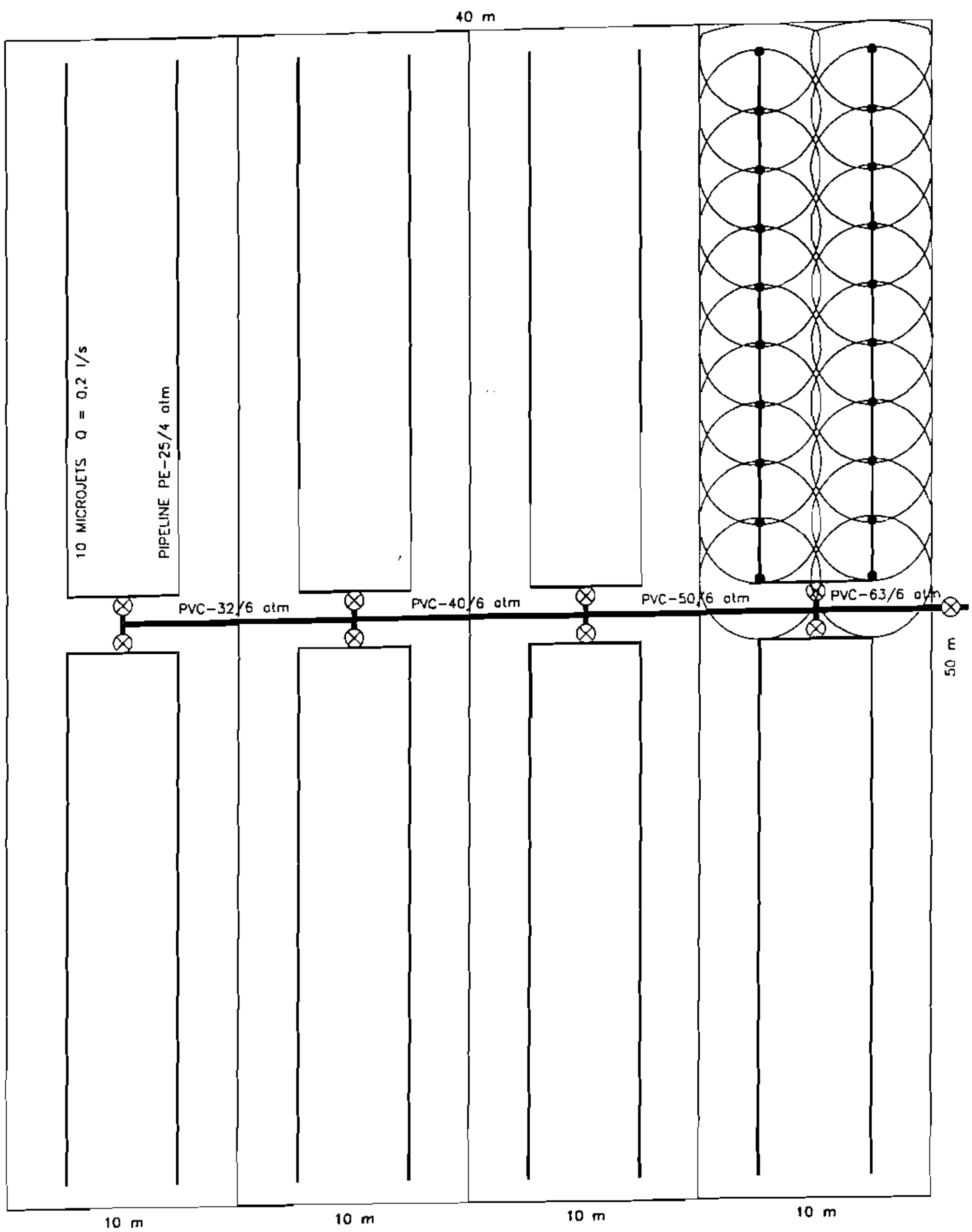
CROPS = TOMATO AND MELON

WATER HEAD FLOW / MICROJET = 70 l/hour

NUMBER OF MICROJETS WORKING = 160

IRRIGATION TIME = 2,0 hours

NET BENEFIT PER ha = 21967 US $



ANNEX VI

CITRUS IRRIGATION SCHEME (1,5 ha)

TREES DISTANCE = 5 m x 5 m

WATER HEAD FLOW / DRIPPER = 12 l/hour

NUMBER OF DRIPPERS WORKING = 300

IRRIGATION TIME = 3,54 hours

DOSES OF WATER PER TREE AND DAY = 85 l

NET BENEFIT PER ha = 2899 US $