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The Cassaire wetland restoration project: defining the reference ecosystem

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Abstract

Defining a reference ecosystem for ecological restoration project is an essential step. The reference can correspond to the historical ecosystem, can be defined to solve environmental issues or can correspond to a socioecosystem. For the restoration of the Cassaire site in the Camargue delta in southern France, the reference ecosystems chosen are: Mediterranean temporary wetlands and Mediterranean meso-xeric grasslands. The choice of these two reference ecosystems appears logical considering their contribution to regional biodiversity. Temporary wetlands and meso-xeric grasslands are rare, adapted to the Mediterranean climate, seriously endangered and host a high species richness. They are potentially achievable restoration targets because patches of these ecosystems remain in the Camargue area and close to the Cassaire site. Moreover, an ecological history approach reveals deep human imprints on ecosystems and ensures that historical restoration targets (the state prior to human impacts) cannot be reached, because they are associated with hydraulic functioning (flooding of the Rhône and Durance) that no longer exists. The restored site is planned to be suitable for livestock grazing, thus presenting a new agricultural opportunity, while simultaneously offering new services, such as hunting.

Keywords: ecological restoration, ecological services, Mediterranean grassland, socio-ecosystems, temporary wetland.

Introduction: Defining reference ecosystem

Ecological restoration is “the process of assisting the recovery of an ecosystem that has been degraded, damaged, or destroyed” (Gann *et al.*, 2019). Defining a reference, i.e. a non-degraded version of a local native ecosystem that is the target of ecological restoration (Gann *et al.*, 2019), is an essential step because it helps practitioners to set restoration objectives, to guide the restoration process and to assess success (Clewell & Aronson, 2007; Miller & Hobbs, 2007). Besides identifying the reference ecosystem, the disturbances that degraded the ecosystem to be restored have to be identified and their effects understood (Hobbs & Norton, 1996; White & Jentsch, 2004). The reference can be defined in different ways: 1) it can correspond to the historical ecosystem; 2) it can be defined to solve environmental issues, for example to restore some ecosystem services or 3) it can correspond to a socioecosystem. The historical ecosystem corresponds to the ecosystem before a severe anthropogenic disturbance (e.g. intensive cultivation). One example of this type of reference is the one used by Aldo Leopold in the first restoration projects in the

1930s in the United States to remedy land-abandonment and aid soil conservation in tallgrass prairies in Wisconsin: “Our idea is to reconstruct a sample of original Wisconsin, a sample of what Dane County looked like when our ancestors arrived here during the 1840s” (Leopold, 1949). Using the pre-disturbance state to guide restoration can be useful if enough is known of the historical conditions and if large areas of the pre-disturbance state are still found in the landscape; however aiming for ecosystems, that precisely replicate the past and that are no more sustainable in the actual context, is a practice that is unlikely to deliver self-sustaining results (Choi, 2007). A reference defined to solve environmental issues corresponds more to rehabilitation or remediation on the restorative continuum (Gann *et al.*, 2019). On example of this is the *Restauration des Terrains en Montagne* (Mountain Ecosystem Restoration) agency which has been carrying out this type of restoration in France since 1860, principally by reforesting degraded pastures to prevent soil erosion (Combes, 1989). Within this paradigm ecological values (e.g. species or habitat with conservation value, biodiversity, or potential habitat for rare, endemic and/or threatened species) are less taken into account and serve as a means to solving technical problems related to human activities. When historical ecosystems are difficult to define or when using them is unrealistic in a context of climate

changes and fragmented landscapes (Millar & Brubaker, 2006), another reference ecosystem must be defined (Jackson & Hobbs, 2009). Reference ecosystems can also be determined with regard to both ecological values and social issues (Choi, 2007; Clewell & Aronson, 2007). These socio-ecosystems consist of a collective construction of integrated, complex and adaptive systems, coupling nature and human societies, with the Human considered as an active component of the ecosystem, and with an integrated approach to human-nature interactions. Under these conditions, the final choice of reference is unavoidably subjective and arbitrary (Choi, 2004), but it leads to public acceptance and a higher probability of restoration success (Gobster & Hull, 2000). While ecological constraints define what is possible and financial constraints determine what is realistic, social constraints determine whether a given restoration project is acceptable (Miller & Hobbs, 2007) and whether it matches local social needs. In such reference ecosystems, successful restoration must be predicated on the communication of project goals and benefits to humans, and on consultations along with open dialogue to evaluate public understanding, acceptance, and support (Miller & Hobbs, 2007).

The Cassaïre project

Restoration project of the Cassaïre site

In an area as modified by human activity as the Camargue delta, where local stakeholders are deeply involved in the management of the environment, reflections around a socio-ecosystem for a restoration project make sense. Moreover, on such a basis, defining a natural state is not straightforward and may not even be appropriate: is the natural state the condition that existed before cultivation or is it the condition that would exist in the absence of all human influences (e.g. containment of the Rhône river)? Considering a reference ecosystem based on conservation objectives linked with the current landscape and local demand seems to be the best way to lead a successful restoration project. This is the case with the Cassaïre restoration project located east of the Camargue area (43°31'N, 4°44'E, Plan du Bourg, Rhône delta, Southern France, Figure 1).

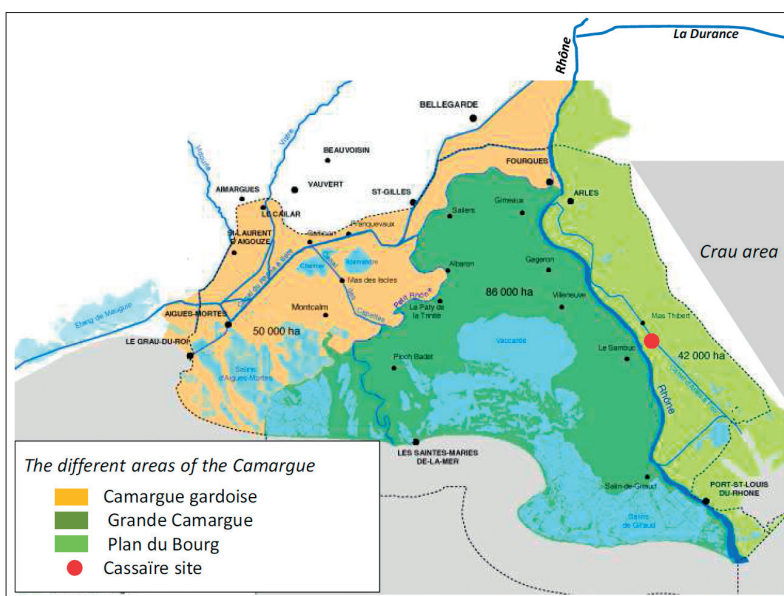


Figure 1 – Location of the Cassaïre site in the Camargue, Southern France. The different areas of the Camargue and the location of the Cassaïre site (red dot) in the Plan du Bourg area. The Durance river, the Rhône, and the Crau area, are also shown. Figure adapted from the official Regional Park of the Camargue area map.

Covering more than 70 hectares, the Cassaïre site is composed of a mosaic of habitats, a majority of fallow land which have been heavily transformed by humans through cultivation-related activities (such as leveling, grading, drainage, irrigation, and amendment). The remaining relic natural habitats (comprising a grand total of less than 7 hectares) correspond to the following three priority habitats according to the Natura 2000 Network of the European Union Habitat Directive (European Commission, 1992): fluvial dunes linked to Rhône sand deposit, meso-xeric grasslands on the highest parts of the site, and salt marshes on the lower parts (Figure 2).

In 2004, after farming cessation, the site was acquired by Conservatoire du littoral et des rivages lacustres (a state conservancy agency) and its management was entrusted to an NGO “*Les Amis des Marais du Vigueirat*”, which now administrates the surrounding National Nature Reserve “*Les Marais du Vigueirat*”. Although the entire project was completely financed by *Agence de l’eau* (the Water Agency), *Conseil régional Provence-Alpes-Côte-d’Azur* (the Regional Council), and *Conseil général des Bouches-du-Rhône* (the Departmental Council), all design and implementation decisions were taken collectively by a steering committee composed of the following stakeholders:

1) Environmental managers: the National Reserve managers of *Les Amis des Marais du Vigueirat* (NGO which administrates the National Nature Reserve), the *Parc naturel régional de Camargue* (the Natural Regional Park of the Camargue), and, at the time of the implementation of the project (2010-2012), the *Office national de la chasse et de la faune sauvage* (the National Office for Hunting and Wildlife), now part of the *Office français de la biodiversité* (the French Office for Biodiversity);

2) Project managers and funders: *Conservatoire du littoral et des rivages lacustres* (a state conservancy agency), *Agence de l’eau* (the Water Agency), *Conseil régional Provence-Alpes-Côte-d’Azur* (the Regional Council), and *Conseil général des Bouches-du-Rhône* (the Departmental Council);

3) Local stakeholders: The hunting association of Mas Thibert hamlet and the Departmental hunting federation;

4) Scientists, experts, and researchers from the Tour du Valat (Research center for

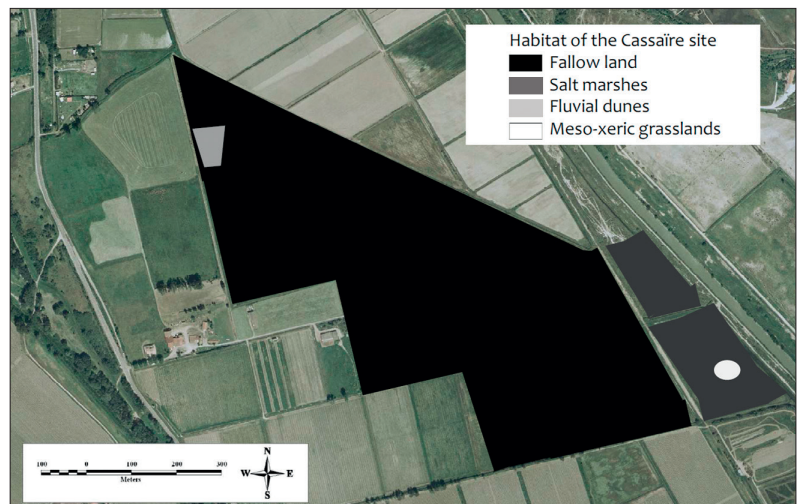


Figure 2 – Habitat map of the Cassaïre site, with a majority of fallow land (in black) and remaining relictual natural habitats (the meso-xeric grasslands in white, the dunes in light grey and the salt marshes in dark grey).

conservation of Mediterranean wetlands), and the Mediterranean Institute of Biodiversity and Ecology (IMBE).

Even when the various stakeholders did not share the same expectations, the various meetings and steering committees resulted in a consensus. It was ultimately decided that the restoration project be developed for sustainable and harmonious development in connection with the neighboring hamlet hunters. The objective of this project was twofold: creating, for conservation value, complementary habitats from those present on the Vigueirat National Nature Reserve, and achieving this while allowing some hunting activity to continue as negotiated with local community stakeholders. Indeed, in the Camargue area, traditional rural activities, especially hunting, are important. Creating a wetland would increase the size of the available hunting ground for town hunters, who do not currently have much. Moreover, it would induce a close collaboration between nature reserve managers and hunters who have drastically different ways of managing wetland hydrology (hunters keep standing water in summer to attract waterfowl, leading to hydrological functioning in contrast to Mediterranean temporary wetlands, whose management has resulted in severe consequences for biodiversity). Because funding for a project can depend on its level of public acceptance (Miller & Hobbs, 2007), local participation is an essential ingredient for project success. The conflicts and compatibilities of the Cassaïre restoration project

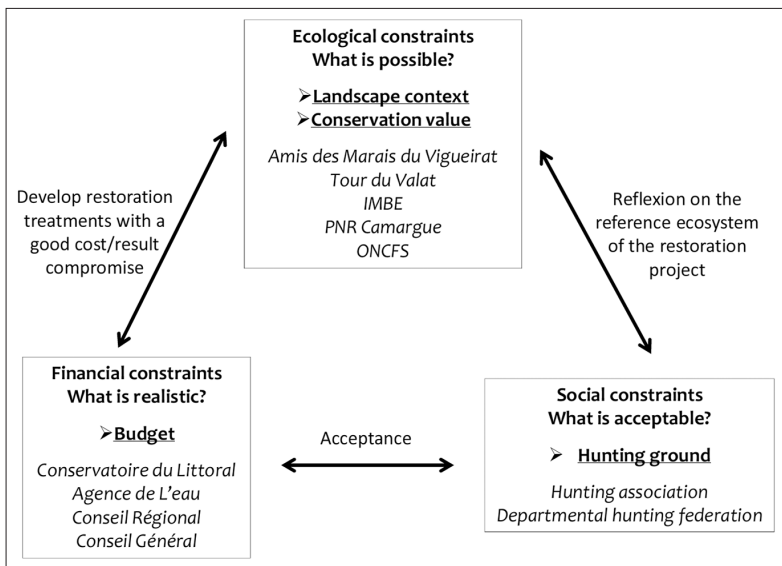


Figure 3 – Conceptual organization chart of the project design modified from Miller and Hobbs (2007).

objectives were carefully considered, and the project stood out as a shining example of co-management that properly takes into account local acceptance, projected benefit, social, financial, and ecological goals and constraints (Figure 3).

As determined by Donadieu (2002), the reference selection process needs to address the following four questions: 1) From whom to restore?, 2) What to restore?, 3) How to restore? and 4) How to evaluate the long-term success of the operation? For the Cassaïre site, the answers to these questions were: 1) for biodiversity and for the hunters, 2) a Mediterranean temporary wetland with high conservation value and suitable for hunting activities, 3) by using advanced engineering techniques, and 4) by using the notion of target species. Indeed, even though the facilitation of hunting activities was a major objective, the primary aim was to create natural habitats similar to the high conservation value habitats found in Camargue, and complementary to those of the Vigueirat National Nature Reserve. The notion of target species is thereby directly linked to the concept of reference ecosystems. These species are the species present in the reference and are usually contrasted with non-target species, which are species absent from the reference. A reduction in the number of non-target species accompanied by an increase in the number of target species can be an objective and an indicator of success in a restoration project, though it must be used with caution (Davis *et al.*, 2011). Because the restoration project

incorporated local stakeholders, other evaluation guidelines, which include social components, could be used as success indicators (such as the support of local stakeholders, hunting tables, and ecosystem services).

Reference ecosystems of the Cassaïre site

Mediterranean temporary wetland

Mediterranean temporary wetlands are depressions, characterized by variable flooding (concentrated in autumn, winter and spring) and a summer dry-out (Grillas *et al.*, 2004). They represent one of the most remarkable Mediterranean habitats, comprising a high plant diversity with many annual species, some of which are rare and endangered. These plants are well adapted to the Mediterranean climate because, by being annual they are able to make it through the dry summer and take advantage of the short favorable periods for reproduction. Examples include *Zannichellia obtusifolia* Talavera & al., *Callitriche lenisulca* Clavaud or *Tolypella hispanica* C.F.O. Nordstedt ex T.F.Allen (Grillas & Duncan, 1986; Grillas *et al.*, 2004). Grazing helps keep the habitat open and to aerate the soil by trampling. These habitats have lost their identity with the work of hydraulic facilities (containment and supply of fresh water) and have been subjected in recent decades to degradation and drastic area reduction due to agriculture, industry, recreational activities, and hunting (Hollis, 1992; Grillas *et al.*, 2004), making this type of habitat rare (Figure 4). Indeed, one of the main causes of degradation in Mediterranean temporary wetlands is water management in support of hunting activities in which water levels are maintained in summer, to attract waterfowl, and this has gradually favored perennial and cosmopolitan species over plant communities that are restricted to temporary wetlands (Tamisier & Grillas, 1994; Aznar *et al.*, 2003). The artificial addition of freshwater in summer is contrary to the natural functioning of wetlands and leads to conflicts and strong contention between conservationists and hunters, a recurrent issue that has been demonstrated yet again in a recent county hunting journal article that is critical of nature reserve managers

Mediterranean meso-xeric grassland

Mediterranean temporary wetlands are found in a mosaic together with many other habitats, including Mediterranean meso-xeric grasslands. It was therefore decided that a topography favorable to meso-xeric grasslands be created in addition to the depressions needed for temporary wetland restoration. A convenient way of simultaneously restoring both habitats is to use the soil that is removed, in creating the depressions, for establishing restored grasslands. A meso-xeric grassland is already present on the Cassaïre site as relics of natural habitats (Figure 2). Such grassland is found on never-flooded old eroded dune relief (fluvial or marine) that is less subject to the influence of salt than lower areas. This habitat has the highest plant richness in the Camargue area (Molinier & Tallon, 1970; Braun-Blanquet, 1973), composed in high proportion of annual species, such as *Brachypodium distachyon* (L.) P. Beauv., *Galium murale* (L.) All., or *Scorpiurus muricatus* L. These grasslands are traditionally managed by extensive on-and-off livestock grazing throughout the year, keeping habitats open, and enhancing biodiversity (Mesléard *et al.*, 1991). Having gone from around 4,000 hectares initially (Tamisier & Grillas, 1994) to less than 2,000 highly fragmented hectares today, they are also the most threatened habitat in the Camargue area (Figure 5). This is essentially the result of topological flattening of dune relief due to cultivation expansion.

Reference choice and landscape importance in restoration

The choice of these two reference ecosystems appears logical considering their contribution to regional biodiversity. Temporary wetlands and meso-xeric grasslands are rare, adapted to the Mediterranean climate, seriously endangered and host a high species richness. The dry phases in temporary wetlands are often considered as a disturbance (Bonis, 1998) on a par with grazing in meso-xeric grasslands (Mesléard *et al.*, 2011). The disturbance regimes of both ecosystems should be understood so that they can be re-established on the restored ecosystems, because they can create environmental heterogeneity and can affect community structure, diversity, and biotic interactions (Menninger & Palmer, 2006). Moreover, these two reference ecosystems are potentially achievable restoration targets because patches of these ecosystems remain

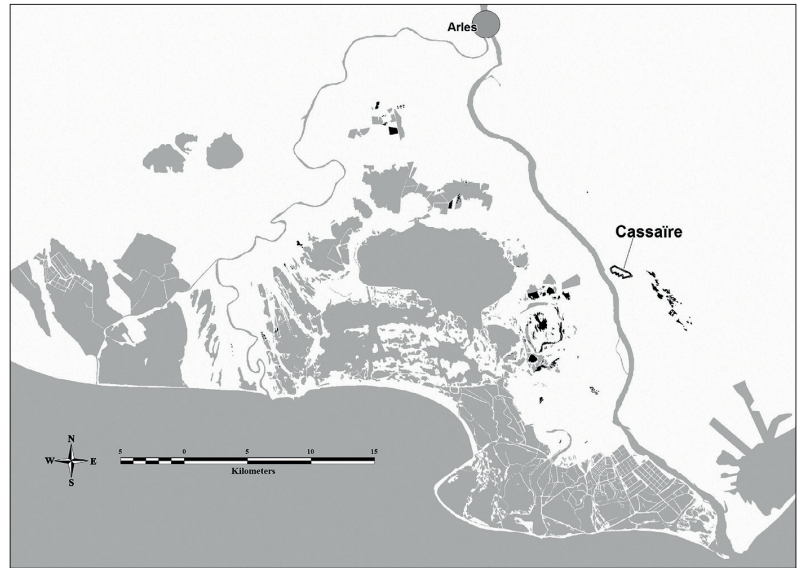


Figure 4 – Distribution of the Mediterranean temporary wetlands (in black) in Camargue area and location of the Cassaïre site. The grey shading indicates the other wetland types in the Camargue area.



Figure 5 – Distribution of the Mediterranean meso-xeric grasslands (in black) in Camargue area and location of the Cassaïre site. The grey shading indicates the other wetland types in the Camargue area.

in the Camargue area and close to the Cassaïre site (Figure 4 and Figure 5). Indeed, reference ecosystems must be sustainable in the future (Choi *et al.*, 2008). A landscape-scale approach can have notable implications for restoration. (1) It provides better guidance for selecting reference sites and establishing project goals. (2) It allows spatial configurations of restored elements appropriate for facilitating recruitment of flora and fauna, with intact regional ecosystems playing the role of propagule sources for colonizing restored areas (Cairns Jr., 1993; Bell *et al.*, 1997; Bornette

et al., 1998; Zedler, 2000; Shackelford *et al.*, 2013). The restored site can therefore have a strong influence on the relictual landscape responsible for exchanges of propagules to support a viable community, maintain biodiversity, contribute to regional dynamics, increase connectivity (Hilty *et al.*, 2012), decrease extinction debts (Smallwood, 2001; Piqueray *et al.*, 2011), have an important role within a metacommunity context (Turnbull *et al.*, 2000), and to potentially play the role of keystone community in fragmented landscape (Mouquet *et al.* 2013).

Ecological history of the Cassaïre site

Aims and methods

Ecological history is a tool that can be used to identify and characterize suitable targets for ecological restoration (Swetnam *et al.*, 1999; Jackson & Hobbs, 2009). Ecological history helps to define the state of the original ecosystem, the natural state of the landscape, and the dynamics of ecosystems. It also serves to assess the nature, duration, and intensity of disturbances (e.g. grazing suppression, cultural eutrophication, or river containment). Even when the historical state cannot be reached, historical information for a given site can be very useful in restoration planning (Swetnam *et al.*, 1999). To identify the history of the Cassaïre site in the grander context of the Plan du Bourg (Figure 1), its ecological history was assessed by searching historical documentary archives, old maps, written descriptions, aerial images, and by interviewing local stakeholders (Table 1).

Table 1 – Documentary sources and archives for the various dates.

Date	Documentary source
1640	Provence map
1760	Rhône mouth map
1770-1778	Cassini map
1811-1829	Country written description
1823-1828	Napoleonic land registry
1830-1901	Land registry
1896	Article about Cassaïre site
1944	US Army aerial images
1947-1998	IGN aerial images
1946-2004	Interviews of the former farmer

Results

Today, the Plan du Bourg area is separated from the Grande Camargue by the Grand Rhône, which is one of the branches of the Rhône river (Figure 1). Conversely, a geological study demonstrated that Plan du Bourg belongs to the Camargue area (Figure 6). The 1640 map of Provence indicates that prior to the containment of the Rhône, a branch of the Rhône formerly ran along the Crau area (Figure 7) to the east of the Plan du Bourg (Figure 1). The floodwaters of the Rhône and Durance rivers formed a permanent stream, the Duransole (Colin, 1904), that flowed freely through the Plan du Bourg. No written descriptions of the vegetation were found for this period, however, it is known that significant amounts of water and associated sediment inputs limited the local salinity and allowed the development non-halophilous riparian vegetation and fluvial dunes.

Cette pente n'existe que dans le Plan-du-Bourg qui n'appartient pas à la Crau, mais qui est une lisière le long du Rhône, bornée à l'Est par les étangs du Galejon, de Ligagnan, les Roubines, l'étang de Meyrane, etc. Elle fait réellement partie de la Camargue par la nature de son sol qui est limoneux et profond sans aucun galet. Autrefois elle tenait à la Camargue, parce que le Rhône coulait où coulent les Roubines qui marquent la limite de la Crau, puisque sur leur rive gauche on trouve le poudingue.

Figure 6 – Extract from County written description, Statistiques des Bouches-du-Rhône (1821).



Figure 7 – Provence map (Louis Cundier) indicating the former branch of the Rhône along the Crau area (1640). The Cassaïre site is located with red dot.

Water levels have been managed since the 14th century (De Villeneuve-Bargemon 1826) to reduce the hostility of the wetland areas and to dry out the Plan du Bourg, leading to the formation of Viguierat wetlands (currently the Viguierat National Nature Reserve) neighboring the Cassaïre site. This regional drying-out is inseparable from the Grand Rhône containment. Maps of 1760 and 1770 indicate that the Cassaïre site presented brush, wetlands and fluvial dunes (Figure 8), the latter having a relic still present today on the site (Figure 3).

The first specific indications of the Cassaïre site appear in the Napoleonic land registry (1823, Figure 9), indicating that the Cassaïre site was mainly composed of brackish marsh and flooded grassland, where grazing was common, and of small areas of vineyard and other cultivation. An extract from the press surrounding the sale of the site (Figure 10, 1896) indicates the presence of vineyards and other cultivation, gardens, and grassland.

By digitizing and analyzing aerial images from 1947 to 1998 (e.g. Figure 11), we detected a drastic reduction in natural habitat (from 69% to 8% of the total area, all of

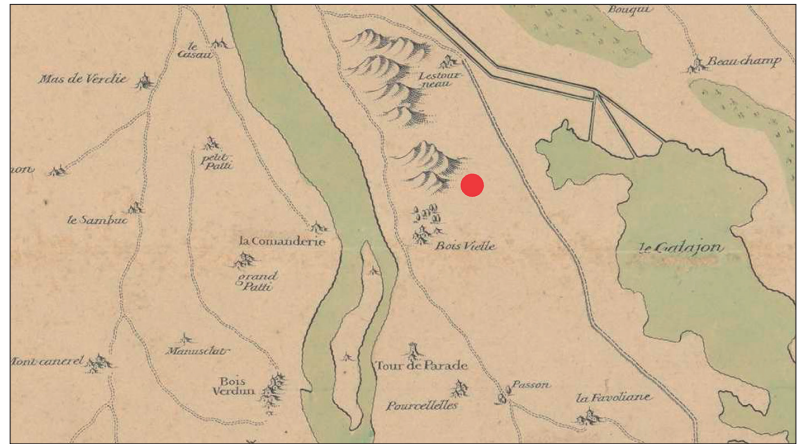


Figure 8 – Rhône mouth map (JB Bourgignon) indicating fluvial dunes (1706). The Cassaïre site is indicated by the red dot.



Figure 9 – Napoleonic land registry of the Cassaïre site delimited in red (1823).

Etude de M^e Tardieu, avoué, à Tarascon, rue Saint-Nicolas, 25.

Vente par Licitation

Après Surenchère

à l'audience des criées tenue par le Tribunal civil de Tarascon, le vendredi dix juillet 1896, à 9 heures du matin, du

Domaine du Cassaïre

situé sur le terroir d'Arles, au Plan-du-Bourg, à vingt kilomètres d'Arles, à trois kilomètres de la gare du Mas-Thibert, ayant une halte même dans la propriété sur la ligne d'Arles à Port-Saint-Louis, d'une contenance totale de 69 hectares, 39 ares, 29 centiares ; comprenant un très beau vignoble d'une superficie de 15 hectares, jardin, terres labourables et herbages, bâtiments de maître et d'exploitation, cave avec ustensiles vinaire, greniers à foin, remises, écuries, bergerie, four à cuire le pain, forge, loge à lapins et à cochons, poulailler, habitation du jardinier. Ce domaine est longé au levant par le canal de navigation d'Arles à Port-de-Bouc et au couchant par la grande route d'Arles à Port-Saint-Louis.

Sur la mise à prix de 23.334 fr. 16 centimes.

Pour tous renseignements, s'adresser à Arles à M^e Arnaud, notaire, et à Tarascon, à M^e Tardieu, avoué poursuivant.

Signé : B. TARDIEU.

Figure 10 – Extract from the press surrounding the sale of the Cassaïre site (1896).

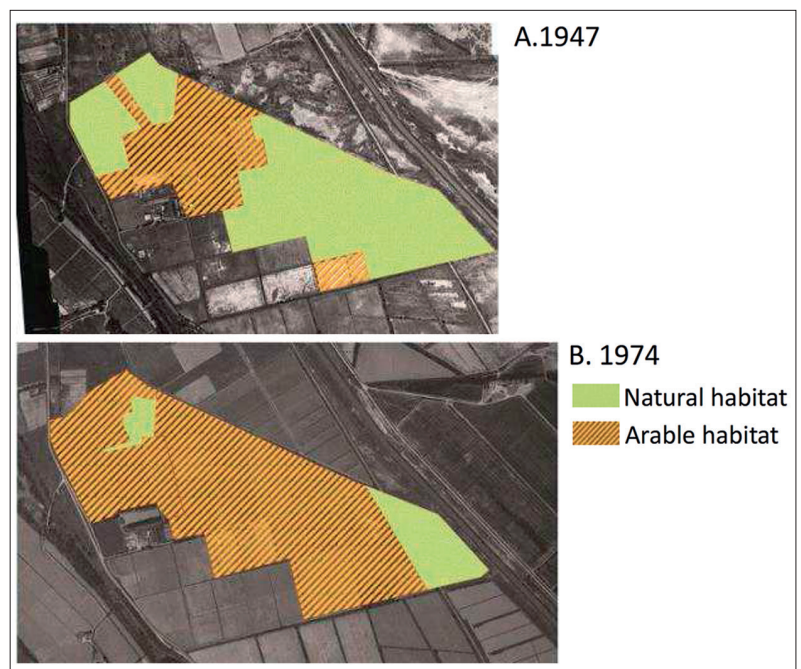


Figure 11 – Example of digitized aerial images showing the natural habitat (in green) and the arable habitat (in shaded orange) from 1947 and 1974.

which corresponds to the actual relic natural habitats, Figure 2) in favor of cultivation (from 31% to 92%, Figure 12). The site was leveled during several decades for arable land. Wheat, sunflower, sorghum, corn, and rice (for desalinating plots) were cultivated. Grazing was applied in autumn and winter on cultivated alfalfa or on natural grassland. In 1976, modernization of agricultural materials and practices led to a reduction in the total number of plots and an increase in plot size, and topographic level homogenization of the remaining plots was performed. In 2004, the site was mainly used for rice cultivation, with a few plots reserved for wheat.

Confirmation of our reference ecosystems

The ecological history of the site reveals deep human imprints on ecosystems and ensures that historical restoration targets (the state prior to human impacts) cannot be reached, because they are associated with hydraulic functioning (flooding of the Rhône and Durance) that no longer exists. The specific history of the site also reinforces our choice of socio-ecosystems because it serves to ensure the actual maintenance of ecological goods and services (Choi *et al.*, 2008; Jackson & Hobbs 2009; Davis *et al.*, 2011).

Conclusion

In the present context, in which the destruction of arable land continues to increase (Morel & Jean, 2010) and where numerous groups fighting for access to arable land continue to emerge, the opportunity and the motivation to restore natural ecosystems on arable land must be called into question. Moreover, as with all human activities, restoration must be equally subject to ethical analysis and justification (Katz, 2000).

Some arguments can be given to support the restoration of Le Cassaire site. First, the former owners had no successors and Le Conservatoire du Littoral et des Rivages Lacustres was the only potential purchaser to show any interest in acquiring the site. Unlike the high-production agricultural holdings in the Camargue area (Mathevet, 2004), the site of Cassaire is a small holding with low agricultural value, and whose reliance on agricultural subsidies provided the primary basis for economic survival. Moreover, by creating a location suitable for livestock grazing, the restored ecosystem presents a new agricultural opportunity, while simultaneously offering new services, such as hunting. Finally, although it would be ethically, financially, and ecologically undesirable to do so, the entire restoration operation could be completely reversed if arable land was needed later, and this is something that cannot be said for former agricultural land that has been filled in with concrete.

Acknowledgments

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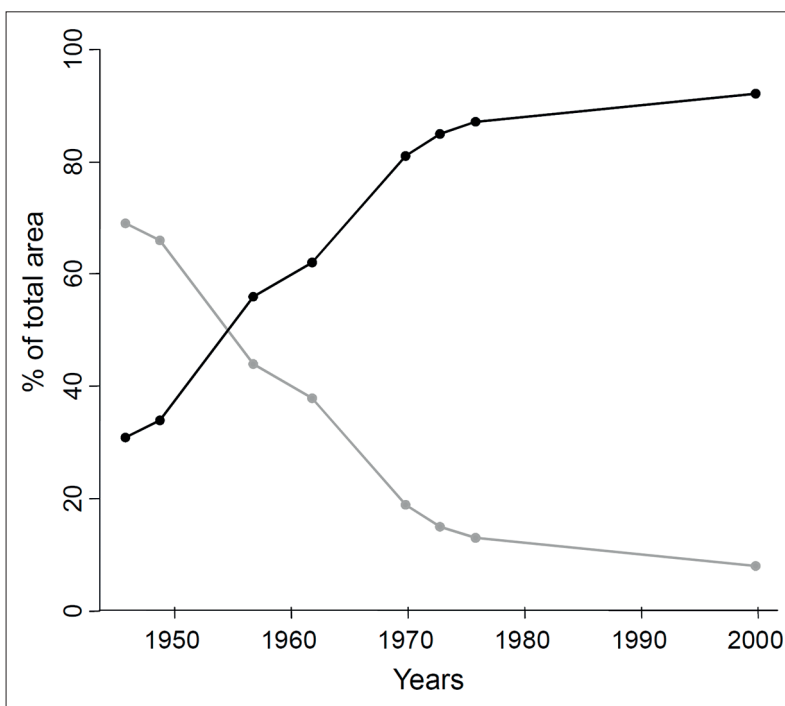


Figure 12 – Evolution of % area in natural habitats (grey lines) and cultivated land (black lines) in the Cassaire site between 1944 and 1998. Data collected from the analysis of digitized aerial images.

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