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Annex 63

Name of Deliverable:

Modello costi - benefici

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Modello Costi-Benefici

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1 Introduction

A Cost-Benefit Analysis (CBA) is one of the most popular tools to understand if a project/alternative is a sound investment. Lately, with growing concerns on the environmental and social spheres the concept has broaden its scope, and started to include typical externalities, such as pollution or social disparity. Therefore the concept of valuation of the ecosystem services was developed (under the subjects of environmental and ecological economics) and different technics are now-a-days used in order to convert environmental impacts (positive or negative) into monetary units, in order to compare with the perceived investment costs (Daily *et al.*, 2000; MEA, 2005).

This deliverable tries to access in a financial and economical approach, the feasibility of the WARBO project Managed Aquifer Recharge (MAR) sites. For this goal, a tentative cost-benefit model is drafted. This cost-benefit analysis will focus on the whole social-economic and environmental system, meaning that it will account all the stakeholders costs and benefits. In real-life, however, the distribution of costs and benefits may change significantly from user to user, calling for a managed solution between all stakeholders in order to achieve a common goal.

The time limit of this analysis will be considered 30 years with a yearly discount rate of 1%.

2 Methodology

The methodology chosen for this analysis follows the classical steps in any CBA: i) Account or estimation of investment costs; ii) Estimation of the maintenance necessities and costs; iii) Assessment of the environmental impacts in the test sites; iv) Valuation of the positive and negative impacts; v) Cost and benefit balance.

2.1 Investment costs

The total costs of the WARBO project weren't included in this analysis due to its investigation nature. This document addresses a more technical and financially orientated solution that would have likely produced more benefits at a lower cost. Since knowledge enhancement in the MAR activities was one of the objectives of the project, some activities were carried out, with a sound scientific value in the respective field, but not indispensable for the test sites operation.

We tried to include, a minimum amount of the monitoring work, the chemical analysis carried out and the hydrogeological and geophysical site investigations, as they are fundamental for any project implementation.

2.2 Operation and maintenance cost

Although MAR technology is simple and almost self-operating, it requires constant monitoring as a possible contamination in the recharged water may impair the aquifer for long time periods (Pyne,1995; EWRI/ASCE, 2001; Maliva & Missimer, 2010). Hydraulic structures failure, such as valves or bypasses, might create damages in the MAR site surroundings, which calls for a regular control.

On the other hand, non-managed MAR activities are destined to lose its efficiency, as water fine particles, trapped gas and biofouling will reduce the permeability on the interface with the aquifer. Therefore, a basic maintenance is required to clean the water filters, remove the organic content, and remove/ destroy the clogging layer (Pyne, 1995; EWRI/ASCE, 2001; Bouwer, 2004). If the MAR site is responsible for other minor impacts, such as pest, a few measures have to be added.

The required frequency of monitoring and water sampling is subject to discussion, and shall be defined according to the source and groundwater quality, pollution potential or geological constrains.

2.3 Environmental impacts assessment

The understanding of the environmental impacts are crucial for the assessment of benefits. All test sites carried out in the WARBO project framework deliver a different set of positive and negative impacts. We carried out a systematic qualitative assessment within all the impacts foreseen and reported for the MAR activities. A list of the impact of the test site in its different categories is presented in Annex 1, considering different classification parameters (significance, signal, temporal and special dimension, probability duration and reversibility). The impact evaluation was considered under the assumption that the test sites would work all year round.

2.4 Impacts Valuation

The valuation of the economical is a rather controversial issue among ecologist and economists. The identification of the total value of a project in the environment can be a hard, time-consuming, and often not necessary task. Therefore the focus shall fall in the impacts or environmental services with higher relevance (WCPA, 1998). In the framework of the WARBO project, that changed from site to site.

In this report, we only address the use value of the impacts, but are aware of the option and non-use value, which only can be assessed through a contingent analysis.

2.5 Cost Benefit Analysis

The comparation of the costs with its benefits is draft. Since it wasn't always possible to convert the impacts into a monetary value it is sometimes made a qualitative (and subjective) valuation, discussing the requirements to reach the economic feasibility of the test sites.

3 Mereto

3.1 Investment costs

The Mereto the Tomba test site was built in 2003, by the Conzorcio Ledra-Tagliamento with the purpose of conducting MAR in the aquifer. According to Civita, 2005 the investment cost reached 2 487 600 000 Italian Lire (1 284 738,60 €), for the construction of three recharge sites: Campo di Carpeneto (Comune di Lestizza); Campo di Mereto (Comune di Mereto di Tomba) and Campo di Sammardenchia (Comune di Pozzuolo del Friuli). All those recharge sites were composed with on sedimentation basin and a total of 5 recharge wells (15 to 23 m depth and 3 meters depth). All hydraulic connections and valve system were also set on the scope of the budget given above.

Under this context, the specific cost for the Mereto test site becomes hard to assess. A third of the total cost would be 428 246.20 €, but it should be mentioned that Mereto had the smallest of the sedimentation basin of all three test sites, and therefore possible less costly. Under the purpose of this report, the investment of the two recharge wells and respective hydraulic structures shouldn't be accounted since they won't be use for the benefits calculation. It is important to mention that the wells weren't operated due to legislative problems, but would have probably rendered the recharge much more effective, as it would have bypassed the perched aquifer.

Considering a different approach, the Mereto infiltration basin totalizes ≈4200 m^3. The current cost of such an excavation shall round the 50 000 €, depending mostly about the material type, and distance to the material discharge point. To this value an indicative value of 10 000 € shall be added to the building of the hydraulic structures for connection with the channel.

To this figure, it should also be added the costs of the construction of the monitoring piezometers. A basic characterization of the hydrogeological area might have been the minimum before the start of the operation.

Table 1 – Investment costs for Mereto test site

Investment item	Cost (€)
Earth works	50000
Valves and hydraulic connection	10000
Piezometers	25000
Hydrogeological characterization	15000
Preliminary chemical analysis	5000
Geophysical profiling	5000
Total	**110000**

3.2 Operation and maintenance costs

In the Mereto test site there are 3 piezometers in the recharged aquifer within the influence area of the infiltration pond. However, to understand the degree of influence of the MAR in the aquifer, the variations on the influence area shall be compared with the variations outside that radius, which shall correspond to the aquifer natural variation. Therefore, 2 more piezometers shall be monitor downstream of the pond. There is one more piezometer in the perched aquifer, which shall be monitored as the only one. Therefore a total of 6 piezometers require a visit twice a month, with water sampling and analysis, plus the monitoring of the recharge water level and quality. With the instrumentation of the piezometers and when confidence in the system in achieved, the monitoring might be reduced to once a month.

The presence of freshwater algae and organic material in the water required the application of a coarse water filter that tends to clog, especially during the heavy rain events, when the water on the channel and river has a higher turbulence. A manual cleaning is required weekly.

Additional maintenance will be required with a little less frequency. Algae growth was observed in the infiltration pond itself, which may be problematic for water quality and clog the aquifer. Algae removal at least three times a week is necessary in order to avoid further problems. Also, it would be advisable to add a sand filter on the bottom of the pond, or at least till the top layer, at least once a week.

No need for pest control was necessary, during the time period of the project, and therefore it won't be considered.

Table 2 – Operational, monitoring and maintenance costs in Mereto Test site

	Advisable frequency			Minimum frequency		
Activity	Number/year	Unit cost (€)	Yearly cost (€)	Number/year	Unit cost(€)	Yearly cost(€)
Piezometer monitoring (six) and Recharge water sampling	28 days	200	5600	12 days	200	2400
Water chemical analysis	28*7 samples	50	9800	12*7 samples	50	4200
Monitoring and chemical analysis control	28 days	200	5600	12 days	200	2400
Filter cleaning	52 days	40	2080	52 days	40	2080
Algae physical removal	3 days	500	1500	3 days	500	1500
Clogging layer destruction	1 day	500	300	1 day	500	300
Total	Total		24880			12880

The maintenance costs of Mereto shall round between the 746 400€ to the 386 400 €, depending on the desirable monitoring frequency and requirements. However, with the application of a discount rate the value range will increase from the 865 000€ to 448 000 €

3.3 Environmental impacts assessment

The highest impact of the Mereto test site was felt on aquifer water quality, with an impressive effluence in the conductivity and nitrate content. The influence area of this effect is still undetermined but it is expected to reach a radius of 200 meters (≈12,5 ha). Smaller impacts are likely to be felt further away, downstream. Effects on the aquifer water quality in depth weren't determined. The extent of this impact is likely to improve greatly if the infiltration pond operates at is maximum capacity.

The impact on the water quantity in the main aquifer is almost negligible, meaning that, although the water was recharged into the aquifer, its availability didn't improve much. However, in the perched aquifer, which according to the stratigraphy of nearby wells as a local to regional importance the water level raised around 3 meters. The extent of this impact is likely to improve greatly if the infiltration pond operates at is maximum capacity.

The presence of a lake will likely create a small wetland, rich in biological activity and with a considerable higher number of species. However, the pond small dimension and without similar structures around, the biodiversity improvement can have just a low significance.

All the negative impacts (Algae, Clogging, and possibility of plagues) are rather operational issues, and with appropriate mitigation measures its impact on the surrounding environment is negligible. The evaporation loses are also of a low importance in the water cycle.

A systematic evaluation of the environmental impacts table for the Mereto test site, considering different classification parameters (significance, signal, temporal and special dimension, probability duration and reversibility), and under the assumption of constant recharge operations is presented in the Annex 1.

3.4 Impacts Valuation

Groundwater quality improvement in the test site is extremely important as: i) allows the improvement of the water body quality status to levels, avoiding possible fines for the non-implementation of the Water Framework Directive (WFD); ii) creates a water source that can be used for agriculture with no treatment costs or for water supply with less cost. The value of the fines of the EU over the non-accomplishment of the good quality status is unknown and therefore impossible to access. As for the water quality improvement, it can be said that a total of 430 000 m3/year of good quality water can be infiltrated, and mixed with the aquifer water, rendering a higher volume of water suitable to agriculture. As it is believed that the Mereto infiltration pond can double its recharge capacity, the Mereto test site shall be responsible for the infiltration of around 860 000 m^3/year of water. Is is a safe estimation to consider that after mixing with the aquifer water, a total of 1,5 Million m3/year water will have improved water quality. This might also have a small impact in the agriculture long term yield as the use of low mineralized water for irrigation reduces the salinization risk.

The benefits of the groundwater level raise are limited to the perched aquifer. However this means that with the recharge, the extraction costs might be reduced if the uptake is carried out from the perched aquifer (around 10 meters) instead of the main aquifer (50 meters deep). The main aquifer productivity, is however much higher, and no well yield is known from the perched aquifer. The construction of new wells is also much lower if they'd need to reach shallower depths, and the pumping costs would be much lower.

The value of the biodiversity is extremely hard to access, as its real effects are unknown, and the highest share of its value is usually of non-use. It is however possible that with a more intricate food chain and more ecological self-control mechanisms, a natural pest control might occur to improve nearby crops productivity, and need for pesticide use.

3.5 Cost Benefit Analysis

The Mereto test site had an investment cost of around 110000 € and an annual cost of 24 880€. This values might be further reduced after a while, mainly in reducing the chemical analysis network, after some confidence in the system is developed, and some CTD data loggers are placed, to yearly costs of around 12880€.

Considering this later figure or a 30 years timeframe the costs of Mereto would reach the 558000 € (1% discount rate) for an effective recharge of around 25,8 million m^3, with improvement in the water quality. This volume is capable of offset the pollution load of 30 to 40 ton/year of nitrates, under the terms of the current directive. The medium infiltration cost rounds 0.022 €/m3.

The Mereto costs might be slightly reduced if the extraction material is valued, clean and calibrated for an extra income.

The savings from the construction of wells and abstraction from the perched aquifer are harder to calculate but we estimate that the well construction would be 50% less. Pumping costs savings are not so straightforward to calculate due to the pumps yield, but it is safe to say that the savings would be around 50% too. However, it is not possible to guarantee that the perched aquifer, even under MAR effects, can meet the current water demands.

The value of the savings from avoiding non-conformity fines is unknown.

In conclusion, the Mereto test site might make economic sense, if there is a strong political will to improve the current groundwater bodies' quality status, especially in what concerns the nitrates directive. MAR activities might even be used in a diffuse pollution offsetting perspective. It shall be added that although large water volumes are infiltrated, its access didn't became any easier, unless the groundwater exploitation paradigm could be changed to the less reliable perched aquifer.

4 Zona Industriale de Ponte Rosso (ZIPR)

4.1 Investment costs

No actual earth works and monitoring structures were developed in the ZIPR test site within the WARBO framework. Rather, a conceptual model was developed aiming a possible future MAR of the phreatic aquifer using the treated industrial, with a phytodepuration plant.

Since the water level is rather shallow (2 to 3 meters above ground), the recharge shall be conducted with the building of an infiltration basin downstream of the phytodepuration plant. No major obstacles (roads, rivers, etc) are foreseen to the implementation of such infrastructure.

The hydraulic conductivity of the aquifer was calculated at 6,3 * 10^{-3} m/s (540 m/d), and the average water resources are estimated in 2000 m3/d. They could, however, be reduced to around 600 m^3/d during the summer months due to the vacation period. Therefore, a set of three to four basins working in parallel should be constructed in order to guarantee that the system is dimensioned for all periods, and that the basic maintenance can be carried on, without closing or compromising the MAR operation activities.

The high permeability ensures that very limited area is required, and therefore the construction of the basins shall have a very limited impact on the current economical activities. Another advantage of such permeability will be a quick dispersion of the water mounding, with diminutive influence in the water level (just at a local level). Therefore the negative effect in the deep rooted trees, due to the raise of water level shall be confined to a local level (Bouwer, 2004).

We therefore assume that the requirements for ZIPR shall round the 50000 €. To this figure it shall be added the costs of a direct derivation from the phytodepuration lakes and a bypass to the stream network.

There is already a very good monitoring network in both phreatic and first confined aquifer (industrial consortium wells). The construction of 1 to 2 relatively shallow piezometers shall suffice to improve the downstream monitoring network, one of wish shall be a little bit deeper to reach the first confined aquifer and monitor the possible communication between aquifers. A basic characterization of the hydrogeological area might have been the minimum before the start of the operation.

Table 3 – Investment costs for ZIPR test site

Investment item	Cost (€)
Earth works	50000
Valves and hydraulic connection	10000
Piezometers	5000
Hydrogeological characterization	15000
Preliminary chemical analysis	5000
Geophysical profiling	5000
Total	90000

4.2 Operation and maintenance costs

No actual localization for the ZIPR test site was decided, but the most obvious place to imagine the location of the small basin is right south of the phytodepuration lakes. We envisage the construction of further 2 more piezometers, and the monitoring of the existing upstream and downstream ones. Therefore the monitoring shall focus on 4 piezometers very close to each other and the water effluent from the phytodepuration plant. However, since the phytodepuration plant has a priceless role to play for the MAR, it is advisable to monitor also the industrial effluent, in order to investigate its depuration capacity.

Although the water to be recharged has a very small load of organic matter and turbidity, algae growth and clogging are still likely to occur. It is recommended to proceed to algae removal at least three times a week in order to avoid biofouling and water quality degradation. Also, it would be advisable to add a sand filter on the basin bottom, or at least till the top layer, at least once a week.

The phytodepuration lakes also require the replacement of its plants, with every year or every two years.

Table 4 – Operational, monitoring and maintenance costs in ZIPR Test site

	Advisable frequency		
Activity	Number/year	Unit cost (€)	Yearly cost (€)
Piezometer monitoring (four) na sduperficial control (two)	28 days	200	5600
Water chemical analysis	28*6 samples	50	8400
Monitoring and chemical analysis control	28 days	200	5600
Algae physical removal	3 days	500	1500
Clogging layer destruction	1 day	500	500
Plant control in the phytodepuration lakes	0.5	4000	2000
	Total		17800

4.3 Environmental impacts assessment

In the ZIPR area the main benefit of the phytodepuration and the MAR infiltration basin will be in the safeguarding of the superficial water resources from a load of heavy metals and high temperature.

The presence of a lake will likely create a small wetland, rich in biological activity and with a considerable higher number of species. However, the infiltration basins have small dimension and without similar structures around, the biodiversity improvement can have just a low significance.

The main negative impacts of the project are related to water quality. The aquifer will likely have a higher content in chloride and sodium, but always within the limits defined by the European Union in terms of quality for the water body good status. Another minor negative impact will be the raise of the water level in the aquifer, which is predicted to be rather low due to the aquifer permeability. Therefore the negatives effects of the water molding shall be almost zero.

Other negative impacts (Algae, Clogging, and possibility of plagues) are rather operational issues, and with appropriate mitigation measures its impact on the surrounding environment is negletable. The evaporation loses are of a low importance in the water cycle.

A systematic evaluation of the environmental impacts table for the ZIPR test site, considering different classification parameters (significance, signal, temporal and special dimension, probability duration and reversibility), and under the assumption of constant recharge operations is presented in the Annex 1.

4.4 Impacts Valuation

The negative impact in the aquifer water quality won't reach the limited regulated in the WFD, and therefore no extra charges for non-compliance will occur. However, the use of the water with a higher content in salt can impair the agriculture productivity in a long term, as it contributes for the soil salinization. At the moment, the aquifer used for irrigation is the confined ones where there are artesian wells, with no pump required.

The positive impact in the superficial stream flow will have a positive effect in the surface water bodies' quality status, and therefore avoid possible fines from the non-compliance. However, its main effect will be in the improvement of the water quality and water related ecosystems, by avoiding chemical and energy stress. The creation of two wetlands (phytodepuration lakes and infiltration pond) shall also enhance the ecosystem diversity and quality. The value of the biodiversity is extremely hard to access, as its real effects are unknown, and the highest share of its value is usually of non-use. It is however possible that with a more intricate food chain and more ecological self-control mechanisms, a natural pest control might occur to improve nearby crops productivity, and need for pesticide use.

However the real value of the MAR in ZIPR relies on its utility in case of an accidental groundwater contamination. The infiltration site will have a capacity to dilute the contamination plume to acceptable levels, and can be used as a tool by decision makers.

4.5 Cost Benefit Analysis

The ZIPR test site has an investment cost of around 85 000 € and a yearly operation cost of 17800 €. This latter figure is unlikely to be reduced due to the delicate nature of the industrial site.

For a 30 years timeframe the costs of ZIPR would reach the 704 000 € (with 1% discount rate) for an effective recharge of around 21,9 million m^3. The medium infiltration cost is of around 0.042 €/m^3.

The Mereto costs might be slightly reduced if the extraction material is valued, clean and calibrated for an extra income.

The value of the savings from avoiding non-conformity fines in the surface water network is unknown. There are no studies to access the biodiversity improvement in the local water network ecosystem and its consequences to the economical welfare.

The option of using MAR in ZIPR test site might make economic sense, if the impacts in the stream network ecosystem of the industrial effluent are significant, and there is a strong political power to control and enforce the load of contaminants in the stream network. Also, there is a very good potential of the site to be let in standby, and be used for pollution control in case of an accidental spill in the industrial area.

5 Copparo

5.1 Investment costs

The Copparo test site infiltration pond was in fact the excavation corresponded to an industrial extraction of sand and clay for economical purposes. This exploration was affected and due to stop when the confined level was reached, and therefore the water rose to the piezometric level. The Copparo infiltration site therefore makes economic sense as it is a byproduct of an existing infiltration.

The only requirement to make the site operational was the construction of the hydraulic connection with the channel and the phytodepuration plant. Since the channel was located right next to the pond, it didn't constitute any major problem. The fact that the Copparo recharge site is in fact a lake, there is no problem in the degasification of the water in the pond, and therefore the lake influent was allowed to free fall. This further reduces costs, to figures round the 5000 €.

To this figure, it should also be added the costs of the construction of the monitoring piezometers. A basic characterization of the hydrogeological area might have been the minimum before the start of the operation.

The geometry of the aquifer Copparo test site, however, requires a much heavier investigation of its geometry. Therefore a much more dense geophysical campaign (when comparing with the other test sites) has to be carried out in order to understand the aquifer geometry, and to conceptualize where are the beneficiaries of the MAR activities.

Table 5 – Investment costs for Copparo test site

Investment item	Cost (€)
Earth works	0
Valves and hydraulic connection	5000
Piezometers	25000
Hydrogeological characterization	15000
Preliminary chemical analysis	5000
Geophysical profiling	15000
Total	65000

5.2 Operation and maintenance costs

In the Copparo test site there are several piezometers suitable for monitoring. However, for the long term recharge 4 piezometers shall suffice. Two are located immediately upstream and downstream in the paleochannel (P11 and P13) and one should be a little bit deeper in the confined aquifer (P14). The last one shall be located outside that radius of influence of the MAR site, to monitor the aquifer natural variation. In terms of the surface water monitoring it is required to monitor the channel effluent, the phytodepuration plant effluent and the water quality in the Recharge pond, preferably at depth.

Since the recharge area is a "natural" lake, no effort is required for the clogging or the algae removal, as long as the mixing waters are compatible and don't promote salt precipitation.

Dredge activities are however advisable in order to promote improvements on the recharge.

Table 6 – Operational, monitoring and maintenance costs in Mereto Test site

	Advisable frequency			Minimum frequency		
Activity	Number/year	Unit cost (€)	Yearly cost (€)	Number/ year	Unit cost (€)	Yearly cost (€)
Piezometer monitoring (four) and superficial control (three)	28 days	200	5600	12 days	200	2400
Water chemical analysis	28*7 samples	50	9800	12*7 samples	50	4200
Monitoring and chemical analysis control	28 days	200	5600	12 days	200	2400
Plant control in the phytodepuration lake	0.5	800	400	0.5	800	400
Lake Dredgind	0.2 times	10000	2000	0.2 times	10000	2000
	Total		23400			11400

5.3 Environmental impacts assessment

Copparo main impact is in the improvement of the lake water surface quality, and therefore of its surface biodiversity. The water in the pond had higher levels of salinity (3000 µS/cm), and will greatly benefit from the input of the recharge water (500 µS/cm). The lake, with an area of around 4 ha will be a major water source for migratory species, and allow the settle of more species, less resistant to salinity.

The implementation of the MAR site, allowed the connection of the lake with the channel network, granting the lake a further purpose as a flooding area in case of heavy precipitation.

The monitoring results showed a limited impact of the recharge activities in the aquifer, especially in terms of quantity. No important level variation was noticed. In terms of water quality a reduction of electrical conductivity of about 500 µS/cm was observed in the nearby piezometers to around 2000 µS/cm. These limited results are likely a consequence of the low recharge time within the scope of the WARBO project, and with continuous operation the results are likely to be clear.

The raise in the water level in the paleochannel might also have a limited effect in the control of the salt water infiltration from the deeper confined aquifer. It is believed that the aquifer is salty due to fossil water raise and a water rise to levels above the confined aquifer piezometric level might help to mitigate the negative effects. However the effect is limited due to the aquifer geometry, to the Copparo infiltration lake influence area and the competence of the confinement layer.

Typical MAR operational problems such as algae and clogging aren't likely to be worsened due to the infiltration. Another negative aspect of the recharge area is the high evaporation losses, as the evaporation area is much larger than the recharge area. It is however, advisable to proceed to dredging activities every 3 years

A systematic evaluation of the environmental impacts table for the Copparo test site, considering different classification parameters (significance, signal, temporal and special dimension, probability duration and reversibility), and under the assumption of constant recharge operations is presented in the Annex 1.

5.4 Impacts Valuation

The main benefit of Copparo test site is in the biological improvement due to the reduction of the water conductivity in a large area. It is very likely that the creation of an environment suitable for a larger number of species will increase the biological activity and the self-control mechanism of the ecosystem, increasing its resilience. This creates the potential for a natural pest control system that improves nearby crops productivity, and its demand for pesticide. The biodiversity improvement will likely also improve the touristic sector, as it will be a focus of interest for bird and nature watchers. The "superficial" nature of Copparo makes it extremely pleasant for relaxation purposes, combining the social and technical spheres.

The effects in the aquifer weren't clear, probably due to the low infiltration times. However, estimations point to 190 000 m^3/year of fresher water, which will likely be stored in the confined aquifer, and might be used as fresh water reserve to an area deeply affected by the salinization. This reserve will be limited to the aquifer geometry.

The effect of the connection with the stream network might reduce the flood frequency and intensity.

5.5 Cost Benefit Analysis

The Copparo cost as an investment cost of around 65 000 € and a yearly operation cost of 23400 €. This values might be further reduced after a while, mainly in reducing the chemical analysis network, after some confidence in the system is developed, and some CTD data loggers are placed, to yearly costs of around 8600€.

For a 30 years timeframe the costs of Copparo would reach the 397 000 € (at 1% discount rate) for an effective recharge of around 5,7 million m^3. The medium infiltration cost is of around 0.081 €/m^3.

The highest share of benefits are foreseen in the biodiversity sector, which is extremely hard to evaluate. However, it is important to understand that a reserve of fresh water might be stored in a aquifer in a still unknown radius of influence but in an area next to the infiltration lake within the borders of the paleochannel, which can be very important for an area subject to strong salinization pressure. No wells are known in the aquifer, and therefore it is hard to estimate savings in the water extraction or treatment.

The Copparo test site might make economic sense, if there is a strong political will in creating fresh water reserves in water bodies/zones under threat or with poor quality. It also might be possible to the administration to predict the construction of these MAR infrastructures as a compensation measure to the environmental impacts (e.g. Landscape and Groundwater vulnerability increase) of the sediments and mineral extractions. Benefits in the development of a green area, for sport and leisure are still to be explored.

Copparo requires a negotiation of costs because the beneficiaries of the fresh water reserve will be very limited in space.

6 Final Remarks

The WARBO project MAR test sites showed that the ratio cost/benefit is low in water rich regions. The MAR feasibility is likely to greatly improve as we move to more water stressed regions (in terms of quality and quantity) where other alternatives such as water savings or pollution control are already developed. Nevertheless the MAR still has a role to play, and can be very efficient under certain political/regulatory context, if strict regulations and law enforcement is applied.

Although that MAR, per se, isn't always economically attractive, if it is joined together as a mitigation measure for pollution load offsetting, vulnerability control and impact compensation, it starts to make sense in the eyes of the economical agents. Recharge: i) in the High Fruilian Plain (Mereto) might be used in an agricultural diffuse pollution compensation scheme, in the industrial areas as a possibility; ii) in the industrial areas might be used for pollution control and as a contingency plan for accidental spills in the aquifer; iii) in the extraction areas, might be used as a compensation for the landscape and aquifer impact.

The ratio benefit/cost can improve if there is a regional strategy in order to create MAR facilities with cumulative positive impacts, and distribution of costs. As an isolated MAR structure as a limited impact in the whole aquifer, a top-down approach to the aquifer recharge problems is required, with the identification of the recharge priorities, suitable points to conduct the activity and a shared solution for costs.

The cost benefit analysis would greatly benefit from the knowledge of the regional water management strategy, as it would be possible to access if the water supply will be decentralized, more concentrated in the non-conventional water sources or which aquifers are seen as potentially useful.

In the following table is presents the cost of the infiltrated m^3 together with the foreseen impacts significance, for all three WARBO test sites. It is clear to see that, despite the sites different recharge rates, the effect of the infiltrated water has a different effect, according to location and objectives.

Table 7 – Summary of the Costs in the WARBO test sites in a 30 years period (considering 1% as the discount rate)

Costs	Mereto	ZIPR	Copparo
Investment	105 000.00 €	85 000.00 €	60 000.00 €
Minimum Operation cost (yearly)	9 400.00 €	17 800.00 €	8 600.00 €
30 years Minimum Operation (1%)	326 977.98 €	619 171.07 €	299 150.07 €
Total 30 years cost	431 977.98 €	704 171.07 €	359 150.07 €
Yearly Infiltration (m^3)	860 000	730 000	189 216
30 years Infiltration (m^3)	25 800 000	21 900 000	5 676 480
€/infiltrated m^3 (1%)	0.017 €	0.032 €	0.063 €

Table 8 – Summary of the Impacts in the WARBO test sites at a long term (0 equals to neutral; + equals to positive and – to negative. One signal: low significance; Two signals: medium significance; Three Signals: significative; Four signals: very significative;)

Impact/Benefit	Mereto	ZIPR	Copparo
Groundwater Quantity	+ (in suspended aquifer)	–	+
Water extraction cost	0	0	0
Groundwater quality	+ +	–	+
Water treatment cost	0	0	0
Sea water/fossil water barrier	0	0	+
Subsidence mitigation	0	0	0
Superficial stream flow	0	+ +	+
Algae and microorganism growth	–	?	?
Clogging	–	–	0
Plagues	–	?	–
Biodiversity improvement	+	+	+ + +
Evaporation losses	–	–	– –

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Annex 1 – Environmental Impact Assessment classification tables

Mereto di Tomba (under the assumption of continuous operation)

Impact	Incidence	Spacial dimention	Signal	Significance	Probability	Duration	Temporal Dimension	Reversibility	Observation
Groundwater Quantity	Direct	Local	+	Low	Certain	Permanent	Immediate	Reversible	In perched aquifer
Water extraction cost	Indirect	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	Currently not used for water supply
Groundwater quality	Direct	Local	+	Medium	Certain	Permanent	Immediate	Reversible	In perched and main aquifer
Water treatment cost	Indirect	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	No treatments applied in the influence area
Sea water/fossil water barrier	Direct	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	Not applicable
Subsidence mitigation	Direct	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	Not applicable
Superficial stream flow	Direct	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	Not applicable; Negletable use of water from the surface flow network
Algae and microorganism growth	Direct	Test site	–	Low	Certain	Permanent	Immediate	Reversible	Effects in the clogging and possible long term water quality
Clogging	Direct	Test site	–	Low	Likely	Permanent	Medium-term	Reversible	Basic maintenance can mitigate this impact
Plagues	Direct	Local	–	Low	Possible	Permanent	Immediate to medium term	Reversible	
Biodiversity improvement	Direct	Local	+	Low	Likely	Permanent	Medium to long-term	Reversible	Magnitude of this impact might be more relevant when considering cumulative impacts with similar infrastructures
Evaporation losses	Direct	Test site	-	Low	Certain	Permanent	Immediate	Reversible	Low ratio of evaporation/infiltration

ZIPR (under the assumption of continuous operation)

Impact	Incidence	Spacial dimention	Signal	Significance	Probability	Duration	Temporal Dimension	Reversibility	Observation
Groundwater Quantity	Direct	Local	-	Low	Certain	Permanent	Immediate	Reversible	Water level is already very shallow. Its rise (in a very small area) might flood deep roots.
Water extraction cost	Indirect	Local	+	Low	Likely	Permanent	Immediate	Reversible	Higher levels can lead to lower pumping power
Groundwater quality	Direct	Local	–	Low	Certain	Permanent	Immediate	Reversible	Slight increase in Sodium and Clorine content
Water treatment cost	Indirect	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	No treatments applied in the influence area
Sea water/fossil water barrier	Direct	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	Not applicable
Subsidence mitigation	Direct	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	Not applicable
Superficial stream flow	Direct	Local	+	Medium	Certain	Permanent	Immediate	Reversible	Improvement on the water streams with less load of temperature and heavy metals
Algae and microorganism growth	Direct	Test site	–	Low	Certain	Permanent	Immediate	Reversible	Effects in the clogging and possible long term water quality
Clogging	Direct	Test site	–	Low	Likely	Permanent	Medium-term	Reversible	Basic maintenance can mitigate this impact
Plagues	Direct	Local	–	Low	Possible	Permanent	Immediate to medium term	Reversible	
Biodiversity improvement	Direct	Local	+	Low	Likely	Permanent	Medium to long-term	Reversible	Magnitude of this impact might be more relevant when considering comulative impacts with similar infrastructures
Evaporation losses	Direct	Test site	-	Low	Certain	Permanent	Immediate	Reversible	

Copparo (under the assumption of continuous operation)

Impact	Incidence	Spacial dimention	Signal	Significance	Probability	Duration	Temporal Dimension	Reversibility	Observation
Groundwater Quantity	Direct	Local	+	Low	Certain	Permanent	Immediate	Reversible	Effect concentrated in the aquifer geometry (paleochannel)
Water extraction cost	Indirect	Indirect	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	No extractions in the target aquifer
Groundwater quality	Direct	Local	+	Low	Certain	Permanent	Immediate	Reversible	Reduction of the aquifer water conductivity
Water treatment cost	Indirect	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	No treatments applied in the influence area
Sea water/fossil water barrier	Direct	Local	+	Low	Likely	Permanent	Immediate to Medium–term	Reversible	Upper aquifer water recharge might contrast the fossil water rising
Subsidence mitigation	Direct	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	Not applicable
Superficial stream flow	Direct	Local/Regional	+	Low	Certain	Permanent	Immediate	Reversible	Not applicable; Negletable use of water from the surface flow network
Algae and microorganism growth	Direct	Test site	–	Low	Unlikely	Permanent	Immediate	Reversible	Further studies are necessary in order to acess if the MAR had a effect in the Algae bloom
Clogging	Direct	Test site	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	Not likely to be conditioned with this kind of MAR
Plagues	Direct	Test site	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	
Biodiversity improvement	Direct	Local/Regional	+	Significant	Likely	Permanent	Medium to long-term	Reversible	Huge improvement in the superficial water quality, with obvious improvement for wildlife; Magnitude of this impact might be more relevant when considering cumulative impacts with similar infrastructures
Evaporation losses	Direct	Test site	–	Medium	Certain	Permanent	Immediate	Reversible	High ratio of Evaporation/infiltration

Label:

Classification Criteria	Classification	Explanation
Incidência	Direct	When a change comes directly from the Recharge site activity
	Indirect	When a change comes from another impact
Spacial Importance	Test Site	Impacts are felt in or just around the MAR facilities
	Local	In a local area, up to some kilometer
	Regional	At a regional level
	National/International	National or transborder level
Signal	Positive	Positive change, compared with the initial situation
	Negative	Negative change, compared with the initial situation
	Neutral	Change, but with no influence for the environment or the human wellbeeing
Importance	Low	Impact is of low importance to the described environmental sector
	Medium	Impact is of medium importance to the described environmental sector
	Significant	Impact can be significant to the described environmental sector
	Very significant	Impact is very significant to the described environmental sector
Probability	Possible	Under the current knowledge it may happen, but further studies are necessary to study the likelihood
	Likely	Likely to occur, but avoidable
	Certain	The impact will happen guaranteed
Duration	Permanent	Will occur as long as the project is running
	Temporary	Will happen just during a time period, and resume to the natural status
Temporal dimension	Imediate	Effects appear in a short time frame
	Medium Term	Effects will be visible in a medium time frame (years)
	Long Term	Effects will appear at a very long time frame
Reversibility	Reversible	Effects are reversible in case the operation ceases
	Irreversible	Effects are irreversible