A-GRID

Agrivoltaics for Noah's ark

Fabiano Spano Architect

1.1 – Introduction

The design of an agrovoltaic system is a challenging topic. Energy production and agriculture compete for the same source : sunlight. Both systems follow precise rules. Finding a perfect balance is challenging.
What if beauty is the solution to the oxymoron?
What if ***A-Grid*** is the solution to the oxymoron ?

1.2 – Grid model

The Grid model derives from the agricultural context . The land grid is made of lines and shapes.
The patterns of shapes are defined by the alternation of different agricultural fields, forests, ecological systems.
Ecological infrastructure developed along the borders of those shapes enhance them and define an alternation of "green rooms".
The point of view at ground level is short and the natural border creates a green stage.
The lines are the result of historical signs layering (Centuriazione Longobarda) , roads and water infrastructures. Those lines give direction and modifies the agricultural pattern.
In our ***Grid model*** we scaled down the territorial grid into the project area. In this way there's a continuity of shapes and lines from the plot to the territory.
The average size of the cell of the grid (called Module) is 17 x 37,5 m and is determined by the optimization of the agricultural operations on the soil and by the admissible span of the structural system.
The grid has 19 x 4 modules.

1.3 – Grid morphing

The Grid is morphed according to those rules:

1. boundaries of the pipeline and electric line
2. Solar exposure optimization
3. Connection of relevant natural areas in the surrounding , through the design plot

Those rules determined modifications in the regular grid and integrates better the design of the system in the context.

1.4 – The canopy - bottom

The image that led our design is the image of a forest canopy . The forest canopy protects the ecosystem below, buffer the effects of temperature and control the microclimate. The PV canopy can provide similar functions to the rice field.

Rice fields has also a unique visual effect, due to the water presence on the ground.

The water reflects the sky, while the PV panels with a reflective glass as backsheet reflects the water. This game of reflections can create unique visual effects, blending together the sky, the ground, the canopy.

2.1 – Tensile model

The structural model of the A-Grid concept is based on a tensile structure system.

After a deep analysis of the construction techniques available and the state of the art for the agrovoltaic systems our choice is to adopt a tensile structure.

This typology of structures has a big potential of development and an high potential in defining geometries integrated in the landscape and in nature.

The reason of that choice are :

1. lightweight materials in the aerial part
2. reduced visual impact of the structure
3. catenary geometries, with better integration with the landscape
4. material saving and reduced environmental impact
5. adaptable geometry to the plot
6. longer distance between supports (37,5 m) , minor number of pillars,
7. minor soil occupation and higher surface dedicated to rice cultivation
8. reduced interference with the agricultural practice
9. integration with agrotextiles
10. integration with precision farming technologies

Agriculture in a climate change times makes a large usage of devices to protect the crops from several threats (rain, hail, insects, solar radiation, wind, …) . More and more the agricultural landscape is populated by agrotextiles that protect the crops.

The agrovoltaic structures have the potential to integrate in the canopy not only the PV production but also the different typologies of agrotextiles.

The usage of a tensile structure for the Canopy makes possible to have a single geometry for all the components, ***the catenary***, making very clean and clear the visual impact.

2.2 – Production model

AGRICULTURE

In the A-Grid project the rice field has a size of 8.2 Ha . We increased also the ecological infrastructure of 0,6 Ha .

This result was made possible by the adoption of a tensile structure with reticular supports, that minimized the soil occupation and made possible the usage of the reticular structure as a support for a new ecological infrastructure.

PV ENERGY

We propose the PV field in two versions. ***Configuration A*** has a ***3 MWp*** of power installed, ***configuration B*** has ***2,25 MWp*** .

Configuration A is made of 76 modules (arrays) divided in 19 sub-fields . This version has an homogeneous distribution of the PV panels on the whole plot.

Configuration B is made of 57 modules (arrays) divided in 19 sub-fields. This version has less productive modules and provide a more differentiated landscape effect, recalling the pattern of the agricultural fields.

Both the configurations provide a wide distribution of the panels, and a very low percentage of covered area (21,7 %) , in perfect proportion with the rice field light requirements.

2.3 – The canopy – Top

In the bird's eye view of the canopy we want to provide a not-geometric effect , with an higher integration with the image of the cultivation below.

The image of the diffused PV panels merge with the image of the rice field.

In this way we avoid the overlapping of artificial geometries imposed by regular PV arrays on the agricultural fields.

3.1 – Solar model

The A-Grid design is based on the assumption that , under a strict control of the PV panels efficiency, is possible to model more harmonic geometries with different orientations . Considering as a reference an optimized array oriented at 37° we managed to design variable curvature surfaces, reaching a combined PV production of 91,5 % .

A ***solar matrix*** allowed us to map the efficiency of PV panels at different orientations.

The solar design actions that led to this result are :

1. Strings orientation from 3° to 30° tilt angle
2. In plane rotation of the PV panels , 0° to 30°, providing a variable visual effect
3. Panels density from 12 to 33 % of the total surface
4. Mean density of 21,7 %
5. 3 strings on each structure module
6. 9 to 12 strings under each inverter
7. 9 MPP tracker , 18 inputs Inverters

8. 19 inverters (one for each array)

The distribution of the panels is homogeneous, providing a diffuse shadow on the rice field, and an homogeneous growth of the rice. Minimizing the production loss.

3.2 – The module

The module is the typical component of our system. In integrates several elements in a unique geometry : PV panels, tensile structure, agrotextiles, support reticular structure, electric system, ecological components, foundations.

3.3 - Experience

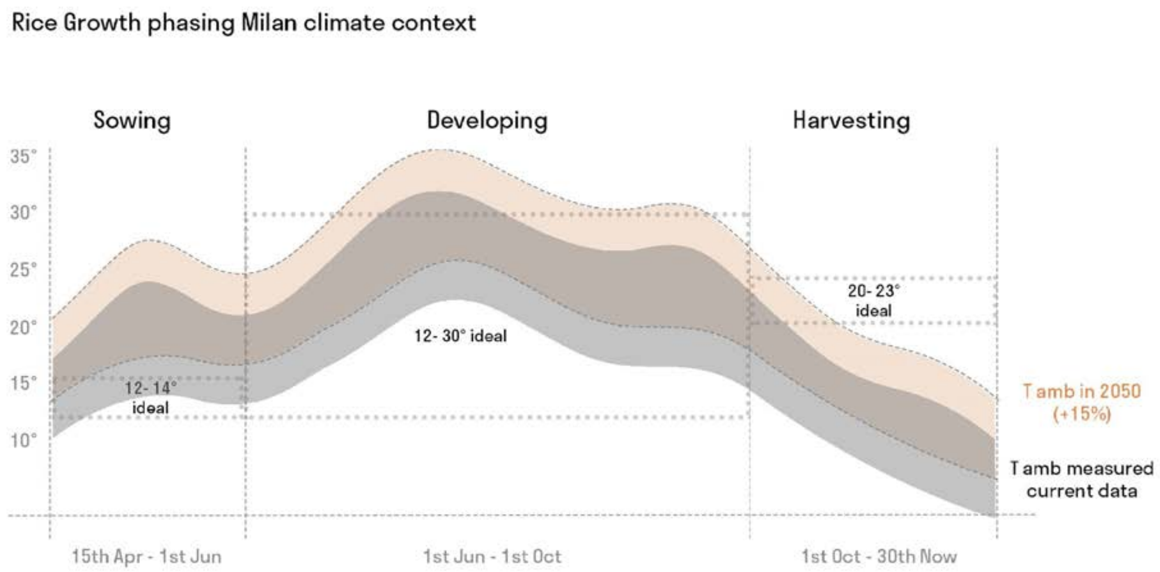
The A-Grid concept is also a space for experience. A panoramic walkway connects the two ecologic remarkable areas located on the left and right side of the plot. The walkway also give unique perspectives on the canopy and the possibility to cross and look at a rice field from above.

3.4 - Climate change model

Climate change is our present. The project has been developed looking at the dramatic climatic situation in the project area.

We also looked at the climate of the next 30 years. With the consultancy of a world leading partner as Transsolar KlimaEngineering we have designed a model based on future climate simulations.

The core of the project is a canopy structure that allows the implementation of several functions, in



order to mitigate the impact of extreme climate conditions and giving the opportunity to continue to cultivate rice even in those conditions .

CLIMATIC CONTROL

In this analysis we compared the year temperature in the present , the projection in 2050 and the ideal ranges for rice cultivation.

The ***A-Grid*** model can provide the following services :

1. Sowing phase . In this phase the medium temperature is higher then the ideal one. The canopy , with his specific geometry can provide a natural ventilation that mitigate the temperature
2. Developing phase. In the developing phase, due to the climate change, we are facing a lack of water, reduced moisture in the soil, higher air temperatures. The canopy, together with thermal control Agrotextiles, can provide more stables temperature and microclimatic conditions
3. Harvesting phase. In this phase the normal air temperature are significantly lower then the ideal ones. In this phase the thermal mass of the PV panels and the use of a thermal reflective agrotextile can provide significant results.

WATER MANAGEMENT

Water scarcity became a dramatic problem. Our design proposal can combine different technologies in order to make possible the rice cultivation even in a water scarcity scenario.

In particular:

1. 18.000 m3 of water storage, located on the left side of the plot
2. water harvesting system
3. Sprinkler irrigation system integrated in the canopy
4. Agrotextiles integrated in the canopy (thermal control, evapotranspiration control)
5. Ground covering

A-Grid concept can integrate in a single geometry all those technologies, fostering the visual impact of the canopy.

The combination of those cultivation techniques and technologies allow a significant reduction of water demand .

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Rice cultivation – water usage				
Irrigation techniques	**submersion**	**mulching sheet**	**green mulching**	**Sprinkler**
	m3 /ha	m3 /ha	m3 /ha	m3 /ha
mean water needs m3 / ha	20.000	20.000	20.000	20.000
Reduction	**0%**	**50%**	**25%**	**65%**
Reduced water volume m3 / ha	20.000	10.000	15.000	7.000
Plot surface Ha (10000m2)	8	8	9	8
Total water needs for the plot	160.000	80.000	135.000	**56.000**
Water storage in the plot m3 / ha				18.000

01

Anthropic and natural semiology

Historical landscapes's signs and and historical invariants

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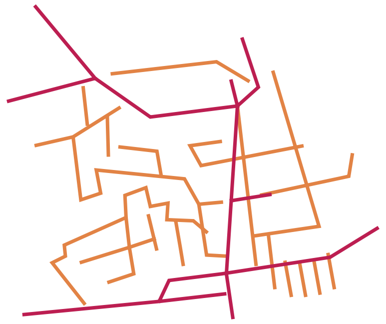
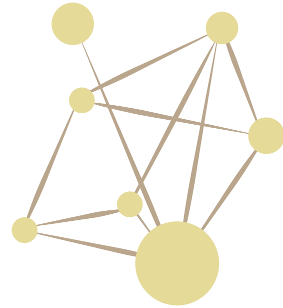
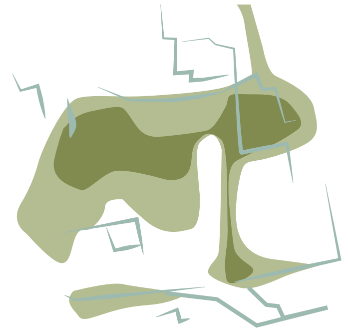
Linear invariant



Spot invariant



Natural invariant



Semiological analysis

Landscape shapes

Legend Anthropic semiology

- buildings of historical and monumental importance
- rural buildings
- nucleus of ancient formation
- asphalt roads
- lombard centuriation
- power line

Legend Natural semiology

- green systems
- water systems
- geen hallways

Legend Historics landscape shapes

- buildings of historical and monumental importance
- asphalt roads
- dirt roads

02

Visual and perceptual values

Study of colors and materials

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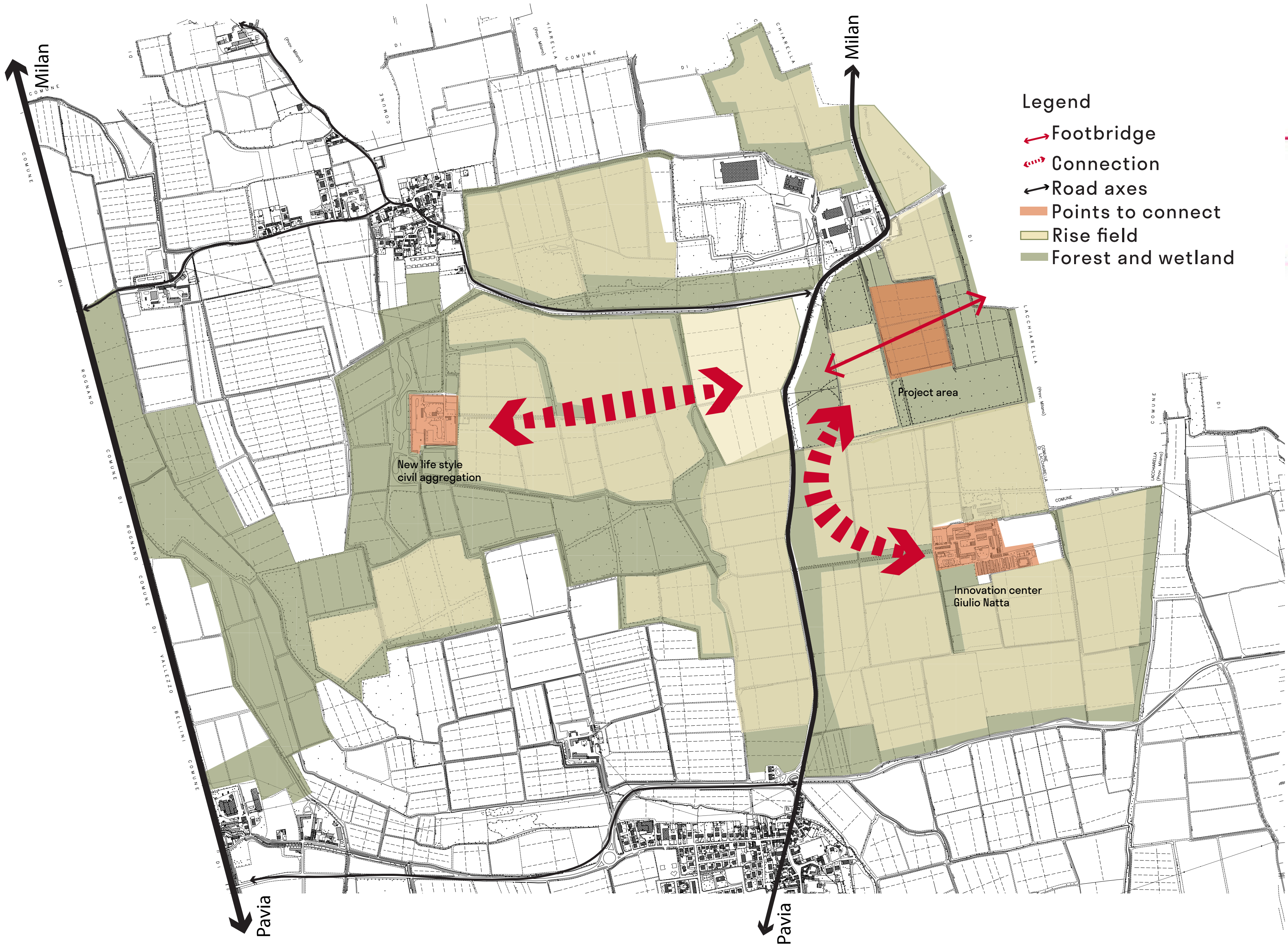
Wetland

Rice field in spring

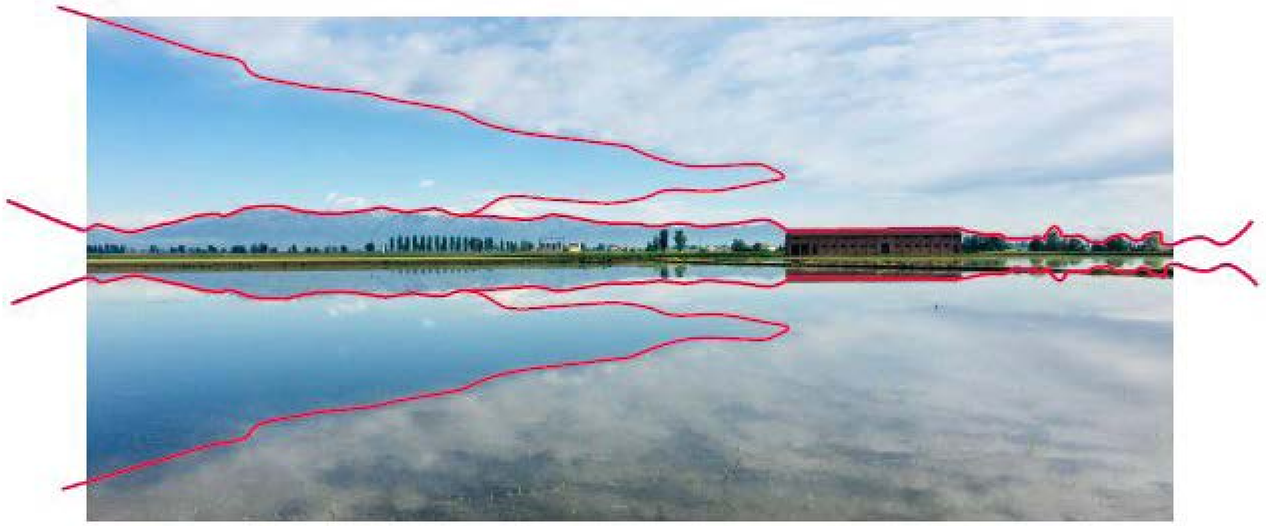
Rice field in summer

Rice field in autumn

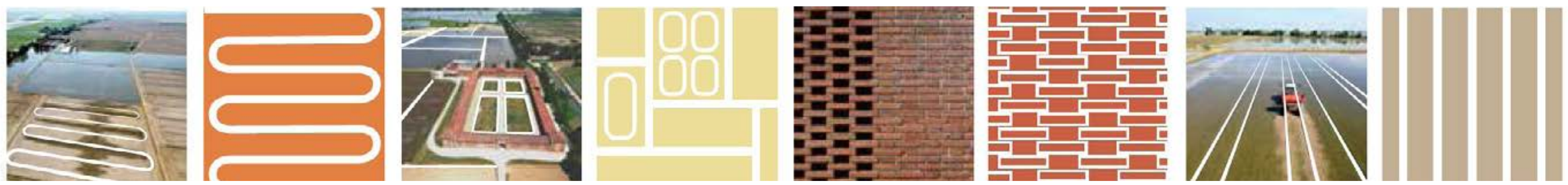
Flow analysis



Reflection of the landscape's shapes



Shapes perception analysis



03

Ecological systems

Agricoltural system

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Ecological system model

Agricolture system model

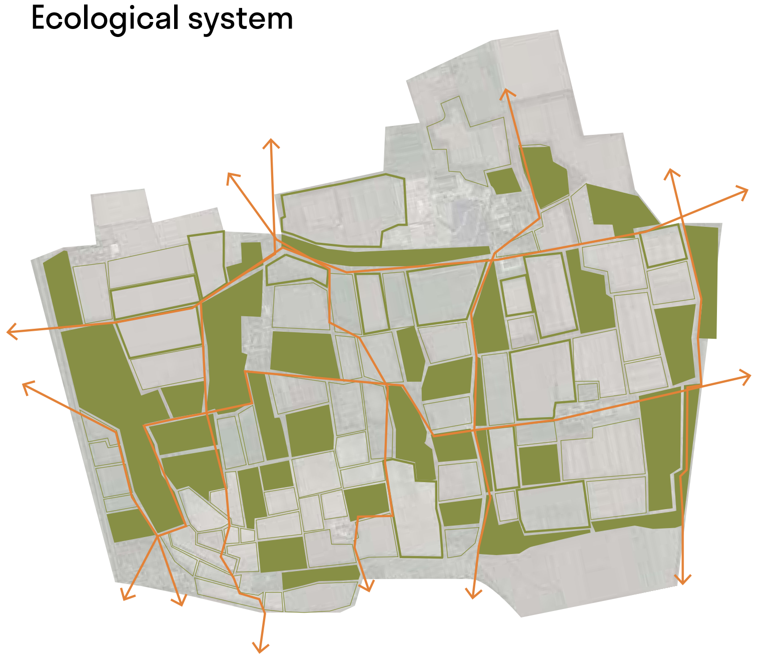
Shape analysis

Simplify grid

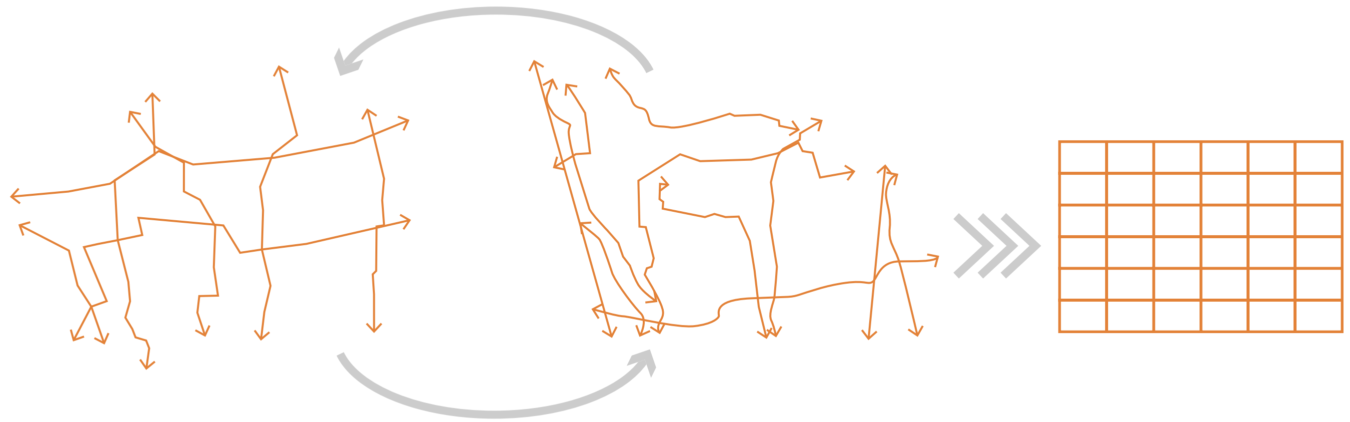
Lines analysis

Simplify grid

Ecological system



Agricolture system model



Ecological systems: woods, wetland, riparian vegetation

Green hallway

Agricoltural systems: rise field

Main roads

ECOSYSTEM SERVICES

CICES classification version 4.3

		Agricultural areas	Wooded areas	Floral nursery areas	Flowerbed	Riparian vegetation	Rows of trees	Canal	Ditch	Pond	Areas for services	What to improve?
PROVISIONING	Cultivated crops	3	0	0	0	0	0	0	0	0	0	- cultivedted crops - surface water - materials processing
	Materials from plants for direct use or processing	0	2	3	0	0	0	0	0	0	0	
	Surface water for non-drinking purposes	0	0	0	0	0	0	2	1	3	0	
REGULATION AND MAINTENANCE	Filtration/sequestration storage/accumulation by ecosystem	1	2	1	1	2	2	0	0	0	0	- filtrationage/storage by ecosystem - ventilation and transpiration - pest control - disease control
	Mediation of smell/noise/ visual impacts	0	3	0	0	3	2	0	0	0	0	
	Mass stabilisation and control of erosion rates	1	3	1	1	3	2	0	0	0	0	
	Hydrological cycle and water flow maintenance	1	1	0	1	2	1	3	3	3	0	
	Ventilation and transpiration	0	2	0	0	2	2	0	0	0	0	
	Pollination and seed dispersal	1	3	2	2	3	1	0	0	0	0	
	Pest control	2	2	1	2	3	1	0	0	0	0	
	Disease control	2	3	1	2	3	1	0	0	0	0	
	Micro and regional climate regulation	2	3	0	2	3	2	2	2	2	0	
CULTURAL	Scientific	3	3	1	0	0	0	1	0	1	0	- scientific - educational - symbolic
	Educational	3	3	1	0	0	0	0	0	0	2	
	Symbolic	3	0	0	0	0	0	0	0	0	0	
	Existence	3	3	0	1	1	1	1	0	2	3	

PROVISIONING
0 - missing
1 - low
2 - medium
3 - high

REGULATION AND MAINTENANCE
Valore 0 - SE assente
Valore 1 - SE basso
Valore 2 - SE medio
Valore 3 - SE alto

CULTURAL
0 - missing
1 - low
2 - medium
3 - high

S.W.O.T. analysis

Strengths — S

- Natural: strategic position, ecological and functional role, territorial identity typical of the mosaic countryside, correlation with the context, extensive renaturation interventions;
- Historical-architectural: evidence of rural architecture, Lombard centuriations;
- Socio-economic: area with a strong agricultural vocation, rice production, increase in renewable energies, new jobs, rural tourism;
- Planners: area recognized as a prestigious agricultural area, intercepts cycling routes, presence of the SUMP;

Weaknesses — W

- natural: perception of the landscape from the ground;
- historical-architectural: intensive agriculture erases the historical signs of the landscape;
- socio-economic: little innovation in technology, renewable energy, sustainable agriculture;
- planners: lack of adequate long-term land and landscape improvement strategies;

Opportunities — O

- creation of new social and economic attractors;
- development of ecological / naturalistic tourism;
- access to regional / national development programs;
- technological agriculture 4.0;
- possibility of triggering technological processes;
- Optimization of agricultural areas;

Threats — T

- difficult management;
- experimental photovoltaic system;
- cymatic changes: drought, high water consumption;
- anthropogenic pressure, environmental pollution;
- use of pesticides and herbicides;

A-GRID

COST ESTIMATION

Configuration A _ 3 Mwp

The cost estimation has been developed using 2022 DEI price list

RESUME

S.01	STRUCTURES	1.971.840,20 €
IB.11	PHOTOVOLTAIC SYSTEM	2.856.873,89 €
	SAFETY	144.861,42 €
	TOTAL	4.973.575,51 €
	Economic offer	-30,00%
	Total amount	**€ 3.481.000**

COST DETAIL

S.01	**STRUCTURES**	**1.971.840,20 €**
	EXCAVATION	57.416,40 €
DEI.015040.e	Soil excavation for foundations trenches, set-section up to 10 meters depth	26.666,40
E.001.031	Landfill station transport	30.750,00
	FOUNDATIONS	1.853.804,60 €
DEI.035076.f	Supply and laying foundations piles over 12 meters long	55.551,80
E.004.040	Supply and laying foundations wooden form-work	48.720,00
DEI.035075	Supply and laying foundations concrete steel-work meshes	341.940,00
E.004.004.c	Supply and laying foundations reinforced cement concrete works	375.592,80
E.010.008	Supply and laying steel structural system	1.032.000,00
	MACHINE/DEVICE	60.619,20 €
N.001.014.d	Mobile elevating work platforms (MEWPs)	30.715,20
N.001.058.b	Hydraulic crawler crane	29.904,00
IB.11	**PHOTOVOLTAIC SYSTEM**	**2.856.873,89 €**
	PV PANELS AND INVERTER	1.770.800,00 €
NP10	Supply and installation of PV panels, model Qcell Q.PEAK DUO, (or similar) nominal power 380 W, on existing frame. Items: 7904	1.580.800,00
NP11	Supply and installation of string solar inverter, model HUAWEI SUN2000 – 185KTL – H1(or similar), mounted on existing frame. Items: 19	190.000,00
	STEEL-WORK	4.370,51 €
E.010.001	Supply and laying steel-work	3.217,07
E.010.010	Hot-dip galvanizing	1.153,44
	ELECTRICAL WORKS	1.022.997,23 €
EA.002.026.b	Supply and laying solar stranded copper PV wire, 5 DIN VDE class. Ø: 6 mm²	168.000,00
EL.003.001.a	Supply and laying single core flexible power cable rubber-insulated G7M1. Ø: 240 mm²	377.475,00
EL.003.001.b	Supply and laying single core flexible power cable rubber-insulated G7M1. Ø: 185 mm²	94.861,80
EL.003.001.c	Supply and laying single core flexible power cable rubber-insulated G7M1. Ø: 150 mm²	59.607,90
EL.003.001.d	Supply and laying single core flexible power cable rubber-insulated G7M1. Ø: 120 mm²	51.048,90
EL.003.001.f	Supply and laying single core flexible power cable rubber-insulated G7M1. Sezione: 70 mm²	13.500,00

EL.003.026.g	Supply and laying PE insulated data cable with tinned copper wire, fire-retardant PVC sheath, type FTP.	2.264,00
EL.004.007.d	Supplay and laying electrical PVC pipe. Ø: 160 mm	117.129,41
F.002.016.a	Supplay and laying reinforced cement concrete manholes drain inspection. Dimension: 100x100x90 cm	6.150,00
EL.003.013.m	Supply and laying low-voltage switchboards, according to CEI standards.	15.410,94
DEI.035164	Supply and laying open swicth.	9.189,00
EL.003.021.i	Supply and laying rotary disconnect switch. Four-pole, In: 1600 A	2.970,22
EL.002.014.g	Supply and laying insulated circuit breaker. Three-pole, In:160 A, Icc: 35 kA standard	8.271,27
EL.004.008.c	Suppley and laying galvanized cable tray, 150 mm minimum width.	1.088,40
EL.003.001.a	Supply and laying single core flexible power cable rubber-insulated G7M1. Ø: 240 mm²	17.975,00
DEI.115001.p	Supply and laying low-voltage electrical transformer, according to CEI and I.E.C. standards.	36.308,77
EL.001.008.f	Supply and laying medium-voltage MV/LV transformer. Dimension: 1.600 x 2.000 mm	751,42
EL.003.018.c	Supply and laying of single-core MV cable, including conduit. Ø: 150 mm²	18.495,00
EL.001.003.b	Supply and laying medium-voltage electrical system protection.	18.385,50
EL.004.007.d	Supply and laying of PVC pipes for electrical power line Ø: 160 mm	4.114,70
	EXCAVATION	58.706,15 €
E.001.003.b	Mechanical soil excavation, set-section up to 2 meters depth, including landfill station transport.	23.746,67
E.001.005.a	Soil excavation by hand tool, set-section up to 2 meters depth, including landfill station transport.	3.912,30
E.001.011	Backfilling	18.522,50
E.001.013	Supply and laying pipes sand bed	12.524,68