Project: Sustainable Hydro Assessments and Groundwater Recharge Projects
Project acronym: SHARP

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APPENDIX: Long version of good practices to be adapted report

GPA 14	Water allocation and efficient water use in agriculture

Involved Project Partners:
Local Councils' Association (LCA)
Regional Agency for Rural Development of Friuli Venezia Giulia (ERSA)

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1. Concise description of the adapted good practice

The efficient use of water for agricultural use is vital to the success of the SHARP project. The agricultural sector has been blamed to be the greatest user of water with one of the lowest water use efficiency and lowest output per unit of water used when compared to all other sectors. Thus, the agricultural sector is being pressured to use methods that make more efficient use of water. In order for the SHARP project to have a tangible effect on groundwater management, all project partners must address efficient water use in agriculture as far as possible.

Meeting the high and rapid increase in the demand for water, while protecting and conserving the resource and the environment is a major challenge. Water availability is an issue as more and more people make use of water resources causing direct competition. Moreover, the reduction in precipitation patterns during the growing season, higher air temperatures, and a lower storage of water and, in the case of Italy, in the snowfields on the mountains during winter time have a direct impact on the available water resource. This condition causes an imbalance in the availability of irrigation water, giving rise to a progressive water shortage and to a critical situation for crops in general. A long period without rainfall coupled with water shortage for primary adduction sources could have critical consequences on agricultural production, if water networks are not replenished adequately., but such a situation affects also the sustainment of the territory.

The partners working on this adaptation are the Local Councils Association (LCA) of Malta and Agenzia regionale per lo sviluppo rurale (ERSA) of Italy. The Region of Fruili Venezia Giulia has an area of 338,562 ha of which 145,400 ha is irrigated. This area is irrigated using different systems including:

Irrigation System	Percentage area covered (%)
Sprinkler Irrigation systems	26.8
Surface Irrigation	20.3
Other	2.1
Extraordinary irrigation interventions pattern	50.8

The irrigation system of the Fruili Venezia Giulia region has been meant to integrate natural water inflow, either from precipitation or groundwater, when these are insufficient for crop growing. The system uses water intakes with surface abstractions from rivers or torrents, and groundwater wells. The main abstractions from rivers predominantly takes place at the foothills of mountains and minor elevations of the region, whereas intakes from groundwater wells occur mostly along the springs belt area.

The following collection irrigation systems are being used in the region: surface irrigation and sprinkler irrigation ; both are managed by the Land Reclamation Consortia, which distribute water to farms according to specific schedules and volumes previously agreed on.

The conservation of irrigated farmland and the environmental benefits connected to irrigation techniques requires an array of optimized interventions like safeguard measures, the protection and conservation of water bodies, the refitting of irrigation systems – especially to increase accumulation, rationalization of water distribution and water saving.

An evaluation of statistical data regarding irrigation in the Fruili Venezia Giulia Region shows that, besides other sporadic forms of irrigation that can be classified as emergency measures; there are still extensive agricultural areas where surface irrigation – a system that requires huge amounts of water- is the dominant form of agricultural water application. The above mentioned statistical data clearly indicate the need for a modernization of the irrigation systems, bearing in mind that some infrastructures have been built many decades ago and have to be refitted to meet modern technological standards, whereas others, which have been installed recently, have not been completed in a way to adequately supply water distribution, though these systems provide water to wide areas in the plains.

The transformation of surface irrigation into sprinkler irrigation is needed primarily to achieve adequate water savings, so that conflicts among different customer types and recurrent water shortages can be restrained. Moreover, this transformation can have a positive outcome for the region in terms of lowering the level of nitrates and phosphorus in sensitive areas that are more exposed to pollution.

As far as irrigation systems are concerned sprinkler systems are considered to be an efficient installation for the distribution of irrigation water especially for the arable crops. For this reason the use of these systems is continuously expanding in Europe. In general the main features of such a system are as follows:

- medium to high volumes of distributed water;
- limited watering times;
- medium to high water pressure.

Advantages compared to surface irrigation:

- high water savings as the quantity used is approximately half of that needed for surface irrigation;
- possibility to irrigate uneven terrain, less need for land grading and irrigation adaptation, also suitable for inclined terrain;
- better adaptation to tree cultivation, like vineyards and orchards;
- reduction of erosive phenomena, structural soil deterioration, percolation and drifting of fertilizers and herbicides;
- less work hindrances;
- suitable to prevent the formation of frost;
- reduction of personnel costs for the distribution of water in the fields.

However, critical issues are linked to high energy costs for system pressurization and high wind sensitivity, but also to defective spray nozzles causing slaking and surface sealing due to water dropping heavily on bare soil, furthermore wetting of foliage in field crops results in increased sensitivity to plant diseases.

In addition to surface and sprinkler irrigation some farms also adopt other irrigation techniques (linear/lateral move systems, center pivot systems, boom systems, drip systems, etc.) distributing water with their own equipment whilst using the consortium's structures only for main water adduction.

For Malta, meeting the high and rapidly increasing demand for water, while protecting and conserving the resource base and the environment, is a major challenge. Legal and administrative measures need to be taken according to a plan emerging from a strategy, which in turn is the expression of a national water policy. To date, it is estimated that the agriculture sector is meeting about 80% of its demand from groundwater while nonconventional sources such as treated effluent and rainwater harvesting are only of marginal importance.

The demand of the agricultural sector cannot be met by groundwater alone. Other efficient water use sources must be brought into play, such as treated effluent and rainwater harvesting. To this effect, unless the demand generated by the agriculture sector is met through the involvement of unconventional sources, the current levels of agricultural activity cannot be maintained. Artificial irrigation is an important aspect of Maltese agriculture. To date, the National Statistics Office (NSO) has not carried out any empirical studies to estimate the volume of water used for irrigation. Consequently, statistics on the sources and types of irrigation have been collected through various surveys. The major problem facing data collectors is that a substantial volume of water used for irrigation is extracted from boreholes that are not metered. As at 2010 the total utilised agricultural area amounted to 11,453 ha of which 3,498 ha is the total irrigated area. The total estimated volume of water used for irrigation between September 2009 and August 2010 amounted to 28.2 million cubic metres[1].

The most widespread sources of irrigation water are the large number of boreholes that abstract water from the mean sea level aquifers. A number of freshwater springs are tapped for irrigation. In some areas, the water emerges from man-made galleries excavated at the Upper Coralline Limestone-Blue Clay interface. These galleries are gradually and slowly replenished by natural spring water from the perched aquifer and periodically emptied into a cistern or reservoir. The deep wells also harvest water from the perched aquifers by pumping.

[1] http://www.nso.gov.mt/statdoc/document_file.aspx?id=3215

Throughout the centuries, several farmers have built or dug small reservoirs in the rock to collect rainwater that is primarily used as a source of supplemental irrigation.

How to achieve an efficient use of water in agriculture

When it comes to the measurement of the efficiency of the system, one of the critical points is the efficiency of the general distribution network. In that case the works and the plans for the maintenance of the distribution network are of crucial importance, especially when the water resources are limited. Water losses in the network reduce the amount of water actually distributed to the cultivations.

Water savings realized through the improvements to the distribution network are of course also beneficial for other sectors than agriculture (for instance civil or industrial use of water) or to extend the land area served by irrigation.

The choice in investments to be effected in order to serve a wider area with irrigation implies a cost/benefit assessment to be carried out by the decision makers: some crops can exhibit a high water consumption, moreover the economic feasibility of new irrigation plants in areas with soil showing a high content of stones, sand and pebbles should be carefully evaluated.

With a given amount of water available for the irrigation purposes, two different strategies can be considered to enhance efficiency of water agriculture use: (i) investments in the irrigation systems applied, as it is the case of the conversion from the "surface" irrigation system to the "sprinkler" irrigation system, or (ii) act on the pricing scheme for water so as to promote a wise behavior in terms of water abstraction by the farmers, e.g. the introduction of the "binomial fee".

At farm level other interventions can be promoted to improve the efficiency of the water available. For instance the farmers can be assisted by a guided-system which indicates "when" and "how" to intervene with irrigation. In fact the "binomial fee" described above can have an economic leverage to promote a wise use of water for agricultural purposes, nevertheless the farmers should also be advised on "when", "what" and "to which extent" to irrigate the crops. The best period for irrigation intervention can be evaluated by means of SW tools able to estimate the water balance of the plant-soil system. In that view specific probes aimed at measuring water availability in the soil can be installed in the farm plots and coupled to small-scale electronic meteorological stations in order to record and process all the available data. The SWs can estimate the proper moment for the irrigation intervention according to the physiological phases of the crop cycle, forecasted precipitations and estimation of the soil water capacity. The whole set of data and technical information processed by the said SW along with the water pricing system, can show the farmer which is the marginal utility of a given irrigation intervention. This approach can demonstrate its benefits in terms of water optimization both for the farmers' income and for the system. In this case the importance of the role played by the advisory services for the farmers is apparent. Advises and information provided to the farmers should be coordinated among the entities in charge of the water distribution for irrigation use, the weather forecast service and the farmers advisory services.

The fee and cost schemes applied

The Water Framework Directive, WFD (2000/60/EC) has identified the conservation and the protection of water quality and the efficient use of water as main objectives in the public management of water resources.

WFD also provides some suggestions on the pricing of water, which should reflect the volume of water consumed by the final user; hence the pricing criterion adopted should be able to promote an efficient use of the water resources.

Two main water supply schemes for Irrigation purposes are:

- Scheduled scheme
- On demand scheme

With the scheduled scheme the farmer is allowed to withdraw a given amount of water from the system following a scheduled timetable (e.g. 1 time every 7d for 2 h). The farmer pays a flat rate contribution for the water used regardless of the amount of water consumed. The tendency is that the available scheduled water is always used regardless of the actual cultivation requirements or of the precipitation. The irrigation network must be kept at a higher engagement rate (i.e. it must be able to cover all the scheduled irrigation interventions regardless of the actual water employment rate), the water abstraction rate of the whole irrigation network must be kept higher than the actual requirement, in that way the groundwater bodies or the river beds can be negatively affected.

The on demand scheme requires the farm to pay only for the water actually consumed. Ideally this pattern should be able to promote awareness to farmers on the costs covering irrigation. The amount of water supplied beyond the real requirements of the cultivation does not increase the crop yield but on the contrary increases the costs resulting in a reduction to the farm income. This on demand water supply scheme should be able to rationalize the water consumption in agriculture in order to achieve water savings.

If the water pools of a given network are fully connected, then the lower consumption of water could represent an additional reserve that could be used by other areas with greater needs (such as the users in the community). The water saved can also reduce water abstraction from groundwater bodies and river beds can be preserved.

Obviously different pricing schemes are applied with the Scheduled pattern and with the “On demand” pattern.

With the Scheduled pattern a flat rate is applied, while with the on demand pattern the fee applied takes into consideration the amount of water consumed. This scheme should work as an economic leverage that could lead to a promotion of an efficient use of water resources.

One possible pricing scheme that can be applied with the on demand pattern is the binomial fee. The structure of the binomial fee considers the following principles:

1. Fixed costs and variable costs are distinguished; the former costs comprises general expenses and costs for derivation and distribution of water in the primary networks, the depreciation of the technical investments and their maintenance; these costs should be portioned among all the agricultural parcels served. The variable costs, which comprise the management costs of the secondary network, the control and measurement tools and the energy costs covering water pumping (known as specific costs), should be partitioned among the owners of the parcels who directly use the water and on the basis of the volume of water actually consumed.

2. The graduation of the fees according to the water consumption. The experience gained over the recent years with severe lack of water resources, shows that even for agriculture, in order to limit water consumption, it is necessary to introduce a progressive fee whose rate should depend upon the amount of water taken up by the farmer, as it was first introduced for the water civil users;
3. The ability of the fee applied to affect, through adequate differentiations, the choice of the farm on the cultivations to be grown. In this view it must be kept in mind that different crops have different levels of water consumption.

The demand for water has been changing over the time, therefore the fixed distribution schemes (for instance the scheduled distribution pattern) is inadequate with respect to the user requirements. The most flexible distribution schemes should be able to become even more flexible as a higher water demand over a longer period of time during the year added with climate change effects is becoming the trend.

The binomial fee foresees a fixed quota and a variable quota.

The fixed quota comprises of:

- Scheduled maintenance costs;
- Ordinary personnel costs;
- Investments;
- Studies, research, consultancy;
- Energy costs

The fixed quota identifies the direct benefits and therefore will be related to the agricultural area concerned.

The variable quota takes into consideration the actual water consumption (and indirectly also the distribution system): on one hand it prohibits water consumption from exceeding the optimum, on the other hand it is an advantage for the farmers who follow the information gained from the water balance as inspired by the efficiency principles. The variable quota is concerned with the variable costs of irrigation (energy costs related to the distribution of water, expenses borne for the personnel overtimes due to irrigation activities).

The application of the binomial fee does not take into account the pricing of the groundwater resources, which, often, are taken up from private wells. The volumetric fee applied to the water supplied by the consortia networks could have adverse effects with respect to the objectives of the Water Framework Directive (EU Directive CEE/60/2000, WFD). In fact the increase in water price, due to the higher fees put into practice by the irrigation consortia in order to recover the costs borne for the irrigation investments effected, could also lead the farmers to increase the amount of water taken up from the groundwater, causing their excessive exploitation that the WFD intends to prevent.

This adverse side-effect could be counteracted through a stricter regulation on the water abstraction from the groundwater wells and supervised by the competent authorities.

Devices and apparatus used for monitoring the water supply to the individual farms

Implementation of different pricing schemes implies the realization of some investments which are concerned with the distribution network and the measurement of water flow to the individual plots, in particular the realization of different underground pipelines network, the installation of individual flow meters apparatus designed to regulate the water distributed to the individual plots and measure the amount of water supplied.

In many of the existing structures and distribution networks it is difficult to proceed with the installations of the flow meters as this implies the re-structuring of the whole distribution network at local/district level.

Measuring merit and inefficiencies at farm level

Beside the water efficiency of the general irrigation network (which compete to the organisms dealing with water distribution), also the within-farm efficiency of the system should be evaluated. Water losses can also occur within the internal distribution network of the farm, water distribution inefficiencies are also related to farm intrinsic characteristics.

The impact of the farm internal inefficiencies can be highlighted with the term "B" in the following computation related to the cost contribution of the individual farm (Ci):

$C_i = (Sf * B_i / \Sigma B_i) + (Sv * V_i / \Sigma V_i)$
where,
C_i : contribution to be paid by the i-th individual farm;
Sf : total fixed costs;
Sv : total variable costs;
B_i : benefit gained by the i-th individual farm;
and
B_i = (Index of provision) * (Index of use limitation) * (Index of delivery) *(Area of the i-th individual farm);
V_i : volume of irrigation water supplied to the i-th individual farm.

In the Bi term the indexes used, aimed to scale the merit of the farm, enable the partition of the costs on the basis of the real benefits gained by the agricultural land as a function of:

- availability of irrigation tools having low consumption (specific Index of provision);
- attitude of the soils (function of the soil characteristics) to increase their productivity through
- the water supply (Index of use limitation);
- water availability on the basis of the existing infrastructures and channels (Index of delivery).

The "Index of provision" and the "Index of use limitation" are mostly concerned with the internal farm distribution efficiency.

At farm level it is then necessary to evaluate the variations in the farm income balance consequent to the introduction of the binomial fee, such as:

- costs to be borne for the adaptations of the irrigation system;
- the increase in the revenues arising from the introduction of cultivations having a higher added value;
- recover of the costs with respect to these two different scenarios, i.e. adaptation of the district irrigation system vs. adaptation of the farm irrigation system.

The different terms of the Ci shown above can be of some help when it comes to evaluate the irrigation costs borne by the system and related to the characteristics of the individual farm.

In order to encourage water use efficiency in agricultural sectors a financial system needs to be in place. A water pricing system is required in order to increase the awareness of farmers on the overall water balance. A 'binomial fee' can be seen as an alternative to the "flat rate fee" which is currently being applied.

The "binomial fee" can be split into two components: one component refers to a fixed quote related to the management costs of the plant, the other component is directly related to the water consumed for irrigation by the individual farm. The binomial fee is aimed to advantage the farms which adopt a "on demand irrigation pattern" instead of a "scheduled irrigation pattern" as the former pattern foresees water supply only when it is really necessary for the crops requirements. The "on demand irrigation pattern" has also a positive impact on the overall balance of the plant as it enables a reduction of the energy costs to maintain the target water pressure of the system.

The application of a binomial fee is also consistent with the guidelines of the Water Framework Directive, WFD (2000/60/EC) which provides some suggestions on the pricing of the water, which should be related directly to the volume of water consumed by the final user; this pricing criterion, in fact, should promote an efficient use of the water resources.

Striving to ensure sustainability of water resources and use in the agricultural sector within the EU is one of the main aims of the SHARP Project. Given that the agricultural sector is one of the main users of groundwater, efficiency of use is paramount. This can be achieved through the involvement of non-conventional sources such as treated effluent and rainwater harvesting, thus preventing sole reliance on groundwater abstraction.

2. Description of adaption process

The steps required for a potentially successful implemented adaptation are as follows:

- The applied irrigation techniques should be improved and changed.

  Ideally the irrigation system is changed from the surface technique to the sprinkler technique in order to achieve significant water savings. This will limit the possible conflicts between the different water users competing over this resource, and the availability of water resources can be kept in check. Such a conversion is also known to be beneficial for the environment in terms of the amount of nitrates and other harmful substances leaching into the nearby areas which are at risk of being contaminated.

  Converting to the irrigation technique this should strictly be connected to a specific restructuring of the individual networks which supply water. This is in order to avoid waste of water especially when droughts take place. This restructuring could also be realized through the adoption of high efficiency irrigation techniques, such as drip irrigation to be adopted with cultivations having high profitability, like horticulture, orchards and vineyards.

  Efficient irrigation methods should be promoted together with the maximization of crop yield efficiency through the use of smart irrigation systems. Furthermore, supply augmentation measures involving aquifer recharge with excess treated effluent and rainwater runoff should be promoted.

Local stakeholders in the region should be encouraged to implement efficient water use techniques in agriculture by means of rain harvesting through dams and reservoirs; fine tube irrigation systems and also by natural spring water harvesting.

Water demand for agriculture is recognized as an essential area for this sector's development and thus agriculture must continue to use available water to best effect. Farmers should be trained in the utilization of smart irrigation techniques and directed towards crop suitability in order to enhance the sustainability of the sector.

- Increase awareness in the rationalization of water use in agriculture

  Increase awareness in the rationalization of water use in agriculture could contribute to water savings that can be realized in favour of the overall system, i.e. further agricultural land that could be served by irrigation, larger amounts of water that could be used for other purposes such as civil and industry and, on the other hand, also lead to a lower water withdrawal from the system.

Concerned stakeholders should be aware through dialogue meetings and information sessions on the importance of water use efficiency in agriculture.

Current local policies and legislation should be revised and amended where necessary to ensure the sustainability of water use. Hence, concerned authorities should participate in future consultation in respect to regulations and policies concerning water use efficiency In the agricultural sector.

This point is concerned with the evaluation on the difficulties/opportunities encountered when it comes to transfer techniques to other regions. Practices carried out in different areas cannot be simply exported in other regions, in fact the systems that have been developed in certain territories are able to match the needs and the requirements of that individual area and there is no guarantee that they could work also in other regions having different rules, different organization, different land use or different crops cultivations.

Nevertheless the water availability and the peak demand of water during the crops growing season make the question of water allocation for agriculture very urgent and even in regions having high precipitation patterns, droughts or scarcity of water for the crops can occur. The need to share good practices and innovation is then apparent.

Some general remarks can be applied. These suggestions have the same and common meaning for all the situation to be examined:

- Optimize the efficiency of the system through the maximization of the system flexibility;
- "technical" and "operational" options to be considered in water allocation;
- The effect and impact of the existing plans for works as well as innovations to be introduced in the system;
- Coordination of the choices of the decision makers on the water allocation;
- The cost/benefit feasibility of new irrigation facilities in soils with low water capacity and for cultivation crops showing high levels of water consumption;
- How to increase the awareness of the farmers on the environmental cost of the water use and the marginal utility of the irrigation interventions
- The role of advisory services and the coordination with other actors.

The role of the partners is to follow the above mentioned steps to achieve an improvement in the efficient use of water in agriculture taking into consideration

The main obstacles in maximizing water use efficiency in the agricultural sector are the following:

- The type of irrigation system adopted

  The type of irrigation adopted limits water allocation and efficient water use in agriculture. Hence, the adoption of 'surface irrigation systems' and the 'extraordinary irrigation pattern' are wide-spread and still practiced, these systems exhibit lower efficiency in water distribution and higher water consumption.
- Lack of information available on water use efficiency

  Informative documentation to stakeholders should be made available thus stressing the importance of water use efficiency in agriculture. This should be done using clear and simple language to make sure this is understood by everyone. Hence, the use of local case studies as examples, illustrations and other visual aids would come in useful.
- Stakeholders including farmers are not aware and/or interested in issues relating to water use efficiency

  This issue can be approached by inviting stakeholders to regional events, information meetings and practical sessions on the benefits of using water more efficiently. This may serve as a positive way to increase their awareness and interests on the problems at hand and to introduce new methods and techniques which would lead to better water use efficiency in the agricultural sector.
- Difficult to implement water use efficiency measures and enforce these in local context

  Training of specialists in this subject area would be required to have enough resources to carry out inspections and spot checks to monitor the activities and implementation measures being adopted by the farmers/land users. These specialists should also organize regular meetings with the stakeholders to oversee their current activities and guide them should they encounter any difficulties.
- Lack of collaboration amongst local authorities and farmers

  Most often collaboration amongst local authorities and stakeholders including farmers needs to be significantly improved. This obstacle can be approached through face to face meetings with both parties concerned so as to express all the views and challenges encountered. In turn, the issues raised would help in seeking consensus between the local authorities and farmers.