

Solar salt works implementation in Ribeira de Aljezur, Portugal – Part 1

An alternative solution for land rehabilitation

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ABSTRACT Ribeira de Aljezur is a rich ecological area located in Parque Natural do Sudoeste Alentejano e Costa Vicentina and belongs to the Natura 2000 network. It is classified as an ecological target area that requires specific conservation actions. Part of the area is not natural due to the existence of ponds belonging to an old semi-intensive aquaculture, whose activity stopped in 2010. Before the area was used to rice and marine salt production although with an uncertainty of when were active for the last time. The fact is that the disappearance of these activities had an impact on the landscape, biodiversity, water regime and local economy. Actually there is a transformed landscape without natural biological settlement and human use. However the area rehabilitation is possible through a solar salt works implementation that can lead to a positive impact on the landscape, increase the biodiversity, increase of water management, and can stimulate the local economy.

The arguments described are not sufficient in Portuguese political and social reality so there will be no state involvement. As for private investors, there are three challenges described as production quantification, bureaucratic approval and risks.

So, legal aspects of solar salt ponds implementation and the risks, described as flooding and coastal inlet closure were analyzed, and the annual production of marine salt was estimated in an average of 2427.349 tons, according to effective evaporation rates average from the last eight years, ponds surface areas and volumes.

Concluding that it is possible to develop an economical and eco-friendly activity as an alternative solution to land rehabilitation in Ribeira de Aljezur.

Key words: Solar salt works, Land rehabilitation, Ecosystem services, Marine salt production, Wetlands, Ribeira de Aljezur, Portugal

1. BRIEF BACKGROUND OF RIBEIRA DE ALJEZUR

Ribeira de Aljezur is located in Parque Natural do Sudoeste Alentejano e Costa Vicentina (PNSACV) in the Algarve southwest coast. It is a 33.7 km water channel [1] and drains an area of 182.9 km² [2]. During the dry season, the stream has almost no freshwater flow, but is influenced by tides [3]. The coastal inlet is adjacent to Amoreira beach and shows an unexpected morphologic resilience resulted from a dynamic equilibrium between tide and wave action. This state is only altered when high magnitude external conditions occur, associated to tide increase forced by extreme fluvial discharges [4]. It is not a real estuary, but a transition system that from an ecological point of view can be classified as a lagoon-estuarine environment [5]. History tell us that Ribeira de Aljezur had several uses, however today almost all of them disappeared taking with them most of its potential and leaving abandoned land.

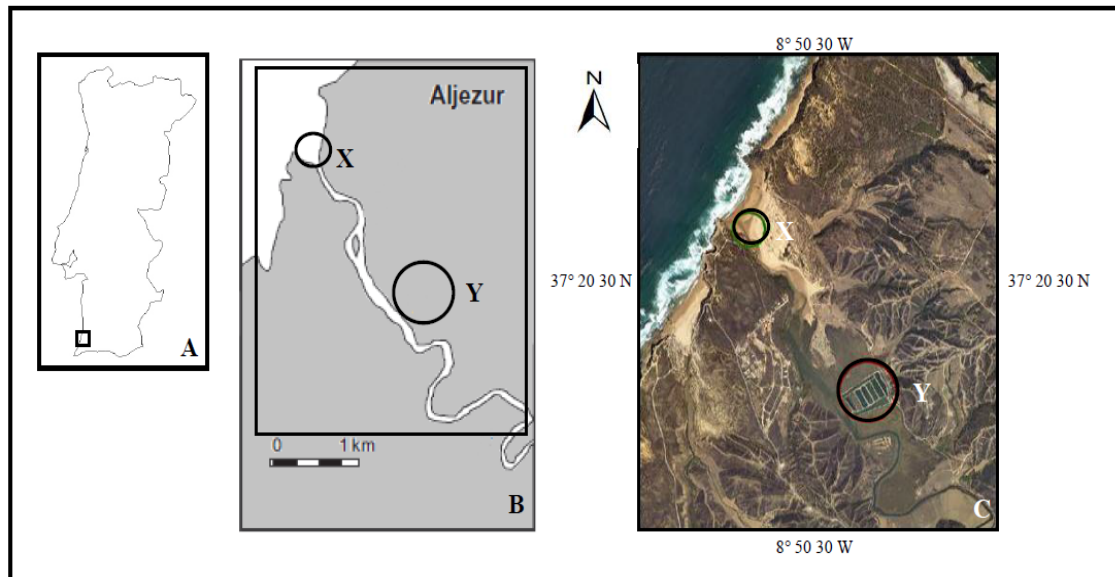


Figure 1: (A) Location of Ribeira de Aljezur in Portugal; (B) Location of the area to rehabilitate (Y) and the inlet (X); (C) Aerial photograph of Ribeira de Aljezur with the area to rehabilitate (Y) and the inlet (X).

2. SPECIFIC AREA OF REHABILITATION

The target area of this study is the area behind the dunes of Amoreira beach. The area is not natural due to the existence of ponds belonging to an old semi-intensive aquaculture, whose activity stopped in 2010. The area surrounding was used to rice and salt production back to the year 1318 [6] and it is possible to observe activity marks in the ground although with an uncertainty of when were active for the last time. The fact is that the disappearance of those three activities had an impact on the landscape, biodiversity, water regime and local economy.

3. ECOLOGICAL CLASSIFICATION OF THE AREA

The area is a specific intervention river area, type I and type II with partial protection and belongs to Natura 2000. The location results, that any rehabilitation activity must follow rules from Plano Especial do Parque Natural do Sudoeste Alentejano e Costa Vicentina Natural (PEPNSACV). This plan aims the insurance of ecosystems equilibrium, the promotion of economic, social and cultural development [7]. The area also belongs to the Public Water Domain [8], National Ecological Reserve (REN) [9] and National Agriculture Reserve (RAN), each with specific management guidelines [10].

4. SOLAR SALT WORKS PRESENCE AND CONSERVATION VALUES

The solar salt works activities are normally present in wetlands, more specifically in salt marshes rich in biodiversity and represent unique biological systems [11], which makes them environmentally relevant activities [12]. Many species live, feed and reproduce in a salt marsh and in a solar salt works area [13]. They provide to the environment biological diversity, including plants, birds, reptiles, fish and invertebrates, prevent flooding and improve water quality [14]. This is why the presence of solar salt works in Ribeira de Aljezur could be an ecological solution for land rehabilitation. Without negative impacts and stimulation of sustainable development.

Usually, even salt producers do not give great importance to its ecological value and it is difficult to estimate an economic value, but it is possible to list the arguments in favor of solar salt works as an environmentally-friendly activity. The presence of solar salt works can control the hydrological regime, promote the area preservation, controlling natural and anthropogenic factors and can also control water quality [15-18].

One example of successful protection is the case of the solar salt works of Margherita di Savoia (South of Italy). An artificial solar salt works located in a protected area with natural interest, belonging also to Natura 2000 and Ramsar list. However, even rare species considered endangered are proliferating there. Migratory species make the area a "stopover" for food and shelter. There is an integrated management, species inventories, naturalistic, biological, microbiological and geological studies and all the stakeholders agree with the role that plays in conservation, due to the lack of negative impacts [19]. Other examples of Ramsar areas, with traditional solar salt works are the cases of Songor Keta lagoon in Ghana [20], Yucatan in Mexico [21] and Rajasthan in India [22].

In the specific case of Ribeira de Aljezur, solar salt works implementation could play an important role in conservation, promoting new biological relationships, biodiversity increase, possible qualification of the water, the regulation of water flow, and a major positive impact on the landscape level.

5. IMPLEMENTATION PROCESS

Ribeira de Aljezur includes spaces with heritage value, natural and cultural, actual or potential, in need of recovery, backup, rehabilitation or retraining, including areas where the dynamics of the changes that were reversed and should be subject to recovery-oriented. The high biodiversity and nature conservation needs led to the designation as a special protection area and included it on SACVNPSP. The plan was approved in order to ensure proper management safeguarding the natural resources, promoting sustainable development and populations life quality, has also the legal administrative and regulation guidelines and must confront the municipal plans. Guidelines with the aim to ensure the development of activities compatible with the equilibrium of ecosystems and the promotion of economic, social and cultural context of a protected area. It was also stipulated that the PNSACV would have responsibility for creating a terrestrial and aquatic interpretive path, and stimulation of environmental awareness activities for the entire domain and therefore to Ribeira de Aljezur [23]. With the solar salt works conservation values, approval and implementation steps will be easily overcome. However Portuguese public institutions do not have the financial capacity to support a large-scale project like this one and therefore there is the need to convince private investors to fund the project. For that it is necessary to analyze the activity risks and estimate the production of marine salt, which later through a business plan will result into a business opportunity for investors.

6. METHODS

Ponds area topographical lifting and mapping: It was made a topographical lifting, with a DGPS (Differential Global Position System) (Trimble 5800) in Ribeira de Aljezur ponds. The data was interpolated on ArcGis 9 through tin function, with Geographic Datum IPCC.UTM and was projected.

Solar salt ponds surface areas and volumes: Solar salt ponds surface areas and volumes in Ribeira de Aljezur were projected, through the ratio between solar salt ponds areas and volumes in a real case in Olhão, Algarve, Portugal. To reservoir, evaporators, crystallizers and barriers the areas ratio were 11,9%, 68,7%, 17,4% and 2% respectively. The volumes ratio were 26,1%, 70% and 3.9% respectively. There is no volume ratio to barriers.

6.1. Estimate marine salt production

6.1.1. Effective evaporation

According to evaporation and precipitation rates from Ribeira de Aljezur (data provided by Direcção Regional da Agricultura do Algarve), between the years 2004 (February) and 2012 (December) were calculated the effective monthly evaporation averages using the following equation: $E_e = E_v - P$ [24]; Where E_e is the effective

evaporation (mm), E_v is the evaporation (mm) and P is the precipitation (mm) per square meter.

6.1.2. Estimate marine salt production mass

To calculate the mass of salt crystallized the following mass of salt crystallization equation was used [25]: $m_s = E_w * 0.035$; Where m_s is the salt crystallized mass (kg), E_w is the volume of evaporated water (dm^3), and 0.035 is the salt mass ($\text{Kg} \cdot \text{dm}^{-3}$) in the water. The E_w used were the monthly averages, minimums and maximums.

6.2. Solar salt works risks

6.2.1. Tide characterization

The tidal was characterized through the tide form number (N_f) and the Mean High Water Spring (MHWS), Mean High Water Neap (MHWN) and the High High Water Spring (HHWS), were calculate [26], according to Sines fundamental harmonic constants and the Portuguese Hydrographical Zero (data provided by Instituto Hidrográfico Português).

6.2.2. Extreme flooding height prediction

The flooding risk height was predicted through the sum of extreme environmental physical factors heights: $Fr_h = HQ_f + ST + HHWS$; River discharge height (HQ_f) according to the most extreme precipitation rates (December, 2010) in the last eight years and a 105 m^2 section (stream width in front of the implementation area), through the equation in Miranda et al., 2002. Storm surge (ST) with 1 m maximum height to the Portuguese coast line [27] and high high water spring (HHWS).

7. RESULTS AND DISCUSSION

7.1. Ponds area topographical lifting and mapping



Figure 2: Actual Ponds 3D survey with Elevation (m) in Ribeira de Aljezur.

After a topographical lifting, it is possible to observe that the actual ponds are typical ponds from a semi-intensive aquaculture. The ponds are differentiated to promote fish development in different stages and the seawater collection is functional. Any future projection should take into account these facts minimizing the use of energy and consequently the management cost.

7.2. Solar salt ponds surface areas and volumes

Through the relationship between solar salt works case in Olhão, the ponds areas and volumes in Ribeira de Aljezur solar salt works were calculated, taking into account the area limitations, 106300 m². So, reservoir, evaporators, crystallizers and barriers were projected with areas of 12649.7 m², 73028.1 m², 18496.2 m² and 2126 m² respectively. The volumes for reservoir, evaporators and crystallizers were 18974.55 m³, 51119.67 m³ and 2774.43 m³ respectively. It was assumed that the differences between effective evaporation rates in Ribeira de Aljezur and Olhão, would not influence the relationship between the surface areas or volumes; however an optimization of the areas and volumes according to effective evaporation should be done.

7.3. Estimate marine salt production

7.3.1. Effective evaporation

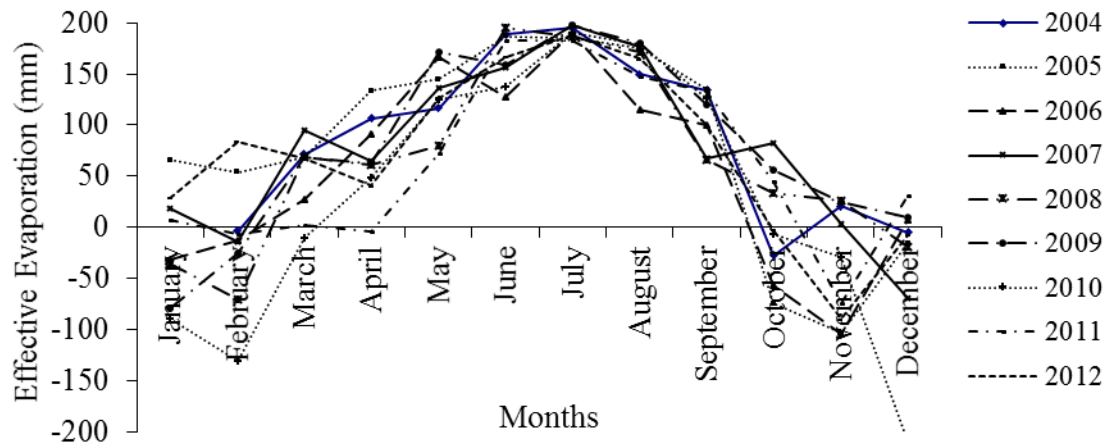


Figure 3: Chart with effective evaporation month average, maximum and minimum from February, 2004 till December, 2012 in Ribeira de Aljezur.

According to Ribeira de Aljezur's average effective evaporation rate, it is possible to produce marine salt between March and September, with the total effective evaporation average of 874.9 mm. Through the maximum effective evaporation values, the estimated production is maintained in the same set of months, with a total effective evaporation of 1105.5 mm. Through the minimum effective evaporation the estimated production will be reduced, between May and September with a total effective evaporation of 563.2 mm. This difference between maximums and minimum values leads to a difference between marine salt estimated productions.

7.4. Marine salt and Fleur de sel Production

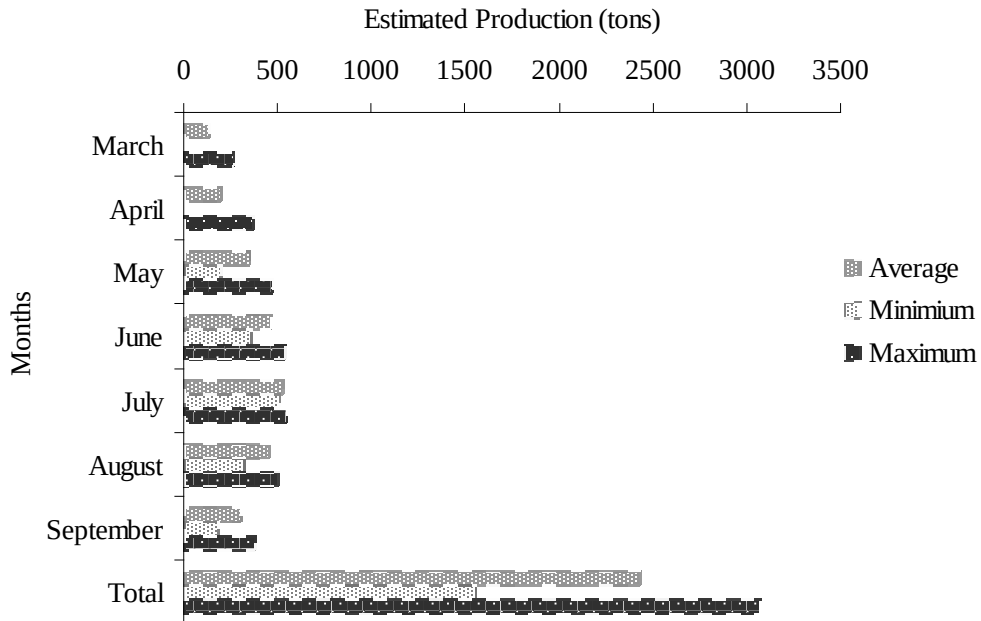


Figure 4: Chart with the annual average, minimum and maximum estimated marine salt production (tons).

Marine salt was estimated according to projected solar ponds surface areas, volumes and the effective evaporation averages, minimums and maximums for each month in Ribeira de Aljezur. With a total estimated production for the average, minimum and maximum of 2427.349 tons, 1555.9 tons and 3067.132 tons respectively.

7.5. Solar salt works risks

7.5.1. Tide Characterization

$N_f = 0,099$; $Z_0 = 2.12$ m; $MHWN = 2.758$ m; $HHWS = 3.584$ m; $MHWS = 3.452$ m

The tide is a semi-diurnal tide and it means that has a tidal regime with a 12h42min frequency, characterized by two high tides and two low tides in each period or tidal cycle. The high water spring is regular with a two-week frequency, which means that it sustains all the effective evaporation and consequently the marine salt production.

7.5.2. Extreme Flooding Risk Height Prediction

$HHWS = 3.584$ m; $H_{Qf} = 1.7485$ m; Portuguese Coast $ST = 1$ m; $Fr_h = 6.3325$; $BH > 6.3325$ m

The flooding risk was calculated based on the external events that may occur in the area. Water peak discharges (1.7485 m) were calculated with precipitation data from December 2010, the high precipitation level in the last eight years and the respective

month average temperature. It is possible that a bigger data set could give higher precipitation values, however the only dataset available for the Aljezur area goes back to 2004 values. High tides (3.584 m) were calculated from the port of Sines fundamental harmonic constants. Storm surge (1 m) as maximum value to storm surge in the Portuguese west coast. This cross resulted on the value at which the salt ponds barriers heights must overcome 6.3325 m ($BH > 6.3325$ m). An error might have occurred, due to the fact that the increase of sea water level in narrow estuaries was despised. However Ribeira de Aljezur channel presents a longitudinal profile with a constant width, up to ponds, so this effect can be neglected. It is a controlled risk managing during the barriers projection.

7.6. Coastal inlet closure

Another risk is the coastal inlet closure that lead to salinity longitudinal profile changes and in case of total closure, the marine tide doesn't reach the solar salt ponds. Which consequently stops marine salt production. Thus the closure bar danger is minimal and temporary, leading then to a natural opening [28] or artificial opening such as in Lagoa de Santo Andre, southwest Portugal [29]. So it is an uncontrolled risk but with practical solution.

8. CONCLUSIONS

The rehabilitation of the old semi-aquaculture area in Ribeira de Aljezur could be possible through an implementation and development of solar salt works.

To achieve legal implementation it is necessary to present the project to the Aljezur Council, which in turn meets with the entities that regulate Ribeira de Aljezur area, including the SACVNP, REN, RAN, all controlled by Ministério da Agricultura, do Mar, do Ambiente e do Ordenamento do Território. The constraint about ecological classification is only surmountable by the argument that the area of the old semi-intensive aquaculture could be rehabilitated to an economical eco-friendly activity. Solar salt works in Ribeira de Aljezur will exert water management, promote hydrologic control and ecology studies in the surrounding area, promote land rehabilitation and consequently will improve the landscape and local economy. However this was a theoretical approach using secondary literature, there is no statistical proof for this specific area that biodiversity, water and local economy will be positively impacted by this technology.

For investors the most important comes with the marine salt production and risks analyses. Environmental and tide characteristics make the area a very good and well-controlled area for solar salt works implementation. Through traditional methods it is possible to achieve an average of 2427.349 tons of marine salt production, which would be a massive production for Portuguese artisanal production reality. The most important risks described as flooding and coastal inlet closure have different perspectives of analyses. Flooding is a minimum risk that should be managed during

the solar salt works barriers high projection, never less than 6.3325 m and coastal inlet closure is a minimum risk with practical solution through an inlet artificial opening. With the approval steps described, the marine salt production quantification and the risks analyzes of this project could be a solution to Ribeira de Aljezur land rehabilitation.

9. The future

Apart from the physicochemical process of marine salt production, through a vision of complementary and an extended attitude to the plurality of man's dimension, solar salt works are much more than marine salt production. Solar salt ponds can be used to inorganic and organic production, to be visited and fundamentally to research. The two most observable groups of organisms to be produced are *Salicornia spp.* [30]; and *Artemia spp.* [31, 32], however there is no optimized systems to produce them. In the other hand the fact that solar salt works being eco-friendly activities could be used to attract tourism and diffuse products [33, 34, 35].

Regarding to research, solar salt works have a great potential. The relationship between time of crystallization and different types of marine salt, the production optimization through a higher wind effect over the water surface or different solar salt ponds structure constituent materials. It is interesting also to develop an economic and social study to show the impacts arising from the tradeoff between aquaculture and solar salt works. All of this research development can increase the transfer of scientific knowledge and traditional know-how as can provide other arguments to Portuguese solar salt works facing globalized markets.

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