The Operating Venetian Lagoon: The Agency of Barene.
A resilient landscape infrastructure towards cultural, ecological and productive heritage preservation.

Amina Chouairi, Student, Delft Technical University
a.chouairi@student.tudelft.nl, chouairi.amina@gmail.com
(+39) 339 8853874
Foulkeslaan 82
Delft, NL 2625RA

Abstract
This paper presents and discusses a research (by design) conducted during a Landscape Architecture Master thesis on the Venetian Lagoon, North of Italy - a territory in constant transition, presenting a landscape of delicate equilibrium, threatened by the combined effects of climate change and consequently sea level rise on one side and human actions on the other (as the extreme flooding event of November 2019 demonstrates).

The research aims to seek for ways how to mitigate the above-mentioned threats by providing nature-based solutions. Therefore, it is necessary to address crucial issues as the Venetian Lagoon hydro-morphological sufferance, the over-engineered flood defence design and the state of neglect of its secondary islands. Secondary objectives the research takes in consideration are habitats restoration, creation of alternative forms of slow-tourism, enrichment of local community livelihood and economical vibrancy, and enhancement of the cultural image of the Venetian Lagoon as a stretched, unceasing water surface consisting of a diffuse sense of horizontality.

From the conducted research, what emerges is the need for redefining the role of the entire Venetian Lagoon in the next future, shifting it from passive to active, from being exploited and consequently damaged, to be able to mitigate future impacts sustainably without losing the spatial characteristics of its territory. To do so, the main strategy proposed is to reinforce the *barene* landscape - fundamental for the hydro-morphological and ecological survival of the lagoon. The *barene*, or brackish marshlands, are a very characteristic landscape formation of sediments inside the Venetian lagoon playing the important role of limiting tidal and wind impacts, favouring water exchange and acting as an expansion vessel. Due to anthropic actions, 70% of the *barene* surface has been lost since the beginning of the 20th century.

The research examines the *barene* acting as a nature-based flood defence (*function*), to recover hydro-morphological sufferance (*flow*) and to support the cultural, ecological and productive heritage (*form*). The *barene* act as pivotal means to achieve a comprehensive vision for the Venetian Lagoon where functions, flows, and forms are implemented and designed as part of a unique co-operating system.

The central basin of the Venetian Lagoon has been chosen as a case-study site, being the most hydro-morphologically damaged area inside the lagoon. After having researched on how natural forces as tides, wind direction and speed influence this portion of the lagoon, different combinations of under-water and above-water concave structures have been proposed aiming to capture suspended sediments and promote accretion. In the most compromised cases, the structures are partially supported by initial dredges, transforming the product of the management of the canals from waste into a resource. The existing islands of the central lagoon are in part connected with the proposed structures, becoming viewpoints, known landmarks, from which the growth and the transformation of this new landscape can be experienced. In the end, the intertwined system of proposed *barene* and existing islands, once grown sufficiently and matured, would produce a beneficial effect over the hydro-morphological, ecological, and cultural surroundings.

1. Introduction.

Nowadays, the Venetian Lagoon represents one of the most impacted and delicate European environments, threatened by the combined effects of climate change and human action. During the last century, its hydromorphological, ecological and environmental functioning have been seriously compromised, together with a conspicuous population abandonment in the historical centre of Venice. Its equilibrium has been more intensively oscillating since the second half of XX century, after decades of intense industrial and mechanical fishing exploitation. Floods as *Acqua Granda* in November 1966, Porto Marghera opening in 1917, and illegal clam cultivation in late 1980s are just a few of those activities that have incredibly damaged the Venetian Lagoon ecosystem.

The research and design hypotheses rely on *The Agency of Barene*, the most distinctive character defining the Venetian Lagoon landscape, and their beneficial hydromorphological and ecological functioning to tackle the quantitative disruptive power of water and promote the qualitative amelioration of the surrounding environment. Therefore, fluxes of water and sediments are considered as primary design tools to propose a shift in terms of water protection system in the Venetian Lagoon: from a hard infrastructural and engineering-oriented approach to a design-with-nature and processes-oriented approach. The design is developed through the implication of lagoon elements characterized by three different levels of dynamism: the most fluid of water (canals for oil ships and containers, cruises, and daily mobility, natural *ghebi,* creeks), *barene* and *vèlme* (appear and disappear according to daily and seasonal tides, grow and erode, in open exchange with the water and winds fluxes), and the islands, the most stable elements.

2. Problem fields.

The three problem fields investigated throughout the research, i.e. the Venetian Lagoon current hydromorphological sufferance, the over-engineered flood defence *Mo.S.E.* project, and the abandoned cultural heritage of the secondary islands, refer to the landscape functioning of the Venetian Lagoon and its consideration as a unique system. In fact, the elements considered and the analysis conducted led to the understanding of a precarious relation between water and sediments fluxes and a diffuse tendency to exclude the areas in between and along the boundaries of the lagoon.

The lowest common denominator is the lack of a systemic, inclusive and comprehensive landscape approach regarding the foreseeable future of the Venetian Lagoon and the proposition of a possible vision considering a desirable amelioration from a spatial and functional perspective.

Nowadays, *forms, functions, and flows* are not being implemented as a unique co-operating system, through a unitary vision, from a landscape architectonic perspective. The Venetian Lagoon functions, or better, serves goals that are distant, and sometimes boycott its own survival. The complexity of this territory has been defined by centuries of anthropic interventions over the natural landscape, taming it to ensure Venetian people survival in the waters of the lagoon. With the technological progress, especially in the last century, the approximate balanced interrelationship between men and nature systems has switched from control-driven to exploitation-driven. The performance, aesthetics, and operating of this delicate ecosystem are being seriously compromised by the contemporary tendency that sees the city of Venice as the gold mine for mass tourism and at the centre of any preservation measure, especially by whom blindly do not grasp that the protection of the lagoon implies without any further effort the safeguard of the city itself.

2.1 Venetian Lagoon hydromorphological sufferance.

Since the early settlements started to grow around V century A.D. to escape barbarian invasions, the Venetian Lagoon started to be shyly manipulated by men. Starting from

XII century though, strong processes of land-filling deriving from the sediments brought inside the lagoon by the main rivers (Piave, Brenta and Sile) were in act.

On one hand, the southern lagoon was strongly threatened by the river Brenta, discharging its water right in front of Venice. Between XIV and XIX centuries, major (and minor) severe modifications to its course has been conducted by the Venetians: multiple diversions executed inside the lagoon itself (1330-1457) which led, in the end, to river Brenta complete diversion outside the lagoon.

On the other hand, the northern lagoon was indirectly influenced by Piave river which, even though not directly discharging in it, with its massive floods was slowly land-filling the upper parts of the lagoon. Therefore, from XVI century on, the Republic of Venice started promoting engineering solutions not just to move away Piave river, but also to transport another river, Sile, into Piave former riverbed for hygienic and defensive reasons: "*the exclusion of the Sile closed what by analogy could be called the "Era of Diversions", which lasted for almost two hundred years, during which the Serenissima developed its utmost commitment to counteract the phenomena of interruption of the lagoon without ever losing sight of the final objective, despite the many difficulties encountered and the costs incurred.*"[1]

For more than five centuries, watercourses have been diverted to exclude the sediments they brought from the Venetian Lagoon and reduce the amount of freshwater discharged. However, "*the interventions carried out by the ancient Venetians on the large hydrographic systems falling in the controlled territories and interfering directly or indirectly with their lagoon, cannot be described as "a good general governance of the waters and an illuminated and overall vision" of hydraulic problems, which official historiography and many common-places continue to attribute to the Serenissima Republic.*"[2]

Without any doubt, the rivers diversion and the consequent reduction in terms of freshwater and sediments discharge can define the starting point of a trend reversal in the hydromorphological behaviour of the lagoon, whose effects have been contained for a long time. In fact, "*land-filling phenomena, which prevailed before the rivers diversion and generated a shallow waters lagoon in which it was difficult to navigate, were replaced, following the rivers diversion, with widespread but slow erosion processes. These processes, initially acting with moderate effects and mainly in a horizontal direction […], only during the last century they have developed with greater intensity also in the vertical direction, increasing the depths of the water areas […].*"[3]

Already since XVII century, the issue regarding the lagoon inlets became arduous and, therefore, the need to implement intra-lagoon connections was growing. Hence the decision to create an internal connection between the port of Malamocco and the basin of S. Marco, to allow ships to dock in front of Venice passing by the best performing Malamocco inlet. This determined an implementation of the network of navigable canals in the portion of the lagoon in front of Lido Island. The spearhead of this improvement plan was the Santo Spirito canal, built in 1726, which, "*did not substantially disturb the pre-existing regime of the tidal currents and did not appreciably alter their general structure or local characteristics.*"[4] This was not the case for the Vittorio Emanuele canal, dug between 1920 and 1925, and Malamocco-Marghera canal, excavated between 1964 and 1968. The latter can be defined as the infrastructural work that most negatively influenced the hydromorphodynamic processes of the Venetian Lagoon since the early human modifications to this territory started to take place.

1 D'Alpaos, "Fatti e Misfatti Di Idraulica Lagunare", p. 54.
2 Ibid., p. 54.
3 Ibid., p. 54.
4 Ibid., p. 87.

Malamocco-Marghera canal, known as the Oil Canal, put directly in communication the Adriatic Sea with Marghera harbour without the necessity of passing by Canale della Giudecca in Venice. It is 15 kilometres long, averagely 200 meters wide, 17 metres deep in its first portion, and afterwards around 12.5 metres deep. It has induced extremely negative effects regards the regime and circulation of the tidal currents, the increase in high water events in terms of number and intensity in the historical city of Venice, Lido Island, and in the whole central basin. Its excavation "*was supported by a project that was not very commendable from a technical point of view and lacked from a scientific acquaintance, even though the knowledge in the field of lagoon hydraulics allowed a less indecorous framing of problems that the insertion of the new route water could have led to the delicate lagoon environment.*"[5] The serious and dangerous consequences of this water infrastructure are evidently noticeable: the central basin of Malamocco is now characterized by flat and poorly articulated seabed depths, in which natural channels have been buried due to the sediment dispersed by the enormous displacement of water masses, and a considerable drop in the average depth has been documented during the last forty years.

2.2 Over-engineered flood defence infrastructure

After the flood that devastated the entire Venetian Lagoon the 4th of November 1966, in 1973 the first "special law" for Venice declared that the city and the whole territory required a particular interest by the central government. This declaration led to a legislative process that lasted for more than thirty years. In 1984, a second "special law" defined the institution of "Consorzio Venezia Nuova". Between 1988 and 1992, Consorzio worked towards the definition of the *prototype* of sluice gates (the Electromechanical Experimental Model, *Mo.S.E.*) and eventually, in 2002, the definitive (but not the executive) project was presented. The constructions started April 3rd 2003, with the opening of the building sites at the three lagoon inlets of Lido, Malamocco and Chioggia simultaneously.

On one hand, following a pure positivistic approach, where everything that exists can be verified scientifically through experiments and observations, therefore understood and controlled, Mo.S.E. flood defence system has been conceived in order to protect the historical city of Venice from high water events, opposing its closable sluices to the threatening tides, in order "*to execute the necessary works for the purpose of preserving the hydrogeological balance of the Venice lagoon and the reduction of high waters in historic centres*"[6]. In addition, this hubristic approach is already embedded in the name itself. In fact, *Mo.S.E.* (acronym of *Modello Sperimentale Elettromeccanico*) loudly recalls the biblical figure of Moses who, on divine indication, has divided the waters of the Red Sea to set free the people of Israel.

On the other hand, the project proposed in 2002 has been developed considering the prediction regarding the relative sea level rise by 2100 of 22 cm, the probable value, and not 31.4 cm, the pessimistic value (developed in 2001 by Co.Ri.La. Consorzio di Ricerche Lagunari). The same year, IPCC (Intergovernmental Panel on Climate Change) predictions for relative sea level rise by 2100 presented 50 cm as probable value, 9 cm as minimum value, and 88 cm as pessimistic value.

The controversial decision of not considering the worst-case scenario, the exorbitant costs (in 2014 the work was 90% completed for a corresponding expenditure of 5,493 billion Euro), and the eternal building procedure (to date the *Mo.S.E.* it is still unfinished and not in function), undoubtedly addresses the case of the *Mo.S.E.* as the key fact in the understanding of recent anthropic modifications in the Venetian Lagoon. Imposing the will at all costs of protecting (but not preserving) the Venetian Lagoon with a strong

5 D'Alpaos, "Fatti e Misfatti Di Idraulica Lagunare", p.90.

6 Ibid., p. 194.

engineered and infrastructured opposition to its natural fluxes and processes has seriously damaged the ecological, social and environmental settings of the system. Without any doubt, the project proposed for the safeguard of Venice and its lagoon, representing the deep contradiction of forcing an electromechanical solution to deal with natural fluxes, failed completely to grasp the complexity of this delicate territory balance.

2.3 Abandoned cultural heritage of secondary islands.

The whole Venetian Lagoon is dispersed with secondary islands. Despite their number and the historical evidence they carry, during the last century of gradual abandonment, the lagoon has witnessed social detachment and unawareness regarding the cultural, architectonic and traditional heritage of its islands.

Through the centuries, the city of Venice and the surrounding centres have built the connective tissue that gives unity to the lagoon, *creating a territory*, in a way that is not so different from what happens in continental cities[7]. All the islands together form a cohesive system, all neighbourhoods of the same city, the Lagoon. However, during the XVIII century, this delicate and intricate structure of interdependencies has been gradually fading away.

Nowadays, interestingly, these abandoned ruins, despite their state of neglection, do not perform too differently from those urban elements, on land, called *campi*, “squares”. The similarity emerges clearly, since these islands are the only dry elements among the lagoon waters, further away from Venice. Undoubtedly, this heritage attracts passers-by and curious locals, perhaps because of its state of abandonment and mystery. The most interesting value these islands have is exactly their ability of performing as open and accessible public spaces, while not being designed to act as such.

3. The Venetian Lagoon: an analysis.

The Venetian Lagoon has been read as a continuous succession of dry, semi-dry, semi-wet and wet environments. This alternation relies on daily and seasonal tide oscillations: every six hours, high tide and low tide alternate, reaching different heights during the year. The average tidal excursion considered in this research at 60 cm.

The dry environment corresponds to Venice historical centre and the secondary islands (in total 30 km^2). Dry elements are defined by a solid and tangible perimeter, are elevated and detached from the water surface.

The semi-dry and the semi-wet environments correspond mutually to *barene*, brackish marshlands, and *velme*, subtidal mudflats. Sometimes they emerge and appear from the water surface, sometimes they are submerged and hidden. This alternation, of appearance and disappearance, based on tidal recurrence, is the most peculiar trait of these elements.

The wet environment corresponds to the waters of the lagoon: canals and open stretches of water occupy the largest portion of the Venetian Lagoon.

These in-between environments, semi-dry and semi-wet, are the ones that establish the most a direct and open dialogue with daily water oscillations. In fact, *velme* and *barene* are composed mainly by fine sediments (silt and clay), which are more prone to be recollocated by water currents. This peculiar feature makes them constantly evolving, almost metamorphic, unsettled environments. Therefore, it has resulted fundamental to understand how this relationship evolves and what forces and matters are directly involved in this millennial dialogue.

First of all, the Venetian Lagoon, presenting three inlets connecting her to the Adriatic

7 Turri, Caniato, and Zanetti, “La Laguna Di Venezia”.

Sea (Lido, Malamocco, and Chioggia), has to be considered as a “system of lagoons” [8] rather than a single lagoon. Through these three inlets, sea currents and tides expand inside the lagoon. These currents, thanks to their different expansion speeds and an intricate network of lagoon canals, are able to reach the borders of the lagoon. This combination of canals and currents define together four hydraulic sub-basins: Treporti, Lido, Malamocco and Chioggia.

The tidal currents expanding within the Venetian Lagoon borders are generated in the Adriatic Sea, which peculiarly is characterized by anti-clock wise curves of tidal propagation. Furthermore, the astronomical tides of the Adriatic Sea are also under the influence of two winds, Scirocco and Bora.

3.1 Threats.

Proceeding through the hydromorphological understanding, many are the perils threatening the correct functioning of the Venetian Lagoon. Through a careful analysis, six degradation trends have been identified:

_Deepening of shallow water seabed

_General flattening and horizontal erosion

_Negative sediment balance

_Higher astronomic tides and faster tidal propagation

_More powerful tidal currents

_More frequent high water events

While researching, the main causes determining these issues have been investigated. The lowest common denominator, exerting the most significant pressure, has been the excavation of big canals, in particular Malamocco-Marghera canal to support Porto Marghera industrialization. Still nowadays the effects of this excavations are perceivable when analysing the major issues the Venetian Lagoon is coping with.

Alongside with canals excavation and Porto Marghera activities, anthropically generated subsidence, resulting from excessive groundwater exploitation, cruises and cargo ships passage through the lagoon, the construction of concrete jetties at the inlets, rivers diversion, and natural eustatism and subsidence are the eight variables influencing directly the aforementioned threats. All the effects and the causes result to be almost inextricably intertwined, feeding greedily on each other.

3.2 Values.

Despite the threatening processes in act nowadays, the true character of the Venetian Lagoon is still embedded in those elements, which in the research have been addressed as values. These are recurrent figures in the collective imagery and memory of the lagoon, pivots, fixed points eternally changing. These elements are the Ecological System of *barene*, the Cultural System of secondary islands, and the Productive System of fishing activities and production.

3.2.1 Ecological System of brackish marshlands: *barene.*

In the Venetian Lagoon, areas with different biological and morphological significance alternate. These can be subdivided into land that is always emerged and land that is submerged during high tides. The former are the islands; the latter are known as *barene*, brackish marshlands, and form the most particular amphibious environment which, as such, is constantly poised between land and water. Their tabular surface is covered by a thick bushy vegetal mantle and it is often crossed by erosion furrows which form tortuous meandering little channels, called *ghebi*.

Barene form the most characteristic environment of the Venetian Lagoon and are home

8 Molinaroli et al., “Thirty-Year Changes (1970 to 2000) in Bathymetry and Sediment Texture Recorded in the Lagoon of Venice Sub-Basins, Italy”.

to halophytic flora, i.e. species particularly suited to living on salty soils, inhospitable for the vast majority of plants. The tides, which create numerous micro-environments on the *barene*, are responsible for creating such peculiar conditions.

The Ecological System of brackish marshlands produce incredible hydromorphological and hydraulics benefits for the lagoon ecosystem. In fact, *barene*

_Have a very high rate of CO_2 sequestration;

_Favour water exchange acting as expansion vessels, limiting tidal impact, reducing its power and speed, and mitigating strong winds;

_Provide the Venetian Lagoon with protection against coastal flooding and erosion.

In fact, the function of vegetated coastal habitats for coastal protection involves, among other benefits, the attenuation of wave transmission onshore. As Duarte (2013) reports, *"seagrasses have a particularly high capacity to dissipate wave energy, whereas salt marshes and mangroves have a high capacity to protect from surges. Moreover, these ecosystems often occur in juxtaposition with seagrass in subtidal areas and salt marshes or mangroves (depending on latitude) in the intertidal zone, thereby increasing their combined effectiveness in protecting from waves and surges"*. In the specific case of the Venetian Lagoon, this co-operation between intertidal and subtidal environments is represented by *barene* and *vèlme*.

Barene have an average height comprised between +0.20 and +0.60 cm above sea level. On the *barena*, the dense vegetation seems to form a rather uniform cover. In reality, very subtle, delicate and almost imperceptible elevation differences in the soil surface lead to the development of a mosaic of akin plant populations. These are perennial halophyte associations consisting mostly of *Puccinellia palustris, Arthrocnemum fruticoso, Halimione portulacoides, Limonium serotinum, Aster tripolium* and other species. *Barene*, according to their elevations (*fig. 01*), are subdivided into four groups: *barena bassa* (low saltmarsh), *barena intermedia* (intermediate saltmarsh), *barena elevata* (elevated saltmarsh), and *bordi elevati* (elevated borders).

Unfortunately, the *barene* ecosystem has suffered a significant reduction in surface.[9] *Fig. 02* indicates the dramatic reduction in surface area suffered by the barene from the early twentieth century to today, with a very strong acceleration of the phenomenon in the last period. This erosive process identifies an erosion rate suffered by the barene landscape of the Venetian Lagoon of more than 300% between XVII and XX century.

Extensive surfaces once subject to flooding only during high tide have progressively changed, assuming for the most part the condition of shallow waters, constantly submerged by water. At the same time an uncountable volume of sediments, but certainly considerable, has moved from the barene to areas of lower altitude (shallow waters and canals) or is no longer resident in the lagoon, having been expelled into the sea[10].

The reduction in surface of the barene landscape can be included in those factors which have concurred in amplifying the hydromorphological deterioration (caused by the threats in section 3.1) of the Venetian Lagoon during the last century.

3.2.2 Cultural System of secondary islands.

The islands of the lagoon environment are uncertain lands that appear, disappear, transform, vary in size and number, change the vegetation that characterizes them. For this intrinsic character of indeterminacy, it is difficult to define a unique number. The stable islands vary from a minimum of 75 to more than a hundred considering many *barene*, *motte* (small outcrops, hillocks, humps) that, due to the phenomenon

9 D'Alpaos, "L'Evoluzione Morfologica della Laguna di Venezia attraverso la Lettura di Alcune Mappe Storiche e delle sue Carte Idrografiche".

10 Ibid.

of subsidence, occasionally appear and disappear. If we consider Venice the islands reach 130 units[11]. Between the northern and central lagoon, 35 secondary islands are located: 23 results in an abandonment state. Out of 35, 17 are state property and the rest are privately owned.

The decline of the lagoon satellite islands began with the fall of the Venetian Republic in 1797, and inexorably continued first with the Austrian domination and then with Napoleon Bonaparte. With the Napoleonic edict of suppression of religious orders in 1810, the monastic seats on the islands were transformed into military headquarters. Religious buildings were transformed into military installations, hospitals, warehouses that have been used until the Second World War. This military function was maintained until the 1970s when the Italian State decided to abandon the islands, concluding that process of degradation and oblivion[12].

These dry outposts, immersed in the lagoon waters, look at each other and in turn are looked at: being faithful to their last military task, they master visually the panorama surrounding them. Moving, *sailing*, through the lagoon the islands appear as a continuous succession: the observer (a sailor, a tourist, an angler, etc.) looks for these landmarks or, better, *water*-marks to orientate herself. This connection between the observer and the object observed is established through the architectonic components (walls, buildings, shape of the island, etc.), letting experience the slow, healing flow of time. That enables us to *see* and, therefore, to *understand* the passing of history, and to participate in time cycles that surpass individual life[13].

3.2.3 Productive System of fishing activities and traditions.

The Productive System of fishing activities is spread on the whole surface of the Venetian Lagoon, and it is mainly dedicated to mussels and clam cultivation, itinerant fishing, and embanked aquaculture valleys along the borders.

Venetian Lagoon fishing activities have a strongly conservative character, which expresses the strength of a tradition nourished by a fruitful relationship between man and territory. Currently the protagonists of lagoon fishing are largely located in the lagoon centres of Burano, Treporti, Pellestrina and Chioggia where it is still possible to perceive the visible, olfactory and sound elements that make up the solid formal and informal organization of the fishing landscape.

Spatially, this system is defined by elements all characterized by a sense of temporality (*fig. 03*). Temporary wooden cabins, nets, poles, and stilts are spread especially on *barene*, used by anglers as depots. In fact, when the equipment for itinerant fishing is pulled dry on the higher *barene*, their thin and vertical profiles contribute in highlighting even more the flat lagoon horizons.

Despite a marked decline in lagoon fishing techniques and activities, the dense meshes of cultural homogenisation sometimes allow the survival of archaic, mostly marginal technical choices. Today the interest in these almost anachronistic practices is supported by the more mature awareness that these technical-cultural relicts have an irreplaceable social function capable of enhancing the historical consciousness of the community[14]. There exists both the design will and the socio-economical necessity to integrate those lagoon workers that live and work with this complex environment, for a basic matter of fact: no one better than them knows the Venetian Lagoon intimate behaviours.

4. Methodology and theoretical framework: *Building-with-Nature* design principles.

11 Cipriani, “Isole di possibilità / Islands of possibilities”.
12 Ibid.
13 Pallasmaa, “The Eyes of the Skin. Architecture and the Senses”.
14 Vallerani, “Il Naviglio Lagunare e La Pesca”.

In order to bridge the existing gap between the problem fields investigated and the territorial values, *landscape resilience*, *landscape as infrastructure* and *Building-with-Nature design principles* have been addressed as fundamental theoretical framework to further develop the design proposal.

More specifically, *Building-with-Nature* flexibly integrates land-in-sea and water-in-land in complex ecosystem, taking into account existing and potential landscape values, in harmony with natural materials and forces, in order to reduce the usage of invasive techniques[15]. The materials considered, loose and mobile, are sand and silt of different composition, sizes and structures, while the fluxes integrated in the planning are tidal actions (ebb and flood), wave actions, sea currents, river outflow, gravity, wind, rain, solar radiation, dune-vegetation, lagoon-brackish marshlands interaction, and marine organisms-sand/silt/coral complex interaction.

According to Deltares, a Dutch Technological Institute, the Building-with-Nature approach is founded on six principles:

_Understand system functioning

_Identify the system's envisaged functions and plan a project or activity accordingly

_Determine how natural processes can be used and stimulated to achieve the project goals and others

_Determine how governance processes can be used and stimulated to achieve the project goals

_Monitor the environment during execution and - if necessary - adapt the monitoring program and/or the project execution

_Monitor the environment after completion, to assess the project's performance and to learn for the future.

In Building-with-Nature design method, interdisciplinary cooperation and planning becomes essential. Within this framework, every discipline needs to address its own objectives and integrate them with the others, to create the conditions for natural processes to happen and function correctly. In the specific case of the Venetian Lagoon, Building-with-Nature method and principles applied within the proposed design will contribute to:

_Mitigate the effects of climate change and sea level rise through the definition of a nature-based flood defence

_Increase landscape resilience and efficacy

_Restore and create *barene* ecosystem habitat

_Increase differentiation and specificity in relation to the identity and functionality of the places.

5. Research-by-Design: *The Agency of Barene*.

The extension considered for the design proposal is the juncture between Lido and Malamocco sub-basins, between Giudecca Island and Malamocco inlet. First, this portion has resulted to be the most degraded area in the entire Venetian lagoon (as explained by the figure about sedimentation and erosion rates between 1970 and 2000); second, it presents the highest concentration of abandoned secondary islands, interestingly relevant from an architectonical and ecological perspective; third, in the proximity of Malamocco inlet, due to the continuous water exchange between the lagoon and the Adriatic Sea, a very high concentration of edible fauna is present: in fact, anglers and cultivators habitually frequent these very prosperous waters.

5.1 Flows and environmental functioning.

15 Waterman, ''Land in Water, Water in Land Achieving Integrated Coastal Zone Development by Building with Nature".

The intervention developed, a system of forty-four *barene* in the central lagoon (*fig. 04*), will take advantage of the forces in act, aiming to re-cover the present damaged hydromorphological conditions. The ultimate goal therefore will be to rebalance the power with which the two sub-basins of Lido and Malamocco interact.
The disposition of the system has been influenced by natural flows and physical elements. The flows considered for the design proposal elaboration are the tides (ebb and flood), the water currents and their speed of expansion, the sediment plumes (i.e. where sediments are more like to deposit) and the wind of Bora. The physical elements considered are the lagoon canal structure, determining water transportation routes, the existing bathymetry, and the islands (*fig. 05*).

As concluded by Miazzi (2007), the system of barene positioned as designed will take advantage of natural process and morphological characteristics and will positively contribute to:

_Interrupt wave formation

_Reduce the speed of tidal expansion

_Break wind gusts

_Capture suspended sediments

_Differentiate above water and underwater morphology

_Increment thin sediment (silt and clay) concentration

_Avoid sediment dispersal

_Natural formation of creeks.

5.2 Technicities: three typologies for 44 structures.

Three different types of structures have been designed (*fig. 06*), according to initial conditions and goals to be achieved for specific locations. The permanent structures (dykes) presented have been designed following the technical combinations found in the manual by Nascimbeni (2007), "*Proposte per la progettazione di interventi di ingegneria naturalistica funzionali alla salvaguardia della morfologia della laguna di Venezia*". Wooden poles and highly resistant geogrids and geotextiles (*fig. 07*) considered for the realization derive from natural fibres (vegetable, wood, etc.) and their degradation and dispersion will not harm the surrounding environment. Thanks to the wide mesh, thicker sediments and vegetal roots will be able to penetrate into the structures and consolidate permanently. As time passes, the sediment accumulated and the vegetation will entirely incorporate the modular structures.

5.3 Construction, maintenance and monitor.

Construction, maintenance and monitor will play an incisive role regarding the effective performances of the design proposal.

Construction will consist of, at first, building the permanent structures (dykes) that will accumulate sediment. Secondly, the walking paths and boat docks spread all over the system. Some *barene*, located in the most endangered part of the site, will be fed with initial sand and silt dredges.

Perennial halophyte species as *Sarcocornia fruticosa, Puccinellia palustris, Halimione portulacoides, Limonium narbonense, Juncus maritimus* will be planted manually. Pioneers and annuals halophyte species will spontaneously grow.

Ordinary maintenance will occur every 12-18 months, and will be carried out by fishermen, anglers, and local workers, equipped with adequate means of transportation and working tools, as well as territorial and geographical knowledge.

Extra-ordinary maintenance will occur, occasionally, after powerful, unexpected and impacting natural events (heavy swells, thunderstorms, extreme *acqua alta*, etc.) and will consist of checking on the structural efficiency.

Monitoring activities as data collection will be carried out every 5 years. In fact, studying the effective physical responses of the central sub-basin will provide insightful knowledge regarding potential benefits or potential deteriorations happening in the system.

5.4 Potential effects on water circulation in the central sub-basin of Malamocco

The *barene* system will determine a (potentially) beneficial effect on its hydraulic and hydrodynamic system. As concluded by Marco Miazzi (2007) in his Master thesis *Analisi degli effetti prodotti dall'inserimento di barene artificiali nella Laguna di Venezia*, the insertion of artificial *barene* in specific locations (corresponding to the designed locations), elevated for +0.50 m over the reference sea level, constitute a significant interruption to the action of the fetch (*fig. 08*). Through the collocation of these *barene*, winds and wind-generated waves' speed and power are significantly mitigated ("*the shielded areas will be characterized by a lower wave height, which will result in lower tangential forces at the bottom and a decrease in the re-suspension capacity of the sediments*"[16]) and the sediment lost in the Adriatic Sea significantly reduced ("*the result of this process will be a reduction in the solid flow rate coming out of the inlet of Malamocco and Lido*"[17]).

The gradual growth and evolution of the whole the system will endure and strengthen the resilient response of the Venetian Lagoon. The development of this nature-based flood defence implemented through Building-with-Nature principles of co-operation will serve, in the short and long terms, the patient reconstitution of those morphological, cultural and productive characters that, over time, have suffered an undeserved state of neglection.

5.5 Functional program

The spatial adaptation of abandoned islands is investigated to both reconnect the central lagoon lost architectonical heritage with the local population and foster alternative and slower tourism. In the specific, from north to south, the islands of San Giorgio in Alga and Sant'Angelo della Polvere, Santo Spirito and Lazzaretto Vecchio, Forte di Sopra, Forte di Mezzo and Forte di Sotto, Ottagono Alberoni and Ottagono San Pietro, and Faro Spignon are integrated within the proposed design.

According to the dimensions, the past functions and presence of architectonic artefacts, a gradient of activities and experiences has been conceived. The first four (San Giorgio in Alga, Sant'Angelo della Polvere, Santo Spirito and Lazzaretto Vecchio) used to be part of the lagoon life, at first monasteries. Due to their dimensions, they are more likely to receive a discrete amount of people. The northern barene, closer to the city of Venice, will be more open and oriented towards a lighter kind of tourism; the islands serve as backbone to structure the new *barene*, as sort of anchoring points.

The second three (Forte di Sopra, Forte di Mezzo, Forte di Sotto) used to be military forts, having a strategic overview on the central part of the basin and Malamocco inlet. The central *barene*, half way from the city and the inlet, are thought to be particularly dedicated to ecological and biodiversity proliferation. They are located in the more degraded area, and the open lagoon here is not at all rich in flora and fauna because of the strong currents that expand during the tides. The islands are included as observation points, detached from the main structures.

The third two (Ottagono Alberoni and Ottagono San Pietro), built in XVI century to defend *La Serenissima* from the Turkish threat, used to be defensive fortifications. The southern *barene*, closer to Malamocco inlet, are implemented to support fishing activities, since in this area freshwater constantly flushes in and salinity is very high.

16 Miazzi, "Analisi degli effetti prodotti dall'inserimento di barene artificiali nella Laguna di Venezia", p. 79.

17 Ibid., p. 79

The *barene* here located will catch the majority of sediments, will become useful breeding area for fauna, and will function as natural environment for fishing activities. The islands will be equipped to sustain anglers with necessary spaces (*fig. 09*).

Faro Spignon, the final island, as the name already reports, used to be the lighthouse signalling the entrance in the Venetian Lagoon from the central inlet of Malamocco. From its peak 13 metres high, the whole designed system of *barene* will appear.

5.6 Accessibility and transportation

According to the program just outlined, from north to south, a gradient in terms of accessibility and transportation is defined.

The first four islands and the northern *barene* are thought to be integrated within the already existing system of Venice ferryboats transportation (ACTV), mainly to take advantage of the nautical equipment of the canals already in use. Equipped stops will be provided on the islands. A walking path, approximately two kilometres in length, will connect the island of San Giorgio Alga and Sant'Angelo della Polvere, and another the island of Santo Spirito and Lazzaretto Vecchio. These paths will take advantage of the physical structures used to create the barene and they will stand 1.00 metre above the water.

The second three islands and the central *barene* will be seasonally accessible, from April to October. Organized excursions with flat bottom boats will be provided to visitors to better sail among the shallow canals. Light water transportation means (as canoes, kayaks, and stand up paddles) can freely meander among the barene.

The third two islands and the southern *barene* will be mainly frequented and used by anglers for productive activities. People and visitors will be welcome especially on Ottagono Alberoni, where a fish market place is thought to be provided by the design.

6. Conclusions.

The conducted research and the strategy proposed engage a significant relevance for what it concerns the Venetian Lagoon itself, with the provisioning of an unprecedented design strategy built on the complex dynamics of water and sediment flows interaction. Furthermore, it provides insights on decoding and designing in places with similar hydromorphological issues and on considering Building-with-Nature approach as a catalyst for the coexistence of resilient water protection systems and strong ecological structures. The main four relevant objectives are:

_Functioning: the Venetian Lagoon correct functioning allows the preservation of the whole surrounding territory, including Venice historical centre

_Mitigating: climate change, and in particular sea level rise, is tackled and its effects mitigated

_Building-with-Nature: nature-based design solutions and building-with-nature design principles are holistically applied through the agency of barene

_Innovating: landscape is read as the provider of a resilient structure, intertwining functions, flows, experiences, usages, and atmospheres evoking the sense of lagoon.

Over time, the proposed *barene* system grows and evolves, providing a multi-functional and resilient flood defence structure, achieved through the application of Building-with-Nature design principles. The design contributes to:

_Enrich biodiversity and expand the habitat of the brackish marshlands of the Venetian Lagoon

_Integrate the abandoned heritage of the secondary islands, opening them to a lighter and continuous flow of local and external tourism, making them part of the leisure and recreational network

_Provide space and useful means to support local fishing and aquaculture activities.

List of figures.

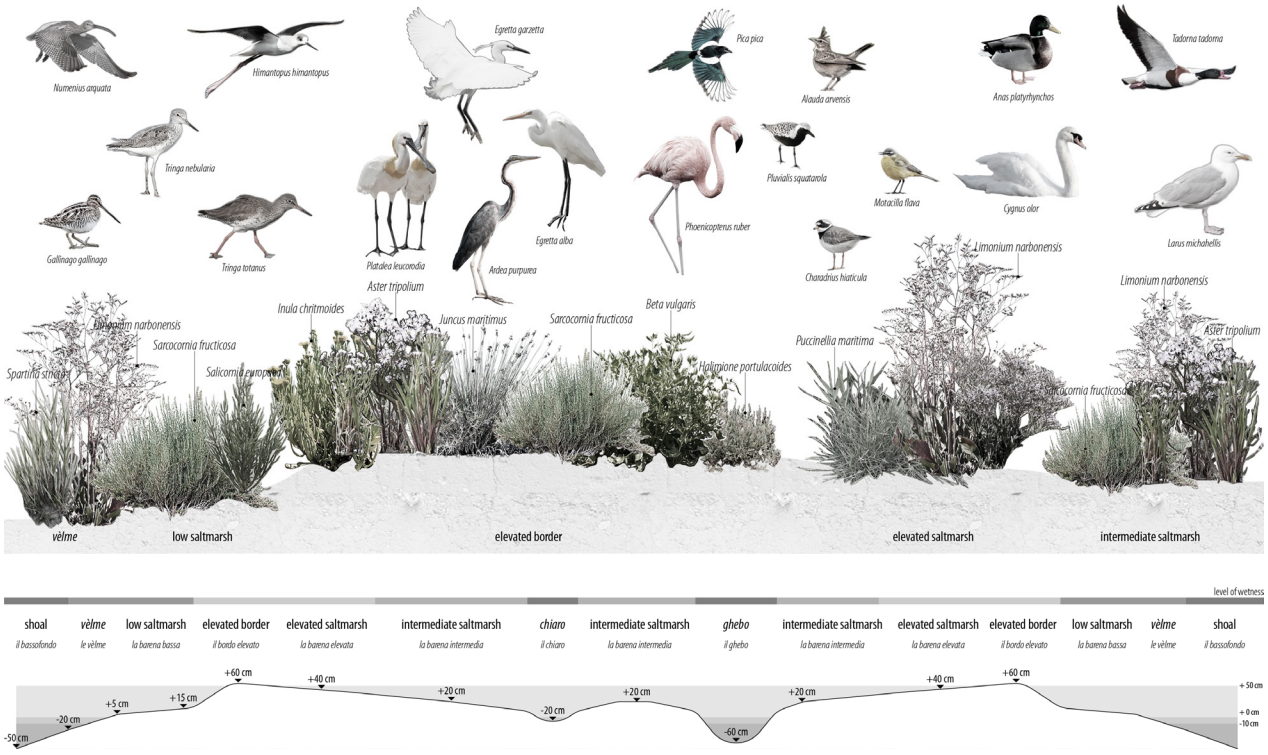


fig. 01 Close up on flora and fauna species populating more frequently the different elevations of a *barena* and schematic section, highlighting the peculiarities of its different elevations. Interesting to be noticed is the relation with daily tides: more than 80% of a barena gets submerged twice a day, when high tides occur.

fig. 02 Historical evolution of the surface occupied by *barene*, from 2013 to 1811 (left to right). Based on data retrieved from D'Alpaos, 2010 and D'Alpaos, 2010.

fig. 03 Temporary and informal fishing traces in the central sub-basin of Malamocco.

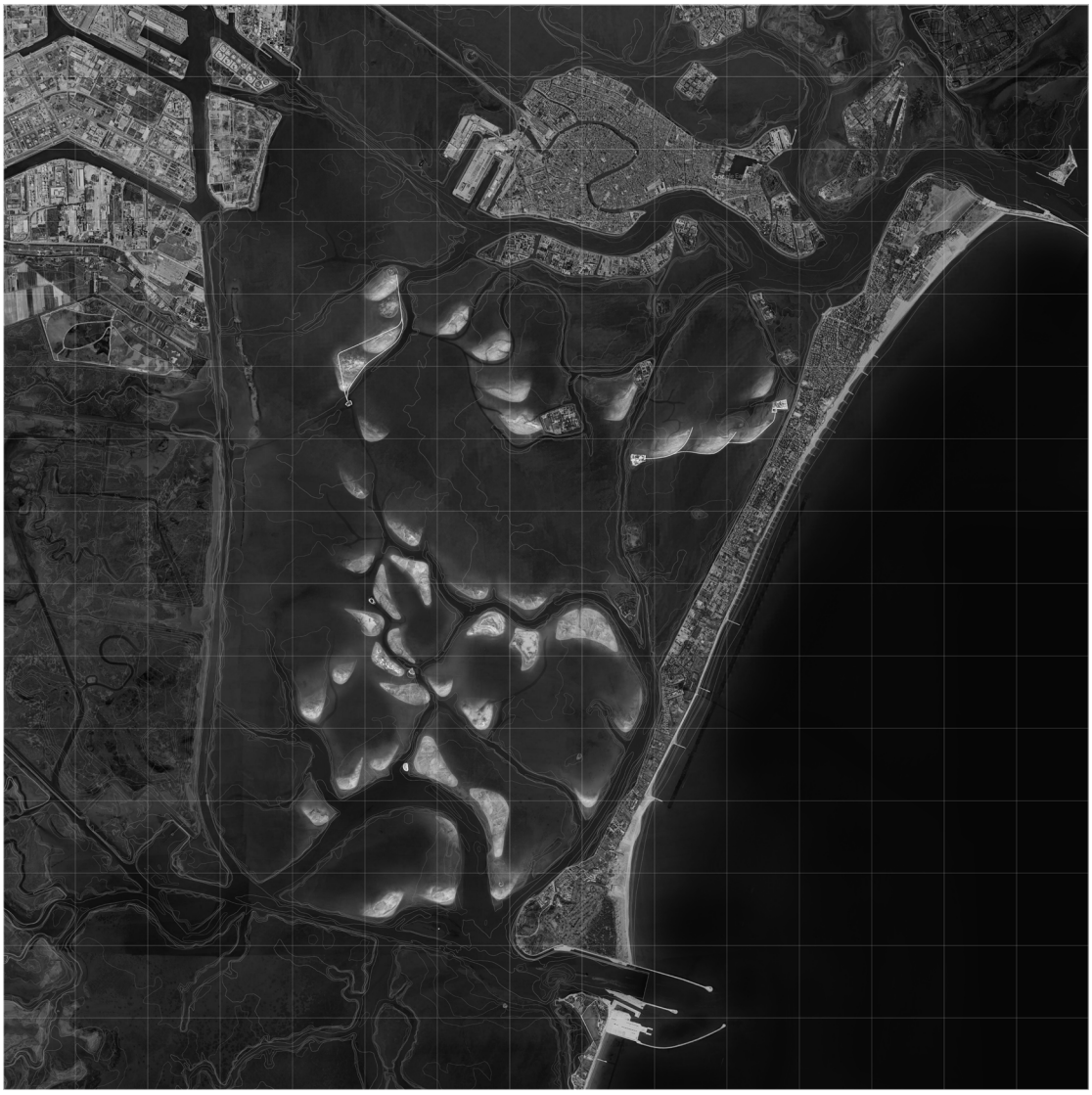
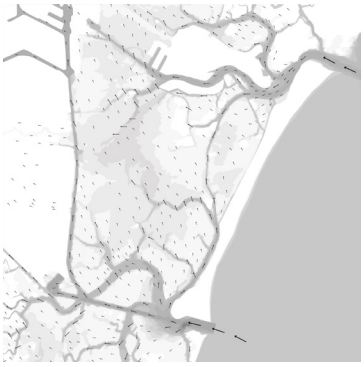
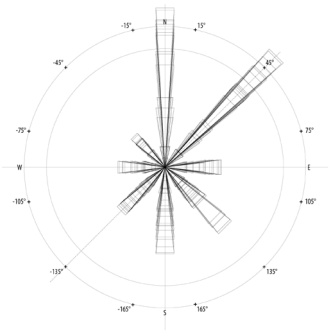


fig. 04 Masterplan of the proposed *barene* system by 2050.

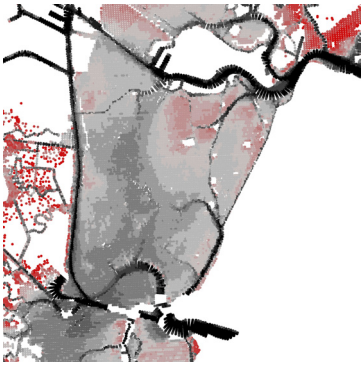


water currents (water)

sediment plumes (sand)



wind direction (air)



bathymetry

islands

canal structure

fig. 05 Fluxes and physical elements influencing the design proposal.

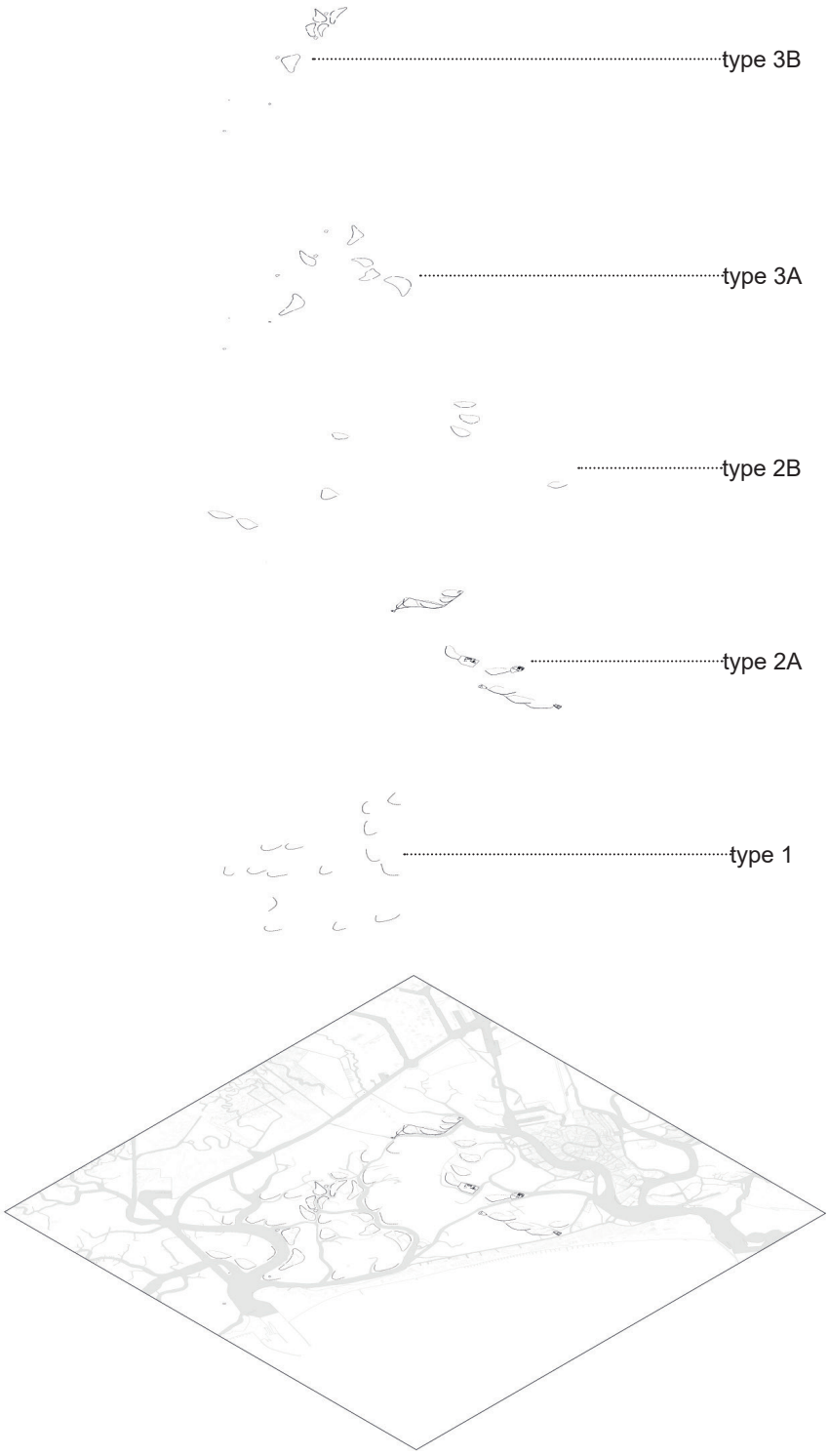


fig. 06 The three types of designed structures and their positioning in the central sub-basin of Malamocco.

a. b. c. d.

fig. 07 Examples of biodegradable materials to be used for the structures' production.

a. Geotextile composed of natural fibres (viscose) derived from cellulose.

b. Geogrid obtained from vegetable fibres from the agave plant.

c. Geogrid obtained from wood fibres from the outer shell of the coconut.

d. Natural fibre geotextile composed of yarns from hemp, Yuta, cellulose and wool.

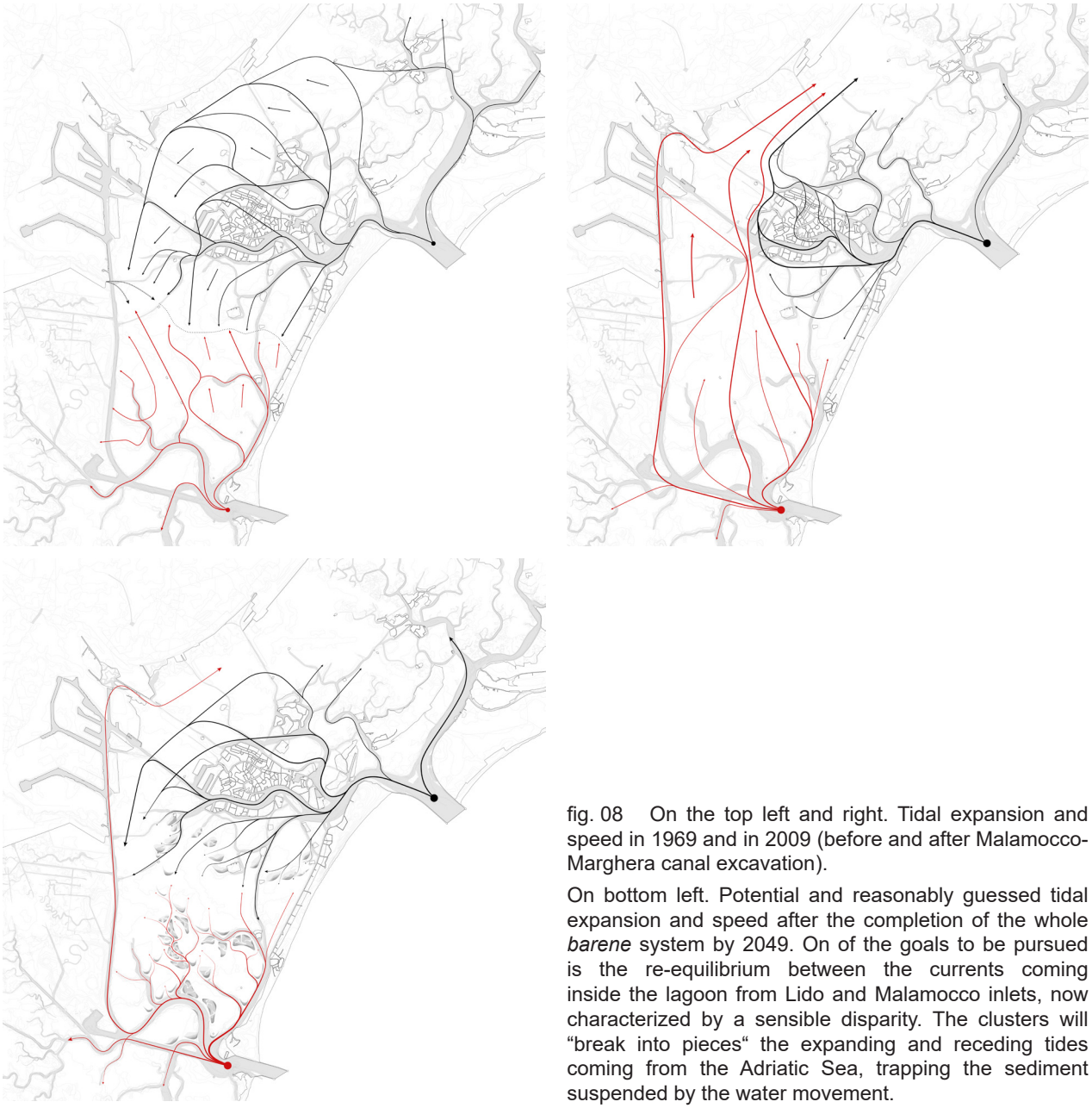


fig. 08 On the top left and right. Tidal expansion and speed in 1969 and in 2009 (before and after Malamocco-Marghera canal excavation).

On bottom left. Potential and reasonably guessed tidal expansion and speed after the completion of the whole *barene* system by 2049. On of the goals to be pursued is the re-equilibrium between the currents coming inside the lagoon from Lido and Malamocco inlets, now characterized by a sensible disparity. The clusters will "break into pieces" the expanding and receding tides coming from the Adriatic Sea, trapping the sediment suspended by the water movement.

fig. 09 Atmospheres on the designed *barene*.

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