Address of Welcome by E.P.Delia, Chairman APS Bank

WATER AND AGRICULTURE IN A COMPETITIVE ENVIRONMENT

Honorable Minister, Ladies and Gentlemen

It is with pleasure that I welcome you to the second APS Seminar on the Development of Agriculture and Fisheries in the Maltese Islands. Last year's meeting on the Role of Insurance in Agriculture made its point, and we are sure that insurance did not remain an academic issue but is being pursued with a purpose by all those involved in the trade.

The feedback that we got from the speakers and participants encouraged us to turn the activity into an annual event. A topic will be presented to a selected audience, the technical aspects considered, and the papers discussed will be published so that the discourse may be continued after the meeting. The purpose of the seminar is to act as a catalyst of ideas that will in turn be developed further in other fora.

Today's subject refers to the relationship between Water and Agriculture in a Competitive Environment. The provision of water supply for drinking and irrigation has been a perennial challenge to the inhabitants of these islands. Every generation adopted the most efficient means at its disposal to ensure an adequate water supply that could satisfy its needs. The same issue is under discussion at present when the demands for water of a growing population and visitors to the Islands have to be met by technological means. The costs of water production cannot be ignored especially by Malta's agricultural and animal-breeding sectors that have been protected from foreign produce for many years but that could possibly have to face stiff competition from imports all the year round in the near future. That is why we wish to emphasise the term 'competitive environment' in today's discussion.

To guide us through the various inter-related issues of the subject we have a distinguished panel of speakers. Together they combine a mixture of local and international expertise in the subject. They can draw on years of experience in the area of water production and use. The speakers come from the Food and Agriculture Organisation, Mr. Jean-Marc Faures and Mr. Ilja Betlem, who will discuss ways of improving water productivity in agriculture and legal issues and approaches in groundwater management respectively. APS Bank is honoured to collaborate with the FAO and I wish publicly to thank this organization for supporting our initiative for the second year running.

Mr. Anthony Mifsud from the Ministry of Agriculture and Fisheries, and Mr. John Mangion from the Water Services Corporation represent the local input to this seminar. They will be discussing irrigation sources and their implications in Malta, and the demand for water by the agricultural sector. This audience will have a lot to think about once these four gentlemen have had their say.

But to start the discussion we are pleased to have with us the Honourable Minister for Agriculture and Fisheries who accepted our invitation to participate in this session. While I augur an interesting and fruitful discussion, I cordially invite the Honourable Minister to present his address.

The Hon. N. Zammit, Minister for Agriculture & Fisheries

OPENING SPEECH

Mr. Chairman, Directors, Ladies and Gentlemen

It gives me great pleasure to be here today to inaugurate this important seminar on "Water and Agriculture in a Competitive Environment". I am also honoured by the presence of our guests from FAO, as this is a reflection of the support and commitment of this agency towards water management problems. I also welcome the presence of all participants in this forum.

Water is undoubtedly the natural resource that is most important for all activities conducted by men. It is vital for health, industry, generation of power and also for agriculture. Furthermore, as most of us are aware, water issues are set to become of major importance in the 21st century.

Agriculture is particularly dependent on water. It is quite safe to make the statement that there can be no agriculture unless a reliable source of water for irrigation is assured. Our regional climatic conditions mean that while other countries enjoy the luxury of steady rainfall for most of the year, we in the Mediterranean need to find ways and means to provide water in periods of relative drought.

In Malta, we have an average rainfall of around 500mm a year. This amount of rainfall is concentrated in a compressed period of time during the winter months. This factor, combined with the topographical features and other characteristics that are unfavourable to the collection and storage of water, means that we live at the mercy of the water cycle. Hence we depend upon the water stored in our aquifers, which water is supplemented by energy hungry desalination plants in the case of potable water provision.

For our agriculture to be able to meet the challenges and to rise to the opportunities of the future, we have to lay the necessary groundwork for the rational use of our water.

With such a limited amount of rainfall, we have to ensure that we make every drop count, if possible, at every stage of its cycle - from rain to drain. The management of water resources is directly linked to the agricultural sector, with the implication that agriculture is dependent on a cycle over which it has no control, or even input.

As such our farmers determine the conditions and the future sustainability of our fresh water resources and, therefore, they are amongst the most important stakeholders in this water scenario. The interests of farmers thus dovetail with those of water managers.

Our water problems arise from an ever-increasing demand from various sectors and practices, agriculture included, that influence water quality. Disturbances are generated by many different sectors of our society and they are often associated with land development. Land-use decisions must therefore recognise the socio-economic importance of water and must include those provisions that ensure sustainability of natural water resources. Today we need a new institutional and legal framework in our islands that would regulate the use of our water resources in an integrated and comprehensive context of our national needs.

From the first stage, that of rainfall, we are faced with the need for the most efficient ways of collecting and storing

this water, be it in artificially constructed reservoirs or through the water tables keeping this water in reserve for the drier months. The polishing of run-off water for irrigation or recharging of the water-table is inexpensive when compared to the cost of desalination. Regretfully, run-off water is available at the time when it is least needed for irrigation, and hence more cost-effective storage schemes need to be devised in future to harvest and store this precious resource.

Water is also the main component of sewage effluent. It is the medium through which we maintain the waste disposal system that is so crucial and fundamental for the health and hygiene needs of modern society. This water must not be allowed to go to waste. At the moment, in our country we already have one plant that is operating and recovering water from sewage in order for it to be used for irrigation of agricultural land that does not lie over aquifers for potable water. We are committed to having the capacity to treat all our sewage within the next few years. This should result in a situation whereby we can meet most of our irrigation needs on land where it is allowable, using water that has been recovered from drainage effluent.

I am here emphasising the concerns of agriculture, which is, after all, the core theme of this seminar. We look forward to a situation when we have sewage treatment plants that, using state of the art technology, provide us with enough quantities of water of the best possible quality. This water can then be used safely, without in any way endangering public health either directly or through contamination of the water table. As a result, less groundwater would be needed for agriculture, making the water tables more available for use in providing drinking water supplied to our homes, thus reducing the need for desalination.

Having however this supply is not enough. There is a pressing need for a holistic approach to the whole issue of the provision of water. There has to be planning for the development of a pressurised-pipe infrastructure for the delivery of this 2nd class water, supplemented by the introduction of water-efficient irrigation devices, and all seen within the larger picture of the preservation of the rural environment.

In this manner, the agricultural sector will be able to provide a variety of agricultural produce at affordable prices, in balance with adequate income for producers and with a positive effect on the landscape, thus living up to its multifunctional character.

This is then our vision, transforming the permanent 'drought' condition of our island to one where sufficient water is available for wise use at a minimum and affordable cost. Thus, we will not any more talk about water as a constraint on development but rather one that facilitates our development and enchances competitiveness.

This can happen if the link between water supply and the agricultural sector is further recognised, strengthened and forged through projects of interest, both hydrological and agricultural.

In an island like ours with scarce natural resources, we are obliged to use the little that we have in the most rational and efficient manner. With this I mean that we need to adopt a collective approach to cope successfully with our environmental constraints while satisfying the needs of our society.

The strategy that we need to follow moves away from conflict and competition. Instead, it promotes a community culture aimed at exploiting our natural resources fruitfully to the benefit of the country at educating all levels of society to create awareness on how water enters into our everyday life. In a nation that is one of the smallest in Europe we must

have an intersectoral dialogue in order to enable the handling of complex water problems - after all water has always been everybody's business!

I would like to publicly thank and acknowledge the help and dedication shown by all who participated in the organisation of this seminar, in particular APS Bank, who directly financed this meeting, and FAO for their presence and continued support and all the participants and guests.

Anthony Mifsud, Ministry of Agriculture & Fisheries

IRRIGATION SOURCES AND IMPLICATIONS IN MALTA

Introduction

The Maltese archipelago consists of 3 main islands: Malta, Gozo and Comino, the total area being merely 315 square kilometres. Malta, the main island, measures 246.6 km^2, Gozo 65.8 km^2 and Comino 2.8 km^2. Out of these 31,500ha just over 10,000ha of agricultural land is cultivated. It is estimated that about 8% is irrigated whereas the rest depends directly on rainfall. The annual average rainfall is about 550 mm of which the affective rainfall is 300 mm/year. Considering that the rainy season normally extends from September to March, vegetables and summer crops are impossible to grow during the dry season ranging from April to August, unless irrigation is applied.

Agricultural Holdings

Agriculture accounts for 3% GDP and 2% employment.
Malta is self-sufficient in fresh vegetables and also self-sufficient in pork, fresh milk and fresh eggs. The number of full-time farmers is constantly on the decrease and now

accounts only to about one thousand plus about 400 full time livestock breeders. The reason for this decrease is mainly the subdivision of the holdings as a result of inheritance. When this holding is subdivided from generation to generation it is no longer viable to sustain a living and hence the large number of part-time farmers which amounts to about 20,000. This trend however does not seem to have a negative effect since the agricultural land is being well cultivated on a part-time basis, very often with an increase of production. The subdivision of the holdings is however creating problems of fragmentation resulting in several fields, or rather, plots of land in different localities and in turn aggravating the problem of accessibility to these fields. Adequate accessibility to scattered small fields is very often the cause of litigation amongst farmers and is restricting agricultural investment. In such cases land cannot be intensively cultivated because of hardship to get the produce out of these areas, the limitation to provide the appropriate machinery for proper cultivation and also to convey irrigation water to the site.

Furthermore, these factors of field size, fragmentation and accessibility are creating problems to design irrigation schemes properly. So far there has never been an attempt for a land consolidation programme which would have to involve the farmers themselves who, however, are very reluctant to relinquish or exchange any part of their holdings.

Soil aspects

Malta's agricultural land is characterised by the sloping terraced fields bounded by retaining rubble walls. These are very often, shallow soils normally ranging from 20 to

75cm soil depth. There are also a few flat areas near valley beds which are very fertile soils such as at Pwales (Ghajn Tuffieha) and Burmarrad. These soils are of sediment origin and are over a metre deep but overly a saline aquifer.

The main soil types are:

(i) Terra Rossa Soil, red soils found on coralline limestone in the North (Mellieha) and in the South East (Kirkop/Zurrieq);

(ii) Xerorendzina soils overlying blue clay rock in Rabat areas;

(iii)Carbonate raw soils, white soils with high calcium carbonate.

However, over the years there has been an extensive movement of soils from one area to another for agricultural land reclamation and addition of soil to existing shallow fields. Hence it is common to find a mixture of soil types in the same locality and even in the same field.

Water permeability in soils vary tremendously depending on the soil type, very low on clay soils to very high in terra rossa soils. Water retention is high only in clay soils and very low in all other soils. Considering the low soil depth of most of the terraced fields, the soil water storage is quite low and hence the need for frequent irrigation sometimes even during the rainy season.

Irrigation demand

The climate in Malta is characterised by a mild wet winter and a hot dry summer. Annual average rainfall is 550mm but varies tremendously throughout the years. Both rain distribution and intensity is very unpredictable during winter; long dry spells and torrential rains are quite common in winter. Normally temperatures range from a minimum of 6°C during the night in winter to a maximum of 40°C in summer. Relative humidity is quite high normally between 65 to 80% notwithstanding the frequent windy conditions.

In 1990 Dr Mitschoff in his report "*Upgrading and Modernisation of Sant'Antnin Sewage effluent irrigation Systems*" carried out a detailed study on the irrigation water requirements for the Sant'Antnin Project area. He personally undertook field investigations and laboratory analysis to establish the soil hydrophysical characteristics which were not available. Based on evapotranspiration and effective rainfall figures, he established the water requirement of most crops. Evapotranspiration rates during the dry season (Appendix 1) is in the region of 3.5 mm/day in April to a peak of 7mm/day in July. Annual water requirements for crops grown all year round vary from 971mm for cabbages to 1291mm for lettuce. The total annual and water requirement based on 300% cropping intensity amounted to 12.000m^3/ha. Dr Mitschoff provided detailed information on crop water requirements, a very useful tool to plan irrigation water supplies and irrigation scheduling.

Irrigation water services

Irrigation water is available from groundwater, a sewage treatment plant and rainwater collected in reservoirs. There are two aquifers, the mean sea level aquifer and the perched aquifer overlying the blue clay layer. Over-pumping of this groundwater resulted in increased salinity to the detriment of agriculture and to the potable water supplied by the Water Services Corporation. So far this water for agriculture is free of charge to farmers, the only cost being pumping costs.

The sewage treatment plant at Sant'Antnin, M'Scala, supplies about 7,000m^3/day to an area of about 250ha. Another three sewage treatment plants are planned to be completed by the next three years. These would potentially provide 50,000m^3/day of treated affluent to be used in agriculture. This water should theoretically substitute the ground water extracted for irrigation to the benefit of potable water supply from this source.

Collection of rainwater into reservoirs, though requiring high investment costs, is quite significant and very important to greenhouse growers because of low salinity, and to serve as supplementary irrigation during dry spells for dry land farming which depends entirely on rainfall.

Increase in irrigated areas

Recent drilling of boreholes especially in the mean sea aquifer has significantly increased agricultural production particularly during the dry summer months. This however, has resulted in a deterioration of the water quality and in a drastic lowering of market prices for all agricultural produce. The local market is very limited and sensitive to over-production. The availability of irrigation water from the proposed sewage treatment plants will exacerbate the problem of demand and supply on the market price of agriculture produce. The matter has to be dealt with carefully – diversification, establish optimum cropping hectarage and possibly explore export potential.

Farmers have now invested heavily especially on irrigation equipment. They must have decent financial returns for their investment and hard labour. The agriculture sector is a very complex industry and its development must be planned properly, even more so if agriculture is upgraded to meet EU directives and regulations.

Upgrading of agricultural management

Several studies and reports have already been made and others are in progress in view of Malta's EU Accession application. A draft report "*Impact Assessment Study: Compliance with EC Nitrate in Agriculture Directive (91/676/EEC) for Malta*" has already been drawn up.

Several reports on disposal of solid and liquid waste are also available. All these reports indicate that agricultural management has to be improved. Agriculture cannot be considered as an isolated industry. It is complementary to various other issues, industry, tourism, economy and more directly to environment and ground water protection.

Increased supply of irrigation water encourages investment in irrigation equipment resulting in intensive cultivation of the agricultural land. This, in turn, necessitates an increase in fertilizer or organic matter application to maximise production to improve the farmers' revenue.

However, consideration must be given to the fact that fertilizers, particularly nitrates and some elements in organic matter find their way into the ground water to the detriment of human health. It is imperative to carry out a detailed soil survey to establish the soil physical and chemical properties to establish the nutrient status of soil, soil depth, water retention capacity, infiltration rates (permeability).

A scientific approach to irrigation scheduling is required to reduce over-irrigation and to limit the leaching of nutrients to the ground water. So far irrigation and fertilizer applications are made by judgement, arbitrarily, rather than by scheduling to meet crop water demand.

Data, however, is still lacking. Areas where groundwater is polluted by nitrate concentrations in excess of 50mg/litres must be identified. The land that drains into these waters must be designated as nitrate vulnerable zones. Once the nitrate vulnerable zones are designated, and practically all Malta would be so designated, the rate of fertilizer application will have to be less than 170N/ha/year and this depends on the N.Status of the soil.

There are also specific requirements for the restriction of organic manure application on shallow soils. Malta soils are very low in organic matter, very often just 1% and rarely over 3%.

Ideally all organic matter derived from the composting plant, farmyard manure, pig slurry and sewage sludge should be incorporated in soils. However, the application rates of organic matter rates will be restricted because of N, P and heavy metals acceptable limits and these again depend on the status of the soil.

Once the soil survey is finalised and the proper data collected, a code of good agricultural practice may be drawn up to direct farmers to adhere to proper irrigation schedules and fertilizer application. Knowing farmers' attitudes, it will be very difficult to implement such directives. The Department of Agriculture has to have the proper institutional set-up to educate and advise farmers on the code of good agricultural practice and moreover has to monitor and implement policies according to directives. Both the manpower and the proper tools are lacking. The Ministry of Agriculture and Fisheries has already acquired EU funds for the introduction of Integrated Administration and Control System (IACS), which will include registration of agricultural land and relevant data resulting from the land survey relating to land use and the physical and chemical status of the soil. Once this information is collected on the Geographic Information System (GIS), this will form the basis of planning a proper agricultural management programme, which may easily be monitored and possibly implemented.

Conclusion

Due to Malta's application to EU accession, an in-depth analysis of agriculture is being undertaken. This reveals the deficiencies of our system and the need for a scientific integrated approach to improve the management of this industry to the benefit of all concerned, farmers, consumers and industrialists. Farmers have to adapt themselves to the challenges that lie ahead of them to adhere to the code of good agricultural practice. They have to find ways and means to maximise their profits to meet the consumers' demand but at the same time respect the exigencies of other sectors and the health aspect of the population in general. Some may choose to go for traditional organic farming; others may wish to disregard the code of good agriculture practice and opt to intensify agricultural production to maximise profits, irrespective of environmental issues and health hazards. Perhaps they may be prepared to make use of GMO products as well. We may choose the last option; perhaps we may finish up consuming a mad melon or a mad pumpkin rather than a mad cow!

APPENDIX 1

Crop data: CABBAGE	Crop file: CABBAGE 4				
Growth Stage	Init	Devel	Mid	Late	Total
Length Stage [days]	91	91	92	91	365
Crop Coefficient [coeff.]	0.75	->	0.75	0.75	
Rooting Depth [meter]	0.50	->	0.50	0.50	
Depletion level [fract.]	0.35	->	0.35	0.35	
Yield-response F. [coeff.]	0.00	0.00	0.00	0.00	0.95

Crop Evapotranspiration and Irrigation Requirements

Climate File: 56efrain — Climate Station: LUQA (Year 1956)
Crop: CABBAGE 4 — Planting date: 1 January

Month	Dec	Stage	Coeff Kc	ETcrop mm/day	ETcrop mm/dec	Eff.Rain mm/dec	IRReq mm/day	IRReq. mm/dec
Jan	1	init	0.75	1.65	16.5	21.1	0.00	0.0
Jan	2	init	0.75	1.60	16.0	22.2	0.00	0.0
Jan	3	init	0.75	1.89	18.9	21.7	0.00	0.0
Feb	1	init	0.75	2.26	22.6	21.9	0.07	0.7
Feb	2	init	0.75	2.56	25.6	21.8	0.38	3.8
Feb	3	init	0.75	2.54	25.4	17.3	0.81	8.1
Mar	1	init	0.75	2.45	24.5	12.8	1.17	11.7
Mar	2	init	0.75	2.43	24.3	8.3	1.60	16.0
Mar	3	init	0.75	2.85	28.5	5.6	2.30	23.0
Apr	1	in/de	0.75	3.31	33.1	2.8	3.03	30.3
Apr	2	deve	0.75	3.71	37.1	0.0	3.71	37.1
Apr	3	deve	0.75	3.88	38.8	0.0	3.88	38.8
May	1	deve	0.75	4.07	40.7	0.0	4.07	40.7
May	2	deve	0.75	4.25	42.4	0.0	4.25	42.4
May	3	deve	0.75	4.55	45.5	0.0	4.55	45.5
Jun	1	deve	0.75	4.86	48.6	0.0	4.86	48.6
Jun	2	deve	0.75	5.17	51.7	0.0	5.17	51.7
Jun	3	deve	0.75	5.28	52.8	0.0	5.28	52.8
Jul	1	de/mi	0.75	5.38	53.8	0.0	5.38	53.8
Jul	2	mid	0.75	5.49	54.9	0.0	5.49	54.9
Jul	3	mid	0.75	5.40	54.0	0.0	5.40	54.0
Aug	1	mid	0.75	5.36	53.6	0.0	5.36	53.6
Aug	2	mid	0.75	5.29	52.9	0.0	5.29	52.9
Aug	3	mid	0.75	4.90	49.0	0.4	4.86	48.6
Sep	1	mid	0.75	4.49	44.9	0.2	4.47	44.7
Sep	2	mid	0.75	4.13	41.3	0.3	4.11	41.1
Sep	3	mid	0.75	3.78	37.8	6.1	3.17	31.7
Oct	1	mi/lt	0.75	3.42	34.2	13.9	2.04	20.4
Oct	2	late	0.75	3.07	30.7	20.7	1.00	10.0
Oct	3	late	0.75	2.86	28.6	17.4	1.12	11.2
Nov	1	late	0.75	2.65	26.5	12.7	1.38	13.8
Nov	2	late	0.75	2.45	24.5	8.8	1.57	15.7
Nov	3	late	0.75	2.21	22.1	12.1	1.00	10.0
Dec	1	late	0.75	1.98	19.8	15.5	0.43	4.3
Dec	2	late	0.75	1.75	17.5	18.9	0.00	0.0
Dec	3	late	0.75	1.72	17.2	20.0	0.00	0.0
Jan	1	late	0.75	1.65	8.2	10.5	0.00	0.0
Total					1264.5	313.0		971.9

Crop data: CARROT	Crop file: CARROT 4				
Growth Stage	Init	Devel	Mid	Late	Total
Length Stage [days]	91	91	92	91	365
Crop Coefficient [coeff.]	0.85	->	0.85	0.85	
Rooting Depth [meter]	0.40	->	0.40	0.40	
Depletion level [fract.]	0.35	->	0.35	0.35	
Yield-response F. [coeff.]	0.00	0.00	0.00	0.00	0.95

Crop Evapotranspiration and Irrigation Requirements

Climate File: 56efrain   Climate Station: LUQA (Year 1956)
Crop: CARROT 4   Planting date: 1 January

Month	Dec	Stage	Coeff Kc	ETcrop mm/day	ETcrop mm/dec	Eff.Rain mm/dec	IRReq mm/day	IRReq. mm/dec
Jan	1	init	0.85	1.87	18.7	21.1	0.00	0.0
Jan	2	init	0.85	1.81	18.1	22.2	0.00	0.0
Jan	3	init	0.85	2.14	21.4	21.7	0.00	0.0
Feb	1	init	0.85	2.56	25.6	21.9	0.37	3.7
Feb	2	init	0.85	2.90	29.0	21.8	0.72	7.2
Feb	3	init	0.85	2.88	28.8	17.3	1.15	11.5
Mar	1	init	0.85	2.77	27.7	12.8	1.49	14.9
Mar	2	init	0.85	2.75	27.5	8.3	1.92	19.2
Mar	3	init	0.85	3.24	32.4	5.6	2.68	26.8
Apr	1	in/de	0.85	3.75	37.5	2.8	3.47	34.7
Apr	2	deve	0.85	4.20	42.0	0.0	4.20	42.0
Apr	3	deve	0.85	4.40	44.0	0.0	4.40	44.0
May	1	deve	0.85	4.61	46.1	0.0	4.61	46.1
May	2	deve	0.85	4.81	48.1	0.0	4.81	48.1
May	3	deve	0.85	5.16	51.6	0.0	5.16	51.6
Jun	1	deve	0.85	5.51	55.1	0.0	5.51	55.1
Jun	2	deve	0.85	5.86	58.6	0.0	5.86	58.6
Jun	3	deve	0.85	5.98	59.8	0.0	5.98	59.8
Jul	1	de/mi	0.85	6.10	61.0	0.0	6.10	61.0
Jul	2	mid	0.85	6.22	62.2	0.0	6.22	62.2
Jul	3	mid	0.85	6.12	61.2	0.0	6.12	61.2
Aug	1	mid	0.85	6.07	60.7	0.0	6.07	60.7
Aug	2	mid	0.85	5.99	59.9	0.0	5.99	59.9
Aug	3	mid	0.85	5.56	55.6	0.4	5.51	55.1
Sep	1	mid	0.85	5.09	50.9	0.2	5.07	50.7
Sep	2	mid	0.85	4.68	46.8	0.3	4.66	46.6
Sep	3	mid	0.85	4.28	42.8	6.1	3.67	36.7
Oct	1	mi/lt	0.85	3.88	38.8	13.9	2.49	24.9
Oct	2	late	0.85	3.48	34.8	20.7	1.41	14.1
Oct	3	late	0.85	3.24	32.4	17.4	1.50	15.0
Nov	1	late	0.85	3.01	30.1	12.7	1.73	17.3
Nov	2	late	0.85	2.77	27.7	8.8	1.90	19.0
Nov	3	late	0.85	2.51	25.1	12.1	1.29	12.9
Dec	1	late	0.85	2.24	22.4	15.5	0.69	6.9
Dec	2	late	0.85	1.98	19.8	18.9	0.09	0.9
Dec	3	late	0.85	1.95	19.5	20.0	0.00	0.0
Jan	1	late	0.85	1.87	9.3	10.5	0.00	0.0
Total					1433.0	313		1128.4

Crop data: LETTUCE 4	Crop file: LETTUCE 4				
Growth Stage	Init	Devel	Mid	Late	Total
Length Stage [days]	91	91	92	91	365
Crop Coefficient [coeff.]	0.75	->	0.95	0.95	
Rooting Depth [meter]	0.40	->	0.40	0.40	
Depletion level [fract.]	0.35	->	0.35	0.35	
Yield-response F. [coeff.]	0.00	0.00	0.00	0.00	0.95

Crop Evapotranspiration and Irrigation Requirements

Climate File: 56efrain   Climate Station: LUQA (Year 1956)
Crop: LETTUCE 4   Planting date: 1 January

Month	Dec	Stage	Coeff Kc	ETcrop mm/day	ETcrop mm/dec	Eff.Rain mm/dec	IRReq mm/day	IRReq. mm/dec
Jan	1	init	0.95	2.09	20.9	21.1	0.00	0.0
Jan	2	init	0.95	2.02	20.2	22.2	0.00	0.0
Jan	3	init	0.95	2.40	24.0	21.7	0.23	2.3
Feb	1	init	0.95	2.87	28.7	21.9	0.68	6.8
Feb	2	init	0.95	3.24	32.4	21.8	1.06	10.6
Feb	3	init	0.95	3.22	32.2	17.3	1.49	14.9
Mar	1	init	0.95	3.10	31.0	12.8	1.82	18.2
Mar	2	init	0.95	3.08	30.8	8.3	2.24	22.4
Mar	3	init	0.95	3.62	36.2	5.6	3.06	30.6
Apr	1	in/de	0.95	4.19	41.9	2.8	3.91	39.1
Apr	2	deve	0.95	4.69	46.9	0.0	4.69	46.9
Apr	3	deve	0.95	4.92	49.2	0.0	4.92	49.2
May	1	deve	0.95	5.15	51.5	0.0	5.15	51.5
May	2	deve	0.95	5.38	53.8	0.0	5.38	53.8
May	3	deve	0.95	5.77	57.7	0.0	5.77	57.7
Jun	1	deve	0.95	6.16	61.6	0.0	6.16	61.6
Jun	2	deve	0.95	6.55	65.5	0.0	6.55	65.5
Jun	3	deve	0.95	6.68	66.8	0.0	6.68	66.8
Jul	1	de/mi	0.95	6.82	68.2	0.0	6.82	68.2
Jul	2	mid	0.95	6.95	69.5	0.0	6.95	69.5
Jul	3	mid	0.95	6.84	68.4	0.0	6.84	68.4
Aug	1	mid	0.95	6.78	67.8	0.0	6.78	67.8
Aug	2	mid	0.95	6.70	67.0	0.0	6.70	67.0
Aug	3	mid	0.95	6.21	62.1	0.4	6.17	61.7
Sep	1	mid	0.95	5.69	56.9	0.2	5.67	56.7
Sep	2	mid	0.95	5.23	52.3	0.3	5.21	52.1
Sep	3	mid	0.95	4.78	47.8	6.1	4.18	41.8
Oct	1	mi/lt	0.95	4.34	43.4	13.9	2.95	29.5
Oct	2	late	0.95	3.89	38.9	20.7	1.82	18.2
Oct	3	late	0.95	3.62	36.2	17.4	1.89	18.9
Nov	1	late	0.95	3.36	33.6	12.7	2.09	20.9
Nov	2	late	0.95	3.10	31.0	8.8	2.22	22.2
Nov	3	late	0.95	2.80	28.0	12.1	1.59	15.9
Dec	1	late	0.95	2.51	25.1	15.5	0.96	9.6
Dec	2	late	0.95	2.21	22.1	18.9	0.33	3.3
Dec	3	late	0.95	2.18	21.8	20.0	0.18	1.8
Jan	1	late	0.95	2.09	10.4	10.6	0.00	0.0
Total					1601.6	313.1		1291.4

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IMPROVING WATER PRODUCTIVITY IN AGRICULTURE

Introduction

This paper intends to provide an overview of the current situation of water resources and use in the world, and options and strategies adopted by countries to cope with increasing water scarcity. It provides a few examples of typical responses of the agricultural sector to the increasing competition for water and pressure by other sectors to improve water use efficiency and increase return from water in agriculture. The issues of integrated water resources management and multiple uses of water resources are discussed and presented as necessary options in countries with heavy pressure on water resources. In particular, the reuse of treated wastewater effluents, very relevant in the case of Malta, is presented as a viable option for agriculture. Finally, the paper argues that a comprehensive approach must be adopted for the successful implementation of water management programmes by which all the forces driving farmers' decisions in water resources management are taken into account and addressed adequately.

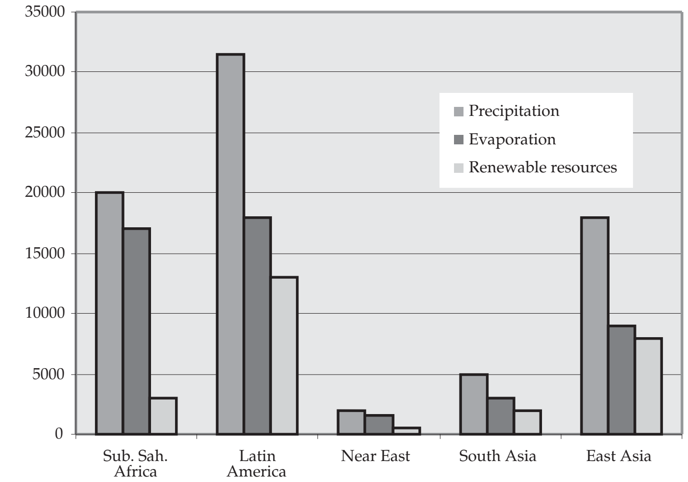
The current situation of Water Scarcity in the world and in the Mediterranean region

Renewable water resources are conventionally described as the portion of precipitation falling on the Earth which does not evaporate and which runs into rivers or infiltrates in the ground to replenish aquifers. Overall, the water resources of the world are estimated at around 40 000 km^3/yr while its withdrawal by man for domestic, agricultural and industrial purposes only accounts for 7% of this total. Such a figure could lead to think that water resources are abundant and that human needs can still be satisfied for many decades before it becomes a scarce resource. Unfortunately, several considerations must be taken into account, which show that the situation is much less favourable. First, remaining at global level, it should be considered that, even with all possible flow regulation structures, only a small part of this water can be diverted for human purposes, the rest of it flowing in regions where it is not necessary or being lost in large floods. In addition, a part which is roughly estimated at 2 300 km^3/yr must be retained in the aquatic ecosystems to ensure basic environmental services and can therefore not be used for human purposes (FAO, 1997).

However, the most important factor in determining water scarcity is the uneven distribution of water resources on the surface of the Earth. Figure 1 shows the overall water balance for selected regions of the world. It presents the total amount of precipitation, evaporation and water resources available for each region. The figure clearly shows major differences between the regions: Near East (which includes all the southern countries of the Mediterranean) has very limited water resources and a high evaporation rate, which translates into even more

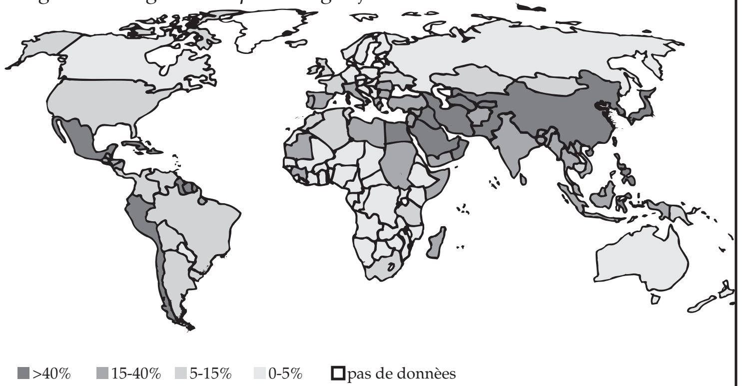
limited water resources. To the contrary, countries of the American continent show a much larger share of water resources.

Figure 1: Regional water balance: uneven distribution of the resources across the world



At the world scale, agriculture represents by far the largest user of water. It accounts for 71% of overall water withdrawal, while cities take about 9% and industries 20%. The situation is even more pronounced in arid developing countries where the agricultural share often represents more than 90% of total water withdrawal. Figure 2 shows the importance of irrigation in agriculture expressed in percentage of arable land. It shows that the countries of the Near East and East Asia rely heavily on irrigation for their agriculture while countries of sub-Saharan Africa and Latin America, for instance, have very limited use of irrigation in agriculture.

Figure 2: Irrigation in percentage of arable land in the world



Source: Aquastat (FAO) et Agrostat (FAO)

This uneven distribution of irrigated land translates into a similar pattern when expressed in terms of agricultural water use. Figure 3 shows agricultural water use expressed in percentage of renewable water resources in 93 developing countries, and shows again, that in the southern part of the Mediterranean, agriculture alone takes over an extremely high share of available water resources. Figure 4 shows the global picture of water withdrawal expressed in percentage of water resources, for all sectors and confirms the high pressure on water resources in the Near East and East Asia.

Figure 3: Agricultural water use in percentage of water resources in 93 developing countries

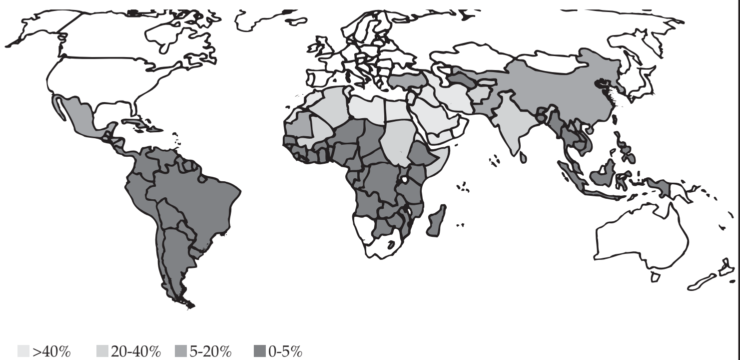
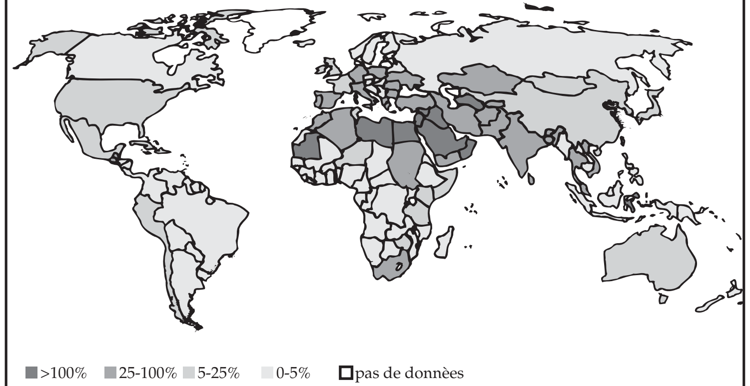


Figure 4: Water withdrawal in percentage of water resources (all sectors)



Source: Aquastat (FAO) et WRI (estimation les plus recentes disponibles en 1998)

Table 1 gives the breakdown of water withdrawal by sector for selected countries and for the world. The Maltese situation shows two major particularities. First, it is by far the country where pressure on water resources is the highest: the rate of use of 362% of water resources is easily explained by the fact that the country relies heavily on desalinated water (which is not considered as water resources in conventional terms). In addition, multiple use of water, including reuse of treated wastewater and overdraft of groundwater also contributes, although to a lesser extent, to a rate of use superior to 100%. As a comparison, a rate of use of 25% for a country is usually considered to correspond to a high level of water scarcity.

Table 1: water withdrawal by sector for selected countries and for the world

Country	MALTA	Cyprus	Italy	Tunisia	World
Agriculture	7 (12%)	180 (77%)	20300 (45%)	2430 (86%)	(71%)
Cities	49 (87%)	55 (23%)	7900 (18%)	370 (13%)	(9%)
Industries	1 (1%)	<1 (0%)	16300 (37%)	55 (2%)	(20%)
Total in % of water resources	362%	30%	27%	74%	8%

The second particularity of the Maltese water sector is that agriculture represents a relatively small share of the overall withdrawal, while cities use 87% of the water. The very high population density of the country and relatively low importance of irrigation in agriculture explain this. In conclusion, Malta is located in a region with high level of water scarcity and within that region represents an extreme case of pressure on water resources.

New challenges in water management

Supply and demand management: improving water use efficiency

Two main stages can be identified in water resources management as water scarcity increases. The first stage, which has taken place since humans have started diverting water for their own uses, is *supply management*. Supply management consists in improving water availability. In irrigation, this consists in constructing the necessary hydraulic infrastructures to ensure that fields can receive a

satisfactory amount of irrigation water when requested. As water scarcity increases, ensuring adequate supply of water for the different users becomes increasingly difficult and costly. A new option then starts playing an increasing role, this is, *demand management*. Demand management consists in reducing losses in the distribution systems, and wastage by users. In agriculture, like in public water supply systems, demand management consists mostly in improving water use efficiency, at all levels. It usually requires a mix of institutional, technical, and educational measures.

In irrigation, technology can play an important role in improving water use efficiency. Table 2 gives typical ranges of efficiency obtained with different on-farm irrigation techniques.

Table 2: Typical efficiencies for different types of irrigation techniques

Irrigation technique	Water use efficiency (%)
Furrow irrigation	30-50
Sprinkler irrigation	50-75
Drip	85-95

An important element to be taken into account in planning water resources management in conditions of high water scarcity is the concept of multiple use of water. The amount of water that is returned to the system after having been used varies greatly between sectors. Table 3 gives the average rate of effective consumption of water by sector (Margat, 1996) and the part of water which returns to the system (return flow).

Table 3: Typical consumptive use and return flow for the three major water use sectors (expressed in percentage of water withdrawal)

Sector	*Consumptive use (%)*	*Return flow (%)*
Agriculture	60-90	10-40
Industries	5	95
Cities	5-15	85-95

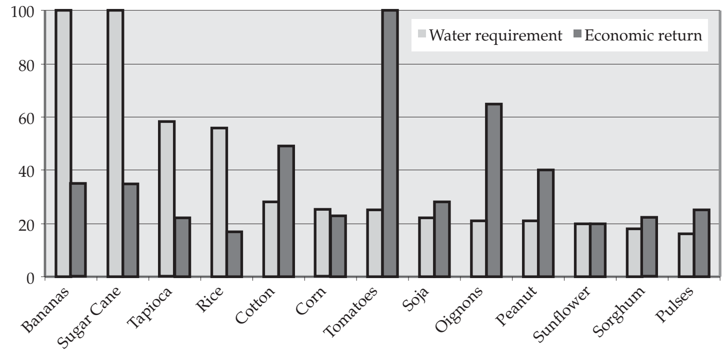
Agriculture is the largest net consumer of water, water being evaporated by the plants to produce biomass. Improved irrigation efficiency tends to lead to increased rate of consumptive use of water in agriculture. Instead, the industrial and domestic sectors are structurally very different from agriculture. Here, water is used for several purposes, including washing, which have a very low rate of effective consumption. Therefore, a large part of the water supplied to the cities is evacuated through the sewage system. Once treated, it is again available for other uses. This issue, and its relevance to agriculture, is discussed more in details in the next section of this paper.

Which unit of measure for water use efficiency in agriculture?

The hydraulic engineer concentrates his efforts in improving irrigation efficiency, be it at the level of the conveyance system or at farm level. He measures progress in terms of m^3/ha of water saved. The agronomist introduces a further step in measuring water use efficiency: he considers the yield of his crop and tends to measure water use efficiency in terms of tons of crop produced with a certain amount of water. Finally, the economist will introduce the concept of economic efficiency or water productivity in agriculture, in measuring the return

obtained from one m^3 of water, expressed in terms of added value of the agricultural production. This last concept finds its justification in the currently accepted idea that water has an economic value. In conditions of competition for water, it is the only way to measure the performance of agriculture and to compare them with other water use sectors. Figure 5 shows a comparison between water requirements and economic return for several crops in Tamil Nadu, India. It shows clearly that economic return and crop water requirements are not correlated. In regions where water is scarce and has a high value, one would tend to argue that the choice of farmers should be for crops having a low water requirement and high economic return.

Figure 5: Irrigation water requirement and economic return

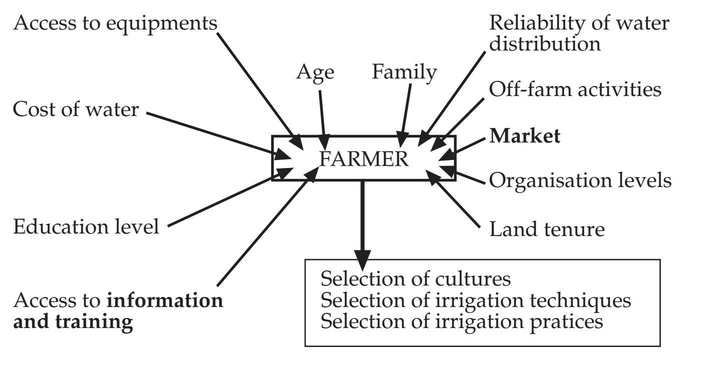


In such a situation, which finds its justification only in cases of water scarcity and severe competition for water, this issue of social and environmental *efficiency* would also deserve special attention. Indeed, in looking for increased productivity in agriculture, one would tend to underestimate the social and environmental costs of highly performing agriculture. Although these elements are particularly difficult to assess, they must be taken into account to ensure sustainability of the production process.

Factors influencing the farmer's choices in irrigation

The choice of crops, irrigation techniques and irrigation practices is not straightforward and depends on many constraints, which are presented in Figure 6. In conditions of high return crops, the market plays a crucial role in the farmer's decision. Access to information and education also plays a role in the choices he makes. The availability of the necessary equipment is also important, together with the access to credit. In addition, several other considerations (age, family, off-farm activities, land tenure, etc.) are taken into account in his decision making process. It is therefore important that any programme aiming at encouraging farmers to improve return from their irrigation water take due consideration of all these factors and proposes an integrated approach to the problem.

Figure 6: Driving forces influencing farmer's choices in irrigation



Conditions for a better return on water in agriculture

Figure 6 therefore shows that increasing water productivity in agriculture requires an integrated vision at all levels. At

the political level, there must be a clear signal from decision-makers that water productivity in agriculture is a priority target of the Government in the framework of the management of its water resources. At institutional level, engineers, technicians, agronomists and extensionists must all receive both the message and the means to address the issue in collaboration with the farmers' community.

The technological and technical aspects of the problem must also be addressed. First, farmers must receive a reliable water delivery service. This is of particular relevance in the case where private borehole systems have to be replaced, for instance, by treated wastewater delivery. As farmers will be requested to grow high return crops, they cannot afford any breakdown in water delivery that could endanger their harvest. Availability of water saving technologies in irrigation must also be secured (quality drip irrigation material) for the delivery of which the private sector plays an important role.

In terms of education, at least two aspects must be covered. On one side, farmers must be aware of the problem of water scarcity, of their role in reducing and degrading water resources, and on the other side, they must learn the ways by which they can help saving water and increasing its productivity in crop production. In particular, they need specialised technical assistance in the field of localised irrigation practices. Awareness raising and communication play an important role in farmers' education. In the early 1990's, the Government of Tunisia, in view of the country's increasing water scarcity, asked for FAO assistance in a large water saving programme in irrigation. The project, which lasted four years, targeted all the stakeholders of the irrigation sub-sector. It introduced a specific curriculum on water saving in the University courses for hydraulic engineers; it trained the hydraulic engineers, agronomists, and technicians in water saving techniques; it involved extensionists and farmers in water saving pilot demonstration projects, and it organized massive campaigns in the southern part of the country to help farmers acquire water saving equipment in irrigation. Finally, it also targeted the decision-makers at higher levels to ensure that adequate funding would be granted for this project.

Farmers' organizations also play a crucial role, both in their traditional fields related to the procurement of farm inputs and marketing, and in the issues related to common use of a shared resources. This is particularly relevant to countries like Malta where agriculture causes severe drawdown of groundwater levels resulting in seawater intrusion and salinization of the aquifers. The control of agricultural pollution is another major issue in which farmers' associations may be able to play a mitigation role.

Box 1: Increasing water productivity : an example from the Loukkos irrigation scheme, Northern Morocco.

In the Loukkos, located in Northern Morocco, FAO and the Government of Morocco have worked together in a project to increase productivity of water in irrigated agriculture. Several tests have been carried out by farmers on different irrigation techniques or practices. One test consisted in switching from sprinkler irrigation to localized irrigation for potatoes. On average, drip irrigation used 2.2 times less water than sprinkler irrigation, and resulted in a production 1.9 times higher. Agronomic return in water was therefore multiplied by 4.2.

In addition, discussions were held between the farmers and a local agricultural bank to test the method of warrantage. Warrantage is a way by which the production is stored in a warehouse after harvest, when prices are very low, in exchange for a short loan by the bank. When the farmer sells his production after a few months at a higher price, he pays back the loan. Such a method allows the farmer to obtain cash when needed just after harvest while still obtaining a fair price for his production. In the case of Loukkos, calculations have shown that the benefit could be multiplied by 2.

In conclusion, in this (extreme) case, a combination of technical and financial tools help raise the economic return in water by a factor 8.5.

Using treated wastewater in agriculture: an option

The use of treated wastewater is a viable option to increase water productivity in conditions of scarce water resources. Indeed, as indicated above, the return flow from cities is usually relatively high and, when treated, can be put again into beneficial use. The type of use that can be made of treated wastewater depends on the quality of the treatment, and of course, of the degree of scarcity of water. In most arid countries, treated wastewater is usually used primarily to water non-food crops. However, technology has reached a point by which any kind of crop can be grown using treated wastewater, as long as adequate control is set up. Guidelines for treatment of wastewater and water quality criteria for use in agriculture have been published and are widely available (FAO, 1985; FAO, 1992).

Treated wastewater can also be used for artificial recharge of aquifers and protection against seawater intrusion. However, the fact that it is used for artificial recharge does not mean that no control must be made on the quality of treated effluents. In extreme cases, wastewater reclamation can be used to supplement drinking water supply, be it through dual water distribution systems or, as it is now the case in Windhoek, Namibia, for drinking water purposes (Haarhoff and Van der Merwe, 1996). Such an example shows that a direct wastewater reclamation system is a practical way of augmenting potable water supplies in arid regions, but it requires comprehensive planning, training and on-going commitment for its success.

The case of Cyprus is a relevant example of programme aiming at promoting the use of treated wastewater in agriculture. The programme started in the 1980's and prepared a set of guidelines and a code of practice (see details in Appendices 1 and 2). The guidelines indicate the type of treatment necessary for each category of crop, and the code of practice indicates in details the procedures to be followed when using treated wastewater in irrigation.

Demonstration plots followed research in station during five years with farmers. The programme successfully demonstrated that safe production could be obtained for the different crops that were tested: Alfalfa, Sudax, and Corn. Indeed, in the case of Cyprus, a relatively conservative approach was chosen by which irrigation of leafy vegetables, bulbs and corns eaten uncooked is not allowed. The research programme also tested irrigation equipment and concluded that the most indicated on-farm equipment was drip irrigation, but associated with an effective filtering system to avoid clogging.

The option of systematic use of treated wastewater in agriculture is highly relevant to Malta: the country has limited conventional water resources, which are already over-exploited in many places, and the country intends to treat all its waste water within the next few years. Apart from establishment of norms and codes of practices, management and control mechanisms, a special effort will have to be made in communication (with farmers, mostly) to ensure that this source of water is no longer perceived as a source of danger but rather as an opportunity for increased water supply for agriculture.

Conclusion

Malta is an extreme case of water scarcity well indicated by its extremely high water use/conventional water resources ratio of 362%. The current situation of irrigated agriculture is unsustainable, as it contributes to groundwater drawdown and seawater intrusion, while also increasing

pollution of aquifers that are particularly vulnerable due to their mostly karstic nature. In view of the important competition for water resources with other sectors, but also between users in the agricultural sector, a comprehensive programme of improved water use management in agriculture needs to be set up.

On the supply side, such a programme should consider all possible sources of water, in which re-use of treated effluents from the cities would play an increasing role. The role of farmers' associations would be instrumental in mitigating groundwater degradation, both in terms of quality and quantity.

On the demand side, priority should be given to crops presenting a high return on water. The fact that these may be export crops is irrelevant, but care should be taken to ensure that environmental degradation due to excessive intensification will not translate into externality costs which would, in the long run, penalize the country's economy and its environment.

Finally, it is probably relevant to indicate that farmers in Cyprus are now paying full cost for desalinated water to irrigate potatoes, which represent an interesting external market for the country. This situation is probably an exception but it shows that high return crops in good market conditions can pay for water at high cost.

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APPENDIX 1

Cyprus guidelines for domestic treated effluents use for irrigation

Irrigation of:	BOD mg/L	SS mg/L	Faecal coliforms /100ml	Intestinal worms/L	Treatment required
All crops (a)	(A) 10*	10*	5* 15**	Nil	Secondary and Tertiary and disinfection
Amenity areas of unlimited access and vegetables eaten cooked (b)	(A) 10* 15**	10* 50*	50* 100**	Nil	Secondary and Tertiary and disinfection
Crops for human consumption. Amenity areas of limited access.	A) 20* 30**	30* 45**	200* 1000*	Nil	Secondary and storage > 7 days and disinfection, or Tertiary and disinfection.
	B)		200* 1000*	Nil	Stabilization - maturation ponds total retention time > 30 days or Secondary and storage > 30 days
Fodder crops	A) 20* 30*	30** 45**	1000* 5000*	Nil	Secondary and storage > 7 days or Tertiary and disinfection
	B)		5000*	Nil	Stabilization - maturation ponds total retention time > 30 days or Secondary and storage > 30 days
Industrial crops	A) 50* 70**		3000* 10000**	Nil	Secondary and disinfection
	B)		3000* 10000**		Stabilization - maturation ponds total retention time > 30 days or Secondary and storage > 30days

A Mechanised methods of treatment (activated sludge etc.)
B Stabilization Ponds
* These values must not be exceeded in 80% of samples per month. Min. No. samples 5.
** Maximum value allowed
(a) Irrigation of leafy vegetables, bulbs and corms eaten uncooked is not allowed
(b) Potatoes, beet - roots, colocasia
Note No substances accumulating in the edible parts of crops and proved to be toxic to humans or animals are allowed in effluent.

APPENDIX 2

Code of Practice for treated domestic sewage effluent used for irrigation in Cyprus

The sewage treatment and disinfection must be kept and maintained continuously in satisfactory and effective operation so long as treated sewage effluent are intended for irrigation and according to the license issued under the existing legislation.

Skilled operators should be employed to attend the treatment and disinfection plant, following formal approval by the appropriate authority that the persons are competent to perform the required duties, necessary to ensure that conditions of (1) are satisfied.

The treatment and disinfection plant must be attended every day according to the programme issued by the Authority and records to be kept of all operations performed according to the instructions of the appropriate Authority. A copy must be kept for easy access within the treatment facilities.

All outlets, taps and valves in the irrigation system must be secured to prevent their use by unauthorized persons. All such outlets must be coloured red and clearly labelled so as to warn the public that the water is unsafe for drinking.

No cross connections with any pipeline or works conveying potable water is allowed. All pipelines conveying sewage effluent must be satisfactorily marked with red tape so as to distinguish them from domestic water supply. In unavoidable cases where sewage effluent and domestic water supply pipelines must be laid close to each other the sewage or effluent pipes should be buried at least 0.5 m below the domestic water pipes.

Irrigation methods allowed and conditions of application, differ between different plantations as follows:

1. Park lawns and ornamental in amenity areas of unlimited access:
   - Subsurface irrigation methods
   - Drip irrigation
   - Pop-up, low pressure and high precipitation rate
   - Low angle sprinklers (less than 11 degrees)
   - Sprinkling preferably to be practised at night and when people are not around.

2. Park lawns and ornamental in amenity areas of limited access, industrial and fodder crops:
   - Subsurface irrigation
   - Bubblers
   - Drip irrigation
   - Pop-up sprinklers
   - Surface irrigation methods
   - Low capacity sprinklers
   - Spray or sprinkler irrigation, is allowed with a buffer zone of about 300 meters

For fodder crops, irrigation is recommended to stop at least one week before harvesting and no milking animals should be allowed to graze on pastures irrigated with sewage. Veterinary services should be informed.

3. Vines:

- Drip irrigation
- Minisprinklers and sprinklers (in case where crops get wetted, irrigation should stop two weeks before harvesting)
- Movable irrigation systems are not allowed

No crops should be selected from the ground

4. Fruit trees
   - Drip irrigation
   - Hose basin irrigation
   - Bubblers irrigation
   - Mini sprinklers

No fruits to be collected from the ground except for nut-trees. In case where crops get wetted irrigation should stop one week before harvesting.

5. Vegetables
   - Subsurface irrigation
   - Drip irrigation

Crops must not come in contact with the effluents. Other irrigation methods could also be considered.

6. Vegetables eaten cooked
   - Sprinklers
   - Subsurface irrigation
   - Drip irrigation

Other irrigation methods may be allowed after the approval of the appropriate Authority. Restrictions may be posed to any method of irrigation by the appropriate authority in order to protect public health or environment.

The following tertiary treatment methods are acceptable:

- Coagulation plus flocculation followed by Rapid Sand Filtration
- Slow Sand Filters
- Any other method which may secure the total removal of

helminth ova and reduce feacal coliforms to acceptable level. Must be approved by the appropriate Authority.

Appropriate disinfection methods should be applied when sewage effluent is to be used for irrigation. In the case of chlorination the total level of free chlorine in the effluent at the outlet of the chlorination tank, after an hour of contact time should be at least 0.5 mg/l and not greater than 2 mg/l.

Suitable facilities for monitoring of the essential quality parameters, should be kept on site of treatment.

John Mangion, Water Services Corporation

THE DEMAND FOR WATER BY THE AGRICULTURAL SECTOR IN MALTA

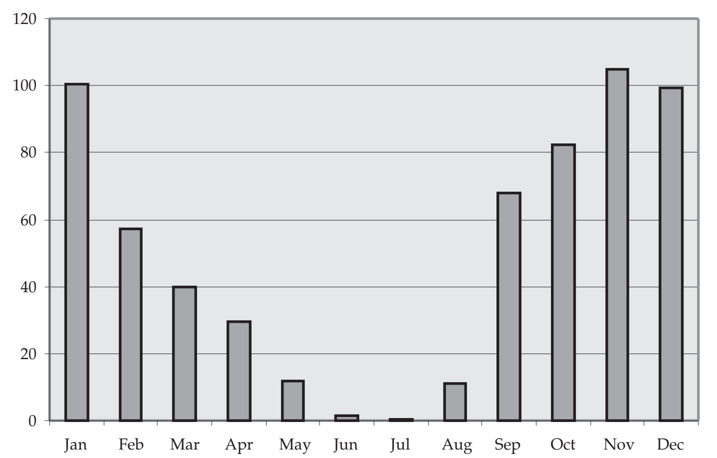
Introduction

The prosperity of agricultural development throughout civilisations has been historically linked to Man's ability to harvest water and use it rationally. Though statistics[1] for 1998 show that agriculture in Malta accounts for 2.7% of the gross domestic product, a growth of 39% has been registered between 1991 and 1998. Obviously this is not only due to technological improvements such as increased fertilisation and higher-yielding crop varieties but also to the growth of groundwater-irrigated agriculture during the last decade. This paper will briefly seek to address the issues concerning the supply of irrigation water in Malta and also the impact of agricultural activities on the quality and quantity of our natural water supplies.

Sources of Supply

Rain-dependent agriculture is practised in 95% of the arable land in Malta and Gozo.[2] The rainy season spreads from September to April with little or no rain during spring and summer, from May to August (fig. 1). While winter crops are rain-irrigated in abundant years, crops sown in spring are irrigated by means of groundwater or other non-conventional sources such as treated sewage effluent.

Fig. 1 Average monthly rainfall at Luqa Airport (1990-1999)



By far the main source of irrigation water is groundwater. The geology of the Maltese islands allows the formation of two types of aquifers, namely:

(i) Small and relatively shallow aquifers occurring in the Upper Coralline Limestone, perched on the Blue Clay aquiclude.

(ii) Deeper freshwater lenses in the Lower Coralline Limestone formation referred to as the mean-sea-level aquifers (MSALAs).

Summarily the main aquifer blocks are the Mean sea-level aquifer and six perched aquifers lying in the north-western region in Malta, and the Mean sea-level aquifer and seven perched aquifers scattered in Gozo.

Recent assessments of all groundwater resources show that the potential production capacity of groundwater reaches 22mm^3 per annum and 6mm^3 per annum in Malta and Gozo respectively. Around 70% of this potential capacity is attributed to the mean sea-level aquifers and the rest to the perched aquifers.

Water Demand

Metered abstraction by WSC, during 1998-1999, registered 16.14mm^3 in Malta and 2.41mm^3 in Gozo. It is well known that the bulk of this abstraction goes for municipal purposes, irrigation requirements being met by abstraction from a high number of private wells that are neither monitored nor controlled. In view of this it is rather difficult to arrive at an accurate figure of groundwater abstraction for irrigation. A census carried out in 1998 registers 800 new wells in addition to about 3000 existing ones, mostly claimed to be used for irrigation purposes, and all of which are not metered.

In these circumstances the planning and allocation of groundwater resources becomes rather arduous and difficult. An estimate of groundwater abstraction for irrigation purposes is therefore presented in this paper based on officially registered irrigation areas and the related irrigation requirements estimated from hydro-climatological and soil parameters.

Table 1 Net Irrigation Requirements according to Mitschoff

Month	**1st Crop**	**2nd Crop**	**3rd Crop**	**Net Weighted Irrigation Requirements m³/ha/month**
January	0	0	0	0
February	341	0	0	341
March	721	0	0	721
April	538	611	0	1149
May	50	1104	0	1154
June	0	1931	27	1958
July	0	2162	67	2229
August	0	1114	936	2050
September	0	512	1041	1553
October	0	0	608	608
November	60	0	393	453
December		0	103	103
Annual total				**12319**

Reference is made to the report by Joseph Mitschoff[3] "Upgrading and Modernisation of San Antnin Treatment Plant" where a calculation of crop water requirements was made for three seasons respectively with 30% cropping intensity as follows:

First Crop - planting in autumn and in winter
Second Crop - planting in spring
Third Crop - planting in summer

According to Mitschoff the net weighted irrigation requirements are those shown on Table 1 and an annual average of 12,319m^3/annum of water are required to irrigate one hectare of land.

Irrigated land

Results of a published census[4] of agricultural land, surveyed in 2000, show that more than 1100ha of land are claimed to be irrigated today. The greater part of this land is located in the Northern and Western districts, two localities where shallow groundwater is readily available from the perched aquifers. (Table 2). The figures for irrigated land in the south eastern district as published by the National Office of Statistics and those endorsed by the Ministry of Agriculture do not tally, as the latter claims 330ha of irrigated land against 170ha declared in the survey. This could be possibly due to incorrect declarations at the time of the survey to evade payment for water consumed, as this is charged in relation to the irrigated acreage owned by farmers. This discrepancy will not influence these calculations as the South Eastern district will not be taken into account for reasons explained further on.

Table 2 Distribution of Agricultural Land

Agricultural Land

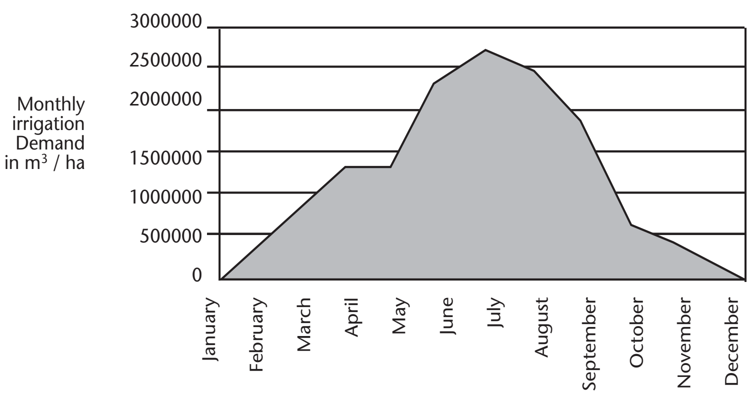
Districts	**Total**	**Irrigated**	**Dry**	**Wasteland**
Northern	2601.533	417.342	1826.737	1826.737
North of harbour	349.741	79.092	241.588	241.588
South Eastern	1960.909	139.514	1579.941	1579.941
South of harbour	523.773	120.524	360.351	360.315
Western	3528.716	303.83	2731.062	2731.062
Gozo & Comino	1748.993	87.109	1473.309	188.765
	10713.665	**1147.411**	**8212.988**	**6928.408**

Table 3. Estimated Groundwater Abstraction for Irrigation Purposes

	Net Weighted Irrigation Requirements m^3/ha/month	Northern District	North Harbour District	South Eastern District	Southern Harbour District	Western District	Gozo Comino	Total Require. (m^3/month)
Area (ha)		417	79	139	120	303	87	1147
January	**0**	0	0	0	0	0	0	0
Febraury	**341**	142313	26970	47574	41098	103606	29704	391265
March	**721**	300903	57025	100589	86897	219061	62805	827280
April	**1149**	479525	90876	160301	138482	349100	100088	1318372
May	**1154**	481612	91272	160999	139084	350619	100523	1324109
June	**1958**	817155	154862	273168	235985	594899	170559	2246628
July	**2229**	930255	176296	310976	268647	677237	194166	2557577
August	**2050**	855551	162138	286003	247074	622851	178573	2352190
September	**1553**	648132	122829	216665	187173	471848	135280	1781927
October	**608**	253743	48087	84824	73278	184728	52962	697622
November	**453**	189055	35828	63199	54597	137635	39460	519774
December	**103**	42986	8146	14369	12413	31294	8972	118180
	12319							14134956
Total daily net requirements								38725.91

Estimated GW abstraction = Total daily net requirements - irrigation requirements for south eastern district 37,439m^3/day

Fig. 2. Monthly fluctuations of irrigation demand.



Estimated Groundwater use for Irrigation

On the bases of Mitschoff's studies, the annual water requirements to irrigate all the declared irrigation areas amount to 14mm^3 per annum (Table 3 and fig.2). It is reasonable to assume that irrigation requirements of the South-Eastern district are met by the production of treated effluent from the San Antnin sewage treatment plant, while all others are obtained solely from groundwater sources. Therefore the estimated utilisation of groundwater for irrigation purposes in Malta and Gozo amounts to 12.5mm^3 per annum (37,000m^3/day).

As previously explained the global productive capacity of our aquifers is around 28mm^3 per annum – a figure that is less than the *sum* (31mm^{3}per annum) of metered groundwater abstraction by WSC (18.5mm^3) and the estimated abstraction to meet irrigation demand in Malta and Gozo (12.5mm^3). In this context, therefore, groundwater abstraction today is exceeding natural replenishment while that used for irrigation is estimated to *take up 40% of the total productive capacity of the aquifers.* With the information available to date it is not yet possible to apportion this abstraction to the different aquifer blocks found in the Maltese islands. More investigations are needed in this respect.

Impact of Agriculture on Groundwater Quality

Agriculture affects the aquifers in two ways.

1) First, the success of crop production is partly the result of improving growth and overcoming crop disease from pests with the help of sophisticated agrochemicals

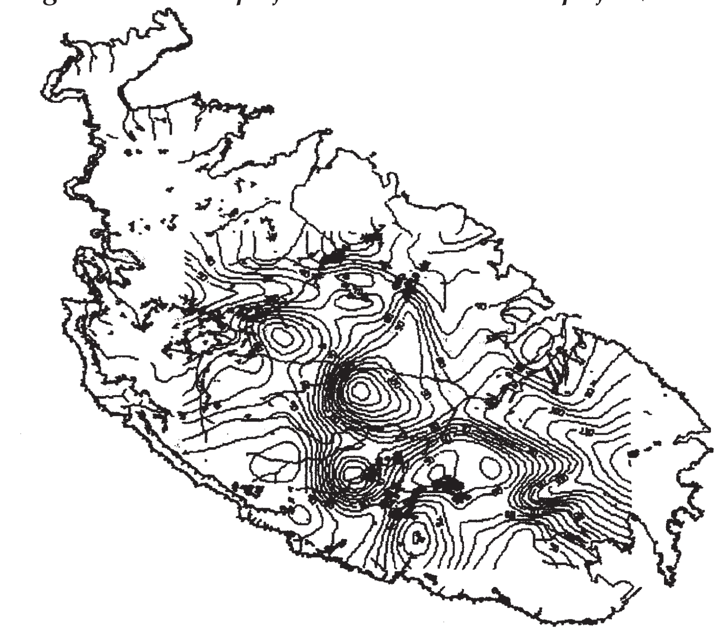
and fertilisers. Obviously the massive application of fertilisers and pesticides deplete groundwater quality with time. Nitrates are a very common problem and are particularly pronounced in the perched aquifers as these lie unconfined in important agricultural districts. In a few areas, nitrates have reached levels that forced a complete shutdown of galleries and pumping stations. Springs are being sparingly used due to high nitrate levels and sporadic bacterial contamination especially after heavy storms. The Bingemma aquifer has depleted in nitrate quality since the development of a greenhouse complex within its catchment, while the Mgarr aquifer will be soon decommissioned from the public supply unless treated for nitrate removal.

The mean sea-level aquifer is also showing alarming nitrate levels (fig. 3) in the majority of abstraction points. Enough evidence is available to correlate high nitrate areas with intensive agricultural land-use. Recent studies for the designation of nitrate vulnerable zones in compliance with EU Directive 921/676EEC were carried out by WSC. Nitrate data series covering four years were analysed and regression trend lines formulated. By projecting forward these trends it was seen that nitrate values in the mean sea-level aquifer are steadily increasing and will increase even further in 10 years time, if left unchecked. Two sample trend lines are shown in figures 4&5.

2) The second impact of agriculture on groundwater quality is derived from animal farming practices. As animal husbandry has today shifted away from a traditional barnyard practice to intensive animal-breeding, the effect of pollution from animal wastes increased consequently. Most of the livestock breeding farms are not equipped with proper disposal facilities

that enable either treatment or disposal of manure and animal slurries. As such, cow-sheds, pig-farms and poultry farms are a constant threat and induce conspicuous point sources of nitrate pollution. Though many of these farms are today maintained impeccably hygienic, *inside*, to avoid the propagation of disease and also improve product quality, the same cannot be said regarding the observance of good practice for the disposal of farm wastes. Cesspits often leak, while manure is left to accumulate in open fields throughout the rainy season thus leaching through the relatively thin soil layer into the aquifer. The locality of Zebbug/Siggiewi, well known for the presence of large pig-breeding farms, happens to have the highest nitrate levels in the mean sea-level aquifer.

Fig.3. Nitrate Map of the Mean Sea Level Aquifer (Malta)



The correlation between farming and nitrate levels has been recently tested in the mean sea-level aquifer. An underground gallery 3km long and lying at an average depth of 90m below the ground, was surveyed this year by taking samples every 100m for nitrate analysis. The gallery spans from Ta' Kandja (Mqabba) to Ta' Bakkja (Zebbug) crosses beneath a quarry zone and the inhabited area of Siggiewi.

The nitrate profile (fig.6) of the gallery revealed a peak of 120mg/l that coincided with an area of disused quarries. On further investigation it transpired that leachates were reaching the gallery from livestock farms that are located inside and around these qaurries. Nitrates below the urbanised area are relatively low, but increase again as the gallery proceeds further north towards Ta' Bakkja, due to crop agriculture on the flanks of Wied Hesri.

Fig.4 Nitrate Trend at Bakkja Pumping Station

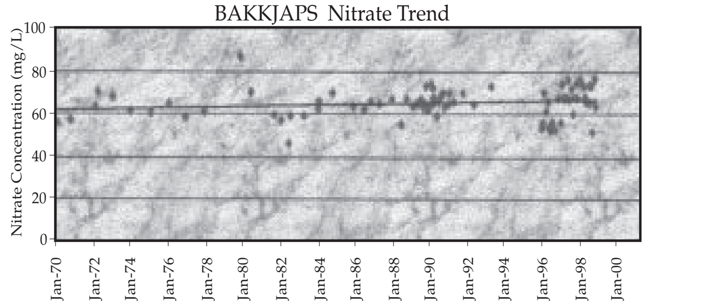


Fig.5 Nitrate Trend at Bingemma Pumping Station

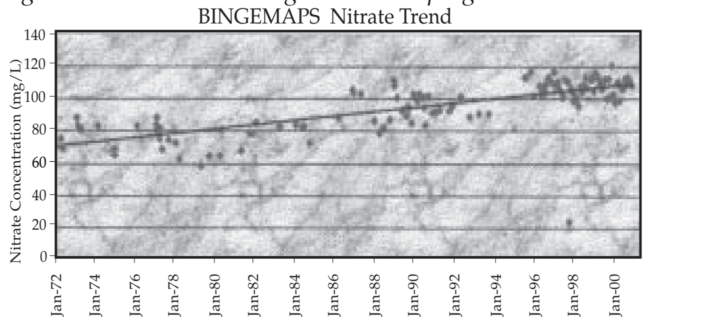
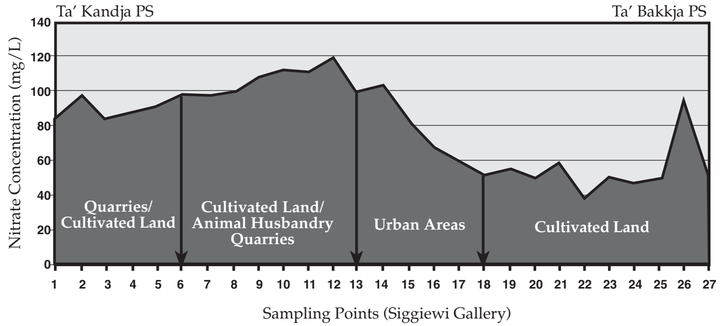


Fig.6 Nitrate profile along Siggiewi gallery and land-use details



Use of non conventional sources - Treated Sewage Effluent

Treated Sewage Effluent (TSE) offers an economic alternative provided that its application to irrigation schemes is treated with caution and in full consideration of public health issues.

In principle, any type of application involving the infiltration of TSE in the ground, as in the case of irrigation or artificial, is constrained by:

- hydrogeological conditions
- the quality of the effluent,
- cost of treatment.

The degradation and/or elimination of microbiological pollutants from surface infiltrations depends on travel time through the unsaturated zone and on retention in the aquifer before abstraction. Our aquifers are geologically composed of fractured karstic limestone having a high permeability, and are moreover unconfined and highly vulnerable to surface pollution.

The absence of a sufficiently thick soil cover reduces further the possibility of filtering or eliminating organic contamination. Surface infiltrations therefore travel in a relatively short time directly from the surface into the aquifers through numerous faults and fissures that intersect the rock strata. Purification in these circumstances is minimal if non-existent. Repeated pollution incidents at Tal-Hlas galleries and the springs, recorded immediately after a spell of heavy rainfall, are ample proof of this.

Recent assessments of aquifer vulnerability define the aquifers as vulnerable in most places and highly susceptible to pollutants released at the ground surface. These studies were based on hydrogeological parameters that have a direct influence on the downward movement of fluids from the ground into the aquifer.

Another point for consideration is the relatively short lag time between recharge and discharge. Due to limited land area it is physically impossible to apply TSE on irrigation areas that are sufficiently distant from abstraction points. Practice in other countries imposes a retention time in the aquifer from six to twelve months before abstraction for secondary purposes - in these conditions groundwater utilised for human consumption.

From a hydrochemical point of view, TSE used for surface irrigation must be of a superior quality than the aquifer beneath the point of application. Tertiary treated effluent with a higher salinity than that of the aquifer will obviously increase salinity levels of natural waters if used for irrigation within the aquifer recharge area. Our aquifers are known to be depleted and irrigation with TSE should be diligently applied so as not to increase further salinity, other contaminants such as nitrates, or even worse introduce substances/organisms that carry ill effects to

public health. Viruses are a serious point of concern - an opinion also shared by the Ministry of Health.

In view of the aforementioned considerations, it is desirable to utilise, tertiary treated TSE exclusively in those areas where flow gradients in the acquifer are directed towards the shoreline, and where groundwater quality is known to be poor and not exploited for potable purposes.

Use of TSE for irrigation in small aquifer blocks

Four agricultural areas are earmarked as test sites where TSE (once available) can be safely applied for irrigation and gradual reinstatement of severely depleted aquifers. Land in these localities is considered to be suitable for irrigation with TSE as the aquifers are heavily overpumped, polluted, and not used for drinking purposes. These are the acquifers at Cirkewwa (310ha), Qammieh (184ha), Pwales (141ha) and Burmarrad/Maghtab (728ha), all of which are detached from each other and from the mean sea-level aquifer south of the Victoria line.

The common factor in all these localities is the intensive agriculture being practised, necessitating consistent supplies of irrigation water. As groundwater is the only source available, it has been heavily overexploited with serious salinisation consequences. Moreover intense fertilisation has increased nitrate levels to over 200mg/lt in some instances.

A supply of TSE in these localities will not only improve agriculture by providing more water for reclamation of wasteland, but will also improve quality of groundwater of these small isolated aquifers.

Conclusion

Groundwater is considered to be a strategic resource of fresh water but there is not enough that can meet the needs of our community. Hence we must adopt an approach whereby we can overcome our natural climatic constraints and concurrently succeed in providing cost-effective supplies of water that can meet the specific needs of various sectors of the economy. A sustainable framework needs to be developed that addresses quality and quantity constraints in an integrated fashion, by recognising the impact of land-use on the sustainable management of natural water resources. A new legal framework is required to apply concepts of priority of use over natural water resources and regulate the management of groundwater in an integrated manner. The present state of affairs is not sustainable and we believe that future regulation should lead to a more rational utilisation that is socially fair, acceptable and respects environmental constraints and public health standards.

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3 *Upgrading and Modernisation of San Antnin Sewage Effluent Irrigation System*. Prepared by Haiste International Ltd based on the work of Dr. Josef Mitschoff

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NATIONAL REGULATIONS FOR GROUNDWATER: OPTIONS, ISSUES AND BEST PRACTICES

Introduction

Groundwater is in general a high-value resource and is especially important as a source of drinking water. In Europe, for instance, 75 percent of drinking water supplies come from goundwater sources, with peaks of up to 98 percent in Denmark. In the United States, groundwater is the source of approximately 50 percent of all drinking water, and 97 percent of that used by the rural population. Although in many countries the most important use of groundwater is for drinking water supply, in other countries or regions other uses may dominate. In Australia, for instance, groundwater accounts for only 14 percent of water use. However, it is an important source of irrigation water and as a water supply for livestock. In India, 50 percent of the water which is used in irrigation comes from under the ground. Groundwater is also important in maintaining the flow of rivers (known in hydrologic parlance as "base flow") in dry periods and in contributing to the water balance of lakes and wetlands.

The sustainable management and use of groundwater resources as a source of drinking water supplies, for irrigation and for other consumptive uses as well as a supplementary source of surface river flows and of wetlands and wildlife habitants calls for increasing attention to two major and interdependent sources of concern, namely, *depletion* and *pollution*. The former is linked to the extraction and use of groundwater, the latter to the contamination of available groundwater supplies from point and non-point (or diffuse) sources. To the extent that either or both (depletion and pollution) threaten the long-term viability of available supplies and the sustainability of their development and use and may become, as a result, the source of social tension and conflict, the legal systems have been prompted to respond with a view to defusing such tension and the potential for conflict. National regulation of groundwater extraction and use and of polluting activities has largely - but not entirely - supplanted private legal remedies available to injured plaintiffs. The comparative review and analysis of available national groundwater legislation illustrate the choice of mechanisms - regulatory and otherwise -, or options, available to the lawmakers in the framing of responses to the challenges posed by groundwater depletion and pollution. The same review and analysis show at the same time emerging trends or a crystallization of best practice approaches, and disclose the issues which available options and emerging best practises raise.

This paper will review and analyze national legislation believed to be representative of the available choice of mechanisms or options and illustrative of emerging best practices and attendant issues. It is worth nothing that the countries whose legislation has been reviewed for the purposes of this paper are representative of a variety of climates - from humid England to arid Niger - and of different legal systems, notably, common law and civil law.

Regulation of well drilling and of groundwater extraction

2.1. Private ownership of groundwater

Traditionally and in accordance with basic principles of Roman law, groundwater has been regarded at law as the property of the owner of the land above. Countries following the Napoleonic Code tradition, as well as countries following the Anglo-Saxon Common law tradition, equally subscribe to the same principle. The Moslem tradition, instead, regards water as a public or communal commodity, a gift of God which cannot be owned. Only wells can be owned, whereby exclusive or priority user rights in the water accrue to the well-owners. Furthermore, the ownership of wells entails ownership of an area around the well in which new wells cannot be dug (known as *harim*, or forbidden area).

Private ownership of land and of groundwater under it entails the accrual of un-restricted enjoyment and user rights, including the right to prospect on one's land for the resource, and to extract and use it, limited only by the equal rights of the neighbouring landowners. If conflicts erupt between adjoining landowners, the disputes are settled through formal and informal mechanisms, notably in the courts of law. Inasmuch as they apparently are meant to react to conflict, these traditional rules of groundwater ownership and use are increasingly at odds with the growing pressure on finite and fragile stocks of resources brought about by the growing demand for good quality water from competing sectors of economic and social development and well-being. To make matters more worrisome, ever more sophisticated, potentially destructive drilling and extractive technologies have become available. Already in reaction to these threats, the

American courts tried to put some fetters on the landowners' un-restricted groundwater withdrawal privileges by imposing a reasonableness requirement on groundwater extraction and use. Under the rule, the landowner is only entitled to use as much water as can be reasonably consumed on the overlying lands. Waste of water and use on non-overlying lands is prohibited. Still, the doctrine allows landowners to withdraw and use groundwater in whatever quantities they need for reasonable and beneficial purposes until the underlying groundwater supply is exhausted. It does not restrict the landowner to the use of a particular quantity of water nor does it guarantee the landowner that the groundwater supply under his land will be preserved from depletion by the withdrawals of others.

2.2. From private ownership to regulation: scope of regulation

The challenge nowadays is to *prevent* expensive and time-consuming conflict or to minimize opportunities for it and, at the same time, to ensure that groundwater reserves are (a) directed to the uses society - or the public - value the most and (b) conserved for future use. In response to this challenge, legal systems, particularly but not exclusively in water-short countries, have increasingly brought the digging and drilling of boreholes, the construction of wells and the extraction and use of groundwater resources under the direct control of the Government. As a result, if one wants to dig or drill bores to prospect under one's own land - or under somebody else's land - for groundwater, the government must be first approached and a permit or authorization obtained from it, subject to terms and conditions. Groundwater pumping tests may also attract separate permit or consent requirements, as under the

legislation of England and Wales.[2] Equally if, following successful tests, one wants to construct a well and put it into production and start extracting and using groundwater, the Government must be first approached and a permit, licence, concession or the like instrument obtained from it, subject to terms and conditions.

For ease of administration, regulatory restrictions and requirements tend to be relaxed in relation to the digging of bores and wells by hand and/or up to a maximum depth, and to the domestic and other household needs. The relaxation can consist of a total waiver of permit or other similar requirements (under the legislation of England and Wales, domestic abstractors of groundwater extracting up to 20 cubic metres per day are totally exempted from licencing requirements, with thought being given to extending the waiver to extractions for any purpose). Under the recently (end 1998) amended legislation of Niger, the extraction of groundwater for whatever do not exceed 40 cubic metres per day.

2.3. Follows: the transition from private ownership to regulation

The governmental assertion of control of groundwater prospection, extraction and use rests on the public property status accruing to groundwater from the statutory vesting of the resource in the public domain of the State (this is the approach reflected in the legislation adopted in Spain and in Italy, respectively, in 1985 and in 1994); or from the statutory vesting in the State of superior user rights (this is the approach followed by the state of Victoria (Australia) as reflected in the Water Act of 1989); or from the statutory vesting in the State of a public trust in the resources on behalf of the people, as reflected in South Africa's 1998

National Water Act; or from the pronouncements of the courts of law, as with the "public trust" doctrine developed by the courts in the Western United States after the declaration of the Supreme Court that the land underlying navigable waters is owned by the states. A critical issue arising in this connection is whether the former owners of groundwater are entitled to compensation from the Government for what could be construed as a taking of constitutionally protected private property rights. Court challenges on these grounds have been experienced in Arizona and New Mexico (United States) and in Spain, in reaction to legislation which vested all groundwater resources in the State and divested landowners and well owners of private ownership rights in groundwater. The challenges and the attendant compensation claims, however, have been consistently rejected by the United States courts and by the Spanish Supreme Constitutional Court alike, and the new legislation upheld, essentially on the grounds that such vesting was justified by the superior common good pursued by the legislation and that reasonable mitigating measures had been provided for in the legislation to militate the impact of the vesting provisions on landowners and well owners.

As a result of groundwater being public property - or being held by the State in trust for the public -, only user (or usufructuaty - type) rights accrue to the owners of overlying land - or to the developers of the resource, if other than the landowners. Such rights are granted by Government (sometimes by the courts, as in some Western states of the United States), following appraisal by Government of an application, and subject to terms and conditions. Among these, terms and conditions as to the duration of the right and as to the quantity and rate of extraction play a critical role in regulating groundwater use. Of note in regard to the former, Iowa (United States) legislation restricts the duration of groundwater extraction permits to less than ten years if the aquifer capacity is uncertain. Of note in regard to terms and conditions regarding extraction, Arizona's (United States) groundwater regulator affirmatively limits the amount of groundwater which can be used by each class of water user. Furthermore, that state's legislation sets the maximum *water duty* or allotment on each farm, based upon the crops historically grown and assuming increasingly stringent measures for the efficient application of irrigation water such as lining irrigation canals and using laser leveling fields.[3]

Groundwater rights obtained from the Government (or from the courts) are granted subject to loss for non-use of the water, for failure to comply with the law in general and with the terms and conditions attached to the right in particular, or if the water needs to be re-allocated to some other use and to another user. In this particular case, however, compensation is payable to the user who is dispossessed of his water right - through no fault of his. Rights are also subject to review, and to variation or adjustments downwards by Government if the circumstances so warrant. Also in this case, compensation is payable to the user on account of the diminution suffered in his right. [4] Rights can also be suspended as a penalty for non-compliance, or in emergencies, in neither circumstance compensation being payable for the damage the right holder may suffer.

The appraisal of an application for the grant of a groundwater extraction permit or the like instrument plays a critical role in the informed allocation by Government of available groundwater resources. The determinations of water resources plans, if available (see below), and the views and objectives of affected water users and of other legitimate affected interests, will provide valuable parameters for the appraisal of applications - in addition, of course, to the data and information on record. Increasing recourse is also being made in this regard to formal Environmental Impact Assessment (EIA) requirements of applications. Under European Union legislation (Directive) adopted in 1997, from March 1999 an EIA will be required of all proposed groundwater extractions giving rise to significant environmental effects as defined in the relevant Directive. Similar requirements had been introduced in France by the 1992 Water Act in respect of water abstraction projects in general, and are being contemplated, also in regard to water abstraction projects in general, in Spain under the guise of amendments to the 1985 Water Act.

Recourse from Government's decisions on applications and on existing permits is generally available before the courts of law or the Government itself.

2.5. Regulations of groundwater "mining"

Where the circumstances of groundwater extraction and use result in the accelerated depletion of the resource - known also as groundwater "mining" - the legal systems tend to respond through legislation providing for the establishment of control areas or districts where stricter regulatory restrictions become applicable or where the mechanisms described above, un-available elsewhere on account of paramount constitutional limitations, become available inside the declared areas or districts. In Texas (United States), for instance, permitting, well spacing and setting extraction limits, all un-available in principle due to that state's subscribing to the rule of private ownership of water by the owner of the land above, become available

inside areas which have been declared Groundwater Conservation Districts. Restrictions, however, are not mandatory as most of the districts which have been established have worked to get landowners to implement conservation measures voluntarily through educational programmes and by providing data on available supply, annual withdrawal, recharge, soil conditions, and waste. In Wyoming (United States), where groundwater extraction and use are governed by prior appropriation, "control areas" can be established where new applications for new groundwater extraction permits are no longer granted as a matter of course, but may be approved only after surviving a string of tests, hearing and reviews. The control area mechanism is provided for by the legislation in force in the majority of the Western states of the United States. In Spain, among several other amendments to the 1985 Water Act the Government is contemplating, one in particular to provide for the declaration by the competent River Basin Authority of groundwater mining areas wherein (a) the Authority may restrict groundwater extractions until (b) a plan for the recovery of the aquifer is made and adopted. The plan will regulate groundwater extraction, including the replacement of individual extractions and of the relevant rights for a "communal" extraction and right.

2.6. Regulations of the well drilling trade

In addition and as a complement to the digging and/or drilling of bores, the construction of wells and the extraction and use of groundwater, also the exercise of the trade of well-driller tends to attract regulatory restrictions meant to scrutinize the professional competency of the individuals performing well drilling operations. This is so in most

Western states of the United States,[5] in Kenya, in The Philippines, in Oman, in Jamaica. With a view to strengthening the provisions laying down professional licensing requirements for well drillers, New Mexico (United States) legislation requires one to contract with duly licensed drillers only.

Charging for groundwater extraction and use

Charging for water abstraction in general, and for the extraction of groundwater in particular, seeks to influence the demand for water and constitutes the chief non-regulatory mechanism available to control water abstraction and use. It is generally practised in combination with the regulatory mechanisms described above. In Belgium, charges are levied on the extraction of groundwater for purposes other than drinking water, with the revenue accruing to a fund for the protection of groundwaters. Belgium is one of the few countries that makes no differentiation in the charge level according to the type of use: still, the charge varies according to the volume extracted. In France, water abstraction charges vary according to volume, area, location and source - with groundwater extraction being charged at 2 to 3.5 times higher than surface water abstractions. Also in Germany charge rates vary according to use and tend to be higher for groundwater extraction. In the Netherlands, a groundwater extraction charging mechanism has been in effect since 1995, with the revenue used in part to fund research into developing groundwater policy plans and the remainder paid to the Finance Ministry as part of general taxation. In England and Wales, no charges are levied on groundwater extractions of 20 cubic metres a day or less for agricultural

purposes. All other groundwater extractions are charged and the proceeds from all water abstraction charges are used to cover the costs to the Government of performing its function of water custodian. The levels and rates of charges are set accordingly and ostensibly do not seek to influence the behaviour of water abstractors. In the state of Arizona (United States), a tax is levied on all users of groundwater according to the volume which is consumed. The proceeds from this tax are directed to purchasing existing water rights and retiring them from use, to conducting water augmentation programmes and to sponsoring research on water conservation.

Controlling pollution of groundwater

4.1. From private law remedies to statutory law

Historically, private remedies have been utilized to address water pollution in general, and groundwater pollution in particular. Tort concepts involving negligence, nuisance and strict liability have been resorted to by injured plaintiffs, in Common law and Civil law countries alike, to seek compensation for the damages suffered as a result of groundwater contamination. These remedies continue to play a role in providing redress for groundwater pollution. However, they are available only after pollution has occured, and their successful fruition by injured plaintiffs is not without difficulty. Furthermore, it is very difficult to clean up an aquifer once it is polluted. Because of this and also of the proliferation of the sources of pollution and of their heightened pollutive potential, the legal systems virtually everywhere have been emphasizing the prevention of new pollution and the gradual abatement of existing pollution through the enactment of water pollution control legislation. With specific regard to groundwater pollution, the available legislation tends to reflect any one or any combination of the following approaches: (a) regulation of the discharging of waste water and other wastes on and under the ground, (b) charging for these same activities and/or (c) regulation of land use. The first two are used in connection with pollution of groundwater from "point"-type sources of pollution, notably industrial outfalls and the outfalls of municipal sewerage systems. The third approach has been resorted to address the "diffuse" pollution from underground storage facilities and from above-ground waste dumps and landfills, and to address pollution from "diffuse"-type sources, notably the runoff and drainage of pesticides and fertilizer-laden cultivated land.

4.2. Prevention and abatement of point-source pollution

Government permits, licenses or authorizations to discharge wastes on or under the ground, including into groundwater acquifers, subject to terms and conditions as to, notably, the composition and quality of the effluent being discharged and the treatment required prior to it being discharged are the hallmark of most regulatory legislation in effect. However, direct discharges into groundwaters can be forbidden outright, particularly if the discharge involves dangerous substances. A two-track system combining permits and strict prohibitions has been adopted already in 1979 by the European Union, with mandatory effect on all Union member countries. Belgium, however, has gone further and banned altogether all direct discharges into groundwaters.

4.3. Prevention and abatement of diffuse pollution

Admittedly, the most insidious threat to groundwater, particularly in the long run, comes from the leakage and percolation under the ground of substances stored or handled in factories, other facilities, waste dumps or landfills; and from percolation under the ground of the runoff and drainage of cropland carrying pesticides and fertilizers. The former threat tends to attract licencing and monitoring requirements in respect of the siting of waste dumps (as, for example, under a statute adopted to this specific effect already in 1982 by Italy). A contemporary statute adopted by the Swiss Confederation restricts the siting, construction and operation of designated facilities handling liquid substances which may adversely affect water resources in general. Under such statute, the Cantons (or states of the Swiss Confederation) are to zone their respective territory into four different classes of water protection areas, calling for restrictions of increasing severity. In more recent times, under a statute - technically, an amendment to the 1959 Water Rights Act - adopted in 1997 by Austria, most landfills will require a permit under the 1959 Act. The operator must provide adequate security, in particular he must provide for future precautionary measures. If the precautions taken prove insufficient the Government may impose additional or other requirements. In extreme cases, the disposal of waste can be suspended temporarily or the landfill can be even closed. Furthermore, the Government may appoint a monitoring body at the expense of the licence holder. This (the licence holder) must submit annual reports indicating the type, quantity and origin of wastes deposited in the preceding year and the results of his monitoring programme. In Spain, among several other amendments to the 1985 Water Act being contemplated by the Government, the River Basin Authorities would be empowered to declare an area experiencing groundwater pollution or the risk of it as a "protected aquifer area". In such areas, the Authortiy's prior consent will be required for the siting of facilities, the extraction of inert materials or any other activity potentially impairing the quality of the water underground.

Cultivation practices have been increasingly attracting regulatory restriction aimed at preventing, abating or minimizing pollution of groundwater from, in particular, nitrates employed in agriculture. At the end of 1991 the European Union has adopted legislation directing member states to designate nitrate-sensitive (or nitrate-vulnerable) areas and to draw up a code or codes of "good agricultural practice". Within the designated areas, the provisions of such code or codes become mandatory for the effected farmers. A delicate issue, raised by the farming community in England and Wales, has recently arisen in connection with the designation of nitrate-vulnerable area. In the challenge before the courts of law to the designation of specific areas under the Union legislation, the farmers plaintiff have contended that it is unlawful for the Government to designate an area wherein non-agricultural sources contribute to pollution from nitrates. The case is significant in that it raises two fundamental issues of environmental protection law as this has evolved in the last twenty-five years, namely, (a) the legitimacy of precautionary measures taken in conditions of scientific uncertainty; and (b) the causation link and the proper relationship between environmental protection and economic - in this case, farming - interests. In the event, the court declined to rule on the issue as it hinged on the interpretation of Union legislation and referred it to the European Court of Justice.

Outside the European Union, the application of animal manure is strictly regulated by statute in, for instance, Estonia.

Other mechanisms and approaches for the controlled development and use of groundwater and for their protection from pollution

5.1. Planning

In response to the growing concern for the long-term viability of available water resources, countries around the globe have been resorting to planning as a preferred mechanism for informed, forward-looking and participatory decision making in regard to the management and development of water resources in general, including their protection from pollution. While the legislation regulating the water resources planning process does not provide separately for groundwater planning, the acquifer can be signed out as the basic ambit of groundwater planning, on a par with the hydrographic basin. This is so in France, for instance, where the 1992 Water Act introduced and regulated a complex water resources planning system based on General Water Plans (*Schémas directeurs d'aménagement et de gestion des eaux:* SDAGE) covering one or more basins, and on Detailed Water Plans (*Schémas d'aménagement et de gestion des eaux:* SAGE) covering one or more sub-basins or an aquifer. With specific regard to the latter, a number of SAGEs are under preparation, covering designated aquifers. The aim of these instruments in preparation is, in general, the reservation of good-quality groundwater to the satisfaction of the drinking water needs of the population, or the appointment of the available groundwater to the competing user groups on a quota basis. A distinctive feature of the Fenech water planning system is the participation of civil society in the formation and adoption of the plans. Another salient feature is the binding effect of planning determinations on governmental water abstraction and groundwater extraction permitting. In other words, if a groundwater extraction permit is granted by Government which is at variance with the determinations of a SAGE or also of a SDAGE, it can be challenged in the courts of law and quashed. This has actually been done in connection with the grant of a permit for the extraction of groundwater for industrial use from an aquifer which the relevant SDAGE (for the Seine-Normandie region) had reserved for drinking water use. The decision was quashed by the court and the permit withdrawn. As a French commentator has put it, the planning instruments available under the French legislation constitute the "best tool for the conservation and protection of aquifers which is available under French law". Also in Texas (Unites States), legislation passed in 1997 instituted a complex water planning system at regional and at the state level and gave the planning determinations a binding effect which they did not use to have under previous legislation. As a result, actions by, among others, the Groundwater Conservation Districts must conform to the adopted plans. However, as noted earlier, the regulatory authority of such Districts - and of Government outside such Districts - in relation to groundwater extraction and use is severely restricted by the prevailing Common Law rule of capture. As a result, the impact of planning determinations on the allocative decisions made by the landowners is speculative at best.

5.2. Users' participation in decision making

The participation of concerned water users in the making of decisions which effect them is widely seen and practised

as an effective vehicle to build support for, and eventual compliance with, unpopular decisions. The water resources planning mechanisms and processes briefly recalled above all provide ample opportunities for water users' participation in the formation and adoption of plans, directly and through their elected representatives to the committees tasked accordingly. Under the 1997 Texas (United States) legislation, Regional Water Planning Groups consisting of, among others, representatives of a wide variety of water users' categories, are to prepare and submit to the state Government a Regional Water Plan for their area. In the French water planning system, the SAGEs are formed and adopted by an ad hoc Local Water Commission one-fourth of whose members consist of representatives of water users. Water users participate also in the adoption of the SDAGEs through their one-third share in the membership structure of the Basin Committees (Comités de bassin).

Users' participation is further fostered by legislation governing the direct involvement of water users in the management of groundwater resources in areas which experience particular problems, notably, accelerated groundwater depletion (also known as groundwater mining) and/or severe groundwater pollution. In Texas (United States), Groundwater Conservation Districts, traditionally formed on petition and vote by effected property owners, tend now to be formed also at Government's instigation of a property owners' election to create a district in so-called "critical areas", i.e., areas experiencing overdraft, insufficient supply, or contamination, based on studies conducted by Government. As noted earlier, whereas these Districts have varied powers including permitting, well spacing and setting the amount of withdrawals, most of them have deferred to the rule of capture and have not imposed mandatory restrictions on the effected landowners' rights to pump and on the amount of water extracted. Most have opted, as a result, for voluntary self-restraint and educational programmes. In Spain, the proposed amendments to the 1985 Water Act mentioned earlier provide, among others, for the compulsory formation of Water Users' Groups from among the users of an aquifer, in particular when the aquifer is, or is at risk of becoming, overexploited (see 2.5 above). These groups are to share in the groundwater management responsibilities of the River Basin Authorities and, in particular, in the management and policing of groundwater extraction rights.

5.3. Conjunctive use of surface and underground water resources

The term "conjunctive use" of surface and groundwater has several different meanings but basically stands for maximizing the beneficial use and economic benefits of both surface water and groundwater through coordinated use. Methods include augmentation of supplies, allocation of costs, groundwater recharge and storage of surface water, and the coordination of rights reflecting the interconnection between the two kinds of sources.

The western states of the United States apply the rule of prior appropriation to interconnected surface and groundwater. As a result, priorities of rights to the use of interconnected waters are correlated and subject to a single set of priorities that encompasses the whole common water supply. In practice, new permits can be refused in the area, permissible total withdrawals can be apportioned among appropriators or curtailed in their withdrawals, the extraction and use of groundwater can be subjected to a rotation system and well spacing requirements can be introduced for new wells. In Texas, under legislation passed in 1997, irrigators using groundwater can move return flows to natural surface streams and divert and use such flows downstream, without fear of losing their water as a result of appearing to "abandon" it. A Government permit to do so is first required, and the amount of return flow available for reuse will be subject to carriage losses in transit as well as any amounts needed by existing appropriators of the return flow. In both California and Arizona water users may store excess water underground when there is surplus flow available. The water is recharged underground subject to call or trade when needed. In addition, Arizona law allows any person to carry out groundwater recharge projects in return for groundwater recharge credits, under the likes of a groundwater "banking" mechanism. These credits may either be used by the recharger or sold to other water users. Arizona law further allows a person to deliver water directly to a farmer to be used by that farmer in lieu of water he would have pumped from under the ground (known as "in lieu recharge"). This effectively leaves in the ground water which the farmer would have pumped. The "in lieu" recharger receives groundwater credits which again can be used by the recharger or traded.

Under Jamaica's 1995 Water Act, interconnected surface and underground water resources can be dealt with as a single source of supply for the purposes of granting new abstraction licenses and curtailing existing licenses, within designated "emergency areas". The amendments being contemplated to Spain's 1985 Water Act reflect a conjunctive use approach in respect of the expanded brief of the River Basin Authorities to implement plans and programmes for the integrated development of surface and groundwater resources; and in respect of the establishment of Boards for the Joint Development of Interconnected Surface and Groundwaters, with water users having a majority share in the relevant membership structure. In England and Wales, where current legislation attracts groundwater recharging within the scope of water abstraction licensing, thought is being given to de-regulation by replacing the licensing requirements with simpler and more expedient consent requirements.

Conclusions

The comparative analysis of the groundwater legislation passed in recent times in different countries suggests that groundwater is fast losing the intense private property connotation it has traditionally had and that user rights in it no longer accrue from ownership of overlying land but from a grant of the Government or of the courts. The public domain status of groundwater underpains the usufructuary nature of individual groundwater rights and the authority of the Government to grant such rights. Vested private property rights in groundwater need to be accommodated by new legislation, with the available case law suggesting that compensation claims are most unlikely to succeed. Regulated rights in groundwater provide the regulator with the flexibility needed to adjust allocation patterns to changing circumstances, to restrain the mining of groundwater and to practise the conjunctive use of surface and underground water, without detracting from the security of tenure which is desirable for investment decisions. Control of waste water discharging on or under the ground, and control of land use practices are the keys to preserving the quality of groundwater from degradation - and the available stocks from irreversible total loss. Groundwater planning mechanisms and users' participation in decision making play a key role in the

success of legislation and, in particular, in reconciling the diversity of circumstances in the field with the uniformity of legislation provisions. In the last analysis, groundwater legislation need not be seen as solely prescriptive or restrictive of individual behaviour - or purely regulatory in scope. Not only can it, as a complement to regulating, seek to influence the behaviour of groundwater users through non-regulatory measures, notably charging. Legislation can also be enabling in scope and purpose, i.e., it can aim at regulation and other measures in incremental fashion and provide for the building blocks of such incremental approach, notably, the assessment of the resource and planning its development, conservation and protection from pollution; the provision of stand-by authority for the Government to experiment with designated regulatory and non-regulatory mechanisms as and where the circumstances so require; and the participation of groundwater users in the making, implementation, administration and policing of regulatory and non-regulatory decisions.

References

1 Paper prepared for the World Bank Seminar on *Groundwater*: Legal and Policy Perspectives, Washington, D.C., 19 April 1999. The opinions expressed are the author's and do not engage or purport to engage the Organization.

2 The dewatering of quarries tends also to attract regulatory requirements. Requirements to this effect have been proposed for introduction in the legislation of England and Wales.

3 The Groundwater Management Act, 1980, contains a further

provision that beginning twenty years after enactment of the Act in 1980, the Department of Water Resources may reduce the highest 25 percent of water duties by up to 10 percent.

4 This principle, sanctioned by the 1991 Water Resources Act of England and Wales, has been the subject of a recent non-judicial test involving the Government-initiated downwards variation of a groundwater extraction licence which was threatening the ecology of a river. In the event, however, the test did not address the issue of compensation.

5 Such as New Mexico, where it is unlawful to drill a well without a licence and the State Engineer is empowered to determine the necessary qualifications for the grant of a licence.

6 In the United States in general, regulations qualifying the exercise of the trade of well driller, and regulations making it unlawful for a contractor to contract with an unlicensed well driller, have been upheld as a legitimate exercise of the police power of Government.

7 The Netherlands, Denmark and Germany have opted for the whole of their territories to be subject to the mandatory controls specified in the Union legislation. In France, about one-third of the country has been classified as Nitrate Vulnerable Zone. According to some commentators, the United Kingdom has taken a more conservative approach and a much smaller area of the country than anticipated has been designated pursuant to the Union legislation.

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EU FRAMEWORK DIRECTIVE ON WATER POLICY

Introduction

This paper seeks to present, in outline, the EU Framework Directive on Water Policy (the Framework Directive),[2] and discuss its main features. The discussion below is an elaboration of a presentation on the subject by the author during the APS workshop on 'Water and Agriculture in a Competitive Environment' held in Valetta on 23 February 2001.

The Directive recently entered into force on the day of its publication in the Official Journal on 22 December 2000. It will have a major influence on the government framework for, and approach to, water management in the EU member States as it sets quite specific standards on the institutional and legal framework for water resources management.

For ease of reference, the Directive can be viewed on the internet: (**http://europa.eu.int/eur-lex/en/lif/dat/2000/en_300L0060.html**). The page also contains links to other directives referred to below, and a search engine using keywords or the Official Journal numbers that are included in the references.

Purpose of the Directive

The purpose of the Directive (art. 1) is to establish a framework for the protection of inland surface waters, transitional waters, coastal waters and groundwater, which:

- prevents further deterioration and protects and enhances the status of aquatic ecosystems;
- promotes sustainable water use based on a long-term protection of available water resources;
- aims at enhanced protection and improvement of the acquatic environment;
- ensures the progressive reduction of pollution of groundwater and prevents its further pollution;
- contributes to mitigating the effects of floods and droughts.

These objectives are to contribute to:

- the provision of the sufficient supply of good quality surface water and groundwater as needed for sustainable, balanced and equitable water use,
- a significant reduction in pollution of groundwater
- the protection of territorial and marine waters;
- achieving the objectives of relevant international agreements, including those which aim to prevent and eliminate pollution of the marine environment.

It thus appears that the rationale for the Directive tills towards protecting the environment and in particular aquatic ecosystems, though considerations of water quantity are put forward as well. Earlier EU legislation has tended to regulate water quality with a view to protecting consumers, be it for bathing or for drinking water purposes,[4] later followed by Directives that specifically targeted the

protection of water from pollution.[5] The current Framework Directive again highlights protecting the aquatic environment as the main objective for intervention, yet water quantity considerations come into view for the first time, linked to environmental concerns but also with a view to ensuring the long term abstraction and use of water.

Outline of the Directive

The Framework Directive in essence provides for the establishment of a river basin approach to water resources management in both its qualitative and quantitative aspects. Specifically it provides for:

- the identification of individual river basins and their designation as River Basin Districts for the purposes of the Directive;
- the designation of a Government agency responsible for the management and administration of the Districts;
- environmental objectives for surface and ground waters;
- River Basin Plans that are to be prepared for each District;
- certain measures that need to be taken in implementing the river basin plans (basic measures and supplementary measures);
- methods of analysis for the river basin districts;
- deadlines for Member States for the implementation in various stages of the Directive.

Establishment of river basin districts

Article 3 prescribes the identification of river basin districts and the designation of competent authorities for the districts. In identifying river basins, member states may combine smaller basins to a larger grouping of basins. With respect to groundwater aquifers, these should be assigned to the most appropriate (surface) river basin in case the acquifer boundaries do not coincide with the extent of the river basin. The Directive does not refer specifically to groundwater aquifers as river basins in case surface waters are irrelevant, as might be the case in Malta. It may be assumed, however, that the same rule would apply to the identification of groundwater aquifers, and that groupings of aquifers may be designated as one river basin district where appropriate.

In addition, Member States will need to ensure the appropriate administrative arrangements, including the identification and designation of an appropriate competent authority for the application of the rules of the Directive within each river basin district. This competent authority may be either a new government institution or an existing body.

Environmental Objectives

Article 4 provides for the main environmental objectives with both surface waters and groundwaters. The objective is to achieve 'good surface water status' and 'good groundwater status' within 15 years after the date of entry into force of the Directive. Member states shall implement the measures necessary to prevent or limit the input of pollutants into groundwater and to prevent the

deterioration of groundwater bodies. Member states shall further protect, enhance and restore all bodies of groundwater, and ensure a balance between abstraction and recharge of groundwater, with the aim of achieving 'good groundwater status'.

Good groundwater status is defined in detail in Annex V-2 of the Directive, and includes indicators and parameters for groundwater levels (quantitative status), and the chemical status of groundwater. In conjunction with Article 8 (Monitoring of surface and groundwater status), the Annex further specifies detailed rules on the establishment, operation and interpretation of a monitoring network to determine the status of groundwater.

Analysis of river basin districts

The Directive seeks to establish a systematic approach in achieving the environmental objectives. It thus prescribes, in article 5, that the various characteristics of each river basin district be determined in accordance with the Directive. This analysis shall include its hydrological and geographical characteristics, a review of the impact of human activity on the status of surface waters and groundwaters, and an economic analysis of water use. Annexes II and III prescribe the technical specifications that shall be applied in analysing the river basin districts. The analysis and reviews must be completed four years after entry into force of the Directive.

Programmes of measures

To achieve the environmental objectives of the Directive, each member state is held to establish a 'programme of measures' for each river basin district. This programme should take the prescribed analysis into account, i.e. on the physical characteristics, economic use and the impact of human activity, and shall consist of 'basic' measures and 'supplementary' measures.

Basic measures are the minimum requirements to be complied with, and these include measures under existing EU legislation 6 and generally measures that promote an efficient and sustainable water use in order to avoid compromising the objectives in the directive. It further specifies a number of 'controls' that member states should have in place which prescribe for each Member State to put into effect the basic regulatory controls over water abstraction and water pollution. The list is exhaustive and the most important measures are:

- controls over the abstraction of fresh surface water and groundwater, and impoundment of fresh surface water, including a register of water abstractions *and a requirement of prior authorisation* for abstraction and impoundment;
- controls, including a requirement for prior authorisation, of artificial recharge or augmentation of groundwater bodies
- a requirement of prior regulation for point source discharges liable to cause pollution, or other means of regulation;
- measures to prevent or control the input of pollutants causing diffuse source pollution.
- a prohibition of direct discharges of pollutants into groundwater. The Directive mentions seven cases where direct discharges may be authorised, provided these do not compromise the achievement of the

environmental objectives of the Directive.

Supplementary measures include all those measures that are taken in addition to the basic measures that contribute to the achievement of the objectives.

River basin management plans

River basin management plans shall be prepared for each river basin district - within nine years of entry into force of the directive. The plans should be reviewed at least every six years. The plans may be supplemented by more detailed programmes that address sub-basins, sector issues or water type to deal with particular aspect of water management.

Member States are to encourage, in general, public involvement in the implementation of the Directive. Specific rules are formulated to ensure the participation of the public at large for the preparation of river basin plans.

Annex VII of the Directive specifies the content of the plans. The twelve-item list contained in the Annex essentially includes the physical status of the river basin, a description of the pressures on the water bodies, and a summary of the measures that are taken in accordance with article 11, the article prescribing the programme of basic and supplementary measures.

Other Provisions of the Directive

Apart from establishing the basic regulatory and institutional framework for water management, the Directive further contains articles on cost recovery for water services (article 9), a combined approach for point and diffuse sources of pollution (article 10), strategies against pollution (article 16), and strategies to prevent and control pollution of groundwater (article 17). The latter two articles oblige the European Commission to adopt specific measures in order to achieve the objectives of the Directive.

Article 9 lays down the principle of cost recovery for water services, and the polluter-pay principle. Member States shall take these principles into account, and the river basin plans must report the progress made in this respect. By 2010, Member States must ensure that water-pricing policies provide adequate incentives for users to use water resources efficiently, and thereby contribute to the environmental objectives of the Directive. In addition, Member States shall ensure an adequate contribution of the different water uses, disaggregated into at least industry, households and agriculture, to the recovery of the costs of water services.

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1 Legal Officer, Food and Agriculture Organization of the United Nations (FAO). This paper does not necessarily reflect the views of the Food and Agriculture Organization.

2 Directive 2000/60/EC of the European Parliament and of the Council of 23 October 2000 establishing a framework for Community action in the field of water policy, Official Journal L 237, 22/12/2000 P. 0001.

3 Council Directive 76/160/EEC of 8 December 1975 concerning the quality of bathing water, OJ L 031 05.02.1976 p.l.

4 Council Directive 75/440/EEC of 16 June 1975 concerning the quality required of surface water intended for the abstraction of drinking water in the States, OJ L 194 25.07.1975 p.26. (see also Council Directive 79/869/EEC of 9 October 1979 concerning the methods of measurement and frequencies of sampling and analysis

of surface water intended for the abstraction of drinking water in the Member States, OJ L 271 29.10.1979 p.44).

5 Council Directive 76/464/EEC of 4 May 1976 on pollution caused by certain dangerous substances discharged into the aquatic environment of the Community, OJ L 129 18.05.1976 p.23.

6 These are: The Bathing Water Directive 76/160/EEC; The Birds Directive 79/409/EEC; The Drinking Water Directive 80/778/EEC as amended by Directive 98/83/EC; The Major Accidents (Seveso) Directive 96/82/EC; The Environmental Impact Assessment Directive 85/337/EEC; The Sewage Sludge Directive 86/278/EEC; The Urban Waste Water Treatment Directive 91/271/EEC; The Plant Protection Products Directive 91/414/EEC; The Nitrates Directive 91/676/EEC; The Habitants Directive 92/43/EEC; The Integrated Pollution Prevention Control Directive 96/61/EC.

7 This could also include the mere registration of discharges, but in that case the registration should be subject to generally binding rules. See article 11 (3)(g)

PROFILE OF AUTHORS

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Mr. Burchi is currently Senior Legal Officer in charge of water legislation with the Development Law Service, Food and Agriculture Organization of the United Nations (FAO) in Rome, Italy. He joined the Service in 1983, where he has held posts of increasing responsibility. In his legal advisory capacity to Governments on water legislation matters, he has undertaken field advisory missions to several countries in Asia, Africa and Latin America. From 1979 to 1983, he served in a legal advisory capacity with the then United Nations Department of Technical Cooperation for Development (UNDTCD) in New York City.

Mr. Burchi is author of some thirty published legal papers and articles on the subject of water law. In particular, he is, the author of FAO Legislative Study No.52 on "Preparing national regulations for water resources management: principles and practice" (1994).

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