PHOTOVOLTAIC LANDSCAPE(S)

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UNIVERSITAT POLITÈCNICA DE VALÈNCIA

PAISAJE(S) FOTOVOLTAICOS

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"And, when you want something, all the universe conspires in helping you to achieve it"

-Paulo Coelho, The Alchemist

ABSTRACT

EN

The development of renewable energy such as solar is a key priority for the European Union. This research and design project aims to understand the territorial impacts caused by photovoltaic infrastructures, with the aim of proposing possible ways to integrate these systems into the landscape, taking into account ecological and landscape objectives. In Spain, it is particularly relevant since concern has recently been expressed about the losses in biodiversity associated with the construction of a large-scale solar energy operations.

ES

El desarrollo de energía renovables como la solar, es una prioridad clave para la Unión Europea. Este proyecto de investigación y diseño se plantea comprender los impactos territoriales que causan las infraestructuras fotovoltaicas, con el objetivo de proponer posibles formas de integrar estos sistemas en el paisaje teniendo en cuenta objetivos ecológicos y paisajísticos. En España, es particularmente relevante ya que recientemente se ha manifestado preocupación por las pérdidas en la biodiversidad asociada con la construcción de campos de energía solar a gran escala.

VA

El desenvolupament d'energia renovables com la solar, és una prioritat clau per a la Unió Europea. Aquest projecte de recerca i disseny es planteja comprendre els impactes territorials que causen les infraestructures fotovoltaiques, amb l'objectiu de proposar possibles maneres d'integrar aquests sistemes en el paisatge tenint en compte objectius ecològics i paisatgístics. A Espanya, és particularment rellevant ja que recentment s'ha manifestat preocupació per les pèrdues en la biodiversitat associada amb la construcció de camp d'energia solar a gran escala.

KEYWORDS

solar energy, solar landscapes, photovoltaic landscape design, biodiversity

energía solar, paisaje solar, diseño paisajístico de granjas solares, biodiversidad

energia solar, paisatge solar, disseny paisatgístic de granges solars, biodiversitat

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OBJECTIVES

The objectives of this research by design proposal are divided into two categories:

Research Objectives:

I. Understand the current state of literature and guidelines relating to solar farms and their landscape impacts, with particular emphasis on biodiversity and ecosystem services.
II. Explore how solar farm development can support landscape rehabilitation strategies.
III. Explore the role of animals as participants in the landscape transformation process.

Design Objectives:

IV. Enhance the relationship of a proposed solar farm, located in Chiva, Spain with the natural landscape, providing improved habitat and biodiversity outcomes, guided by ecological principles.
V. Promote and reflect the identity and culture of the local community through proposed landscape strategies and a small scale site intervention.

THE RENEWABLE ENERGY TRANSITION AND THE LANDSCAPE

Sijmons et al. 2014 states that "It should be clear that an energy transition is not only necessary, but also far reaching and difficult." In the introductory chapter of the "Landscape and Energy: Designing Transition" the authors depict a challenge of the energy transition: the idea of "the landscape as a battleground" where they argue that the transition to renewable energy will have a far-reaching effect on the meanings, values, memories, and emotions we have assigned to the landscape. This is because in the current landscape, a large part of energy generation and supply has been concealed - gas lines run underground, the generation of electricity is "a plume on the horizon, where a distant plant is fired by coal that comes from invisible underground mines…" (p.17) We have therefore created a global energy system that has a considerable footprint, but is reasonably hidden from view from our everyday lives, where the distant coal mines are not a part of the image we form of the landscape. According to the authors, this has allowed society to "maintain the illusion that our use of energy has not radically changed our landscape" (P.17). However, the transition to renewable energy systems breaks this illusion, because the distance from production to consumption is greatly reduced, with energy being generated in a much more decentralized way. This means energy supply becomes more visible in our everyday environment and "we will be directly confronted on a daily basis with the production that is necessary for our consumption" (p.17), which produces tension at the time of project development.

Renewable energy expansion on a large scale is critical for the decarbonization of the global economy. The European Commission's proposal for the first European Climate Law aims to write into law the goal set out in the European Green Deal – for Europe's economy and society to become climate-neutral by 2050. This translates to greenhouse gas emissions reduction target of at least 55% by 2030 in order to obtain this goal. Solar energy will play a critical role in contributing to the alternative energy mix to mitigate climate change and meet policy milestones. This expansion must be properly planned and managed to maximize environmental advantages while minimizing perceived and actual negative impact. (Bennum et al. 2021

THE EMERGENCE OF SOLAR LANSCAPES

This energy transition will create new landscapes. Energy has always been a driver of landscape change and the transition towards renewable energy is no different, it will alter the landscapes around us, and as Selman (2010) claims, this "will involve landscape changes that attract protest and opposition, and which may prove barrier to the rapid adjustments necessary to substantially reduce our carbon footprint." This transition implies the emergence of new landscapes and the significant loss of traditional landscapes. This may sound like a bleak outlook, but the author theorizes that we can develop an "acquired aesthetic" much like the concept of "acquired taste" where we become accustomed to the landscape typology and character of renewable landscapes and that we can "learn to love" the landscapes when we begin to understand their underlying narrative. The idea is that we can accept these replacement landscapes when they possess a "coherent and edifying new narrative that is coupled with contemporary social and economic realities." The author argues that the rapid deployment of renewable technologies will probably be at a faster pace than our ability to accept these changes, but there are some broad principles that will make this transition smoother.

These principles, presented on the next page, are envisioned as a type of manifesto, and will guide the project strategies and small intervention presented in subsequent chapters.

These guiding principles support the terminology used in other publications, such as the term "Sustainable Energy Landscape" which is defined as a "physical environment that can evolve on the basis of locally available renewable energy sources without compromising landscape quality, biodiversity, food production and other life-supporting ecosystem services" (Stremke and Dobbelsteen, 2012).

Locals protest the proposed solar plant in Méntrida, Spain. Photo Credit: Salvemos Los Campos

A Solar Landscape Manifesto (Selman, 2010):

I. Mass produced solutions and developments, insensitive to local need and character, are less acceptable than projects that have a demonstrable link and complement local environmental services.

II. We can learn to love landscapes where we are able to read "stories of endeavor, solidarity, enterprise, community and purpose".

III. Society prefers cultural landscapes which can be understood as familiar and coherent, where the landscape creates a sense of place, tells a story of human ingenuity, adaptation, wisdom, and generates a source of pride.

IV. Change in an informed and democratic way can produce a landscape that people support because they help write the underlying narrative.

The emergence of this new landscape typology has impacts, that are perhaps not fully understood due to the relatively new nature of solar technology and its deployment at scale. The investigation of the connections between solar power and the environment is a relatively new field of study and the landscape impacts of this technology have received far less attention. The study by Mérida-Rodríguez et al. 2015 served as the foundation of understanding landscape impacts of solar operations for this brief literature review.

The effect that photovoltaic plants have on the landscape is determined by both their outward appearance and the meanings that people associate with the existing landscape and or the new landscape that is formed with their installation. The varying geometries, compositions, textures and colors of solar operations and the way they communicate with the surroundings can have visual or physical impacts on the landscape, which then may influence the overall meaning someone might assign to said landscape. Landscape meaning will likely change depending on the individual and their connection to the territory. Some may perceive a solar plant as a sign of progress, associating it with "clean, renewable, and environmentally friendly energy" while another person may not be able to see past the perceived industrial nature or its association with the change it induced upon a landscape, they had emotional ties to. This brief review will not focus on the complexities of societal perception of solar farms, instead it will focus on the physical landscape.

Location: Due to the economic conditions and the availability of land, solar operations are typically located in rural areas, where the landscape is considered as part of local or regional identity. The authors recognize that within rural landscapes, the impact upon agricultural terrain is perceived as being less significant, because human presence has introduced regular shapes, human constructions, and altered vegetation patterns. In more naturalized spaces, the contrast of a solar farm with the existing landscape character is often more notable. The location of a solar operation in an open area, with their large dimensions and reflective surfaces, makes them visible from many places. Their location near transport networks (highways, local roads, trails) increases the number of potential observers which amplifies the visual effect of the operation.

Overall Design: Photovoltaic plants, by nature of their energy density, tend to cover larger areas of land in comparison to other sources of energy. The contrast between the size of the plant and the pre-existing plots of land can have significant visual impact, which the authors claim could be remedied by adapting the shape and size of the plant to the existing plots of land. The author does not discuss however, how this would translate to an actual project of medium to large scale, where fencing, cabling, and management scenarios would have to be altered for the solar plant to mirror the existing plot structure. On the flip side, the authors state that fragmentation can also have significant impact due to the introduction of gaps, unusual geometries, and the color contrast between the patches of panels and the surrounding landscape. The authors then continue to discuss topographical alterations that are sometimes required, including the introduction of geometrical shapes and lines, the physical movement of terrain (which is avoided as much as possible due to increased cost) and the installation of panels perpendicular to contour lines.

Components: By nature of the technology itself, the industrial, metallic, and "futuristic-looking" components contrast sharply with surrounding rural uses and constructions. Photovoltaic panels have reflective properties, which can make them visible from great distances, which creates a visual impact not only at the site location, but in the surrounding vicinity. Monocrystaline silicon modules are typically between blue and grey in color which may blend in well with surrounding bodies of water, but may product greater contrast in the semi-arid landscape of Spain. Letcher and Fthenakis (2018) add to this, stating that solar farms with large numbers of panels will stand out in fields with dominating colors of greens, yellows, or browns. The coloration of the landscape changes throughout the year, more so than the variation in grays of solar panels under different light conditions. The color of the solar farm can create a markable contrast with the surrounding landscape, however this contrast could mimic some elements typically associated with the agrarian landscape such as plastic agricultural netting used to protect crops, glasshouses, polytunnels, and industrial farm structures.

Internal Organization of Components: The authors claim that the way the components of a photovoltaic installation are grouped together is of "outstanding visual importance, especially from the middle and long distance, from which the design of the individual component is less noticeable." The greatest impact occurs from the difference created between alternating strips of structures and unoccupied land, when the rows are positioned perpendicular to natural contour lines, when there are different orientations mixed within the same installation, or when similar row alignments or patterns do not exist within the surrounding landscape as a form of reference. This is an interesting observation, particularly when considering some of the characteristic landscapes of rural Spain, such as olive groves and vineyards, where row linearity is a common feature.

The authors include a very brief discussion of proposals that could aid in landscape integration and or lessen the landscape impact. However, it is a little difficult to comprehend how the authors qualitative criteria translate into real world scenarios.

In the planning stages the authors suggest possible site options such as "the selection of flat or plateau terrains, with reduced viewsheds, low visual impact on populated or busy areas and far away from high-quality views and from exceptional elements in the landscape, especially those of a cultural nature. They also recommend that plants be sited on unproductive land as this new function would give the landscape more coherence or purpose." They also suggest that the size of photovoltaic plants remain small to medium size, adapting their dimensions to the size and dimensions of nearby farms. In addition, they suggest the external morphology fit within the characteristic shapes of the farms around them, "be they linear or en masse, geometrical or irregular." The author´s conceptual proposals don't necessarily account for the technological design requirements or cost associated with making said adjustments. One said example is the authors suggest adjusting the color of the dividing lines between photovoltaic cells, matching the colors with surrounding landscape, or the exploration of new shapes for the modules. These are valid considerations and should be explored but are quite cost prohibitive and could render a project not feasible.

Planning and design for landscape integration can reduce possible landscape repercussions of solar installations while providing added value or improved landscape quality. The word integration or the act of integrating means to form, coordinate, or blend into a functioning or unified whole. Landscape integration can be defined as a territorial intervention that aims to guide and shape a landscape transformation to achieve harmony with a referenced landscape (Mérida-Rodríguez et al. 2015)

According to the National Consortium of Solar in the Landscape, based in the Netherlands, there are three main challenges to explore for the integration of solar farms:

1. Aesthetics: To maintain and or strengthen social acceptance of large-scale solar farms in the landscape through the alteration of color, shape, size, layout at an acceptable additional cost.

2. Nature Value: Understanding the impact of solar farms on the soil and nature value, which they refer to as biodiversity, asking how can the solar farm be a catalyst for adding value.

3. Functionality: The functional integration of agriculture and photovoltaic systems to create a multifunctional agricultural landscape, creating synergy.

Exploring the theme of “landscape integration” needs to be multidisciplinary in nature, with a range of stakeholders such as project developers, financial service providers, designers, consultants, knowledge and government institutions in order to ensure that solutions are technologically feasible, economically viable, and there is a supportive policy environment that would allow them to be scaled across various landscapes.

The following section briefly explores these three themes relating to landscape integration:

Landscape Aesthetics and Visibility

Due to the cost prohibitive nature of adapting solar technologies, in terms of structural forms, shapes, sizes, or coloration, this project will not delve deeper into these modifications. This literature review is being used to inform a real-life project scenario, where such modification could render the project no longer economically feasible. However, literature and project examples suggest that the vocabulary surrounding “aesthetics” often refers to or is associated with “visibility” and thus: the screening of the solar site in the surrounding landscape. As the age old saying goes, beauty is in the eyes of the beholder, something that can be seen is something that can be critiqued for its presence.

As solar farm projects increase, the visual and landscape impacts are being increasingly explored, debated, researched, and legislated. Aesthetics is probably the most complex challenge, as it is deeply rooted in societal perception of landscape and landscape change. Landscape is frequently used as an aesthetic argument against renewable energy development, which questions the values, representations and practices that underpin our view of the landscape. When the dialogue of a solar facility is framed from an aesthetic perspective, one might argue that they are nothing more than, and no different than, the traditional industrial facilities whose influence on the landscape must be minimized or hidden from view (Blaschke et al. 2013).

The literature review for studies regarding the visual impact has been inconclusive, as there is not a lot of research pertaining to this area of solar development to date. Chiabrando et al. (2009) came to this same conclusion, stating that there is a considerable lack of academic literature that concentrates on the assessment of visual impact of photovoltaic operations, and there is no consensus on assessment procedures at an international level.

Solar panels are typically low-rise structures, with an average distance of 2.5 meters from ground to the top of the structure. In flat landscapes, low-level structures do not have long-distance visibility, but elsewhere, effective screening and topography can limit the zone of visual influence to within the site or within proximity of the site only. In such circumstances, the general population may be unaware that the installation even exists (Letcher and Fthenakis, 2018). Sanchez Ormeño, in her graduation thesis mentions the “makeup of infrastructure” in her research, when referring to the establishment of perimetral vegetation to screen the solar site from public view. Many impact studies and government approvals of solar projects require some level of site screening to this end, to hide the industrial nature of the solar site from the surrounding landscape. A brief review of environmental impact studies in Spain concludes that most seem to include “pantalla vegetal” or vegetative screening as a remediation measure to screen the site from the viewshed, typically from urbanizations and other developments. The debate on whether a solar project should be fully screened, partially screened, or fully open to the surrounding viewshed is a debate that that has no right or wrong answer. Mérida-Rodríguez et al. (2015) state that “An essential aim of landscape integration of photovoltaic power plants must be to insert the modules and panels, their main components, into the landscape more effectively. This does not necessarily mean hiding them; indeed, their prominent position in the landscape can be maintained if the right measures are taken."

Nature Value

Perhaps one of the most recent, more comprehensive literature reviews, on the ecological impacts of ground-mounted photovoltaic solar panels was performed by Tayor et. al. (2019), with the purpose of comprising literature that explores the interactions between PV solar panels and ecological features including organisms such as invertebrates, birds and bats. The authors recognize that to date, there is a relatively limited number of research papers, and many are site or context specific. The overall goal of the review was to apply knowledge and lessons learned to solar power development in the United Kingdom, but as the studies are global in nature, it is useful for sites around the world.

It is understood that ground mounted solar panels have the potential to cause impact on nature as they are installed on land which typically has at least some value to wildlife, however the degree of impact remains to be determined due to the complexities of wildlife studies and the time required to build up empirical data. Perhaps one of the most important takeaways from this literature review is that, as a whole, there is little empirical data on the subject of the impact of ground-mounted PV panels, and that at times, the limited available research has been stretched to address gaps in knowledge.

This section will highlight some of the key takeaways and discussion from the review performed by Tayor et. al. (2019) References cited in this summary can be found in the original review.

Invertebrates:

Aquatic Invertebrates: At present, there is limited evidence of the negative impact of PV solar panels, located in rural areas, on aquatic invertebrate populations. Horvath et al. (2010) published a study about the possible attractiveness of solar farms to aquatic invertebrates located next to a river from which the invertebrates emerged. This study concluded that the horizontal, polarized, reflective surface of the panels may attract aquatic invertebrates, inducing egg-laying in locations where egg survival is unlikely. The authors of the study suggest that some consideration in the siting of solar farms near water bodies with known presence of aquatic invertebrate species would be an appropriate measure. However in the broader picture, another series of studies performed by Kriska et al. concluded that the potential attraction of invertebrates to highly polarized, reflected light occurs in many manmade surfaces, such as asphalt roads, parked cars, and glass buildings, therefore experimental design would need to take into account other man-made features in the landscape and their potential ecological impacts on invertebrate populations. It also remains unclear whether this habitat susceptibility varies between the presence of still or moving water. It is hypothesized that impact of solar siting near water bodies would have greater impact on still water species (lagoons, lakes, ponds) as opposed to species located near riverine habitat where the water flows and the geometry is more sinuous.

Butterflies: Ewers et al. (2006) concludes that species response to habitat loss or fragmentation is generally a result of life history traits, with sedentary and specialist species being more affected than more mobile or generalist species. The authors state that butterflies are widely acknowledged to be sensitive to habitat fragmentation. To test this theory Guiller et al. (2017) studied the impacts of utility scale solar energy operations on Rhopalacera butterly community movement in mediterranean agro-ecocystems. The results of the study suggested that both mobile and sedentary species coped with these changes in landscape structure.

Vertebrates:

Birds: There are several types of solar energy generation systems and their effects on birds vary. The only system to be reviewed in this research is ground-mounted solar PV arrays. This eliminates a lot of literature as much of the studies concerning solar energy impacts on birds are from large concentrated solar systems in the United States, where several large facilities, employing mirrors and solar light concentration, are in the desert along migratory routes. This has resulted in reported mortality caused by collision and singeing (burning).

There are media reports and grey literation that suggest that water birds may confuse large solar arrays with water bodies, increasing collision incidents of birds and PV arrays. Bernath et al. (2010) observed birds such as black kite and swallow attempting to drink from plastic sheets, which led the authors to hypothesize that these species were attracted to polarized light, suggesting that these birds could collide with panels, which also reflect polarized light. Harrison et al. (2017) concludes this unlikely poses a risk to birds who drink from a perched position. Very little additional research has been found to support these claims, furthermore the authors found no studies from the UK or Europe.

Dwyer et al. (2018) explore the possible

effects of renewable energy, which included solar, on raptor species. The authors stated that effects such as direct mortality, habitat loss, avoidance, and displacement rarely occur in isolation, meaning that the impacts of the solar facility are co-occurring with other anthropogenic modifications in the surrounding area. Devault et al. (2014) found that raptor abundance was higher pre-construction compared with post-construction at one solar site, which could suggest avoidance of the facility. This could be from the bare earth which unsuitable for hunting or nesting by raptors or from increased human activity in and around the solar site. It is important to take these findings with caution, as the study does not describe the habitat management at the PV sites, it only states that adjacent grasslands had taller vegetation than PV enclosures. Therefore, without fully understanding the vegetative management scheme of the solar facility and the complete landscape mosaic of its surroundings, it is difficult to apply lessons learned from this study to other sites constructed near raptor habitat. Therefore, every finding must be applied with caution during project design, as most existing studies are so site specific that it is difficult to translate findings to another geographic location and management scheme.

Walston et al. (2016) estimate that utility scale solar energy avian mortality is considerably lower than bird mortality from other human causes, from roadways, building collisions and wind or fossil fuel development. The study recognizes that bird fatalities can occur as a direct result of ground-mounted PV solar facilities, but in lower numbers than concentrated solar facilities.

The effects of bird displacement by solar panels are inconclusive, species specific, and furthermore, site specific. Dwyer et al. (2018) comments on the possible indirect effects of solar energy development on bird populations, which could be habitat loss, displacement and avoidance. There have been hypothesis that ground-nesting birds might be attracted to solar parks due to the available of a safe nesting area (as security fencing could reduce predator movement), however Montag et al. (2016) found that skylark tended to use undeveloped control plots more than solar farms. Their hypothesis as to why this was the case was that the ground-nesting birds prefer an unbroken line of sight, thus generally avoiding solar array enclosures.

To fill in these knowledge gaps, there needs to be investment in data collection, impact assessment, pre-construction and post-construction monitoring of project sites. This represents a partnership opportunity between private industry actors and public research institutions, this is particularly relevant for project sites located near universities.

Bats: The current studies pertaining to the impact of ground mounted solar PV are inconclusive. The literature review performed by Tayor et. al. (2019) concludes that there has been no research that directly addresses the impact on bats. Studies show that bats may mistake horizontal surfaces for water bodies and vertical surfaces for open flight paths, but there is currently no evidence that translates this into collision in the context of solar farm operations. They cited Harrison et al. (2017): “In order to determine the impacts of solar PV developments on bats, experimental or observational research is urgently required and should be conducted on a species guild bases in the UK due to behavioral differences and variation in ecological requirements.” The study includes a table with experimental approaches which can be used as a foundation for research studies. This same statement can be applied across geographies, as bats are probably one of the least understood mammalian species, with large data gaps which makes planning for their conservation difficult (Frick et al. 2020).

Biodiversity:

The main takeaways from the review by Tayor et. al. (2019) were that there is a considerable lack of research on the effect of solar energy installation on biodiversity and that studies should focus on ecological interaction, ecosystem-wide effects and landscape level impacts. Existing studies come to the consensus that proper siting can reduce the overall impact of the site and proper management for wildlife can contribute to biodiversity.

Gasparatos et al. (2017) supports this, suggesting biodiversity friendly operational procedures. After construction, approximately 70-95% of ground area remains available, which means the security of the site and the average 20-25 year lifespan of the project can support wildlife and contribute to biodiversity targets under proper management scenarios.

Tayor et. al. (2019) summarizes recommended practices from various sources, which include:

I. Installation or protection of boundary features such as hedgerows, ditches, stone walls, field margins and scrub, which are already typical features in rural landscapes separating plots and filling in spaces that are not cultivated.

II. Planting grassland with native grasses and flowers.

III. Controlled grazing by sheep, with pause in spring and summer to allow vegetation growth and seeding.

IV. Installation of artificial structures such as next boxes, hibernacula, and log piles.

Conventional vegetation management at solar facility sites includes the removal of biomass, disturbance of soil, placement of gravel, installation of the solar infrastructure, establishment and maintenance of turf grass species, mowing and herbicide application, which are intended to minimize and prohibit the growth of vegetation within the facility footprint. In recent literature, such practices have been criticized as conflicting with biodiversity goals and contributing to greenhouse gas emissions, which are released when vegetation is removed, and soil is disturbed during site preparation (Walston et al. 2018; Hernandez et al. 2015).

There has been a shift in dialogue surrounding solar farms and their role in the landscape. In a thought piece published on “The Conversation” Margaret Birney Vickery argues that solar farms can be attractive and functional landscapes, both visually appealing and contributing to habitat and ecological function of the landscape, converting “lifeless slabs encircled by chain link fences” to sites that are “attractions,” providing ecosystem services, such as habitat to local wildlife and an socio-economic value (Vickery, 2020).

This shift in thought is supported by Semeraro et al. (2018), with the authors stating that land converted to solar farm use can become "multifunctional land for economic activities: production of electricity, production of honey and medicinal plants; ecological role: enhancement of ecosystem services related to pollination and social role: ensure the welfare of the population by supporting food production and social activity." Randle-Boggis et al. (2020) supports this claim, stating that the relatively minimal land disturbance required during solar park operation, the anticipated lifespan, and the ability to stipulate land management provide excellent conditions to enhance positive ecosystem impacts and minimize negative

effects. In the case of the project proposal contained within this research by design final master´s project, the anticipated project site will be owned and managed by the project developer, this represents an opportunity to place nearly 400 hectares under a unique management plan for ecosystem services, supporting natural areas and more productive agriculture lands located within the vicinity.

Agrivoltaics

Since many solar farms are located in rural areas, the development of solar facilities often occurs on land previously used for farming operations. In fact, Solar PV power potential is often greatest over croplands (Adeh et al. 2018). Some researchers and media outlets have depicted this as a “battle” or “conflict” for land use.

What if solar farms could produce energy and support agricultural operations? The idea of multifunctional land, presented by Semeraro et al. (2018) supports the notion of Agrivoltaics, also known as agrophotovoltaics or agrisolar, which is the practice of co-developing land for solar photovoltaic electricity and agriculture at the same time. There has been much industry discussion of the topic, as evidenced by recent articles in PV Magazine, an online resource of news, emerging research and developments in the solar industry. According to a recent news article, Enel, an Italian renewable energies firm, recently launched an experimental program to integrate agricultural schemes into its solar plants in Spain, Greece and Italy. The true innovative challenge, according to Enel, is “to define an optimal integrated management model for the operation and maintenance activities of photovoltaic power plants and agricultural companies without changing the layout of the power plant, even occupying part of the area under the panels, and always using low-height crops that are appropriate for the environment” (Sánchez Molina, 2021).

Every agrivoltaic project is unique in that it must be tailored to the project site´s specific agronomic, environmental and socioeconomic characteristics. According to “Agrisolar Best Practices Guidelines” published by Solar Power Europe, each agrivoltaic project must establish a Sustainable Agriculture Concept which implies a “tailor made approach” to each individual project, which requires that agrisolar installations are adapted to “farm size, location, soil topography, local climate conditions, impacts on biodiversity, and water management, in addition to the consideration of local rural communities (Solar Power Europe, 2021).

The agrivoltaic scheme, likely most suitable for this exploratory project, is animal husbandry. Grazing within ground mounted solar plants is a very common approach, where pasture and grassland are allowed to grow between and below the solar modules, with ruminant animals acting as agents of vegetation management. Sheep are particularly suited as they do not interfere with the solar infrastructure and there is typically no need to adapt the height, spacing, or inclination of the solar systems. Other types of animal husbandry are being explored, but may require structural modifications, which increase project cost (Solar Power Europe, 2021). It has been reported that cattle tend to rub against the solar structures, which may cause damage due to the size and weight of cattle. Goats have been known to chew at cabling and climb on top of structures, which increases maintenance cost (Letcher and Fthenakis, 2018).

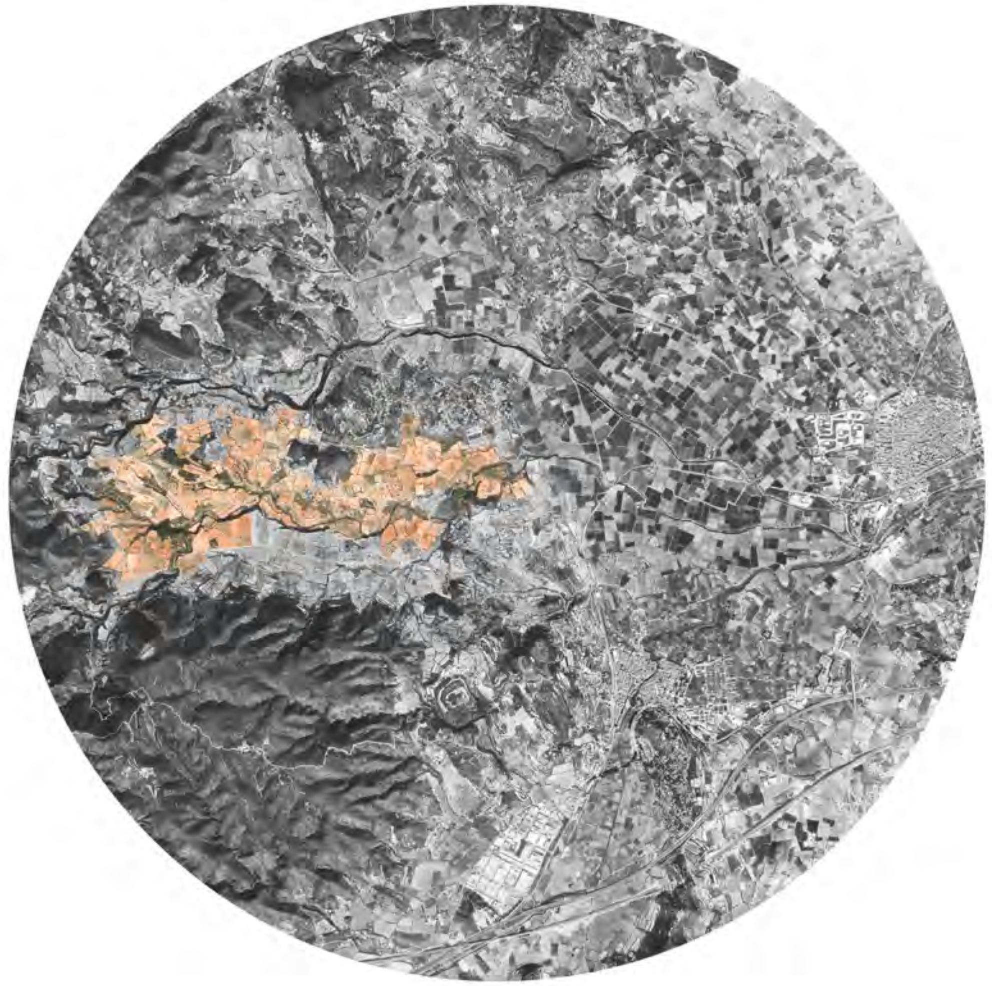
A landscape of vineyards and algarrobos. Chiva, Spain. Photo Credit: Author

Solar parks, with their widespread geographic distribution, could provide significant land area for enhancing biodiversity across Spain, contributing to landscape-level conservation and forming a network of sites that can provide a relatively secure and minimally disturbed refuge for the duration of the project life, which on average is 25 years.

The Campos de Levante photovoltaic plant, proposed by Italian Multinational, Falck Renewables, is projected to have 110 MW of installed power and includes an implantation area of 394 hectares with a planned occupancy area of 269 hectares. The location of the solar plant is projected in the municipality of Chiva and will be comprised of independent enclosures, each with its own fencing and access, in which all plant infrastructure will be contained, except for the electric line, which extends 8,2 km from Chiva to Godelleta substation. The proposed electric line exceeds the scope of this project and will not be included in analysis or strategic proposals.

This next section serves as the analytical foundation to later explore opportunities for supporting nature in the proposed solar development. It is believed that in order to truly integrate into the "landscape" the proposal must extend beyond the fenced boundaries of the solar site, attempting to situate the development into a broader cultural and landscape context.

TERRITORY



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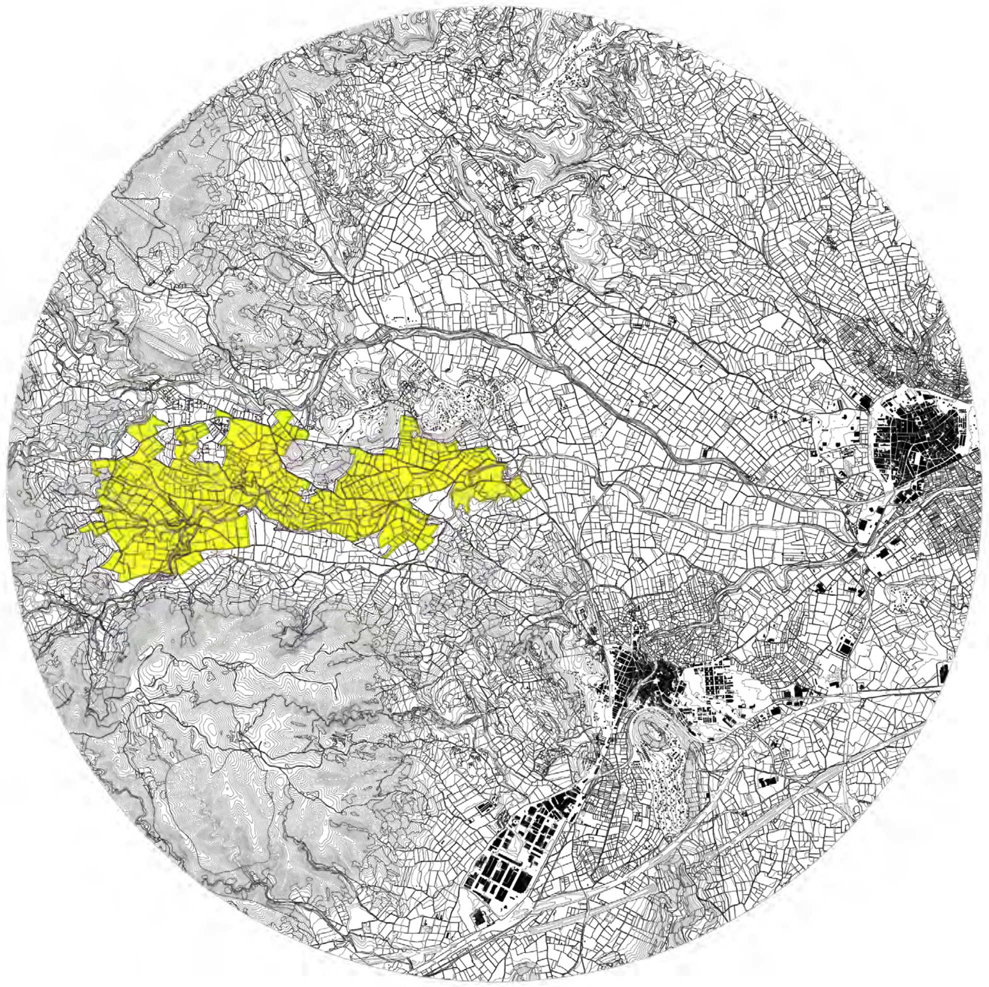
Data source: Institut Cartogràfic Valencià

The project site is located in the Llano de Brihuela, at the base of the Sierra de Chiva.

PARCELIZATION



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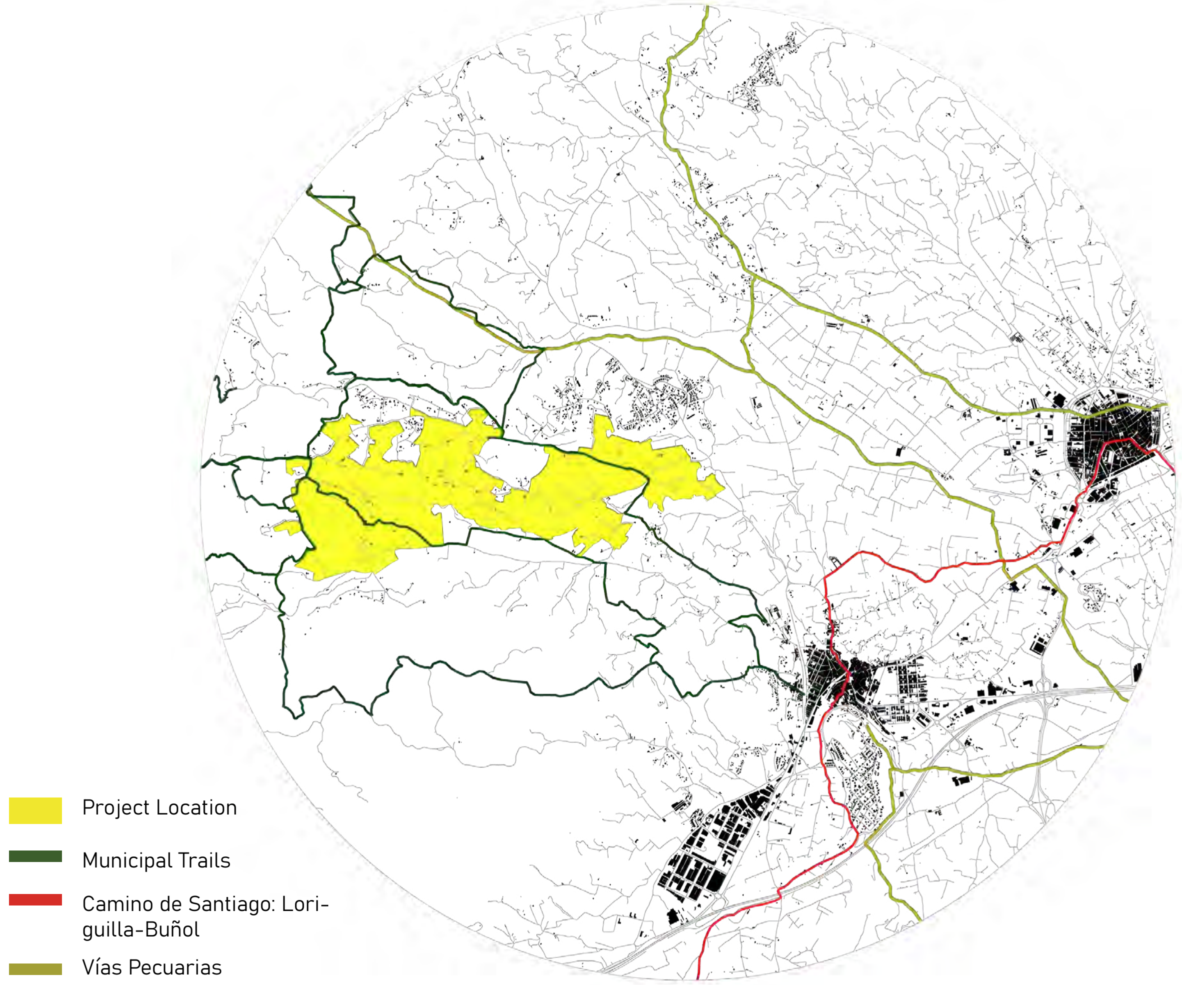
Data source: Institut Cartogràfic Valencià

The parcelization of the study area is characterized by many smallholder agricultural parcels, with irregular geometries. Falck Renewables currently has reached agreements with 300 of the 350 property owners within the study zone highlighted in yellow, which means that the 300 individual parcels could be transformed into groupings at project implementation, changing the parcelization pattern of the landscape .

MOBILITY



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Data source: Institut Cartogràfic Valencià

The study area is well positioned to take advantage of recreational trails promoted by local, regional and national entities. Notable are the number of municipal trails that connect to larger regional networks, including a sub-route of the Camino de Santiago and the vías pecuarias. The field visit confirmed that the site is accessible by foot, within 30 -45 minutes walking distance from the Chiva train station.

VIEWSHED

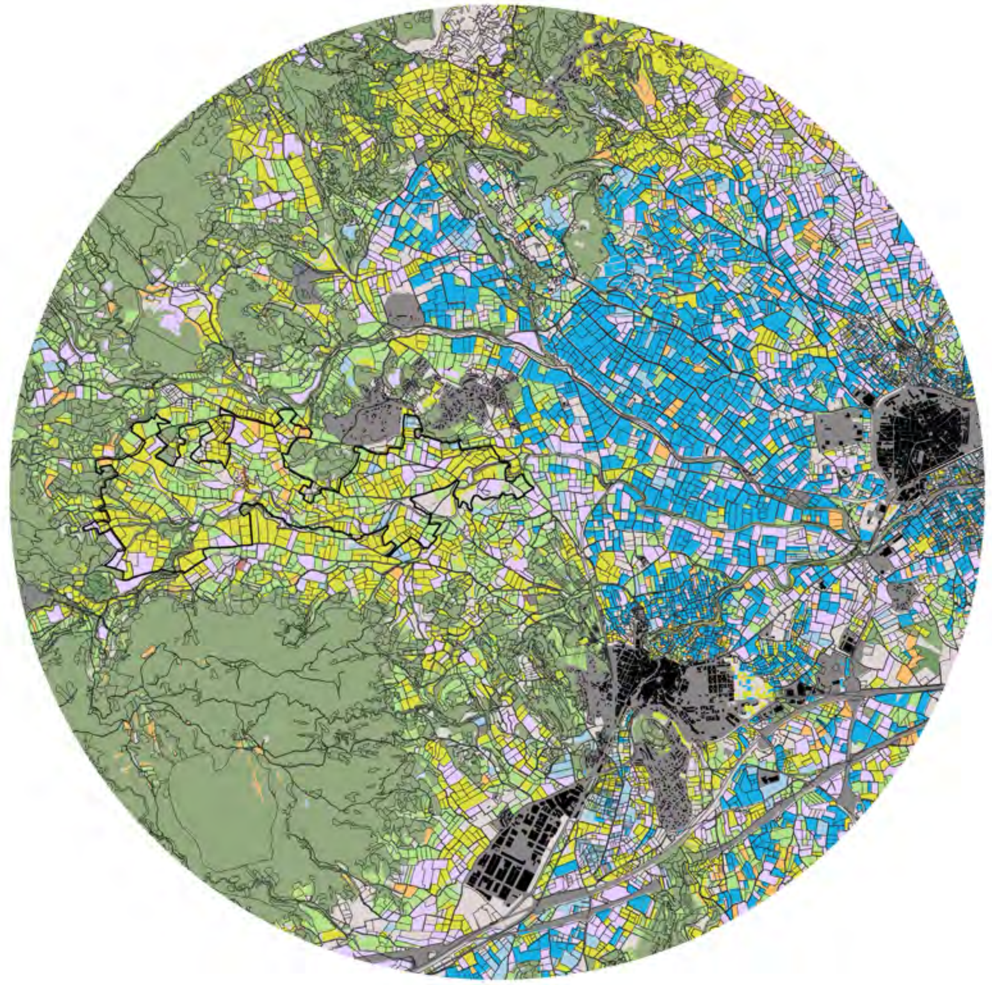
Scale: 1:50.000

Data source: Institut Cartogràfic Valencià

- Project Location
- Municipal Trails
- Theoretical Observer Points
- Viewshed

Using QGIS software, hypothetical observation points were chosen in the landscape to test the degree of visibility of the project site. The points chosen are external to the project site and the majority located along the municipal trail system or are easily accessed from the trail or surrounding urbanizations. The QGIS software does have limitations, as it is not able to determine how landscape features such as buildings and trees would impact visibility, the analysis relies exclusively on the topography of the terrain and the height of the observer (assumed to be 1.6 meters).

CULTIVATION



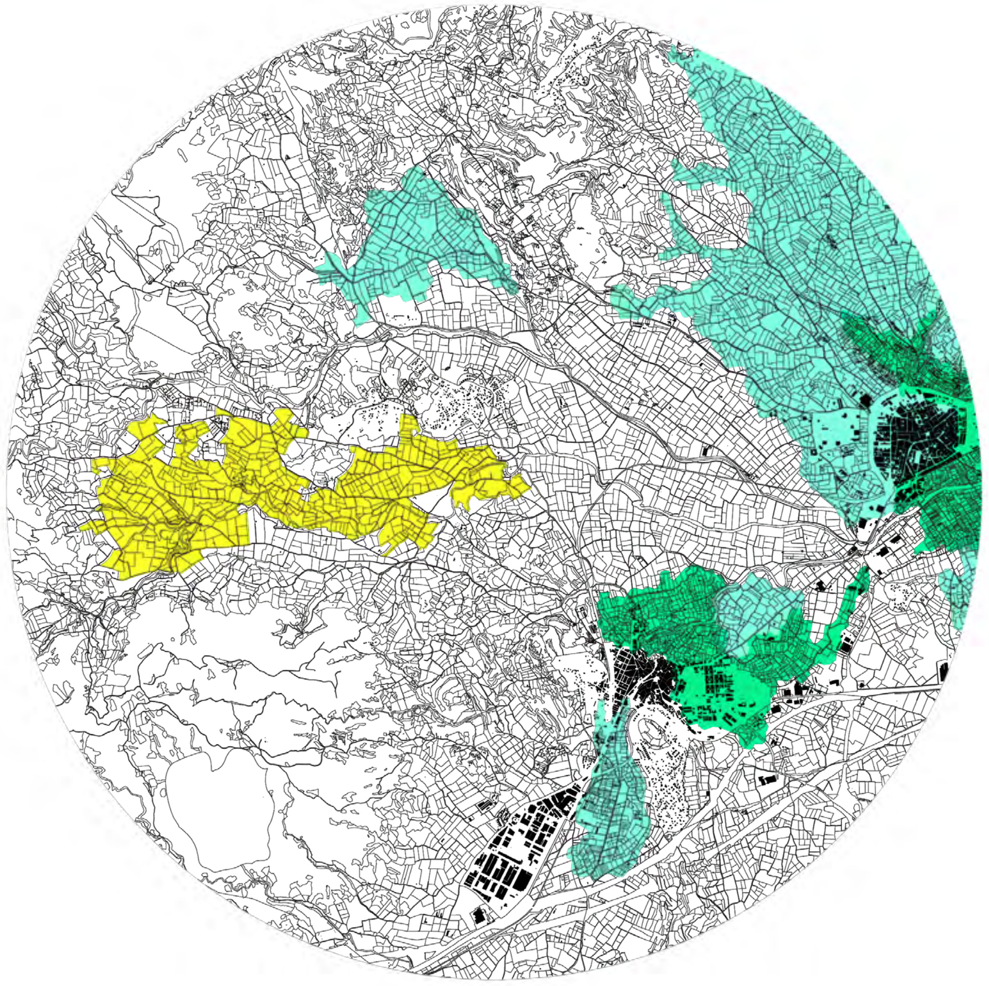
Scale: 1:50.000

Data source: Institut Cartogràfic Valencià

- Dry land farming
- Irrigated Farming
- Dry or Extensive Irrigated Fruit Trees
- Intensive Irrigation Fruit Trees
- Olives
- Clear Forest
- Scrubland
- Meadows and grasslands
- Firewall
- Vineyards
- Dense Forest

The project site is characterized by a dryland farming system, with notable presence of algarrobo (*Ceratonia siliqua*), olive groves, almond trees, mixed with vineyards, abandoned plots, dense stands of pine, and small groves of scrubland. The broader project area, is characterized by mediterranean vegetation typical of the mountain system to the southwest and heavily irrigated crops located to the northeast.

AGRONOMIC LAND VALUE

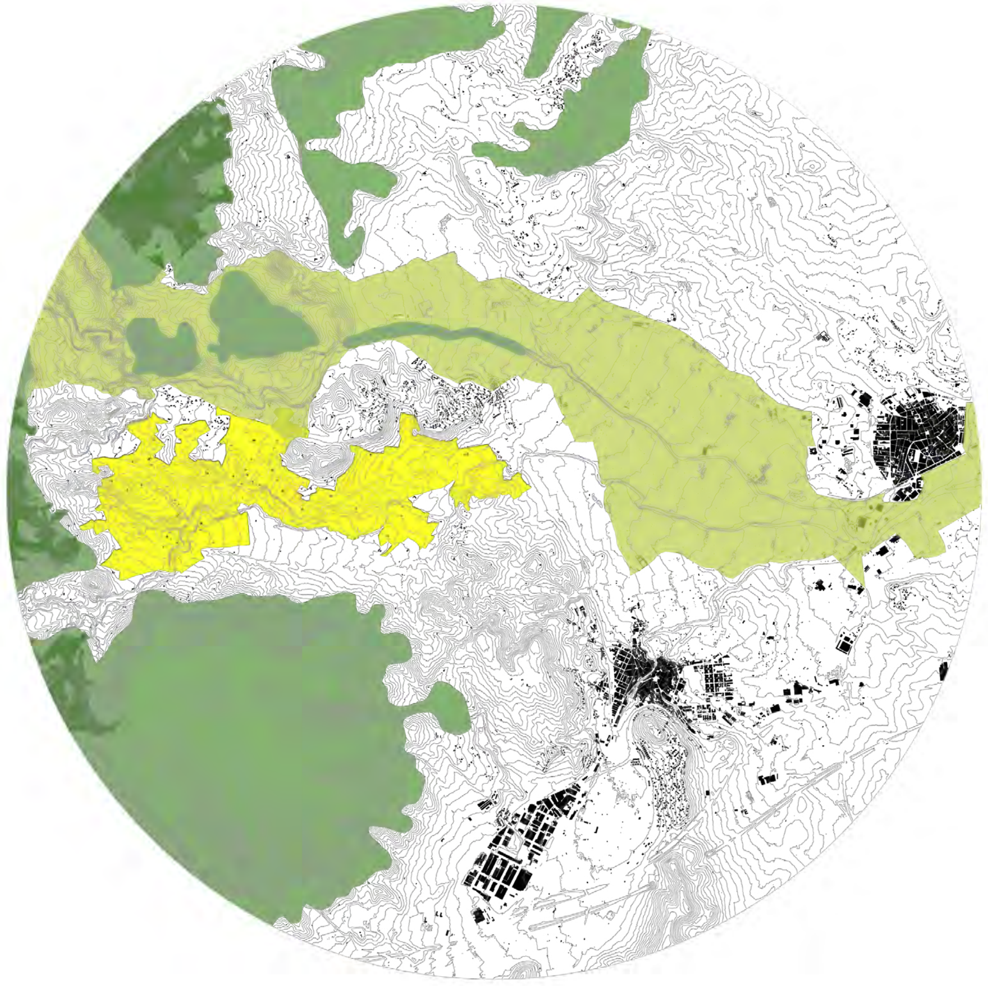


Scale: 1:50.000
Data source: Institut Cartogràfic Valencià

- Very High Value
- Elevated Value
- Project Site

Areas that represent Capacity for agricultural land use classified as 'Very High. Class A 'and' High. Class B, both of which are used to analyze compliance with the provisions of article 10 of Decree-Law 14/2020, which contains "Measures to accelerate the implementation of facilities for the use of renewable energies" The decree requires that solar facilities "use as little soil as possible of high agrological value, not being able to be implanted in soils of very high agrological capacity." The project site does not have soil classified within these categories.

ECOLOGICAL CONNECTIONS

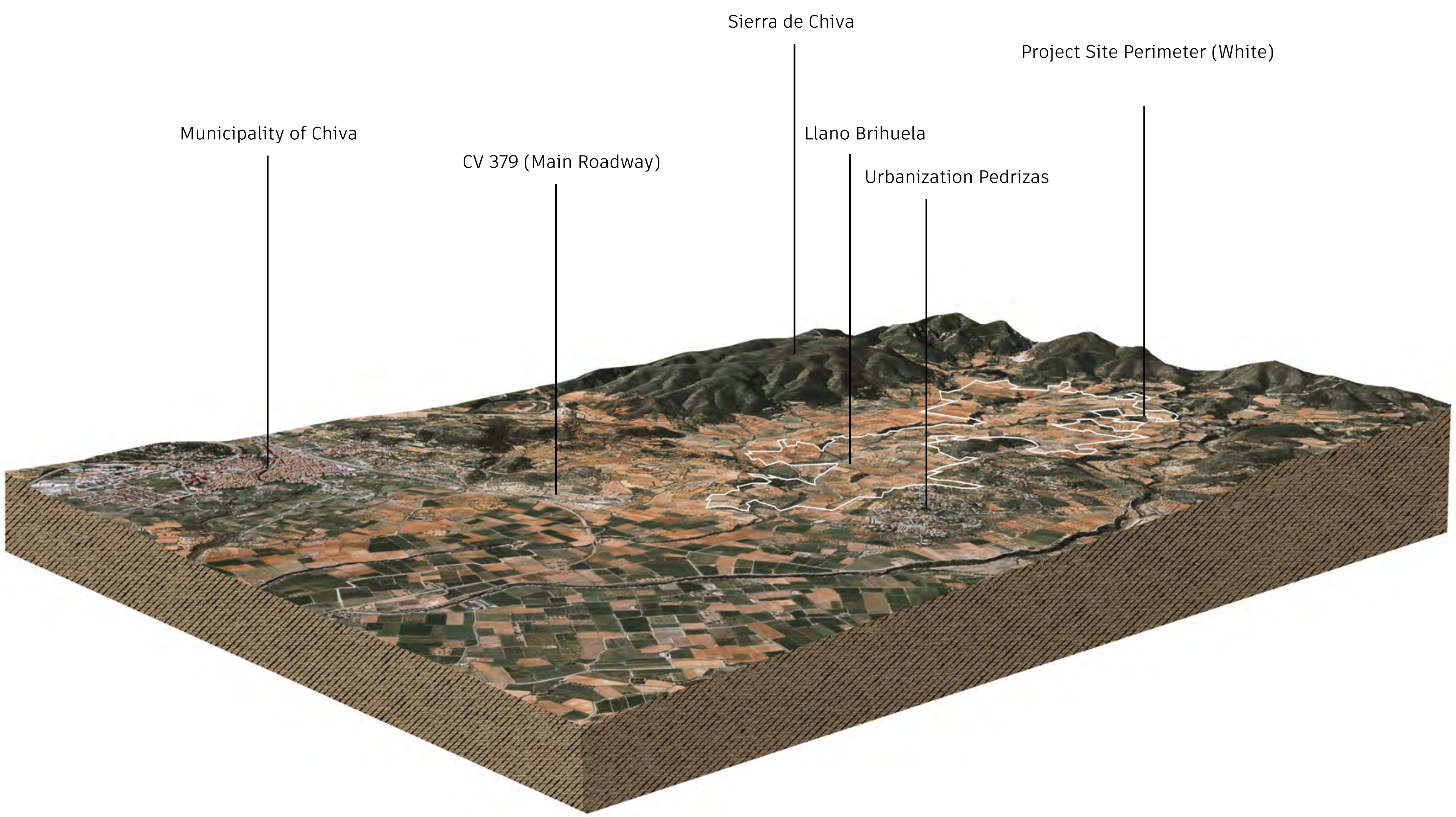


Scale: 1:50.000
Data source: Institut Cartogràfic Valencià

- Valencian Community Habitats
- Territorial Corridor
- Paraje Municipal
- Project Site

The project site is located near to, but not within, several areas designated as being of ecological value. The location of the project site, offers a unique opportunity for the project developers to enhance onsite biodiversity, supporting the territorial and fluvial corridors in the vicintity. The territorial corridors layer refers to the main corridors identified for the overall territorial connectivity in the Community of Valencia, which has been published in the Territorial Strategy of the Valencian Community (ETCV). The Paraje Municipal, with nearly 5,500 hectares of land, is the largest Municipal Natural Area in the Valencian Community. The "Habitats" layer identified for the Valencian Community, at a scale of 1: 50,000, is from the Ministry of the Environment and Rural and Marine Affairs, which is the entity responsible for maintaining The Atlas and Manual of Spanish Habitats, a product of the National Inventory of Biodiversity or National Inventory of Habitat and Taxa. Maximising habitat connectivity helps increase biodiversity. River corridors and flood basins, migration routes, and geographical features are all possible linkages. These contribute to the improvement of the ecological network by expanding habitats and providing connections for species to forage and migrate.

TOPOGRAPHIC CONTEXT



Transhumance

Transhumance is a long-lived tradition in Spain. It is the seasonal movement of livestock between fixed summer (highland) and winter pastures (lowland). This tradition dates as far back as prehistoric times, as early as the reign of the Visigoths from the fourth century to the seventh century, with regulations supporting the use of the territory by transhumant flocks traveling across nationwide networks. In the mid-1700s, around five million sheep were participating in transhumant groups, but transhumance began to wane in the nineteenth century and nearly vanished in the 1970s and 1980s. The environmental services it offered, as well as its relevance to the territory's agrarian culture and heritage, have been increasingly recognized (Oflanagan et al., 2011).

The "Archivo del Reino de Valencia" has accounts of transhumance within the community of Valencia. The most common livestock units were sheep and goats. The earliest and most comprehensive mention is the "Manifeiest de bestiars" (1510-1663) which has accounts of the livestock from Castilla and Aragón that arrived in Valencia to pasture in the winter months. In Valencia, there were essentially three landscape units that received these mobile livestock, Maestrat-Plana de Castelló, Llanura Central Valenciana, and Orihuela. The municipality of Chiva belonged to the Llanura Central Valenciana landscape unit, where it is known that the livestock would pasture at the foot of the mountain ranges "piedeomontes" and in dry farming areas (agricultura de secano).

The Cañada Real del Reino de Valencia

This Cañada Real is located within the general vicinity of the study site. It is a via pecuaria, which is a route or track along which transhumance livestock traveled in pastoral migrations. Their use for this purpose was essential for hundreds of years on the Iberian Peninsula. Today, the attributed benefits of these routes include the role they play in supporting indigenous breeds and extensive livestock farming, their role as ecological and biological corridors, their historical and cultural value, and recreational value-ranging from hiking, bicycling, horse riding, among other activities (Pradas and del Río, 2014).

Chiva and The Camino de la Lana or the "Wool Route"

The Camino de la Lana from Valencia is a pilgrimage route to Santiago de Compostela promoted by the Asociación Jacobea de Requena, an organization dedicated to the history, promotion and dissemination of the pilgrimages and the roads that, since at least the 15th century, connected Valencia to the city of Compostela. The Camino de la Lana connects Valencia-Alicante with Burgos (where it connects with the French Way) through Cuenca. It follows old paths linked to livestock and trade, especially wool. It is still a fairly unknown path in the Jacobean world, and few pilgrims have traveled it. Located to the south east of the project site, it could serve as a valuable recreational connection to the municipal routes contained within the project area (Asociación Jacobea de Requena, n.d).

Trasterminancia

Transhumance is said to have occurred between "tierras frías" above 1200m and "tierras calientes" below 400m. There are also accounts from the cronistas Viciana (1564) and Escolano (1610) of local, indigenous varieties of livestock that were concentrated in the intermediate "tierras templadas" that were between 400 and 1200m, located in the mountains and valleys of Ports de Morella, El Maestrat, Espadà, Calderona, Serranía del Turia, Meseta de Requena, Caqroig-Ayora and Alcoi. With Chiva´s position of

240m above sea level, it is unclear if it was a host to the indigenous varieties, but it is known that they were involved in "trasterminancia" which means that they alternated between pastures in cultivated areas in the winter and mountains and dehesas in the summer (Haba and Deusa, 1990). The publication by Haba and Deusa did not provide names for these local varieties, but further research revealed a local variety of sheep that matches the geographic context, the Oveja Guirra.

Transhumance Routes of Spain

01	Zamorana	06	Galiana
02	De la Plata	07	Soriana Oriental
03	Leonesa Occidental	08	Soriana Occidental
04	Leonesa Oriental	09	Conquense
05	Segoviana	10	Del Reino de Valencia

Source: Prepared by author with data from Miteco.gob.es

HISTORICAL AGRARIAN CONTEXT (CONT´D)

The Guirra Sheep of Valencia

The "Guirra" sheep or "Roja Levantina" is an indigenous sheep to Valencia and was given its name due to the characteristic red color of its hair and skin. Its closest ancestor is likely the African sheep variety Bení Ahsen, which hails from the Atlantic Coast of Morrocco and likely arrived to Spain due to trade relations between the Spanish "Levante" region and this area of Africa. This variety, which is included in Spain's Official Catalog of Livestock Breeds, is known for its high-quality meat, plentiful milk, and excellent fleece. Despite this, it is believed that just approximately 5,000 specimens exist today. The Ministerio de Agricultura, Pesca y Alimentación classifies this variety as in danger of extinction. There are numerous local efforts that are working to preserve this valuable piece of agrarian history. The lead organization, Asociación Nacional de Criadores de Raza Guirra (ANGUIRRA) was founded in 1997 and seeks to promote the conservation of the species, promote its commercial properties and products, and support studies and investigations. Another organization that has emerged is "Esquellana" which is a cooperative formed to recuperate the wool of the Guirra Sheep, reactivate its textile use, dignify the occupation of the shepherd and conserve the species through its economic initiatives.

The breed is raised in a generally difficult environment, which is determined by high temperatures and low rainfall, which means the vegetation patterns are highly seasonal with plants that are difficult to digest and can be of low nutritional value. They are very well known for their high rusticity, which allows them to take advantage of the hot, dry summers and low quality pastures (Ministerio de Agricultura, Pesca y Alimentación, n.d.).

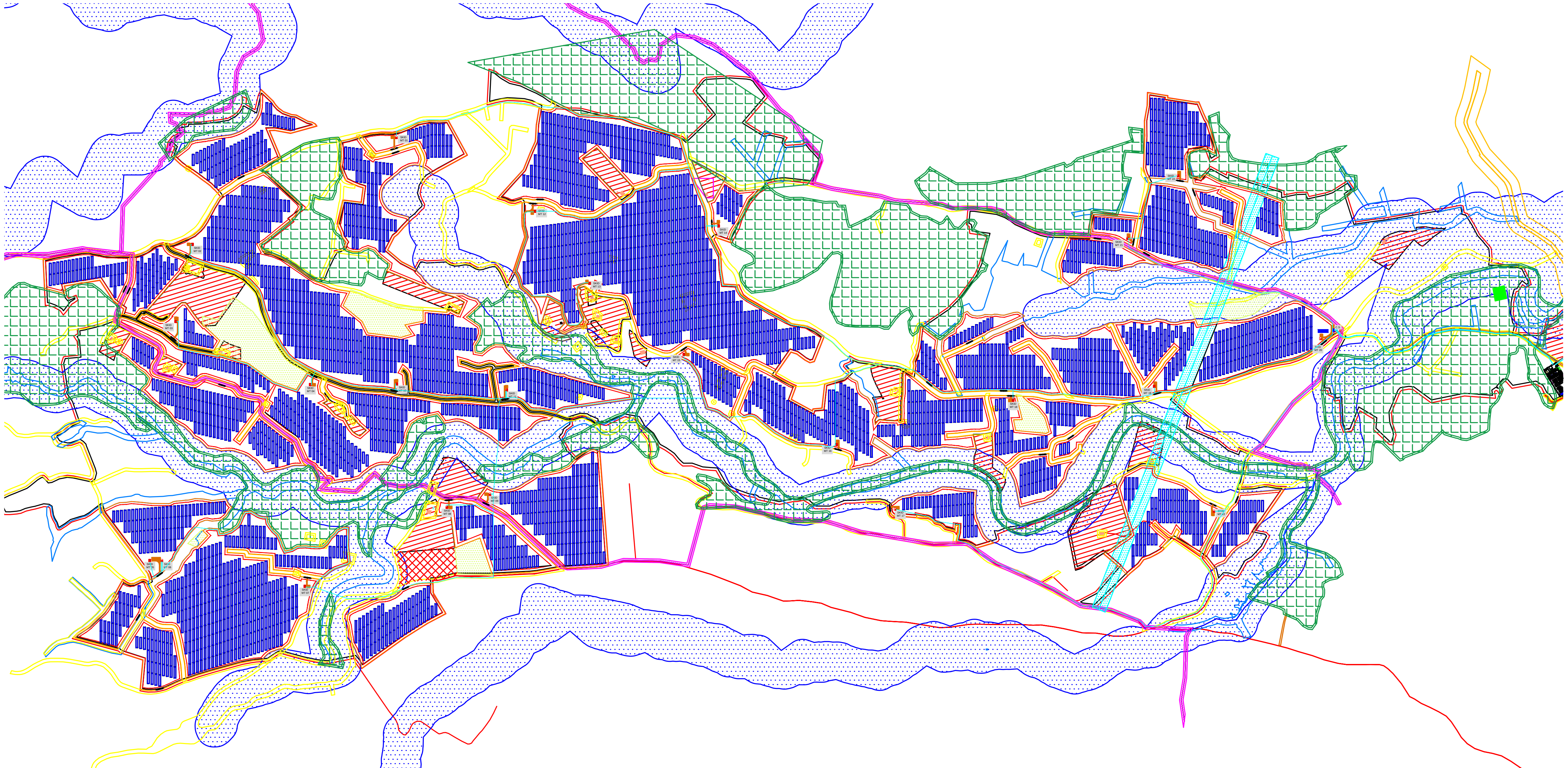
Therefore it is suggested that project developers promote the utilzation of Guirra sheep as it supports cultural heritage, restituting a local animal breed in a landscape where they may have once roamed beneath the olives and algarrobos. It also provides the opportunity for the production and marketing of cheeses, milks, meat and wool that can be designated not only as local, but may contain a special label denoting that it was produced from a solar operation. It could possibly obtain a higher premium in the market, which would encourage farmers to maintain this production system which is beneficial for biodiversity (Metera et al. 2010).

Guirra sheep at pasture. Photo credit: Levante-EMV

Where sheep once sought the shade of the Olives and Algarrobos, they can now find shade in the emerging solar landscape.

PROPOSED SOLAR PLANT LAYOUT (PROVIDED BY PROJECT DEVELOPER)

This thesis explores ways to integrate the developer´s proposal into the landscape, without intensive modification of layout or technologies. This was perhaps the biggest challenge, as modifications significantly increase project cost and efficiency. This means strategies and concepts contained within the following section were rather limited in the scope of their ultimate design.

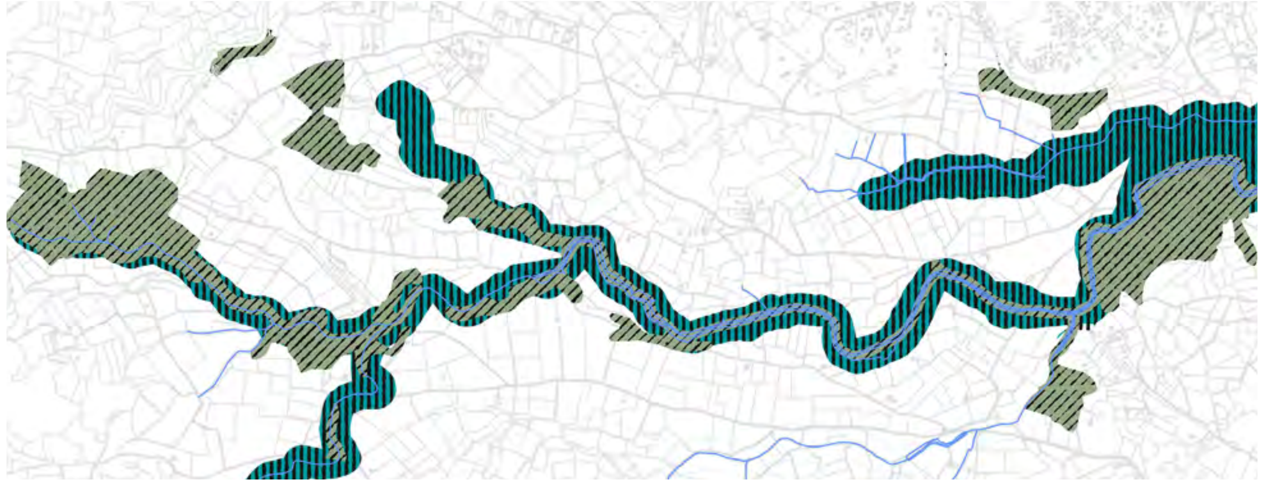


Main characteristics	
PV Module's Peak Power	570 Wp
Nº Modules per string	28 units
Total PV Modules	197,400 units
Peak Power Capacity	112.52 MWp
Grid limitation	100.00 MWac
Nº Tracker 2Vx28	3,525 units
Pitch	11.0 m
GCR	45.64%
Trackers that colision the terrain	557 units

Restrictions	
Existing Roads	
Riverbed	
OHL	
Restricted areas according to RDL-14/2020	
Castral Hydrologhical restrictions	
Protected Route	
Client restrictions	
CV-379 road	

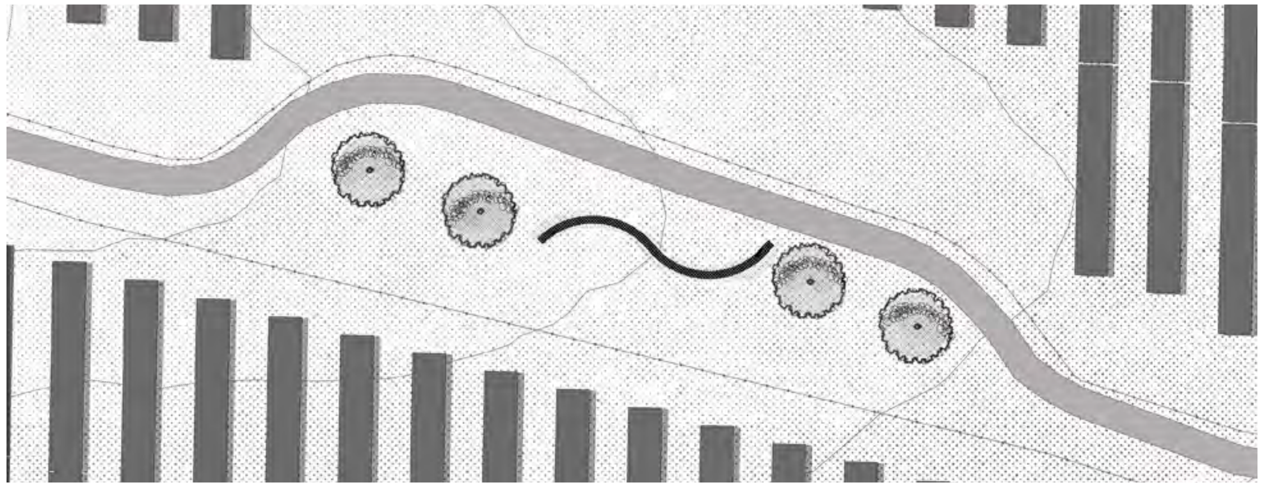
PROPOSED TERRITORIAL INTERVENTIONS

1 SOLAR GRAZING OPPORTUNITIES



2 RIPARIAN OPPORTUNITIES

3 FOREST TRANSITION OPPORTUNITIES



4 SITE INTERVENTION: THE GROVE OVERLOOK

SOLAR GRAZING OPPORTUNITIES

Scale: 1: 15.000

The fenced in areas of the solar development represent opportunities for grazing and vegetation management that support biodiversity.

Solar Grassland or Dehesa

The site offers a unique opportunity to explore "agrivoltaics" within the context of grazing and native grassland flora in the Valencia region. Since the land area associated with the solar modules must be maintained free of vegetation that could shade the panels, it seems appropriate that the vegetation scheme would be more conducive to grassland conditions. In addition to contributing to food and feed production, pastures and meadows create a distinct landscape and serve as a habitat for a diverse range of plant and animal species, resulting in a high level of biodiversity. Grazing animals can help to sustain or restore biodiversity in open landscapes, as well as contribute to grassland's aesthetic and recreational value (Kaligarič and Škornik, 2016).

There are accounts of the Llano Brihuela, where the project is situated, as being the "last dehesa" of Valencia (Asociación Cultural Centro de Estudios Chivanos, 2020). A dehesa is a multifunctional agrosylvopastoral system that is a mixture of woodland and grassland. Paleo (2010) identifies three vegetation layers characteristic of the dehesa ecosystem: A herbaceous layer that is seasonal, very rich in species, and is comprised of plants that are adapted to survive low fertility soils, hot, dry summers and cold winters. The shrub layer, in grazed or tilled dehesa systems, is typically not as prevalent. Shrubs are typically present on steeper slopes and areas where it's difficult for animals to reach. The tree layer in the typical dehesa has a dominant species of oak at densities of 20 to 100 adult trees per hectare (anywhere from 10 to 50 percent crown coverage). Tree density depends on the history of the site and its management history. (Paleo, 2010).

Therefore, it is proposed to maintain grassland conditions in the fenced in areas, with shrubbery limited to the perimeter areas, paired with a restorative pine to Oakland scheme (to be discussed in the next section). This segregates the typical dehesa ecosystem, but when the project site is viewed as a whole, it could possibly achieve the same functions.

Grazing Schemes

The quantity of individual fenced in areas within the project site, lends itself to the implementation of various grazing schemes. This will introduce habitat heterogeneity into the project site, meaning each particular paddock can be managed with a unique set of goals or objectives. Implementing alternative management regimes would help a larger diversity of species if solar sites consist of many fields, as in the current plan. For example, one field may be grazed all year to favor species that need low vegetation height, while others may be grazed on a different timetable, resulting in differences in not just height but also the species that emerge under various conditions (Montag et al. 2016). This idea is supported by Huntsinger et. al. (2007), who studied the variation in response to grazing within grassland flora, concluding that there is no single grazing scheme that will be optimal for all native species, therefore a pasture management plan that varies the timing and intensity of grazing on a landscape scale will probably enhance the abundance of native plants, more so than the application of a uniform grazing scheme or the complete cessation of grazing over an entire area.

Furthermore, as animals move between different fenced in areas, they assist in the spread of plants throughout the system through the process of zoochory, or seed dissemination by animal coat adherence or droppings, which is a crucial function in grazed environments. It influences the dynamics of colonization and the spatial organization of the vegetation, among other things. Many plant species are thought to be dispersed, at least in small quantities, by sheep as they travel through grassland, according to several studies. However, it is recognized that for the conservation and restoration of species-rich grassland communities, a better understanding of these dynamics will be required (Kaligarič and Škornik, 2016).

Determining a final grazing scheme, particularly with the end goal of environmental protection and biodiversity, requires careful planning. The choice of breed, the number of animals in a given pasture, and the amount of time given for pasture before rotation or removal should be suited to local conditions and conservation goals to achieve the desired outcome. There is no universal solution, and many programs are developed using literature and case studies. Metera et al. 2010 stresses that a fundamental prerequisite for a successful program is a "deep understanding of the relationship between herbivores, plant and animal communities and the abiotic environment." The author adds that predicting the ecosystem effects of a particular grazing scheme should include modeling of spatio-temporal distribution of herbivores and plant species, influence-zones, successional stages and their subsequent responses.

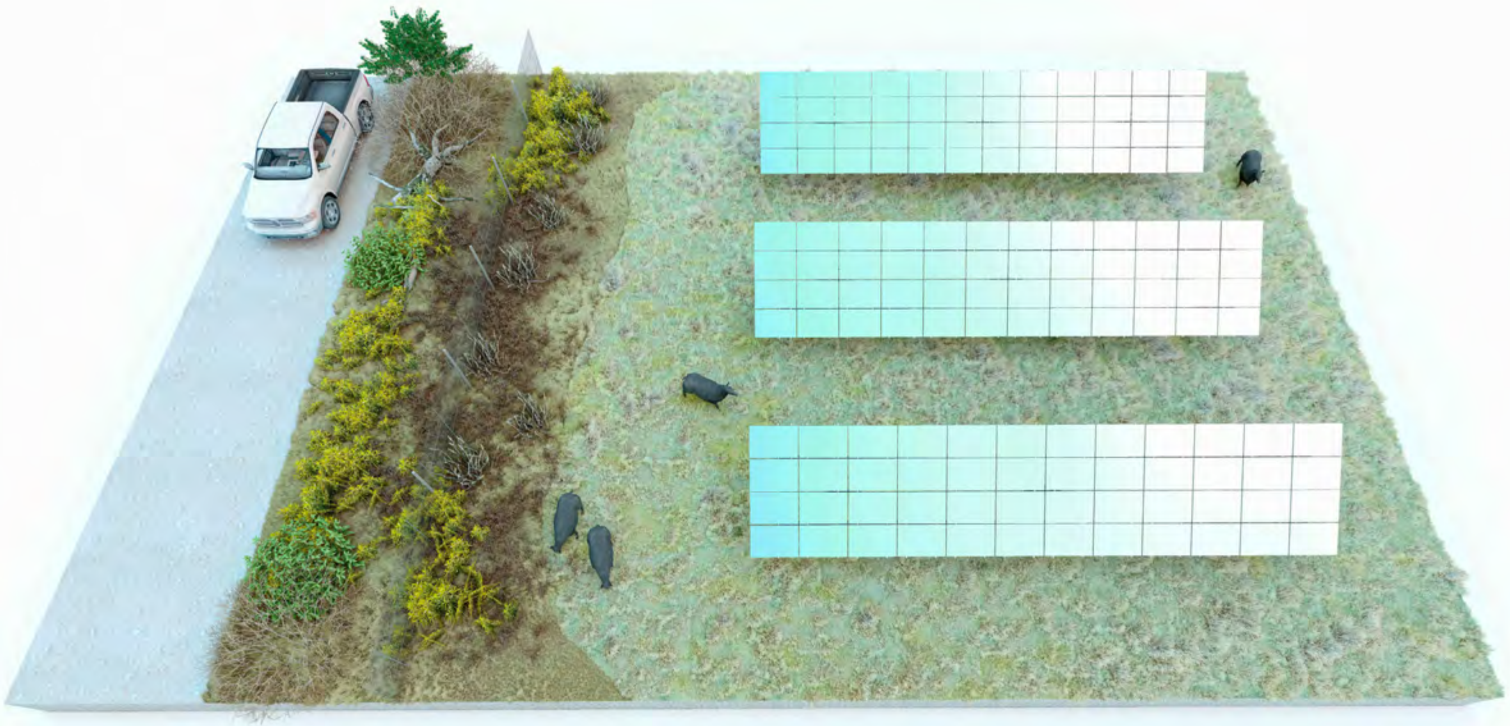
Seed Mixture

The proposed seed mixture was obtained from consultation with "Battle," a spanish company belonging to the agricultural sector specialized in the production and commercialization of seeds. Due to the size of the property, it was important to research commercial seed mix availability to ensure availability at the time of project execution. The seed variety chosen for the given climatic conditions of the study zone was "Masprado Secano" which is for long-duration pastureland. This seed mix is not only suitable for pasturing animals, in terms of energy and digestibility, but it also can improve soil structure through the increase of organic matter, improvement of water cycling, and erosion reduction.

The proposed seed mixture for pasture contains the following species: (1) *Trébol subterráneo ssp. subterraneo (2) Trébol subterráneo ssp. brachycalicinum (3) Trébol resupinatum (resup) (4) Trébol balansa (5)Trébol vesiculoso (6) Medicago scutellata (7) Medicago truncatula (8) Esparceta (9) Zulla (10) Ray grass westerw.* 2n (11) Ray grass inglés 2n

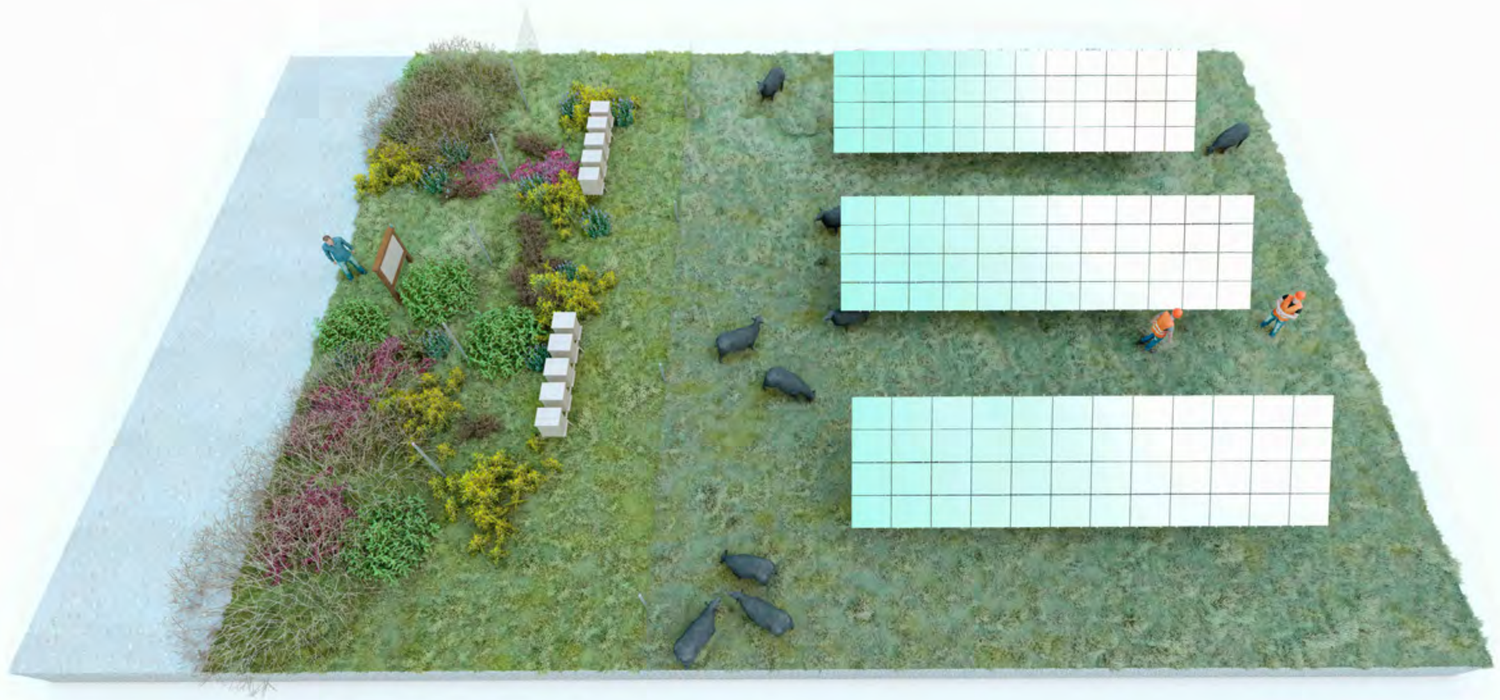
Technical documentation provided states that to establish the seed mixture, it is recommended to sow the seeds in fall, between September and November. Soil testing will provide the fertilization requirements, but the company recommends P2O5 supplemented by K2O. In the first year, when the soil and vegetation permit pasture, sheep should be allowed to pasture for short time periods to remove undesired vegetation that emerges with the seed mix. The first time at pasture should be when the root systems are well established, and the plants reach around 10-12cm in height. When the plants reach maturity and begin to flower, there should be no pasturing, this is to ensure that the plants are able to produce the seed necessary for the upcoming years. This creates a soil seed bank, which ensures the continued persistence of the seed mix. When the vegetation has matured and reaches full maturity, the plot should be heavily pastured to remove standing vegetation, preparing the plot for new growth in subsequent years. In the following years, a similar pattern should be followed, allowing for pasture when plants reach significant size, reducing pasture loads during flowering periods, followed by more intensive pasturing to ensure removal of tall, dry vegetation.

SHRUBBERY PERIMETER



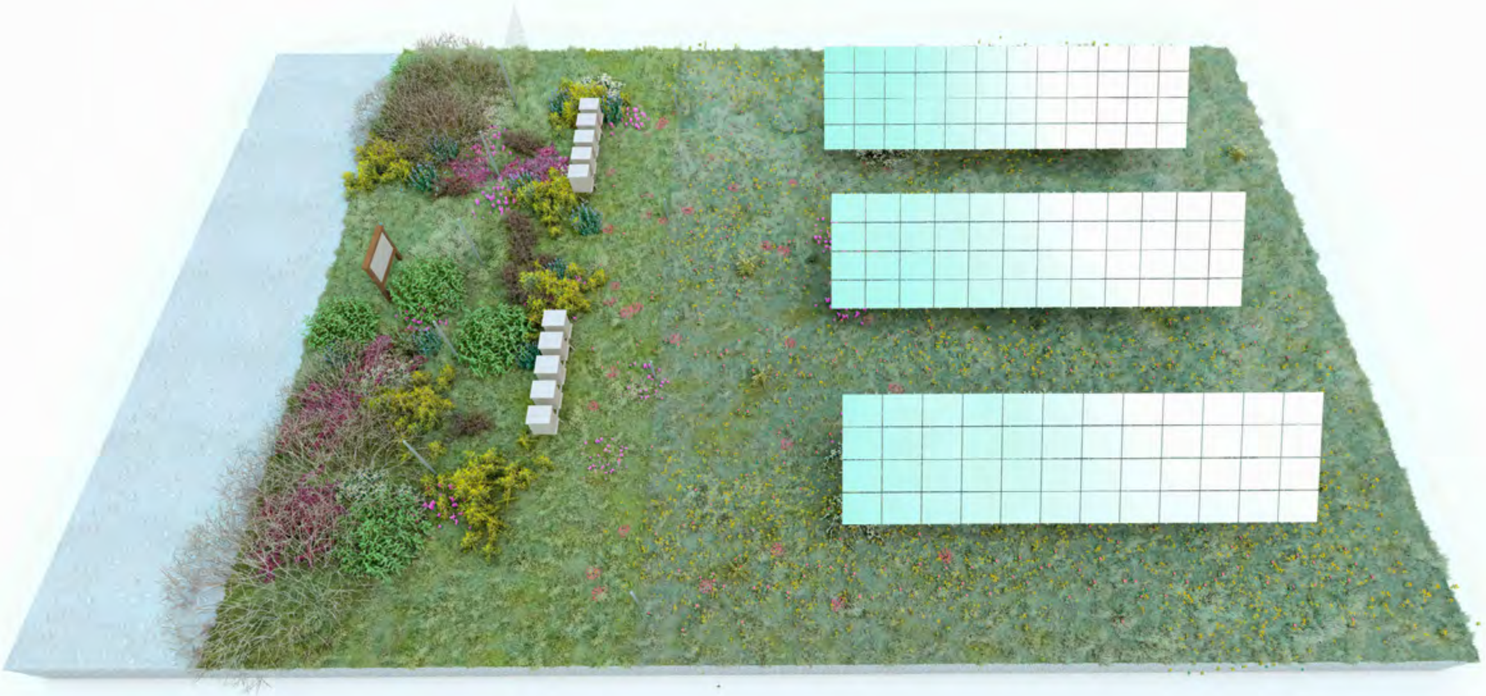
This vegetation management scheme allows for perimeter shrubbery, both internal and external to the fenced compound. This provides visual screening and habitat for small wildlife such as birds and rabbits, common to the study area. Sheep typically feed on shrubs when they have exhausted herbaceous forage, so managers must note when sheep begin feeding on shrubbery to move them to the next enclosure. There is also the possibility to include spiny or heavily scented vegetation, which sheep tend to avoid, such as: *Salvia lavandulifolia*, *Berberis hispanica*, *Prunus ramburii*, *Crataegus granatense*, or *Rosa spp*. One study explored the role of this type of "matorral" vegetation in the regeneration of oak forests, and found positive correlation between shrubs and oak regeneration, meaning that oak sapplings had higher survival rates in matorral, as they were protected from grazing animals and the intense summer heat and drought conditions (Zamora et al. 2001).

POLLINATOR STRIP + APICULTURE



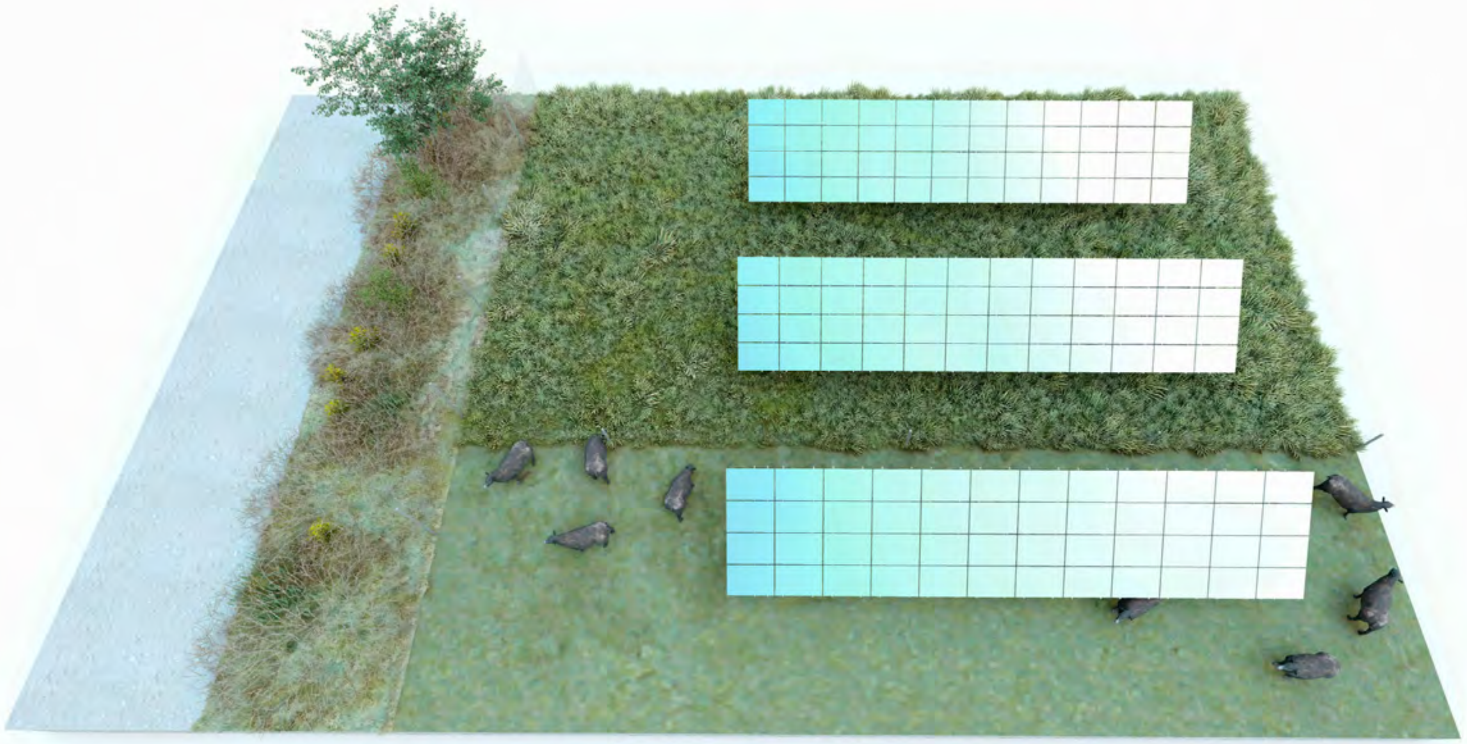
This scheme includes a small perimeter area for apiculture operations. The inclusion of a "pollinator strip" or a band of vegetation that supports pollinator species could create a viable corridor for pollinators to travel through the study area, and support surrounding agricultural operations. Evidence suggests that flowering plants sown in strips or blocks can provide food sources for pollinating insects. In a comprehensive review of 80 individual studies pertaining to pollintor strips, it was concluded that a total of 64 studies show some benefits to one or more wildlife groups. In addition, Sixty-five individual studies reported the effects of flower strips on invertebrates. Of these, fifty reported positive effects, with increased abundance and/or biodiversity. (Dicks et al. 2020). For security purposes the apiculture should be located within the fenced in area, but educational signage from the perimeter would allow visitors using the municipal trails to read about the sustainability efforts at site and view the apiaries. To keep sheep from grazing in this area, additional fencing may be required.

WILDFLOWER MEADOW + APICULTURE



This scheme takes the pollinator strip one step further. The management objective of this paddock is to support wildflower species, which means that sheep do not graze the area during flowering season (hence no sheep are depicted in the following illustration). Careful consideration for the flowering and seed times is necessary to ensure long-term survival of the target plant species. Sheep can be very beneficial to maintaining wildflower meadows, when they are introduced at the appropiate times, they can help to eliminate vegetative competition, as well as fertilize and spread seed. There are examples of mediterranean climate grasslands in California where biologists are using grazing to maintain diversity and promote native wildflowers (Huntsinger et al. 2007).

ROTATIONAL GRAZING



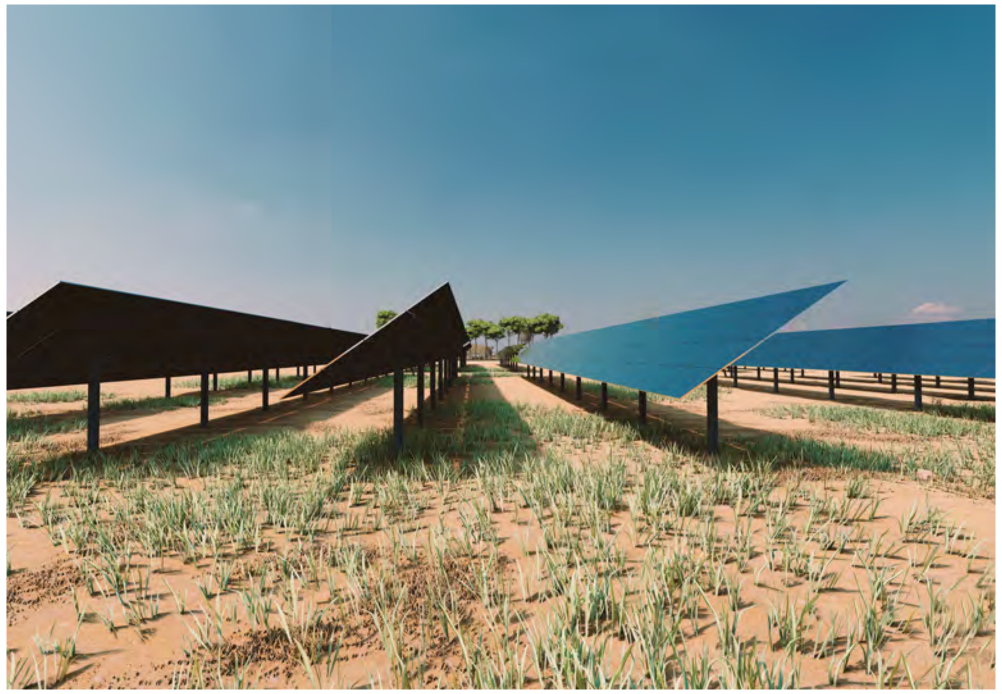
The rotational grazing scheme may be more applicable in the larger fenced in areas. This management scenario divides existing enclosures into smaller fragments, and livestock are moved from one section to another. The areas are divided by mobile fencing, that can easily be assembled and disassembled. This allows more control in the areas that sheep are feeding, which means vegetation managers can adjust sections of pasture as they see most fit, based on their overall objectives.

SOLAR GRAZING OPPORTUNITIES: THE LANDSCAPE TRANSITION

Current

Many of the current sites that will be developed currently have stands of algarrobos or olive trees. Some have been abandoned, while others appear to be actively managed.

1-2 months after construction



After site construction, the site is revegetated, animals will not be able to pasture until adequate coverage is achieved and the plants have strong root systems.

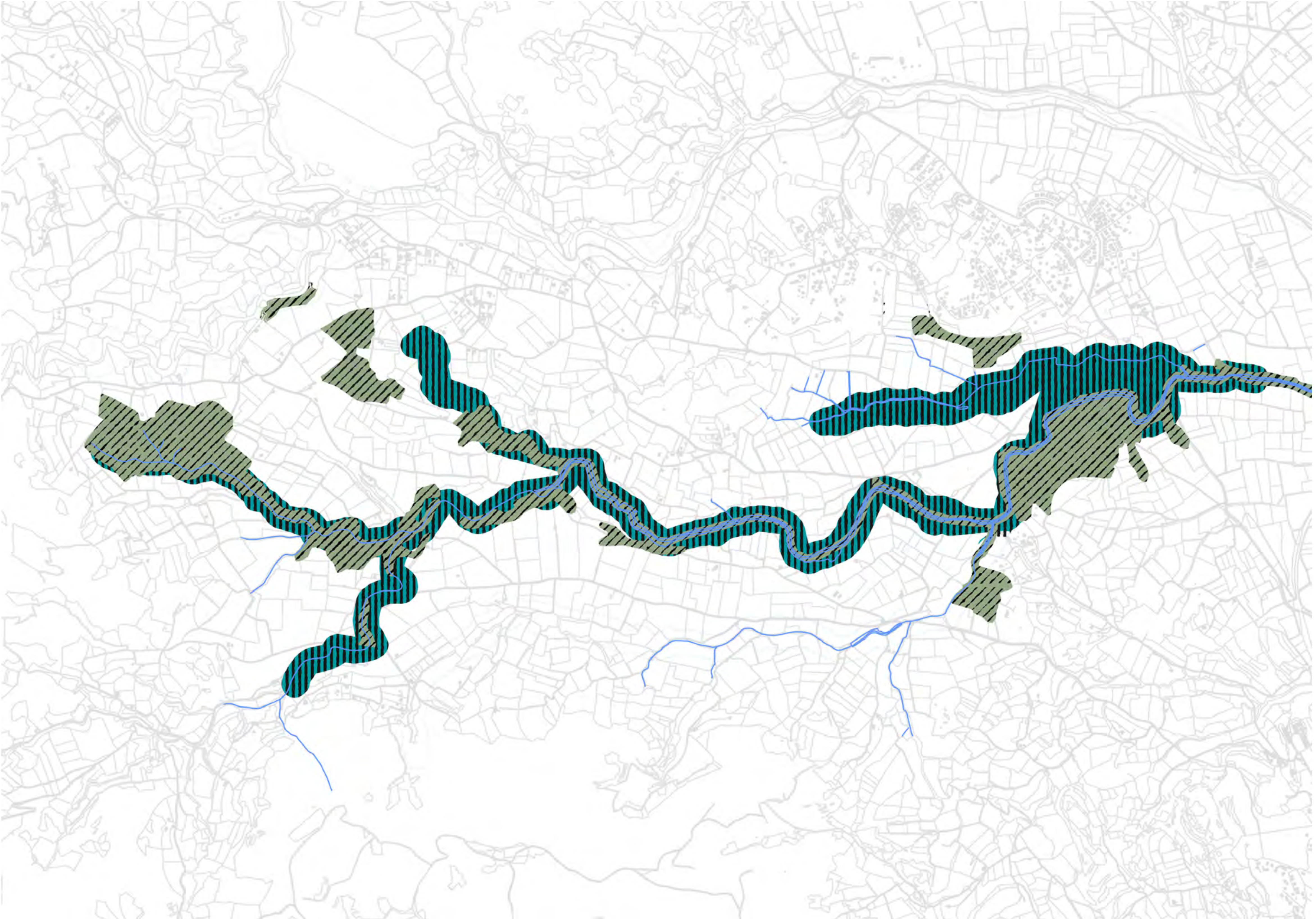
1-2 years after vegetation establishment

This image depicts a future where solar panels, animal husbandry, native grasses and wildflowers all cohabit the same, multifunctional space. It may take several growing seasons, with active pastoral management, for a mature vegetation community to form.

Solar Grazing

This regenerative grazing scheme in which sheep graze within solar enclosures under various management scenarios, provides the animal with the ideal amount of forage while allowing the herbaceous layer to regrow and strengthen its root system, resulting in increased carbon storage and improved soil health. Sheep are used as fertilizers and seed dispersers throughout the system, which means that, under proper management, over the lifespan of the solar operations, a richer mosaic of vegetation and habitat will develop and evolve.

RIPARIAN RESTORATION OPPORTUNITIES



Scale: 1: 15.000

A mature stand of Arundo Donax at the project site. Photo Credit: Author

Riparian Restoration

During site visits to the project zone, the presence of giant reed (Arundo donax) was noted in the riparian zones adjacent to the areas slated for solar development. In many instances, forming monospecific stands of vegetation, blocking the view of the watercourses, and prohibiting passage. The evaluation of environmental impact for the project confirms this observation, stating that, at present, all the riparian zones, in general, are almost exclusively dominated by Arundo donax, and for this reason the riverbanks lack well-stratified natural communities. Due to the proximity of the riparian zones to the project site, it is believed that a comprehensive territorial strategy cannot ignore the current health status of this ecosystem.

Giant reed poses issues for the ecological management of water courses, particularly in the Mediterranean where drought conditions are common. A. donax transpires more water per unit area than native vegetation and increases the risk of fire in invaded areas. Furthermore, it modifies the physical, chemical, and biological characteristics of the ecosystem it colonizes, such as altering the microclimate and providing little habitat suitable to native wildlife. Its removal from the ecosystem is complex due to the aggressive nature of its rhizomes and its quick growth, but its removal is necessary for the restoration of riverine systems throughout the world. Deltoro Torró et al. 2012 explored the effectiveness of removal methods, which can be resumed as chemical, physical, mechanical or introducing competition.

Chemical methods rely on herbicide application. Physical methods rely on the use of opaque coverings to block light from reaching the plant or the total inundation of the giant reed area. Mechanical methods include the removal of the rhizome and repeat cuttings. The introduction of competition is a newer technique being explored, where the stand of giant cane is cut and then covered with live tree limbs which block light and introduce competition as they become established.

Inspired by the concept of grazing and the dehesa ecosystem, and taking advantage of available construction equipment that will be used during the solar plant construction, this riparian restoration strategy proposes mechanical extraction, paired with herbivory and the introduction of living limbs of Salix to control giant cane.

The environmental impact review included a list of species that may be present within the vicinity of the project site. A number of bat species were listed, *Miniopterus schreibersii, Myotis capaccinii, Rhinolophus euryale, Rhinolophus ferrumequinum,* and *Rhinolophus hipposideros*. In a study of summer foraging habitats of bats in a Mediterranean region of the Iberian Peninsula, Rainho (2009) concluded that the most suitable habitats for the bat communities were fresh-water habitats with riparian vegetation and/or within autochthonous broadleaf forest, for example rivers, streams, or small weirs within oak woodlands or shrublands. This study supports the restoration of the riparian habitat, utilizing in part the live willow branches, a broadleaf tree, and also fits within the broader strategies of dehesa-style landscape restoration, combining grasslands and oak forest restoration to support local bat species.

RIPARIAN RESTORATION STRATEGY OVERVIEW

1. Current State

2. Mechanical methods

3. Animal Grazing

4. Live Branches covering

5. Vegetation Establishment

6. Self-Maintaining Ecoystem

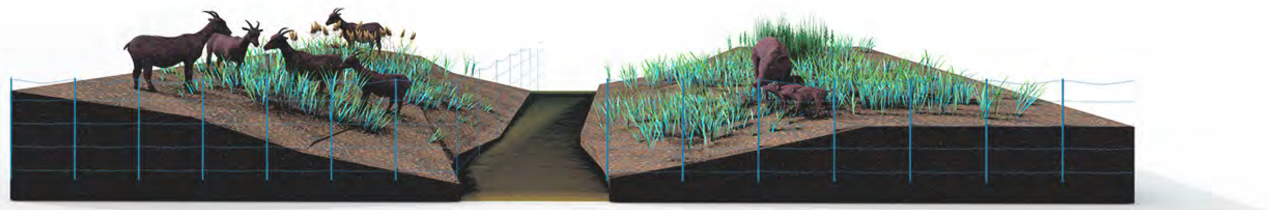
RIPARIAN RESTORATION STRATEGY DETAILS

1. Current State

2. Mechanical methods

In order to fully understand the scope of this undertaking, a more detailed assessment of the presence and stage of establishment of Arundo donax in the project zone should be performed. Prior to the riparian restoration project, it would be important to understand details such as the, percent vegetative coverage of the species, the depths of their rhizomes, soil structure, slope of terrain, access points for heavy equipment, and environmental regulations pertaining to the alteration of terrain and/or the removal of vegetation in watercourses.

The live branch coverage method requires that vegetation be cut twice prior to the application of the live branches. The objective of this is to deblitate the plant. The first vegetation clearing (desbroce) should take place at the end of august, with the second occuring at the end of september. Taking advantage of the variety of construction equipment that will be available in the zone, this could save on equipment cost. It is understood that slight modifications to the terrain might also be warranted, to achieve a more gradual slope, to smooth soil, or to access difficult areas.

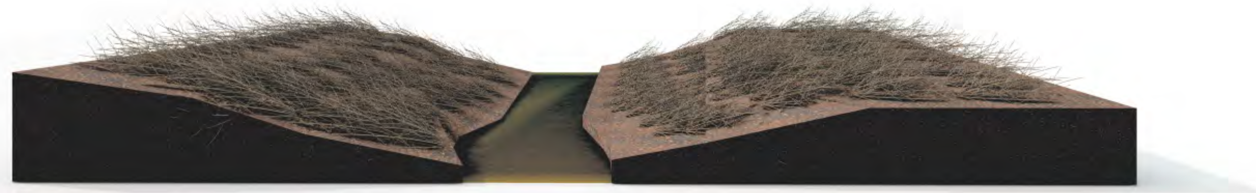


3. Animal Grazing

The use of animal herbivory to control vegetation was thought of for two principal reasons. The project site is quite large and perhaps the whole site cannot be planted with live willow in the first year. This means, unless other methods are applied, that the vegetation management of Arundo donax will need to continue with successive clearings. To reduce cost, herbivory could be a possible solution. The two herbivores selected for this experimental idea are goats and wild boar.

The book “Weed Control in Natural Areas in the Western United States” mentions the use of Angora and Spanish goats as the most successful grazers of giant reed stating that “goats can have several advantages over mechanical and chemical control methods; they are less costly and can negotiate slopes too steep to manage with machines. Angoras are prefferred over Spanish goats because of their smaller size and ease of transport.” Offering a word of caution, they added that “since goats will trample or browse virtually any vegetation within a fenced area, any desireable trees or shrubs must be protected.”

Sus scrofa, or wild boar, referred to as jabalí in Spanish, is often considered a nuisance for its destructive behavior. Its rooting activity offers a possible solution for uprooting giant reed rhizomes, which is needed to kill the plant. Sandom et al. (2013) found that wild boar invested up to four more hours daily to rooting during the autumn and winter than the spring or summer, mainly due to food availability. This timeframe could pair well with a broader management strategy, with vegetation clearing in August/ September, and then boar rooting in the late-fall to winter to truly weaken the plant and prepare the soil for live branch coverage.



4. Live Branches

The planting of the live willow branches should occur during the winter months and preferrably on softly sloped banks. The branches are layed down and fixed with galvanized wire stretched between iron pegs or wooden stakes. After placement, they should be covered with a thin layer of soil to stimulate rooting. Branches should be around 3-4 cm in diameter and have a minimum length of 120 cm, which allows them to be more easily introduced in the substrate, ensuring better survival rates. In the first year, light irrigation might be necessary, depending on the climatic conditions. According to Deltoro Torró et al. 2012 the live branch method is optimal when the goal is to remove Arundo donax with simultaneous habitat regeneration.

5. Vegetation Establishment

This illustrates initial vegetation establishment. The area should be monitored continuously to ensure that appropriate species are colonizing the space. Should there be remergence of giant reed or other undersired vegetation, prompt action can prevent it from becoming established across a wider area.

6. Self-Maintaining Ecoystem

With proper management and time, a functional riparian ecosystem should emerge. This system will have various levels of vegetation, which can support a variety of organisms.

The Return of the Bats

As a result of these efforts, years later, a greater diversity of bats can be observed hunting in the riparian ecoystems of the project area.

FOREST TRANSITION OPPORTUNITIES

Scale: 1: 15.000

The project developer has identified several "green areas" outside of the solar enclosures that could be available for remediation purposes. It is hypothesized that they may be suitable for reforestation opportunities. Several areas, such as the one depicted on the next page, are dense pine stands.

Present Site Conditions

The environmental impact review states that natural woody vegetation in the project has a mosaic formation, typically forming along the margins of agricultural plots, on rocky outcrops, steep slopes and in ravines. There are no noticeable manifestations of the original forest community, which is the mediterranean oak forest. As a result of reforestation efforts to fight local erosive proccesses, dense stands of Pinus halepensis exist throughout the project site, as pictured in the background of the photo above.

Pine to Oak Transition

One of the biggest challenges for the restoration of Mediterranean broadleaf forest is the transformation of existing, monospecific pine plantation to a more diverse, resistant and resilient forest ecosystem. In many parts of Spain, due to massive reforestation efforts, there are large stands of dense, under thinned, and structurally simple pine trees. Due to their density, they have almost no understory, which means the forest floor contributes little food source to wildlife. The stands are prone to fire, disease and drought dieback.

When thinned, which is the process of decreasing tree density, new species can colonize the space. This provides opportunity for the establishment of oaks and understory vegetation, such as *Juniperus spp., Arbutus unedo, Crataegus monogyna, Rosa spp., Rhamnus spp., Pistacia lentiscus*, all of which are dispersed by animals. Villar-Salvador (2016) posits that old pine stands can be an opportunity to create mixed forests or restore previous forest systems when properly managed. The author argues that the most cost-effective management strategy is thinning pine plantation near remnants of woodland, because it is assumed that the soil will have a bank of seeds that will germinate under the new light and environmental conditions of a cleared pine stand. However, Villar-Salvador recognizes that all too often it is unlikely that an existing pine stand is near a woodland remnant and that more research is needed to know how large, how many, and how far these patches of woodland must be from the pine stand for this to be an effective method of woodland restoration.

In the absence of woodland remnants, and in cases of limited funding, the author recommends clearing sections of the pine forest and planting small islands of understory vegetation (mentioned above), the idea is that once these islands of vegetation begin producing seeds, frugivorous species will then begin to distribute the seeds throughout the pine stand, aiding in the regeneration of the understory. The production of seeds has to be accompanied by additional pine thinning to ensure an adequate environment for understory seed germination, where a main determinant is light on the forest floor.

The time it takes for species of oak to reach seed production could prohibit regeneration by this method, as Quercus ilex takes 20-30 years to produce seeds under standard Mediterranean conditions. Studies have showed that summer irrigation for three years after planting could reduce time to seed production to 9 years (which would be within the lifespan of the photovoltaic operations). The diagrams in this section highlight the transition from pine to oak forest, demonstrating how the forest structure will change under thinning conditions. No time frame has been assigned.

Present Day: The dense pine forest allows little light to hit the forest floor, creating sub-optimal conditions for the growth of understory vegetation.

After Clearing: Species begin to colonize the forest floor. Dead standing and fallen trunks provide habitat and add nutrients to the soil. The colonization process should be monitored to ensure native vegetation communities have advantage.

Years Later: Oak species dominate the space. Consultation with an agronomist revealed that oak species such as *Quercus ilex rotundifolia* will reach four to five meters in height after 25 years under standard mediterranean climatic conditions. The slow growing nature of this tree means it could also be suitable in perimeter plantings near photovoltaic operations, as the risk of shading in early years is minimal.

Birds in the Landscape

The concept of forest regeneration led the research by design proposal towards briefly exploring how birds would be impacted by, supported by, or could become a part of this broad landscape transformation.

Building off the vegetation islands theory posed by Villar-Salvador, several case studies highlight the role of Eurasian jays (Garrulus glandarius) as a seed dispersal agent for oak species. Pesendorfer et al. (2016) hypothesizes that this mutualism is expected to become even more important for conservation of oak ecosystems and should be considered an efficient conservation tool. The species is a scatter-hoarder, which means they select seeds at the source plant, transport them in their bill, and deposit them in small patches. When the seeds are not recovered by the hoarder, and the environmental conditions are right, they can germinate.

Since there appears to be no residual oak stands in the immediate project vicinity, and due to the amount of time it takes a planted oak to reach sexual maturity, it is hypothesized that if oak acorns are strategically placed in pine stands, they could be distributed throughout the landscape. Pesendorfer et al. (2016) reviewed existing literature and it was found that the Eurasian jay in southeastern Spain is capable of dispersing oak seed up to 1.000 meters This would require someone to actively monitor seed sites, assess whether the birds are taking the seed, and replenish stock when necessary. Small hanging feeders are proposed, with a mesh lining, which allows air passage, keeping the seeds from rotting. This is hypothetical in nature, but could serve as a pilot study.

An older study from Germany found that oaks regenerated in pine forests at a density of 2-4 thousand trees per hectare. Due to low numbers of seed producing oak trees, they attributed the regeneration to the Eurasian jay, which had moved into the pine forest (Mosandl & Kleinert, 1998). Since pine forest is suitable habitat for the jay, it is expected that the thinned pine stands could likely receive or be the artificial source (through feeders) of oak seeds.

La Mantia et al. (2019) found that the ability of perching structures, like trees and shrubs, can support seed dispersal in the landscape. The authors explored the use of artificial structures, such as branch piles and human made perches as useful tools to induce seed dispersion. Their literature review revealed that artificial structures did enhance seed rain richness and density (depositing of seeds via feces). Their study, performed on seven Mediterranean island old fields, showed that even small perches had a positive contribution towards aiding in seed dispersal. When woody vegetation is removed from site during project construction, it is recommended that limbs be placed throughout the landscape to create perching opportunities. The idea is to place limbs and other structural elements where shrub vegetation should be encouraged. It is hypothesized that the same opportunities exist with bird houses and along the fence line of the development.


Artificial seeding of thinned pine forest utilizing feeders containing acorns.


Eurasian Jay visits bird feeders located in thinned pine stands, redistributing acorns in the landscape.

Birds as Site Engineers

Felled trees are left on site of a recently thinned pine forest to provide perching structures for birds, while artificial bird houses encourage habitation of the new clearing.

Birds deposit seeds as they travel between the perches and bird houses creating islands of new vegetation that emerge in the thinned forest area. Over time, these plants mature, produce seeds, and aid in the further proliferation of diverse vegetation.

These graphics combine the island theory approache presented by Villar-Salvador (2016) with the artificial perches approach presented by La Mantia et al. (2019) to aid in the restoration of a thinned pine forest. As birds rest on the perches (fallen log, shrubbery, and bird boxes) their droppings deposit seeds on the ground, eventually leading to germination. It is envisioned that this same strategy can be employed along the perimeter of the fencing of the solar sites, allowing for a continuous vegetative hedge to form.

Supporting Barn Owls

Barn owl boxes can be be placed in open countryside in isolated trees or trees that overlook open habitat, the thinning of the pine stands and the development of the solar grazing areas produces suitable habitat for the barn owl. This particular box was designed using barnowltrust.org instructional materials.

Supporting Raptors

Although little scientific evidence exists as for the impacts of solar panels on raptor species, their notable presence in the study area might be considered in a landscape proposal. It is hypothesized that the elimination of trees due to the solar farm development and/or the thinning of the pine plantations may reduce perch opportunities in the vicinity. Therefore low-cost perches are proposed to be distributed within project perimeters. However, careful consideration should be taken for their placement, particularly if the site is being managed for a particular species. For example, if an area is being managed for a specific bird species, and raptors are a likely predator, this could create a barrier effect inhibiting the proliferation of the species which is under a wildlife management scheme. The raptor perch was designed following the United States Department of Agriculture "Artificial Perches for Raptors" guidelines, produced in 1996. Since the project site will likely open up the viewshed of the area, it is hypothesized that supporting raptor species in the overall project design could aid in bird watching tourism. Creating viewpoints and overlooks for the observation of raptor species could be a considerable nature-based tourism opportunity.

Raptor Perch.
Ready-Mix Concrete Base
4.5 meter galvanized steel piping
Wooden block perch

A LANDSCAPE WOVEN TOGETHER

Scale: 1: 15.000

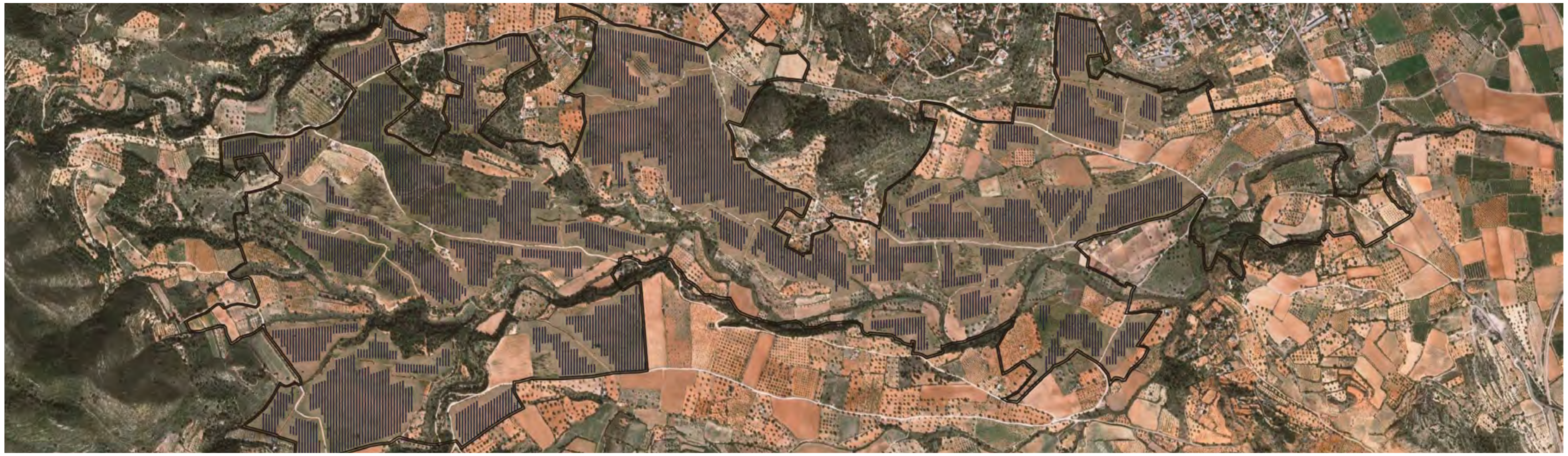
These three strategies: grazing, riparian restoration, and forest opportunities, create sopportunity for broadscale territorial rehabilitation, all driven by a the emergence of a solar landscape.

A LANDSCAPE WOVEN TOGETHER

These three images explore landscape change after the proposed strategic interventions.

A. Current satelite imagery of the project site, with clear parcelization, presence of cultivated and abandoned secano plots.

B. The structure of the fenced in areas and the establishment of grassland like conditions transforms the traditional geometries produced from the olive and algarrobo groves into a a more continuous landscape pattern.



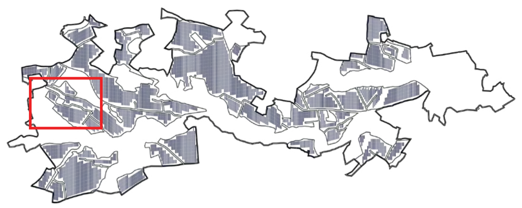
C. Anticipated aerial image of the project site with full build out of the solar modules.

Scale: 1: 15.000

SITE INTERVENTION: LOCATION

39.491372° , -0.779490°

The current layout of the solar modules, roadways and fencing was provided by the project developer and overlayed onto existig satelite imagery.



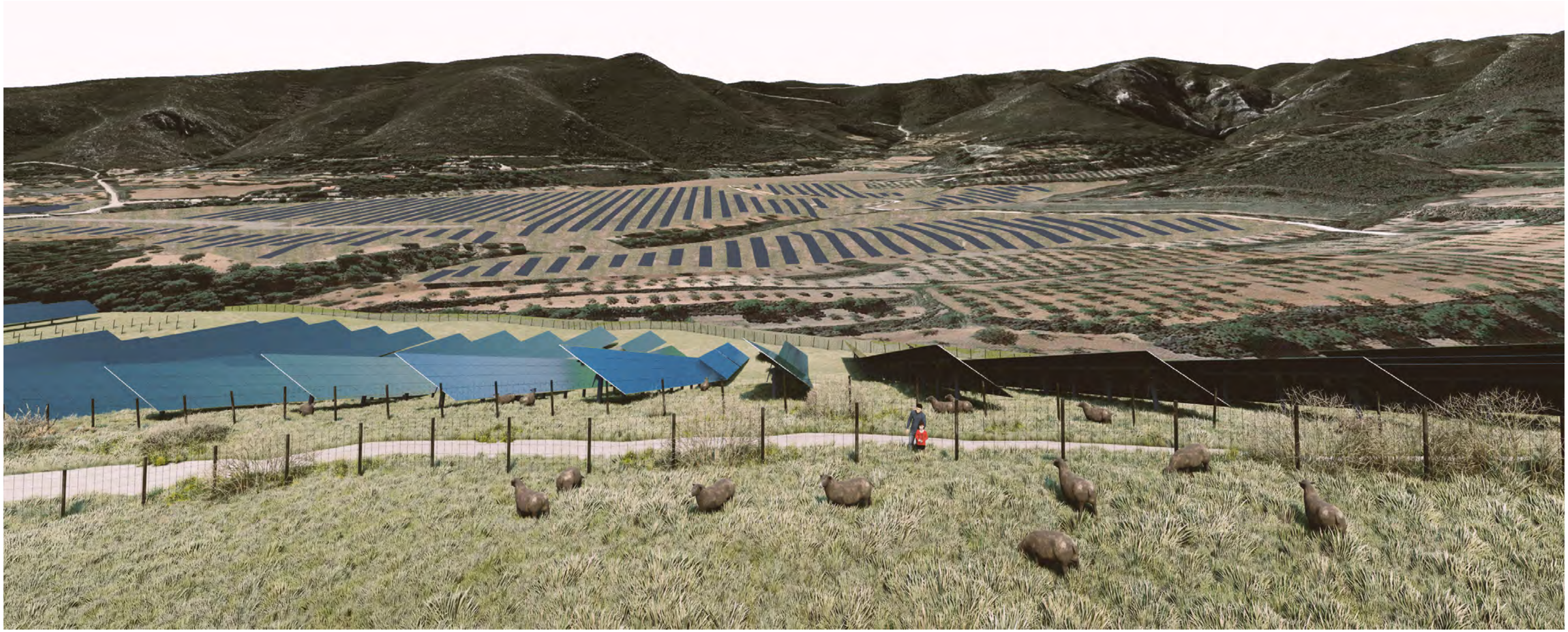
SITE INTERVENTION: VIEW 1

While on site visits, this open clearing was particularly notable for its views of the surrounding landscape. This location has been chosen to explore the visual impact of the implementation of strategies previously discussed. The solar development is anticipated to enclose the existing road on both sides.

Two individuals can be seen observing the sheep grazing within the solar compounds. Due to the topography of the terrain, the view of the surrounding mountains remains unspoiled. The fencing, measuring two meters in height does not hide the solar operations, allowing for the curious onlooker to view this emerging landscape element.

SITE INTERVENTION: VIEW 2 VISUALIZATION

Existing View. Photocredit: Author

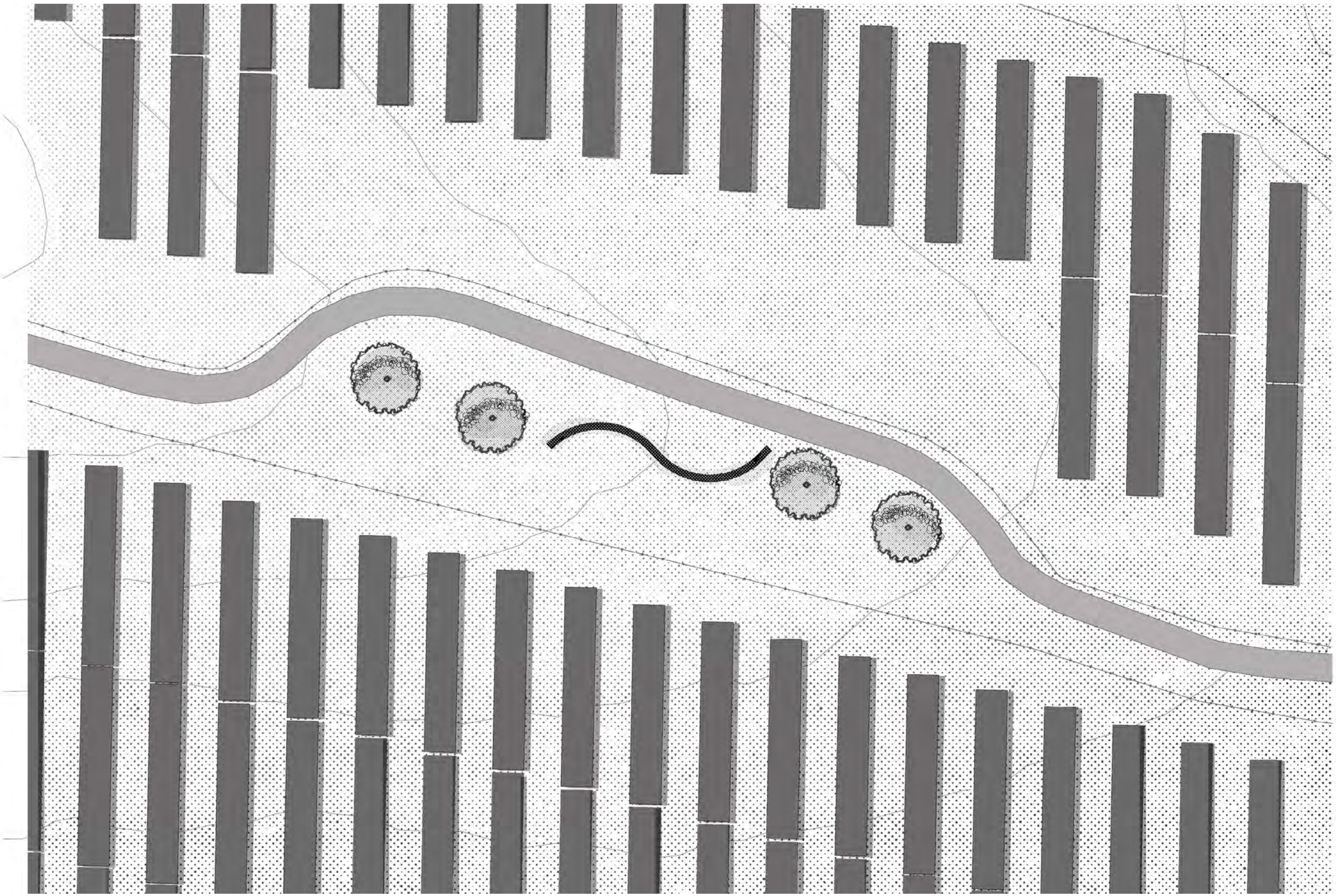


A combination of AutoCAD, Civil3d, Sketchup, Google Earth Pro, and Photoshop were used to determine the approximate location of the proposed solar arrays. The terrain in the foreground was modeled and rendered, then later combined with imagery from Google Earth Pro to produce the background image that depicts the extent of panel placement in the landscape. The installation of the solar modules actually opens up the viewshed of the surrounding mountain range.

SITE INTERVENTION: WALKING UP THE HILL TOWARDS THE OVERLOOK

This rendering represents the view a user will see as they move up the hillside, towards the proposed overlook. One will notice that gradually shrub vegetation begins to fill in the perimeter of the fenced in area along the roadside. This is anticipated to continue as birds and other animal engineers spread seed from fruiting plants throughout the project zone.

SITE INTERVENTION: SITE PLAN LAYOUT OF PROPOSED OVERLOOK



Scale 1:500

The layout of the fenced in area has been altered slightly to accomodate for an overlook area. The original distance from the modules to the fence was 32 meters, that has been greatly reduced to allow for the overlook point. This provides an opportunity for the developer to provide a low cost recreational ammenity, allowing people to connect the project with the surrounding landscape. Four olive trees are planted, symbolic of the agricultural operations of the zone along with stacked rock formations which are characteristic of the study area.

SITE INTERVENTION: THE VIEWSHED OF THE OVERLOOK

The overlook area provides a view of the mountain range in the background, offering users a place to rest and contemplate the solar landscape and its surroundings.
One will notice that users are reading the educational signage provided by the project developers.

Stacked rock at the edge of farm fields

Stacked rock surrounding the base of an Algarrobo tree.

These photos taken during the site visit serve as design inspiration for the overlook elements. Simple and rustic, the elements tie the intervention to the history of the agrarian landscape.

SITE INTERVENTION: THE OVERLOOK

The gabion structure pays hommage to the stacked rock that can be found on the agricultural field edges. The olive trees are protected by Valonas (in half-moon formation), which are dry stone constructions that surround the trunk of some trees, especially olive trees but also almond and carob trees, to protect them from the wind. This use of vernacular elements in the overlook area creates a juxtaposition of past and present, allowing people to view the new landscape around them while being deeply rooted in the socio-cultural context of the past. Educational signage to educate the public of this history is encouraged.

CONCLUSION

This exploratory research project briefly examined the landscape integration of solar farms, their general impact upon the territory and wildlife, and their ability to be a driving change for landscape rehabilitation. Overall, the strategies and design interventions sought to enhance the attractiveness of a rural territory, while promoting sustainable agricultural practices, regenerating depleted land, and supporting the transition to a decarbonized economy. This energy transition, and subsequently the landscape transition that occurs with it, offers a unique opportunity for landscape designers and architects to contribute their knowledge and understanding of the territory and its various environmental, economic, and social dimensions in order to maximize landscape and environmental outcomes. Returning to the book, "Landscape and Energy: Designing Transition," the author perhaps offers the best conclusion: "We want to let the energy sector see the spatial dimension of their work field. And we want to show spatial designers that the energy transition is a genuine design challenge. For citizens, businesses, and officials, we want to present the transition in energy and space as a social issue that is important and unavoidable, difficult yet promising." (Sijmons et al. 2014, p. 11-12).

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