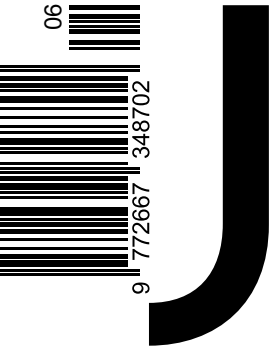


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# DU

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*SUPERVALLEY:  
Reimagining  
Regenerative  
Landscapes and  
Circular Practices in a  
Transition Project*

*Filippo LaFleur*

This article explores the transformative potential of depleted agrarian spaces as catalysts for ecological transitions within post-metropolitan regions. Drawing on doctoral research in the Po River Valley mega-region of Northern Italy, the investigation examines how agricultural territories experiencing soil depletion can be reconceptualized through agro-ecological planning and design frameworks. The research positions soil regeneration as a foundational strategy within an ecology of repair, establishing degraded agrarian spaces as critical sites for intervention in future urban-rural systems. Through a multiscalar research-by-design methodology grounded in 25-hectare landscape units, the paper presents the "Super Valley" project: a spatial investigation for transforming depleted agricultural land into multifunctional regenerative landscapes that simultaneously restore ecosystem functions, maintain cultivation productivity, and generate diverse bio-based circular economies. The project explores how exhausted landscapes might become foundations for new ecologies-economies by regenerating carbon, water, and nutrient cycles. The innovation lies in integrating spatial design with urban-rural metabolic analysis to reimagine circular resource flows for regenerative territorial processes. The findings suggest pathways through which an ecology of repair applied to degraded agrarian spaces could transform sites of extraction into foundations for territorial regeneration, while acknowledging significant implementation challenges related to governance, economics, and social acceptance.

## INTRODUCTION

### FROM DEPLETION TO REGENERATION IN OPERATIONAL LANDSCAPES

Contemporary territories worldwide face unprecedented pressures from converging urbanization processes and environmental degradation. The Po River Valley mega-region in Northern Italy exemplifies this critical condition, where intensive agricultural practices across 4.95 million hectares have transformed once-fertile alluvial soils into depleted landscapes characterized by diminished water retention, compromised carbon sequestration, and disrupted nutrient cycles. This transformation embodies what Brenner and Katsikis<sup>1</sup> term "operational landscapes"—geographies of primary production that sustain urbanization processes while incurring environmental costs associated with resource extraction.

#### 1.1 Situating the Research: Po Valley Territorial Studies

The Po Valley represents one of Europe's most extensively studied urbanized regions, with a rich scholarly tradition examining its territorial transformations. Italian urbanists have documented the region's evolution from agricultural hinterland to what Turri<sup>2</sup> termed the "Padana megalopolis"—a vast, polycentric urban system unlike traditional European city models. Branzi's<sup>3</sup> concept of agronica captured the hybrid rural-urban condition emerging across the plain, while Secchi's<sup>4</sup> analysis of the *città diffusa* (diffused city) revealed how urbanization dissolves traditional urban-rural boundaries, creating complex territorial mosaics. More recently, Viganò et al.<sup>5</sup> conceptualized the "horizontal metropolis," describing how low-density urbanization generates new spatial logics requiring novel planning approaches.

This research acknowledges and builds upon this extensive body of work while deliberately adopting a different perspective. Where most territorial studies prioritize analysis of the built environment and urban expansion patterns, this investigation centers on the unbuilt—the agricultural matrix that constitutes over 80% of the Po Plain. Rather than viewing agrarian spaces as residual territories or simple production zones, the research positions them as active platforms for ecological transition and territorial regeneration. This shift in focus—from urbanization processes to agricultural landscape transformation—represents the primary contribution to existing scholarship on the Po Valley.

#### 1.2 Research Gaps and Novelty

The academic discourse on degraded landscapes has traditionally focused on conservation and protection strategies, often treating depletion as an irreversible condition that requires mitigation rather than active regeneration<sup>6</sup>. However, emerging scholarship in landscape urbanism and ecological design suggests that depleted territories possess latent regenerative potential when approached through systematic design interventions<sup>7, 8</sup>. This perspective aligns with delta urbanism's emphasis on dynamic landscapes and the land-water-atmosphere continuum, recognizing degraded agricultural territories as active agents in territorial transformation rather than passive recipients of environmental damage<sup>9</sup>.

Recent policy frameworks, particularly the European Union's Soil Strategy for 2030<sup>10</sup> and the Nature Restoration Law<sup>11</sup>, acknowledge soil degradation as a critical challenge that requires coordinated intervention

- 1 Katsikis, 2020
- 2 Turri, 2000
- 3 Branzi, 1982
- 4 Secchi, 2005
- 5 Viganò et al., 2018
- 6 Ahern, 2013
- 7 Belanger, 2016
- 8 Waldheim, 2016
- 9 Meyer et al., 2010
- 10 European Commission, 2021
- 11 European Parliament and the Council of the European Union, 2024

across large-scale territories. The EU Soil Observatory<sup>12</sup> reports that soil degradation costs European economies tens of billions of euros annually, with the Po Valley experiencing particularly severe impacts from prolonged droughts and extreme weather events<sup>10</sup>. In Italy alone, the 2022 summer drought cost the agricultural sector an estimated €6 billion<sup>13</sup>, while the 2023 Emilia-Romagna floods caused over €8 billion in damages<sup>14</sup>. These events underscore the urgent need for landscape-scale interventions, addressing both environmental restoration and climate resilience.

Despite growing recognition of the impacts of soil degradation, significant gaps persist in academic literature regarding systematic approaches to agrarian space transformation at territorial scales. While studies on nature-based solutions<sup>15</sup> and ecological restoration<sup>16</sup> provide valuable frameworks, they typically address discrete interventions rather than integrated territorial-scale transformation strategies. Research on urban-rural linkages<sup>17</sup> and peri-urban agriculture<sup>18</sup> examines functional relationships. However, it rarely addresses the spatial design of regenerative systems or their integration with regional metabolic flows.

This research addresses these gaps by developing and testing an agro-ecological planning and design framework specifically for operational landscapes. The investigation makes three primary contributions:

1. Methodological: Integrating spatial grammar development, multi-scalar research-by-design, and quantitative performance assessment within an agro-ecological planning framework
2. Empirical: Providing spatially explicit demonstrations grounded in 25-hectare landscape units analyzed through collaboration with agricultural innovation partners (Simbiosis.Tech, Neorurale Hub), offering quantified performance parameters for regenerative interventions
3. Conceptual: Positioning degraded agrarian spaces not as residual territories requiring protection, but as active platforms for multiple transitions—ecological, economic, social—through systematic spatial reconfiguration and metabolic redesign

The Super Valley project serves as a research vehicle for exploring these contributions, offering spatially explicit scenarios while acknowledging significant social, economic, and governance challenges inherent in implementing such transformations.

## *THEORETICAL FRAMEWORK*

### *OPERATIONAL LANDSCAPES AND ECOLOGIES OF REPAIR*

#### *2.1 Operational Landscapes in Post-Metropolitan Regions*

The theoretical foundation builds upon Brenner and Katsikis's<sup>1</sup> concept of operational landscapes—territories of primary production that support urbanization processes through resource extraction and cultivation. These landscapes constitute crucial components of contemporary urban metabolism, yet they remain systematically undervalued in traditional planning discourse. The Po Valley exemplifies this condition, where intensive agricultural production supports the broader Padano-Alpine-Adriatic mega-region (approximately 25 million inhabitants) while experiencing severe environmental degradation.

- 12 Scarpa et al., 2022
- 13 ANBI & CNEL, 2025
- 14 Regione Emilia-Romagna, 2025
- 15 Cohen-Shacham et al., 2016
- 16 Griscom et al., 2017
- 17 Piorr et al., 2011
- 18 Seto et al., 2012

Post-metropolitan regions, characterized by polycentric urban agglomerations and declining urban densities<sup>19</sup>, represent paradigmatic sites for reimagining territorial futures. The dissolution of traditional urban-rural boundaries generates complex territorial mosaics where agricultural spaces become increasingly integrated with urban systems while losing environmental structures and functions. This spatial condition represents a phenomenon transcending static urban-rural divides, requiring new approaches to territorial design that embrace transformation rather than reinforcing existing structures.

- 19 Soja, 2000
- 20 Bonfante et al., 2019
- 21 Makarieva and Gorshkov, 2007
- 22 Munafò, 2020
- 23 Lal, 2004
- 24 Carpenter & Bennett, 2011
- 25 FAO, 2016
- 26 Mang & Reed, 2012

### 2.2 Soil Depletion as a Territorial Metabolic Crisis

The degradation of agrarian spaces represents more than landscape simplification—it constitutes fundamental disruption of territorial metabolic cycles. Understanding soil depletion requires examining interconnected biophysical processes operating across scales, from microscopic soil organisms to regional hydrological systems.

Water cycle disruption manifests as diminished organic soil matter, reduced water retention capacity and infiltration rates, and altered evapotranspiration patterns. Recent studies in the Po Valley have documented reductions in water retention capacity of 40-60% in intensively cultivated areas<sup>20</sup>. This creates cascading effects: diminished retention exacerbates flood and drought cycles, while reduced evapotranspiration disrupts regional precipitation patterns through what Makarieva and Gorshkov<sup>21</sup> term interruption of the "biotic pump" effect—the atmospheric moisture recycling enabled by terrestrial vegetation.

Carbon cycle degradation transforms agricultural soils from carbon sinks to carbon sources. National System for Environmental Protection<sup>22</sup> indicate that Po Valley agricultural soils have lost an average of 40% of their organic carbon since 1950, representing not only climate impacts but also reduced capacity to support diverse agricultural and ecological systems. This depletion reflects what Lal<sup>23</sup> describes as the "carbon debt" of industrial agriculture, a debt that must be repaid through systematic regeneration strategies.

Nutrient cycle disruption reduces soil biodiversity and organic matter, creating dependencies on synthetic fertilizer inputs that link local agricultural systems to volatile global supply chains and geopolitical instabilities<sup>24</sup>. This dependency creates both ecological vulnerabilities (downstream water quality degradation through nutrient runoff) and economic vulnerabilities (exposure to global commodity price fluctuations).

These three processes interact synergistically, creating feedback loops that accelerate degradation. Reduced soil organic matter decreases water retention, which stresses vegetation, which further reduces organic matter inputs—a downward spiral documented across intensively cultivated regions globally<sup>25</sup>.

### 2.3 Toward Regeneration: Ecologies of Repair

The paradigm of regeneration fundamentally reconceptualizes relationships between human intervention and ecosystem health, positioning designed landscapes as active agents of ecological restoration rather than merely extractive systems<sup>26</sup>. This regenerative approach transcends conventional restoration methodologies by embracing transformative pro-

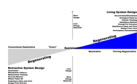
cesses that enhance both ecological resilience and productive capacity within degraded landscapes. Rather than pursuing historical baselines, regenerative design acknowledges the irreversible nature of anthropogenic change while harnessing the inherent adaptive capacity of ecological systems to achieve enhanced functionality.

27 Altieri, 2018  
28 Gliessman, 2014  
29 Roggema, 2016  
30 Prominski, 2017  
31 Lenzholzer et al., 2013

Central to this regenerative framework is recognizing that degraded landscapes retain latent regenerative potential that can be systematically activated through strategic design interventions. This potential manifests through "ecologies of repair"—hybrid systems integrating ecological restoration with productive functions to create landscapes of enhanced resilience and biodiversity. Agro-ecological planning emerges as a critical methodology for operationalizing regenerative principles within productive landscapes<sup>27, 28</sup>. This approach facilitates the development of integrated nature-cultivation systems that simultaneously restore ecosystem services while maintaining agricultural viability through diversified cropping systems, agroforestry integration, riparian corridor restoration, and the establishment of circular resource flows, thereby eliminating waste streams.

Through this regenerative lens, landscape intervention becomes a practice of ecological amplification, where designed systems generate positive feedback loops that enhance both environmental and social outcomes (Figure 1).

figure 01 — page 20



## METHODOLOGY

### RESEARCH BY DESIGN AND SPATIAL GRAMMAR DEVELOPMENT

#### 3.1 Research by Design

This investigation employs research by design as its primary methodology, recognizing spatial design's capacity to generate knowledge through iterative exploration of complex territorial conditions. As articulated by Roggema<sup>29</sup> and Prominski<sup>30</sup>, research by design proves particularly valuable when addressing "wicked problems", such as soil degradation that resist purely analytical approaches and require integrated solutions across multiple scales and domains.

This article presents selected findings from a comprehensive PhD investigation. While the full dissertation addresses detailed quantitative methodologies, extended case study analyses, and comprehensive economic assessments, this article focuses on spatial design contributions and territorial transformation strategies. The research deliberately prioritizes spatial and ecological dimensions over socio-cultural and governance factors. While farmer decision-making processes, community acceptance factors, and governance innovations represent critical areas for future investigation, they fall outside the scope of this article. However, farmer inclusion from project inception would be invaluable for feasibility and real-world implementation of such transition projects.

The methodology operates through systematic cycling between analysis, synthesis, and projection, described by Lenzholzer et al.<sup>31</sup> as "projective research," enabling the investigation of future possibilities while grounding speculation in an empirical understanding of existing conditions.

### 3.2 Multi-Scalar Framework and Empirical Grounding

The research operates across three scales, each revealing different dimensions of transformation potential:

**Mega-regional scale (110,393 km<sup>2</sup>):** The Padano-Alpine-Adriatic region (Figure 2), encompassing the entire Po Plain and adjacent territories. At this scale, analysis focuses on understanding broader patterns of urbanization, agricultural intensification, and environmental degradation.

**Sub-regional transect (180,000 ha):** The Milan-Pavia corridor, selected as a representative transect exhibiting characteristic patterns of diffused urbanization, intensive agriculture, and soil degradation. This transect serves as the primary site for detailed spatial design investigation and quantitative performance assessment.

**Local scale (25-hectare units):** Individual landscape units serving as fundamental building blocks for regenerative intervention. This scale provides empirical grounding for the entire investigation. Each 25-hectare unit (500m x 500m) represents a manageable design and implementation scale, while being large enough to demonstrate improvements in ecosystem function. The research systematically analyzed diverse land unit types across the transect—intensive monocultures, peri-urban interfaces, riparian zones, degraded woodlands—developing site-specific spatial configurations for each condition. Performance parameters were calculated at this scale in collaboration with agricultural technology partners Simbiosis.Tech and Neorurale Hub, then aggregated to demonstrate landscape and regional transformation potential.

This multi-scalar approach demonstrates how site-specific regenerative strategies aggregate into landscape-scale transformation while maintaining concrete grounding in implementable interventions (Figure 3).

figure 02 — page 20

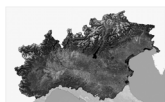
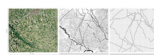


figure 03 — page 20



### 3.3 Spatial Grammar and Sampling

Central to the methodology is the development of a systematic vocabulary of landscape interventions through analysis of contemporary best practices. The research analyzed over thirty case studies of successful agro-ecological interventions, providing concrete empirical evidence for the development of spatial grammar. The following key reference projects are included in this section:

#### Agricultural enterprises and farms

- Neorurale Hub (Milan): An innovative peri-urban agricultural cooperative integrating production, education, and community engagement.
- Cascina Santa Brera (Milan): A regenerative farm that demonstrates diversified production systems within a metropolitan context.
- Iside Farm (Pavia): An agroecological enterprise pioneering organic production and direct marketing.

- Fattoria Granducale (Tuscany): A large-scale regenerative agriculture company integrating livestock, cropping, and agroforestry.
- Biodistricts and agricultural territories
- Bio Valle Camonica (Lombardy): A mountain biodistrict that coordinates organic transition across municipal boundaries.
  - Cilento Biodistrict (Campania): A coastal biodistrict that integrates agriculture, tourism, and landscape conservation.
  - Parco Agricolo Sud Milano: A metropolitan agricultural park that demonstrates integration of production, ecology, and recreation at the landscape scale.
- Riparian and ecological restoration
- River restoration projects in Veneto and Emilia-Romagna provide templates for transforming agricultural drainage into ecological corridors

Each case was systematically analyzed through site visits, document review, and practitioner consultations. Key spatial principles were extracted and redrawn as axonometric diagrams, creating what the research terms "spatial grammar" — a systematic vocabulary of landscape elements and configuration logics (Figure 4). This grammar includes linear elements (hedgerows, riparian buffers, vegetated corridors) and surface elements (agroforestry systems, constructed wetlands, diversified cropping patterns) that function as building blocks for larger territorial strategies.

figure 04 — page 21



### 3.4 Integrating Quantitative Performance Assessment

Spatial design proposals are evaluated using performance parameters derived from scientific literature on nature-based solutions, agroforestry systems, and soil carbon sequestration, adapted to Po Valley conditions through collaboration with agricultural technology partners. This integration of quantitative assessment with spatial design investigation enables credible evaluation while maintaining the design's projective capacity.

Key performance categories and sources that have been defined are:

- Carbon sequestration: Based on IPCC guidelines<sup>32</sup> and meta-analyses of agroforestry and regenerative agriculture<sup>16, 23</sup>, and adapted to Po Valley soil types and climate conditions;
- Water retention: Calculated using FAO guidelines for soil water holding capacity improvements under different management practices, calibrated with local soil data from ISPRA<sup>33</sup>;
- Biodiversity: Estimated using habitat quality models correlated with landscape diversity and connectivity metrics<sup>34</sup>;
- Energy generation: Based on agrivoltaic system performance data from recent European installations<sup>35, 36</sup> (Dinesh & Pearce, 2016; Weselek et al., 2019); and
- Material flows: Quantified based on established yields for timber, fiber crops, and biomass production in temperate climates.

Parameters were first established at the 25-hectare unit scale through detailed spatial configuration and performance modeling. These unit-scale parameters then served as multipliers for aggregate landscape and regional assessment. This methodology enables scalable parameterization while maintaining concrete grounding in site-specific interventions.

35 Dinesh & Pearce, 2016  
36 Weselek et al., 2019  
37 Robinson, 1990  
38 Dreborg, 1996  
39 Blum et al., 2019

### 3.5 Backcasting and Future Studies

The investigation employs backcasting methodology, a strategic planning approach derived from futures studies that grounds spatial interventions within plausible transition pathways<sup>37</sup>. This methodology operates by establishing an ideal future scenario—specifically, the Super Valley vision of comprehensive soil regeneration—and systematically working backward to identify critical enabling factors, required milestones, and necessary interventions. Unlike conventional scenario planning, which extrapolates from current trends toward probable futures, backcasting prioritizes normative outcomes by starting with desirable end-states and reverse-engineering the pathways necessary to achieve them<sup>38</sup>. This approach enables more transformative design strategies by liberating planning processes from the constraints of existing conditions and current trajectories.

The backcasting framework operates through the development of thematic futures across six interconnected domains: finance, agriculture, energy, health, water, and urbanism (Figure 5). These thematic scenarios provide the enabling context and transition paradigm necessary for comprehensive spatial transformation. For instance, the projected emergence of robust carbon credit markets generates financial incentives for soil carbon sequestration practices. At the same time, technological advances in distributed renewable energy systems facilitate the integration of agrivoltaic installations within agricultural landscapes. The convergence of advances in soil health and gut microbiome research creates opportunities for agricultural landscapes to function as pharmaceutical systems, where soil microbial diversity directly enhances both ecosystem resilience and human health outcomes through the soil-human microbiome connection<sup>39</sup>.

These thematic futures converge within the Super Valley vision—a comprehensive territorial transformation that positions the Po Valley as a regenerated landscape, where soil health serves as the foundation for integrated systems of carbon sequestration, biodiversity restoration, renewable energy production, circular bio-based economies, and human wellness.

figure 05 — page 22



## THE SUPER VALLEY SPATIAL DESIGN FOR TERRITORIAL REGENERATION

### 4.1 Geographic Context and Critical Conditions

The Po Valley mega-region encompasses approximately 4.95 million hectares of predominantly agricultural land within a total plain area of 5.96 million hectares, representing one of Europe's most extensive and intensively cultivated territories. The region's flat topography and alluvial soils

have historically supported diverse agricultural systems; however, twentieth-century industrialization has created simplified landscapes that are now vulnerable to climate change and environmental disruption.

The Super Valley project at the sub-region transect scale focuses on a 180,000-hectare transect extending from Milan south through agricultural plains to Pavia, selected as representative of broader Po Valley conditions. This transect encompasses diverse territorial components; however, the predominance of intensive agriculture (142,483 hectares predominantly devoted to maize, rice, and wheat monocultures) is clear.

Current conditions reflect the broader crisis of operational landscapes. Soil organic carbon levels have declined by an average of 40% since 1950<sup>33</sup>, while water retention capacity has decreased by up to 60% in most intensively cultivated areas<sup>20</sup>. Biodiversity indices show dramatic reductions, with native plant and animal species largely displaced by agricultural monocultures. These conditions create vulnerability to extreme weather events while reducing landscape capacity to provide ecosystem services (Figure 6).

figure 06 — page 22



#### 4.2 Territorial Transformation Strategy

The Super Valley project proposes a systematic reconfiguration of the regional landscape through the strategic deployment of spatial grammar elements. Five primary transformation strategies address different territorial components:

**Ecological Corridors:** The transformation of transportation infrastructure and waterways into green and blue highways provides habitat connectivity while maintaining their primary functions. Road networks become linear parks with native vegetation (Figure 7), while agricultural drainage channels evolve into naturalized riparian corridors that support biodiversity and improve water quality (Figure 8).

figure 07 — page 23

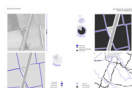
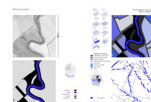


figure 8 — page 23



**Ecotone Zones:** The reconfiguration of urban-rural interfaces as productive edge conditions that mediate between built and agricultural environments. These zones integrate food production, renewable energy generation, and community facilities within landscape settings that provide multiple ecosystem services (Figure 9).

**Agro-Ecological Productive Surfaces:** The transformation of simplified agricultural monocultures into diversified systems that combine food production with carbon sequestration, biodiversity conservation, and water management (Figure 10). Strategies include agroforestry, cover cropping, rotational grazing, and integration of constructed wetlands.

figure 9 — page 23

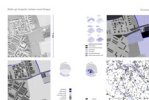
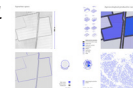
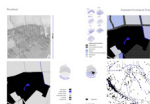


figure 10 — page 24



Expanded Ecological Zones: The enhancement of existing woodland fragments through strategic expansion and improved connectivity is illustrated in Figure 11. These areas provide habitat for native species while offering opportunities for carbon sequestration and sustainable timber production.

figure 11 — page 24



Multifunctional Facilities: The development of agro-hubs that integrate processing, logistics, research, and community functions within regenerative landscape settings. These facilities support the transition to regionalized food systems while providing economic opportunities for rural communities.

#### 4.3 The Spatial Dimension of the Super Valley

The implementation of regenerative strategies across the 180,000-hectare transect (Figure 12) suggests significant environmental and economic benefits through systematic landscape transformation. Quantitative analysis provides a comprehensive framework for evaluating outcomes across agricultural lands in transition:

- Carbon-Water Sponge Systems: 129,500 hectares (91% of agricultural transformation), incorporating enhanced soil organic matter, agroforestry, and cover cropping—providing a foundation for both carbon sequestration and hydrological management.
- High-Diversity Landscape Features: 62,645 hectares (44% of agrarian space), incorporating hedgerows, field margins, agroforestry, and constructed wetlands, creating ecological connectivity throughout the productive landscape.
- Field Margins: 26,068 hectares (18.3% of transformed area), providing critical transitional zones between cultivated areas and environmental systems.
- Wetland Systems: 4,355 hectares (3.1% of the transformed area), reestablishing hydrological processes essential for regional water management.
- Agrivoltaic Systems: 9,685 hectares (6.8% of the transformed area), demonstrating dual-use landscape potential.

figure 12 — page 24



Based on the results from the spatial data, the performative dimension has also been quantified. Performance estimates calculated across the transect include:

- Carbon sequestration: 0.63 megatons CO<sup>2</sup>/year
- Water retention improvement: 1.90 billion liters additional capacity; 285 million m<sup>3</sup> storage
- Renewable energy: 7.7 gigawatts potential annual generation
- Timber production: 22,170 tons/year from polycyclic forest management
- Biodiversity: Estimated 300% increase in habitat quality indices

Analyzing these performance estimates allows a critical contextual assessment. The performance estimates represent potential outcomes rather than guaranteed results. The 0.63 megatons of CO<sup>2</sup> sequestration represent approximately 0.5% of Lombardy's annual emissions. The 1.90 billion liters of water retention could supply approximately 26,000 people annually. The 7.7 gigawatts represent about 1.3% of Italy's current electricity consumption. While significant at the landscape scale, these improvements alone cannot achieve regional carbon neutrality or complete climate adaptation—they demonstrate how agricultural landscapes contribute to broader transition strategies while enhancing multiple ecosystem services.

The transformation strategy acknowledges significant trade-offs, particularly the conversion of approximately 32% of current agricultural land to environmental systems.

## URBAN-RURAL METABOLISMS AND CIRCULAR RESOURCE FLOWS

### 5.1 From Linear to Circular Metabolisms

The Super Valley project recognizes that spatial transformation alone cannot achieve comprehensive regeneration without corresponding reorganization of resource flows and economic relationships. Urban-rural metabolism—the exchange of materials, energy, and information between urban and agricultural systems—provides a framework for developing circular resource flows supporting ecological restoration while creating socio-economic value<sup>40, 41</sup>.

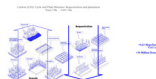
Traditional linear metabolisms extract resources from agricultural landscapes for urban consumption, generating waste streams that become pollution sources. The Po Valley exemplifies this pattern: agricultural production oriented toward distant markets, dependence on synthetic fertilizer inputs sourced globally, and organic waste streams from urban centers that are disposed of rather than recycled.

The Super Valley proposes circular metabolisms that eliminate waste by systematically reintegrating organic materials, nutrients, and energy into regional systems. This reorganization requires both spatial infrastructure (biogas facilities, processing centers, distribution networks) and institutional mechanisms (cooperative structures, municipal procurement policies, waste management systems).

### 5.2 Resource Cycle Integration: Five Interconnected Flows

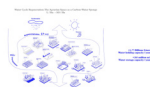
Carbon (CO<sup>2</sup>) Cycle and Plant Biomass: The deployment of environmental systems results in 39 million additional trees, sequestering an estimated 0.63 megatons of CO<sup>2</sup> annually while improving soil structure and water dynamics. This creates "carbon-water sponges" — systems where carbon sequestration and hydrological improvement reinforce each other synergistically, as shown in Figure 13.

figure 13 — page 25



Water Cycle: Enhanced soil organic matter and strategic wetland placement increase water availability by 1.90 billion liters and storage capacity by 285 million m<sup>3</sup> (Figure 14). This represents approximately 13,380 liters additional Available Water Holding Capacity per hectare—a 15-25% improvement over current degraded conditions. To contextualize scale: 285 million m<sup>3</sup> storage capacity could buffer approximately 20% of the transect's agricultural water demand during drought periods.

figure 14 — page 25



Energy Cycle: Agrivoltaic systems (9,685 hectares) generate an estimated 7.7 gigawatts annually (Figure 15). Recent research suggests that properly designed systems can maintain 80-90% of agricultural productivity while generating substantial electricity<sup>35, 36</sup>. However, these systems remain relatively novel in Italian agricultural contexts, requiring navigation of complex regulatory frameworks and building farmer acceptance.

Material Cycle: Beyond food production, regenerated agricultural landscapes generate diverse renewable materials: timber (22,170 tons annually from 2,217 hectares of polycyclic forest management), hemp fiber, and organic rice by-products (Figure 16). Timber production could supply approximately 5% of Lombardy's annual construction timber demand, demonstrating landscape multifunctionality.

figure 15 — page 26



figure 16 — page 26



Organic Carbon Cycle: Urban organic waste from the transect population (1,825,905 individuals) provides input for soil regeneration through biodigester facilities. Based on standard per-capita organic waste generation (240 kg/person/year), the transect generates approximately 438,218 tons of organic waste annually, transformable into 19.8 million tons of organic fertilizer and 2,244 million standard cubic meters of biogas (Figure 17).

This transformation exemplifies urban-rural symbiosis: urban "waste" becomes agricultural input, eliminating synthetic fertilizer dependence while providing renewable energy. However, realizing this potential requires a substantial infrastructure investment and institutional mechanisms for coordinating waste flows across municipal boundaries (Figure 18).

figure 17 — page 26



figure 18 — page 27



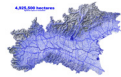
### 5.3 Regional Food System Transformation

The investigation's multi-scalar framework enables the exploration of transformation potential at the mega-regional scale through upscaling transect-based parameters. The 180,000-hectare transect establishes multipliers calculated from a 25-hectare unit analysis:

- 3 tons of CO<sup>2</sup> sequestered per hectare
- 44 watts of electricity generated per hectare
- 13,700 liters of increased water-holding capacity per hectare
- 795 additional trees per hectare

Applied across Po Valley's 4.95 million hectares of agricultural land (Figure 19), these parameters suggest potential for 22 megatons of annual CO<sup>2</sup> sequestration, 267.8 gigawatts of renewable energy generation, 65 billion liters of increased water-holding capacity, and 1.3 billion additional trees. The mega-region's population (24.88 million) could generate 3.09 million tons of organic waste annually, producing 180,600 million cubic meters of biogas and 270 million tons of organic fertilizer—sufficient for approximately 10.8 million hectares (85% of Italy's total agricultural area). These regional projections primarily serve to illustrate the magnitude of potential transformation, recognizing that real-world adoption would likely proceed incrementally and concentrate in areas with favorable enabling conditions.

figure 19 — page 28



## DISCUSSION

### IMPLICATIONS, LIMITATIONS, AND FUTURE DIRECTIONS

#### 6.1 Contributions to Landscape Urbanism and Delta Urbanism

The Super Valley project demonstrates that operational landscapes need not remain sites of depletion and environmental degradation. Through systematic application of agro-ecological principles and strategic spatial design, these territories can become foundations for regenerative practices that support both urban systems and ecological health. This reframing has significant implications for the scholarship and practice of landscape architecture, urban planning, and territorial.

The investigation challenges the conventional separation between natural and artificial systems that characterizes much contemporary planning practice. The hybrid environmental-cultivation systems proposed in the Super Valley transcend these categorical distinctions, creating new landscape typologies that embrace rather than resist human intervention as a catalyst for ecological regeneration. This approach recognizes that anthropogenic landscapes, when properly designed and managed, can enhance rather than degrade ecosystem functions while maintaining productive capacity.

The project highlights the crucial importance of multi-scalar thinking in territorial design and agro-ecological planning frameworks. Local interventions gain transformative significance through systematic aggregation into landscape-scale patterns, while regional strategies require site-specific implementation to achieve their regenerative goals. This scalar integration is essential for addressing complex environmental challenges that transcend administrative boundaries and span multiple temporal and spatial dimensions.

The investigation reveals how agrarian spaces can function as active agents in regional metabolic systems, generating circular resource flows that eliminate waste while creating socio-economic value (Figure 20). By positioning soil as living infrastructure and recognizing the spatial agency of biophysical cycles, the project contributes to emerging paradigms in territorial planning that prioritize regenerative capacity over extractive productivity.

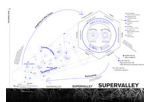
figure 20 — page 29



## 6.2 Methodological Contributions

The research contributes methodological approaches potentially applicable beyond the Po Valley context, as illustrated in Figure 21.

figure 21 — page 29



**Spatial grammar development:** Systematic analysis of reference cases and abstraction of spatial principles creates a transferable methodology for extracting design knowledge from existing practices. However, successful transfer requires attention to geographic and cultural contexts.

**Multi-scalar integration grounded in unit-level analysis:** The framework for connecting local interventions (25-hectare units) to territorial transformation (180,000-hectare transect to 4.95-million-hectare mega-region) demonstrates how research by design can operate across scales. This scalar integration is essential for addressing complex environmental challenges that transcend administrative boundaries.

**Quantitative performance assessment integrated with spatial design:** Integration of design speculation with quantitative evaluation provides credibility while maintaining the design's projective capacity. Yet this integration risks false precision—estimates should be understood as indicative of the magnitude of transformation rather than precise predictions

## 6.3 Policy and Practice Implications

The Super Valley project suggests new directions for planning policy and practice supporting territorial regeneration:

**From protection to transformation:** Current planning frameworks often treat agricultural land as a residual category, requiring protection from development, rather than an active agent in territorial transformation. The project illustrates the value of more dynamic approaches that can accommodate and guide landscape evolution while achieving environmental and economic objectives.

**Integrated competencies:** Professional practice requires new competencies integrating spatial design skills with an understanding of ecological processes, agricultural systems, and regional economics. The project highlights the value of collaborative approaches that bring together designers, farmers, environmental scientists, and policymakers in developing territorial strategies.

**Regional infrastructure for circular economies:** Diversified, regionalized food systems require processing facilities, distribution networks, and market infrastructure that is currently underdeveloped. Public investment can enable private transformation by creating an enabling infrastructure for circular resource flows.

## 6.4 Critical limitations

The Super Valley project acknowledges several significant limitations:

**Performance uncertainties:** Quantitative estimates rely on parameters from scientific literature, but actual performance depends on innumerable site-specific factors. Carbon sequestration estimates, while based on published literature, may overestimate actual outcomes given the challenges of maintaining sequestration rates over long periods.

Biodiversity improvements depend on successful recolonization by native species, which may take decades and could be constrained by regional extinction patterns.

**Economic viability:** The transformation strategy assumes economic viability that requires critical examination. Transition financing (implementing regenerative practices requires substantial upfront investment with returns over years/decades), market structures (diversified regionalized food systems require infrastructure largely underdeveloped), and land rent pressures (areas near Milan face intense development pressure) all present significant challenges. The research lacks a detailed economic analysis of these challenges—a significant limitation that requires future investigation.

**Governance and institutional challenges:** Implementing territorial transformation requires governance mechanisms largely absent from current frameworks. Fragmented authority across EU, national, regional, and municipal levels; predominant private property ownership (90%+) in relatively small parcels; and conflicting policy objectives between agricultural productivity and environmental protection all represent significant barriers—perhaps more fundamental than technical or economic obstacles.

**Socio-cultural dimensions:** The focus on spatial and technical dimensions led to insufficient attention to socio-cultural factors essential to implementation success. Agricultural transformation ultimately depends on farmer adoption of regenerative practices. Research on agricultural innovation<sup>42, 43</sup> reveals that adoption is influenced by a range of complex factors, including risk perception, peer networks, technical knowledge, and cultural identity.

**Territorial variability:** The Milan-Pavia transect represents characteristic, but not universal, Po Valley conditions. Areas below sea level in delta regions, salinization along the Adriatic coast, and varying urbanization intensities (particularly Veneto's diffused urbanization, where ecotone zones may dominate) require adapted approaches. Water drainage systems in some areas might counteract planned soil water retention. The gridded analytical approach effectively assesses transformation potential but does not replace situated design which requires detailed local knowledge.

### *6.5 Lessons learned for practice*

Despite limitations, this investigation offers insights potentially valuable for practitioners and policymakers, e.g.:

**For landscape architects:** Think territorially, act locally. Effective strategies connect local interventions to territorial patterns through systematic spatial grammar. Integrate spatial and metabolic analysis—sustainable landscapes require understanding both spatial form and resource flows. Engage deeply with agricultural knowledge: Successful agricultural landscape design requires collaboration with agricultural specialists. Quantify performance while acknowledging uncertainties.

**For agricultural communities:** Build on existing strengths rather than replacing traditional practices entirely. Create demonstration projects in representative contexts to build confidence. Develop cooperative mechanisms that enable coordination across properties. Access transition financing through EU agricultural funds, carbon credit programs, and innovative financing mechanisms.

For policymakers: Integrate agricultural and environmental policy to remove current fragmentation. Invest in regional infrastructure for diversified food systems. Create enabling regulations that remove barriers while maintaining environmental protection. Support knowledge transfer through extension services, farmer networks, and demonstration projects.

### *6.6 Future Research Directions*

This investigation opens up numerous avenues for future research, focusing on several subjects. For instance, economic analyses could be conducted, including farm-level financial assessment, regional economic impacts, and financing mechanisms. Moreover, farmer adoption studies can be utilized to examine decision-making processes, barriers, and strategies for building social infrastructure. Furthermore, governance innovation can be used to investigate institutional mechanisms that enable coordinated territorial transformation. One could also utilize comparative studies across other operational landscapes to identify common principles and context-specific adaptations. In addition, a climate-adaptation assessment of regenerative landscape performance could elaborate on underprojected climate scenarios, and biodiversity monitoring through long-term pilot projects could validate improvement estimates. Finally, upscaling pathway investigation could enable researchers to examine how localized successes multiply into landscape-scale transformation

## *CONCLUSION*

### *TOWARD REGENERATIVE TERRITORIAL FUTURES*

This research examined the transformative potential of depleted agrarian spaces as catalysts for ecological transitions within post-metropolitan regions, using the Po Valley as a critical case study. Through the Super Valley project—a spatially explicit exploration of a 180,000-hectare transect—the investigation suggests how agricultural territories experiencing soil depletion might be reconceptualized through agroecological planning and design frameworks.

The research makes three primary contributions: methodologically, developing integrated approach combining spatial grammar development, multi-scalar research-by-design grounded in 25-hectare units, and quantitative performance assessment; empirically, providing spatially explicit demonstrations with quantified transformation estimates (0.63 megatons CO<sub>2</sub> sequestration, 1.90 billion liters water retention increase, 7.7 gigawatts renewable energy across study transect); conceptually, positioning degraded agrarian spaces not as residual territories but as active platforms for multiple transitions through systematic spatial reconfiguration and metabolic redesign.

However, research also reveals significant implementation challenges. Economic viability remains uncertain given current market structures. Social and cultural dimensions require deeper investigation. Governance mechanisms for coordinating landscape-scale transformation across property boundaries remain largely undeveloped. These challenges suggest realizing the Super Valley vision requires not only spatial design and technical knowledge but also institutional innovation, economic restructuring, and social movement building largely beyond landscape architecture's traditional scope.

This recognition suggests opportunities for expanded disciplinary roles—landscape architects as facilitators of multi-stakeholder processes, developers of governance innovations, and bridges between technical knowledge and social practice.

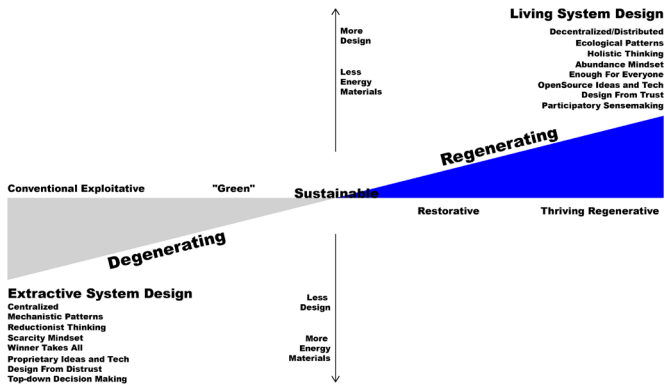
Landscape as a platform for multiple transitions: Critically, investigation reveals landscape as a platform where territorial transformation enables simultaneous advancement across ecological, economic, social, and technological domains. Following Bonomi's<sup>44</sup> concept of territorial platforms as dynamic spaces for innovation and development, Super Valley demonstrates how agrarian spaces function as integrated platforms where diverse transition processes converge and reinforce one another. The landscape platform facilitates the energy transition through agrivoltaic systems, promotes the circular economy transition through organic waste processing, supports the ecological transition through soil regeneration, and fosters the social transition through new forms of cooperation and territorial consciousness.

Looking forward, the urgency of ecological crises—climate change, biodiversity loss, and soil degradation—demands transformative action at territorial scales. Super Valley project explores how such transformation might be technically and spatially feasible, offering pathways from depletion to regeneration. The challenge lies not in imagining better futures but in building social, economic, and institutional capacity to realize them.

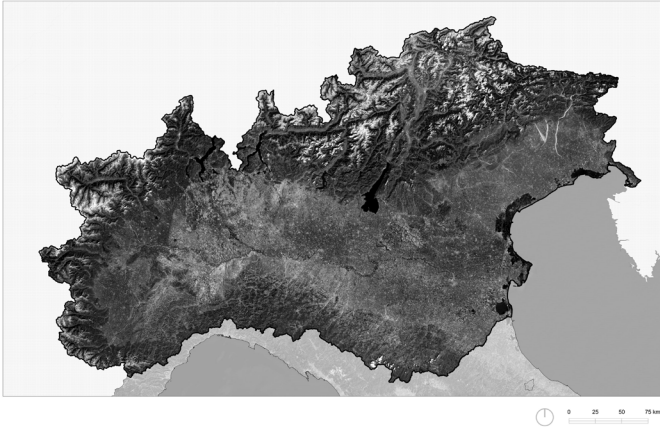
This challenge defines the next phases of research and practice: moving from spatial speculation to implementation, from design vision to institutional innovation, and from individual projects to territorial transformation. By reimagining agrarian spaces as integrated platforms for multiple transitions, this investigation aims to open new horizons for such work and contribute to broader efforts that navigate the complex, interconnected transitions of the 21st century toward more regenerative territorial futures.

#### ACKNOWLEDGMENTS

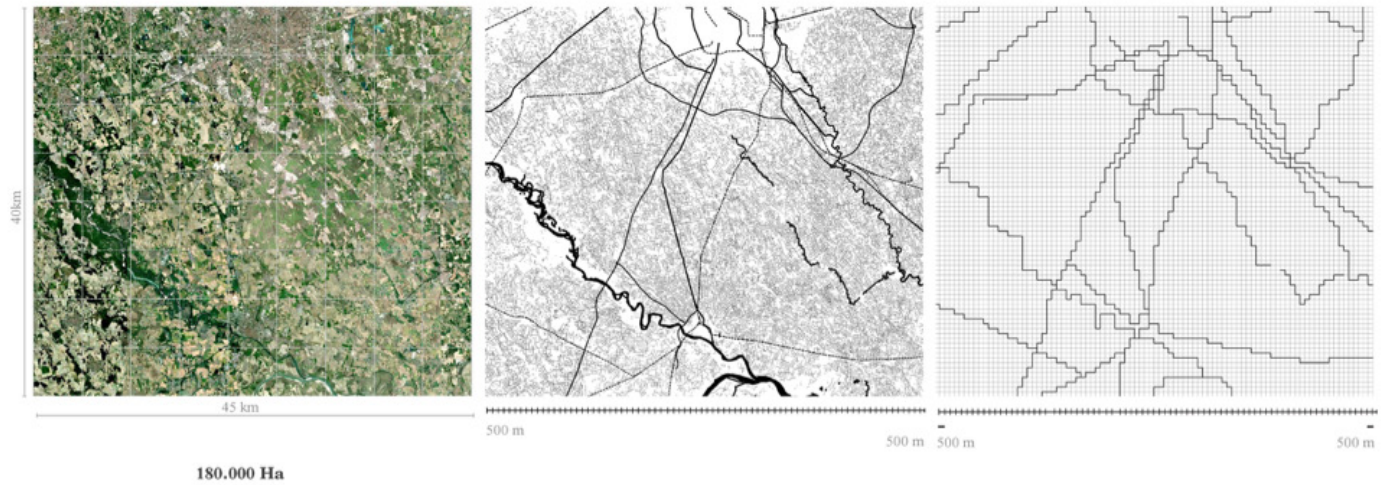
The contribution wouldn't have been possible without the support of research assistants Gloria Signorini, Letizia Alderighi and Jonatan Arnaboldi, photographer Riccardo De Vecchi and innovation partner SIMBIOSI.



01



02

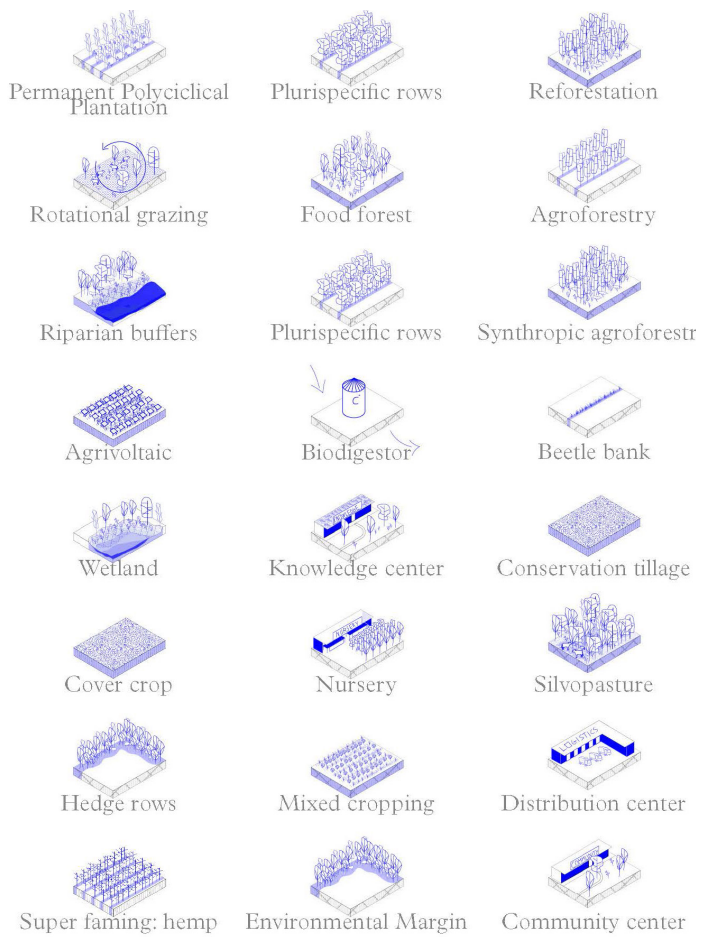


03

01 Degeneration-Depletion vs Repair-Regeneration trajectories. Adapted by author based on Bill Reed's trajectories of ecological design, illustrating the conceptual framework that positions regenerative design as transcending conventional restoration approaches by embracing transformative processes that enhance both ecological resilience and productive capacity within degraded landscapes. (LaFleur, 2025)

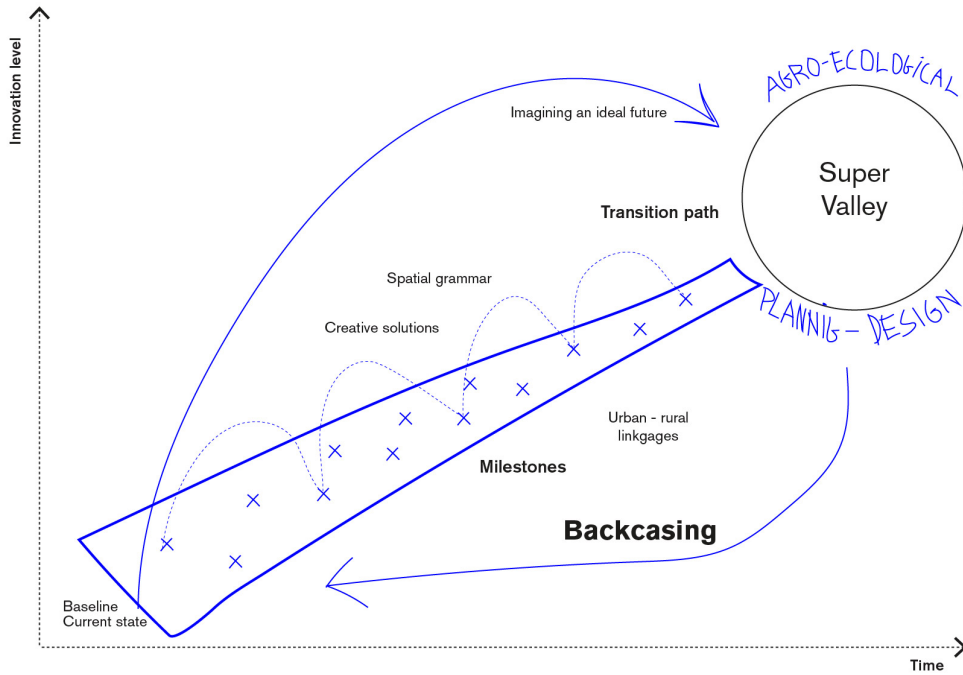
02 Satellite image composition of the Alpine-Padano-Plain area showing the extensive agricultural matrix across the mega-region. The image reveals the predominant agricultural land-use patterns and the scale of potential territorial transformation within the 4.95 million hectares of operational landscapes (LaFleur, 2025)

03 Multi-scalar research framework diagram illustrating the progression from mega-regional analysis (110,393 km<sup>2</sup>) to local interventions (25-hectare units), demonstrating how site-specific regenerative strategies aggregate into landscape-scale transformation through systematic design methodology (LaFleur, 2025)

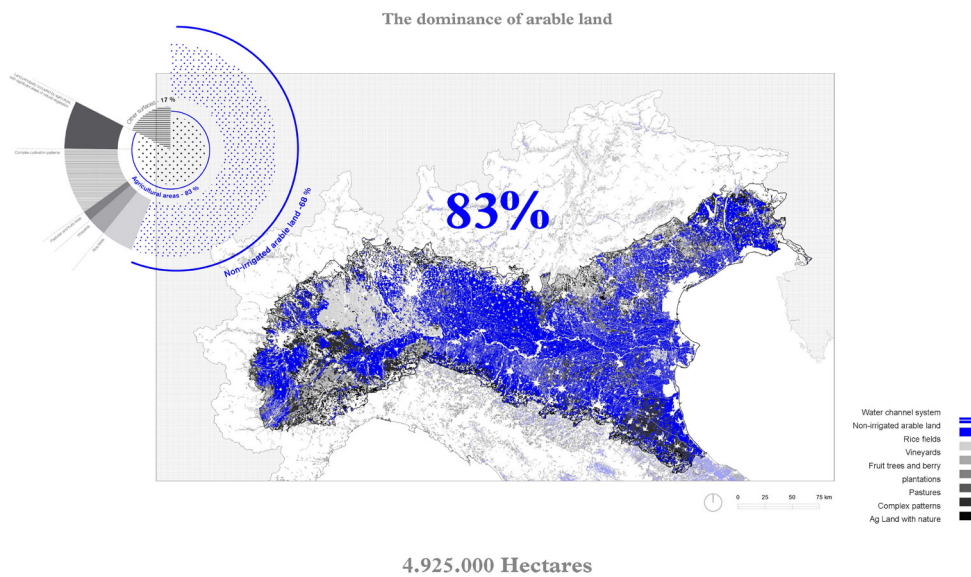


04

04 Spatial grammar sampling methodology, which involves the systematic analysis and abstraction of contemporary best practices into essential spatial principles. Based on over thirty case studies of successful agro-ecological projects, which were redrawn as axonometric diagrams to extract their spatial principles for future deployment (LaFleur, 2025).



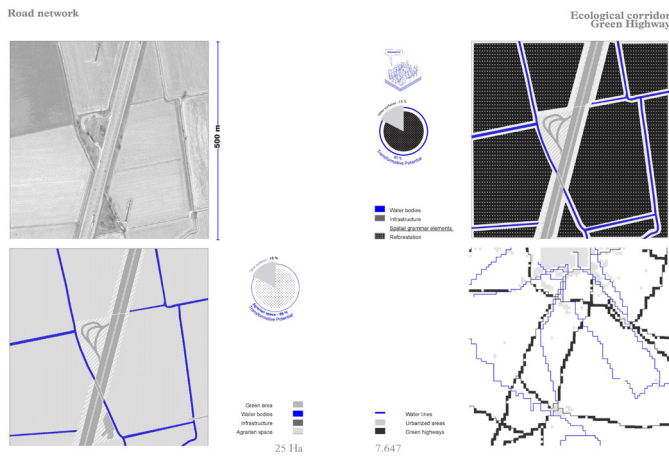
05



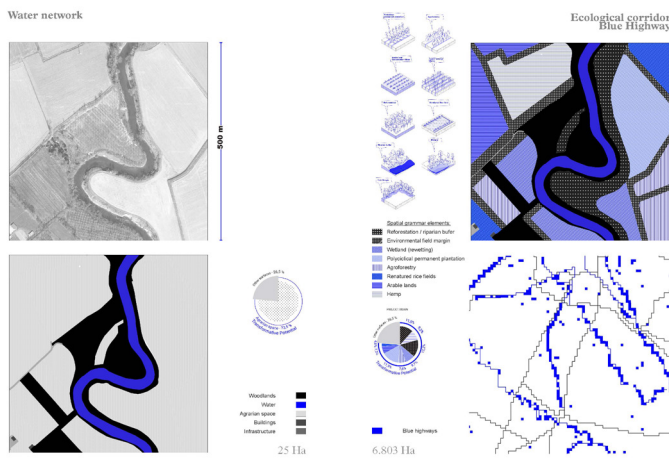
06

05 Backcasting methodology and thematic futures framework. The diagram shows how six interconnected domains (finance, agriculture, energy, health, water, and urbanism) converge within the Super Valley vision, working backward from an ideal future scenario to identify critical enabling factors and necessary interventions for comprehensive territorial transformation (LaFleur, 2025).

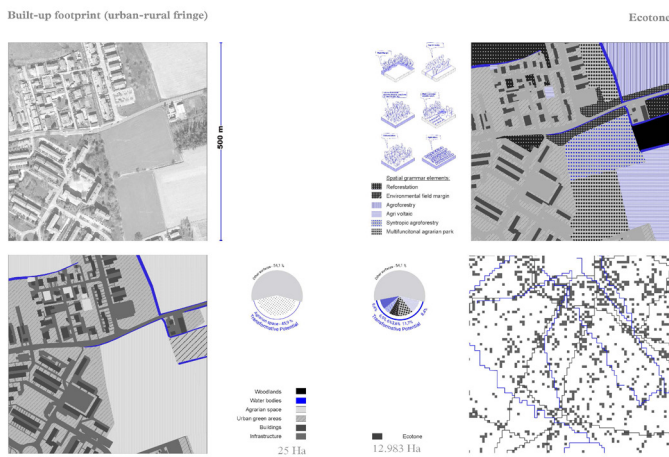
06 Geographic context of the Po Valley mega-region illustrating current critical conditions. The visualization reveals the extent of intensive agricultural practices across the territory and identifies areas most vulnerable to climate change and environmental disruption, establishing the spatial framework for regenerative intervention (LaFleur, 2025).



07



08

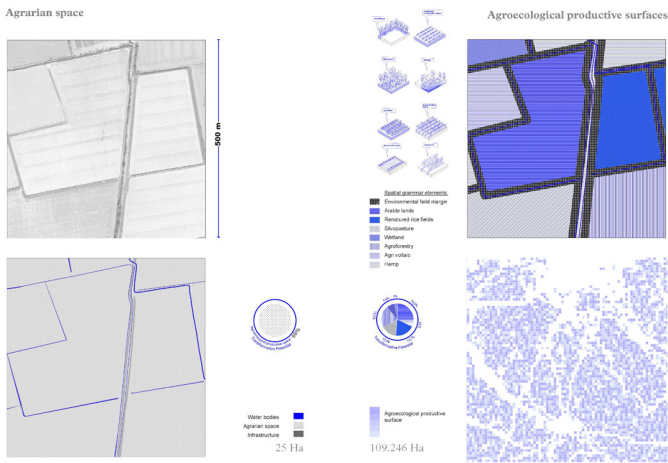


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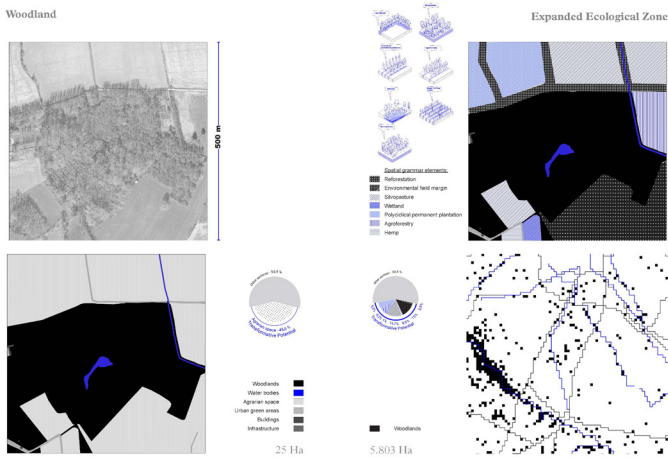
07 Transformation of transportation infrastructure into ecological corridors (Green Highway). The diagram demonstrates how road networks can be systematically redesigned as linear parks with native vegetation, providing habitat connectivity while maintaining primary transportation functions through strategic integration of environmental systems (LaFleur, 2025).

08 Blue Highway transformation strategy for water infrastructure. The illustration demonstrates how existing agricultural drainage channels and waterways can evolve into naturalized riparian corridors that enhance both water quality and biodiversity while supporting regional hydrological management and habitat connectivity (LaFleur, 2025).

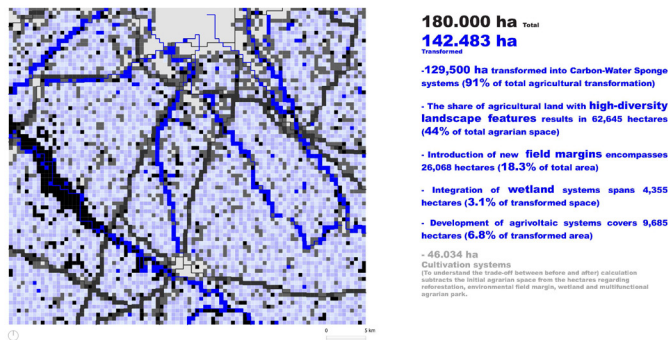
09 Ecotone zones transformation at urban-rural interfaces. The diagram illustrates how transitional areas can be reconfigured as productive edge conditions that integrate food production, renewable energy generation, and community facilities within landscape settings that provide multiple ecosystem services while mediating between built and agricultural environments (LaFleur, 2025).



10



11



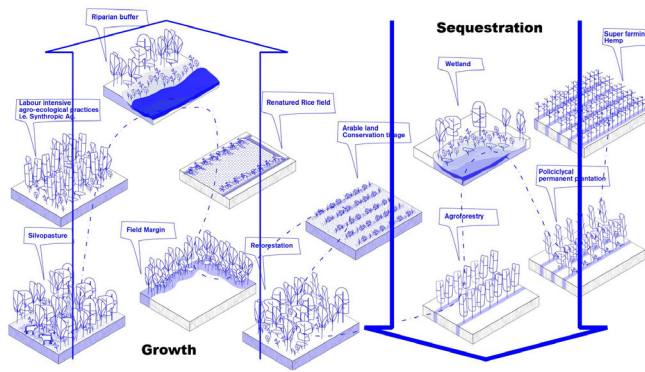
12

10 Agro-ecological productive surfaces transformation strategy. The illustration demonstrates how simplified agricultural monocultures can be systematically transformed into diversified systems that combine food production with carbon sequestration, biodiversity conservation, and water management through the integration of agroforestry, cover cropping, and constructed wetlands. (LaFleur, 2025)

11 Expanded ecological zones transformation show enhancement of existing woodland fragments. The diagram illustrates strategies for strategic expansion and improved connectivity of forest systems, providing habitat for native species while offering opportunities for carbon sequestration and sustainable timber production within the agricultural matrix (LaFleur, 2025).

12 Spatial grammar elements quantification across the Super Valley transformation. The diagram provides comprehensive spatial analysis of the 180,000-hectare study area, showing the distribution and scale of different intervention types including Carbon-Water Sponge systems (129,500 hectares) and high-diversity landscape features (62,645 hectares) (LaFleur, 2025).

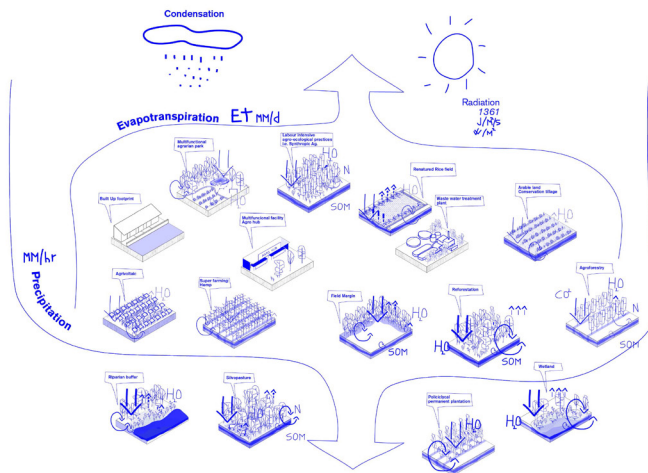
Carbon (CO<sub>2</sub>) Cycle and Plant Biomass: Sequestration and plantation  
Trees / Ha - CO<sub>2</sub> / Ha



+0,63 MegaTon  
Co<sub>2</sub> / y  
+39 Million Trees

13

Water Cycle Regeneration: The Agrarian Space as a Carbon-Water Sponge  
L / Ha - M<sup>3</sup> / Ha



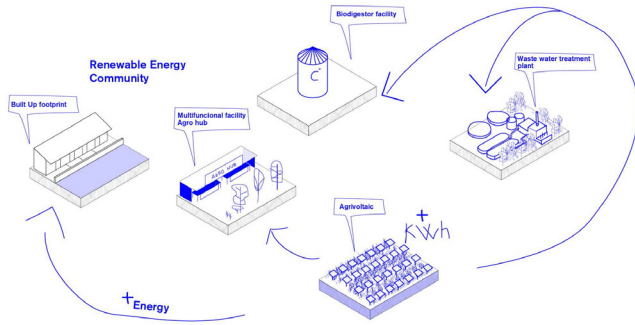
+1,77 Billions Liters  
Water holding capacity / year  
+285 million m<sup>3</sup>  
Water storage capacity / year

14

13 Carbon cycle and plant biomass sequestration systems within the Super Valley framework. The illustration demonstrates how the integration of 39 million trees creates synergistic relationships between carbon storage and hydrological functions, showing the transformation of agricultural fields into carbon-water sponges that sequester 0.63 megatons of CO<sub>2</sub> annually (LaFleur, 2025).

14 Water cycle regeneration through carbon-water sponge systems. The diagram quantifies improvements in regional water management, showing increases of 1.90 billion liters in water availability and 285 million m<sup>3</sup> in storage capacity, with enhanced water dynamics providing 13,380 liters of additional Available Water Holding Capacity per hectare (LaFleur, 2025).

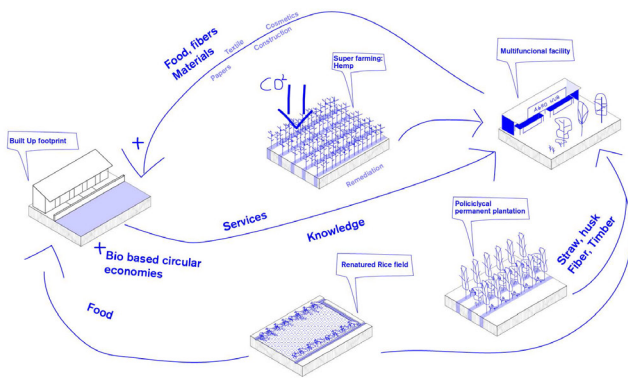
The Energy Cycle: Energy – food nexus through distributed agrivoltaic systems  
KW / Ha



**+7,7 Giga Watt  
Electricity produced / year**

15

The Material Cycle: Bio-based circular economies  
Ton/Ha



**+Rice Straw: 115,785  
tons/year** Bioplastics, construction materials, packaging alternatives

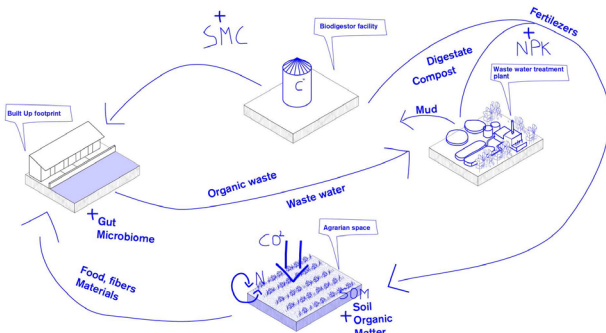
**+Rice Husks: 20,069  
tons/year** Biomass energy, building materials, soil amendments

**+Hemp Fiber: 86,462  
tons/year** Textiles, construction materials

**+Timber: 22,170  
tons/year** Sustainable Construction, Furniture

16

The Organic Carbon Cycle: Beyond synthetic fertilizers, circular resource flows and soil regeneration



**+19,8 Million  
Ton / organic fertilizers / year**

**+803,492  
Hectares with  
ORGANIC FERTILIZERS**

**+2,244 Million  
Smc / year BIOGAS**

17

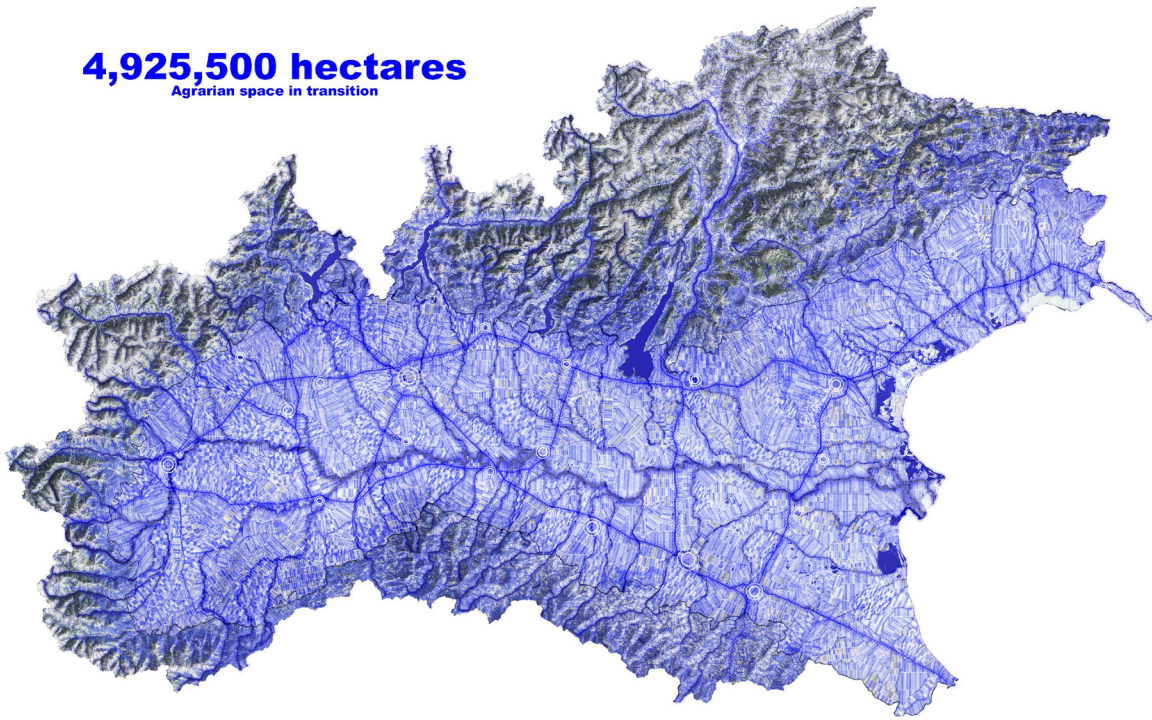
15 Energy cycle through distributed agrivoltaic systems. The illustration demonstrates the dual-use potential of agrarian spaces where solar energy generation is combined with continued agricultural production, generating 7.7 gigawatts annually while maintaining productive capacity and contributing to regional energy independence (LaFleur, 2025).

16 Material cycle and bio-based production systems. The diagram highlights the potential for agricultural landscapes to generate diverse renewable materials beyond food production, including timber (22,170 tons annually), hemp fiber, and organic rice by-products, illustrating the shift from resource extraction to cultivation within circular territorial economies (LaFleur, 2025).

17 Organic carbon cycle and circular resource flows between urban and agrarian spaces. The illustration demonstrates how urban organic waste from 1,825,905 individuals can be transformed through biodigester facilities into valuable inputs for agricultural productivity (organic amendments) and energy generation (biogas), eliminating synthetic fertilizer dependencies (LaFleur, 2025).

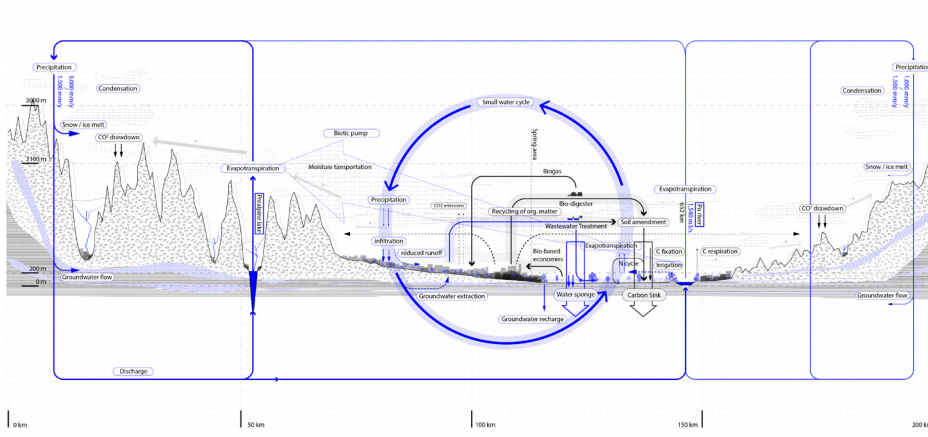


**4,925,500 hectares**  
Agrarian space in transition

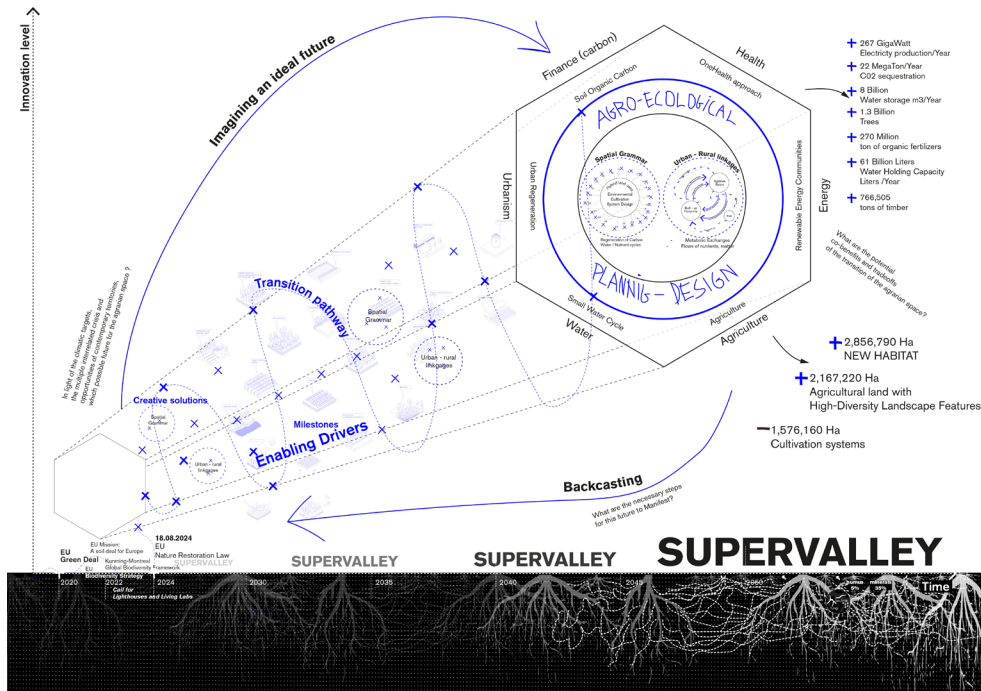


19

19 The Super Valley as an open system illustrating complex metabolic flows and resource exchanges. The diagram illustrates the interrelationships between renewable energy inputs (sun, wind, rain), spatial-performance elements, and various resource cycles, demonstrating how the regenerated agrarian space functions as an integrated platform for territorial metabolism and circular resource flows (LaFleur, 2025).



20



21

20 Super Valley as a living infrastructure system across the transformed landscape. The visualization illustrates how the territorial transformation establishes a comprehensive network of ecological and productive functions that support both regional development and territorial regeneration, positioning soil as the foundational infrastructure for multiple ecosystem services and transitions (LaFleur, 2025).

21 Methodological framework of the PhD project SUPERVALLEY showing the integration of research approaches. The diagram illustrates how the investigation bridges theory and practice in territorial design through systematic integration of spatial grammar development, backcasting methodology, and quantitative performance assessment within the agro-ecological planning framework . (LaFleur, 2025).

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[delta-urbanism@tudelft.nl](mailto:delta-urbanism@tudelft.nl)  
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#### Authors

Filippo LaFleur  
LAND  
Italy  
ORCID ID: 0009-0000-6312-5386

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