AN OVERVIEW OF IRRIGATION SYSTEM PERFORMANCE ON THE ISLAND OF MALTA

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SUMMARY – The island of Malta has a typical Mediterranean climate with an annual precipitation of circa 500mm spreading over the October to March period. The semi arid environment has always provoked the indigenous population to develop and adopt techniques that would maximise water harvesting and distribution efficiency. Within the nine year span (1991-2000), the agricultural land in Malta decreased by an estimated 1,164 hectares, reaching a total land base of 10,738 hectares. Despite this loss, the National Statistics Office registered an increase of 420 hectares in irrigated land. This could be interpreted as 1) water availability has increased or 2) efficiency in water distribution has increased. Furthermore, protected cropping through the use of greenhouses and cloches equipped with drip irrigation systems are now increasing in use and popularity. The use of treated sewage water was a key factor in stimulating agricultural development in the south region. Irrigation efficiency may be measured using a variety of indicators, such as: area under irrigation, amount of produce marketed, volume of water storage, and deterioration of ground water resources. A review of irrigation under a Maltese context is presented.

Key words: irrigation systems, irrigation water management, irrigation efficiency, Malta.

INTRODUCTION

Scarcity of available fresh water was always a matter of everyday concern in Malta. Efforts in attempting to secure access to water can be traced back to 3,000 BC . The Misqa Tanks, a system of dug out water cisterns complemented with a network for rainwater collection, supplied drinking water by gravity to the underground Mnajdra temples (Schembri 2003).

During the 200 year reign, the Arabs had a significant influence on the Maltese language and agriculture. They introduced the technique of dry-stone wall construction and new crops such as carob, olive, citrus, figs and cotton. Although not many records from this era exist, a quick glance at the surrounding Maltese landscapes made of stepped terraces is an immediate assessment of the prevalence of agriculture. These new settlers had a good understanding of how to conserve and manage scarce water supplies. They are accredited for introducing irrigation methods, or at most improved upon the local methods used during the Roman or earlier periods and adapted them to suite their new products and systems of agriculture. Water harvesting machines like the norija, or waterwheel were also introduced.

Irrigation, defined as the supply of water to land or crops is based on the assumption that water is readily available for irrigation. Under situations of water scarcity, the concept of efficient irrigation systems should have a holistic approach, and address primarily efforts that secure water availability, and then deal with the efficiency of water deliverance. This approach will be adapted in reviewing the situation in Malta. The objective of this paper is to present a review of the development of irrigation techniques and to discuss irrigation efficiency in Malta

MALTESE NATURAL WATER RESOURCES

Since Malta has no permanent body of surface fresh water, the natural percolation of rainwater through the porous limestone rock and its accumulation in aquifers renders it as the sole natural fresh water resource. The Semi Arid nature is characterised with hot, dry summers and mild, wet winters having an average annual precipitation of 530mm (highly variable from year to year). An estimated 70% falls within the six month window October to March, summer account for only 1.5% of the total rainfall (Bowen-Jones *et al.,* 1961). Precipitation is stored within the soil fraction and ultimately seeps down into the aquifers. An estimated 16% to 25% of the annual rainfall infiltrates to recharge the aquifers (Morris, 1952; Newbery, 1968; Chetcuti, 1988; Chetcuti *et al.*, 1992).

The Main Sea-Level Aquifer consists of a lens of freshwater floating on denser saline water in Coralline Limestone rock formation at sea level. It is the largest body of fresh water reserve in Malta. Other aquifers of importance are the Perched Aquifers, consisting of rainwater trapped in the permeable Upper Coralline Limestone due to the underlying layer of impermeable Blue Clay. Wherever the Upper Coralline Limestone/Blue Clay interface is exposed, water leaks giving rise to springs. Apart from desalination of sea water, aquifers form the only source of large natural fresh water bodies. Groundwater is exploited for municipal and industrial use and by farmers and others for irrigation and industrial purposes. Half of the water used for municipal supply comes from the aquifer, whereas the other half comes from the four seawater desalination plants.

The limited natural supply of water is a significant restriction on the productivity of the Maltese agriculture sector. The efficient and effective management of water resources that are available to farmers is therefore essential.

Water budget

Table 1 Crude water balance in Malta (inches)

	August	September	October	November	December	January	February	March	April	May	June	July	Total
Precipitation	0.2	1.1	3.1	3.6	3.8	3.5	2.2	1.6	0.9	0.4	0.1	0	20.5
ET potential	6.7	4.8	3.0	1.8	1.4	1.3	1.2	1.9	2.7	3.8	5.1	6.7	40.1
Moisture surplus			0.1	1.8	2.4	2.2	1.0						7.5
Moisture deficiency	6.5	3.7						0.3	1.6	3.4	5.0	6.7	19.6

Adapted from Bowen Jones et al., 1961

The water balance is essentially the relationship between requirements as expressed by potential evapo-transpiration and the availability of water from precipitation. From the above table it can be seen that annual potential evapo-transpiration exceeds annual precipitation by nearly 100%. A moisture surplus of 7.5 inches from October–February is offset by a total deficiency of 19.6 inches during the remaining seven months. Unless sources of supplemental irrigation water are available, this moisture deficiency is a significant limiting factor to crop production.

Rainfall during the month of October provides moisture when demand is relatively low, i.e., when rate of plant growth is at its slowest. Conversely, when the potential for plant growth is high, natural moisture is almost completely absent. Thus supplementary watering is a must to ensure decent crop performance and yields.

The erratic rainfall patterns have motivated the development of techniques to lessen the dependency on rain fed agriculture. The National Statistics Office estimates that irrigated land is increasing and currently stands at 1,143 hectares (10.7% of agricultural area). The incentive to irrigate is considerable. The value of production from irrigated land is on average at least 3.5 times that from dry land farming. In the case of potatoes, the net economic return from irrigated land may be up to 20 times higher than that from the same area under rain fed forage wheat production.

Cropping patterns

Rain fed agricultural crops are either planted prior to the October rains and watered artificially until adequate natural moisture is available, or sown mid-way through the rainy season when soil moisture is available. Under such cultivation methods a single crop is possible in all but the driest of years. Traditionally, these areas follow a 4-year rotation. Year 1: potatoes or onions, Year 2: cereals, wheat or barley. Year 3: legumes such as Sulla (Hedysarum coronarium) as a fodder crop and Year 4: potatoes or onions.

In areas with year round access to irrigation water, three crops per year are possible. Although such areas are limited, the adoption of appropriate technologies has led to an increase of irrigated land by 420 hectares during the period 1991-2000 (Table2). Irrigated land lends itself to the intensive cultivation of fruits and vegetables such as new potatoes, salad crops, tomatoes, artichokes etc. This type of farming has grown with the development of tourism to meet the demand for fresh high value food.

In an increasingly competitive market, access to irrigation will become more and more important in producing the necessary yields and product quality required to secure an adequate economic return for Maltese farmers, especially those full-time farmers whose livelihoods depend solely upon agriculture. Furthermore, the provision of good water quality will be essential for the diversification of agriculture into higher quality products or value added crops such as cut-flowers and organically-grown vegetables.

Table 2 Land classification 1980-2000 (in hectares)

	1980		1986		1991		2000	
	Dry	Irrig	Dry	Irrig	Dry	Irrig	Dry	Irrig
Malta	9520	458	7958	627	8454	681	6964	1054
Gozo	2289	32	1920	37	1544	42	1505	89
Total	**11809**	**490**	**9878**	**664**	**9998**	**723**	**8469**	**1143**

Adapted from National Statistics Office

IRRIGATION PRACTICES AND IRRIGATION SYSTEMS IN MALTA

Evidence of early irrigation systems

The linguistic contribution of the Arabs concerning irrigation works and irrigation farming may lead one to presume that the names of a number of localities bear witness to the extent of irrigation that was carried out (Jaccarini 2002). Places carrying names like *Saqajja, Saqwi* or *Habel is-saqwi* may give evidence as to the adoption of some sort of organised irrigation system. Other reference to water include *Bir* (well or water cistern), *Menqa* (water enclosure), *Nixxiegha* or *Ghajn* (spring), *Qattara* (trickling water) and *Ilma* (water). The fact that these place names are of Arabic origin coupled with the discovery of a number of earthenware pipes during constructions of the Wignacourt aqueducts, give sufficient evidence that water resources were well exploited well before the time of the Knights.

Irrigation Water Harvesting

The ultimate aim of water harvesting is to address water shortages in such a manner that would offer an alternative source to the unreliable rain water supply and to store water not only to overcome seasonal variations but also periods of drought.

Natural spring water harvesting

The first most probable and simple technique was the channelling and collection of free running spring water into reservoirs. Evidence shows that Maltese agriculture was based on: 1) rain fed agriculture, 2) the use of irrigation channels, 3) storage systems situated in combination with water catchments areas and 4) natural springs. In areas where the impervious layer of Blue Clay outcrops beneath the Upper Coralline Limestone, water is caught directly from spring lines and used to irrigate arable land, other courses are diverted into collecting cisterns or large capacity reservoirs.

Surface runoff water harvesting

The next technique employed addressed the maximisation of water capture from surface runoff together with the adaptation of various systems for water distribution (Jaccarini 2002). The heavy early rains very often exceed the soil water holding capacity. The excess water discharges through the retaining rubble walls (the absence of mortar allows excess water to drain off easily). Closely related to these perimeter walls other dry stone construction (rain culverts or tunnels) allow water to flow freely on the rock substratum beneath the soil, minimising soil erosion and preventing pressure from building up against the walls.

A crude system of surface runoff harvesting by water diversion is still widely used by farmers. The *sieqja*, *qangha* or *ilquh*, is a creative, practical and effective system. It is a make shift device in the form of a small directional water dam consisting of either rolled up pieces of sack cloth secured by means of a stone chips; or moulded out of cement. Set strategically downhill just beyond an entry point and at an acute angle to the soil retaining walls, it will divert rainwater towards the field. If set at an obtuse angle it will achieve the opposite effect and deviate water away.

Groundwater harvesting

The Arabs could have possibly been responsible for the introduction of a water lifting device the *Sienja*. Driven by a draft animal, a number of buckets draw up water from a deep artesian well fed by horizontal galleries which collect water from the groundwater table. Water is stored in a reservoir and distributed to the field via rock-cut channels.

Storage systems

Considerable amount of runoff water that would have otherwise been lost is diverted into underground reservoirs. These large cisterns, dug beneath fields and excavated out of solid rock were roughly hand-hewn in the shape of an inverted cone. They were usually coated with a rendering of puzzolana, a volcanic ash-lime mixture which formed good hydraulic cement (Hughes 1956). These larger reservoirs were used for supplementary irrigation. These large wells are marked either by a stone well-head (*Horza*) or by a type of well-head kerb. This second type is a two sided pillar rise seven or eight courses above a plain box-like *herza* to support a slightly curved or rectangular monolith lintel from which hangs the chain block for hosting the water bucket. Another and more basic contraption which works on the same principal is the *gabja*; two poles meeting at an angle to which a pulley is attached to draw up bucket of water from the well (Jaccarini 2002). A total of 9,069 reservoirs and wells were recorded during the last Census and more than half were constructed before the 1975.

Irrigation water distribution

Many well heads can be seen in the countryside, usually adjacent to large irrigation reservoirs or raised stone water tanks (*hawt*) from which water could flow down into several winding u shaped conduits or *swieqi* for distribution. When necessary, the flow of water in some of these channels could be diverted by blocking it at certain crucial points with a stone plug or *maksar*. Though largely superseded by the electricity powered pump, this old gravity driven system of water distribution through stone culverts is still utilised in some regions of the Maltese islands especially on slopes where courses flow from fresh water springs.

Fine tuned irrigation

The above review clearly shows that the inhabitants of Malta ranked natural water management high on their list of priorities. Within reason one can also understand that most of the techniques employed were simple and worked on the principle of runoff water deviation, channelling and collection down stream, all with the help of gravity. These efforts were matched with the science of irrigation management vis-à-vis crop production.

Dr Alain Blondy (2003) outlines the history, economic and diplomatic relevance of the Maltese orange during the 18th century. He also dwells into the agronomic aspects of this industry and gives detailed information on the cultivation and irrigation. While emphasising the importance of soil moisture, he goes on to say that water has to be as tepid. In summer, the trees were watered by spring water that had previously lied stagnant for a few days in open *gwibi* (above ground water cisterns). Trees were watered in the first days of June, as soon as the temperature reached 25°C. This process was repeated every eight or ten days, until September. In summer, watering was done between sunrise and sunset, in autumn only in the mornings.

Water lifting devices

Besides utilising stored rainwater, farmers sometimes tapped the water table by digging manually a vertical shaft or *spiera* some 15m down into the rocks and then pumping water up to the surface from an underground reservoir. The old, traditional way of raising water above ground by means of a donkey driven water wheel or chain pump (*sienja* or *norija*) became obsolete many decades ago and the once popular wind powered American water pump though still being exploited by some farmers has been largely superseded by the more efficient electric pump.

Electrifying the countryside is probably the single most significant factor contributing in one way to an improvement and in another to the deterioration in irrigation system efficiency. The feasible energy source coupled with cheap reliable electric pumps have put at the hands of the farmer enormous water lifting potential. A significant increase of irrigation pumps was evident in the post 1994 years, with 2,790 being purchased since then, representing 48% of all irrigation pumps installed. As expected, these pumps were concentrated mainly in the western and northern districts where irrigated agricultural land is more predominant than in other districts. Thus it is no surprise that the ever ingenious Maltese farmer has focused in tapping into the ground water resource leading to a gradual increase in total area classified as irrigated land. The availability of abundant water at the push of a button has resulted in two significant issues.

1. The ease of access to fresh water at relatively low cost has had a snowball effect in that more farmers are tapping into ground water and more is being used (even for non-agricultural use), leading to the gradual deterioration of this reserve.
2. Furthermore, this comfort has led to the slow but steady degeneration of old but proven techniques of rain water harvesting.

PERFORMANCES OF IRRIGATION SYSTEMS

Irrigation Inefficiency

Notwithstanding the fact that many farmers have invested heavily on irrigation systems, mainly drip and sprinkler irrigation, there are still practices which lead to inefficiencies in irrigation water use. These can be divided into two main categories: 1) inefficient system setup and 2) inappropriate irrigation practices.

Irrigation system setups inefficiencies are mainly the results of lack of technical know how. Poor designs fail to take into account pressure losses along the system leading to uneven distribution. The incorrect layout of the system (especially sprinklers) can also lead to uneven distribution and water losses beyond the field boundaries. This is a common occurrence since fields are small and of irregular shape. Omission of accessories from the system due to ignorance, financial restrictions or trial and error affects the overall performance of the system. A common scenario is the complete elimination or the use of an inappropriate filter for a drip system (groundwater looks clean), resulting in clogging of drippers. Pressure gauges, when installed, are neglected. Lack of know how is apparent when irrigation systems and equipment used are not suitable for the size of the field, type of soil and crop. Using cheap material or excessive recycling of certain items coupled with lack of maintenance of the system can lead to inefficiencies (clogged emitters, dirty filters and leaks).

Unsuitable irrigation practices are also the result of lack of information on crop-water requirements, soil moisture properties and evapo-transpiration. Inefficiencies in this regard are due to a number of issues. The lack of basic data lends itself to application rates resulting in surface ponding and runoff if high capacity drippers are used on clay soils and on the other extreme, deep percolation if low capacity drippers are used on sandy soils for a long time. The absence of soil moisture monitoring and/or irrigation scheduling, results in guesstimated decisions on when and how much to irrigate. Irrigation scheduling is very primitive, usually based on past experiences. Over irrigation during the early stages of growth when the root zone depth is shallow, results in excessive evaporation from the wetted soil and deep percolation. Evaporation could be reduced with the use of mulch, but deep percolation cannot be stopped. The lack of irrigation expertise is reflected in the fact that most farmers irrigate on a time base and choose to completely ignore the water volume aspect. Irrigation in windy conditions or during the hottest hours of the day results in significant losses due to evapotranspiration. All this coupled with the improper selection of crops according to water availability and water salinity create a complex system that is far from the ideal situation with regards to efficient water use.

Irrigation Water Management

There are three potential sources of irrigation water:

A) Storm and rainwater collected in underground cisterns or surface reservoirs with capacities from 100-2,000m^3. Although this water collection may seem relatively insignificant, it is very important at a local level for the irrigation in the absence of rainfall during critical growth periods in spring and summer.

B) Presently, the most common source of irrigation water is the extraction of groundwater. The number of unregistered boreholes is estimated to run into the hundreds. These boreholes presents an additional and unregulated tapping of the limited freshwater resource and exposes the fragile aquifers to over-extraction, saline intrusion and pollution risks.

C) Treated sewage effluent (TSE) is currently used to irrigate 280 hectares of agricultural land in an area of Malta outside the groundwater protection zone. Only some 10% of sewage water is being currently treated and reused.

The numerous water harvesting and storage facilities, boreholes and springs (A and B) bear legal ownership and are the property of the farmers. These systems are administered individually or in groups by farmers themselves. The format of water distribution management is a classical farmer managed irrigation system administered by the farmers with little or no interference by third parties to impose rules and regulations. Under these systems farmers are not subjected to usage fees. Once capital investment is paid up, the price associated with this water use is just the cost of energy used in the lifting of water. The relatively cheap cost of energy has unfortunately led to abuse leading to over pumping, especially in the case of ground water extraction. None the less, in farmer owned land, producers are investing heavily in efficient systems.

Distribution of treated sewage effluent (C) is under the jurisdiction of central government. The Plant provides 17000m^3/day to about 500 farmers. Treated effluent is pumped into five large main reservoirs with a total capacity of 13,500m^3 situated on high grounds. Water is distributed to farmers by gravity through a distribution network consisting of open concrete channels.

There is an urgent and pressing need to manage the irrigation water resource in a sustainable manner. Discouraging the further exploitation of groundwater by farmers and encouraging the increased use of both harvested rainwater and treated sewage effluent should rank high on the list of priorities. However, there are numerous obstacles to achieving this namely:

1. The continuing trends in the drilling of new boreholes;
2. Many dam systems built across many valleys to catch runoff rainwater are dilapidated and ineffective at trapping rainwater due to heavy sedimentation, accumulation of rubbish, overgrowth with vegetation etc. In 1993, Water Services Corporation estimated that a total of 18 dam systems with a total capacity of 37,000m^3 were no longer in use, this number is likely to have increased significantly since then. Dams are beneficial to increase the aquifer recharge and to use this water for irrigation.
3. Traditionally, farmers made huge efforts to collect rainwater. The simplest consisted of underground wells hewn out of the rock beneath the fields. Where spring water was available, larger reservoirs, open or covered, above or below ground were built. Today, with the availability of water from the mean sea level aquifer, the effort to harvest rainwater has diminished drastically, many of the existing cisterns and reservoirs found on farms are used for the storage of extracted groundwater rather than rainfall collection. Where irrigation is directly from boreholes, reservoirs have become obsolete and often abandoned.
4. There is currently no infrastructure in place for the more wide scale distribution of TSE, including the availability of additional large-scale reservoirs for the storage of treated effluent until the dry season. Water from the Sant'Antnin Sewage Treatment Plant is stored into five large open reservoirs from which it is then conveyed to the fields by means of open channels. This system proved to be very inefficient for many reasons, mainly: vulnerability to damage and vandalism, it is very prone to leaks and over spilling and also the uncontrolled use of water by farmers with many unauthorised connections resulting in little or no water at the end of the line.
5. Due to land fragmentation and problems of access, the installation of appropriate irrigation networks for utilising both harvested rainfall from the larger river dam systems and TSE remains problematic.
6. Many farmers lack the appropriate technology (e.g., micro-irrigation techniques) to use the alternatives of harvested rainwater and TSE effectively;
7. The salinity of water distributed from the Sant' Antnin Sewage Treatment Plant has increased to unacceptable levels and risks causing localised soil salinisation.
8. There remains some opposition to the use of the TSE on the grounds of its perceived "image" and safety.

INDICATORS OF IRRIGATION EFFICIENCY

Most of the water produced in Malta goes for municipal purposes. Irrigation as well as industrial water requirements are met by secondary waters, privately abstracted groundwater and treated sewage effluent. A high percentage of extraction from private wells is illegal, unregistered and uncontrolled. Likewise, treated sewage effluent is highly abused, though metered at the plant's outlet. Its uncontrolled use and misuse has resulted in an imbalance in the allocation of water resources. This has exacerbated further the drilling and exploitation of groundwater.

In such a situation, the management of groundwater and water sources in general becomes a very difficult task. One of the tools which need to be included in any water management policy is the formulation of a set of performance indicators. These indicators have to be agreed by the stakeholders involved, including the Government, Service Providers, Regulatory Authorities, Farmers' Representatives and NGO's.

Unfortunately, no official indicators are in use to address irrigation efficiency. However, a number of indicators could be put forward to come to a reasonable estimate. Possible indicators which can be used to benchmark improvements in irrigation efficiencies could include:

1. Local and regional improvement in chloride levels of groundwater which indicate less groundwater abstraction
2. Irrigated area to irrigation water ratio which can give an indication on the improvement of irrigation methods to increased land for irrigation

3. Crop produced to irrigation water ratio applied which indicates the improvement in irrigation methods with increased production of crops
4. Type, amount and economic value of crop to type, amount and economic value of irrigation water ratios to indicate the technological advances in the best utilization of waters with different qualities for different types of crops with the best net return value.
5. Amount of rainwater harvesting used for irrigation as a factor of the total amount of water resources available for irrigation to indicate the improvement recorded on the culture adopted by users to utilize alternative, cheaper and environmental friendly water resources for irrigation
6. Percentage losses in distribution systems per kilometre of pipeline and/or volume-wise to indicate the overall improvement in the methods adopted to account for all water produced before the water reaches the location of its application
7. Number of farmer complaints related to water availability to indicate whether the availability of readily available water is on the increase.
8. Cost of water to be used for irrigation can indicate whether the overall irrigation schemes are improving in efficiency. If efficiency improves, any savings can be reflected on the water tariffs to the consumer. This could encourage users to adopt and use efficient irrigation schemes, and/or expand their business etc..

REFERENCES

Blondy Alain (2003). A treasure of 19th century Malta: the Maltese orange. *Treasures of Malta* 28:7-11.

Bowen Jones, H., J. C. Dewdney, and W. B. Fisher, (eds.) (1961). *Malta: A background for development*. Durham: Durham University Press

Chetcuti, D. (1988). *The climate of the Maltese Islands*. B.Ed. (Hons.) dissertation, University of Malta.

Chetcuti, D., A. Buhagiar, P. J. Schembri, and F. Ventura (1992*). The climate of the Maltese Islands: A review.* Msida: Malta University Press.

Hughes J. Quentin (1956). *The building of Malta during the period of the knights of St. John of Jerusalem 1530-1795*. London: Alec Tiranti Ltd.

Jaccarini J. Carol (2002). *IR-RAZZETT: The Maltese Farmhouse*. San Gwann: P.E.G. Ltd, Malta

Morris, T. O. (1952). *The water supply resources of Malta*. Valletta: Government Printing Office.

Newbery, J. (1968). The perched water table in the upper limestone aquifer of Malta. *J. Inst. Water Eng.* 22:551-570.

Robert Schembri (2003). *The Development and Management of Desalination Operations in Malta*.