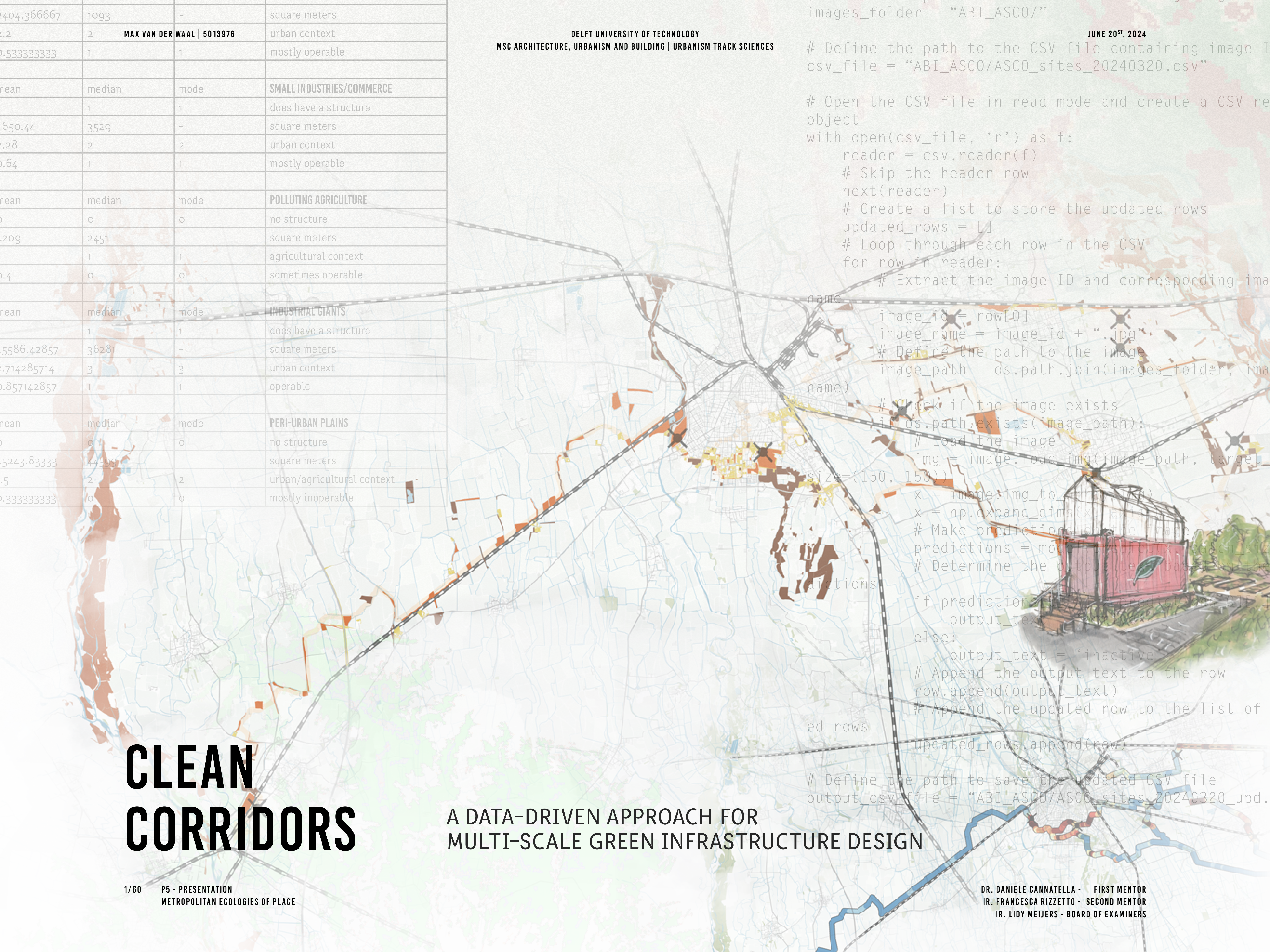
MAX VAN DER WAAL | 5013976

DELFT UNIVERSITY OF TECHNOLOGY
MSC ARCHITECTURE, URBANISM AND BUILDING | URBANISM TRACK SCIENCES

JUNE 20ST, 2024



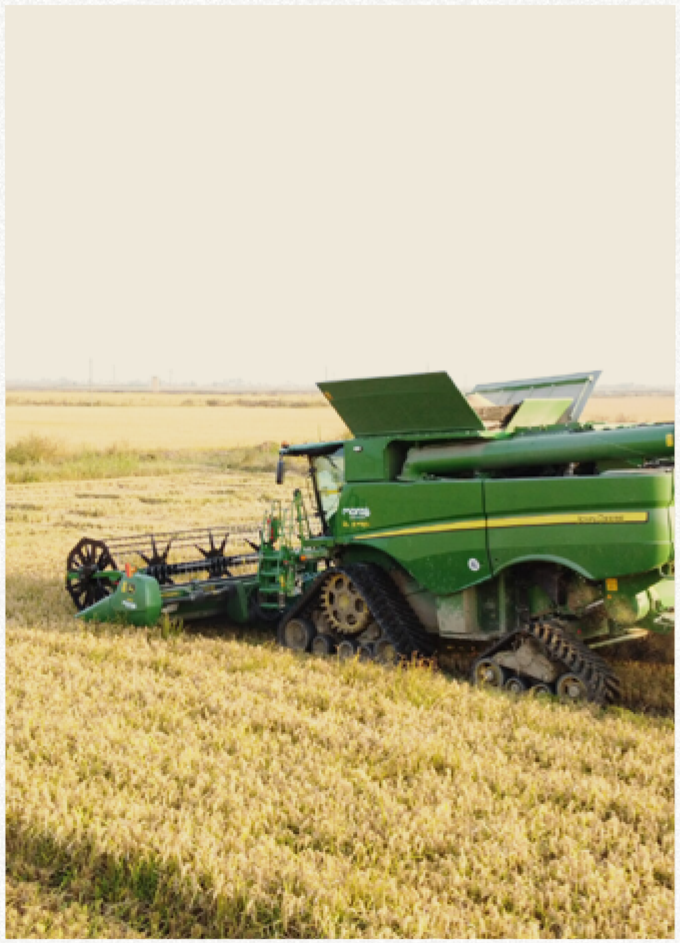
CLEAN CORRIDORS

A DATA-DRIVEN APPROACH FOR MULTI-SCALE GREEN INFRASTRUCTURE DESIGN

P5 - PRESENTATION
METROPOLITAN ECOLOGIES OF PLACE

DR. DANIELE CANNATELLA - FIRST MENTOR
IR. FRANCESCA RIZZETTO - SECOND MENTOR
IR. LIDY MEIJERS - BOARD OF EXAMINERS

THE UNDERLYING PROBLEMS



MECHANIZED AND INDUSTRIALIZED

AGRICULTURE

1

MECHANIZED HARVESTING OF RICE IN VERCELLI, PIEMONTE.
IMAGE FROM: HTTPS://WWW.RISOITALIANO.EU/NUOVI-CALI-A-VERCELLI/, MAY 16TH, 2023

HEAVILY PRODUCTIVE

INDUSTRIES

2

INDUSTRIAL SKYLINE OF VERCELLI,
PIEMONTE. OWN IMAGE

GROWING TRENDS IN

URBANIZATION

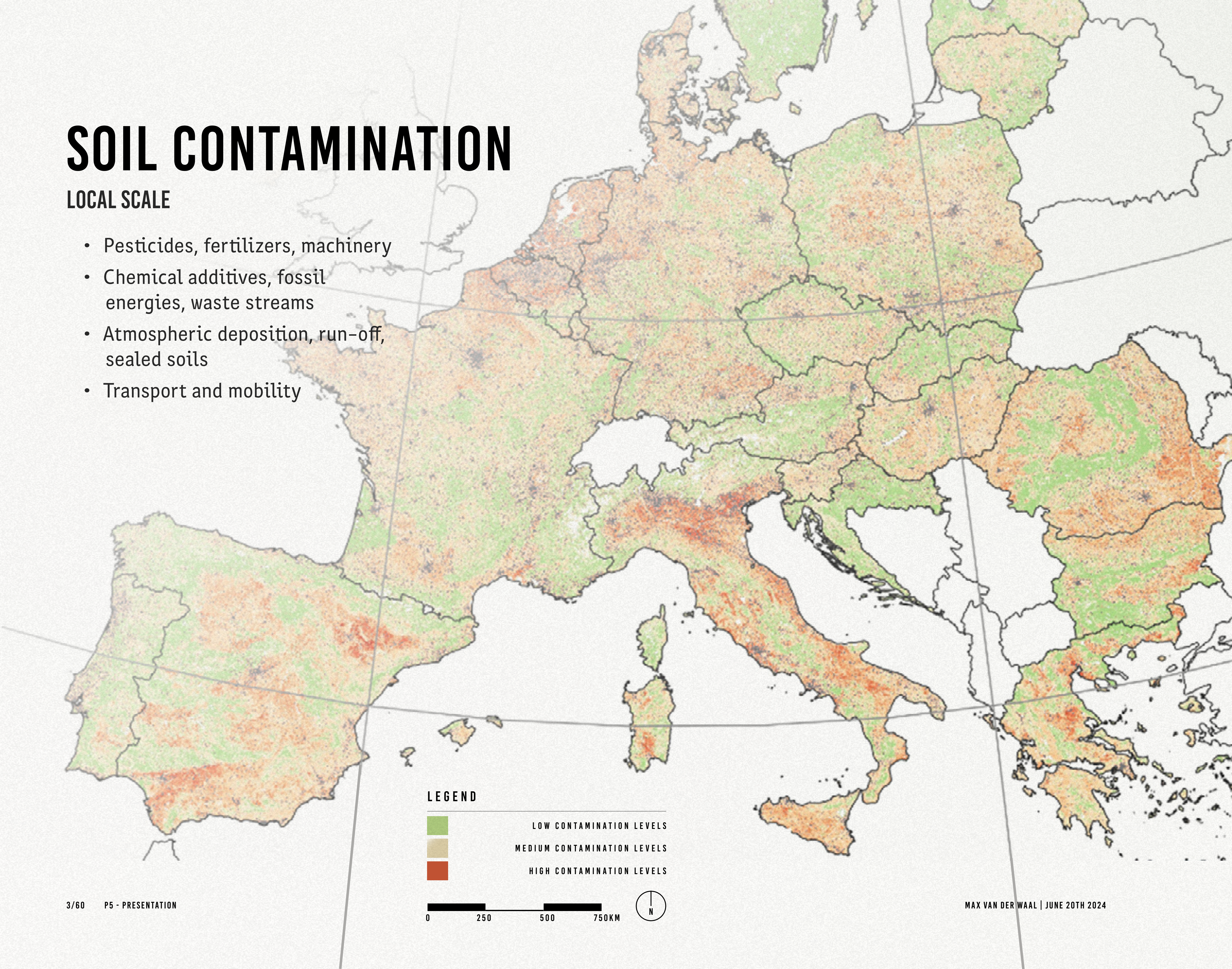
3

URBAN SCENE IN TURIN, PIEMONTE.
OWN IMAGE

SOIL CONTAMINATION

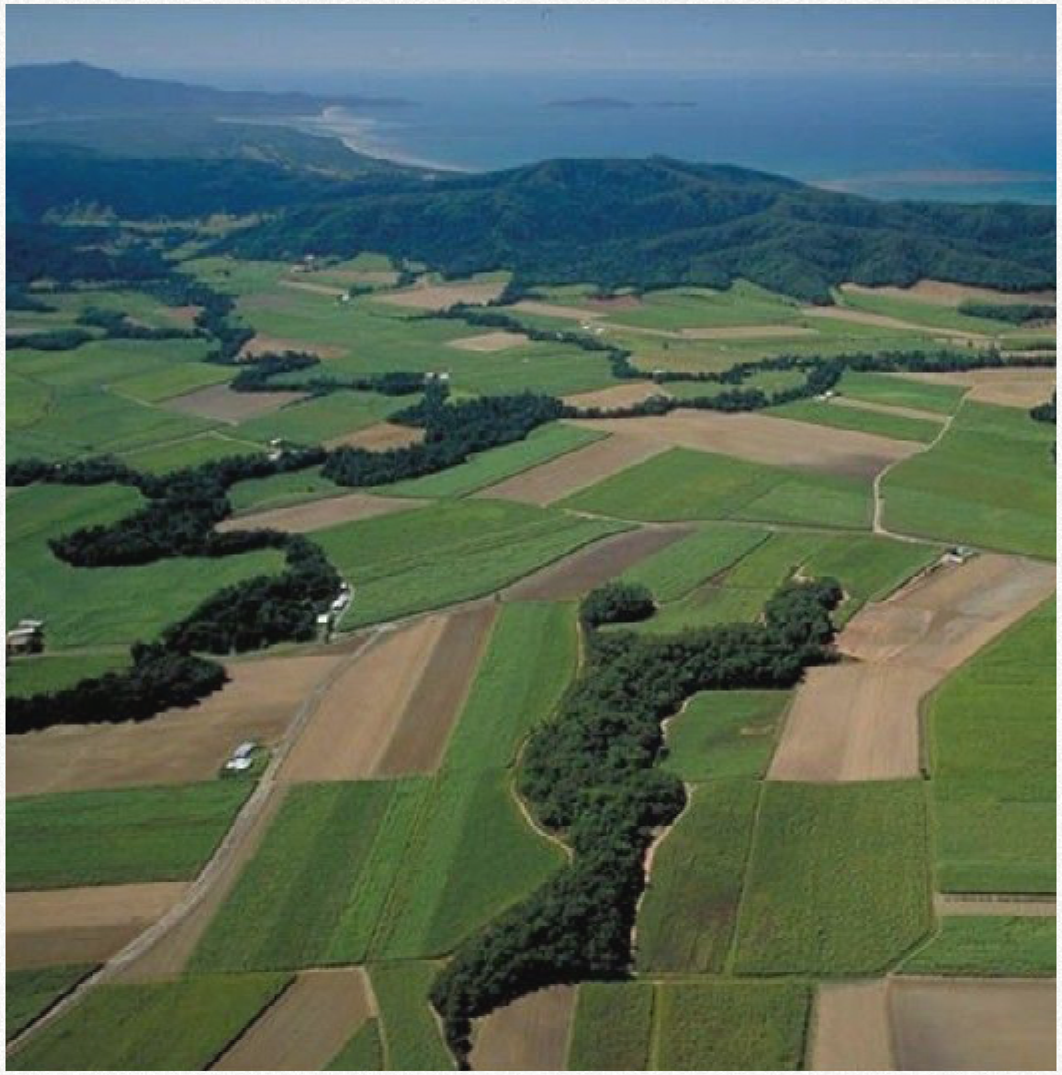
LOCAL SCALE

- Pesticides, fertilizers, machinery
- Chemical additives, fossil energies, waste streams
- Atmospheric deposition, run-off, sealed soils
- Transport and mobility



LANDSCAPE FRAGMENTATION

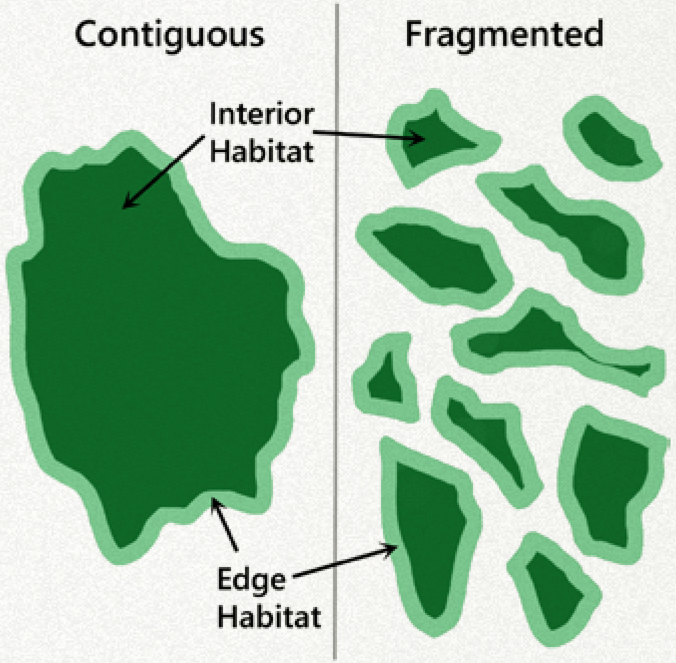
REGIONAL SCALE

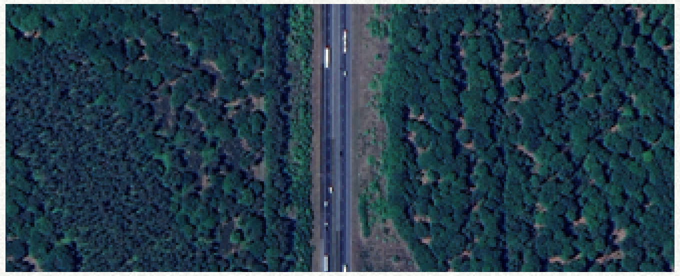


Connectivity within the ecological structures is essential as animal movement and ecological flows prevent contribute to gene flow, pest management, pollination, seed dispersal, and many others.

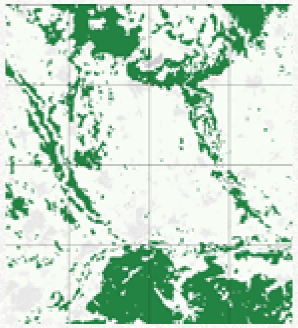
FROM 'CONNECTIVITY: A FUNDAMENTAL ECOLOGICAL CHARACTERISTIC OF LANDSCAPE PATTERN' BY G. MERRIAM (1984)

LEFT: LANDSCAPE FRAGMENTATION SHOWN IN AERIAL VIEW (GATHERED FROM: HTTPS://GARDENERSCOACH.WORDPRESS.COM/2013/03/17/HABITAT-FRAGMENTATION/, MARCH 17,2013)
TOP-RIGHT: HABITAT FRAGMENTATION AND EDGE EFFECTS, BY CANADIAN CENTRE FOR TRANSLATIONAL ECOLOGY. 2019 . GATHERED FROM: HTTPS://CCTE.CA/RESOURCES/FIG5.1.HTML
MID-RIGHT: INFRASTRUCTURE FRAGMENTING THE NATURAL LANDSCAPE INEAR DRIEBER-GEN,THE NETHERLANDS, AIRBUS 2024.
BOTTOM-RIGHT: FOREST LAND-COVER IN PCENTRAL PIEDMONT, FROM COPERNICUS LAND MONITORING SERVICES 2015-2019.

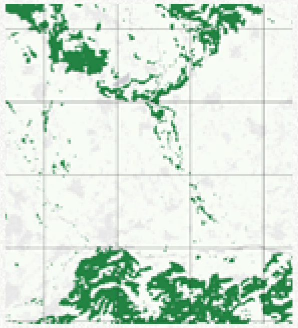




INFRASTRUCTURE AS CAUSE FOR LANDSCAPE FRAGMENTATION



PIEMONTESE FORESTS IN 2015

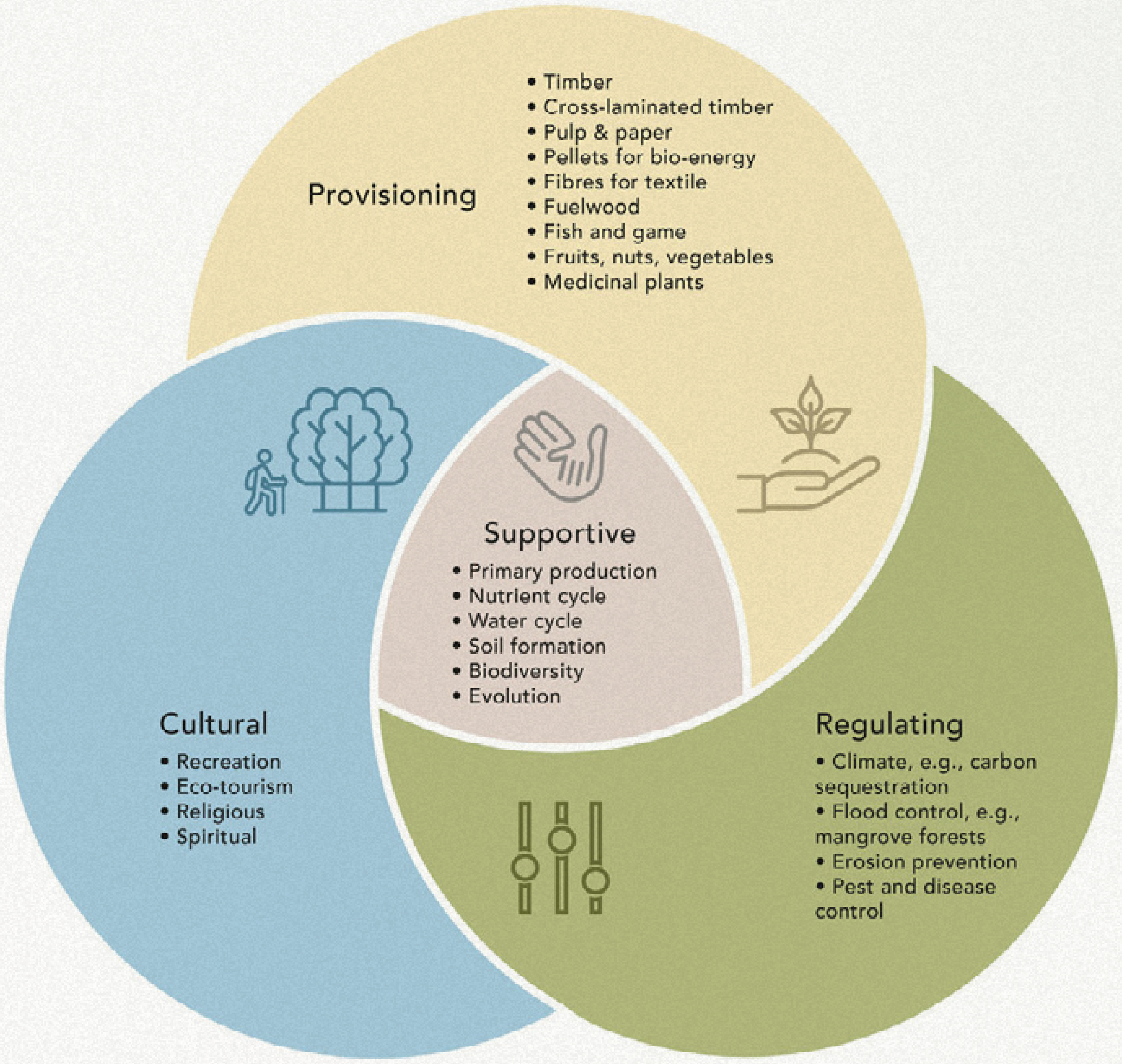


AND IN 2019...

BACKBONE OF OUR EXISTENCE

ECOSYSTEM SERVICES

- Human (and non-human) life is based on natural processes (climate regulation, food production, photosynthesis, water cycles, etc.)
- ES depend on healthy ecosystems and balanced natural landscapes
- ES emphasizes the interrelationship between ecological health and human prosperity

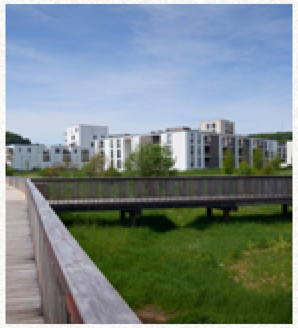


ECOSYSTEM SERVICES CATEGORIZED
IMAGE FROM "ROADMAP TO DEVELOP A STRESS TEST FOR FOREST ECOSYSTEM SERVICES SUPPLY" BY KRAMER ET AL. ,2022

GREEN INFRASTRUCTURE

- Designed to deliver ES and enhance biodiversity
- Applied across all different scales
- GI-planning ensures connectivity of ecosystems and collaboration between individual GI-elements
- Sustainable way for environmental adaptation and mitigation
- Gaining popularity and recognition


GREEN ROOFS


WATER RETENTION PARKS


FOREST PLANNING

"A strategically planned network of natural and semi-natural areas with other environmental features, designed and managed to deliver a wide range of ecosystem services, while also enhancing biodiversity."

EUROPEAN COMMISSION, 2019

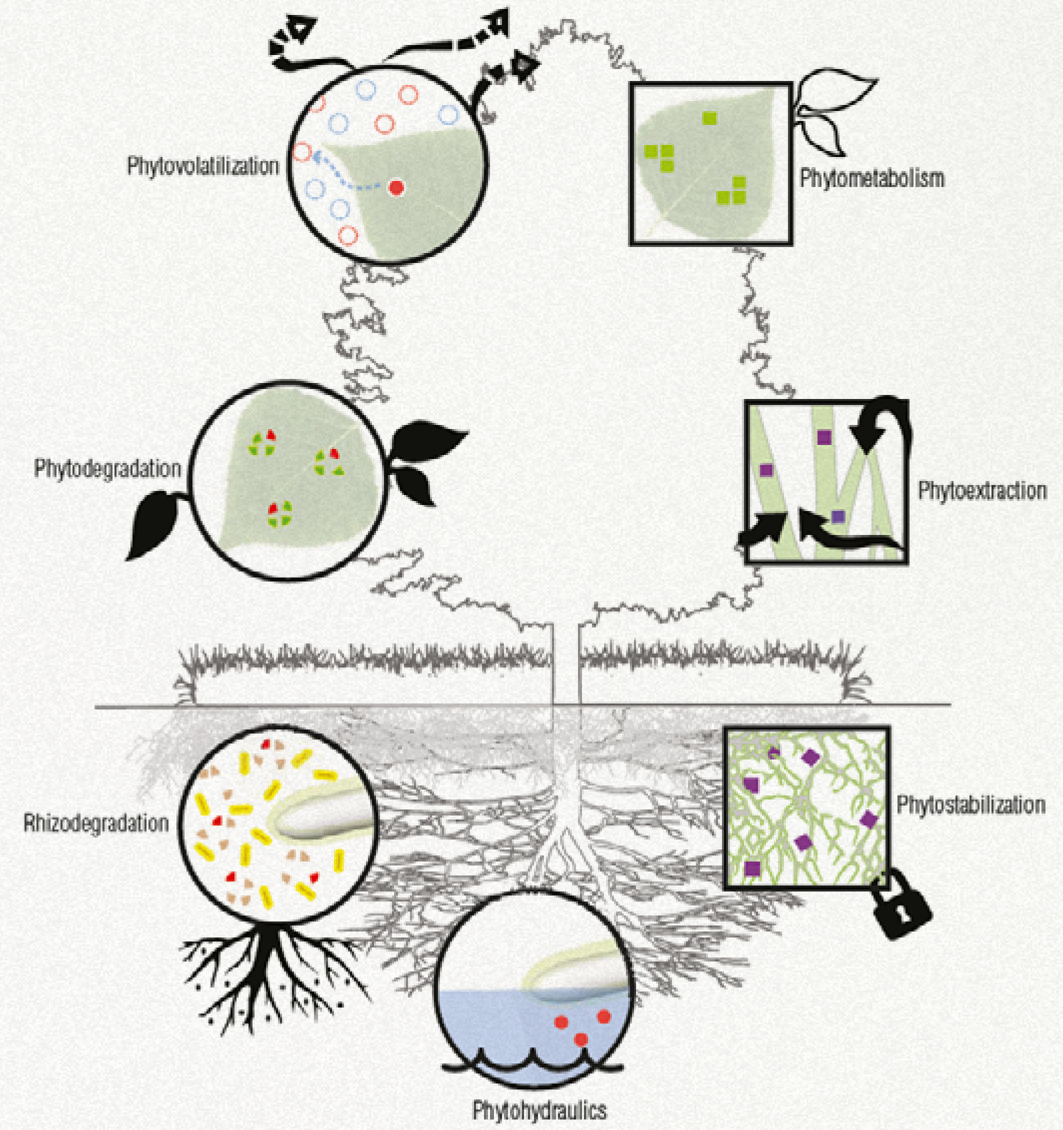

IMAGE OF RIPARIAN GREEN STRUCTURE ALONG THE PO-RIVER [PHOTOGRAPH], BY SEANSHOT, GETTYIMAGES (HTTPS://WWW.ISTOCKPHOTO.COM/PHOTO/AFTER-RIVER-GM999077318-270212471).

PHYTOREMEDIATION

Def. The use of green, plant-based systems to address the contamination of soil, water or air. Multiple phytotechnologies exist, each using different mechanism to absorb, stabilize, or degrade harmful contaminants.

Pros. Cost-effective, recreational & aesthetic purposes, potential economic benefits (e.g. biofuel, construction material, phytomining), ability to strengthen ecosystems & biodiversity, health benefits,.

Cons. Long-term investment, lot of technical and practical requirements, often requires maintenance, no guaranteed success.



PHYTOMECHANISMS: SUMMARY DIAGRAM, FROM: KENNEN, K., & KIRKWOOD, N. (2015). PHYTO: PRINCIPLES AND RESOURCES FOR SITE REMEDIATION AND LANDSCAPE DESIGN, P.41, FIGURE2.13A.

OVERVIEW OF THE DIFFERENT PHYTOTECHNOLOGIES

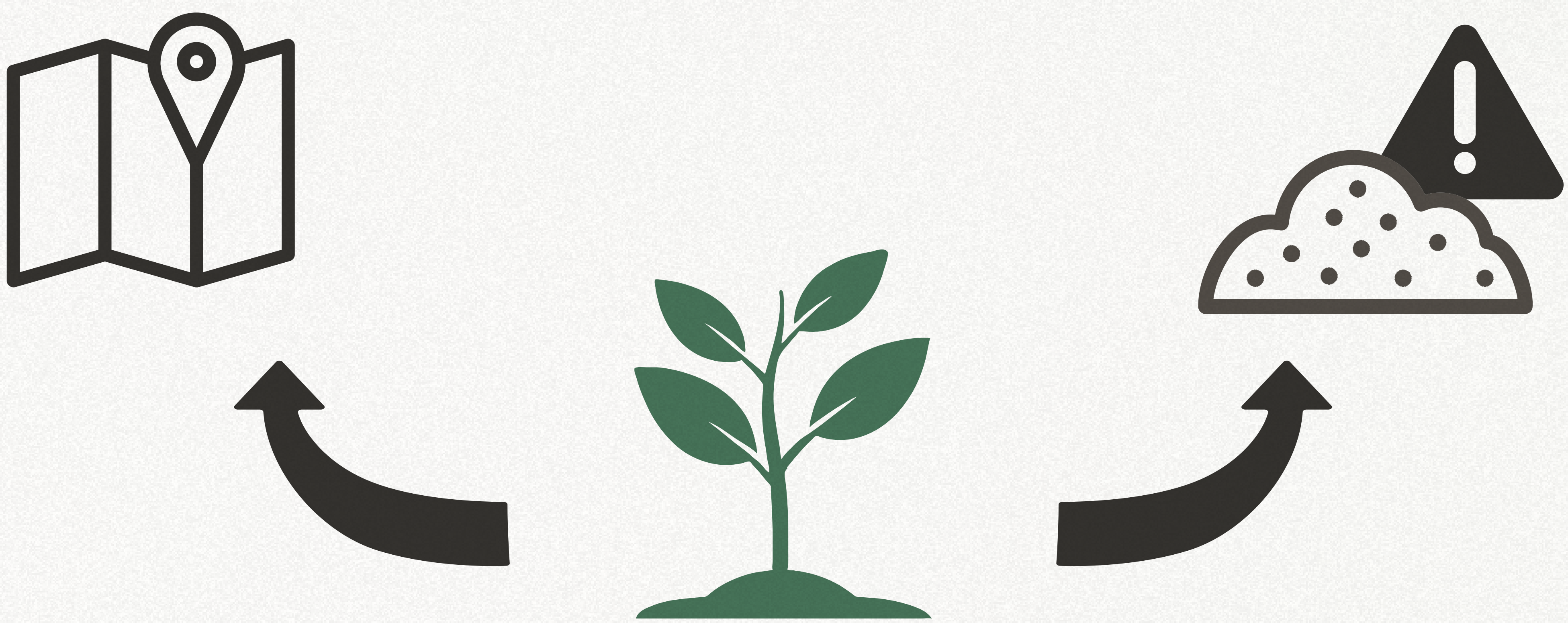
SCALAR CHALLENGE

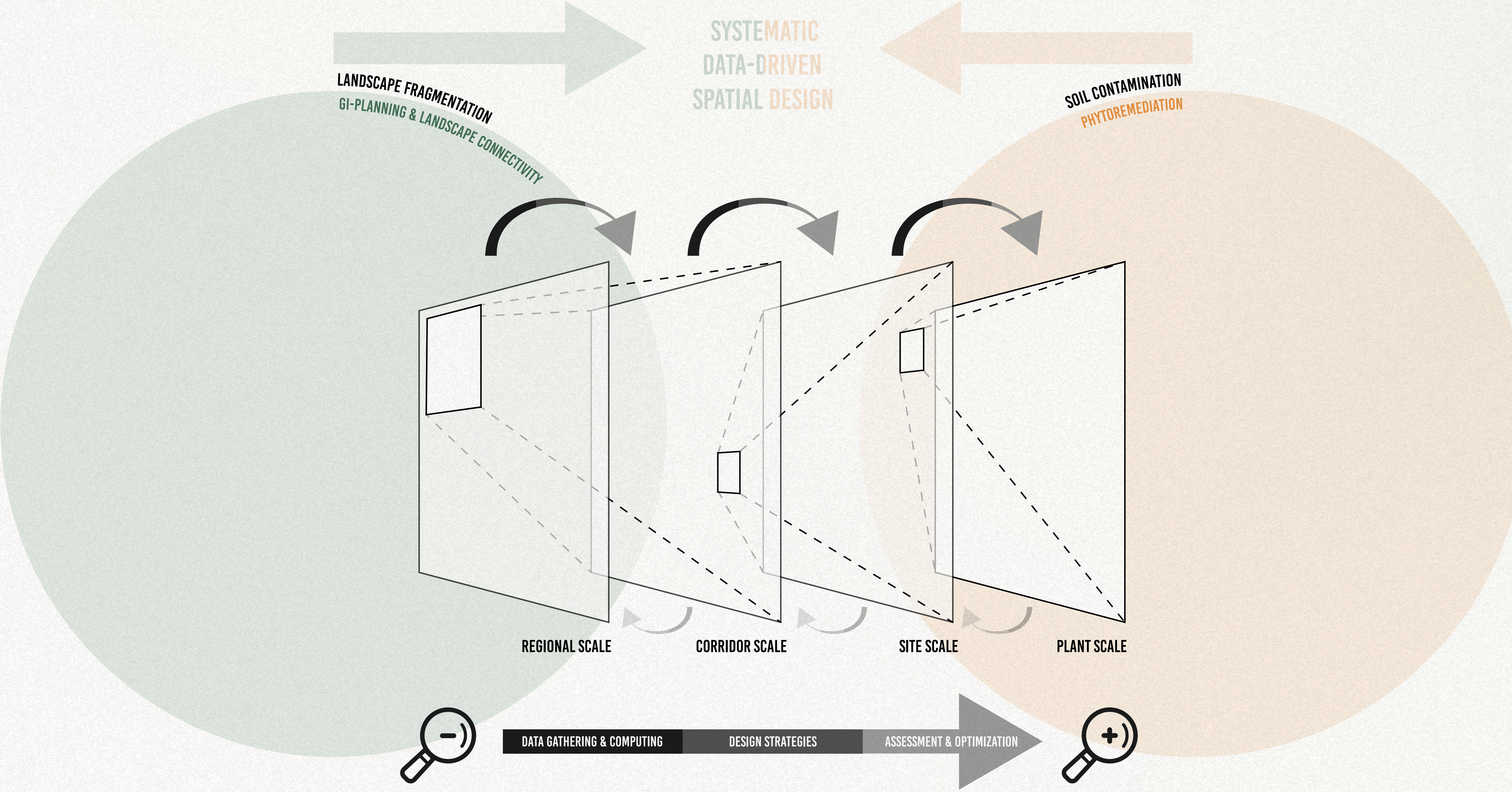
REGIONAL SCALE

Planning new green infrastructures in the most strategic locations improves landscape connectivity and ecosystem health

LOCAL SCALE

Selecting the right plants can help in addressing soil contamination in a sustainable and nature-based manner.





HOW CAN PHYTOREMEDIATION BE INTEGRATED IN REGIONAL SCALE GREEN INFRASTRUCTURE DESIGN?

REGIONAL

UNDERSTANDING

What are the components of the current natural landscape structure, and how can they be enhanced? SQ1

OPTIMIZING

Where would a new green corridor most effectively enhance landscape connectivity? SQ2

selecting & zooming in

CORRIDOR

UNDERSTANDING

What strategies can be used to design the green corridor path based on spatial structure? SQ3

OPTIMIZING

Which design strategies are most effective based on ecological movement potential? SQ4

selecting & zooming in

SITE

UNDERSTANDING

What types of contaminated sites exist within the study area? SQ5

OPTIMIZING

What design patterns can be applied to the redesign of contaminated sites? SQ6

selecting & zooming in

PLANT

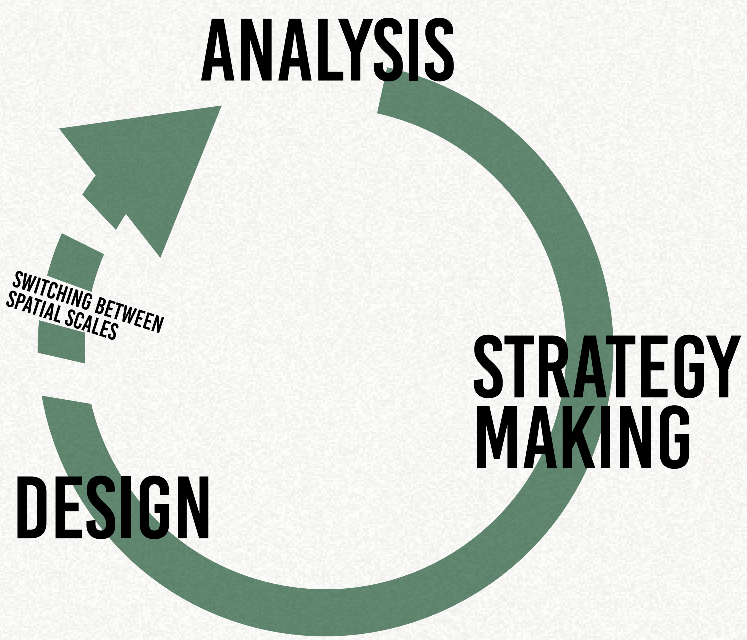
Which plant species are suitable for the selected design patterns and site-specific conditions to effectively remediate the local soil? SQ7

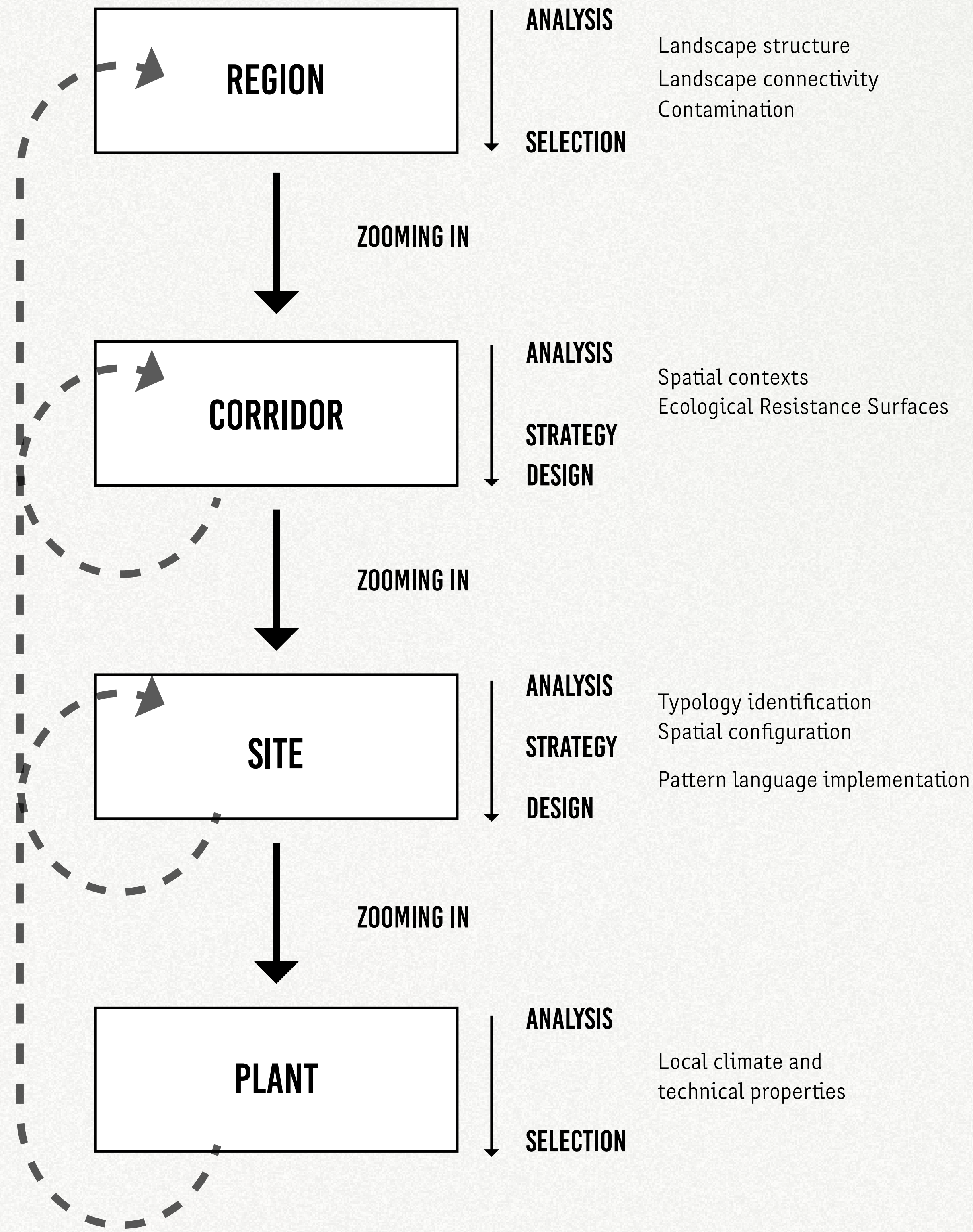
HOW CAN PHYTOREMEDIATION BE INTEGRATED IN REGIONAL SCALE GREEN INFRASTRUCTURE DESIGN?

MAIN RESEARCH QUESTION

DATA-DRIVEN DESIGN APPROACH

- Based on accessible open-data
- Uses data-analysis to construct design strategies
- Uses quantifiable and assessable analysis methods
- Systematically works across spatial scales





WHERE CONTAMINATION AND FRAGMENTATION MEET

PIEMONTE, ITALY

- Enclosed by the Alps and the Apennines
- Industrial triangle
- Fertile and arable plain
- >1.250 contaminated sites
- +- 25,000 km^2

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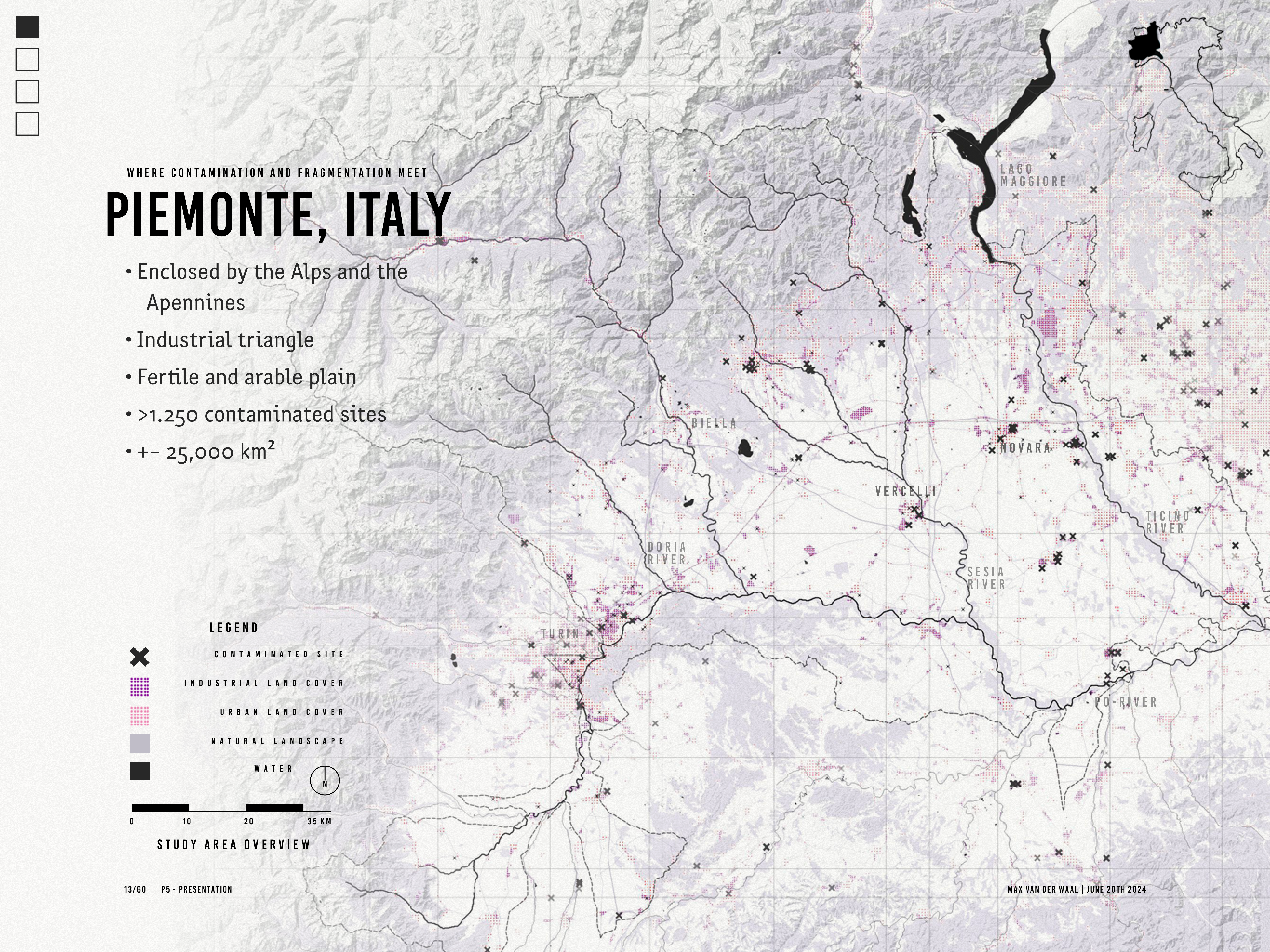
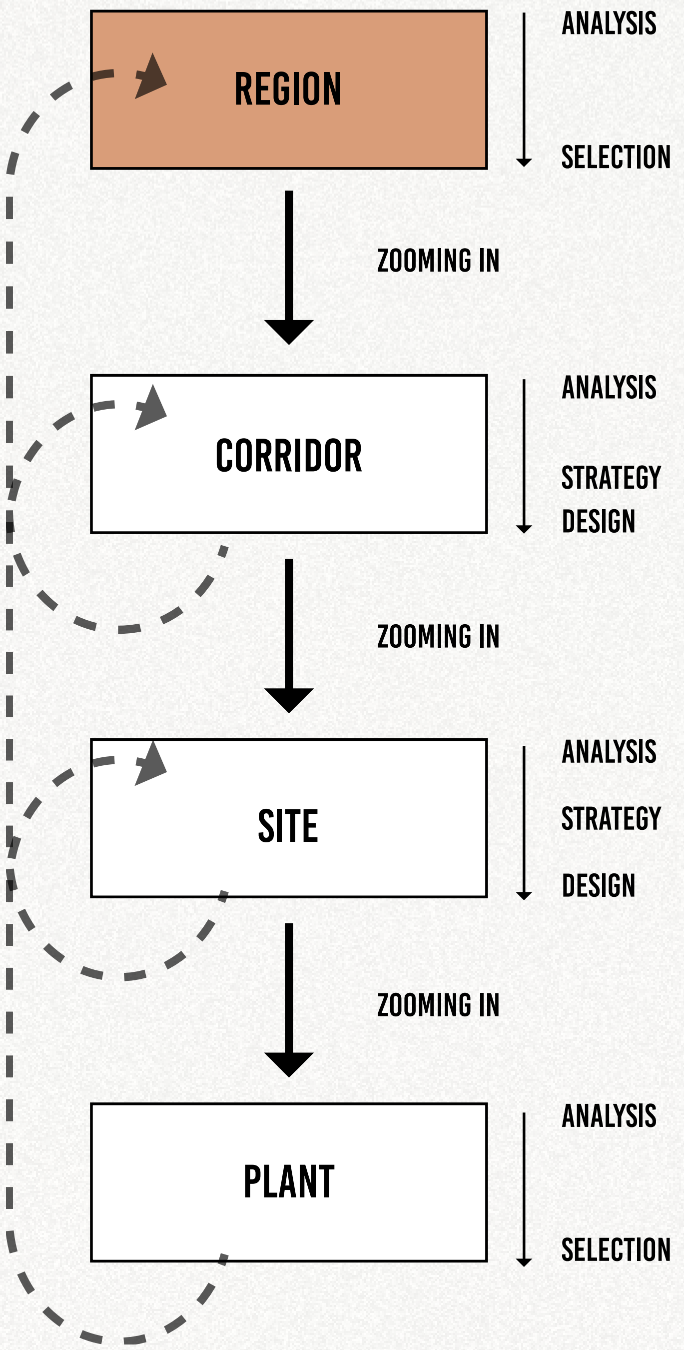


STUDY AREA OVERVIEW



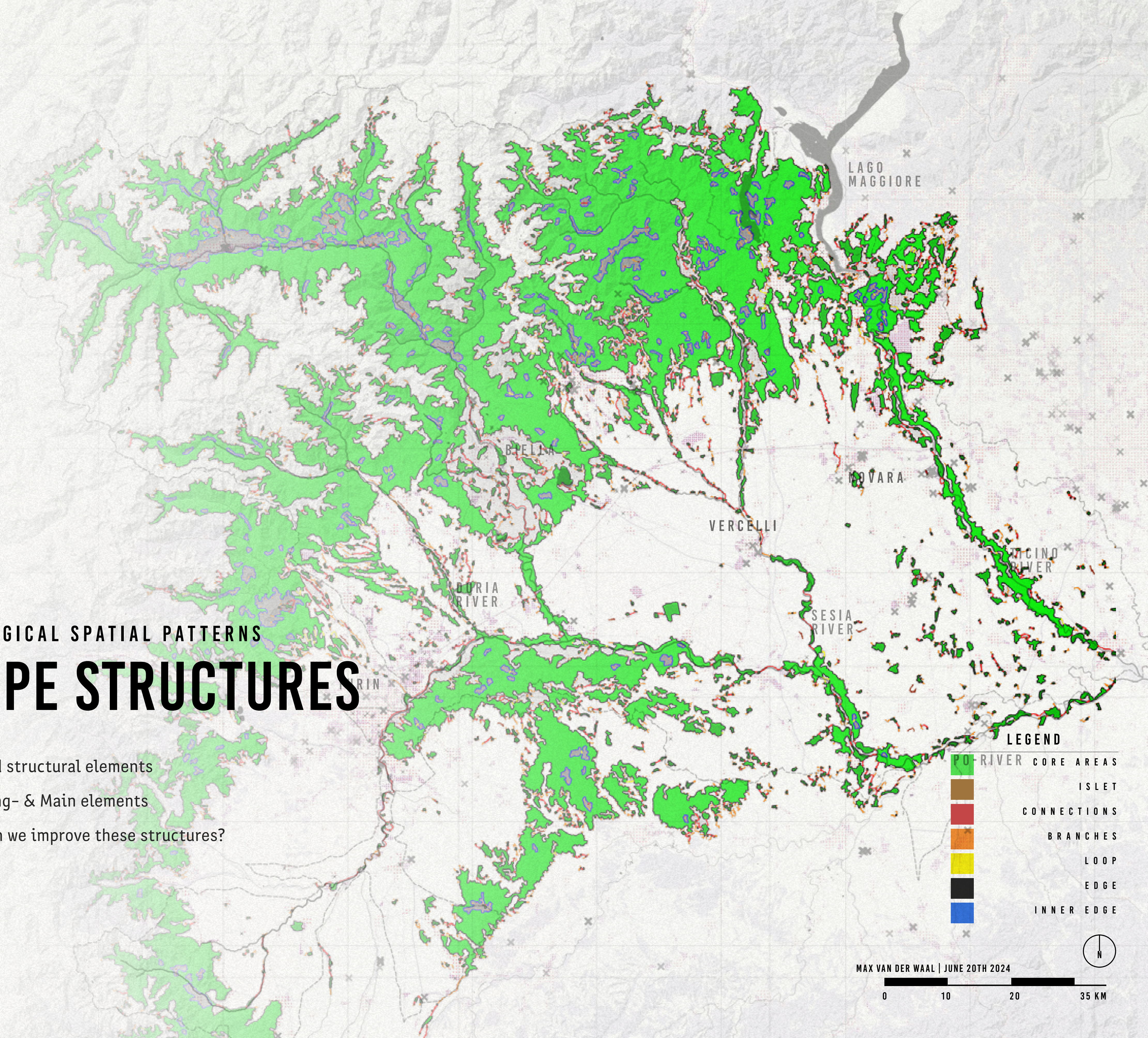
REGIONAL -SCALE

Where does new GI have the most impact?

MORPHOLOGICAL SPATIAL PATTERNS

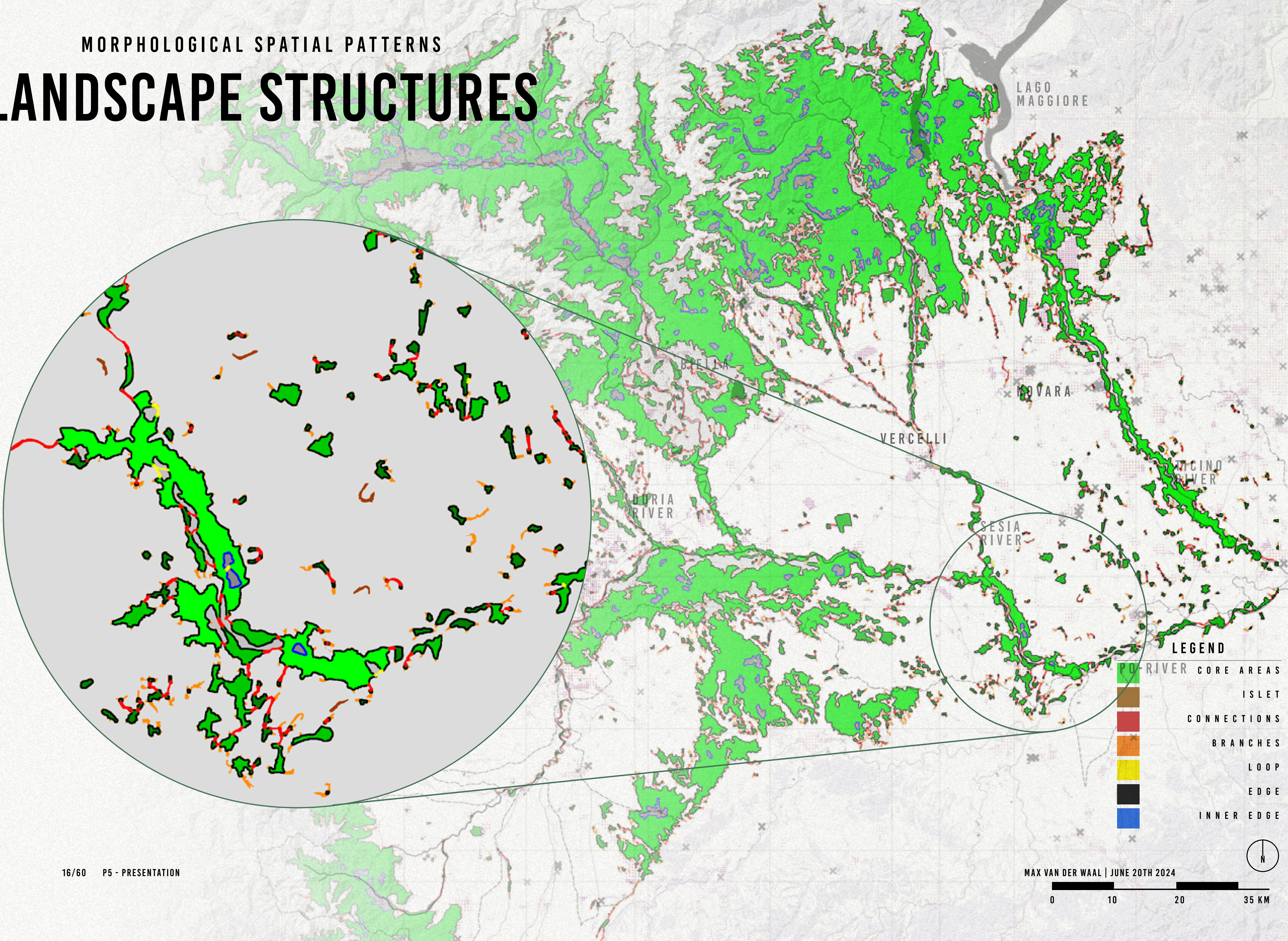
LANDSCAPE STRUCTURES

- Classified structural elements
- Connecting- & Main elements
- Where can we improve these structures?



MORPHOLOGICAL SPATIAL PATTERNS

LANDSCAPE STRUCTURES



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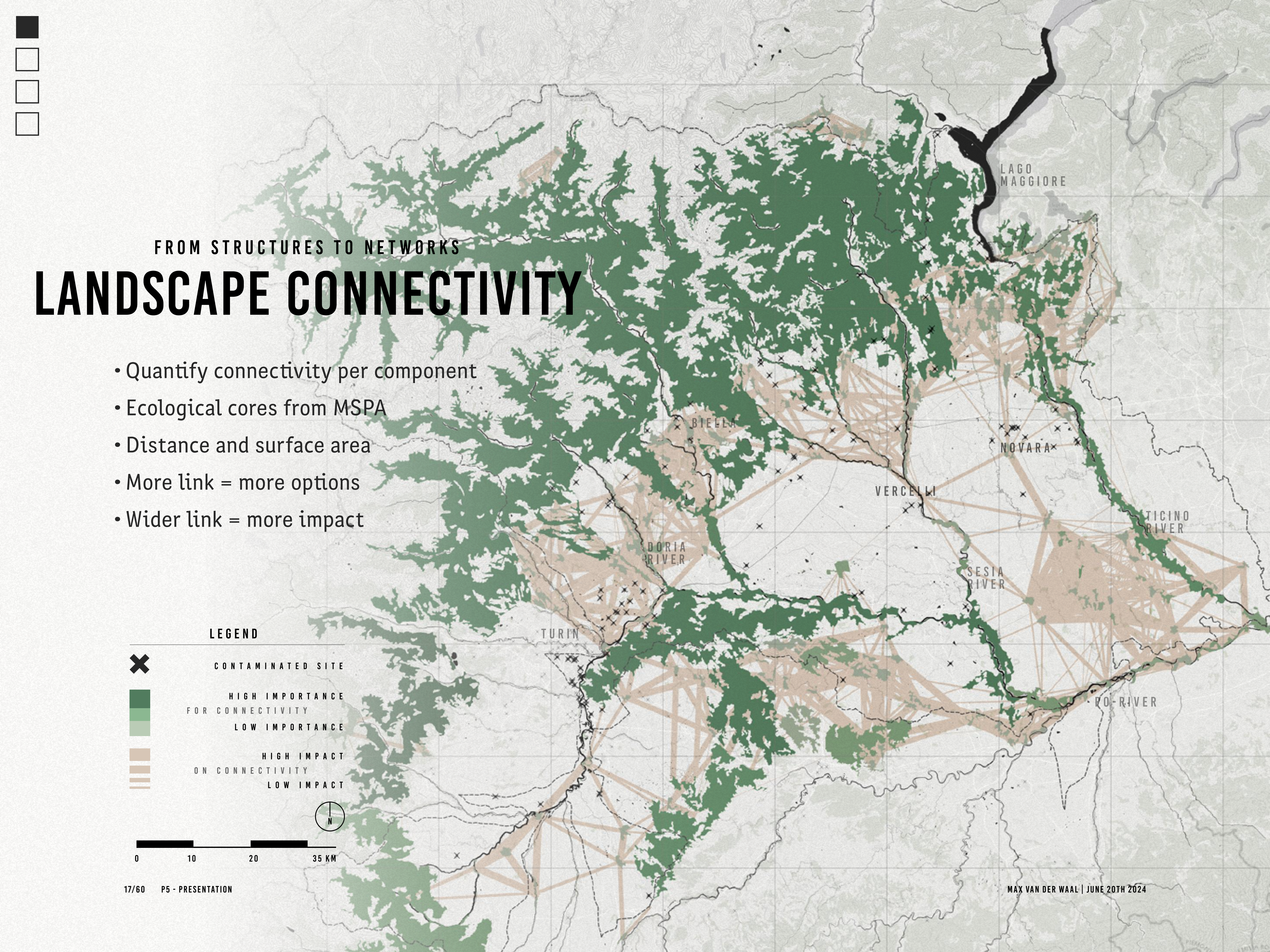
FROM STRUCTURES TO NETWORKS

LANDSCAPE CONNECTIVITY

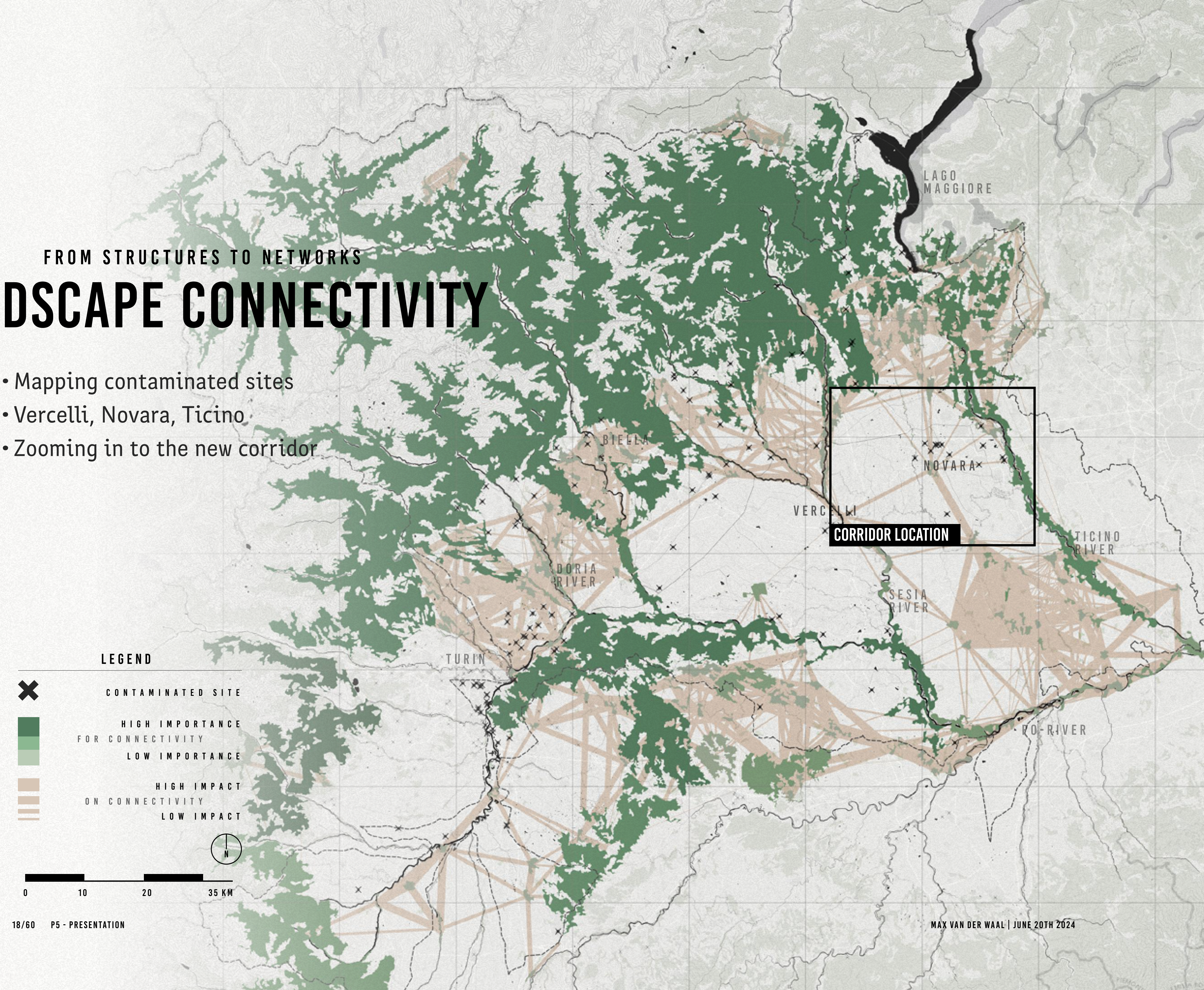
- Quantify connectivity per component
- Ecological cores from MSPA
- Distance and surface area
- More link = more options
- Wider link = more impact

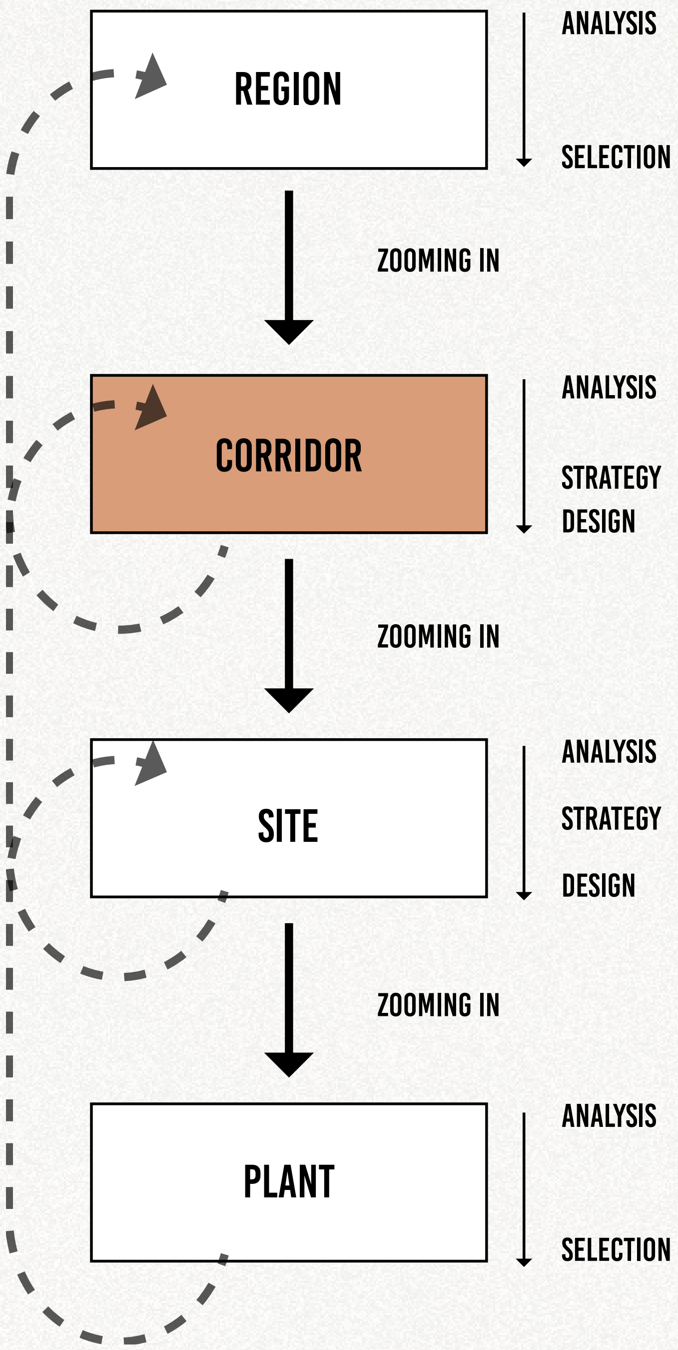


FROM STRUCTURES TO NETWORKS

LANDSCAPE CONNECTIVITY

- Mapping contaminated sites
- Vercelli, Novara, Ticino
- Zooming in to the new corridor



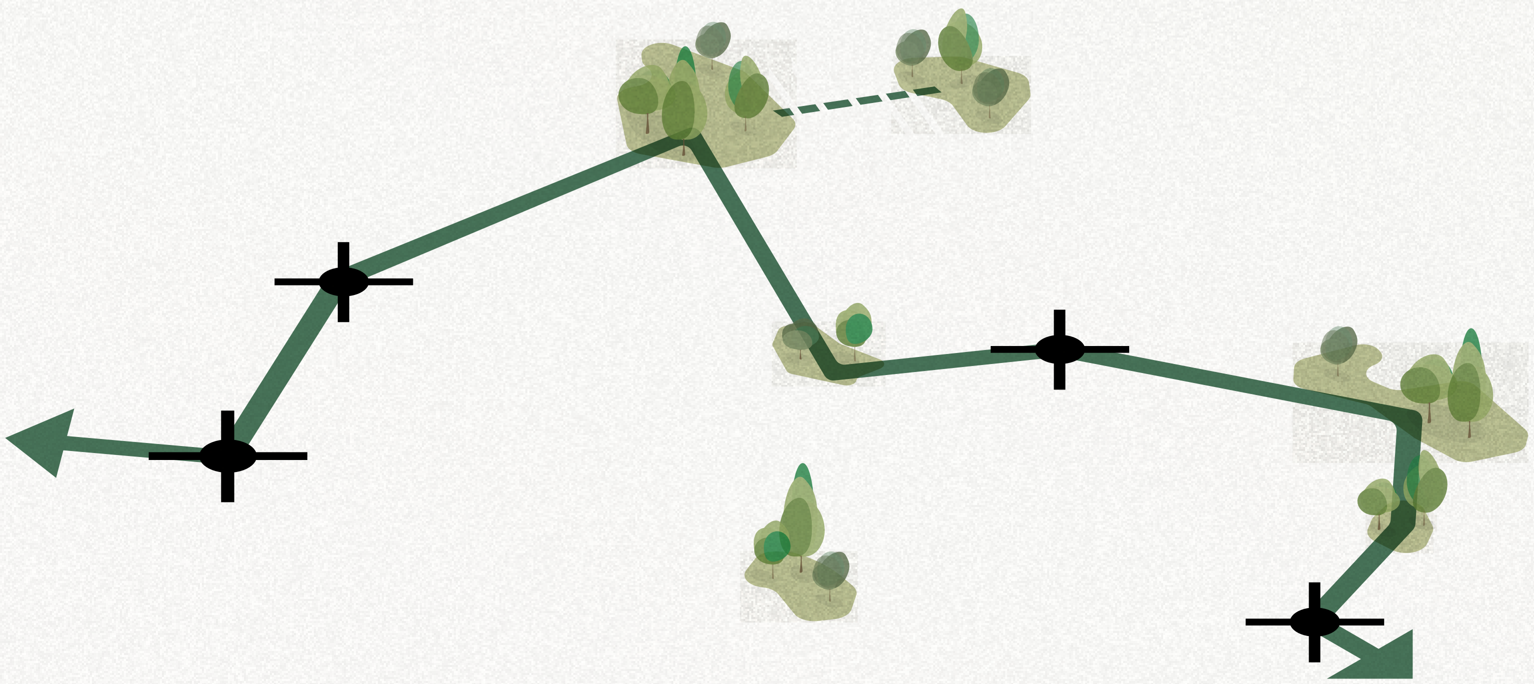


CORRIDOR -SCALE

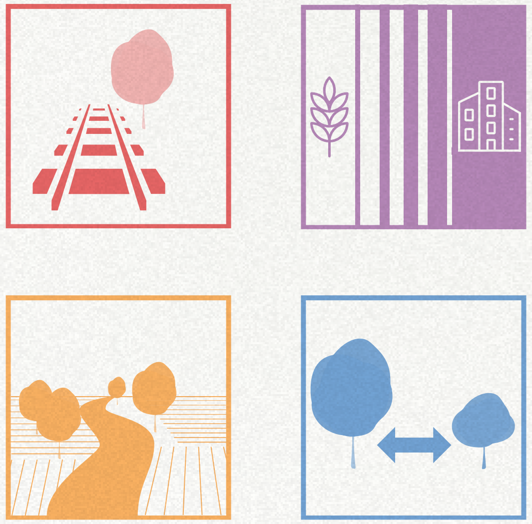
How to design the corridor to optimize ecological impact?

CORRIDOR LOCATION

CONNECT THE DOTS

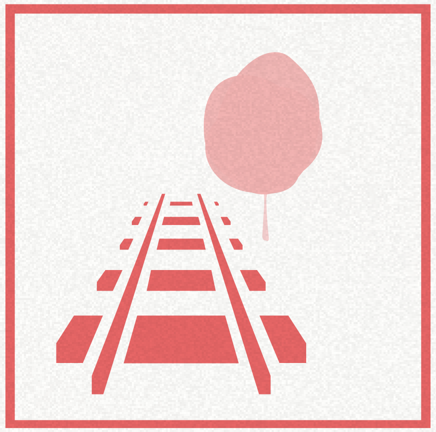


- Between ecological cores
- Remediation sites
- Include existing green elements whenever possible



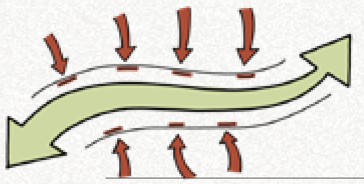
FOUR

DESIGN STRATEGIES

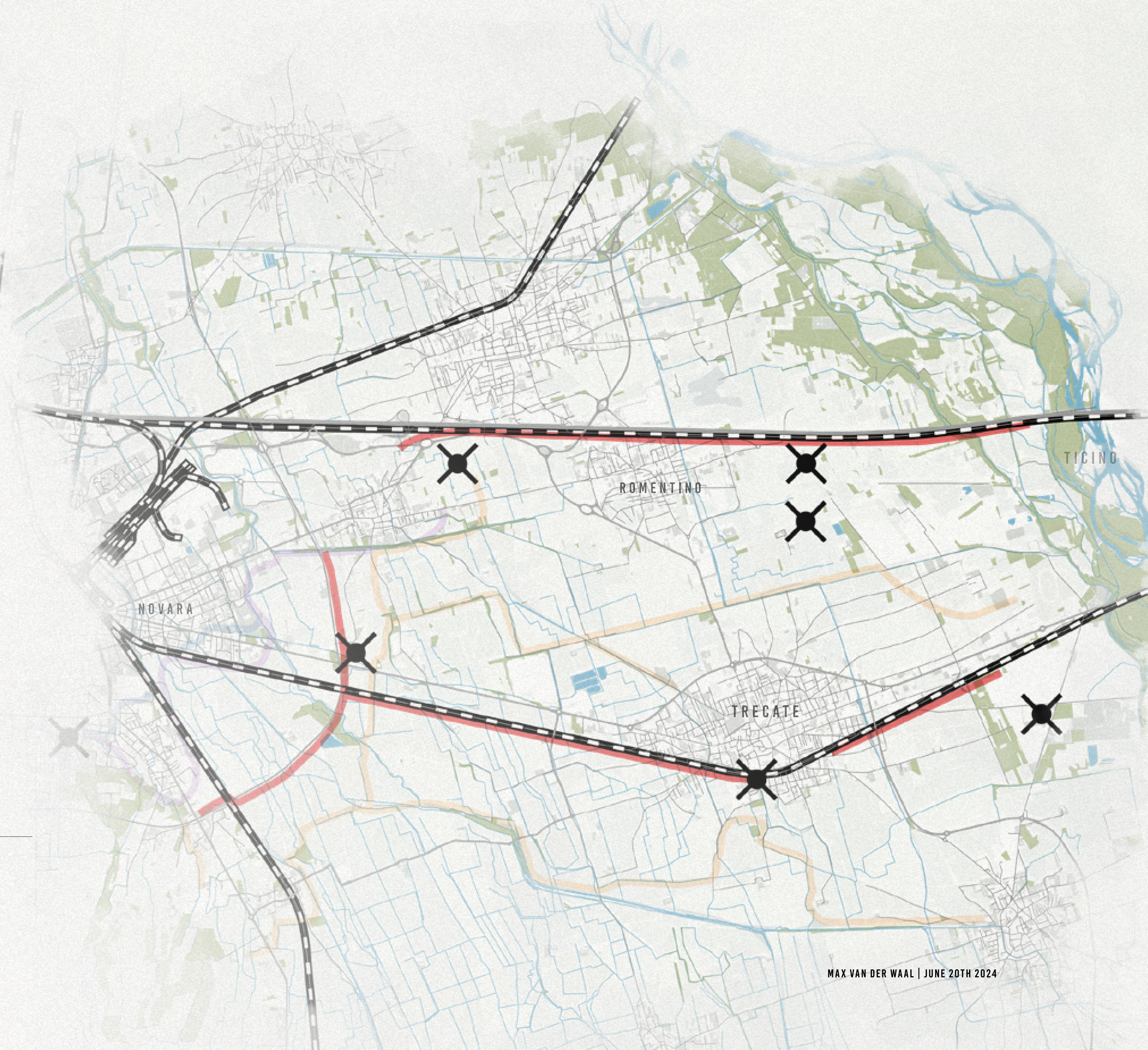


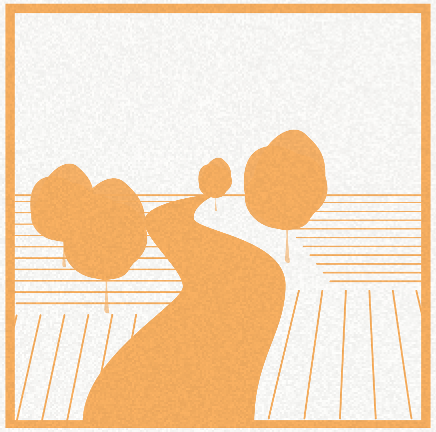
GUIDED BY LINEAR
GRAY INFRASTRUCTURE

- Spatially guiding
- Vegetation buffer
- Improving quality of the landscape behind



BUFFERING

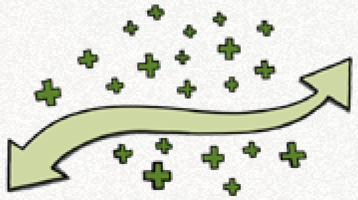




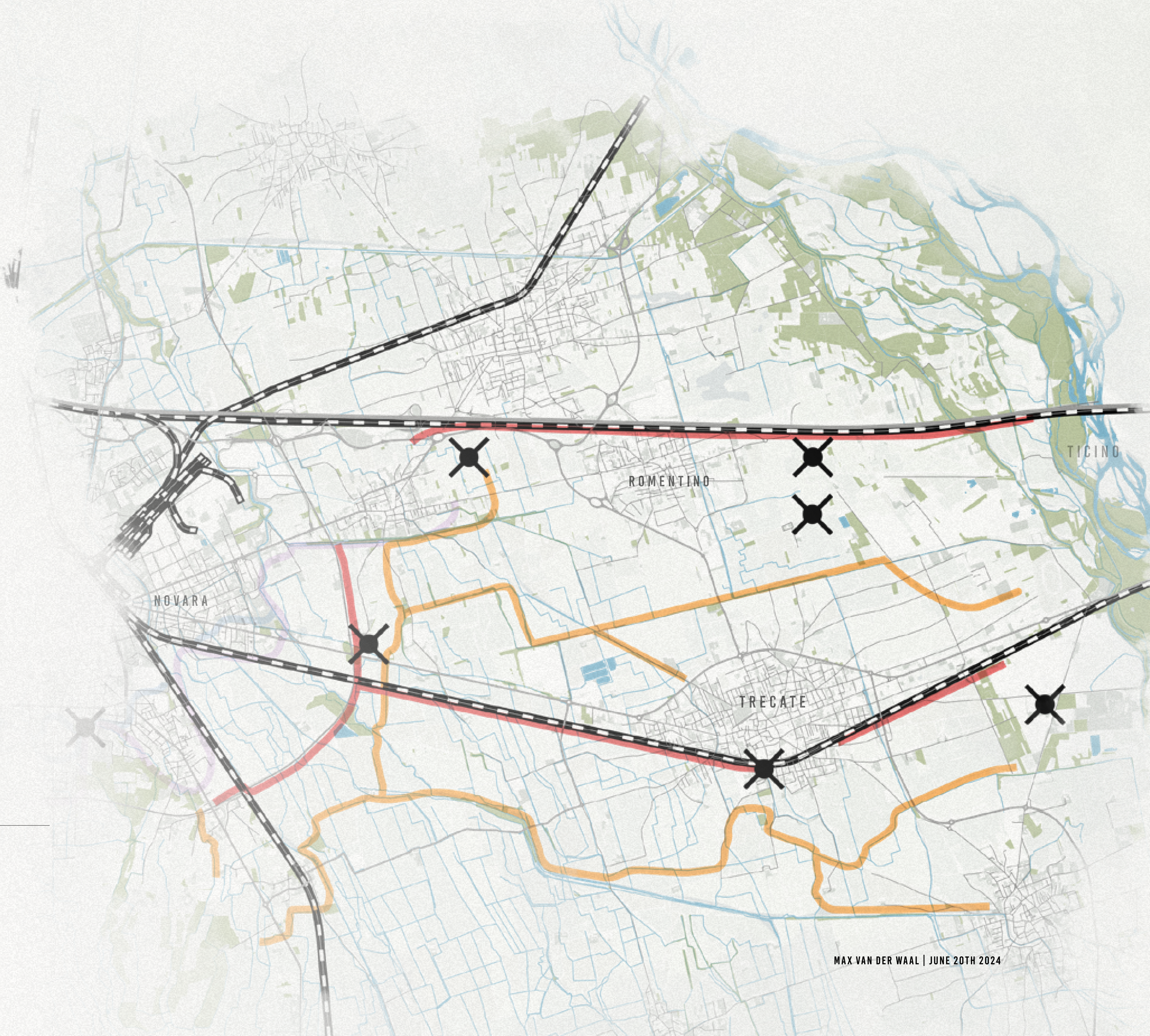
STAYING MOSTLY

LANDSCAPE CENTERED

- Minimal ecological resistance
- Pollination and ES provisioning
- Agriculture and Rural landscapes



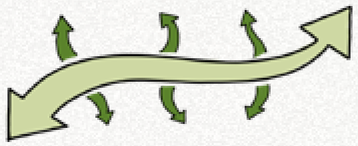
PROVIDING



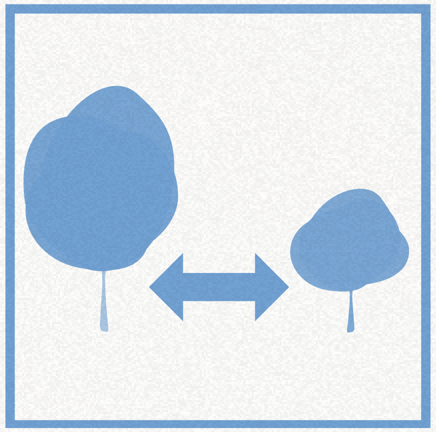
IMPROVING

RURAL-URBAN GRADIENTS

- Peri-urban spaces
- Reconnecting the city to the agricultural landscape
- Open landscape



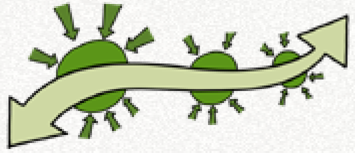
CONNECTING

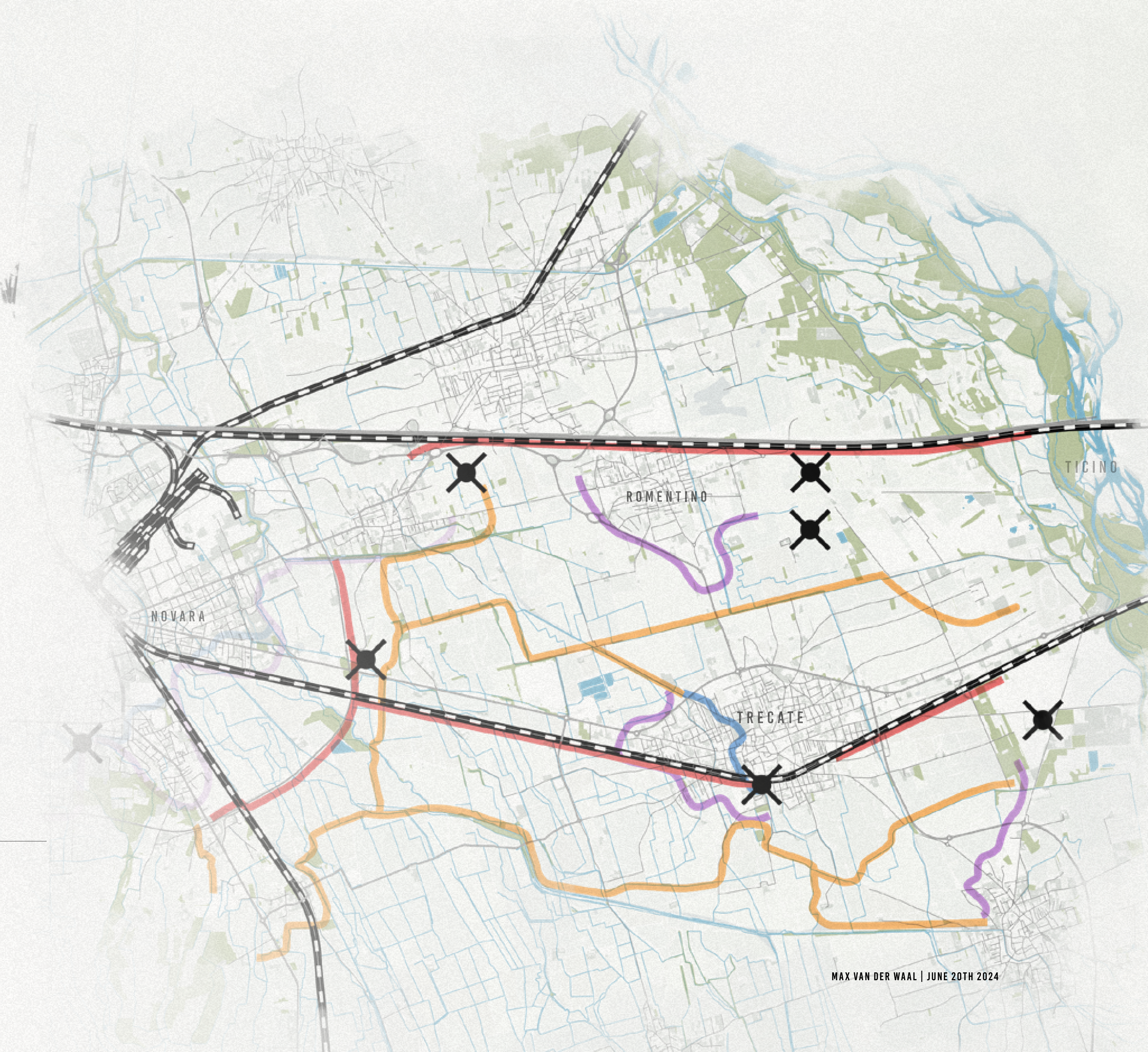


CONNECTING TO THE

URBAN GREEN STRUCTURES

- Going “through” the urban cores
- Valuable urban green spaces
- Urban biodiversity

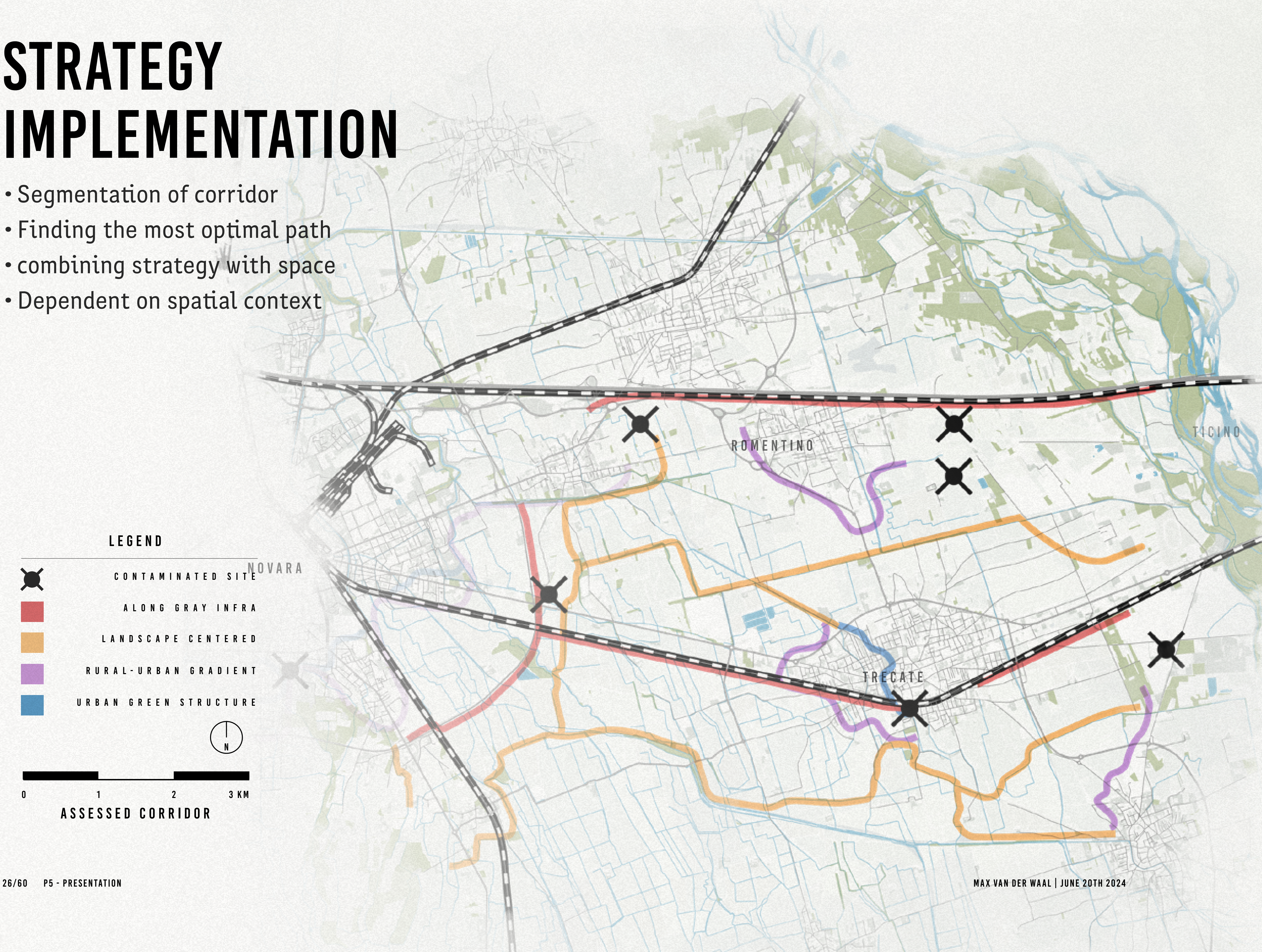




GATHERING

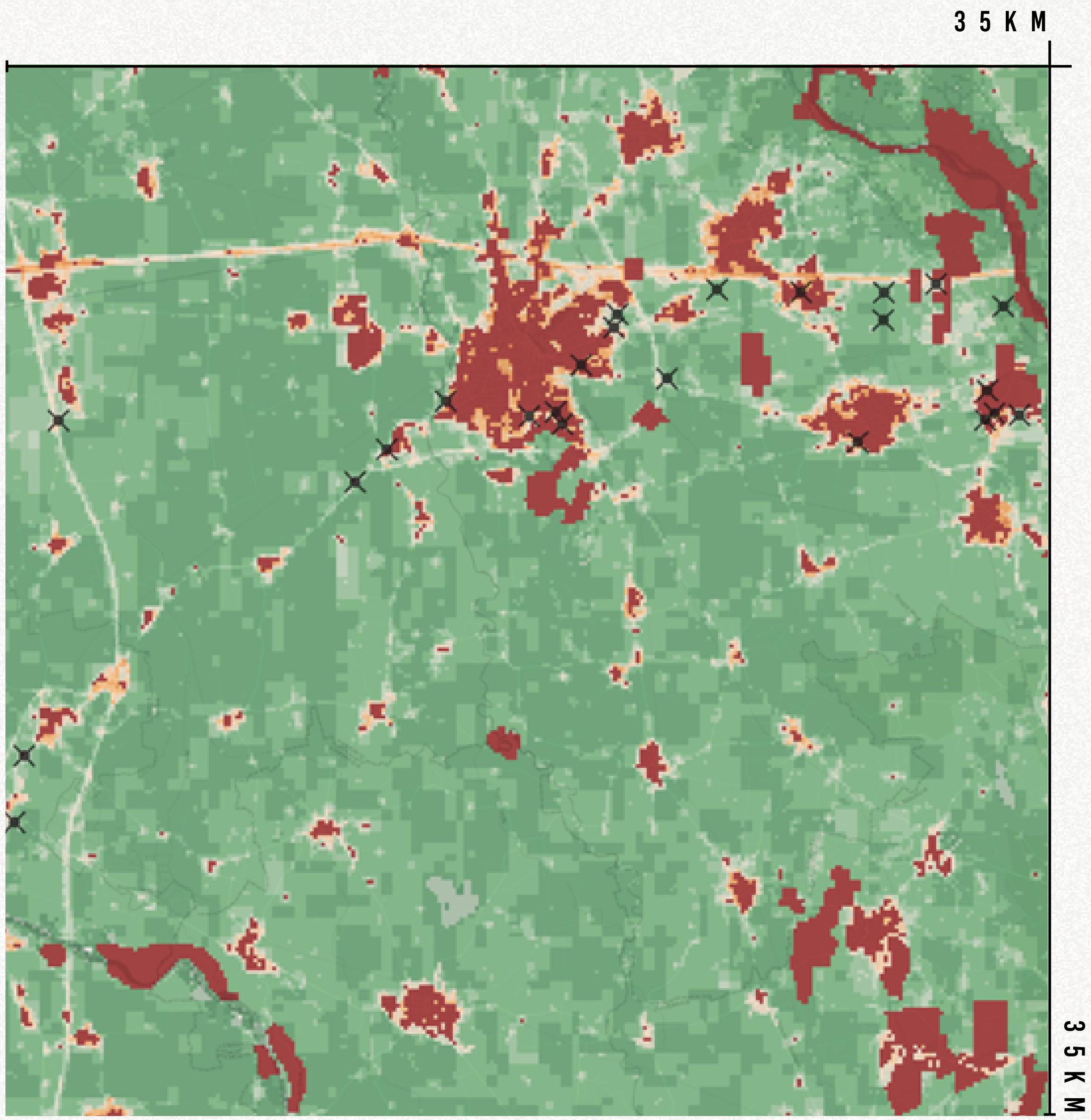
STRATEGY IMPLEMENTATION

- Segmentation of corridor
- Finding the most optimal path
- combining strategy with space
- Dependent on spatial context

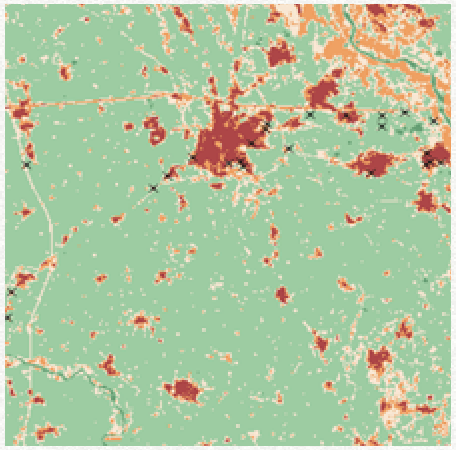


ASSESSING THE STRATEGIES

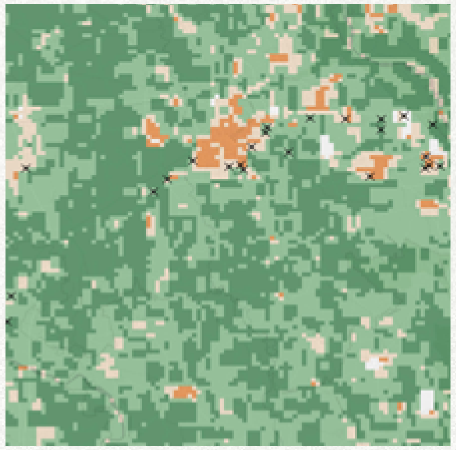
SUPPORTING CONNECTIVITY AND WILDLIFE MOVEMENT



CUMULATIVE ECOLOGICAL RESISTANCE SURFACE MAP



NORMALIZED
BUILT UP-INDEX



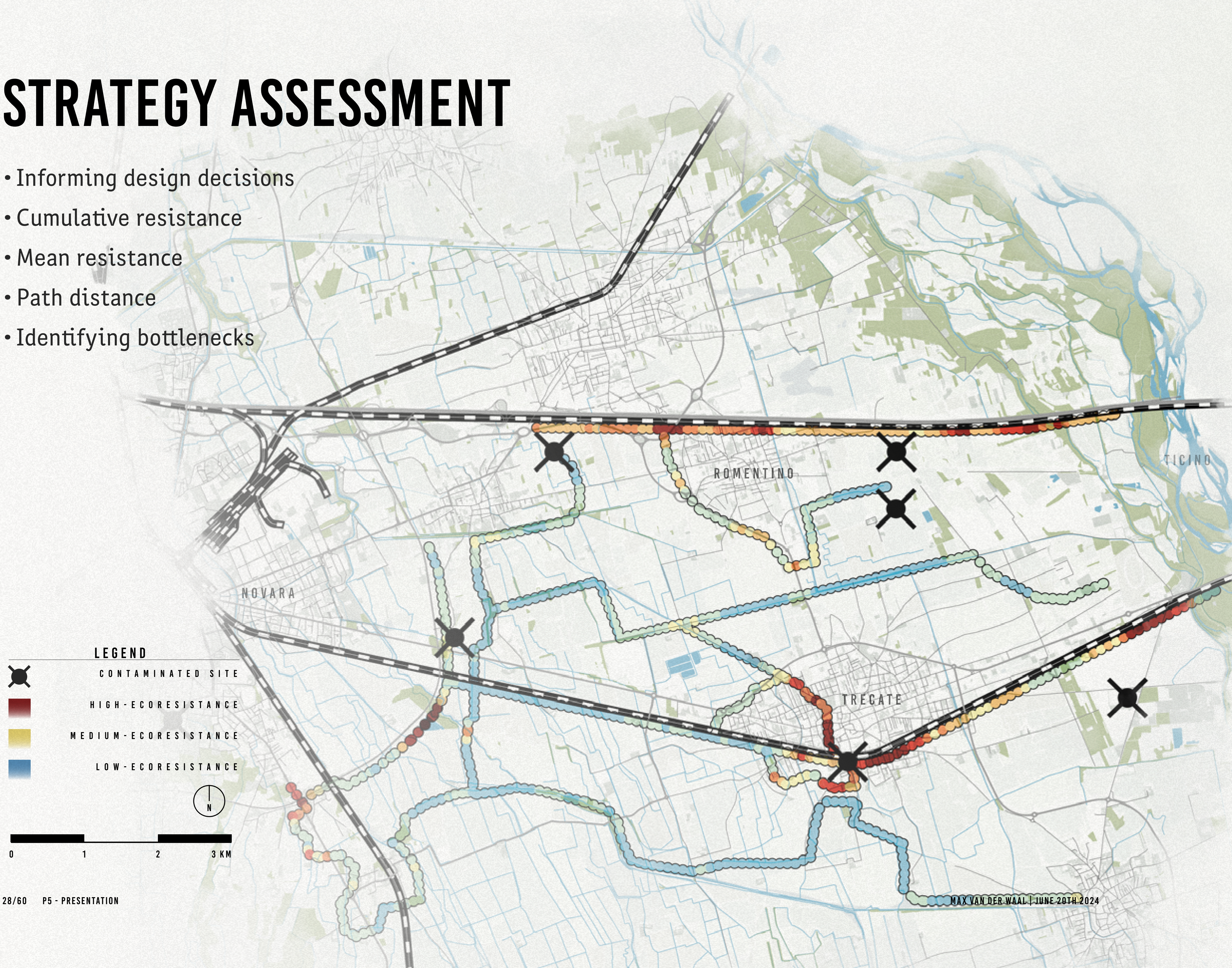
NORMALIZED
VEGETATION DENSITY

NORMALIZED
ROAD DENSITY

CLASSIFIED
LAND-USE/LAND-COVER

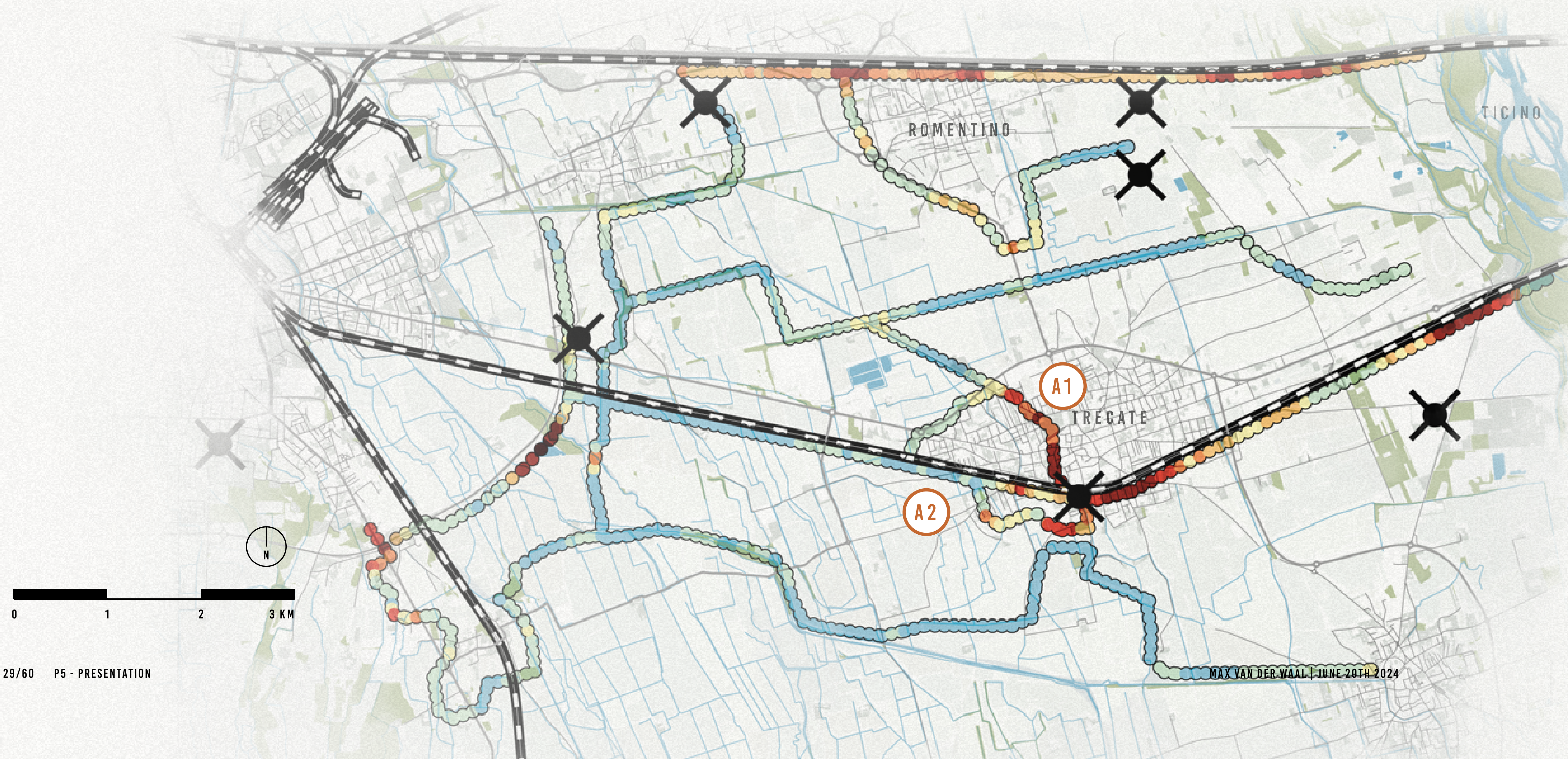
STRATEGY ASSESSMENT

- Informing design decisions
- Cumulative resistance
- Mean resistance
- Path distance
- Identifying bottlenecks



STRATEGY ASSESSMENT

Strategy A.1 – Urban Green Structure			Strategy A.2 – Urban-Rural Gradient
Cumulative resistance	92.5	145.0	Cumulative resistance
Mean resistance	4.0	2.7	Mean resistance
Median resistance	4.1	2.4	Median resistance
Overall distance	2,314 meter	5,369 meter	Overall distance



STRATEGY ASSESSMENT

- Informing design decisions
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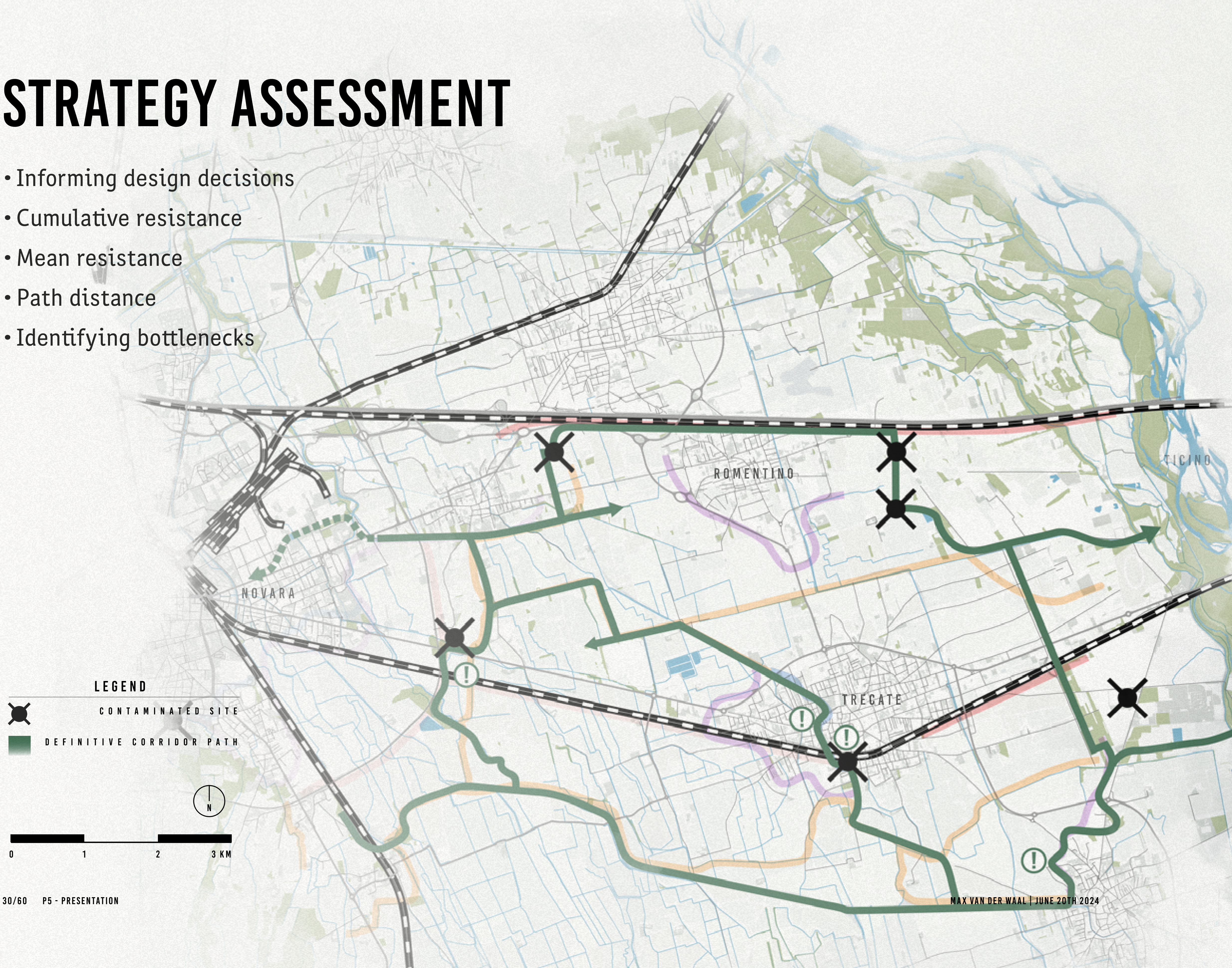
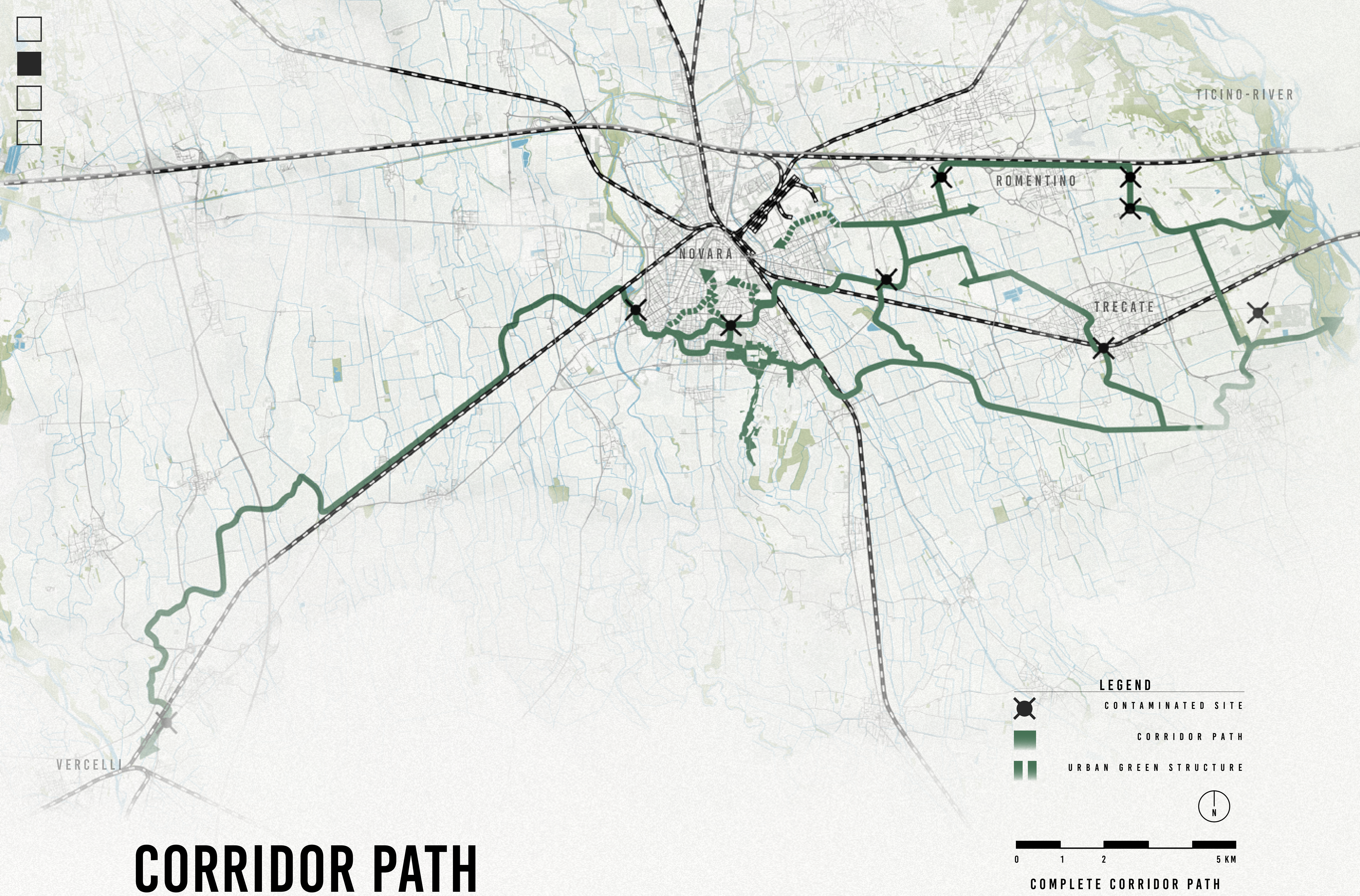
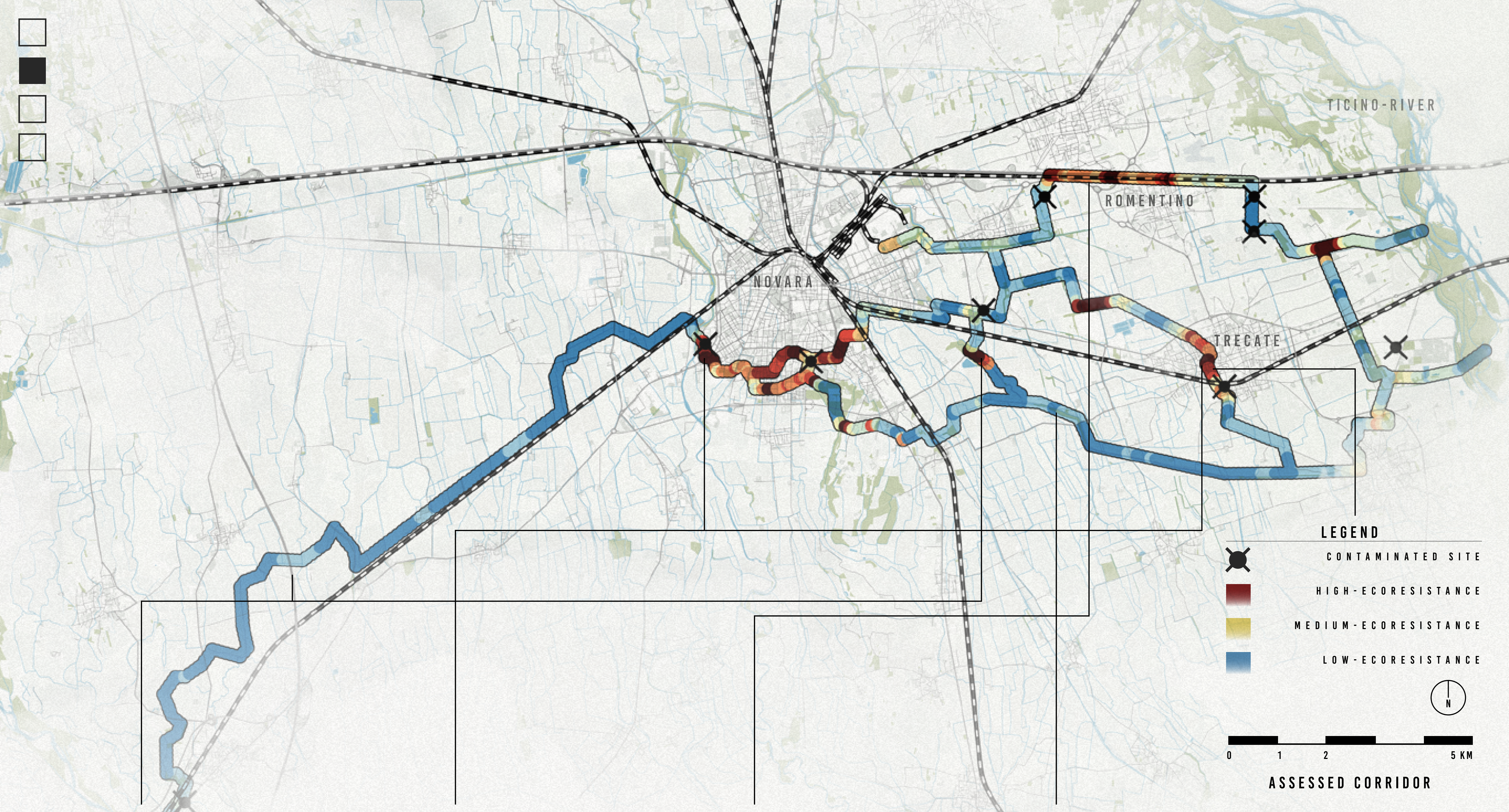




CORRIDOR PATH

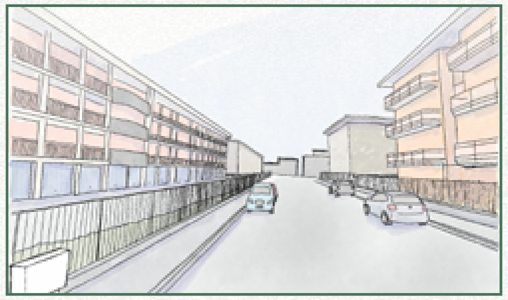


LINEAR-PERPENDICULAR

CROSSING INFRASTRUCTURES

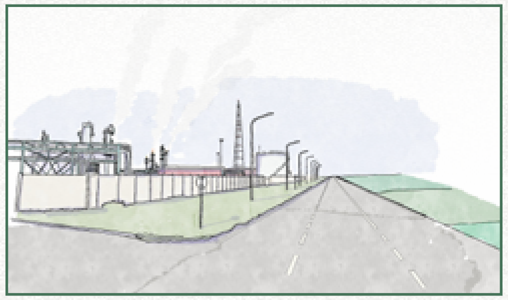
LINEAR-LONGITUDINAL

GRAY STREET PROFILES



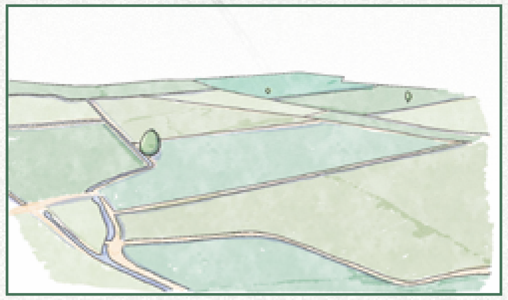
PATCH

INDUSTRIAL CLUSTERS



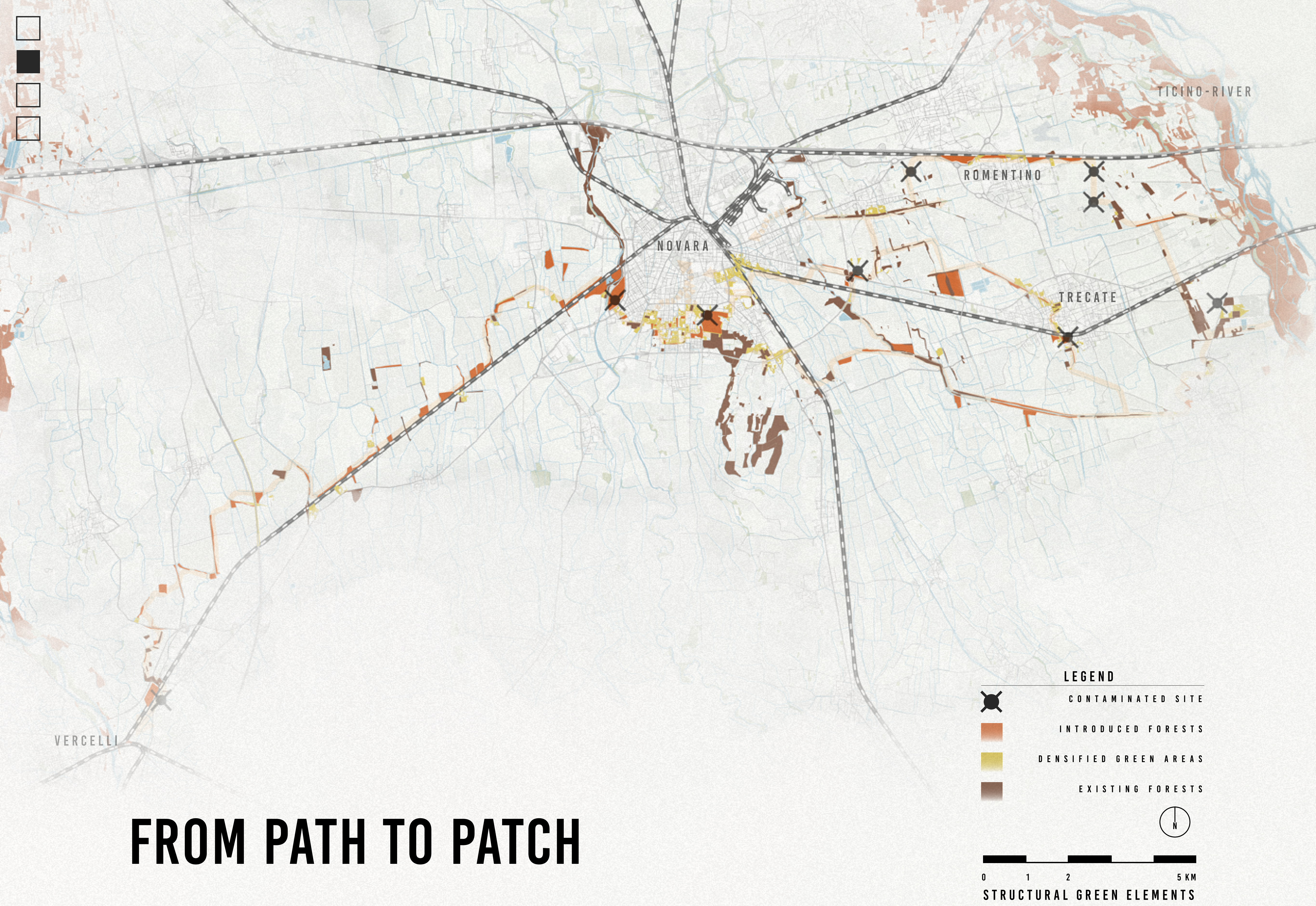
PATCH

MONOCULTURAL LANDSCAPES

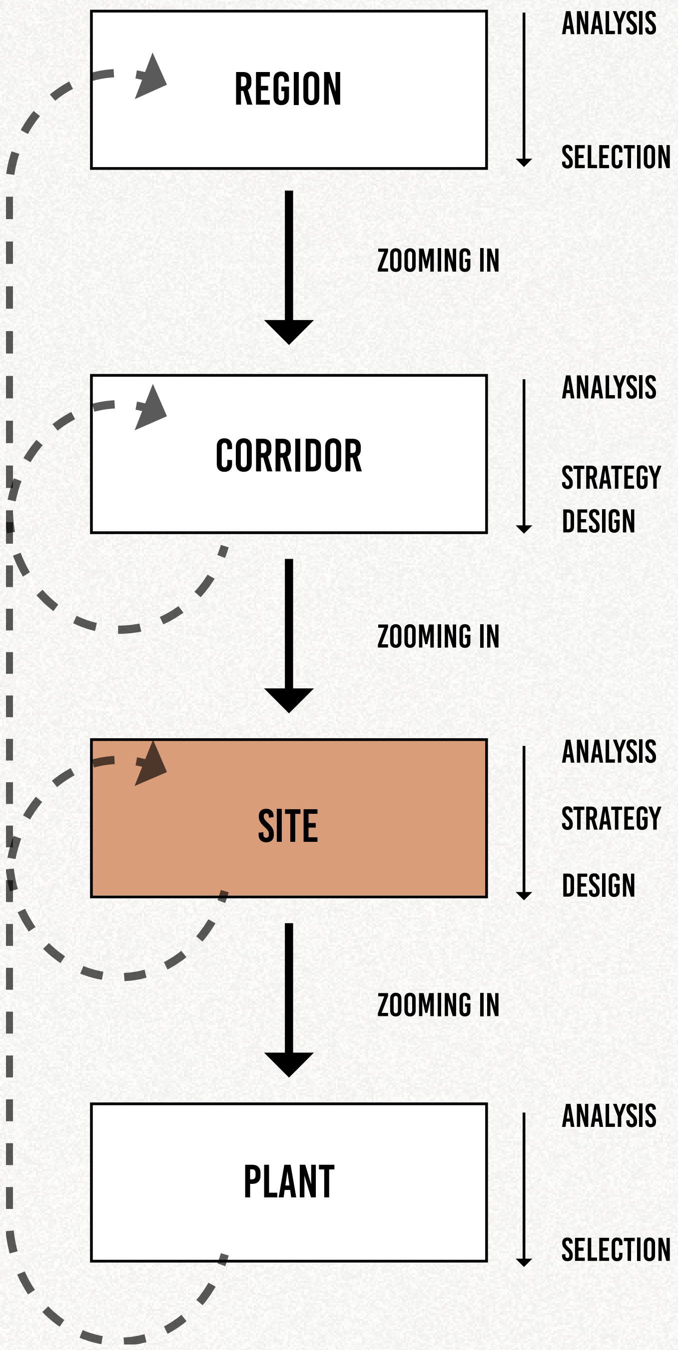


MICRO-PATCH

NON-ECOLOGICAL GREEN



FROM PATH TO PATCH



SITE-SCALE

How to redesign these sites while including space for phytoremediation?

REDESIGNING CONTAMINATED SITES

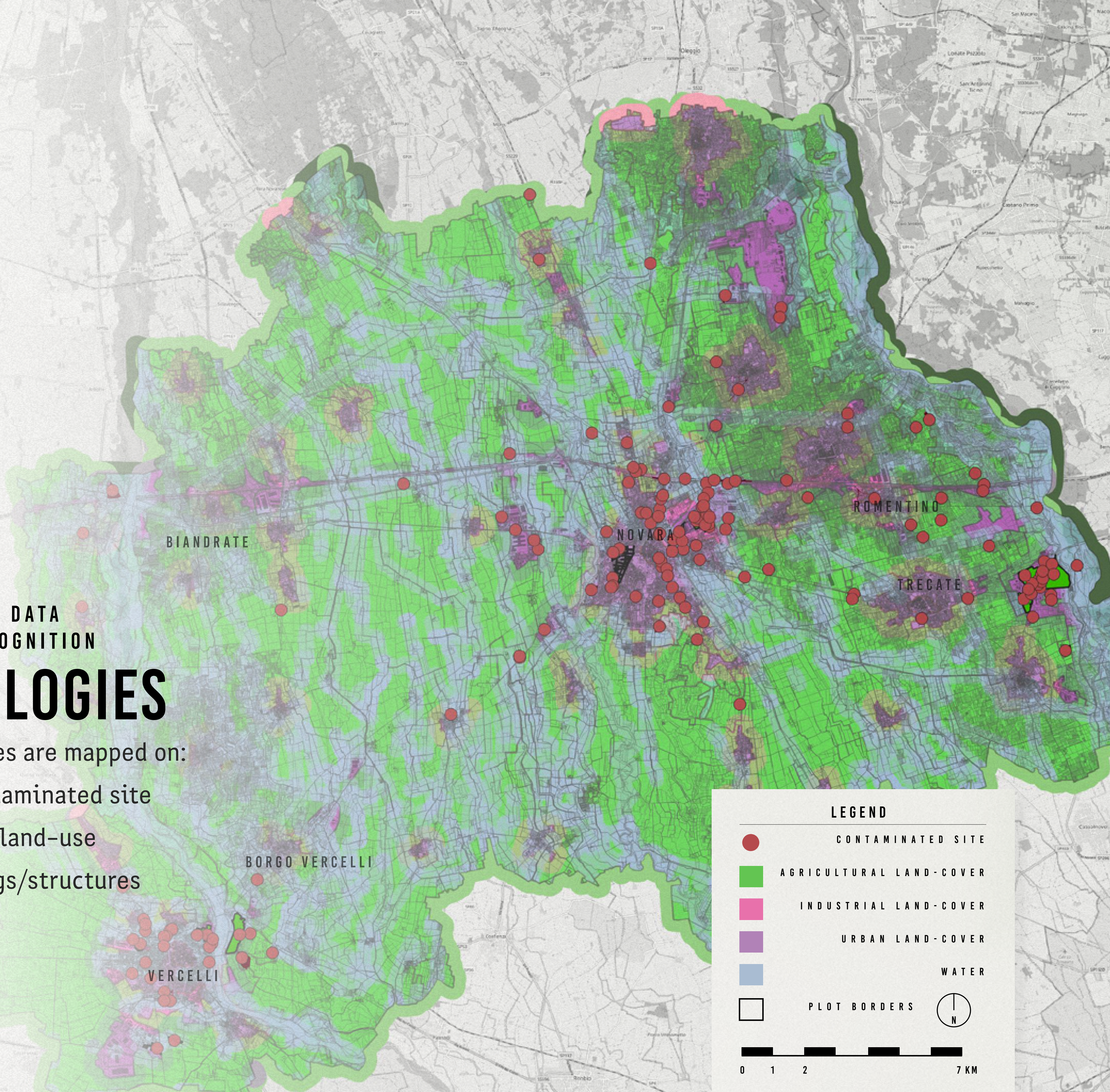
INTEGRATION OF CONTAMINATION

USING SPATIAL DATA
FOR PATTERN RECOGNITION

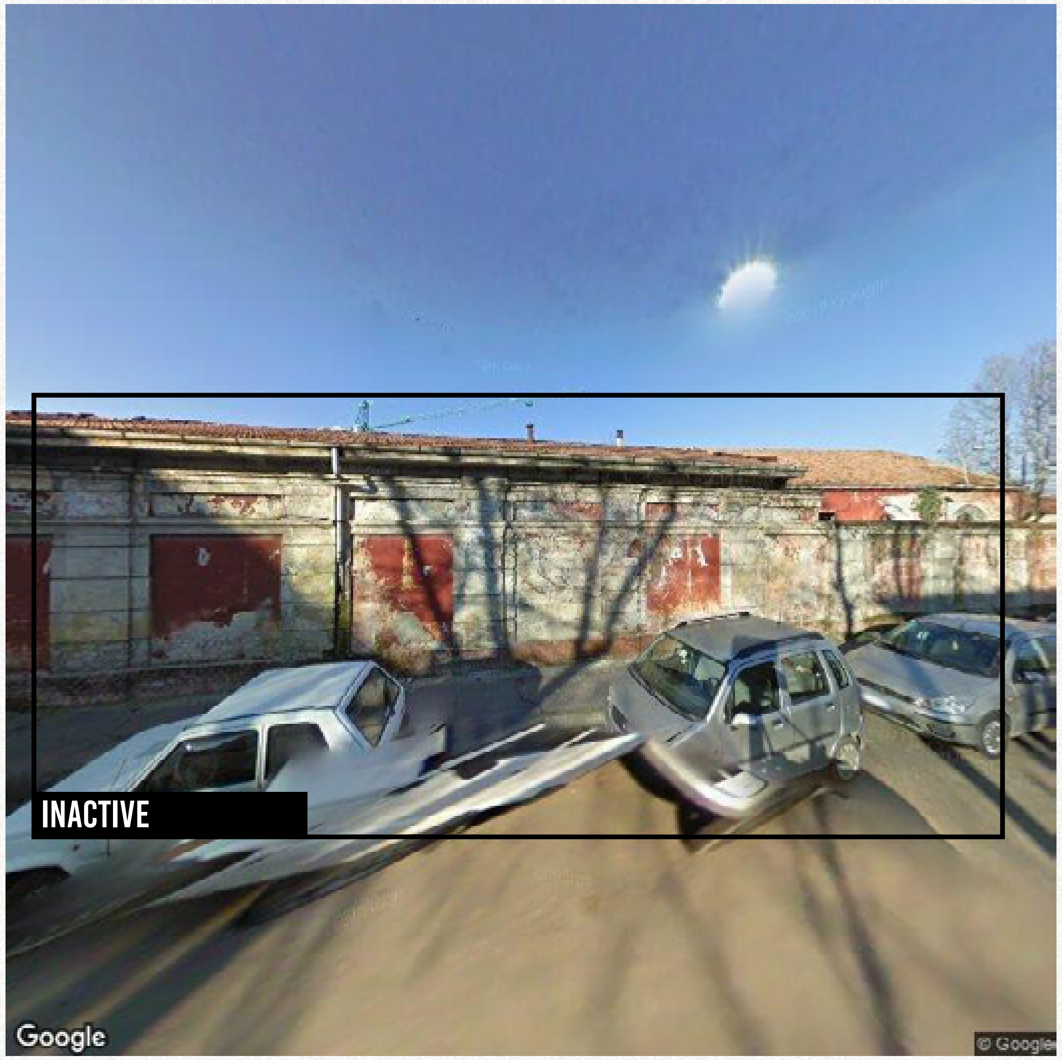
SITE TYPOLOGIES

171 contaminated sites are mapped on:

- Surface area of contaminated site
- Spatial context and land-use
- presence of buildings/structures
- State of operability



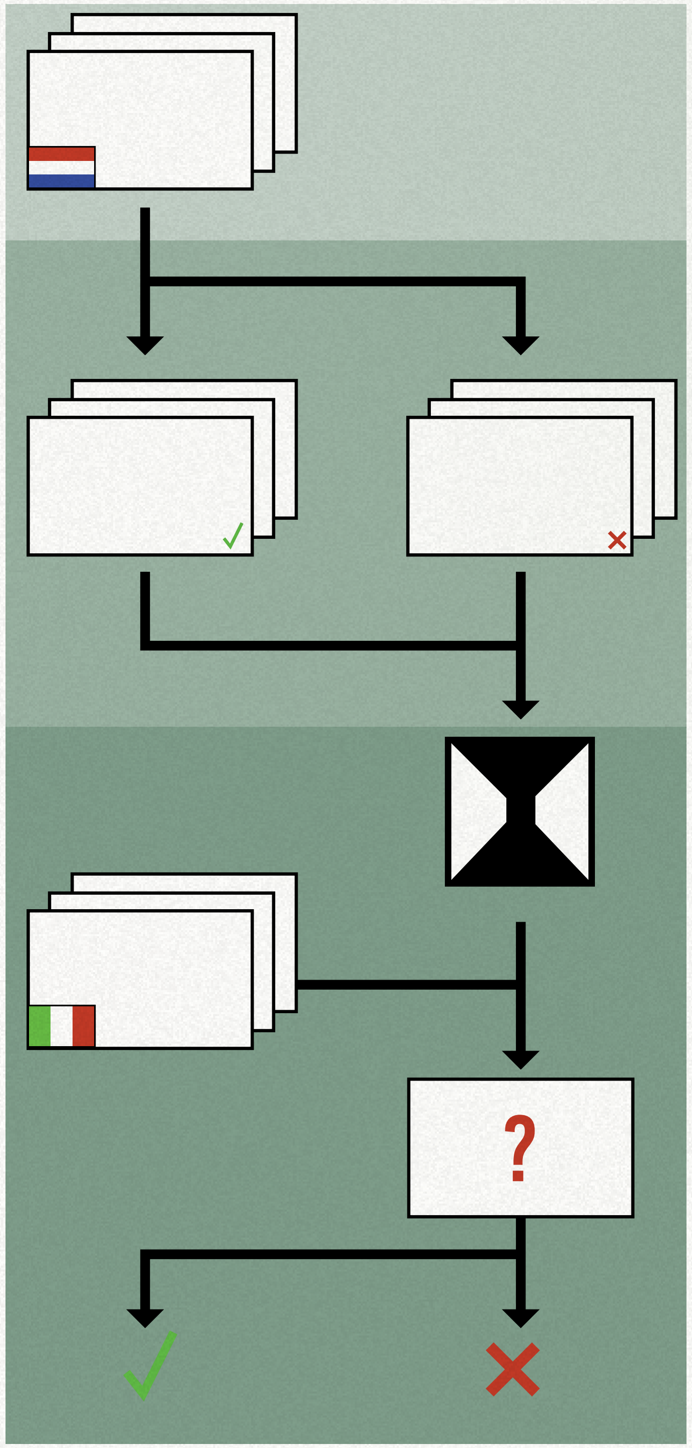
MAKING USE OF NEURAL NETWORKS

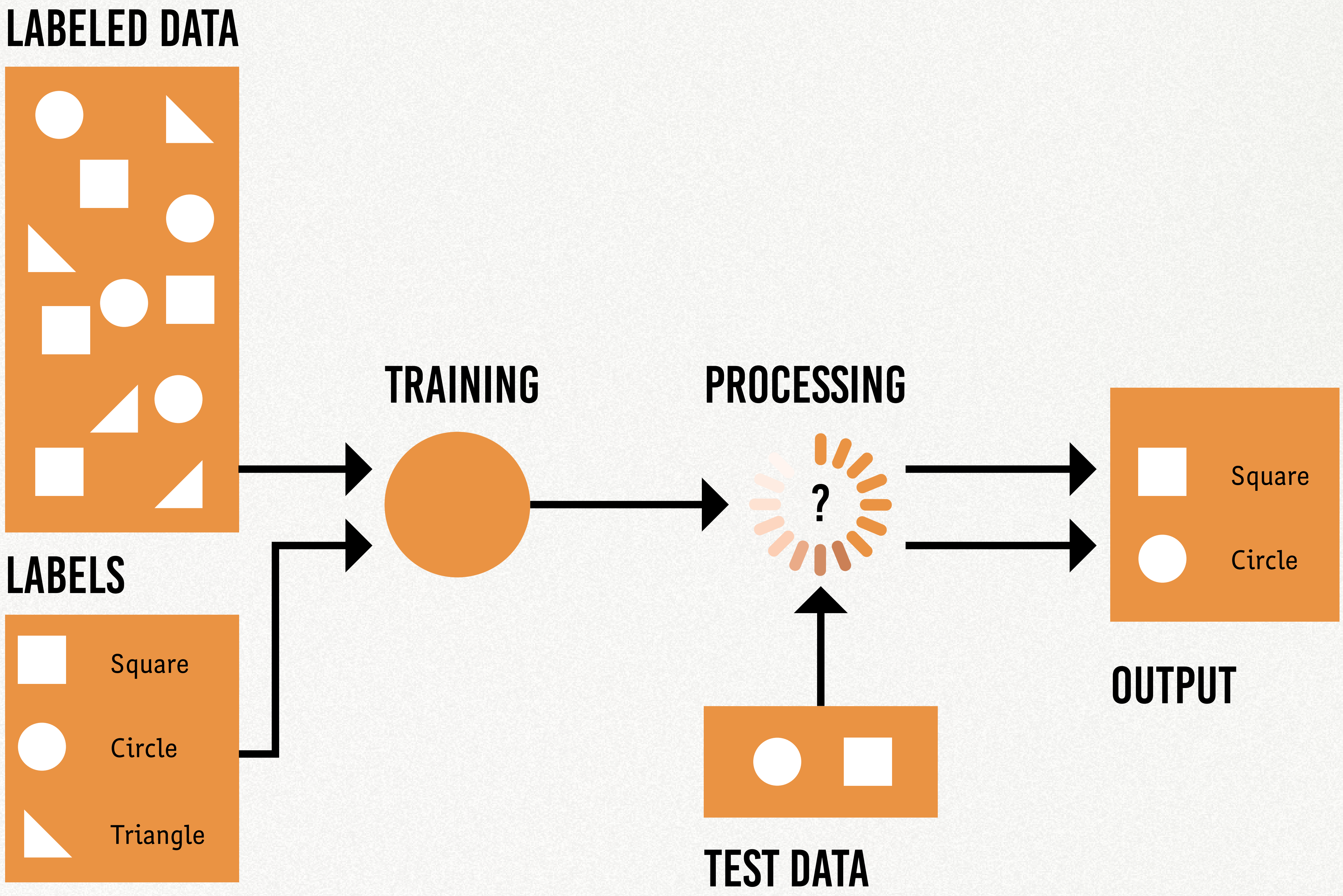


Using machine learning and convolutional neural networks, we can overcome data gaps, by using similar data from other locations and contexts to predict the values for our actual research area.

LEFT: OUTPUT OF THE NEURAL NETWORK COMPARED TO THE INPUT IMAGE, EXEMPLARY CASE OF AN INOPERABLE BUILDING IN NOVARA-NORTH

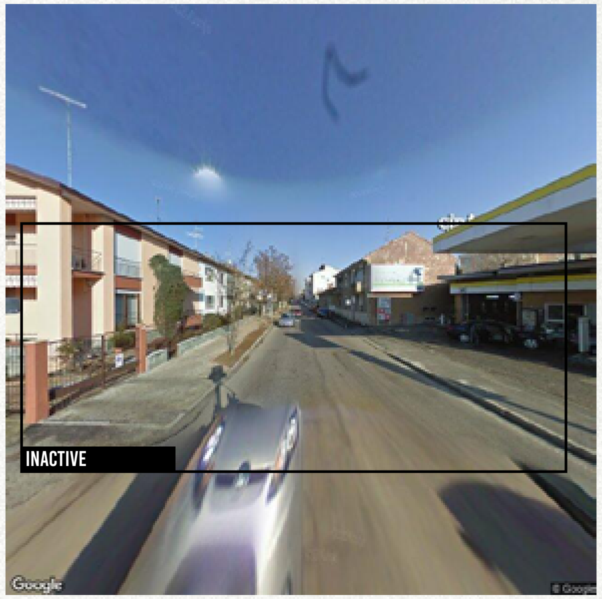
RIGHT: SCHEMATIC DIAGRAM OF THE NEURAL NETWORK INVOLVING TRAINING ON DATA FROM DUTCH CASES



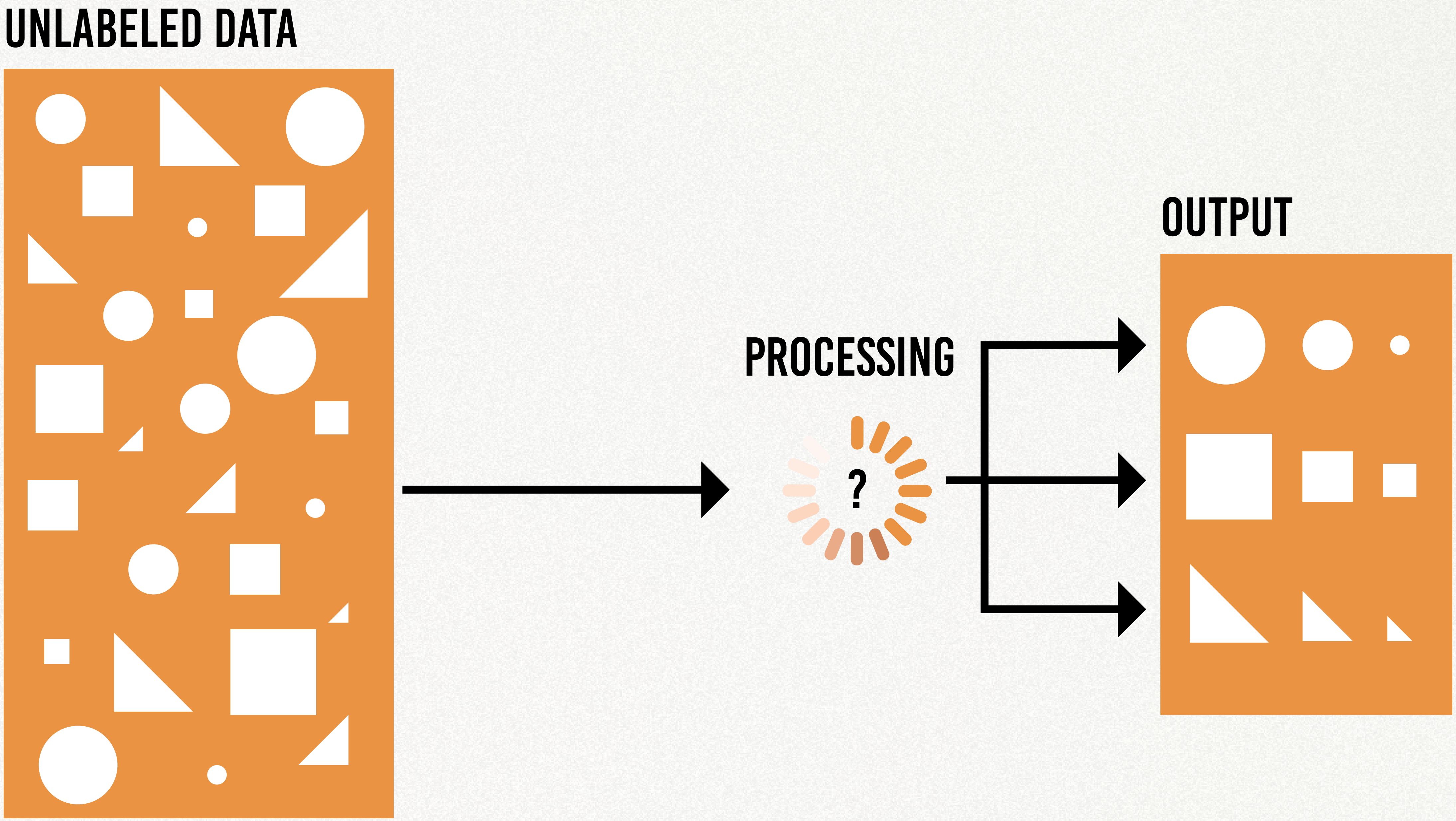

LABELED DATA
LABELS
Square
Circle
Triangle
TRAINING
PROCESSING
?
TEST DATA
OUTPUT
Square
Circle

MAKING USE OF NEURAL NETWORKS

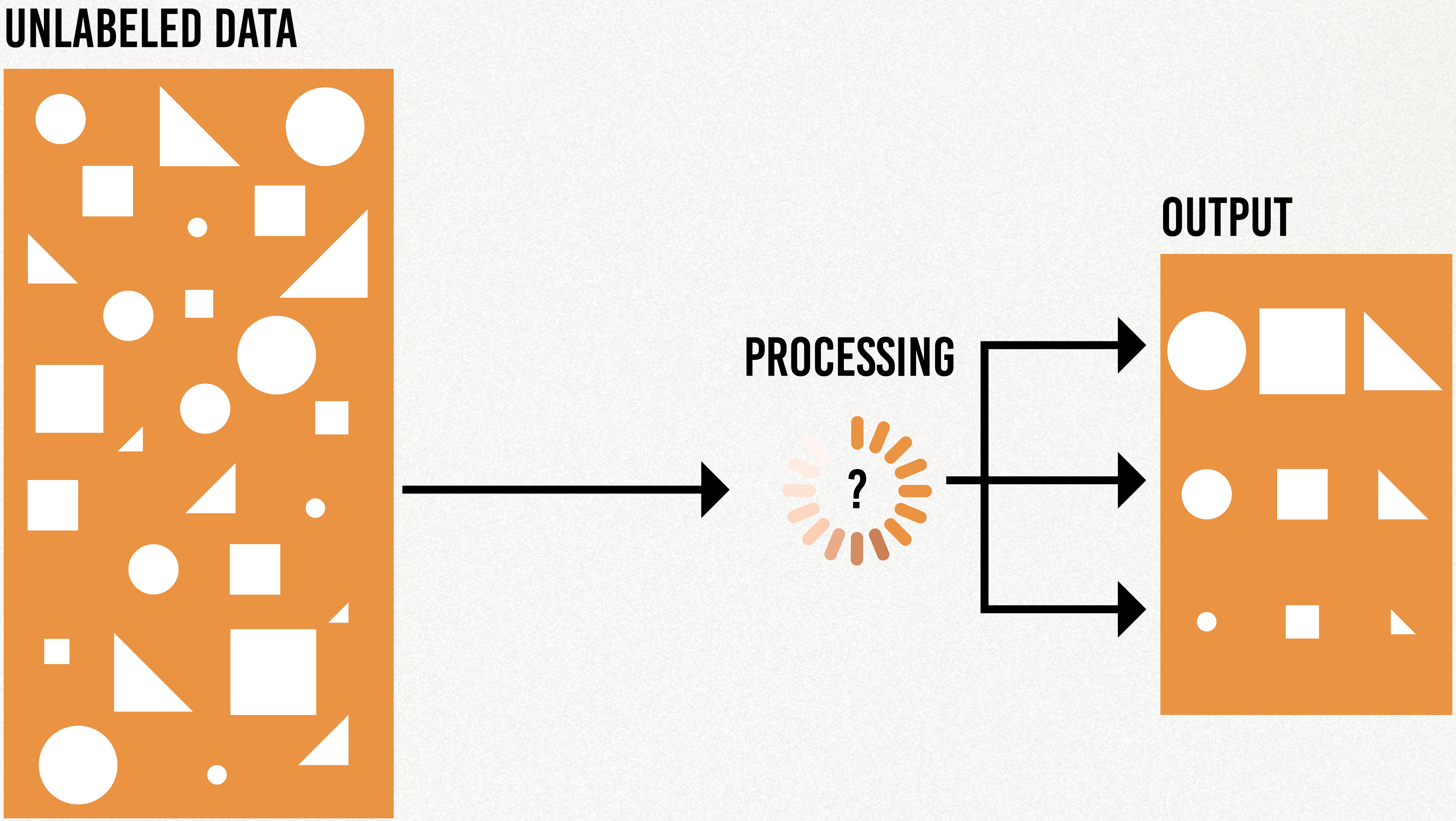
- Cultural and (geo)morphological differences between training and study area
- Inaccuracies in coordinates and locations
- Covered sites and locations
- Processing artifacts
- Site versus building
- Multiple buildings in frame



HOW TO CATEGORIZE?



HOW TO CATEGORIZE?



K-MEANS CLUSTERING

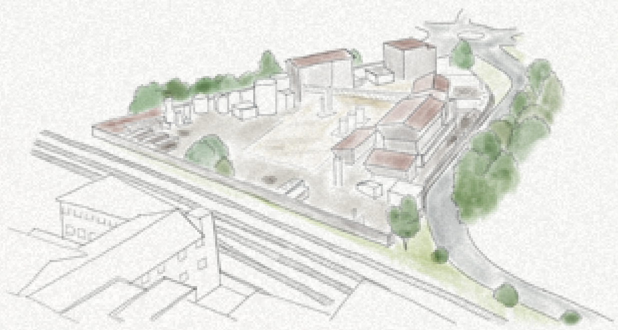
- Unsupervised machine learning algorithm
- 5 different clusters, based on 4 different criteria
- Categorizes the sites in the study area
- Results can be transferred to other contexts, but new typologies can emerge

RESULTS SUMMARY

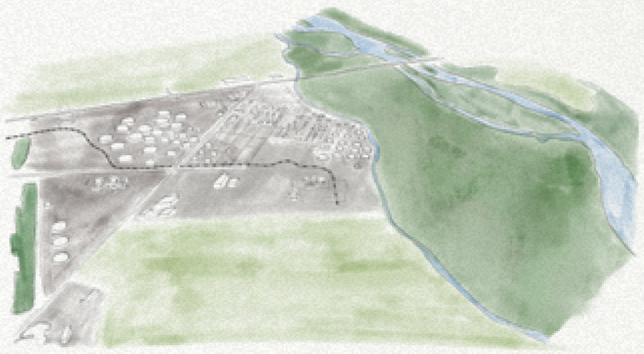
CLUSTERTYPE 1	mean	median	mode	30/83 SITES - 36%
Structure	0	0	0	no structure
Plot size	2404.366667	1093	-	square meters
Context	2.2	2	2	urban context
Operability	0.533333333	1	1	mostly operable
CLUSTERTYPE 2	mean	median	mode	**25/83 SITES - 30%**
Structure	1	1	1	does have a structure
Plot size	4650.44	3529	-	square meters
Context	2.28	2	2	urban context
Operability	0.64	1	1	mostly operable
CLUSTERTYPE 3	mean	median	mode	**15/83 SITES - 18%**
Structure	0	0	0	no structure
Plot size	4209	2451	-	square meters
Context	1	1	1	agricultural context
Operability	0.4	0	0	sometimes operable
CLUSTERTYPE 4	mean	median	mode	**7/83 SITES - 8%**
Structure	1	1	1	does have a structure
Plot size	45586.42857	36281	-	square meters
Context	2.714285714	3	3	urban context
Operability	0.857142857	1	1	operable
CLUSTERTYPE 5	mean	median	mode	**6/83 SITES - 7%**
Structure	0	0	0	no structure
Plot size	45243.83333	44599	-	square meters
Context	1.5	2	2	urban/agricultural context
Operability	0.333333333	0	0	mostly inoperable

SITE TYPOLOGY

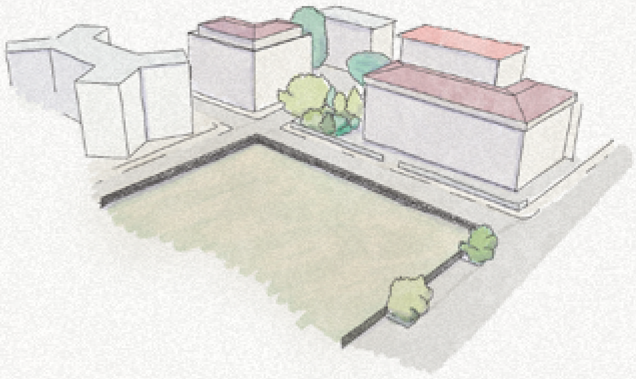
- 5 different types
- Each with differing combinations of spatial properties
- All in need of a fitting approach to address their contaminated soil



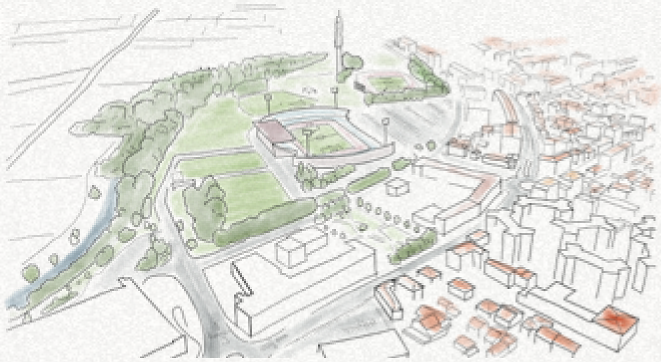
SEMI-URBAN
INDIVIDUAL INDUSTRIES



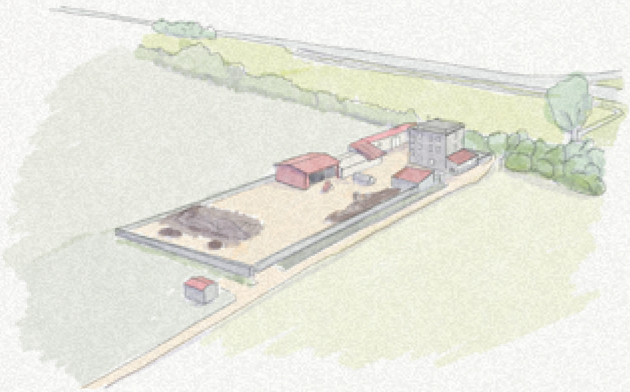
MASSIVE AREAS OF
INDUSTRIAL GIANTS



ISOLATED PATCHES OF
URBAN INCIDENTS



EMPTY PLOTS IN THE
PERI-URBAN PLAINS



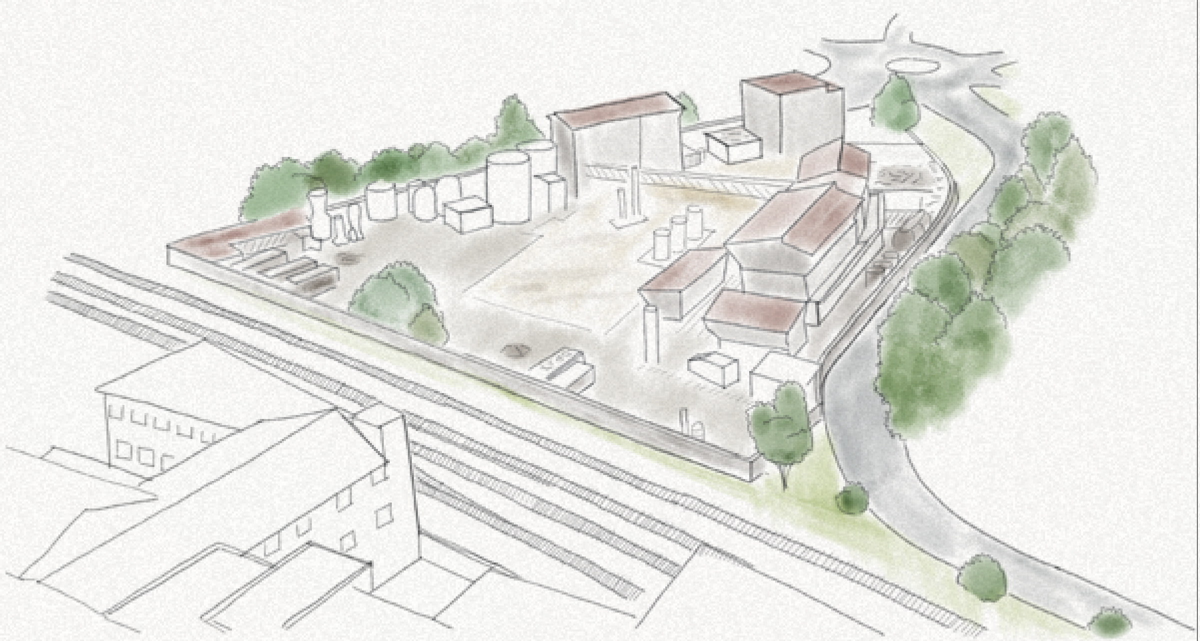
EMPTY AND RURAL
POLLUTED AGRICULTURE

INDIVIDUAL INDUSTRIES

INDUSTRIAL OR COMMERCIAL LOCATIONS

NEAR OR IN URBAN AREAS

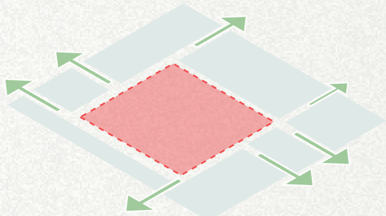
This type of contaminated site has a small to medium sized plot, ranging from 1,000 to 15,000 m². The sites are typically situated in urban areas, but can be found in industrial zones as well and host one or multiple buildings. Operability of these sites differs between individual sites.



REDESIGN STRATEGY

TRANSFORMING STRUCTURES

INTRODUCING SOCIAL PROGRAM



CONNECTING TO THE URBAN CONTEXT

Often enclosed by urban landscapes, these locations hold immense value for hosting social program and elevate the living environments of local residents. The often large industrial buildings are transformable into (temporal) office spaces, community hubs, urban farming practices, or pop-up stores.

REDESIGN DIRECTIONS FOR INDIVIDUAL INDUSTRIAL SITES

30% OF ALL SITES

0.1 TO 1.5HA PLOT SIZE

100% PRESENCE OF BUILDINGS OR STRUCTURES

64%* ABANDONED

*NOT-ACCOUNTING FOR INACCURACIES IN DATA-GATHERING AND NEURAL-NETWORK RELIABILITY

HOW TO EFFECTIVELY REDESIGN THESE CONTAMINATED SITES?

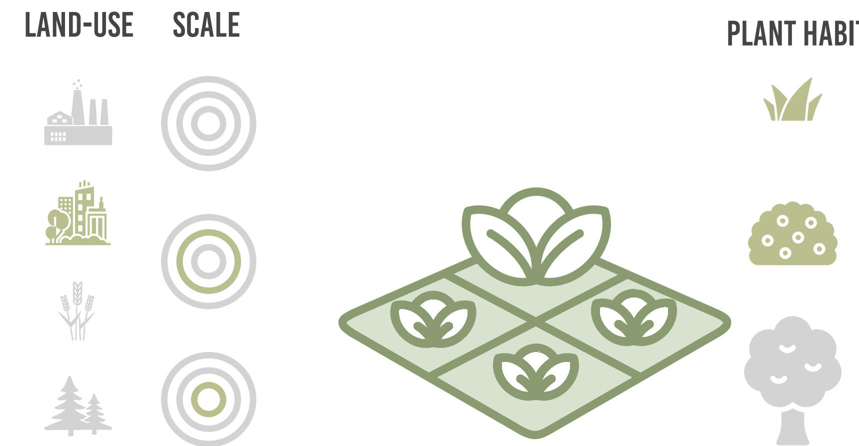
PATTERN LANGUAGE

"A pattern language empowers designers by offering a collection of proven solutions and best practices, which can be adapted to fit specific needs and contexts."

JOHN VLISSIDES IN "PATTERN HATCHING: DESIGN PATTERNS APPLIED", 1998

- Context and land-use
- Intervention scale
- Plant habit & size
- Remediation strategy
- Phasing and temporality

COMMUNITY GARDEN



Converting urban or peri-urban polluted sites into **community gardens** fosters community participation and well-being. Through education on pollution, phytoremediation, and farming practices, residents engage in sustainable soil remediation efforts. Hyperaccumulators, alongside pollution-resistant crops, aid in this process while gradually revitalizing the soil. By promoting local food production, these gardens enhance food security and strengthen community bonds.

REQUIRED SCALE/SPACE

- Landscape (>1ha)
- Site (<1ha)
- Micro (<100 m²)

APPROPRIATE LULC

- Industrial
- Urban
- Agricultural
- Natural

PATTERN DESCRIPTION

Definition and primary properties of the pattern in max. 250 words.

REMEDIATION STRATEGY

- Remediation
- Stabilization
- Buffering
- Tolerance

PATTERN TITLE

VEGETATION REQUIREMENT

Requirements on growth habit or vegetation type to make it fit the spatial intervention.

- Herbaceous
- Shrubs
- Trees

APPROPRIATE PHASE

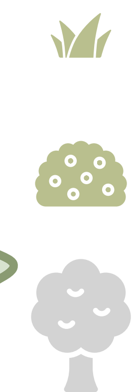
Requirements on growth habit or vegetation type to make it fit the spatial intervention.

- Herbaceous
- Shrubs
- Trees

COMMUNITY GARDEN

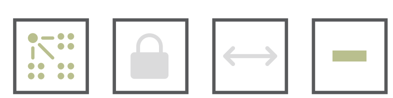
LAND-USE   SCALE

PLANT HABIT



Converting urban or peri-urban polluted sites into **community gardens** fosters community participation and well-being. Through education on pollution, phytoremediation, and farming practices, residents engage in sustainable soil remediation efforts. Hyperaccumulators, alongside pollution-resistant crops, aid in this process while gradually revitalizing the soil. By promoting local food production, these gardens enhance food security and strengthen community bonds.

REMEDIATION STRATEGY

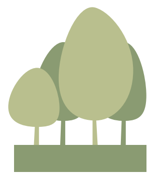


PHASE
START
MID
END

WHAT DESIGN INTERVENTIONS CAN BE USED TO REDESIGN THE CONTAMINATED SITES?

POCKET PARK

LAND-USE SCALE PLANT HABIT



Transforming pollution sites into **pocket parks and urban green** spaces offers a sustainable solution for remediation and community revitalization that enhance urban aesthetics, biodiversity, and local green structures. Converting pollution sites into pocket parks promotes recreational activities, social interaction, and mental health benefits for residents. Pocket parks and urban green transformation turns once-neglected spaces into valuable assets for urban living.

REMEDIATION STRATEGY PHASE START MID END

INDUSTRIAL BUFFER

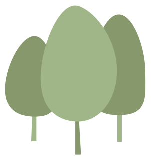
LAND-USE SCALE PLANT HABIT

Buffer zones around active industrial sites mitigate pollution emissions, prevent runoff, and deter future pollution spread. This strategy establishes a separation between urban well-being and industrial pollutants, safeguarding community health. By containing pollution and restricting industrial encroachment into urban areas, buffer zones foster environmental protection and urban sustainability.

REMEDIATION STRATEGY PHASE START MID END

PROTECTED NATURE

LAND-USE SCALE PLANT HABIT

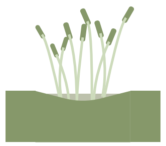


In remote and heavily contaminated sites unsuitable for socio-economic solutions, **transformation into natural habitats** through phytoremediation offers an ecological remedy. Specifically chosen phytoremediating species that require no harvest, restore ecological balance and provide habitat for diverse wildlife. Though less beneficial for human uses due to lacking infrastructure, this approach strengthens ecological resilience and fosters biodiversity.

REMEDIATION STRATEGY PHASE START MID END

CONSTRUCTED WETLANDS

LAND-USE SCALE PLANT HABIT



Constructed wetlands mimic the natural processes of wetlands, utilizing a combination of vegetation, soil, and microbial communities to treat polluted water. As water flows through the wetland, pollutants such as heavy metals, nutrients, and organic compounds are absorbed, transformed, or degraded by plants and microorganisms. These wetlands are a long term solution and can only be implemented in sites which allow for remediation over longer periods of time.

REMEDIATION STRATEGY PHASE START MID END

SUSTAINABLE PARKING LOT

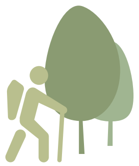
LAND-USE SCALE PLANT HABIT

Sustainable parking spaces employing semi-open pavement and hyperaccumulators allow rainwater to penetrate the ground, reducing runoff and facilitating natural filtration processes. Hyperaccumulators planted in these spaces absorb and detoxify pollutants from the soil, gradually remediating contamination. This approach is especially useful in urban and industrial areas which are bound to car accessibility.

REMEDIATION STRATEGY PHASE START MID END

LEISURE PARK

LAND-USE SCALE PLANT HABIT



Large-scale, severely polluted areas offer potential for transformation into l**eisure and recreational parks**, integrating phytoremediation in phased approaches. Incorporating amenities like walking and cycle paths, bird watching spots, and skateparks revitalizes urban and peri-urban landscapes. This strategy, complemented by existing green structures, enhances environmental sustainability, biodiversity and community well-being.

REMEDIATION STRATEGY PHASE START MID END

COMMUNITY GARDEN

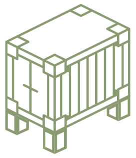
LAND-USE SCALE PLANT HABIT

Converting urban or peri-urban polluted sites into **community gardens** fosters community participation and well-being. Through education on pollution, phytoremediation, and farming practices, residents engage in sustainable soil remediation efforts. Hyperaccumulators, alongside pollution-resistant crops, aid in this process while gradually revitalizing the soil. By promoting local food production, these gardens enhance food security and strengthen community bonds.

REMEDIATION STRATEGY PHASE START MID END

TEMPORAL ELEVATED PROGRAM

LAND-USE SCALE PLANT HABIT



Temporary elevated program combined with phytoremediation offers a sustainable approach to site remediation. Utilizing containers for the program enhances convenience in transformation and transport, facilitating easy adaptation to varying site conditions and allows for placemaking. Elevating the program maximizes the planting area for hyperaccumulators, optimizing pollutant absorption in compact urban spaces, where pollution sites are of limited size. Mulitple units can be combined for application in larger plots.

REMEDIATION STRATEGY PHASE START MID END

VERTICAL FARMING

LAND-USE SCALE PLANT HABIT

Repurposing inactive polluted warehouses and industrial buildings into **urban/vertical farms** presents a dual solution for environmental remediation and sustainable food production. By utilizing the ground floor for phytoremediation and hyperaccumulators, pollutants can be absorbed and detoxified, improving soil quality. Meanwhile, multiple floors can host sustainable, local food production, maximizing land use efficiency.

REMEDIATION STRATEGY PHASE START MID END

BUILDING TRANSFORMATION

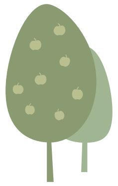
LAND-USE SCALE PLANT HABIT

Former **industrial** sites with abandoned structures hold potential for **conversion** into residential spaces, offices, retail areas, and ateliers, among other functions. Shifting the focus away from heavy infrastructure and transportation allows for more pavement conversion to open soil, facilitating phytoremediation. Incorporating temporary functions can gradually transition the area into a green space, preparing it for future development.

REMEDIATION STRATEGY PHASE START MID END

ORCHARDS

LAND-USE SCALE PLANT HABIT

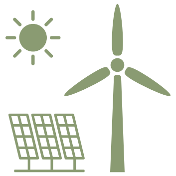


Transforming larger polluted peri-urban and urban plots into **orchards** offers a multifaceted solution by combining phytoremediation with diverse tree species. This approach revitalizes connections between food production and the urban environment. Orchards not only mitigate pollution through phytoremediation but also serve as educational tools, teaching communities about sustainable food production and the remediation of polluted landscapes.

REMEDIATION STRATEGY PHASE START MID END

GREEN ENERGY PRODUCTION

LAND-USE SCALE

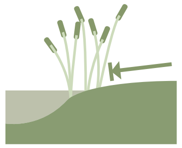


In areas lacking social opportunities, transformation can prioritize **green energy production** by integrating phytoremediating plants with photovoltaic panels or wind turbines. Combining greenery with PV panels enhances energy production efficiency. This solution, devoid of direct social benefits, targets locations where alternative design options are undesirable or unfeasible.

REMEDIATION STRATEGY PHASE START MID END

STORMWATER FILTERS

LAND-USE SCALE PLANT HABIT



Stormwater filters can capturing and treating runoff laden with pollutants. These filters, typically installed in urban areas, can be strategically placed in locations prone to runoff from paved surfaces, industrial areas, and agricultural lands, mostly along paved infrastructure. Stormwater filters help prevent further soil contamination and water pollution.

REMEDIATION STRATEGY PHASE START MID END

BIO-ENERGY PRODUCTION

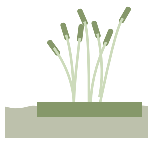
LAND-USE SCALE PLANT HABIT

Hyperaccumulators yield significant biomass quickly, offering an economic opportunity for **biofuel and bioenergy production** in polluted landscapes. As this transformation option requires a lot of infrastructure and processing, this solution is most feasible in larger plots outside urban areas due to space constraints and the absence of other social values.

REMEDIATION STRATEGY PHASE START MID END

FLOATING WETLANDS

LAND-USE SCALE PLANT HABIT



Floating wetlands consist of buoyant platforms supporting wetland vegetation, which efficiently absorb and detoxify contaminants from water bodies. By harnessing the natural filtration capabilities of plants like reeds, cattails, and water hyacinths, floating wetlands offer a sustainable solution for water purification while improving biodiversity and habitat quality.

REMEDIATION STRATEGY PHASE START MID END

REDESIGN OPTIONS USING A

PATTERN LANGUAGE

CLOSED PHARMACEUTICALS FACTORY - TRECATE

CONTAMINATED SITE REDESIGN

IMPLEMENTATION SHOWCASE

CONTAMINATED SITE REDESIGN

TRECATE PHARMACEUTICALS

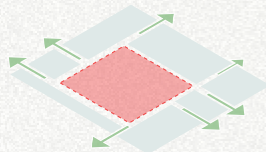
- Close to the urban center
- Bordering the railroad tracks
- Methanol, Ethanol, Aceton, Kaliumhydroxide, Nitric acid, Sulphuric acid, Talc, Palladium (Pd), Platina (Pt), Nickel (Ni)

CONTAMINATED SITE REDESIGN

TRECATE PHARMACEUTICALS

TRANSFORMING STRUCTURES

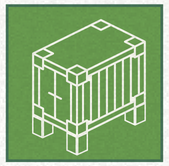
INTRODUCING SOCIAL PROGRAM



CONNECTING TO THE URBAN CONTEXT

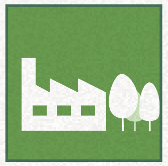
1. **Community center** in transformed factory buildings
2. Temporary food production in elevated **greenhouses** and **repurposed storage containers**
3. Community gardens; options for **flower gardening** or small-scale **food production**
4. **Vegetation buffer**, covering the site from noise, air, and soil pollution from railroad traffic
5. Improved recreational values for the biopark by the **connection to the community center** and **petting zoo**
6. Existing **parking lot** is repaved with **permeable pavement** and phytoremediating grass species
7. Reconnecting the green with the city center by adding **pedestrian pathways** and **green street profiles**

USED PATTERNS



Temporary program

Community gardening



Buffer zones

Recreational park

Sustainable parking

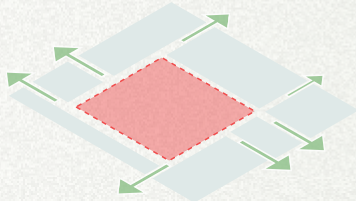
Structure transformation

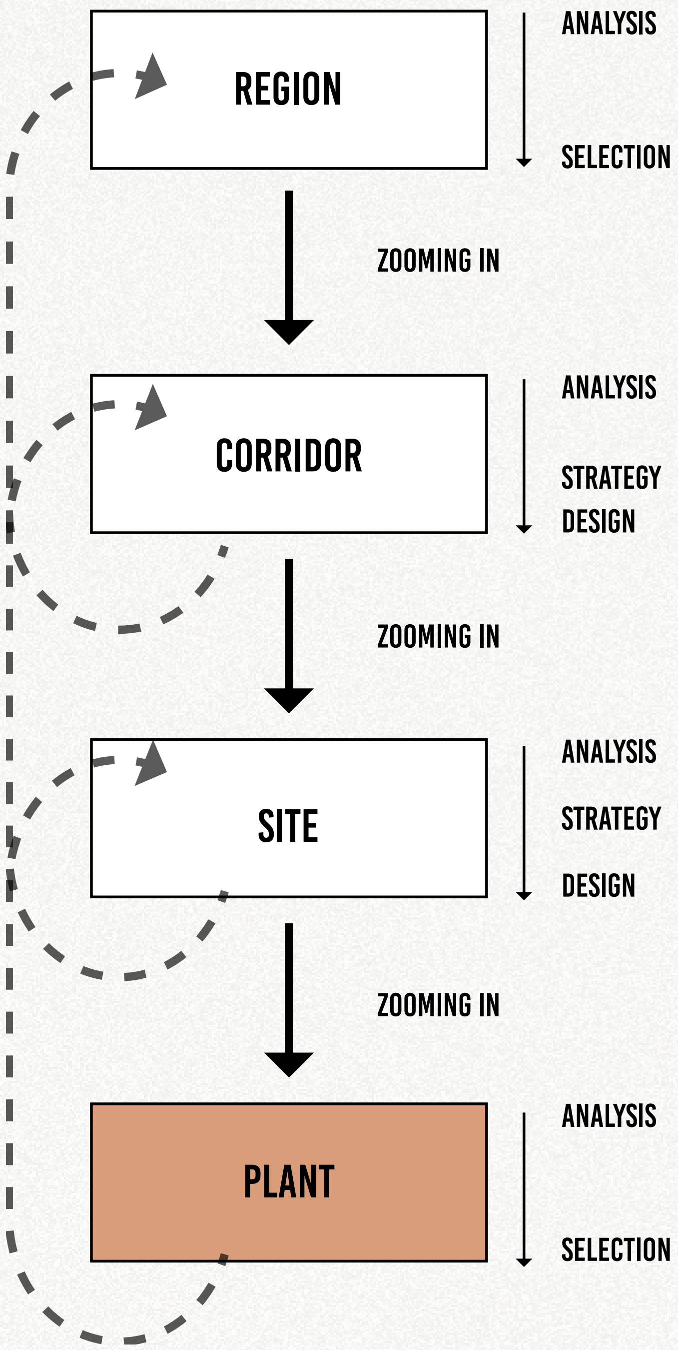
Pocket parks

CONTAMINATED SITE REDESIGN

TRECATE PHARMACEUTICALS

TRECATE PHARMACEUTICALS





PLANT-SCALE

How to select the right plant species to fit the local contaminant, site characteristics and introduced program?

PLANT SELECTION WORKFLOW

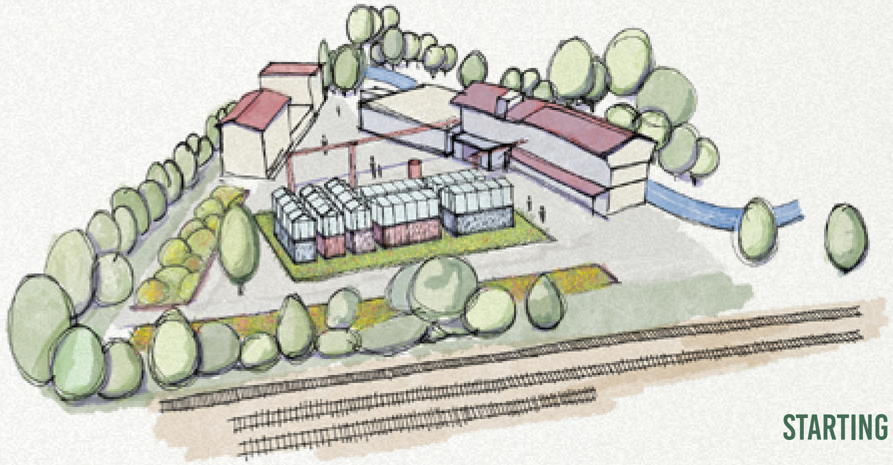
1. FITTING THE CONTAMINANT & LOCAL CLIMATE

2. INVASIVENESS & NATIVITY

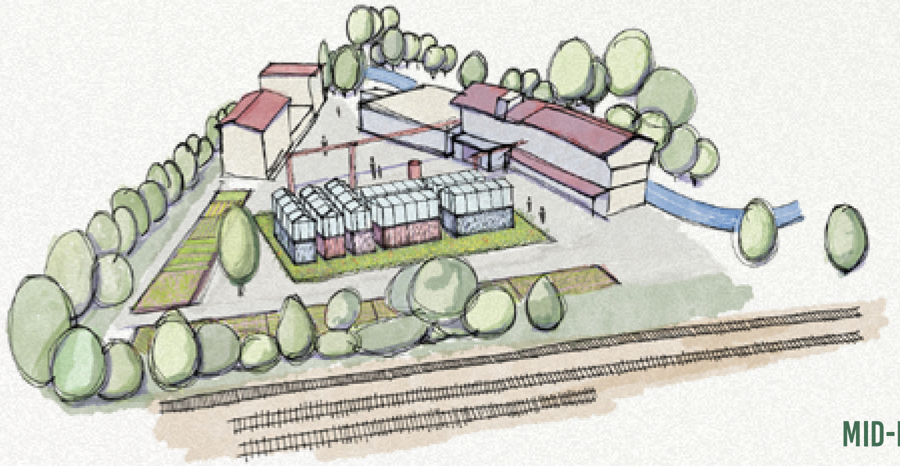
3. ROOT DEPTH & SEASONAL VARIATION

4. CO-BENEFITS & SOCIO-ECONOMIC OPPORTUNITIES

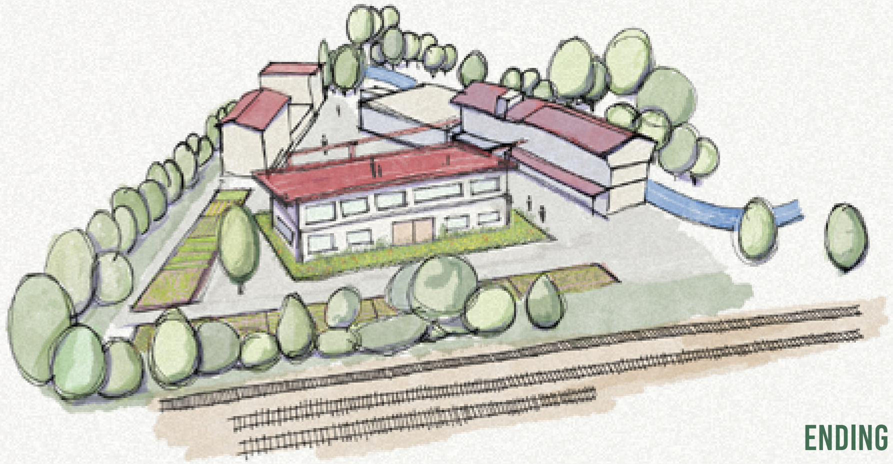
PHASING



STARTING PHASE



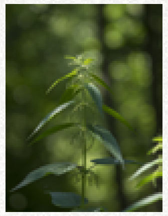
MID-PHASE



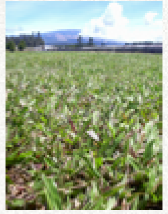
ENDING PHASE

PHYTOREMEDIATION

FESTUCA ARUNDINACEA - TALL FESCUE
- Perennial grass (<165cm)
- Hyperaccumulator of arsenic, copper, lead & zinc
- Phytostabilization,-extraction,-degradation & rhizodegradation



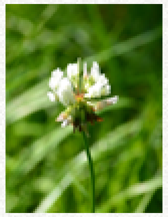
URTICA DIOICA - STINGING NETTLE
- Herbaceous perennial plant (0.9 - 2m)
- Accumulator of PAHs and PCBs
- Rhizodegradation
- Valuable source for butterfly larvae, nettle extract can be used as pesticide/fungicide



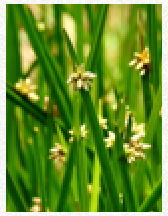
AXONOPUS COMPRESSUS - CARPET GRASS
- Perennial grass (<15cm)
- Accumulator of lead, zinc, copper, cadmium, PAHs
- Phytoaccumulation
- Useful as permanent pasture or groundcover

POPULUS NIGRA - BLACK POPLAR
- Deciduous tree (25-30m)
- Accumulator of heavy metals & hydrocarbons
- Phytoextraction & -accumulation

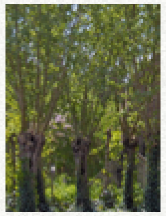
POPULUS ALBA - WHITE POPLAR
- Deciduous tree (<20m), fast-growing
- Accumulator of arsenic, lead, copper, manganese and zinc
- Phytostabilization & phytoaccumulation
- Root depth of ±50cm



TRIFOLIUM REPENS - WHITE CLOVER
- Herbaceous perennial plant (5-10cm)
- Accumulator of diesel, petrol, PCB & PAHs
- Rhizodegradation

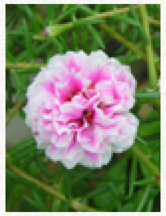


SCIRPUS MUCRONATUS - BOG BULRUSH
- Perennial herb (20 - 30cm)
- Accumulator of petrol hydrocarbons
- Phytoaccumulation
- Considered as a weed in rice fields

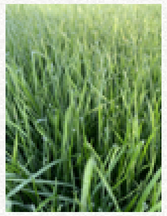


SALIX ALBA - WHITE WILLOW
- Deciduous tree (10-30m)
- Accumulator of petroleum hydrocarbons
- Phytoextraction & -accumulation
- Useful for basket-making

HIRSCHFELDIA INCANA - SHORTPOD MUSTARD
- Annual shrub (<1m), fast-growing
- Accumulator of Lead, Cadmium, Copper & Zinc
- Phytoextraction
- Fast-growing and fast-spreading



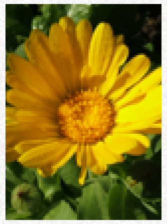
PORTULACA GRANDIFLORA - MOSS ROSE
- Annual flower (<30cm)
- Hyperaccumulator of aluminium, copper, iron & zinc
- Phytoextraction
- Valuable food source for honeybees and butterflies



LOLIUM PERENNE - PERENNIAL RYEGRASS
- Herbaceous grass (10-90cm)
- Accumulator of pentachlorophenol, Cd & Hg
- Fast growing, high yields
- Used for animal fodder or biomass
- Phytoextraction & rhizoextraction

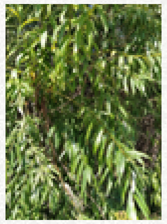
POPULUS DELTOIDES X TRICHOCARPA - HYBRID POPLAR
- Type/habit (size/height), growing speed
- Accumulator of petrol hydrocarbons
- Phytodegradation,-extraction &-stabilization, Rhizodegradation Fast growing

FESTUCA RUBRA - RED FALLOW
- Perennial herb (<20cm)
- Accumulator of phosphorus, nitrogen & PAHs
- Rhizodegradation & phytorextraction
- Low maintenance



CALENDULA OFFICINALIS - MARIGOLD
- Herbaceous perennial (<80cm), short-lived
- Accumulator of cadmium & lead
- Phytoextraction
- Valuable food source for butterflies, edible and used in salads or as garnish

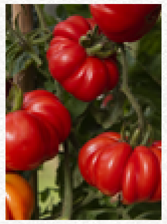
IRIS X GERMANICA - BEARDED IRIS
- Annual flowers
- Hyperaccumulator of Aluminum, Arsenic, Cadmium, Copper, Flourine, Manganese, Zinc
- Rhizofiltration



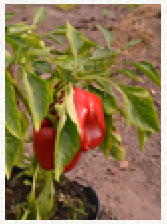
SALIX DASYCLADOS - SHRUB WILLOW
- Woody perennial (3-4m), fast-growing
- Accumulator of petrol hydrocarbons
- Phytoextraction & rhizodegradation

FICUS CARICA - COMMON FIG
- Woody perennial (<4m)
- Tolerant of petrol hydrocarbons
- Tolerance
- Fruits can be grown and consumed in (slightly) contaminated soils

CITRUS AURANTIFOLIA - KEY LIME
- Woody perennial (<5m)
- Tolerant of petrol hydrocarbons & several heavy metals
- Tolerance
- Fruits can be grown and consumed in (slightly) contaminated soils



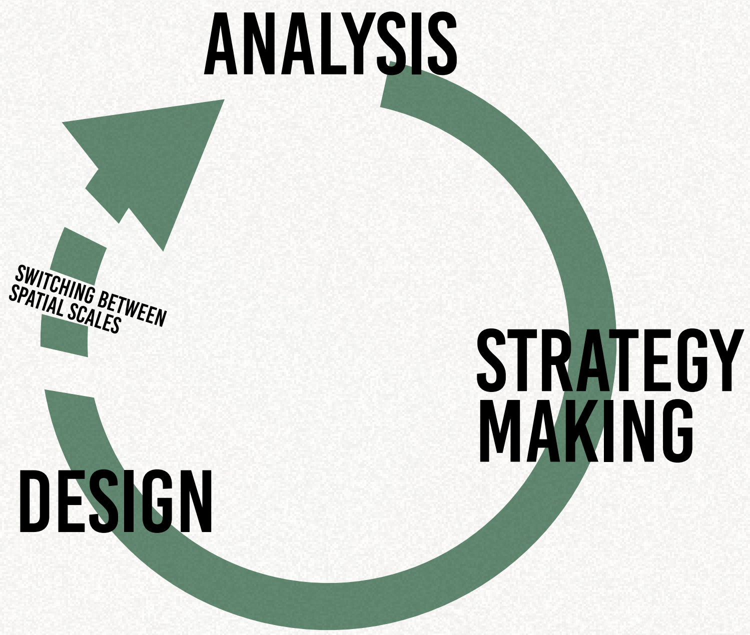
SOLANUM LYCOPERSICUM 'COSTOLUTO FIORENTINO' - BEEFSTEAK TOMATO
- Perennial herbaceous (0.2 -1.8m)
- Tolerant of petrol hydrocarbons & heavy metals
- Tolerance
- Fruits can be grown and consumed in (slightly) contaminated soils, sow together with Marigold as nat. pesticide

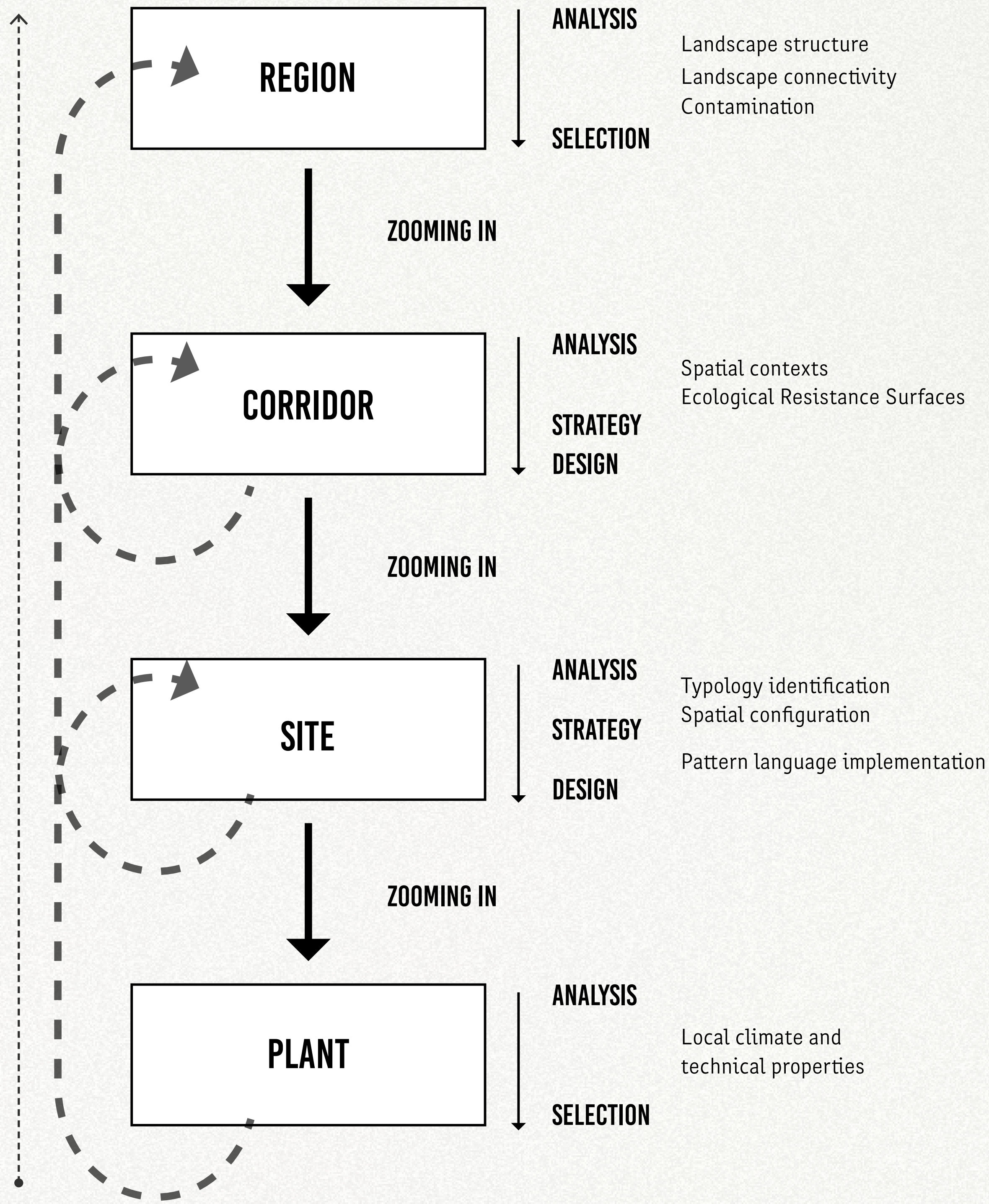


CAPSICUM ANNUUM - SWEET PEPPER
- Perennial herbaceous (0.3 -1.2m)
- Tolerant of petrol hydrocarbons & several heavy metals
- Tolerance
- Fruits can be grown and consumed in (slightly) contaminated soils

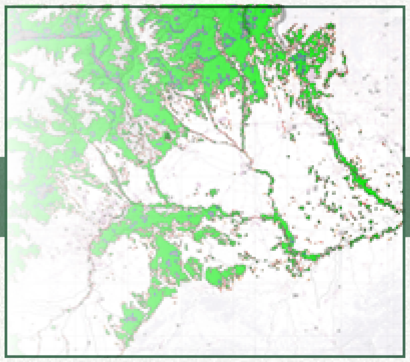
CONCLUSION & REMARKS

- Allows for quick design explorations across multiple scale
- Communication and collaboration between stakeholders
- Data-driven and customizable to context
- Top-down/bottom-up

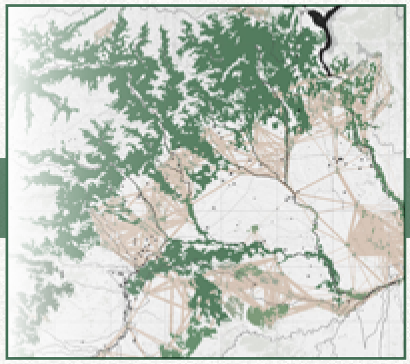




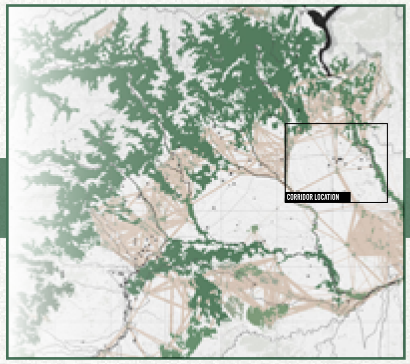
REGION



LANDSCAPE STRUCTURES



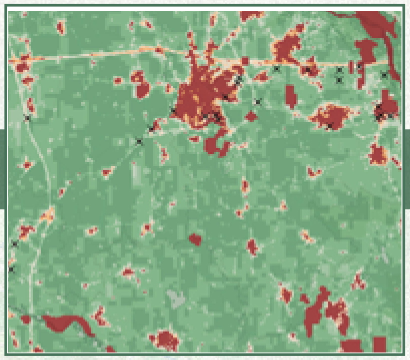
NETWORK ASSESSMENT



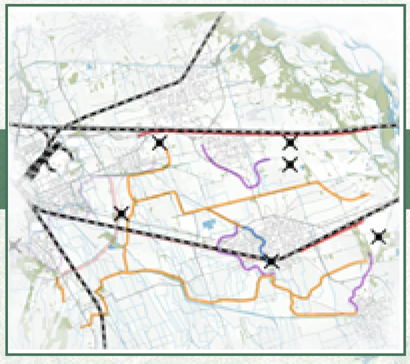
CORRIDOR SELECTION

DESIGNING CORRIDOR

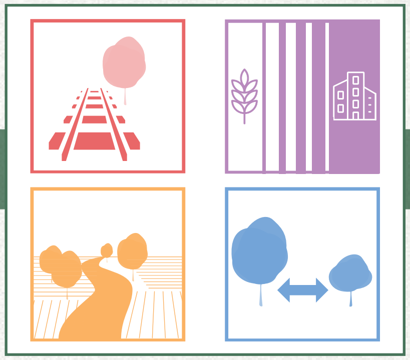
ASSESSING STRATEGIES



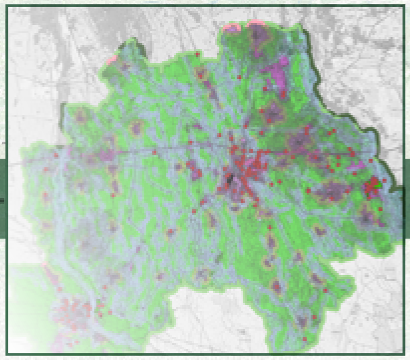
ASSESSMENT PREPARATION



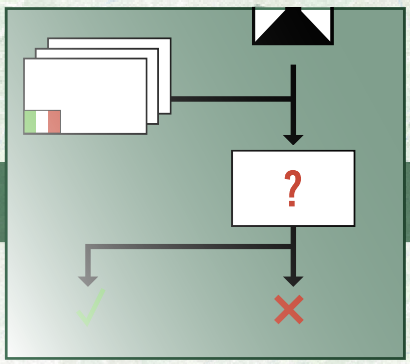
IMPLEMENTING IN SPACE



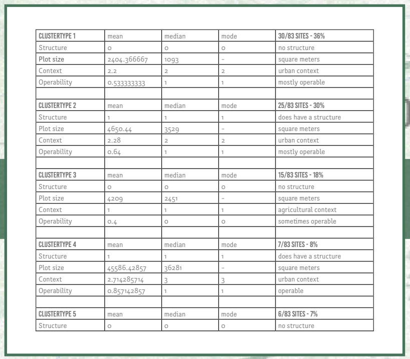
CORRIDOR PATH STRATEGIES



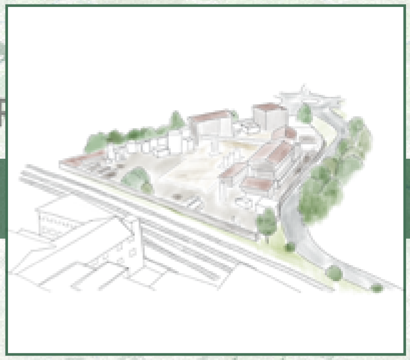
DATA GATHERING ON SITES



CROSSING DATA-GAPS



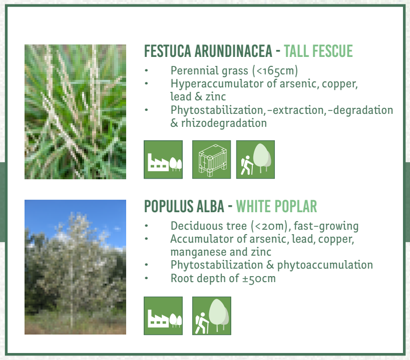
PATTERN EXPLORATION



TYPOLOGY-MAKING

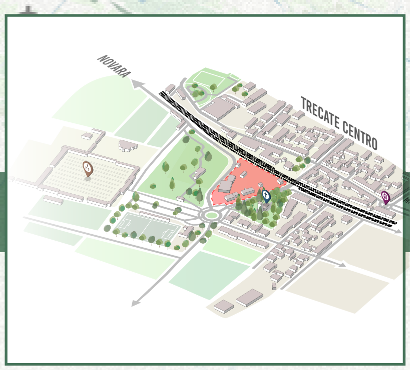
PATTERN LANGUAGE

PLANT



SPECIES SELECTION

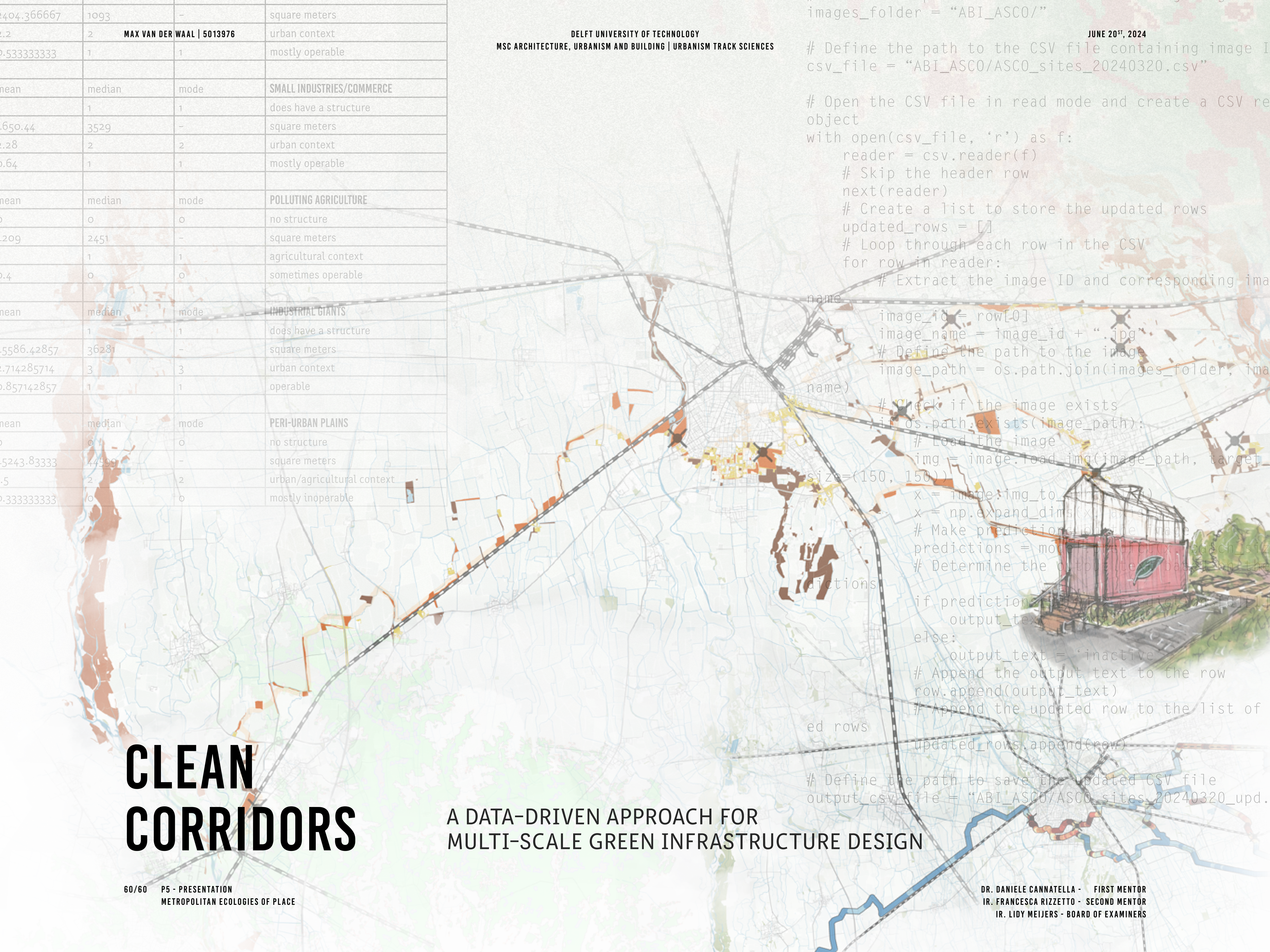
REDESIGN WITH PATTERNS



SITE ASSESSMENT

SUMMARIZING THE

DESIGN AND PLANNING PROCESS



CLEAN CORRIDORS

A DATA-DRIVEN APPROACH FOR MULTI-SCALE GREEN INFRASTRUCTURE DESIGN

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IR. FRANCESCA RIZZETTO - SECOND MENTOR
IR. LIDY MEIJERS - BOARD OF EXAMINERS