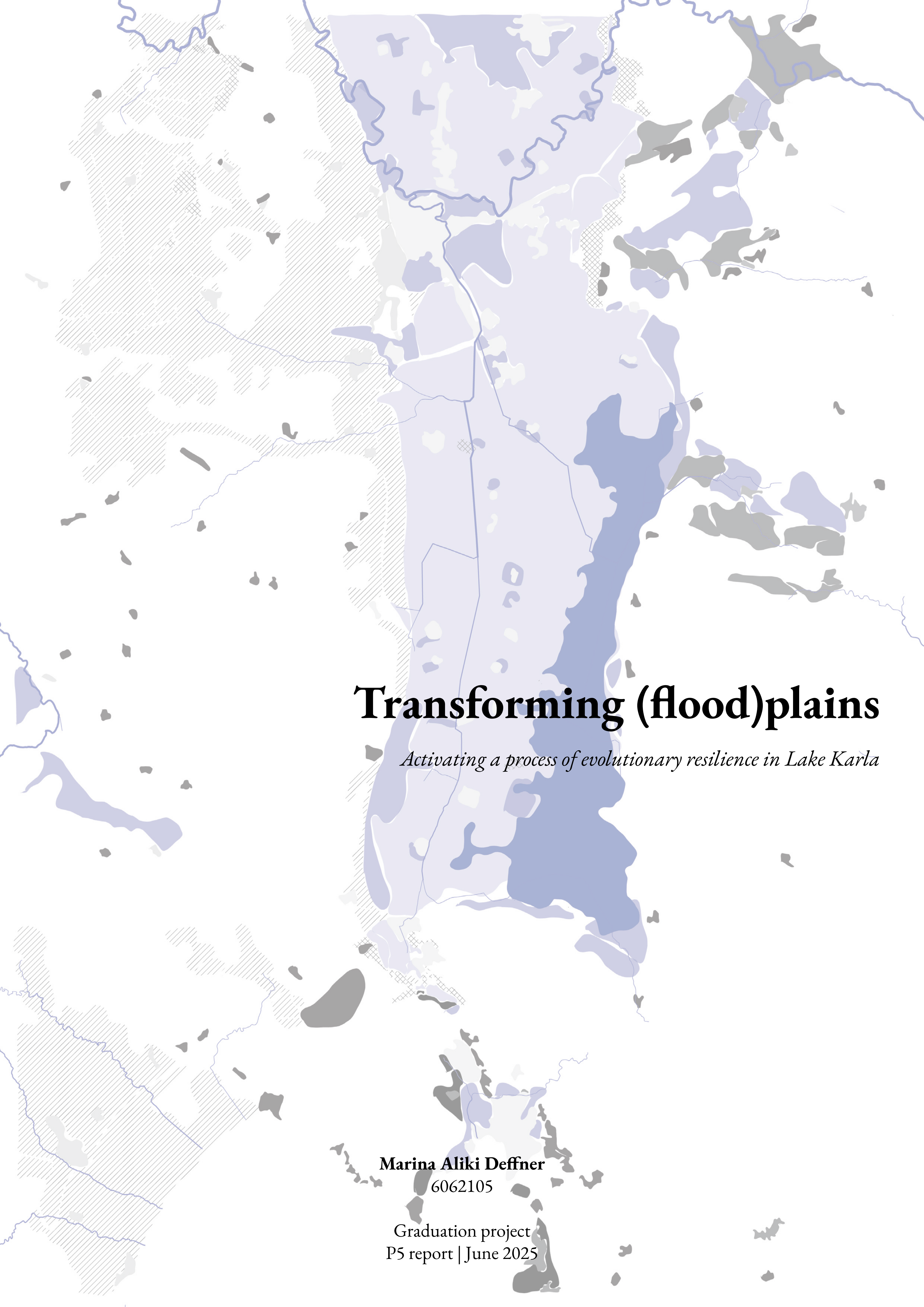

Transforming (flood)plains

Activating a process of evolutionary resilience in Lake Karla

Marina Aliki Deffner
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Graduation project
P5 report | June 2025

Colophon

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Graduation project

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June 2025
P5 Report

All the visual material has been produced by the author unless stated otherwise. Please find a detailed table of figures, with complete references, at the end of this report.

Cover image. Projective drawing, September 2024

Σαν σε πρωτοαντίκρυσα απ' το βουνό ψηλά
του Λαμαρτίνου η λίμνη
στα χείλη μου έφτασε απαλά
Κάρλα, ω λίμνη πανώρια
κάθε στιγμή που σε κοιτάζω, σε θαυμάζω.

Στα ήσυχα νερά σου καθρεφτίστηκε ο έρωτας,
και ήταν η στιγμή μεγάλη,
ανάμεσα στον πόλεμο και το σκοτάδι.

As I first saw you from the mountain above
lake of Lamartine
to my lips it came softly
Karla, oh lake of panoply
every moment I look at you, I admire you.

In your quiet waters love was reflected,
and the moment was great,
between war and darkness.

Klelia Hala, 1998 in Rouskas (2001), translated by the author

Figure 01. Karla Reservoir, December 2024

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First of all, I would like to thank my mentors, Diego Sepulveda Carmona and Luca Iuorio for their guidance, support and valuable feedback throughout my graduation process. Specifically, I would like to thank Diego for his enthusiasm and passion, which allowed me to embrace the complexity of this project, and for pushing me to expand my systemic thinking in relation to biophysical and socio-technical conditions. I am also very thankful for Luca, whose critical comments and questions inspired me to push the boundaries of what I previously considered design and helped me understand that it is something deeper, more complex and intrinsic than I originally thought. They both opened my eyes and expanded my world to new knowledge and understanding, for which I am very grateful.

I would personally like to thank Kleanthis Syrakoulis for helping me get around Larissa city and the surrounding area and introducing me to the local people, whose knowledge proved invaluable for the completion of my project. I am also very grateful to Dimitris Goussios, with whom I had my first actual encounter with the flood-affected area in Farsala and Megalo Euydrio.

I would like to thank Dimitra Gaki and Fotis Natsioulis, for sharing photos from their personal archives with me and for allowing me to use them in my project. The same goes for Vania Tloupa, who was gracious enough to give me access to her personal archive and for giving me permission to use her father's photos, the Thessalian photographer Takis Tloupas, in my thesis.

I am grateful to all the people who I talked with in Larissa, Volos and the surrounding area. Without their voices, the voices of Lake Karla of the past and the present, the voices of the people inhabiting this landscape, my project would not have been the same.

I would like to thank my father for accompanying me during my two fieldwork excursions and helping me navigate my academic journey. I am grateful for my mother, who is always there for me, even from afar. Their unwavering support and belief in my abilities mean the world to me.

I am thankful to my friends back home Chara, Markos, Charitta and Charalambos, for always making me laugh, and for their help and encouragement.

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Abstract

The agricultural plains of Thessaly in Greece have been historically sensitive to flooding. These floods result in extreme socio-economic, spatial and environmental consequences, whose severity is heavily impacted by human actions manipulating the natural ecosystems of the region. Specifically, the extensive urbanization of Thessaly's agricultural landscape – one of the main productive agricultural cores of Greece – combined with the anthropogenic alteration of the hydrological system to address the region's water scarcity problem, are leading towards the appropriation and exhaustion of the water ecosystem. This has contributed to the extent of the negative consequences in extreme cases of flooding, such as this of September 2023, and to the system's inability to cope, recover and adapt to these events. Therefore, there is an imperative need for the reconfiguration of the existing water and land management framework through transformative actions grounded on ecosystem-based adaptation (EbA) and nature-based solutions (NBS), in order to enhance the system's adaptive capacity to flooding. An area near the Karla Reservoir is used as a case study. The proposed transformations both inform and are informed by local practices, and are supported by land policies, aiming to create an integrated framework for environmental co-management with the intention of activating a process of evolutionary resilience of the Thessalian plain to flooding.

This project proposes a new conceptual framework for understanding risk and its components and a methodological approach for defining how the conditions of different systems affect risk and contribute to the systems' biophysical and socio-technical limits. A set of criticality and transformability criteria is defined to locate the crucial areas – the critical zones – with the potentiality of transformation. This process is executed by superimposing the biophysical and socio-technical limits and taking into account the current coping and recovery capacities as expressed by the current centralized processes and local adaptation practices. Then, a set of transformative actions is proposed, consisting of biophysical measures drawing from soil and landscape-related nature-based solutions and of socio-technical measures aiming to enhance the learning capacity and preparedness of the community. These actions are subsequently implemented in a critical zone adjacent to the Karla Reservoir, through strategic, systemic, sub-systemic and specific design explorations, with the aim to concretely spatialize the proposed measures by showcasing possible negotiations between agriculture, water and nature. Finally, an adaptation framework and phasing through adaptive design pathways showcases and evaluates the operability of the proposed transformation. The overall goal of the project is the creation of a successful model for environmental co-management, integrating coping, recovery and adaptive capacity, and resulting in fostering evolutionary resilience.

Keywords: flood risk, adaptive capacity, ecosystem-based adaptation, nature-based solutions, environmental co-management, evolutionary resilience

Personal motivation

photo by Fotis Natsioulis

Figure 02. Inundated Kalamaki Reservoir

Growing up, I always had a very personal relationship with the region of Thessaly, since I spent a lot of my holidays there, in the coastal city of Volos. My undergraduate thesis at the National Technical University of Athens was also dedicated to this region, albeit for an entirely different topic and area. Therefore, it seemed only fitting that I would work in Thessaly also for my master's graduation project, bringing the completion of my studies to a full circle.

I was vaguely aware of the case of Lake Karla since I was very young. During one of my visits to Thessaly, I met a girl named Karla, which is a very unusual Greek name, and it sparked my interest. Then it was revealed to me that her parents had named her like this in remembrance of Lake Karla, who at this point in the early 2000s was still dried up, and the plans for her restoration as an artificial reservoir were just about to be completed. These people were mourning the lake as it used to be; a natural ecosystem and cultural landscape that was eliminated supporting the agricultural development of Thessaly during the middle of the 20th century. This story touched me deeply and it stayed dormant within me, until it was resurfaced by the recent events.

In September 2023, Thessaly was hit by two consecutive storms, Daniel and Elias, that resulted in excessive flooding with severe socio-economic, spatial and environmental immediate and lasting consequences. Seeing images on the news from the place I so loved submerged under water for days, and then the ecological destruction that followed with thousands of dead fish washing out from the tunnel that directs water from Karla Reservoir to the Pagasetic Gulf, catapulted my motivation to deal with the topic of flood resilience in the region, under the lens of a sustainable water and land management. Recognizing Lake Karla as a vital point during these floods, since the plain regained its former character as a wetland, awoke again my interest in her story, and started my process of problematization about the operability of this system in order to enhance its faster recuperation and future resilience in the event of flooding.

Coming from an architecture background, I never had the opportunity to work on such multi-scalar and interdisciplinary topics like this, bringing together themes of hydrology, flood risk mitigation, water scarcity, as well as land and water management through adaptive strategies. Consequently, delving into this topic and trying to contribute something to a place that means so much to me was a very fulfilling experience.

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photo by Fotis Natsioulis

Figure 03. Flourishing biodiversity in time of crisis

01 | Problematization

Situating Lake Karla

Figure 04. Thessaly Water District

Figure 05. Pineios River Basin

Lake Karla – or more correctly Karla Reservoir, since she is an artificial lake– is located in the southeastern part of the Region of Thessaly in Central Greece. Administratively, she is subject to the Prefectures of Larissa and Magnesia, yet organically she is part of Pineios River drainage basin. Pineios is the third longest river in Greece, its length amounting to approximately 205km (Bathrellos et al., 2018). It originates from Pindus Mountain Range in the northwestern part of Thessaly, and drains into the Aegean Sea in the east, forming a delta. Its drainage basin (PRB) covers the majority of Thessaly Water District (National Water District EL08) which, according to a National Water Committee decision, is divided into two river basins, the aforementioned Pineios River Basin (EL0816), and Almyros-Pelion Stream Basin (EL0817). EL08 is further divided into sub-river basins, following the INSPIRE directive (2007) and the Water Framework Directive (2000/60/EC) (Tsakmakis et al., 2020). Lake Karla belongs to the sub-basin with INSPIRE ID 2070, the most intensely cultivated among the 9 sub-basins in PRB, and she also constitutes the largest lake in PRB, with an area of 34.92km^2 (Tsakmakis et al., 2020). Thessaly itself is the third most financially productive region (Tsakmakis et al., 2020) but the most productive agricultural region in the country (Bathrellos et al., 2018) since it is home to the second largest plain in Greece, after the Macedonian plain (Loukas et al., 2007).

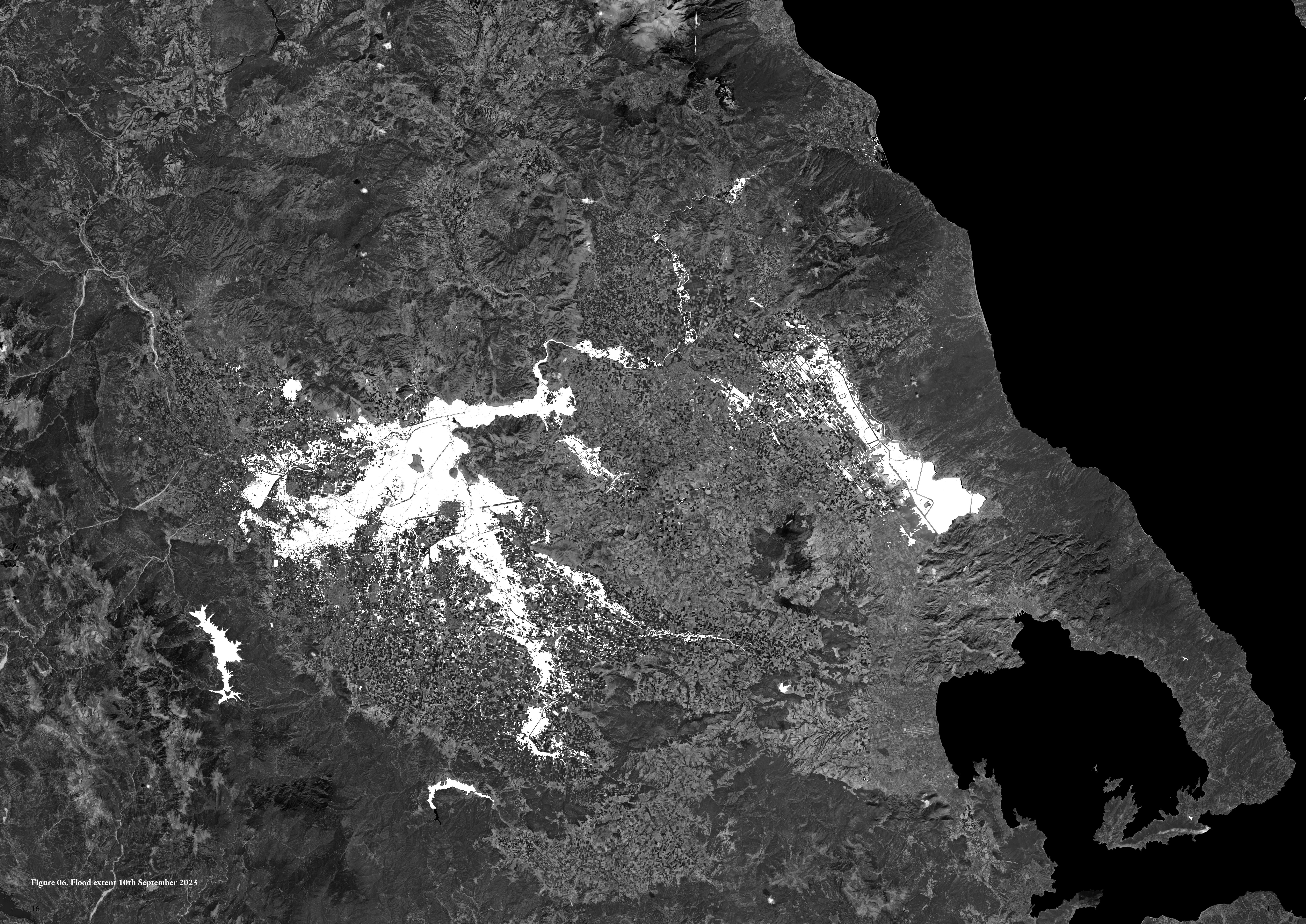
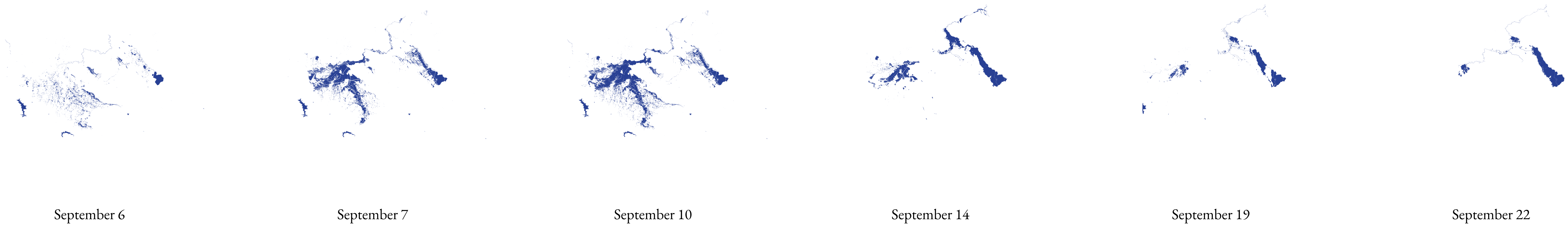


Figure 06. Flood extent 10th September 2023

Problem field

Storm Daniel and subsequent flood

Flood extent and timeline



“Storm Daniel”, as named by the Hellenic National Meteorological Service emerged in the Ionian Sea (Lekkas et al., 2023). On September 4th 2023, heavy rainfall commenced over the region of Thessaly, acquiring cyclone characteristics on the next day, and shifting completely to a Mediterranean tropical-style cyclone on September 9th (Chatzigeorgiadis et al., 2024). On September 10th it moved towards Libya, finally dissipating two days after that, on September 12th. The extreme rainfall event and unimaginable water levels – several monitoring stations reported receiving 400-600mm of water within a 24h timeframe – resulted in a flood, starting on September 6th, that stayed in the area for several days.

On September 7th, the phenomenon escalated rapidly, reaching its peak on September 10th (Chatzigeorgiadis et al., 2024). After that, the floodwater started gradually decreasing, however, a substantial amount of water persisted for multiple days, specifically within the sub-basin of Lake Karla, due to the failure of the Pineios embankments near Gyrtoni Dam (Lekkas et al., 2023). According to the local people, the water disappeared completely in May 2024, 9 months after the event. Therefore, it is evident how crucial this area is to the flood risk management of the entire region.

Figure 07. Timeline of flood

photo by Fotis Natsioulis

Figure 08. Water traces in Megalo Euydrio, December 2024

Figure 09. Flooded cotton - dancers

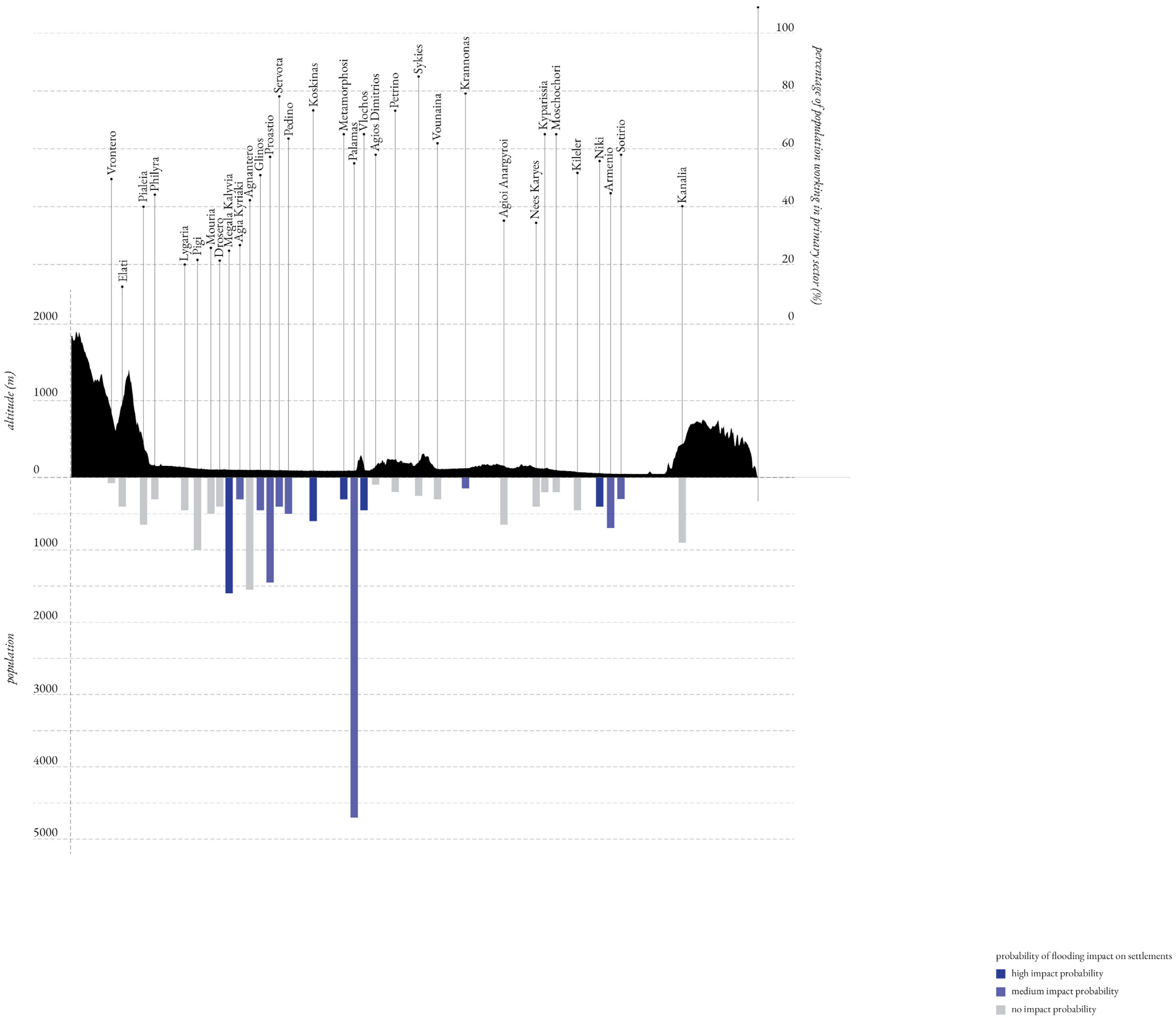


Figure 10. Socio-ecconomic impact, City-Human investigation

According to the analysis of Chatzigeorgiadis et al. (2024), 116 settlements with a total of 61.667 residents (not including the city of Larissa) were affected by the flood. 27 of those settlements were heavily impacted, with 21 of them flooded, including Vlochos, Megala Kalyvia and Metamorphosi which were completely submerged under water for days. There were 18 human casualties, mostly located in the settlements of the western Karditsa plain and the Almyros-Pelion Stream Basin (Lekkas et al., 2023). Buildings in the area that were impacted by the flooding suffered structural damage, experiencing stability issues due to erosion and undercutting phenomena (Lekkas et al., 2023). Additionally, residential buildings in many rural areas, which are mostly non-engineered – were inundated for several days, with the water level reaching the roof of the ground floor, or even up to the first floor, leading to serious damage, or even eventual collapse (Mavroulis et al., 2024). The storm's financial loss was estimated to billions of euros (He et al., 2024). Based on data from the Association of Greek Insurance Companies, there were over 4.000 property losses, whether those were residential properties, businesses or other (Lekkas et al., 2023). Furthermore, the agricultural and livestock production was severely compromised, due to the destruction of crops, fertilizers and mechanical equipment, causing an enormous hit on regional and national economies (Dimitriou et al., 2024).

In this diagram, the socio-economic impact of the flood in various settlements along a longitudinal section of the Pineios River Basin is presented. Settlements with a high population number, and with a high percentage of people working in the primary sector of the economy were severely affected by the flood, highlighting the most vulnerable social groups to this natural hazard.

photo by Fotis Natsioulis

Figure 11. Confusion about boundaries, Karla Reservoir pumping station

photo by Fotis Natsioulis

Figure 12. Endless water

photo by Fotis Natsioulis

photo by Dimitra Gaki

Figure 13. Thick cracking mud, lasting effect

Figure 14. Persistent inundation, lasting effect

Spatial impact

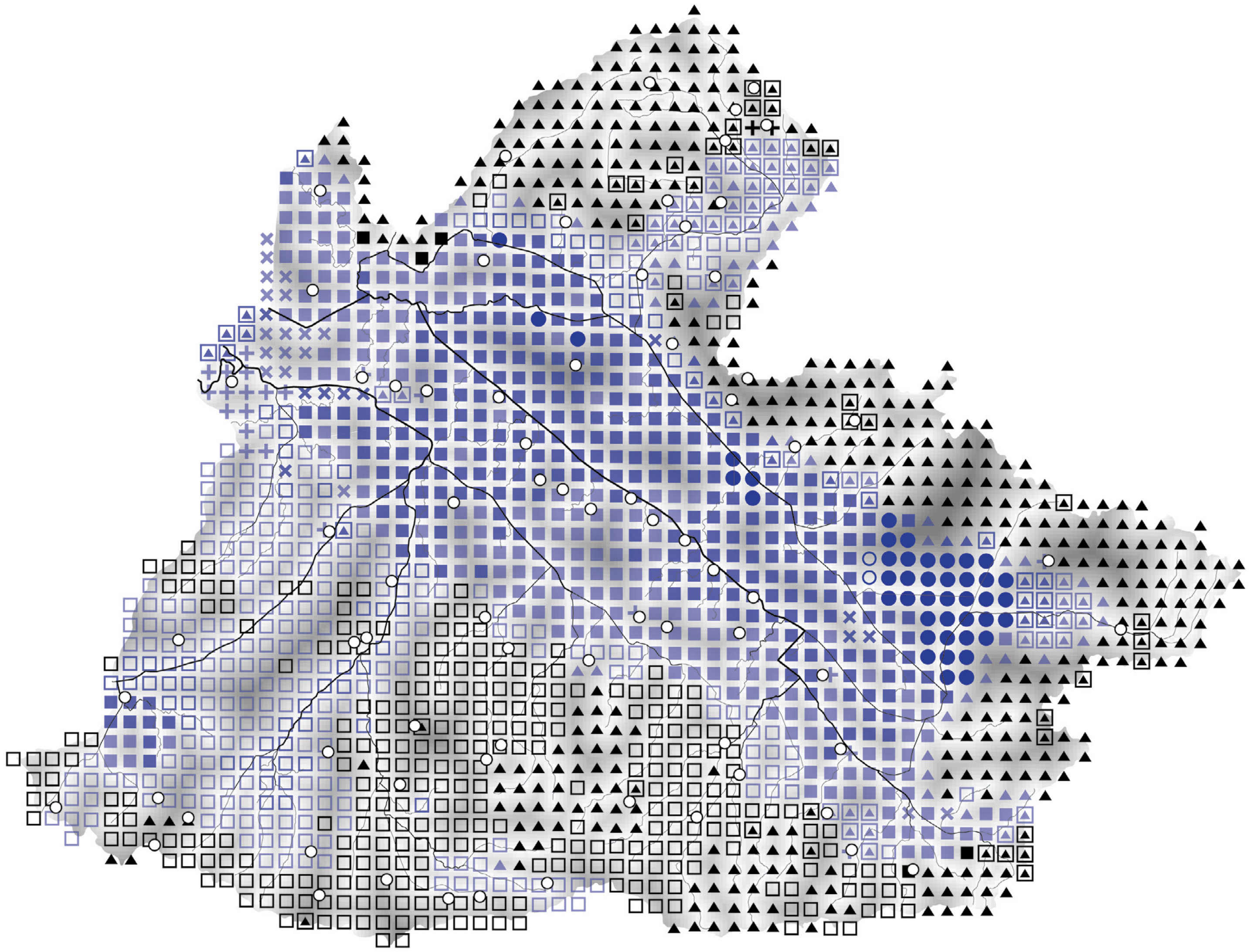
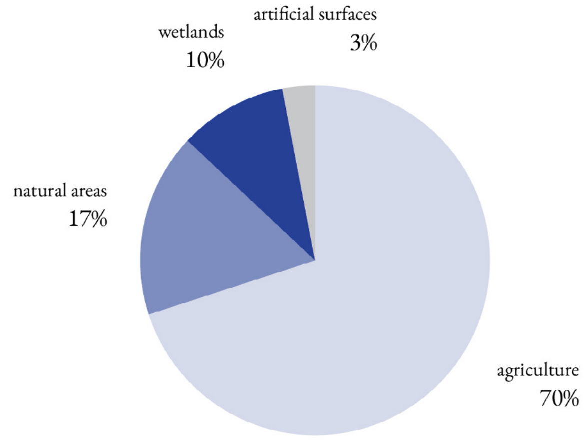


Figure 15a. Spatial impact, More than City-Human investigation



According to calculations, approximately 83.000ha of land in Thessaly was inundated (Chatzigeorgiadis et al., 2024; He et al., 2024) The area that was mostly impacted by the flood was agricultural land, with 70% of the area that was inundated belonging to this category. However, forests and other natural areas were also affected (17% of inundated area) (He et al., 2024). Cotton was the most affected crop, the flooded area occupying almost a third of the total area planted with it in the Thessalian plain. Durum wheat and other types of wheat were also impacted, as well as fodder plants, maize, seed production and tomatoes (He et al., 2024). Additionally, transport and flood protection infrastructures were affected, such as the national road connecting Larissa to Thessaloniki and a lot of local roads, especially in the Almyros-Pelion Stream Basin (Lekkas et al., 2023). In total, more than 3.000km of road network was affected (Chatzigeorgiadis et al., 2024). 180km of rail network was destroyed, including parts of the Thessaloniki-Athens axis, the Palaiofarsalos-Kalambaka section and the Larissa-Volos section, which still remains without use (Lekkas et al., 2023). Bridges and embankments were also weakened and/or destroyed. Finally, a large volume of sediment and debris was carried with the water, resulting in entire areas being covered by a thick layer of mud, and alterations to port bathymetry and coastal areas morphology (Lekkas et al., 2023).

Figure 15b. Spatial impact, inundated area by land cover type (adapted from He et al., 2024)

photo by Fotis Natsioulis

Figure 16. Flood waste in Farsala, December 2024

Figure 17. Dead fish, Lake Karla

photo by Fotis Natsioulis

The flood also resulted in a large-scale ecological disaster. 110.000 dead animals and 135.000 dead birds were reported, amounting to 7% of the livestock in the region (Lekkas et al., n.d.). The most affected species were sheep and goats, as well as ornithoids, followed by bees, cattle and pigs (He et al., 2024). The quality of surface water bodies was also affected, being contaminated by waste water plants, dead animals and debris transferred from the flooding (Lekkas et al., 2023). Additional sources of pollution of the flood water and consequently of the surface water bodies were animal excrement from livestock farms and the pesticides that are extensively used in croplands. Those affected the groundwater, surface water and soil quality, threatening the existing ecosystems, biodiversity, as well as human health with impacting the water supply (Mavroulis et al., 2024). Furthermore, an abundance of flood waste was created, concentrated in piles that were planned to be disposed of in landfills without treatment or separation. Even 1.5 year after the event, some of them had not been removed yet, continuing to pose risks to public health and the environment (Mavroulis et al., 2024). Specifically for Lake Karla, oxygen depletion was observed after the event. This led to a large number of fish – which had multiplied in the stagnant waters of the extended Lake Karla – dying out due to the high temperatures of the summer of 2024 that led to the rapid evaporation of the persistent floodwaters. Moreover, after one year the lake was measured to be in eutrophic condition, in contrast to the pre-flood hyper-eutrophic state. However, the pre-existing poor status of the lake ecosystem constitutes it resilient to the disturbances caused by the flood, which was also verified from the in situ measurements of nutrients (Perivolioti et al., 2024).

An interesting contradiction is the images of abundant aquatic birds that concentrated in the seemingly revived Lake Karla, an image of hope and prevalence of nature above all this destruction and catastrophe.

Figure 18. Contradictions, Lake Karla

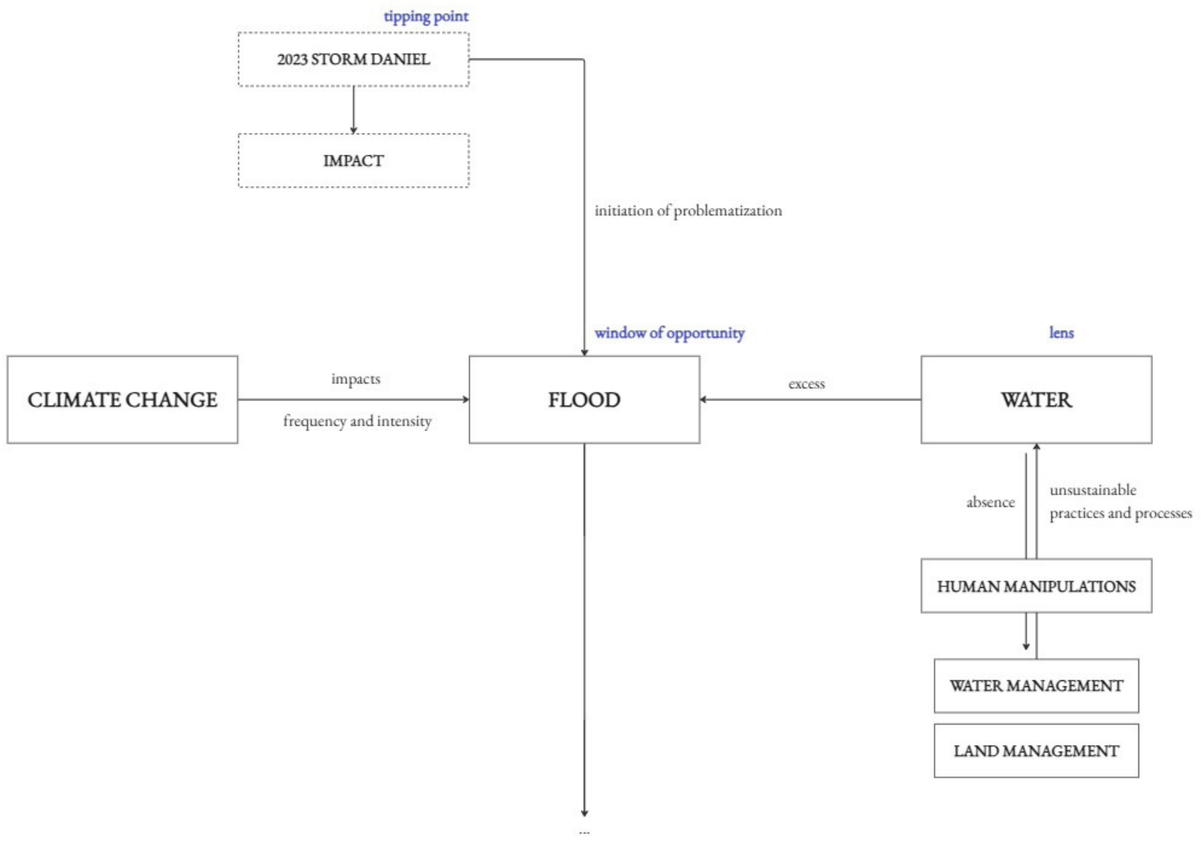


Figure 19. Problem field

The problem field is defined by the notion of flood, which is impacted by climate change, and exacerbated also by unsustainable practices of water management and persistent human manipulations of the natural ecosystem. The flood of September 2023 in Thessaly following storm Daniel is the tipping point initiating my problematization, framing the flood as a window of opportunity to be examined under the lens of water – in excess or absence.

Flooding in Greece and Thessaly

Rising frequency and intensity

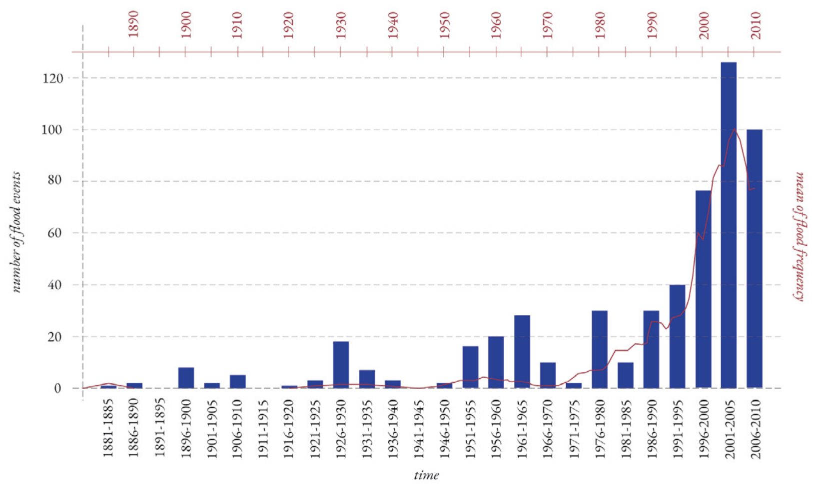


Figure 20. Number of flood events and frequency 1881-2010

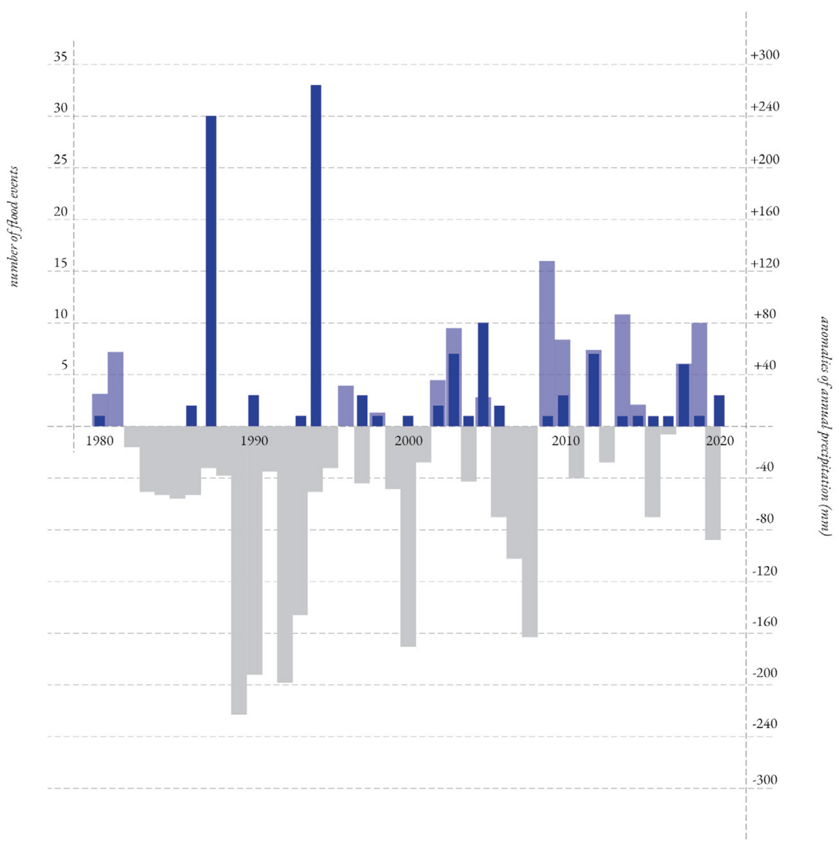


Figure 21. Number of flood events and precipiation anomalies in the PRB 1980-2020

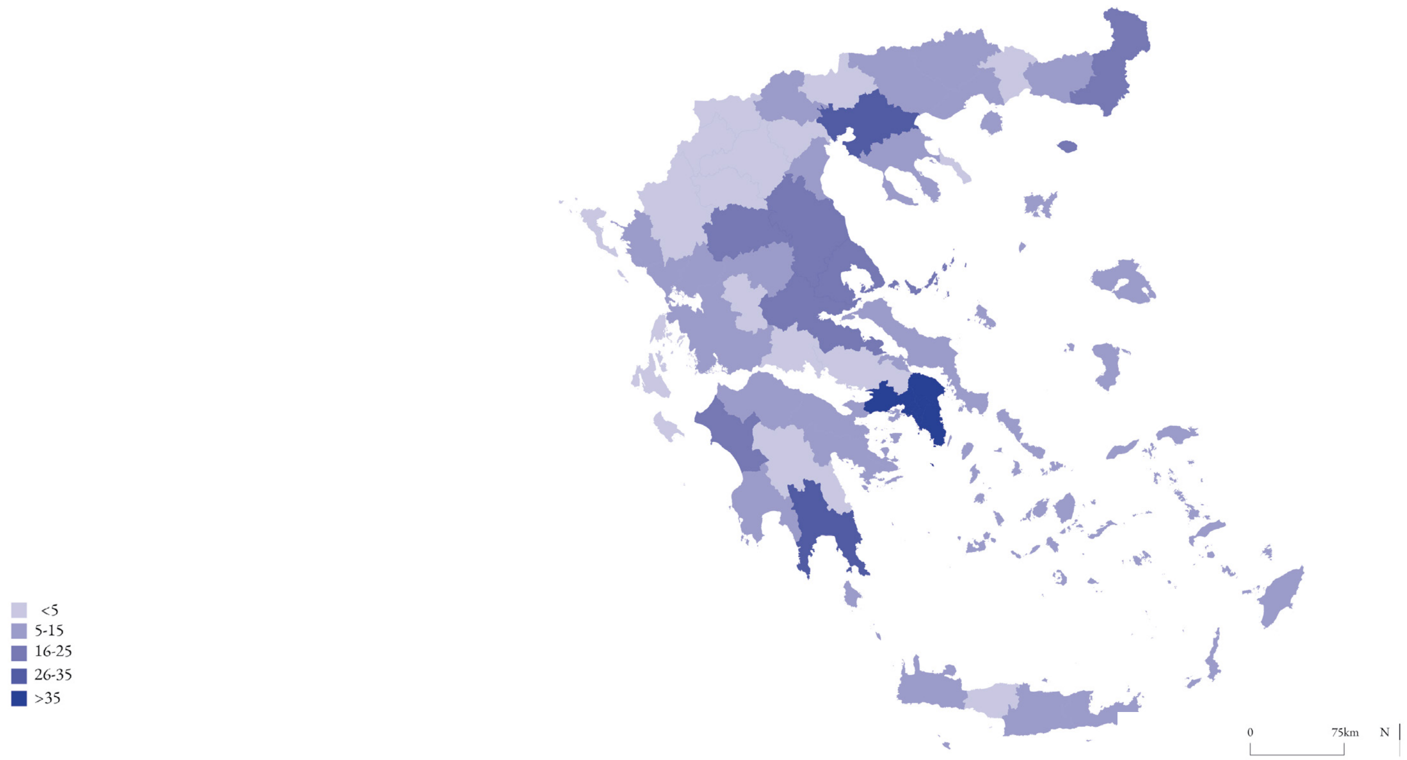


Figure 22. Number of flood events per administrative unit 1881-2010

Flooding in Greece has been common since the ancient times, consisting mostly of flash floods (Diakakis et al., 2012; Evelpidou et al., 2023). However, during the last three decades, the number of flood events has significantly increased. Specifically, in the period from 2000 to 2015, the highest number of floods per year was noted, yet the last 10 years are showing a decrease in this trend due to the implementation of flood protection measures (Evelpidou et al., 2023). Concerning the yearly flood frequency, an increasing trend was noted from 1980 to 2007, with that year being the critical point signifying the start of a pronounced decrease (Evelpidou et al., 2023).

The most events are clustered in prefectures with extended urbanized environments such as Attica, Thessaloniki and Larissa (Diakakis et al., 2012). Other areas presenting increased flooding problems are Patras, the south of Peloponnese, the eastern part of Evros in the north, and – most interestingly – all the prefectures of Thessaly (Larissa, as mentioned before which is drained by the major river Pineios, Trikala, Karditsa and Magnesia) (Diakakis et al., 2012; Evelpidou et al., 2023; Karagiorgos et al., 2013). Specifically for the Pineios River Basin, there was an increase in the flooding events during the period 1990-2010, with the maximum value of flood occurrences number in 1994 (Bathrellos et al., 2018).

It is also important to note that even though the annual precipitation in Greece has been reduced, as a result of climate change, the intensity of rainfall events has escalated, as highlighted by the alternating anomalies between high and low precipitation. Specifically, in Pineios River Basin, the precipitation trend grew from the 1950s to the late 1960s, followed by a shrinking phase until the early 1990s. However, during the last two decades, the alterations between intensely dry and wet years is more frequent (Varlas et al., 2022).

Natural tendency

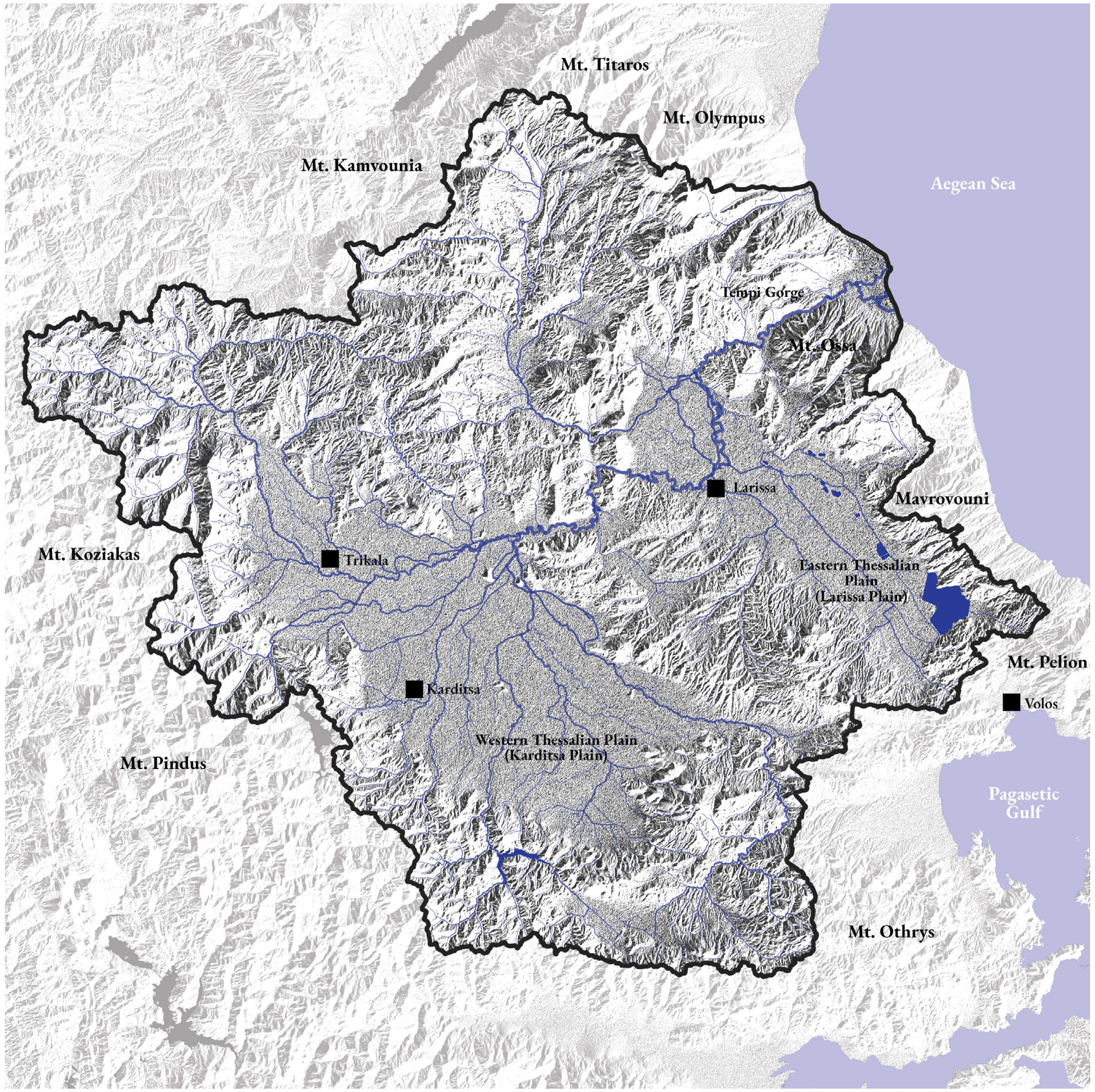


Figure 23. Pineios River Basin (PRB) recognition

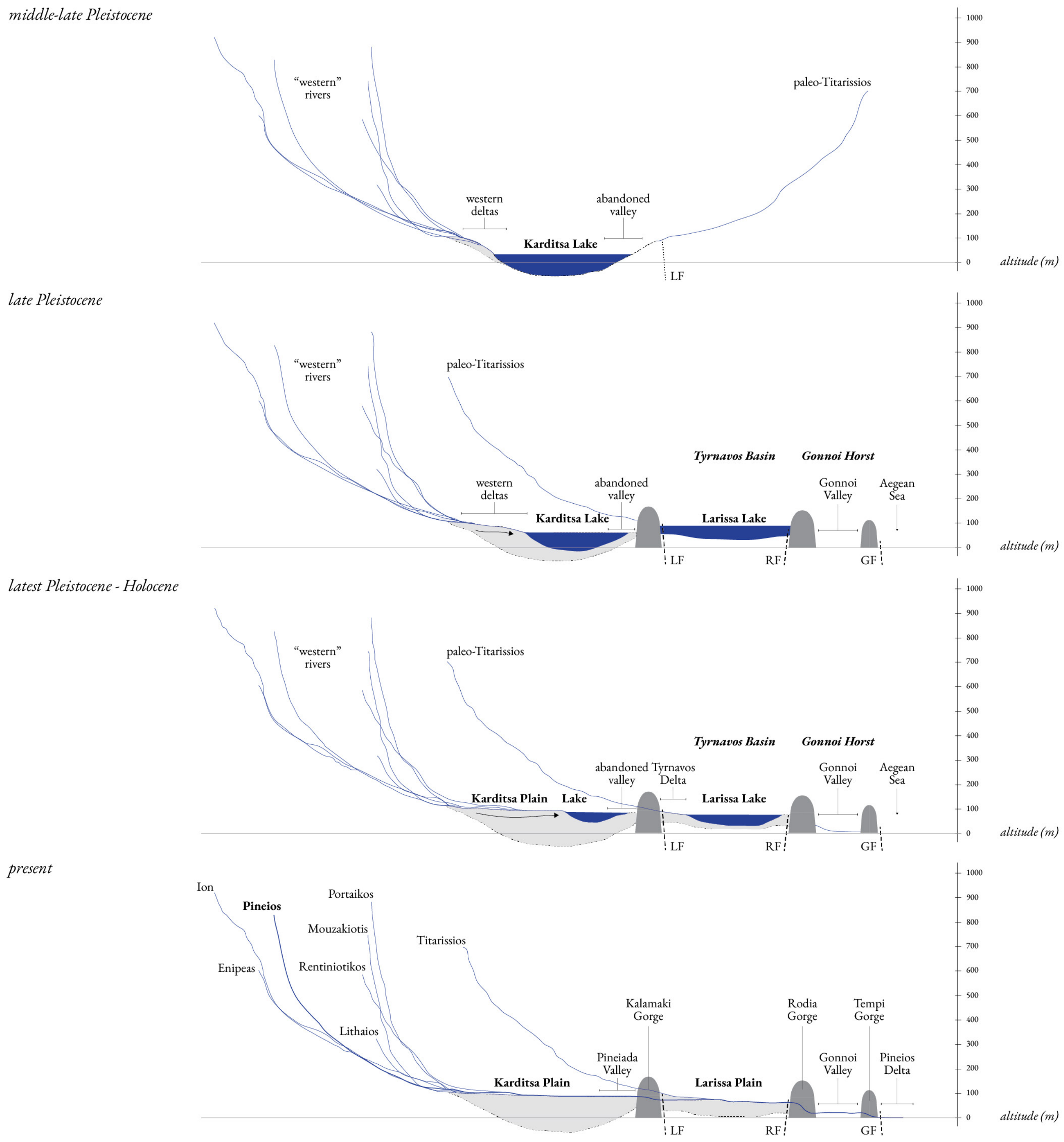
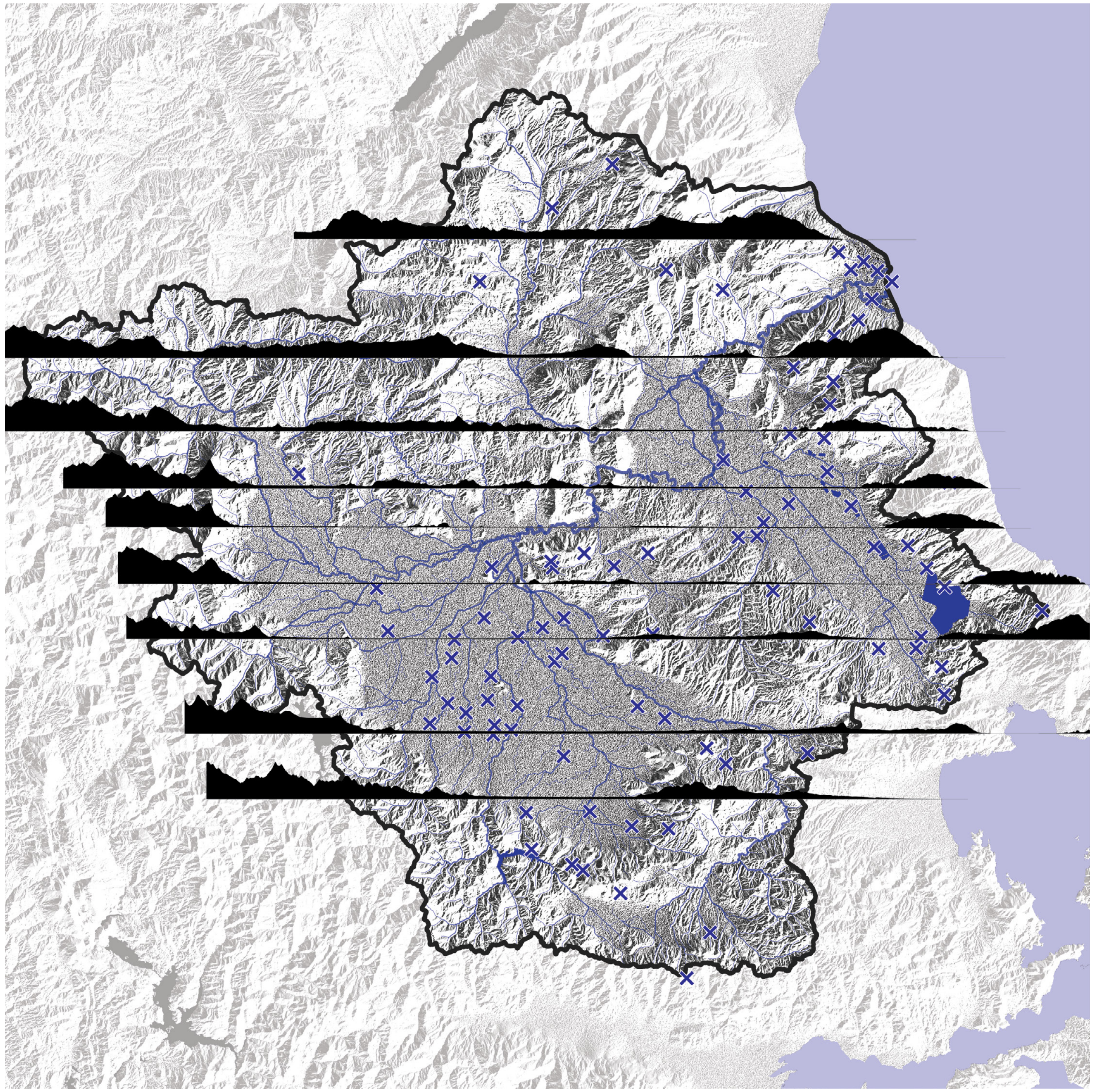


Figure 24. Hydrographic evolution of Thessaly (adapted from Caputo et al., 2022)



0 10km N

Ecosystem

historic floods

Strahler stream order

Figure 25. Natural tendency, More than Human - More than City investigation

The Thessalian plain, belonging to PRB, is divided into two parts by a low hill – the western plain of Karditsa and the eastern plain of Larissa. It is enclosed by mountains; Mt Pindus and Mt. Koziakas to the west, Mt. Titaros and Mt. Kamvounia to the north, Mt. Olympus and Mt. Ossa (Kissavos) to the north-east, Mavrovouni and Mt. Pelion to the east and Mt Orthrys to the south, which creates a watershed with a very narrow exit to the Aegean Sea, through the Tempi valley. The major tributaries of Pineios River are Portaikos, Mouzakiotis, Rentiniotikos, Malakasiotis, Pamisos, and Enipeas to the west and south and Ion, Lithaios, Titarisios and Neochoritis to the north (Bathrellos et al., 2018; Caputo et al., 2022). As evident, Pineios River Basin is shaped like a low-lying bowl, surrounded by mountains, which directly contributes to its natural tendency to flood since the ancient times (Bathrellos et al., 2018).

In fact, many ancient historians have reported that Thessaly was originally a lake until processes of erosion caused the formation of the Tempi valley, which caused the water to exit through there to the Aegean Sea (Rouskas, 2001). According to popular belief, on top of mountainous formations like Meteora and Titaros, there can even be found hooks were fishermen tied their boats (Rouskas, 2001). It has been proven that the entirety of Thessaly is an extensive intra-mountainal depression formed by two smaller depressions, the western and the eastern, with the latter consisting of smaller graben basins in staggered arrangement (TEE, 1999). Evolutionary processes that happened during the Neogene and Quaternary periods resulted in the draining of the Thessalian waters and the formation of the plain (TEE, 1999) as well as the two lakes of Nessonis, a bigger and shallower marshy area which was drained during the period of the Ottoman rule (Rouskas, 2001), and Voivis, the smaller one and otherwise known as Lake Karla.

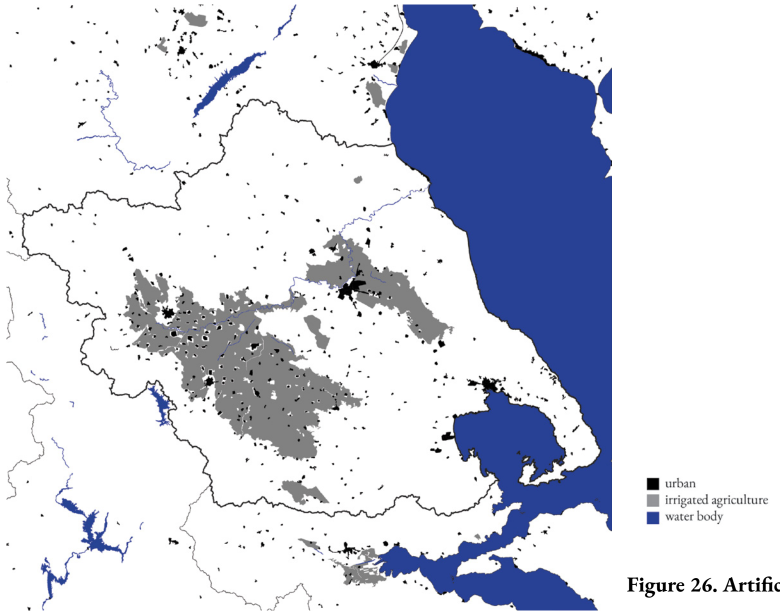


Figure 26. Artificial surfaces and irrigated arable land 1990

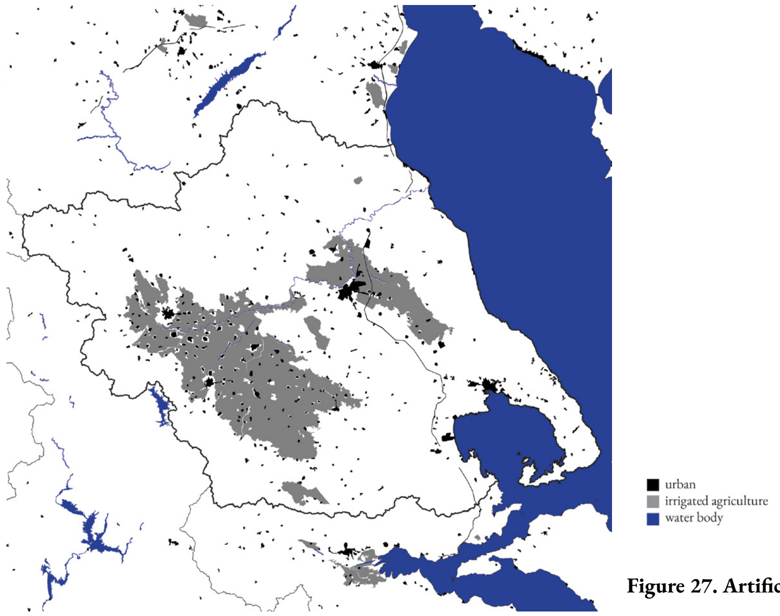


Figure 27. Artificial surfaces and irrigated arable land 2000

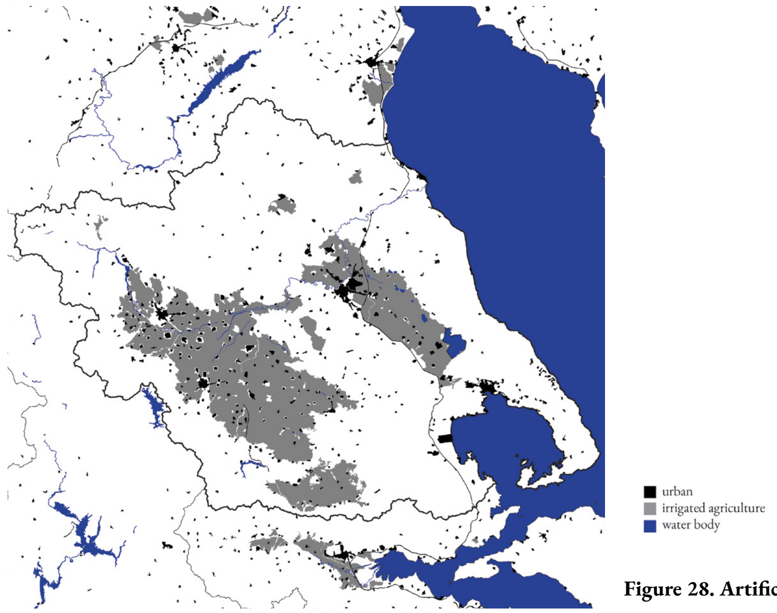


Figure 28. Artificial surfaces and irrigated arable land 2018

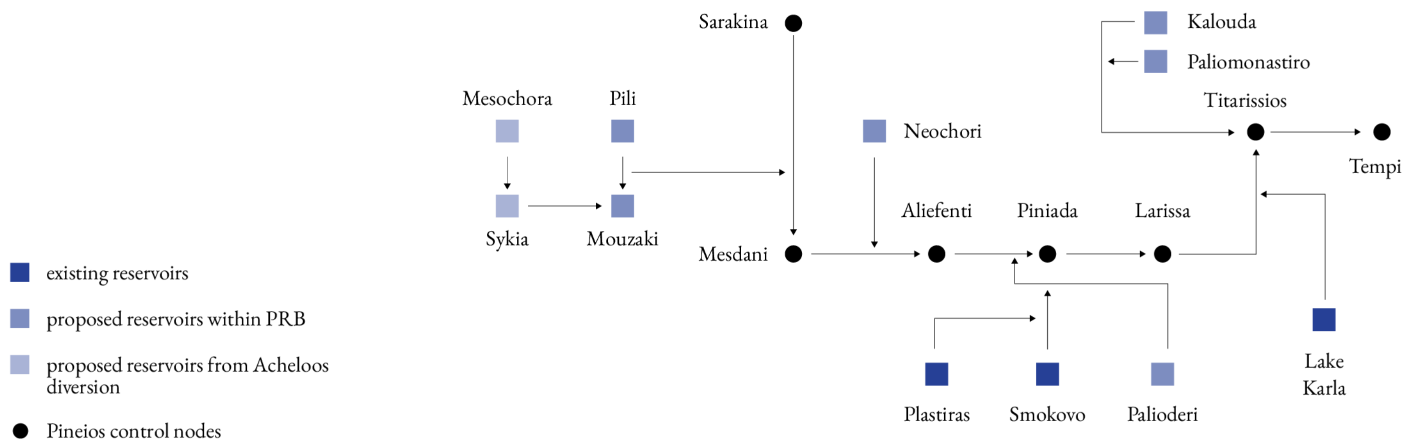


Figure 29. Proposed and existing reservoirs and their operation model
(adapted from Loukas et al., 2007)

Predominantly, the areas in which a high number of floods is concentrated are urban (Evelpidou et al., 2023), due to the increased sealed surfaces and reduced natural areas for water retention (Karagiorgos et al., 2013). However, the increase in population has led to pressures for urban expansion, causing land use change and settling in unsuitable locations, therefore resulting in a growing number of flooding occurrences (Diakakis et al., 2012; Karagiorgos et al., 2013). In the last years, factors affecting the severity of flood consequences are not solely environmental, but related to human activities and interventions, such as building constructions near channel beds, creating barriers to river channels, and alterations in natural watercourses, as well as deforestation (Diakakis et al., 2012; Evelpidou et al., 2023).

Floodplains are favorable areas for settlement because they are fertile, flat and easy to excavate and in proximity to water. This has contributed to the urbanization of those plains, resulting in a growing number of disastrous flood occurrences, despite the construction of heavy flood protection works such as dams, channels and levees (Bathrellos et al., 2018). Specifically, the floodplains of Pineios were originally marshy and lacustrine areas with two paleo-lakes located there during the Quaternary period but were later covered and dried up. Coincidentally, historical flood occurrences are spatially clustered there (Bathrellos et al., 2018). These floodplains have been cultivated since the Neolithic period, with settlements starting to appear in the pre-Classical period. Until 1920, agricultural practices were limited on the flat areas, but the rapid increase in the population due to the immigration from Asia Minor, led to multiple land use changes in the area and the intensification of agriculture (Evelpidou et al., 2023). Cultivation gradually moved towards the low hills, limiting natural vegetation (Evelpidou et al., 2023) and turning existing pastures into tillable land, a process of land reclamation that was intensified with the subsidies from the European Union during the 1960s (Arapostathis et al., n.d.). Other alterations include the dredging of stream beds, stream diversions (Evelpidou et al., 2023), covering up streams and destroying meanders to turn them into linear channels (Arapostathis et al., n.d.). It is important to note the consistent increase of flood events along with the growing number of population associated with the intensification of cultivation activities (Evelpidou et al., 2023)

Even in the last 20 years, these processes of operalization of the agricultural landscape are evident, with the constant modifications to the natural hydrosystems.

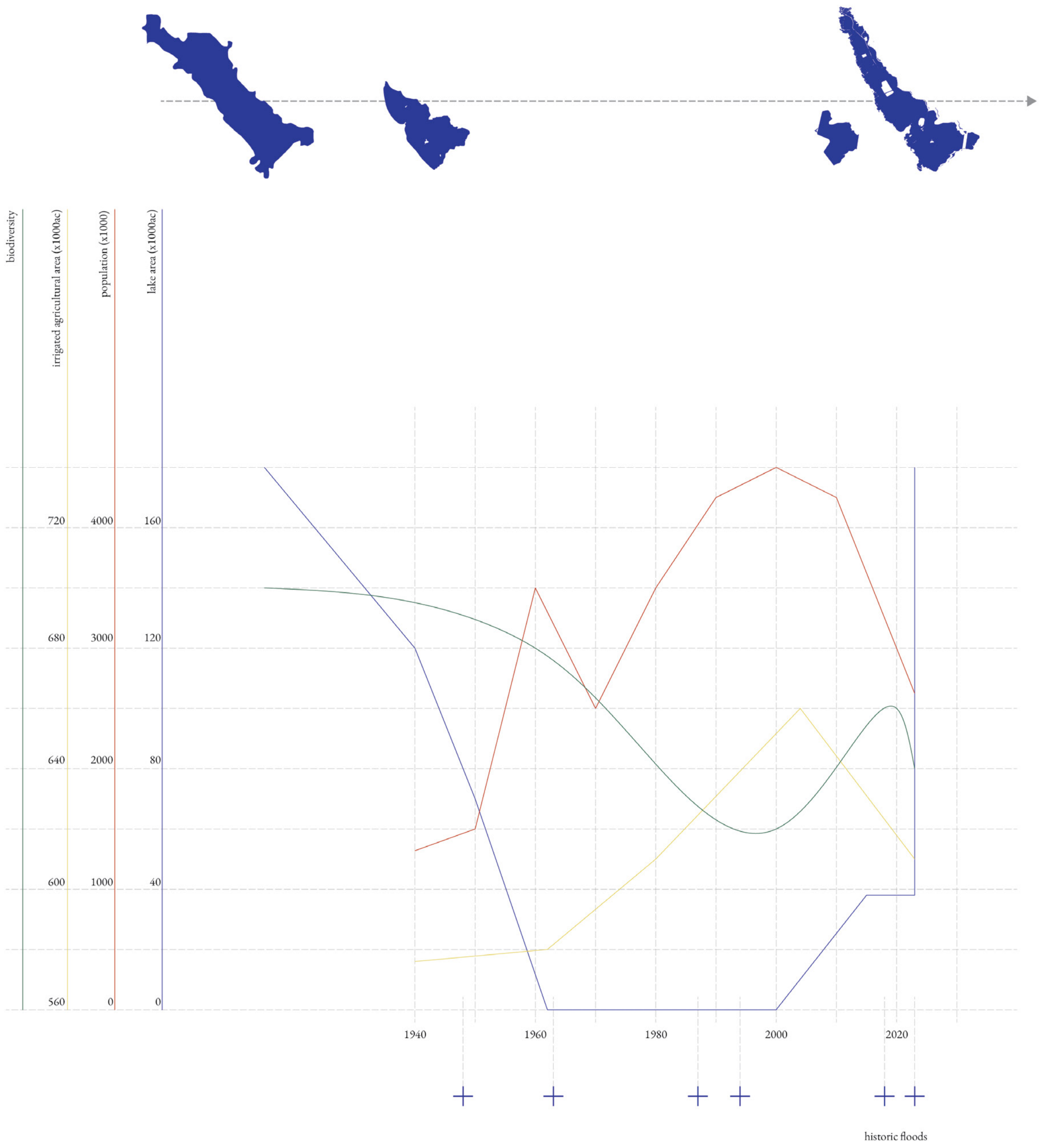


Figure 30. Limits

Thessaly is the second largest plain of Greece and the center of Greek agricultural production. In 2021, 23% of Gross Value Added (GVA) of the agricultural sector came from this region. Specifically, 21% of the plant of production and 13% of livestock production is concentrated in there (Arapostathis et al., n.d.). The main annual products are cotton (which consisted of 42% of Greek annual production in the 2000s), maize and wheat on the plains, while orchards and vineyards are located on the foot of the eastern mountains (Mylopoulos et al., 2009; Pisinaras et al., 2023). However, the rapid agricultural development and the unregulated way water resources have been managed in the last four decades have created serious problems regarding the depletion and degradation of surface and groundwater resources which are already close to the limits of ecological disaster (Arapostathis et al., n.d.). This has resulted in Thessaly dealing with one of the most extreme water resources problem currently (Loukas et al., 2007; Polyzos et al., 2009).

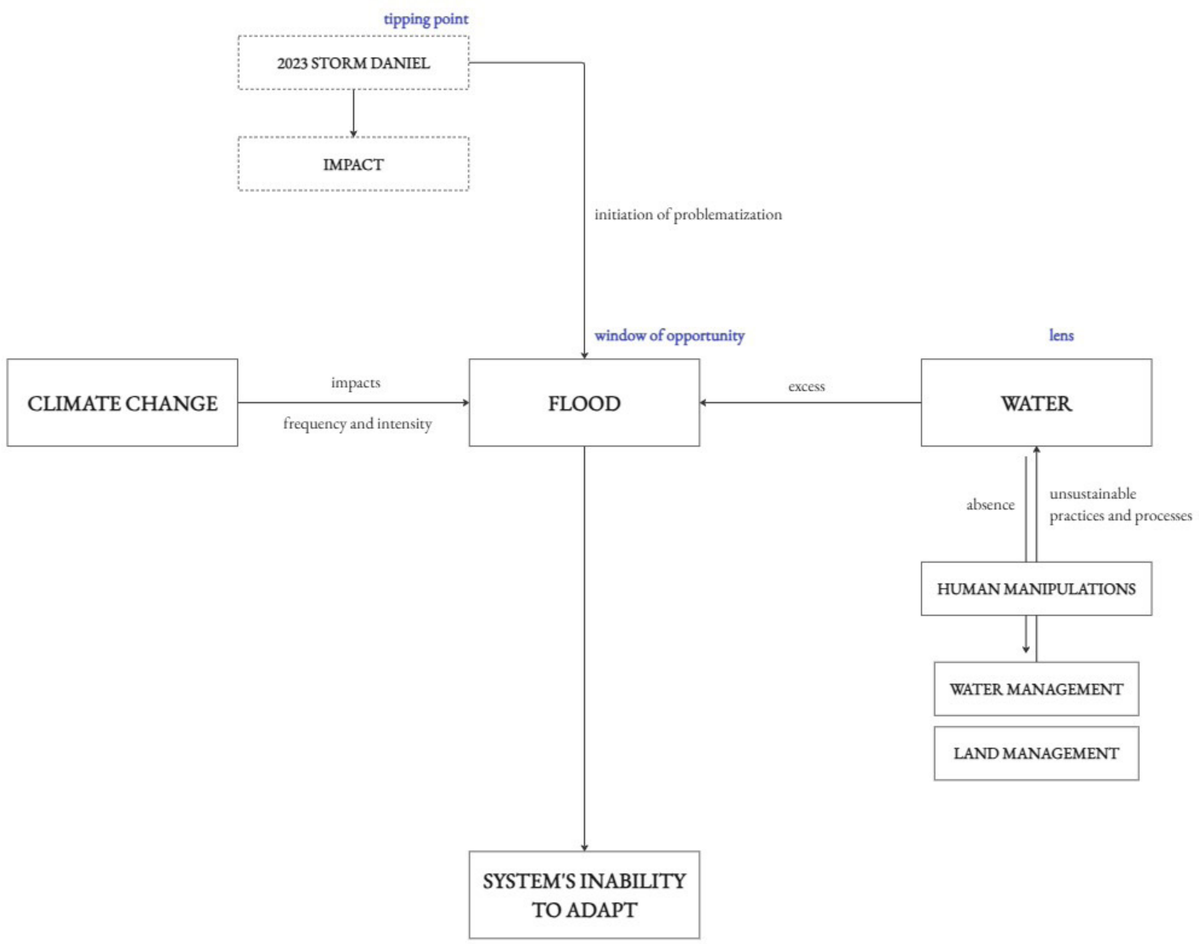
Specifically, 94% of water abstraction in the PRB is used for irrigation purposes. The increasing demand for irrigation water since 1980, following the drainage of Lake Karla, due to the water intensive crops like cotton, has led to a series of unsustainable practices regarding groundwater abstraction which has resulted in the exploitation of groundwater resources and disturbing the hydrological balance (Pisinaras et al., 2023). This deficiency has catapulted the rapid decrease of the cultivated cotton area by 54.000 ha in the last two decades, amounting to 84.000ha currently, while 20 years ago the respective area was 150.000ha (Arapostathis et al., n.d.). Additionally, the aging trend in the population working in the primary sector, combined with the high reliance on European subsidies (Mylopoulos et al., 2009) has contributed to the deterioration and dis-investment in the agricultural sector.

Nevertheless, almost half of the total area extent of the Water District (1.337.700ha) is still cultivated land (roughly 600.000ha). During the flood of 2023, 83.000ha of land was inundated, 70% of which was agricultural land, because of these unsustainable practices of urbanization and water management.

photo by Takis Tloupas

Figure 31. Morning on the plain, 1966

Problem statement



The agricultural plains of Thessaly, Greece, located in the Pineios River Basin, have the natural tendency to flood, as the flattest and lowest parts of the region (Bathrellos et al., 2018). However, the changing climate patterns, which cause more frequent events of extreme precipitation, combined with a series of human-induced processes of manipulation, are contributing to the system's inability to cope and recover in the event of flooding (Dimitriou et al., 2024). These processes are described by the extensive urbanization of the former floodplains for agricultural purposes coupled with continuous alterations of the natural system to combat water scarcity (Evelpidou et al., 2023). Additionally, inadequate planning processes and persistent unsustainable practices regarding water management, as well as the linear, short-visioned and sectoral approaches to flood risk mitigation, further exacerbate the system's inability to recuperate, pushing it to its limits. If a solution is not found, the accumulation of strains will lead to the total exhaustion and degradation of the most productive agricultural core of Greece (Bathrellos et al., 2018). Therefore, a reconfiguration of the water and land management system is necessary in order utilize the operability of the floodplains to activate long-term adaptive transformations, which in turn will foster resilience to flooding.

Figure 32. Problem statement

Research aims and outcomes

This research aims to first examine and ultimately enhance the operability of the Thessalian (flood)plains through a transformative process, for the system to be able to better cope, recover and adapt in the event of flooding, using the area of the Lake Karla system as a case study. The overall goal is to initiate a process of evolutionary resilience to flooding. To achieve that, an integrated design is proposed that takes into account the regional processes and local adaptation practices to the increasing flood risk during times of uncertainty.

Therefore, firstly it is essential to comprehend from existing literature how flood risk is defined as a function of hazard, vulnerability and exposure, as well as what different systems are related to those notions and how they also interrelate with each other. This understanding facilitates the assessment of Lake Karla's current coping and recovery capacities, which are defined by biophysical and socio-technical limits and alterations. By superimposing those limits, critical areas (*critical zones*) within a range of transformability potential are identified, where transformative actions can be implemented in order to activate a process of socio-ecological (or otherwise *evolutionary*) resilience (Davoudi et al., 2013) through an ecosystem-based adaptation. These adaptive transformations are evaluated through an Ecosystem Services Assessment model and tested by design explorations on strategic, systemic and specific levels. Finally, an adaptation framework is outlined, delineating how this process of negotiation between different human and non-human actors can be supported through possible collaborations of different stakeholders and how it can be institutionalized and phased through governance mechanisms.

Therefore, the expected outcomes can be summarized as follows:

1. A comprehensive theoretical and spatial understanding of risk literature and system interrelations.

2. An assessment of Lake Karla's coping and recovering capacities, and a categorization of critical areas within a range of potentiality for transformation.

3. Design explorations, testing and evaluating the proposed adaptive measures on strategic, systemic and specific levels.

4. Pathways and recommendations for the adaptation of the proposed transformation.

Research questions

Main research question

How can an ***integrated design*** of the **Lake Karla** system, with the implementation of successful **land management policies**, incorporating **land transformation strategies**, bridge the gap between **coping**, **recovery** and **adaptive capacity** to ***flooding*** in Thessaly, activating a process of ***evolutionary resilience***?

It is important to note that those questions have been organized in clusters according to Peter Marcuse's paradigm of Critical Planning: analyse, propose, expose and politicize, which will be explained in detail in the next chapter.

Sub-questions

***What* | Analyze**
How is **flood risk** defined by the relations between *hazard, vulnerability and exposure* (in the Thessalian context)?

What are the **systems** and **sub-systems** related to hazard, vulnerability and exposure that need to be explored in order to assess Thessaly's flood risk, and what are their *interrelations*?

***Why* | Expose**
What are the current **environmental, physical, social and economic conditions** of Lake Karla's system, affecting hazard, vulnerabilitz and exposure and how have they been *altered*, resulting in a spatial and socio-economic transformation?

What are the current **policies and plans** for flood risk mitigation and water management and what kind of *conflicts and alignments* exist with local sensitivities and adaptation practices?

What are the current **coping and recovery capacities** of Lake Karla's resilience to flooding and how are they defined by *biophysical and socio-technical limits*?

***How* | Propose**
What are the **critical zones**, defined by a set of criteria for c*riticality and transformability*, highlighting possible areas of intervention within the Lake Karla system?

What **transformative actions**, grounded on *ecosystem-based adaptation and nature-based solutions,* need to be implemented in order for the system to become ***resilient*** to flooding and how do they perform under an **Ecosystem Services Assessment** model?

How can the implementation of *biophysical and socio-technical measures* through strategic, systemic and specific **design explorations** redefine possible negotiations between agriculture, water and nature, catapulting a ***paradigm shift***?

***How so* | Politicize**
How can the proposed transformations be integrated and phased through an adaptation framework, towards an integrated **environmental co-management** of the region, which fosters ***evolutionary resilience***?

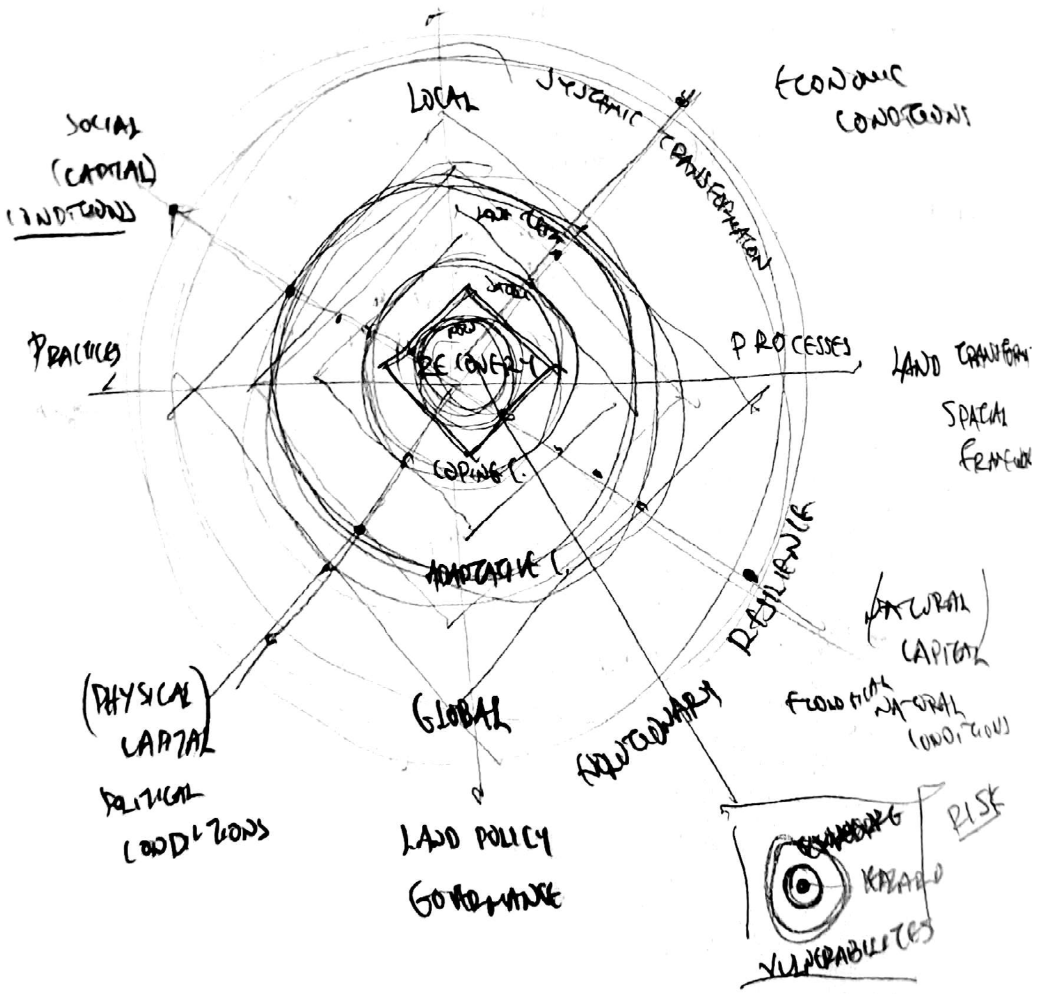


Figure 33. Conceptual framework exploration

02| Research framework

Analytical framework

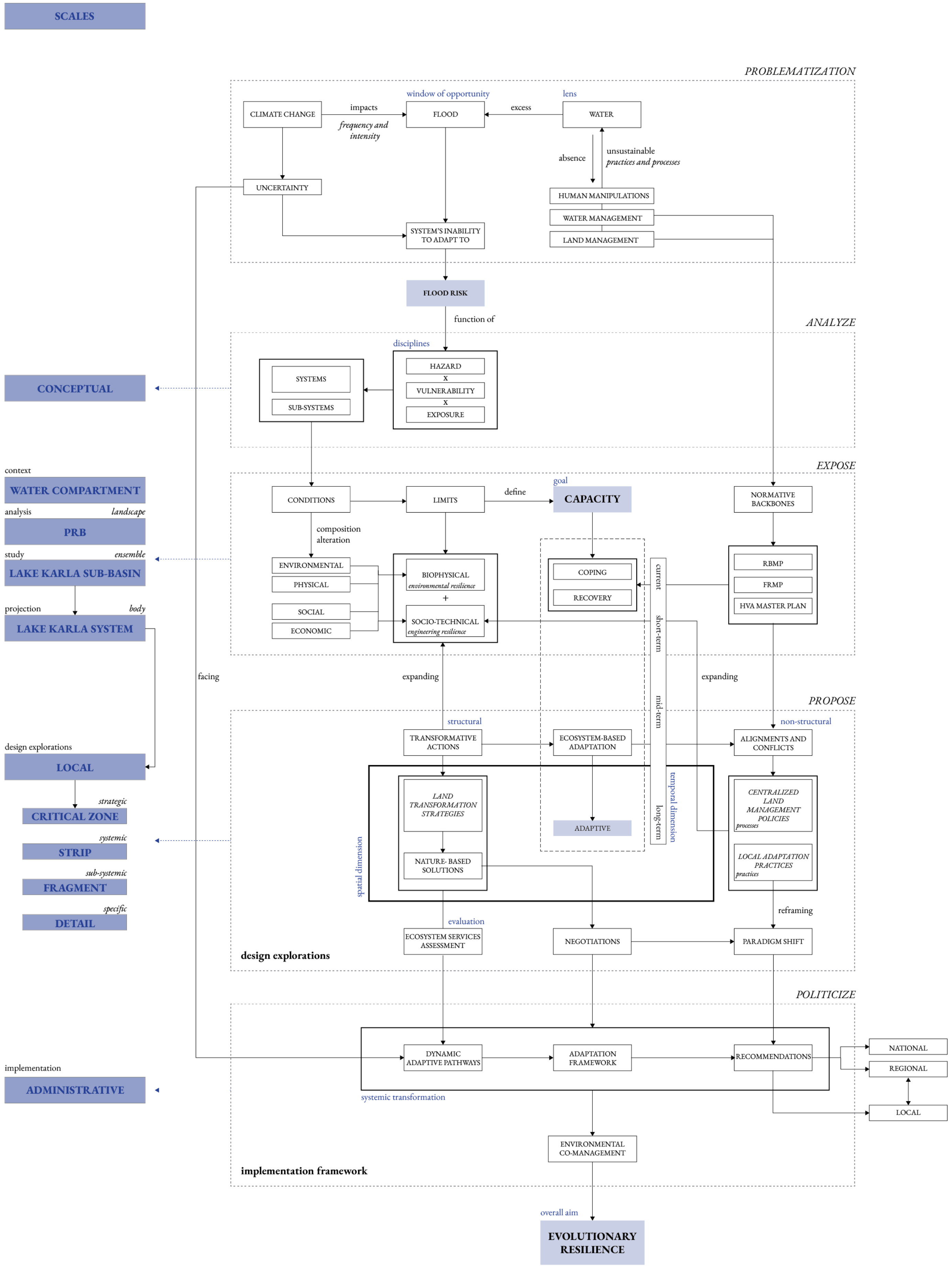


Figure 34. Analytical framework

This diagram presents the overall project trajectory, showcasing the progression from the problem definition to the way this is tackled through adaptive transformations. It is also separated into my four main methodological steps, which are analyzed further in this chapter and organize the structure of this graduation project.

Specifically, the transition from my problematization phase to the analytical and design phase is highlighted, by recognizing the urgency to examine the notion of flood risk and its components, hazard, vulnerability and exposure. Systems and sub-systems related to these disciplines are identified and their respective environmental, physical, economic and spatial conditions – current and altered – are examined in order to come to conclusions about the biophysical and socio-technical limits of the system which define its coping and recovery capacities. At the same time, existing policies and plans functioning as normative backbones are studied, which also inform the current, short-term and mid-term capacity to flooding.

The core of the project lies in the transition from coping and recovery capacity to integrating adaptive capacity, which happens through the proposal of transformative actions based on the biophysical and socio-technical limits, with the aim to expand them. This results in land transformation strategies which are aligned with the values of ecosystem-based adaptation and are expressed through nature-based solutions, which are evaluated through an Ecosystem Services Assessment. The proposed measures are informed by centralized processes and local adaptation practices, in order to define possible alignments and conflicts that need to be reframed through a paradigm shift achieving a negotiation between them and the proposed nature-based solutions.

In the last stage of the project, dynamic adaptive pathways are used as a phasing tool, and an adaptation framework is outlined, providing recommendations for the successful implementation of the proposed transformative measures.

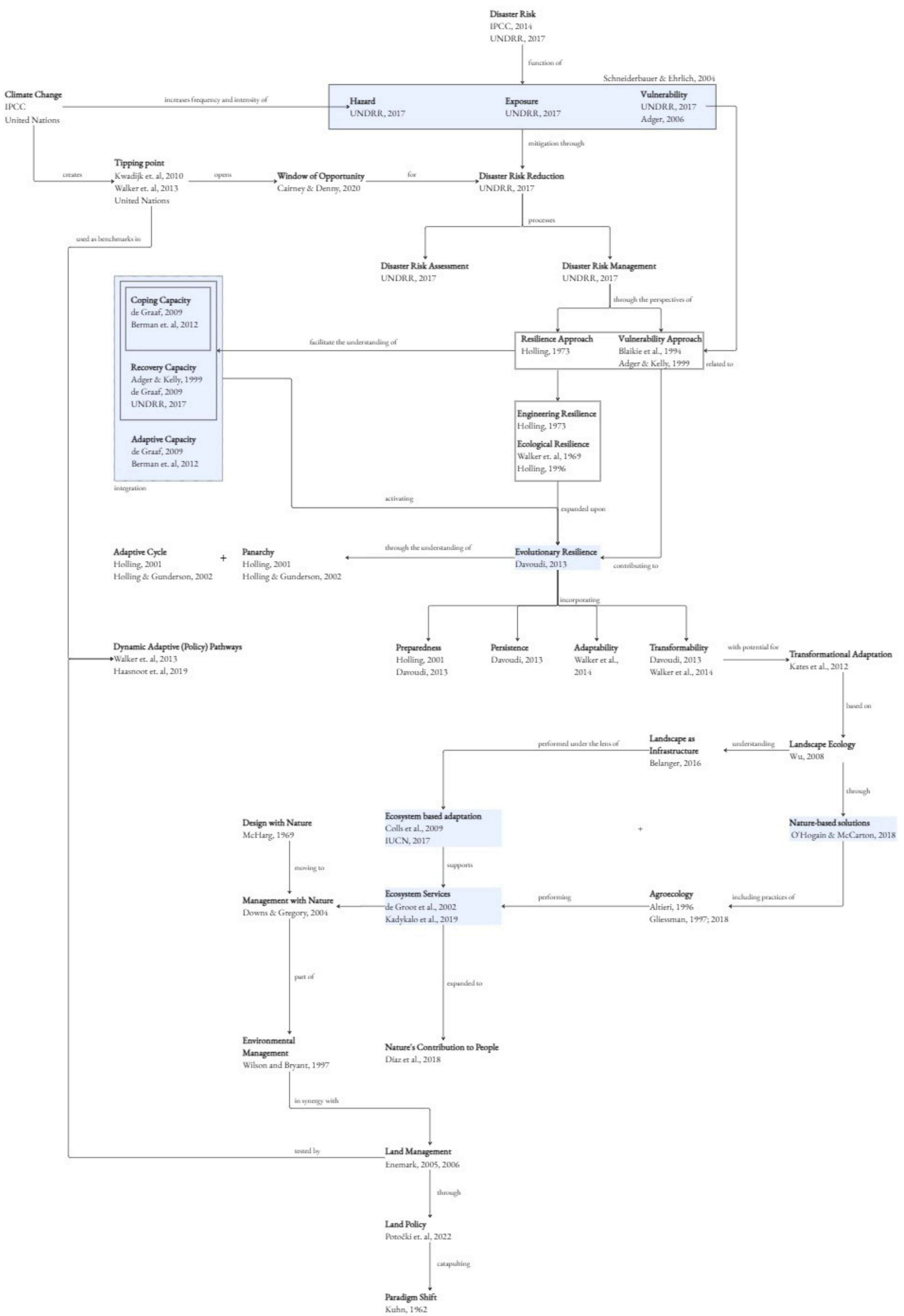


Figure 35. Theoretical framework

This diagram represents the theories upon which my project is based on, and the relations between them. Climate change refers to long-term changes in weather patterns and temperature and is driven mostly by human activities (United Nations, 2025). It impacts the frequency and intensity of extreme weather events and natural hazards, such as fires, droughts and floods therefore exposing communities and ecosystems to risk. Risk, recognized as the potential for consequences when something valuable is threatened and the outcome is not certain (IPCC, 2014a), is composed as a function of hazard, exposure and vulnerability (Schneiderbauer & Ehrlich, 2004; UNDRR, 2017a).

Risk = hazard x exposure x vulnerability

"Risk is the potential loss of life, injury, or destroyed or damaged assets which could occur to a system, society or a community in a specific period of time, determined probabilistically as a function of hazard, exposure, vulnerability and ***capacity****"* (UNDRR, 2017)

"Hazard is a process, phenomenon or human activity that may cause loss of life, injury or other health impacts, property damage, social and economic disruption or environmental degradation" (UNDRR, 2017)

"Vulnerability are the conditions determined by physical, social, economic and environmental factors or processes which increase the susceptibility of an individual, a community, assets or systems to the impacts of hazards" (UNDRR, 2017)

"Exposure is the situation of people, infrastructure, housing, production capacities and other tangible human assets located in hazard-prone areas" (UNDRR, 2017)

It is important to recognize the interdependence between the three components of risk, namely hazard, exposure and vulnerability, expressed visually in various ways. Firstly, in Crichton's triangle the size of the risk corresponds to the size of the triangle. Therefore, if one of the variables (hazard, exposure, vulnerability) is zero, then the hazard equals zero as well (Crichton, 1999). The International Panel of Climate Change (IPCC) depicts risk at the convergence of hazard, exposure and vulnerability (IPCC, 2014b). Both approaches understand and express those three components as individual factors, and in their co-occurrence is where risk manifests. Thus, specific actions for reducing hazard, vulnerability and exposure can be proposed, but their prospects are defined by biophysical and socio-technical limitations (IPCC, 2014b).

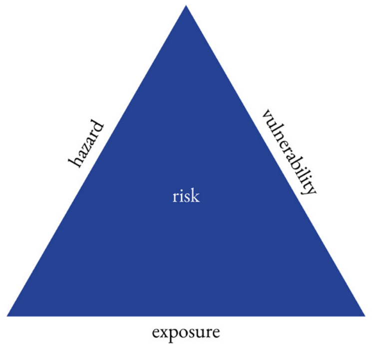


Figure 36. Crichton's triangle (adapted from Crichton, 1999)

Extreme events, induced by climate change, provide tipping points, thresholds after which a change in system is irreversible and does no longer need external forces to maintain the new pattern (United Nations, n.d.b; Kwadijk et al., 2010). After passing this point, the existing strategies are no longer effective and a new strategy is needed (Walker et al., 2013). Consequently, in this moment of change and collapse, a window of opportunity is opened for the creation of novel adaptive strategies (Cairney & St Denny, 2020) in order to initiate transformation and progress to a more desirable trajectory (Davoudi et al., 2013; Thaler, 2018). Disaster Risk Reduction (DRR) aims in preventing, reducing and managing risk (UNDRR, 2017d), is facilitated by processes of Disaster Risk Assessment in order to identify and understand the extent of the risk (UNDRR, 2017c), and then operated through Disaster Risk Management (DRM) , which is defined as the implementation of disaster risk reduction policies and strategies (UNDRR, 2017d).

Figure 37. Risk Framework from the Intergovernmental Panel for Climate Change (adapted from IPCC)

DRM is understood through different perspectives, two of them related to this project being the Resilience Approach, greatly expanded upon by Holling, who emphasized the notion of *persistence* of systems and their ability to absorb change (Holling, 1973), and the Vulnerability Approach, which highlighted the way socio-political and economic conditions influence a system's susceptibility to harm and its inability to cope with shocks (Blaikie et al., 2003). Both of these approaches have similar key parameters and interests – the stresses a system undergoes, its sensitivity and adaptive capacity (Adger, 2006).

Coping, recovery, adaptive capacity

"Coping capacity is the ability of people, organizations and systems, using available skills and resources, to ***manage*** *adverse conditions, risk or disasters"* (UNDRR, 2017)

"Recovery capacity is the ability of a society to respond and to ***recover*** *to the same or to an equivalent state as before the emergency"* (de Graaf, 2009).

"Adaptive capacity is the ability to prepare in advance for stresses and changes and to ***adjust****,* ***respond*** *and* ***adapt*** *to the effects caused by the stress associated with future climate change"* (Berman et al., 2012)

Coping capacity is identified as the short-term and immediate response to risk, with the objective of reducing damage. It is activated during the emergency (de Graaf, 2009). After the disaster has occurred, recovery capacity is activated with the aim of recovering as quickly and effectively as possible. Restoring and improving systems of a community affected by disaster, in alignment with the principles of sustainable development and "build back better" is imperative (UNDRR, 2017). However, the recovery time can vary greatly depending on the spatial extent and the severity of the disaster. On the other hand, adaptive capacity is the capacity of a society to anticipate and foresee future developments and impacts, while recognizing that every decision is made in the face of uncertainty (de Graaf, 2009). Adaptive capacity highlights a more permanent change, a long-term transformation of the system and its existing practices of structuring, functioning and organization (Berman et al., 2012). There is the potential to build adaptive capacity on top of coping and recovery capacity by linking the resilience and vulnerability approaches, activating in this way a process of evolutionary resilience. Resilience approach focuses on the interrelations between ecological and social systems and sub-systems, while vulnerability approach highlights the role of socio-political structures and stakeholders within climate change adaptation. The role of governance and institutions – whether they are formal or informal, private or public or civic – as crucial components of adaptive capacity is present in both of these approaches, through the collection of assets, information and skills (Berman et al., 2012).

Evolutionary resilience

Engineering, ecological and socio-ecological resilience – or as defined by Davoudi – *evolutionary resilience*, are three general concepts of resilience, the first two focusing on the notion of a stable equilibrium to which the system bounces *back* in the case of the former, and bounces *forth* in the case of the latter (Davoudi et al., 2013). Engineering resilience is founded in stability and the potential of the system to return to this steady state of equilibrium (Holling, 1996), while ecological resilience recognizes the potential of the system to jump to a different stability domain, therefore to adapt (Walker et al., 1981; Holling, 1996). However, both approaches identify nature as a stable domain. The novelty of evolutionary resilience lies in the fact that it recognizes human and natural systems as interdependent. It incorporates the dynamic nature between persistence, adaptability and transformability of ecological systems under shocks and stresses caused by climate change, but also includes a fourth dimension, the one of preparedness, highlighting the importance of the intentionality of human interventions (Davoudi et al., 2013). Persistence is tied to short-term robustness, while adaptability emphasizes the importance of flexibility and resourcefulness as well as the capacity of actors and community as a collective to manage resilience (Walker et al., 2004). Transformability is what sets evolutionary resilience apart from engineering and ecological resilience, centering innovativeness and creativity, with being able to recognize transformative potential after a phase of destruction and define new systems (Davoudi et al., 2013; Walker et al., 2004). Finally, preparedness is what completes the framework of evolutionary resilience, encompassing the capacity of foresight, as well as the learning capacity of humans, translated into intentional actions in order to better anticipate risk and reduce uncertainty (Davoudi et al., 2013). Evolutionary resilience is based on the concept of the adaptive cycle, in which change happens in four phases: growth, conservation, creative destruction and reorganization (Holling, 2001; Gunderson and Holling, 2002). These phases are not sequential, and systems can operate not within just one cycle, but in multiple, happening in different scales with simultaneous interactions. Gunderson and Holling (2002) defined this as the basis of panarchy.

Transformability is recognized as a critical term regarding evolutionary resilience, focusing on the potentiality of imagining radically different futures, especially after a threatening event. The subsequent actions are defined as transformational adaptations (Kates et al., 2012), organized in three groups; those with a very large scale of implementation, those novel to a region or a system, and those transforming a place and changing locations. Transformational adaptations can also be planned or autonomous, responsive or anticipatory, while they can be characterized as transformational in one scale, but in others not; however with the possibility to become transformational, if maintained for enough time (Kates et al., 2012). Specifically, transformational adaptations relating to transforming a place of a human environment can be grounded in landscape ecology.

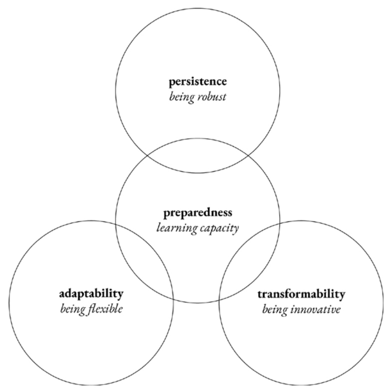


Figure 38. Evolutionary resilience components (adapted from Davoudi et al., 2013)

Landscape ecology, a notion that was developed in 1939 by the German geographer Carl Troll, recognizes landscapes as spatial mosaics with distinct biophysical and socio-technical conditions. Its aim is to study and enhance the relationship between these complex spatial patterns and ecological processes, in multiple scales and levels of organization (Wu, 2008). This multifaceted concept creates room for different approaches in macro-, meso- and microscales, while understanding the heterogeneous nature of landscape and the impact of landscape fragmentation in a patchwork of many different land uses – caused by urbanization and industrialization processes – on biophysical systems (Bélanger, 2009). Engineering biophysical elements of the landscape such as hydrology and topography create constructed ecologies usually tied to urban development.

However, if those practices are performed under the lens of Ecosystem-based Adaptation, focusing on sustaining and managing healthy ecosystems through community-based adaptation, they can enhance the system's resilience and play an important role in climate adaptation and disaster risk reduction (Colls et al., 2009). This can happen with the implementation of nature-based solutions, natural and constructed systems which support and are supported by natural processes and generally require less funds and energy for operation and maintenance (O'Hogain & McCarton, 2018). Nature-based solutions include practices of agroecology, which was originally defined as the "*science of sustainable agriculture*" (Altieri, 1996; Gliessman, 1997; 2018), but now the definition has expanded with recognizing the importance of radically transforming agriculture aiming at a more sustainable food system (Gliessman, 2018). It is highly important to note that agroecological practices, along with other nature-based solutions, provide environmental, social and economic benefits by performing Ecosystem Services (European Commission, n.d.).

Ecosystem Services, categorized as regulating, provisioning and cultural is a re-conceptualization of ecosystem functions – goods that satisfy human necessities in a direct or indirect way – translated through human values (CICES, de Groot et al., 2002). The term of Ecosystem Services was recently expanded upon with the introduction of Nature's Contribution to People, since some experts recognized the need to broaden the concept into capturing the various knowledge systems and actors experiencing either positive or negative effects of nature in their "quality of life" (Díaz et al., 2018; Kadykalo et al., 2019). This framework, however, still needs to be developed, exploring the transition from "services" to beneficial or harmful "contributions". The overall aim is to foster a more inclusive and context-specific perspective, recognizing culture as well as local and indigenous knowledge as important elements of an assessment framework (Díaz et al., 2018).

Taking into account Ecosystem Services is a way to move from the notion of "design with nature", introduced by Ian McHarg, to a more holistic approach of "management with nature" as discussed by Downs and Gregory to "environmental management" (Downs & Booth, 2011). Environmental management is the "*direct or indirect manipulation of the environment with the aim of enhancing predictability in a context of social and environmental uncertainty*" (Wilson & Bryant, 1997) and is mainly focused on managing human behavior in alignment with environmental principles, not managing the environment itself (Nel & Kotzé, 2009). The aim of environmental management seems to be – in a way – enhancing the *adaptive capacity* of a system. This discipline works in synergy and is encompassed within the overarching concept of land management, defined as all the activities which are related to the management of land with the goal of sustainable development (Enemark, 2005.; 2006). Land management is directly related to Disaster Risk Management, since a way to achieve risk reduction is by implementing nature-based solutions, which can involve multiple scales, and therefore space. Consequently, a need for coordination of the proposed land transformations with the perspectives of the landowners and of the people managing the land is necessary, facilitated by land policy (Potočki et al., 2022). The goal of the creation of such a framework in order to implement actions of transformational adaptation is to catapult a paradigm shift, defined by Thomas Kuhn as a "*fundamental change in the understanding of a field of study*" ('Paradigm Shift', 2020). A paradigm shift in this case is the reframing of the current understanding of risk and the transition of current practices and processes related to the existing coping and recovery capacities towards more adaptive local transformations, including nature-based solutions. Finally, these adaptive strategies, their phasing and their interdependency, can be tested and evaluated through Dynamic Adaptive (Policy) Pathways (Haasnoot et al., 2019; Walker et al., 2013).

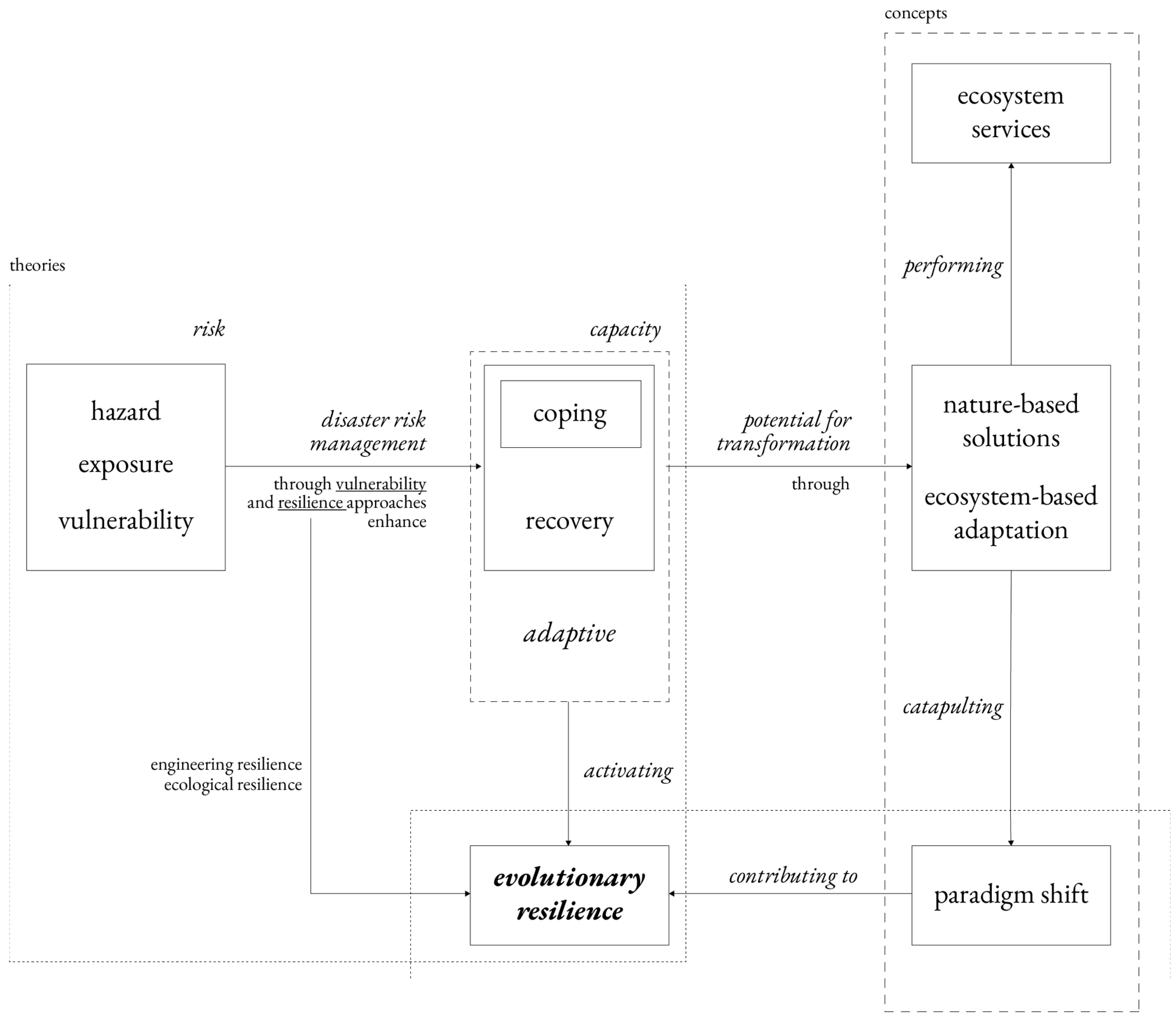


Figure 39. Main theories and concepts

Conceptual framework

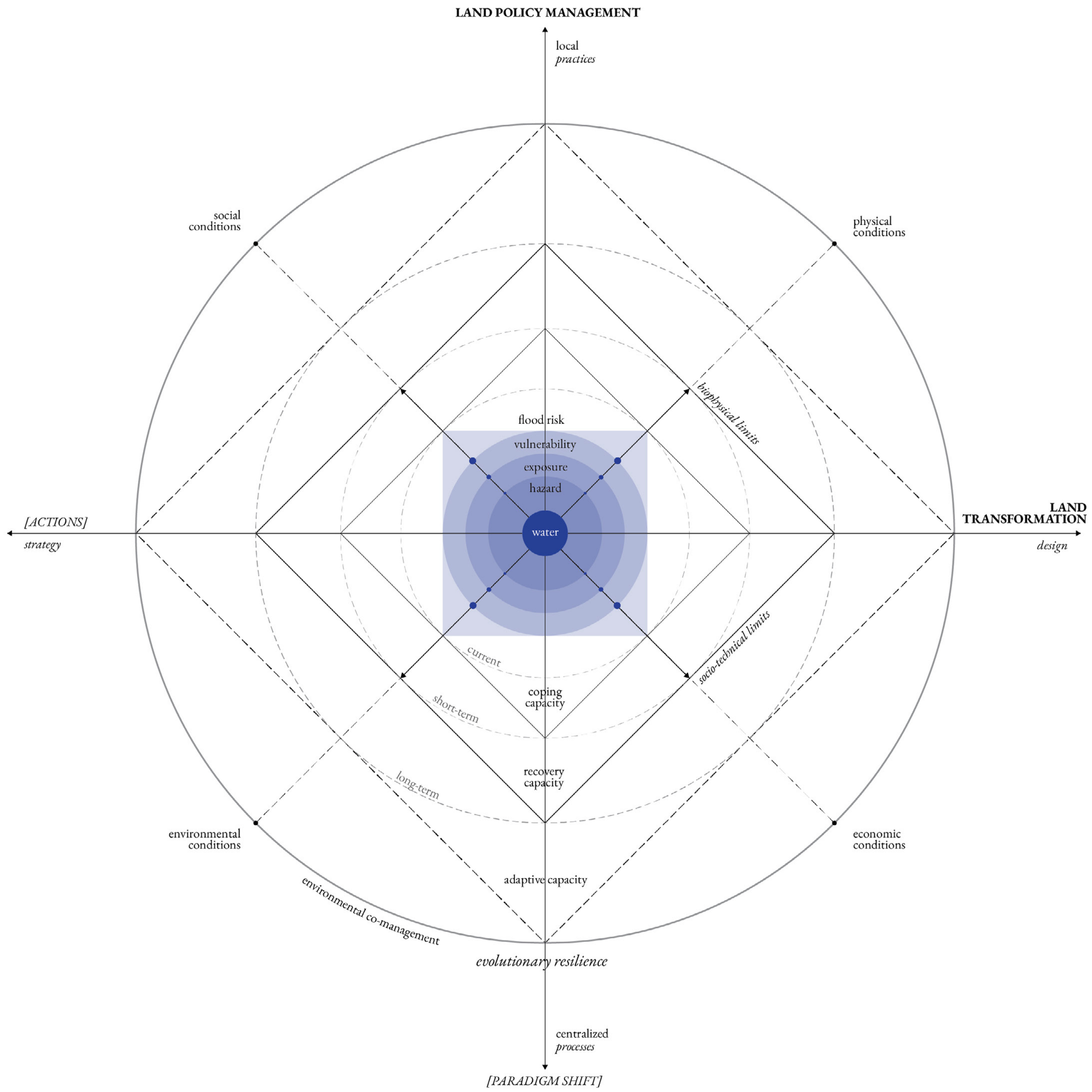


Figure 40. Conceptual framework

The conceptual framework is constructed inwards to outwards, with homocentric shapes signifying a process that keeps expanding towards a desired future.

In the center of the conceptual framework the lens under which everything is examined is located, which in this case is the water. An unusual or unprecedented excess of water can result in flood, which is the *hazard*, located in the first one of the three homocentric circles reverberating out of the center. Hazard, together with vulnerability and exposure constitute a system's flood risk. This system has conditions, whether those are environmental, physical, social and economic, which either intensify the hazard or directly affect its vulnerability and exposure to flooding, and they are located as points on the inward circles. Consequently, the sum of these conditions defines the limits of the system to cope and recover from flooding, and those limits can be either biophysical (mostly those regarding environmental and physical conditions) and socio-technical (mostly those regarding social and economic conditions). Those limits then, in turn, define the system's current coping capacity, as well as the very short-term recovery capacity in the event of flooding, depicted by rhombus shapes surrounding the flood risk rectangle. The goal is to be able to recognize those limitations and create conditions to utilize and possibly expand them, transcending to a long-term adaptive capacity of the system to flooding, which is projected with a dashed line. This can happen through transformative actions ranging from strategy to design, which are located on the horizontal axis piercing through the shape and supported by a paradigm shift activated by land management policies informed by centralized processes and local practices (located on the vertical axis). The projected desired future encapsulates those actions into an integrated environmental co-management approach, activating a process of evolutionary resilience to flooding, which is the overall aim of the project and located on the outermost circle of the framework.

It is important to note once more that all the shapes are homocentric, and the reason is that it is not a linear process that moves from one step to the next, but an expansive one, where all the elements continue to co-exist and are incorporated within each other, without discarding any of them.

Methodological framework

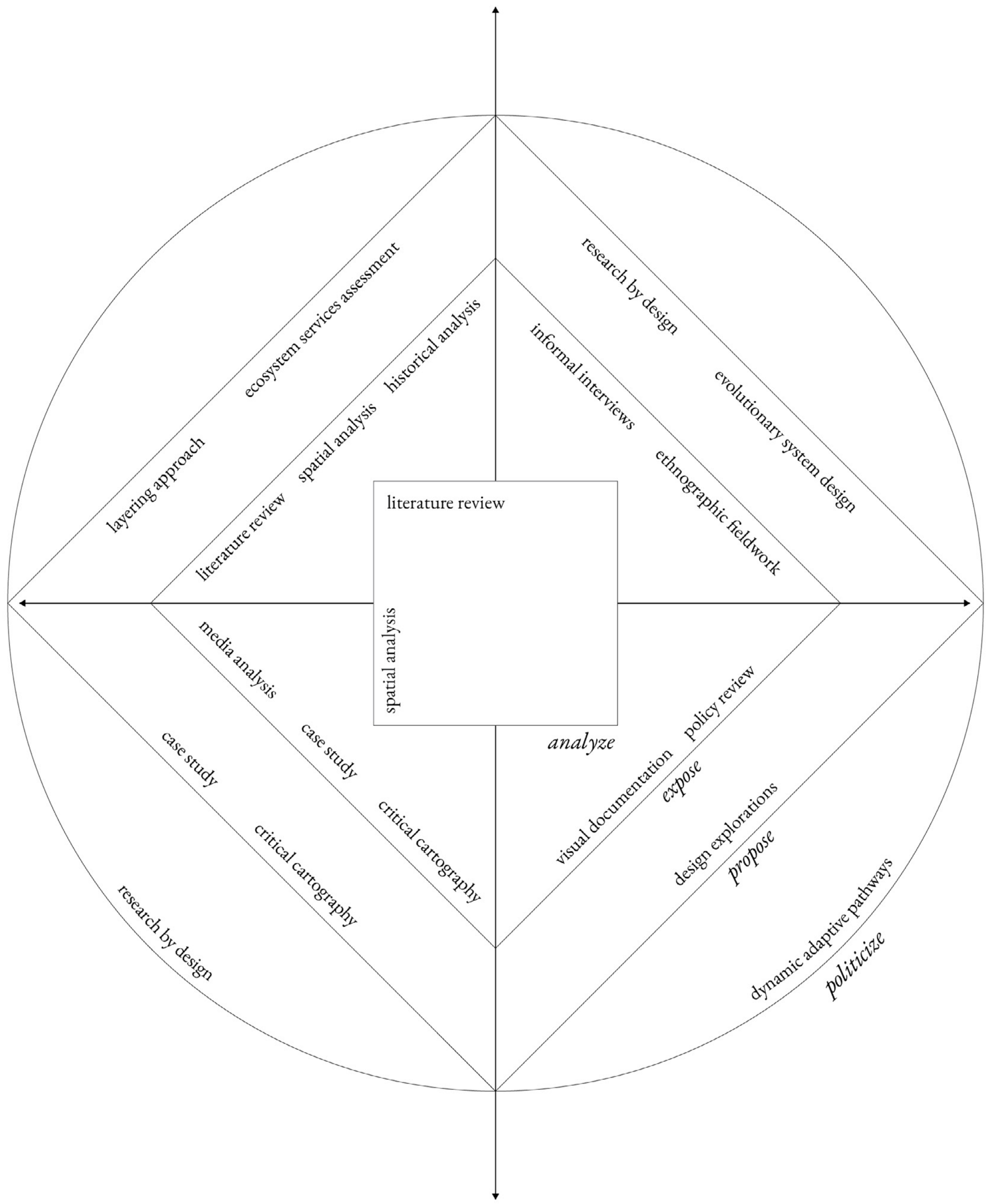


Figure 41. Methodological framework

My methodological framework, as aforementioned, is based on a "paradigm of critical planning", introduced from the lawyer and urban planner Peter Marcuse, whose work focused largely on gentrification, justice and the concept of the *right to the city*. Specifically, Marcuse argues that research should follow the sequence of "analyze, expose, propose, politicize", in order to move from the realm of theory to "radical urban practice" (Marcuse, 2009).

Analyze means taking a step back in order to examine the roots of a problem, as well as the actors that are involved and the conditions that make it materialize (Marcuse, 2010). *Expose*, which in some cases encompasses the analyzing step, means to bring to light the underlying issues that are located beneath a surface-level problematization, using critical urban theory as a tool (Marcuse, 2009). This includes disclosing the conclusions drawn from the analysis to the public and highlighting the potential consequences of the project. Multiple alternatives are also presented, with the aim of making the planning process completely transparent to the public. This step plays a crucial role in making informed decisions about planning strategies in order to move forward to the proposal. The *propose* phase consists of the development of a vision which is realistic and feasible working with the directly affected groups. Then to *politicize* these actions, means to disclose the possible conflicts that might arise during the implementation of the project and how those can be resolved by supporting the organization strategy (Marcuse, 2009).

In my project, I re-interpret this framework and organize my research questions to clusters according to the four steps, which then also align with my conceptual framework. Firstly, after recognizing flood risk as the main problem, the *analyze* phase for me consists of understanding the systems that are related to the notions of hazard, vulnerability and exposure and how they are interrelated with each other, in order to come to conclusions about the conditions that need to be examined. Secondly, *exposing* means disclosing the current conditions as well as the transformative processes that have contributed to their altered state. This, together with criticizing the existing plans for flood risk mitigation and the showcasing how they come in conflict with local values, result in the identification of the area's coping and recovery capacities to flooding, as defined from the biophysical and socio-technical limits of the system. Defining these capacities and limits is a crucial step in order to proceed with the *propose* step, in which a maximized vision utilizing transformative actions grounded in Ecosystem-based Adaptation is presented. Finally, to *politicize* means to evaluate the performance of the proposed spatial and institutional transformations, assess the possible implications that might come up during the stage of the project implementation and a suggest a recommendation on how to negotiate the necessary trade-offs, presented through an adaptation framework.

Literature and policy review
It is important to examine the existing academic literature in order to strengthen the theoretical underpinning of my project. Therefore, special focus should be given on the definitions of risk, capacity and resilience. Additionally, research should be conducted about the terms that will assist me in the development of my proposal, such as ecosystem-based adaptation – specifically nature-based solutions – environmental co-management and ecosystem services assessment. Combined with this thorough literature review, it is imperative to study the existing policies and plans that are put into place so as to understand the current context of centralized processes and how they can challenge local dynamics.

Spatial and historical analysis
Spatial analysis through a Geographic Information System (GIS) approach is also necessary to situate these abstract concepts of vulnerability and exposure spatially. The goal is to understand the conditions and dynamics of the area, in order to later define the limitations of the system's capacities to flooding. It is essential also to comprehend the processes of alteration the system has undergone through historical analysis and how this has impacted the present state and could be detrimental to reaching those limits.

Stakeholder analysis
Stakeholder analysis will be used in order to understand the power dynamics between different actor groups and individuals in the area, as well as their varying interests, needs and potential impact. This is then necessary in order to configure alternative paths and locate possible alignments and synergies between institutional collaborations.

Site visit
Fieldwork, consisting of on-site investigation and collecting data, is essential to gain a deeper understanding of the current conditions of the area, which is impossible to happen solely through desktop research. Through informal interviews and ethnographic fieldwork, the deeper nuances and sensitivities of the system will be revealed, and visual documentation will assist in capturing the sense of the place, creating intrinsic motivations and visions for possible transformative actions that could be implemented.

Case study
Using the Lake Karla system as a case study, the scope of the project is limited to a feasible scale of implementation, where the research hypothesis is tested. The possible results then can be upscaled.

Critical cartography and layering approach
Critical cartography, which includes the process of overlaying the current conditions, is imperative in order to locate the areas where biophysical and socio-technical limits have been reached or not, therefore defining the "critical zones" within a range of potential transformability.

Dynamic adaptive pathways
Dynamic adaptive pathways (here used as dynamic adaptive design pathways) is an approach developed by Deltares and TU Delft and is based on the concepts of Dynamic Adaptive Planning and Adaptation Tipping Points (Haasnoot et al., 2019) in order to propose alternative paths between different strategies that can provide a framework for decision-making in a future that is uncertain. It also provides signaling points in order to identify where decisions need to be revisited and make adjustments to the proposed plans. Here this approach will be used as an evaluation and phasing tool.

Research by design
Research by design is integrated by making a research hypothesis that then will be tested through the phase of design implementation in the local scale and its subsequent possibilities of upscaling to the sub-basin and river basin scale. The proposed transformations will then be evaluated in order to define the possible implications and how they can be resolved.

Ecosystem Services Assessment
Ecosystem Services Assessment is an approach that deals with the evaluation of the benefits that nature and ecosystems provide to the human society (Häyhä & Franzese, 2014). Therefore, during the politicize step of my project, it is crucial to assess and evaluate the way the proposed transformation performs under this framework and how different values, whether those are environmental, social and economic have been enhanced through a resilient water resource management.

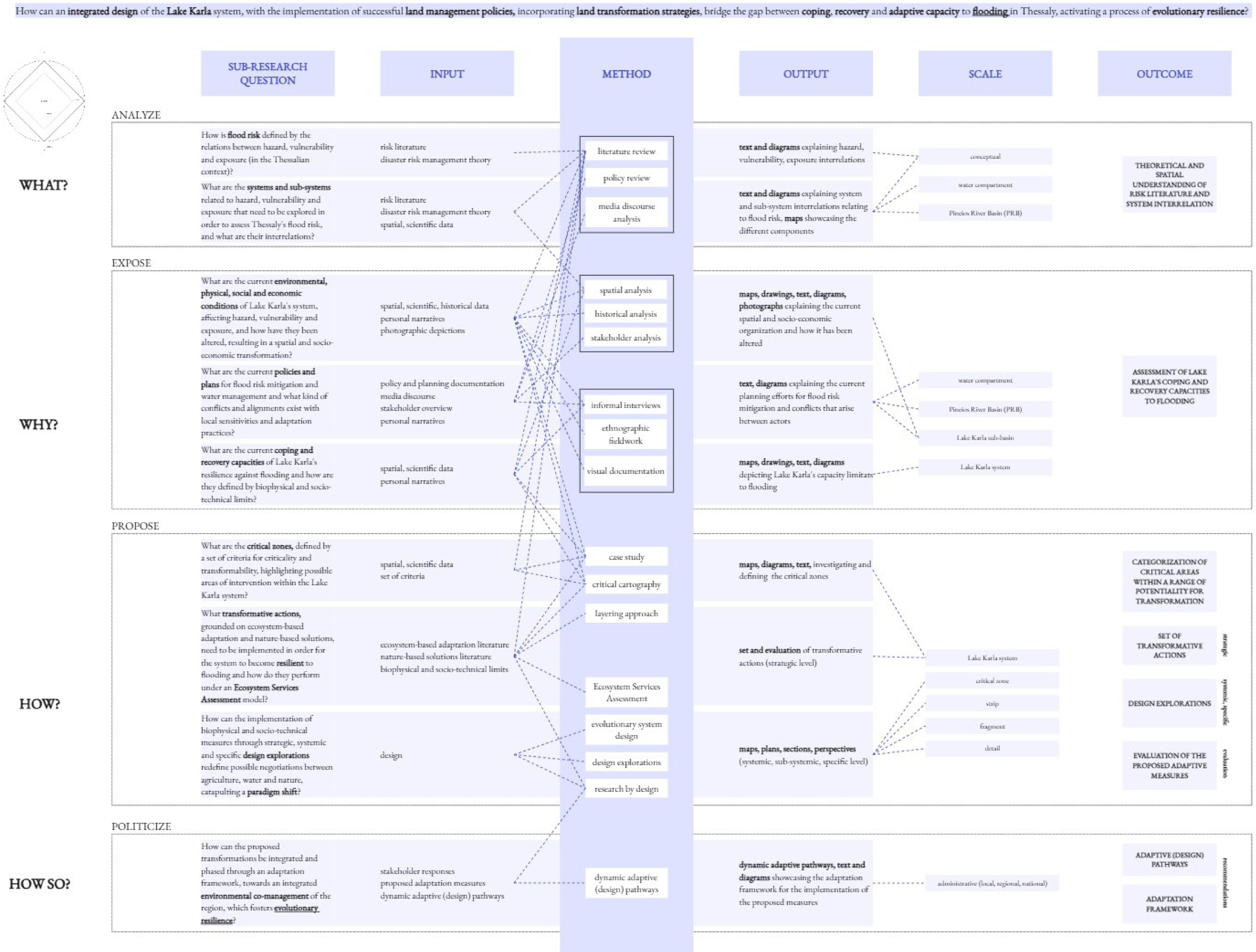


Figure 42. Input-method-output-outcome

Project timeline

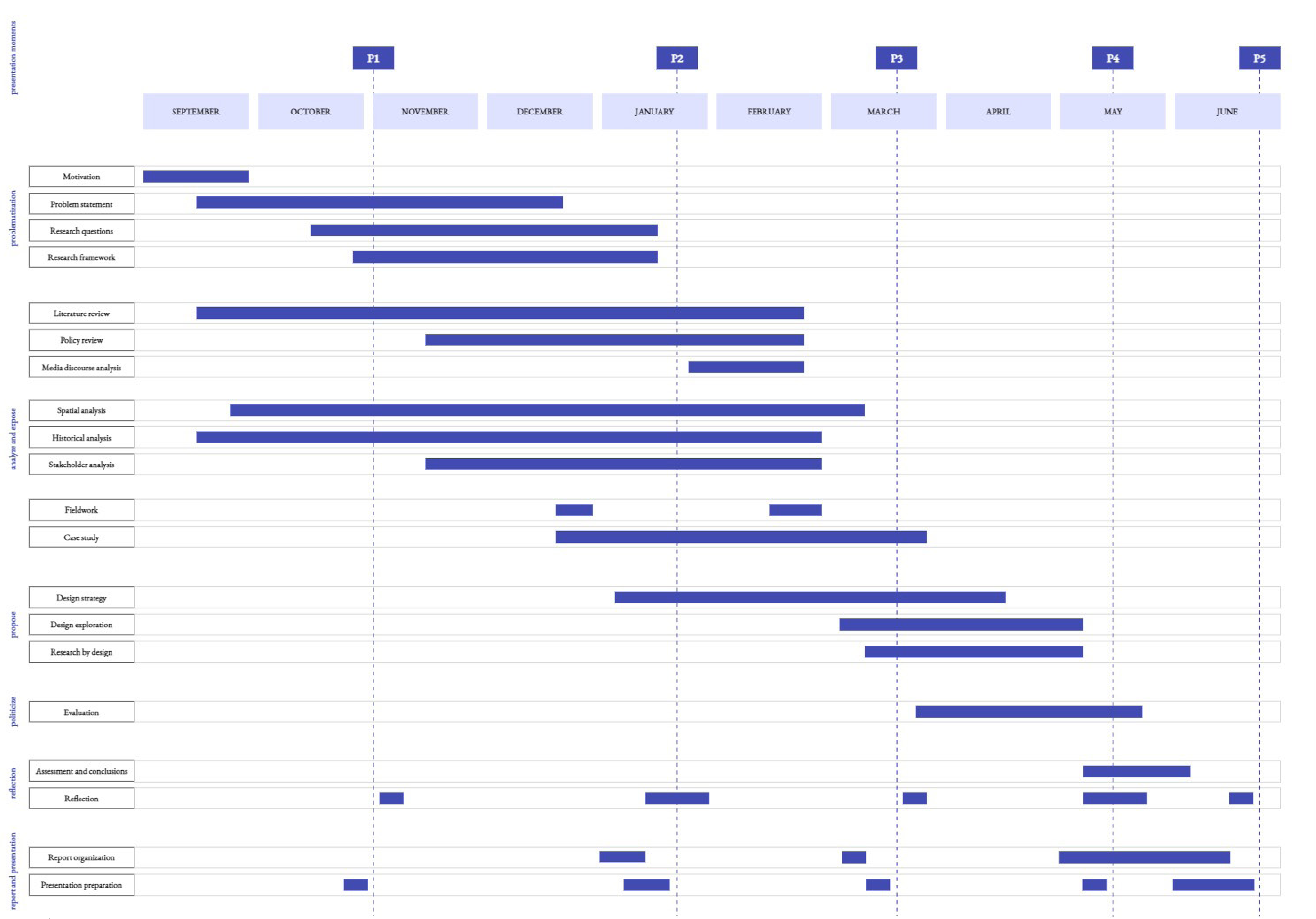


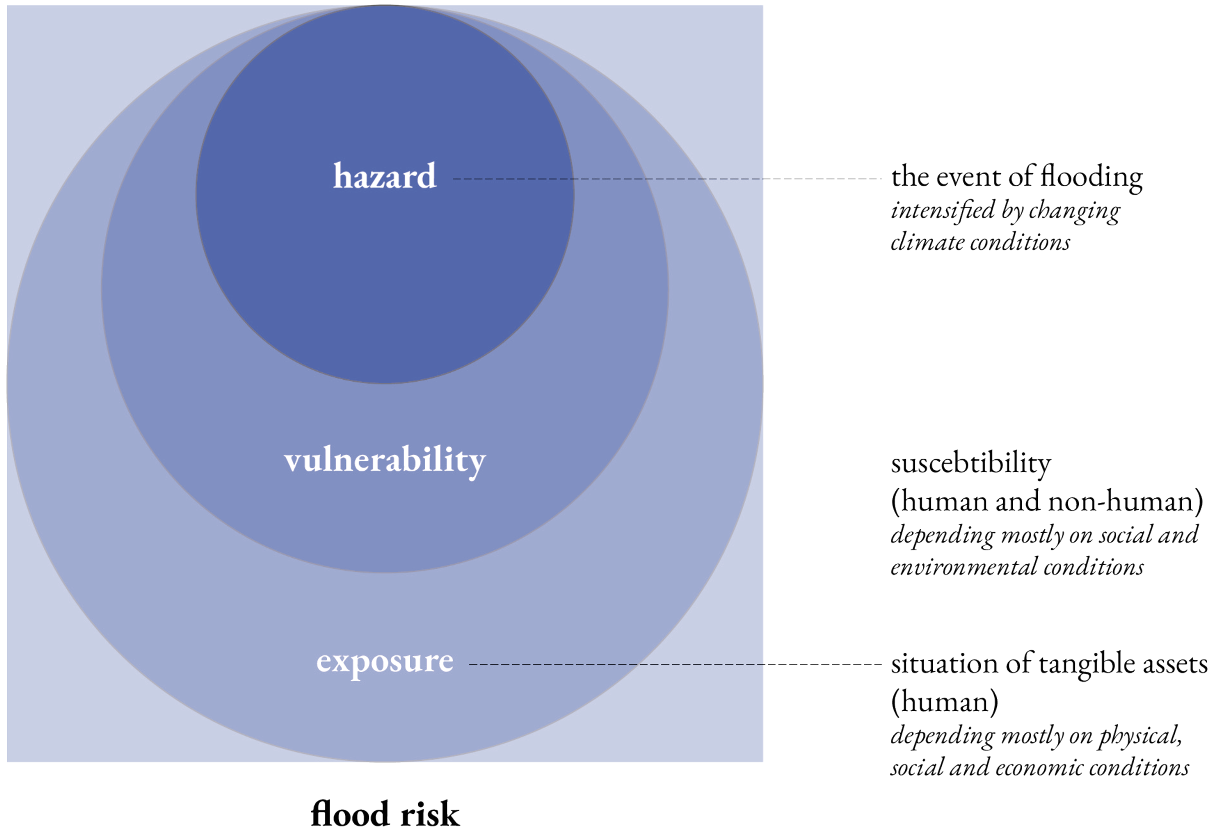
Figure 43. Project timeline

photo by Fotis Natsioulis

03| Analyze

Figure 44. Dried mud, Lake Karla

Hazard, vulnerability, exposure



First, it is important to define how flood risk is composed of the notions of hazard, exposure and vulnerability, specifically in the Thessalian context. Therefore, a review and subsequent reframing of the existing conceptual framework for risk, as presented in the *Research framework* chapter is necessary. The result is a new proposal for understanding risk and its components, yet it remains a subjective iteration, inspired by the existing literature and the personal understanding of the contextual conditions.

Figure 45. Hazard, vulnerability, exposure (adapted from conceptual framework)

Hazard is identified as the event and the scope of flooding, whose frequency and magnitude are directly impacted by the changing climate patterns and conditions (Borowska-Stefańska, 2024). Exposure is understood as the existing developments and situation of tangible human assets that could be subject to loss, while vulnerability – whose definition still remains ambiguous – is the susceptibility of human and non-human actors to a natural hazard, an existing condition influenced by socio-environmental factors (Borowska-Stefańska, 2024).

Existing literature has recognized those three components as related but simultaneously independent from each other (Crichton, 1999, IPCC, 2014b). Borowska-Stefańska (2024) proposed a reviewed framework, identifying exposure as a factor of vulnerability along with susceptibility and resilience, expanding on the Vulnerability approach. However, I believe their proposed understanding of the term *resilience* is more geared towards engineering resilience, while embedding in the term *vulnerability* elements of ecological as well as *evolutionary resilience*, such as the capacity to anticipate, cope, resist and recover from a disaster.

Thus, even though I do believe that the distinction between hazard, exposure and vulnerability should be clear, in my reading they are not separate notions, but they are layers built on top of each other. Hazard, which is the disastrous event of flooding, functions as the central point of departure in this conceptual framework. However, in my personal understanding, including exposure as a factor of vulnerability is not entirely representative, since most of the times it comes from the understanding of vulnerability as *social vulnerability* – meaning human. According to the UNDRR (2017) definition vulnerability is identified as the physical, social, and environmental conditions which increase the sensitivity and susceptibility of communities, as well as systems to a disaster, consequently expanding the term to the realm of *non-human actors*. Therefore, this means that vulnerability of a system to a natural hazard could be inherent, not necessarily defined by human actions – but influenced by them. Nevertheless, exposure, which is the situation of tangible – human – assets is *defined* by human actions, and functions then not simply as a component of vulnerability, but as an added layer on top of it. In conclusion, the framework followed during this project locates hazard in the center and then expands outwards, with vulnerability and exposure built up in overlapping layers.

In the next page, the diagram depicts the systems and sub-systems relating to hazard, vulnerability and exposure respectively, as well as how they interrelate with each other. Hazard concerns the event of flooding as well as the climate parameters, with changes in the latter impacting the former. Vulnerability is mostly dependent on social conditions expressed by demographics, as well as environmental conditions such as soil conditions and natural processes, while the existing biodiversity also plays a large role. Finally, exposure, which depends on physical, social and economic conditions is defined by the existing land management practices and economic activities, infrastructures and human habitat.

System and sub-system interrelations

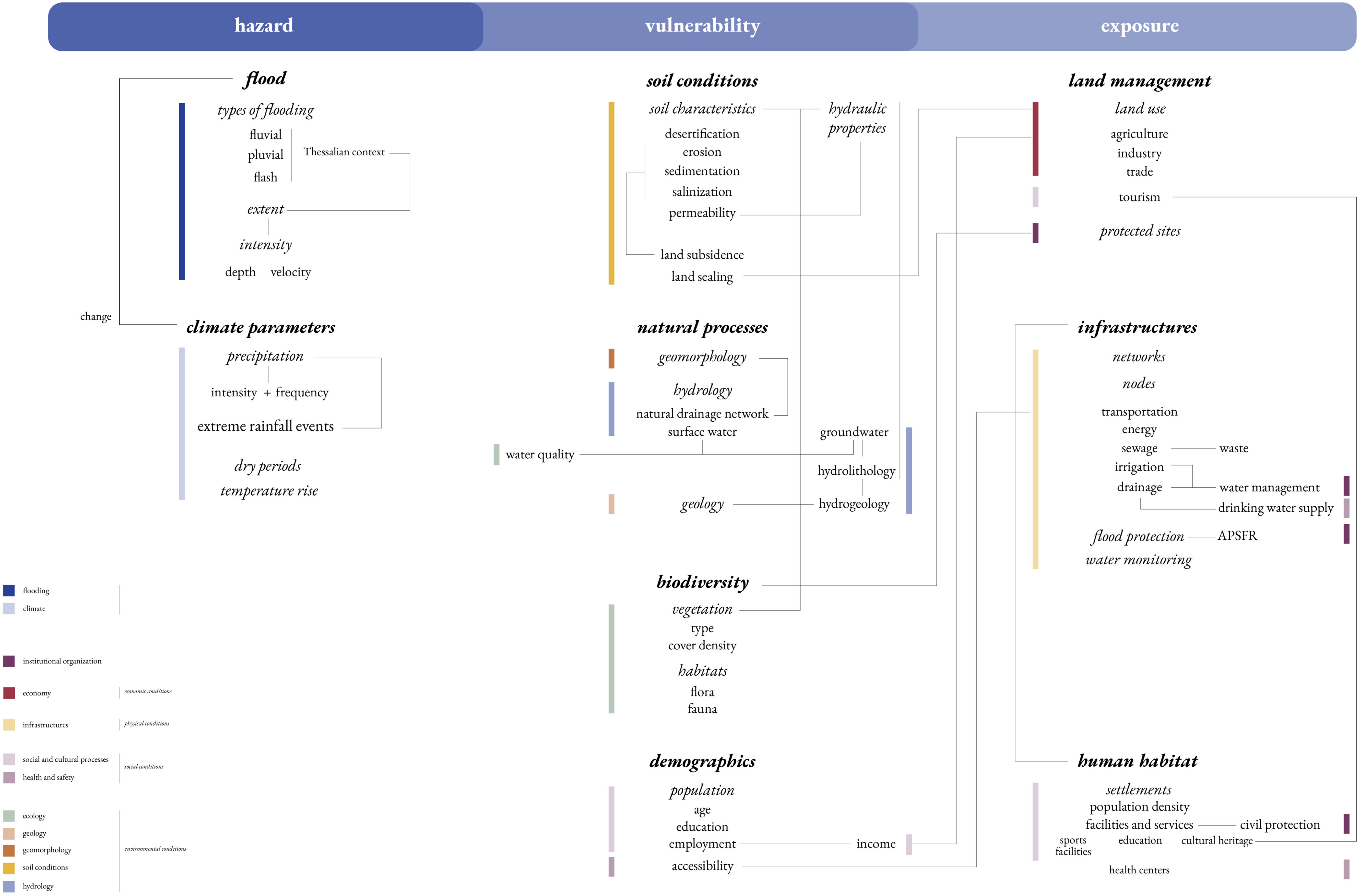


Figure 46. Systems, sub-systems and interrelations

Flood and climate parameters

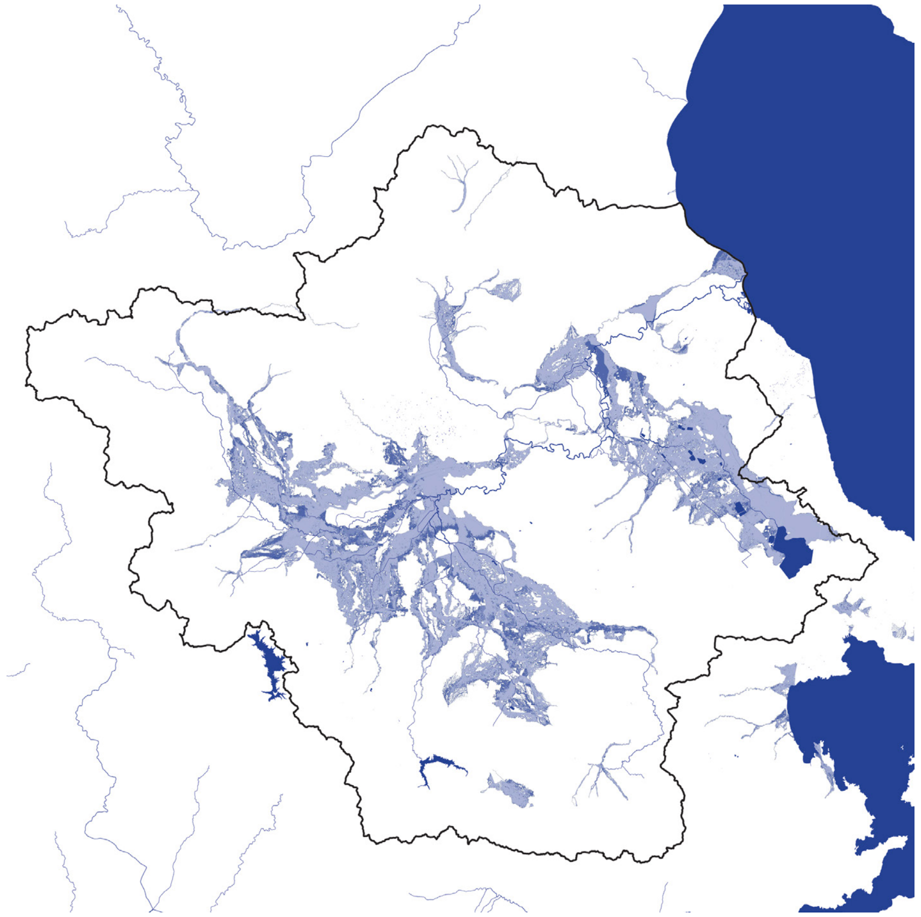


Figure 47. Flood scenarios

T50

T100

T1000

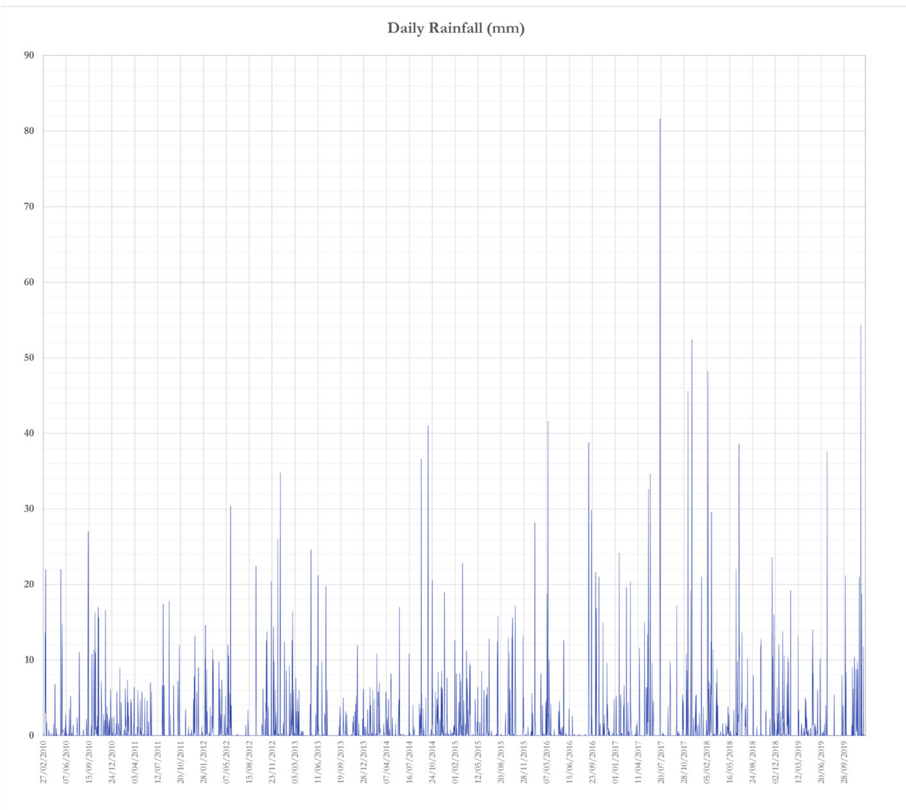


Figure 48. Daily rainfall trends 2010-2019

0 25km N

Geomorphology and hydrology

Figure 49. Geomorphology and hydrology

quaternary alluvial sediments

neogene sediments

metamorphic formations

clastic formations

carstic formations

igneous formations

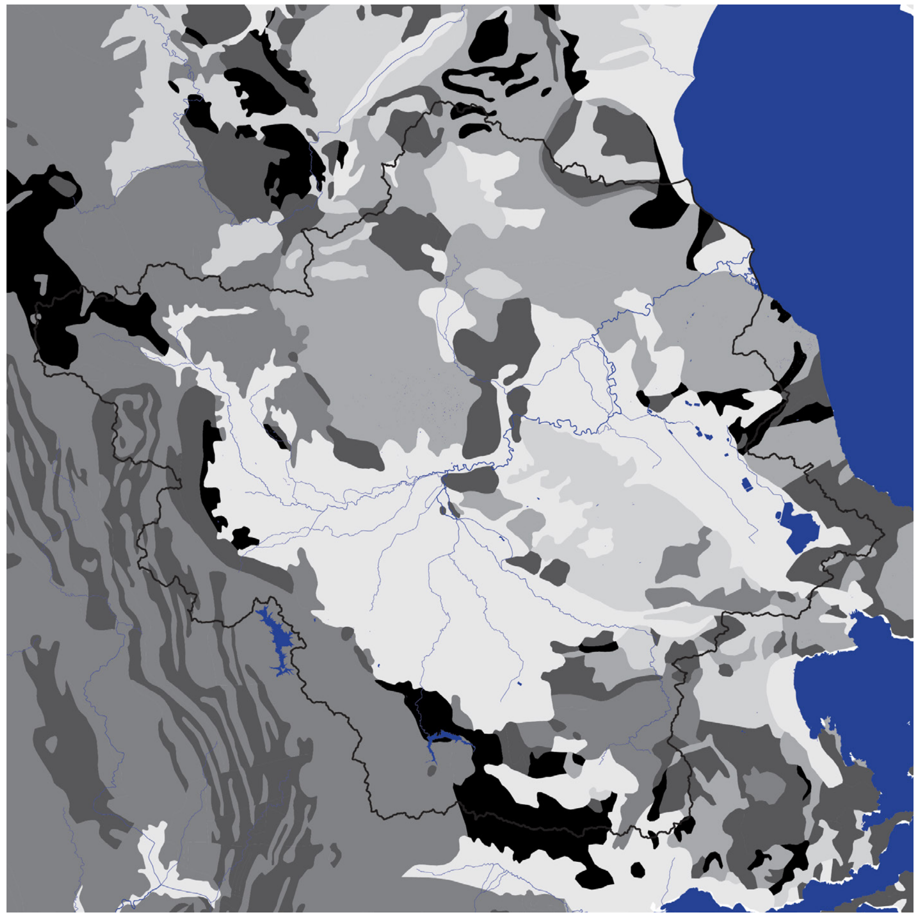


Figure 50. Simplified geology

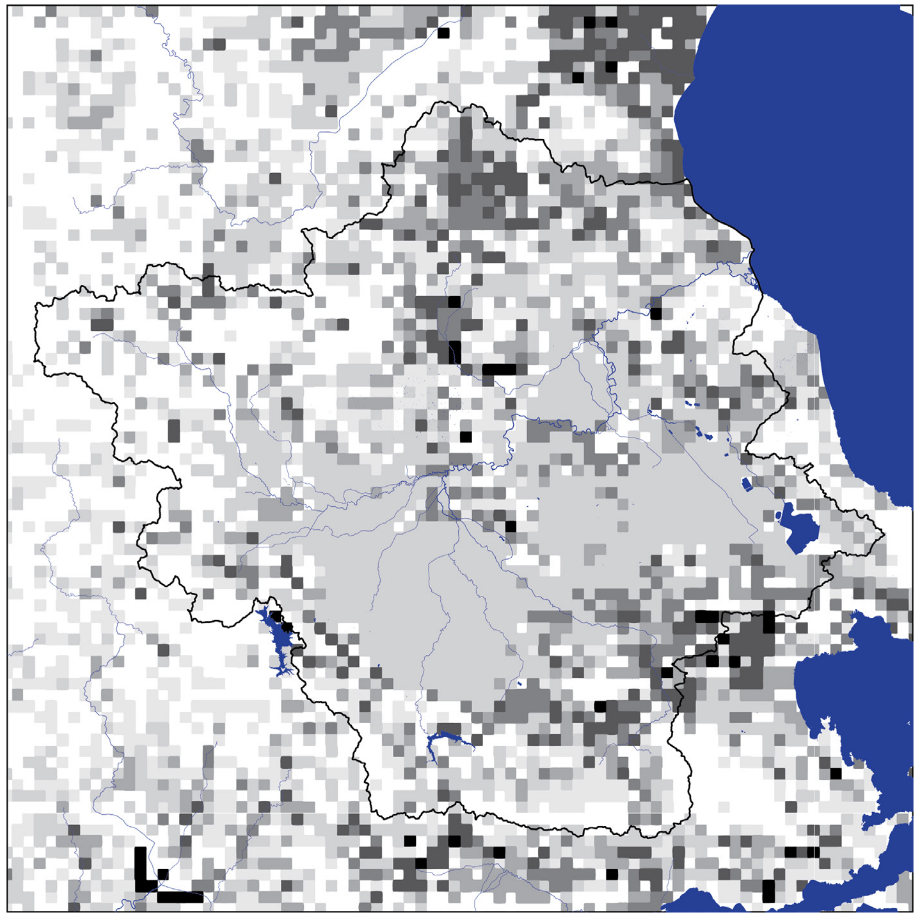


Figure 51. Desertification risk

not affected
potential
fragile factor 1
fragile factor 2
fragile factor 3
critical factor 1
critical factor 2
critical factor 3

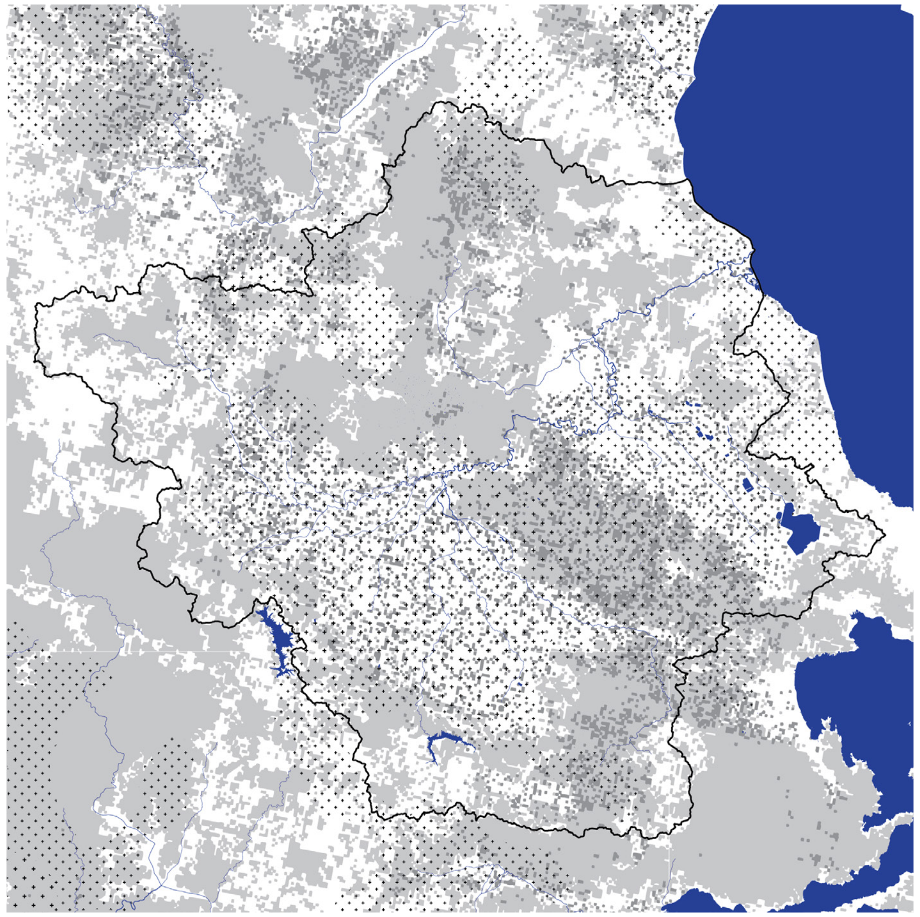


Figure 52. Erosion

water erosion
tillage erosion

erodibility K_{st} factor 0.023-0.029
erdibility K_{st} factor >0.03

0 25km N

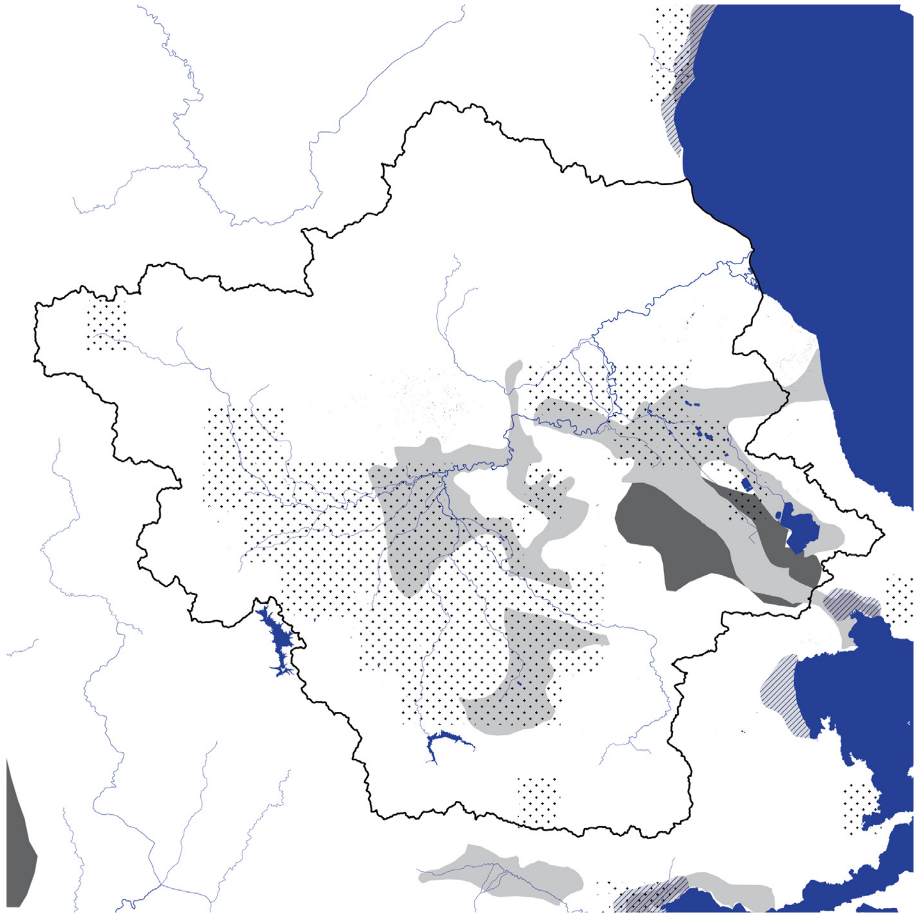


Figure 53. Salinization

saline soils <50%
saline soils >50%
seawater intrusion
secondary salinization risk

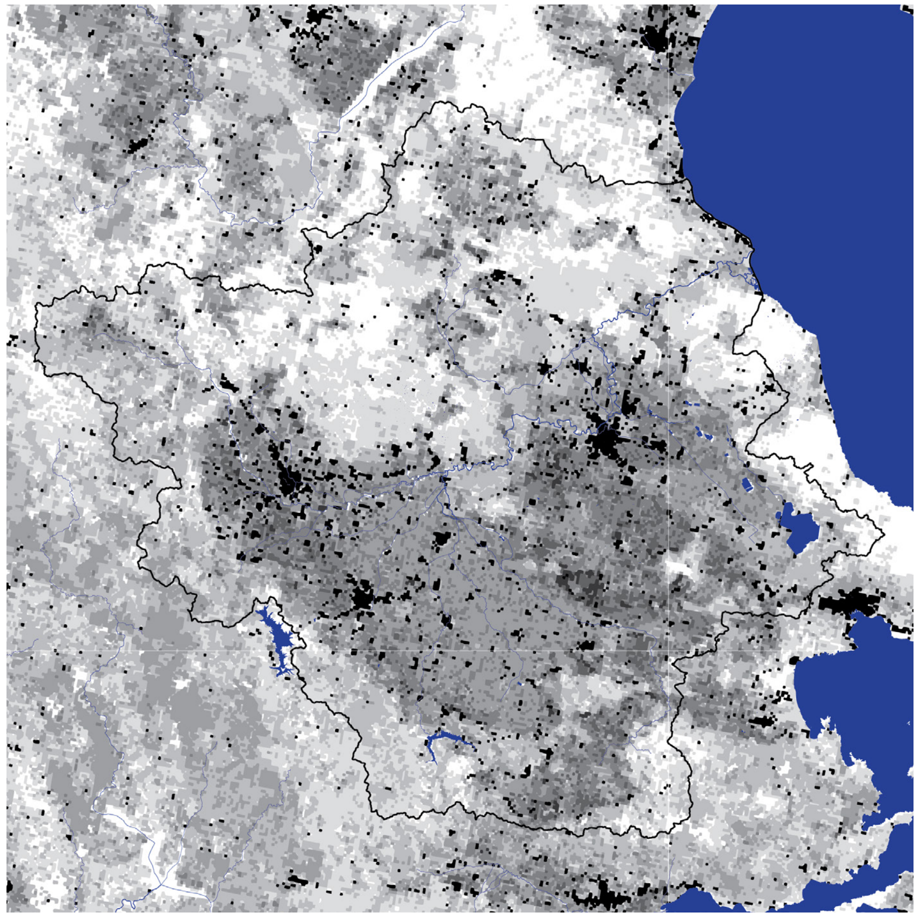


Figure 54. Sum of soil degradation factors

1
2
3
4
5
6
7
8

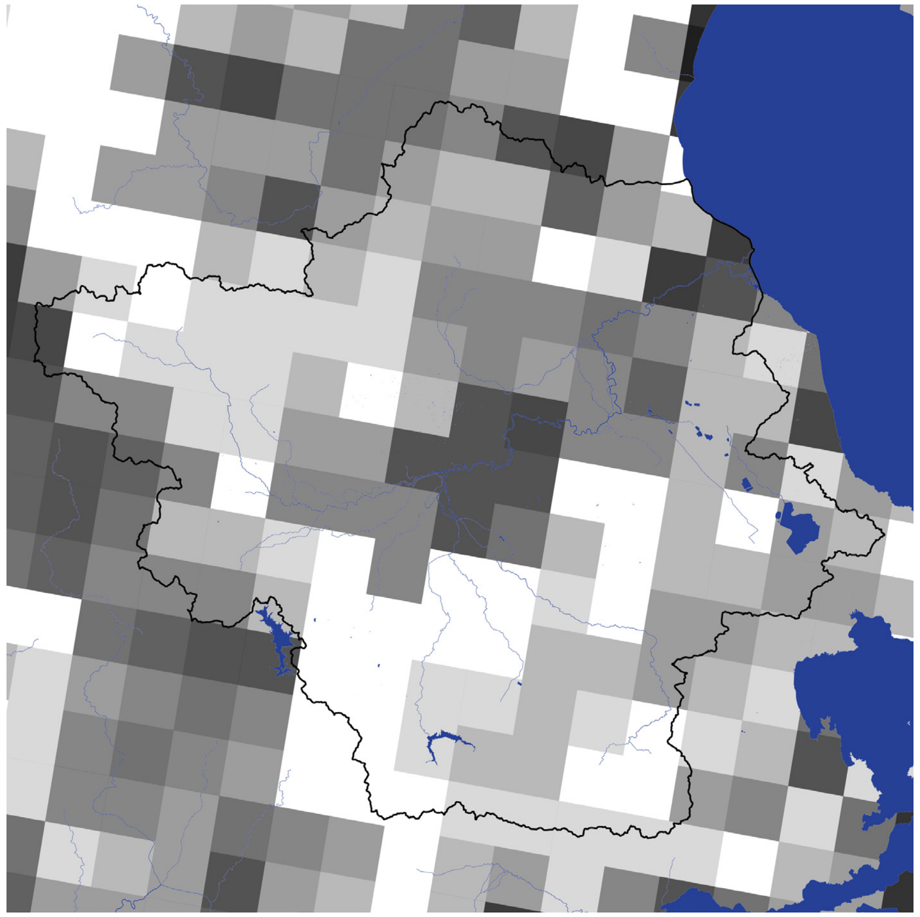


Figure 55. Habitats distribution density

high habitats distribution density

low habitats distribution density

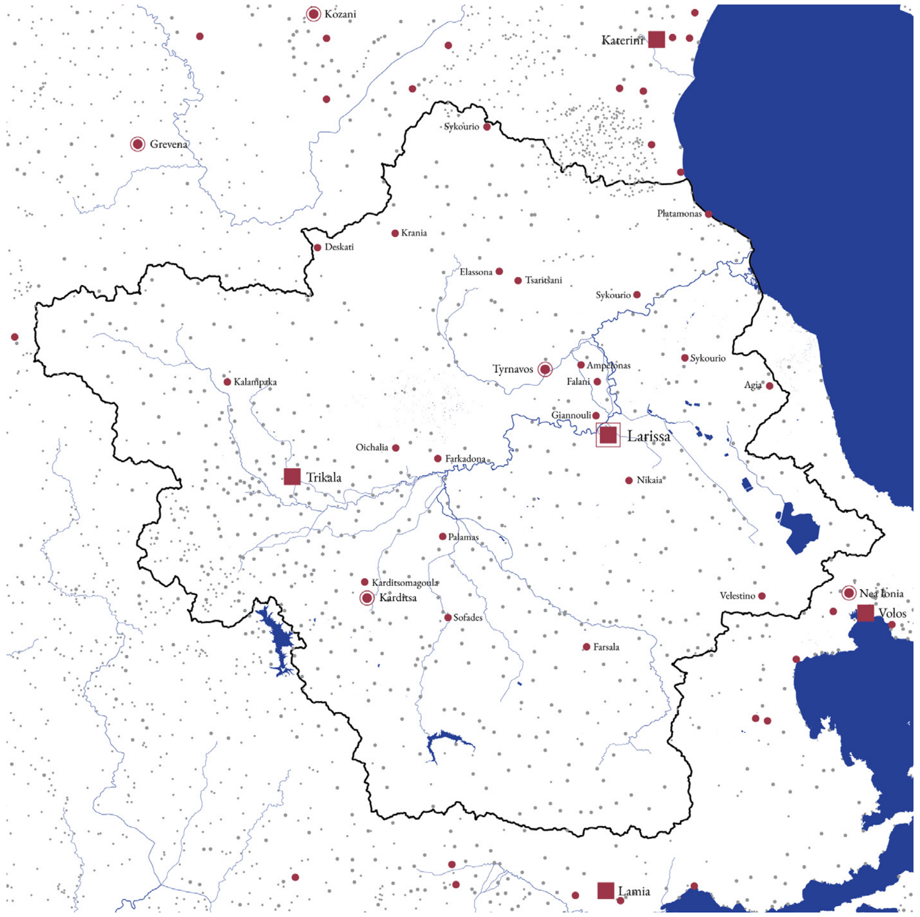


Figure 57. Human habitat

- hamlet <100
- village 100-2.000
- small town 2.000-10.000
- large town 10.000-50.000
- city 50.000-100.000
- city 100.000-200.000

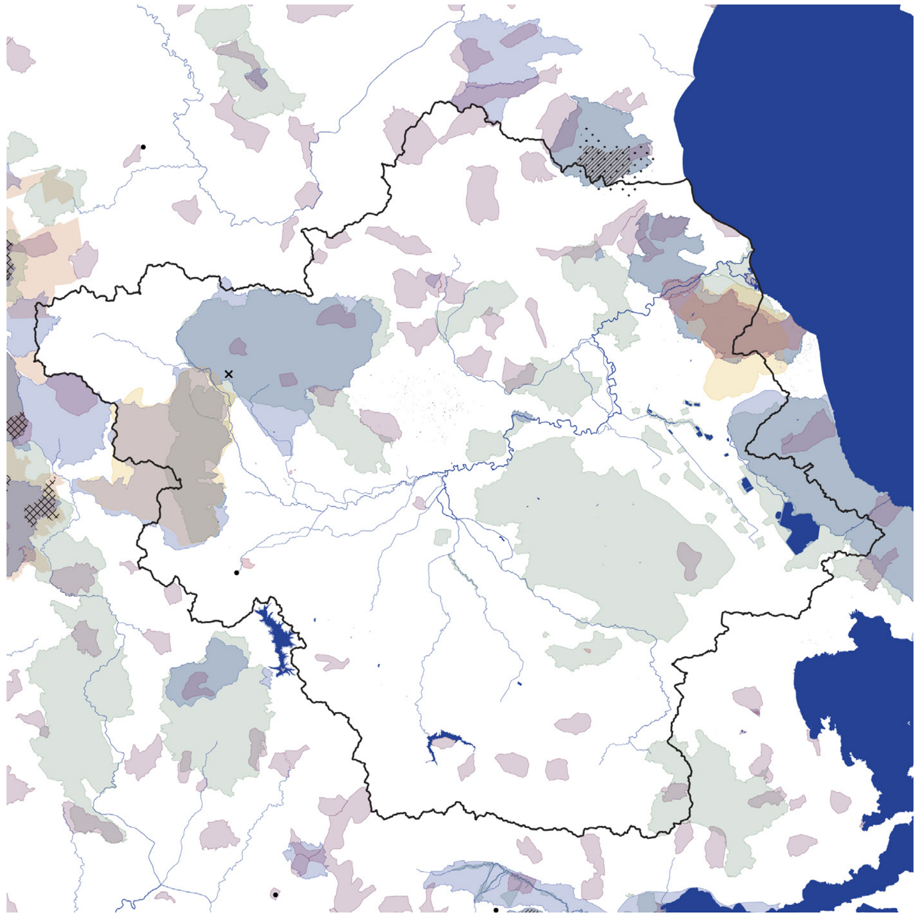


Figure 56. Protected areas

- game breeding stations
- world heritage site
- UNESCO biosphere reserve
- core zone in national woodland park
- nature reserve zone in national park
- aesthetic forest
- controlled hunting area
- wildlife refuge
- Natura 2000 (Habitats Directive)
- Natura 2000 (Birds Directive)
- national park

0 25km N

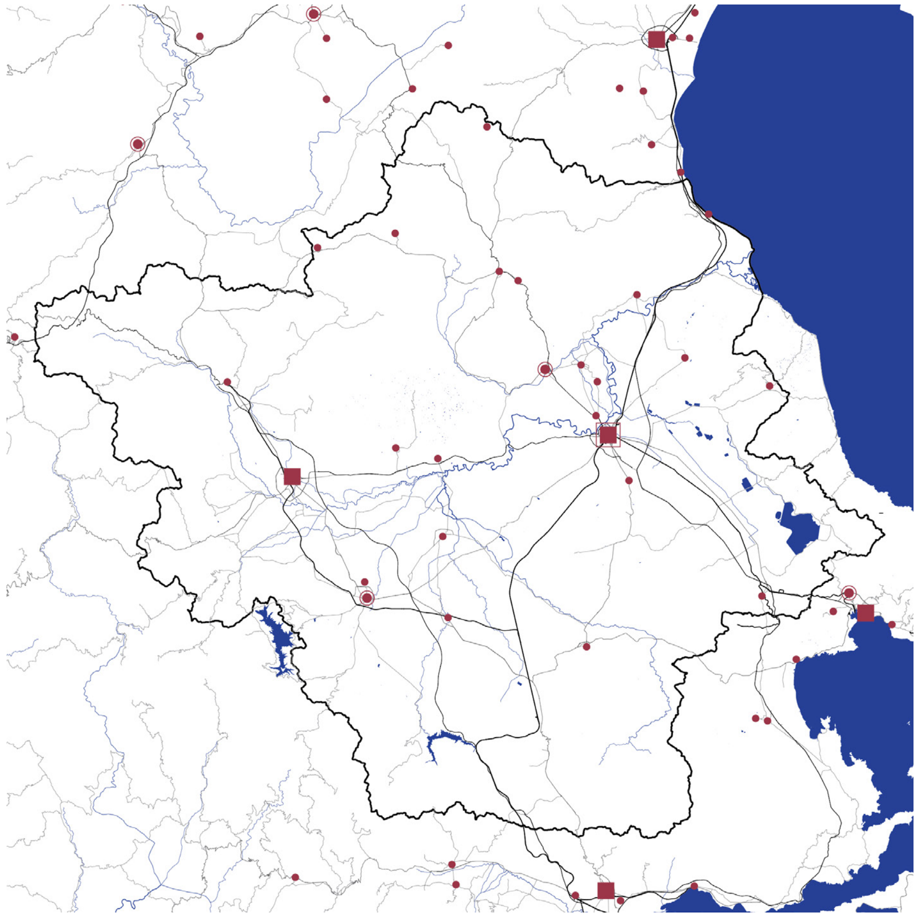


Figure 58. Transport infrastructures

- railway
- motorway
- primary
- secondary

Land management

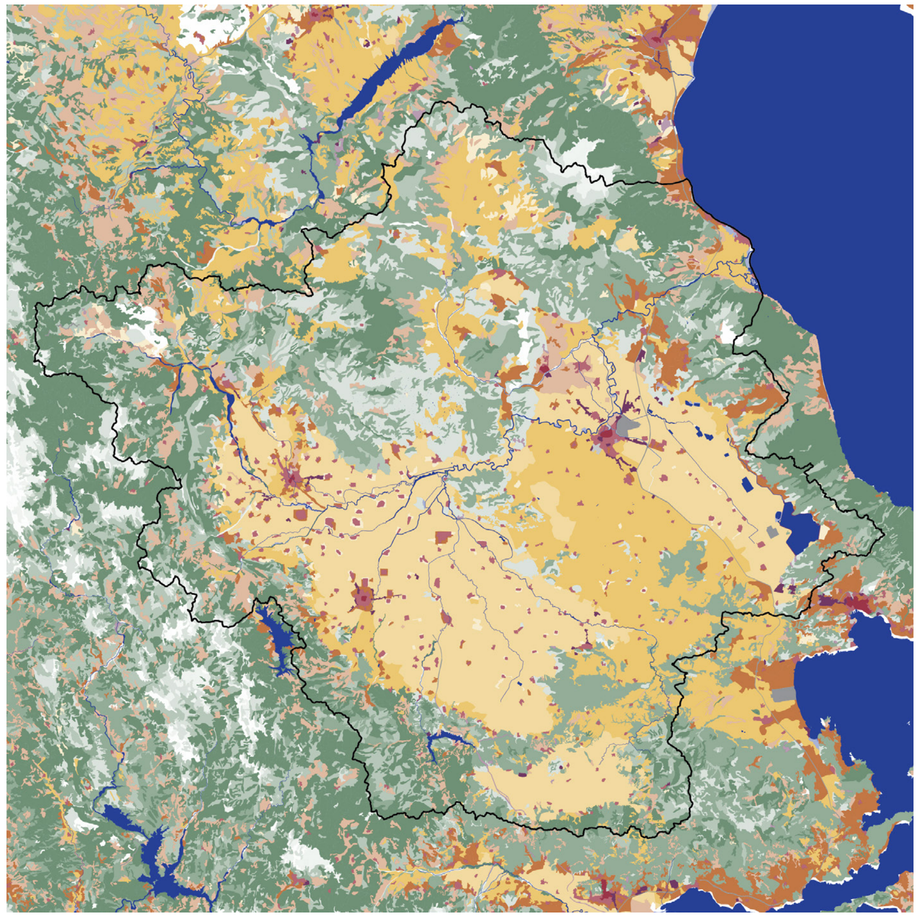


Figure 59. Corine land cover 2018

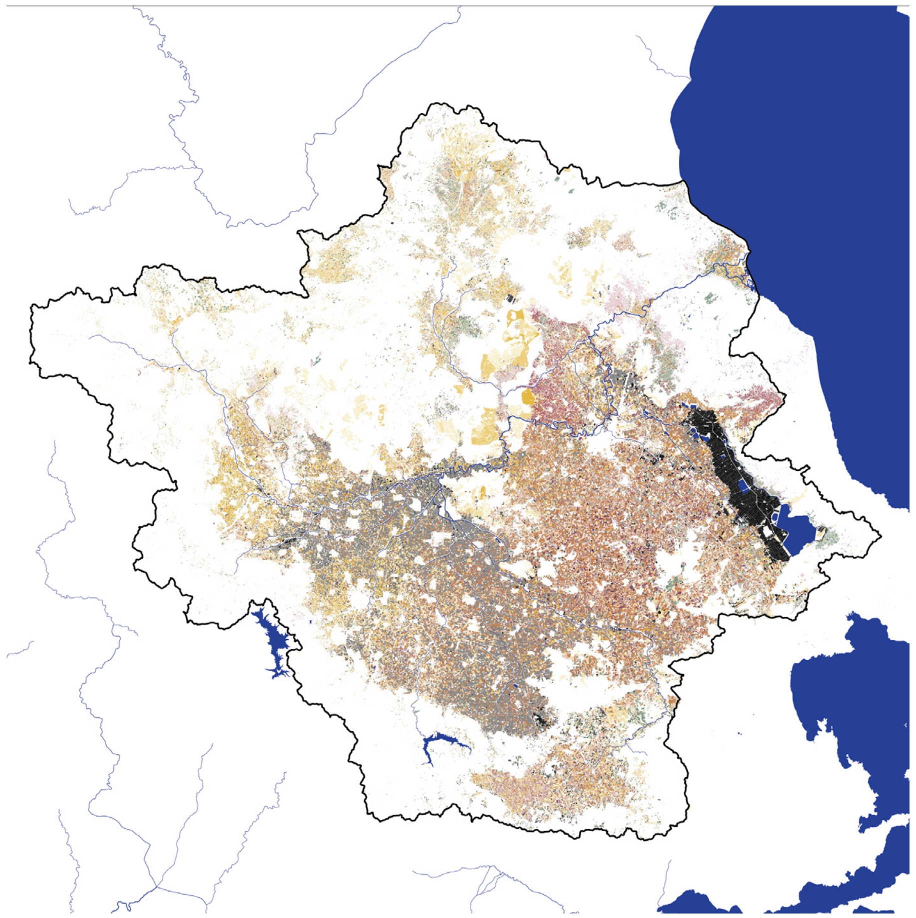


Figure 60. Crop types 2024

Figure 61. Morning in the cotton fields, December 2024

04| Expose

Scales

During the problematization, analysis (presented in the *Analyze* and *Expose* chapters) and moving towards the proposal stage of the project (examined in *Propose* and evaluated in the *Politicize* chapters), a process of going through various spatial scales was implemented.

Specifically, the Water District (*context*) is only recognized at a contextual level during the problematization stage of the project, in order to relate the administrative scale of the Region of Thessaly to the spatialized issues related to flooding and water scarcity. However, the starkly contrasting characteristics and conditions between the Pineios River Basin (PRB) and the Pelion-Almyros Stream Basin already call for a differentiation between them, which leans in favor of the PRB (*landscape*), where the critical areas of the agricultural floodplains are located.

Separate components of *vulnerability* and *exposure* to the flood hazard are examined and presented in this scale, to facilitate understanding of the broader conditions. Highlighting how crucial the sub-basin of Lake Karla (INSPIRE ID 2070) is to the flood risk management of the entire region, creates the need for further examination on this scale (*ensemble*). The composition and alteration of various components related to *hazard*, *vulnerability* and *exposure* are overlapped and presented together, in order to define the biophysical and socio-technical limits of the system, which are understood and projected on the scale of the Lake Karla system (*body*, to be elaborated later).

Figure 62. Spatial scales

Lake Karla

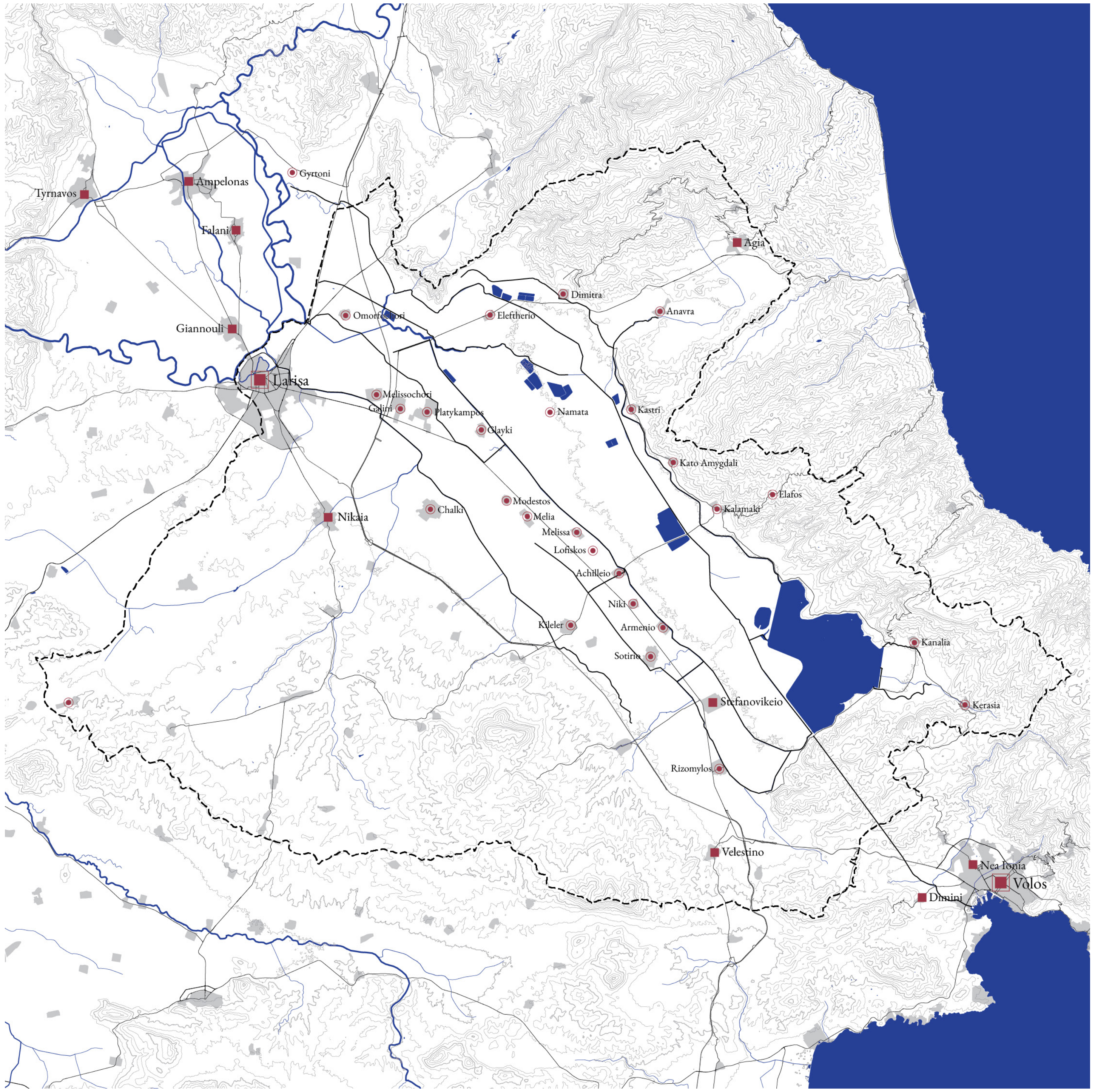


Figure 63. Recognition of Lake Karla area

As mentioned before, Lake Karla – or as originally called, *Lake Voivis* from the god Apollo (*Phevos*) – was created after evolutionary processes resulted in the formation of the Tempi Valley and the subsequent drainage of the Thessalian Lake towards the Aegean Sea. She was one of the biggest and most ecologically important lakes in Greece and contributed to the development of settlements whose economy was based on water. Specifically, the people from the mountainous villages to the east like Kanalia, Keramidi and Amygdali were fishermen, livestock farmers and lumberjacks (TEE, 1999, while the population of the plain villages to the west like Armenio, Sotirio and Achilleio were predominantly farmers (Dodouras et al., 2014).

Figure 64. Natural banks, December 2024

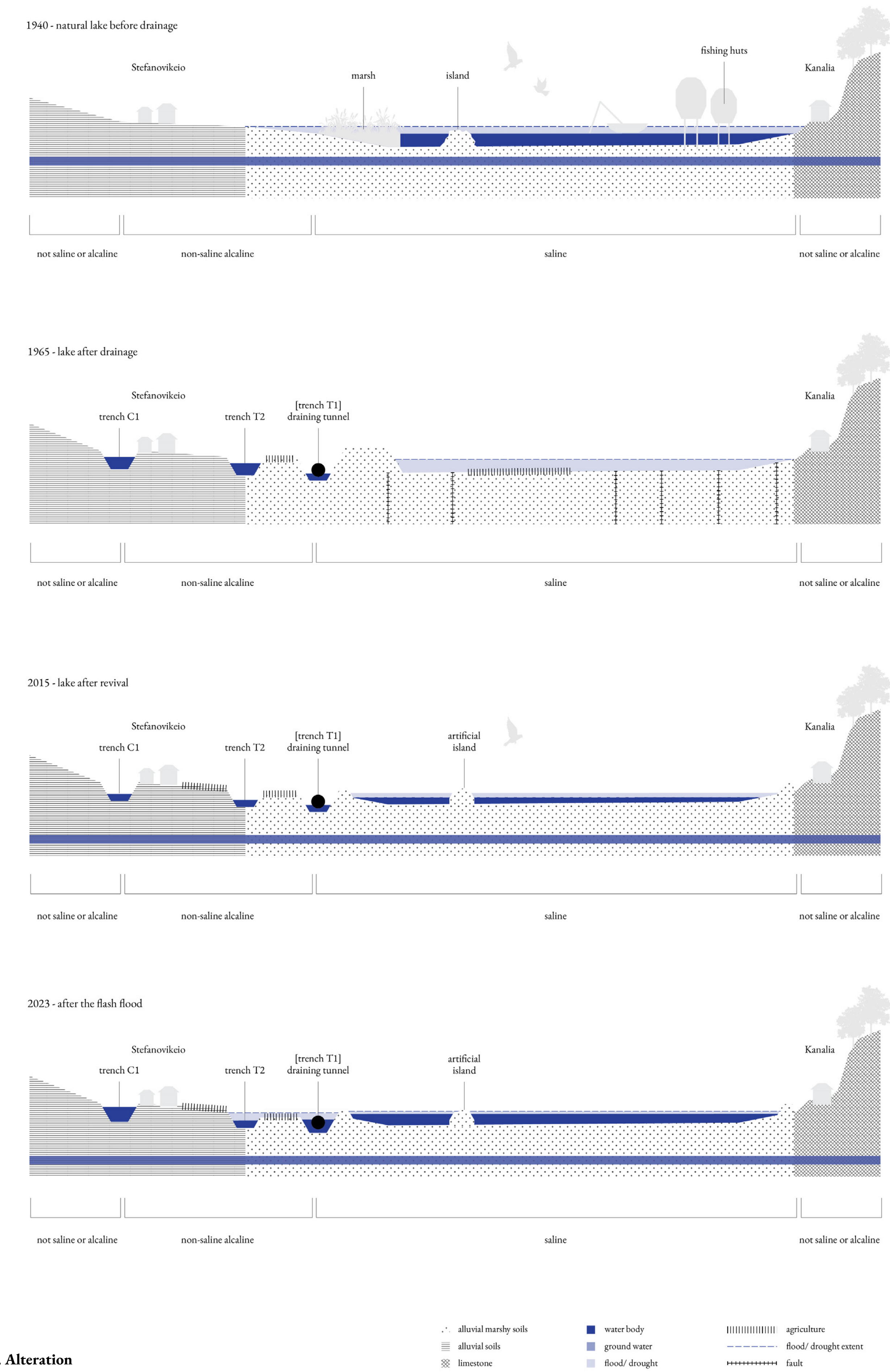


Figure 65. Alteration

Due to her location on the part of the Thessalian plain with the lowest altitude, Lake Karla received water not only from rainfall and her own watershed, but also the floodwaters of Pineios, as well as water from the Asmaki Stream to the north and the Velestino sources to the south, therefore resulting in her constantly fluctuating size (TEE, 1999) from 4500 to 18000 ha (Zalidis et al., 1995). However, it has also been recorded that when Lake Voivis was inundated and the level of Pineios River was low, the water travelled in the opposite direction from the Asmaki Stream towards the Pineios River (Rouskas, 2001).

Following several big floods in the beginning of the 20th century, the delineation of her maximum and minimum allowed levels happened in 1939 (TEE, 1999), as well as the construction of flood protection works at Pineios River in 1940 (Rouskas, 2001), which diverted the water from Asmaki stream, resulting in the decrease of her size. The continuous lowering of the lake's level (from 5,5m before WWII to 2m in 1950) (TEE, 1999) intensified the processes of salinization, alkalization and pollution of her waters. The persistent fluctuations of the water level, the flood-prone marshy and swampy soils, the complicated ownership status of land and the subsequent decrease of fish production (TEE, 1999) as well as the intense presence of mosquitos which led to the spread of diseases such as malaria (Chatzilakos, 1995) led to her complete drainage in 1962, even though this was never the original plan. On the contrary, partial drainage of the lake and the creation of an artificial reservoir in her original location had been proposed, which would happen through a drainage network and a tunnel directing the water into the Pagasetic Gulf (Loukas et al., 2007). The reservoir and drainage network would have been used not only for irrigating the newly "uncovered" agricultural land, but also for the protection of the area from floods (TEE, 1999). However, the reservoir was never constructed, and the lake was completely drained. It is important to note that this decision was supported by the population of the lakeside villages, with the hope to acquire agricultural land since the fish production was so low that fishing as main employment was not financially viable anymore (TEE, 1999).

The complete drainage of the lake had extreme environmental, financial and social consequences. Regarding the environmental impact, the fauna and flora were severely affected, especially migratory birds who now had lost one of the most important stops, altering their migration cycle and the ecological balance of the entire country. The drainage also led to the extinction of fish and mammal species like carp fish, lynx and otters as well as a large part of the aquatic vegetation, which in turn impacted the forest wealth of the entire area (TEE, 1999). Soil degradation due to erosion and salinization was another consequence, as well as the appearance of ground fissures and seawater intrusion in the plain settlements, which was a direct impact of the decline of the groundwater level caused by unregulated drillings by farmers to supply water for irrigating their fields (TEE, 1999). Furthermore, sea pollution of the enclosed Pagasetic Gulf increased, caused by the transportation of sediment and chemicals used in fertilizers (TEE, 1999).

Society and economy were also affected, since a significant part of the population of the area that supported themselves through fishing had to turn to farming, losing not only their main employment but their way of life. This led to population decline with people relocating to bigger cities like Larissa, Volos, Thessaloniki and Athens (TEE, 1999). Additionally, it also caused general political unrest, with people demanding land redistribution that was never completed. Consequently, the land remained either in the hands of the state, temporary rented to "landless farmers", or was confiscated illegally from individuals with political and financial power (Dodouras et al., 2014). Yet, large parts of the uncovered land remained either uncultivated or unproductive since the soil never reached the preferred composition to successfully support agricultural practices while also many people found their crops completely destroyed after events of flooding (Rouskas, 2001; Loukas et al., 2007).

Figure 66. Karla Reservoir, at the floodgate, December 2024

After experiencing these severe consequences after the drainage, the authorities decided to restore the lake, by constructing an artificial reservoir at the location of the natural lake (Panagopoulos & Dimitriou, 2020). Therefore, from the 1980s a series of studies commenced in order to re-establish a functional reservoir and wetland, which would provide a range of Ecosystem Services (Panagopoulos & Dimitriou, 2020). In 2000, the decision was taken by the Greek government in order to restore the lake, and the plan for a new dual-purpose 3800 ha reservoir was finally realized during the 2000s. Karla Reservoir, besides flood protection for the area, provides water for the needs of irrigated agriculture in the eastern Thessalian plain, functions as a drinking water supply source for the city of Volos and performs environmental and ecological functions, such as aquifer recharge and biodiversity restoration (Zalidis et al., 2004; Panagopoulos & Dimitriou, 2020).

Figure 67. Karla Reservoir, at the floodgate, December 2024

The biotic environment of the lake

Lake Karla was one of the most important wetlands for fish and bird faunas. Specifically, the most common fish species of the lake was carp fish (*Cyprinus carpio*), or sazani (*σαζάνι*) as the locals called it. Other species of fish included the roach (*Rutilus rutilus*), chub (*Barbus graecus*) and goby (*Gobio gobio*) (Rouskas, 2001). As for the birds, more than 143 species were registered, either permanent or migratory, with 55 of them protected by the EC Directive 79/409 (Zalidis et al., 2004). The lake was home to typical wetland birds like ducks, herons and pelicans, predators like eagles and vultures, as well as plain birds like grouses (TEE, 1999). Otters were the only local wetland species regarding mammals (TEE, 1999).

Figure 68. Birds, December 2024

Lake Karla was a space where a unique traditional way of life was developed, an organized society of fishermen that span through centuries. Especially in the beginning of the 20th century, fishing was very profitable for the national economy due to the high taxation. Consequently, a fishing union was created in 1918, and men were allowed to fish after they obtained a "fishing license" (Dodouras et al., 2014). They were supervised by a steward, three managers and five marsh guards, assigned from the public sector (TEE, 1999). The fish production was significant, contributing to the food security of the area, especially in times of crisis like the period of German occupation during WWII (TEE, 1999).

photo by Takis Tloupas

Figure 69. Society of customs, 1953

The fishermen were only men, coming mostly from the mountainous villages near Lake Karla. They would descend in groups of usually 2-5 people and settle in circular reed huts in shallow waters. Every weekend, they would sell their fish on one of the three fish ladders next to the lake (Rouskas, 2001), and – in rotation within the group – they would return to their homes, their wives and children once every two weeks (TEE, 1999). The fishing period lasted approximately 9 months, commencing on the Assumption of the Virgin Mary on August 15th and ending on Easter (TEE, 1999). During the summer, they were forbidden to fish, in order to let the fish reproduce – this period of approximately three months was called *strike (απεργία)* (Rouskas, 2001). This way of life, this unique expression of a male-dominated society organized with its own rules, lasted until the drainage of the lake in 1962. Then this entire lacustrine civilization, an entire settlement of 100 fishing huts built on the lake among the reed beds, was completely eradicated.

photo by Takis Tloupas

Figure 70. Fishing, 1953

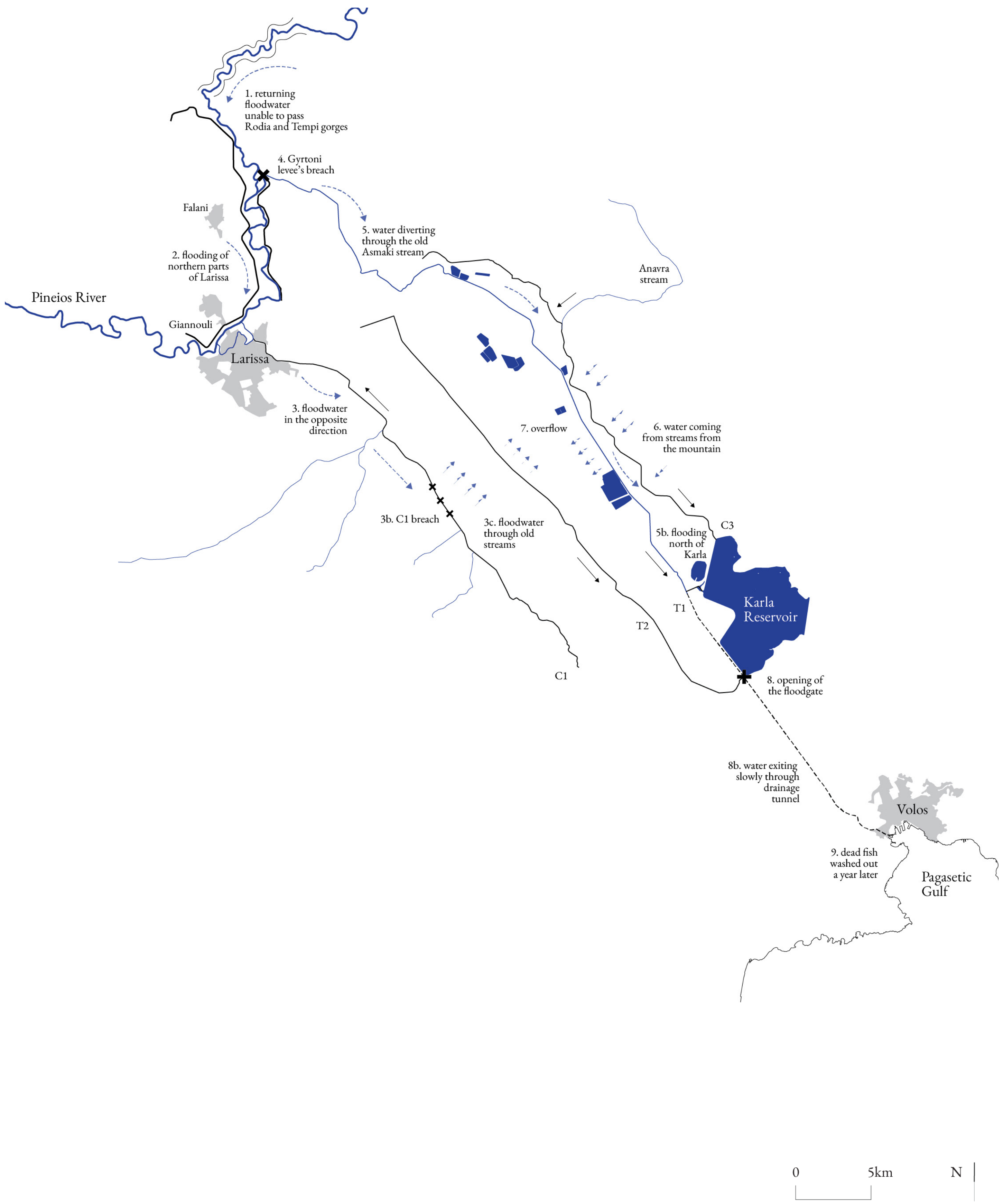


Figure 71. Lake Karla system

For the purposes of this project, it is important to define a spatial scope for the analysis and exposure of the current conditions but also the biophysical and socio-technical alterations that have contributed to the present situation. Even though the sub-basin 2070 – theoretically functioning as a closed system, belonging to the Pineios River Basin – could be considered a viable choice for a spatial unit of study, human alterations and processes observed during the flooding of 2023 call for a different definition of what the current *Lake Karla system* is.

Firstly, it is important to recognize that Lake Karla is and has been inextricably linked to Pineios River, through Asmaki Stream in the past, and now through the intricate drainage network constituting of collectors and trenches. The most important works are Collector 1 (C1) which collects water from the south-western streams and direct them to Pineios River (Zalidis et al., 1995), Collector 3 (C3) which collects water from Anavra stream and discharges into Karla Reservoir and Trench 1 (T1) which is located where Asmaki Stream used to be and collects surface waters. T1 used to connect directly to the tunnel that was created to drain the waters from Lake Karla into the Pagasetic Gulf (Zalidis et al., 1995). The tunnel's length is approximately 10km with 8.5m/sec drainage capacity (TEE, 1999), and transcends the boundaries of the sub-basin 2070, consequently linking the Pagasetic Gulf and Volos to the Lake Karla system. A similar function to T1 was the one of Trench 2 (T2), another important artery which collects the surface waters of the south-western part of the Eastern Thessalian plain and currently directs them to the Karla Reservoir (Zalidis et al., 1995).

In the first days of the September 2023 flood, the drainage network supporting Karla Reservoir performed quite successfully its flood protection function, since the amount of water was within its *coping capacity*. Nevertheless, there was so much water coming from the western Thessalian plain, following the course of the Pineios River, that it was not able to go through the narrow Tempi Valley. As a result, water started coming back towards Larissa, flooding the northern suburbs and threatening the city itself. Then, the levees near the Gyrtoni Dam broke, diverting the water away from Larissa and into the easter Thessalian plain, resulting in its extensive flooding. Therefore, it is essential to also recognize Gyrtoni Dam as a point of interest, completing the spatial extent of what is referenced in this project as *Lake Karla system*.

Socio-economic transformations and planning decisions

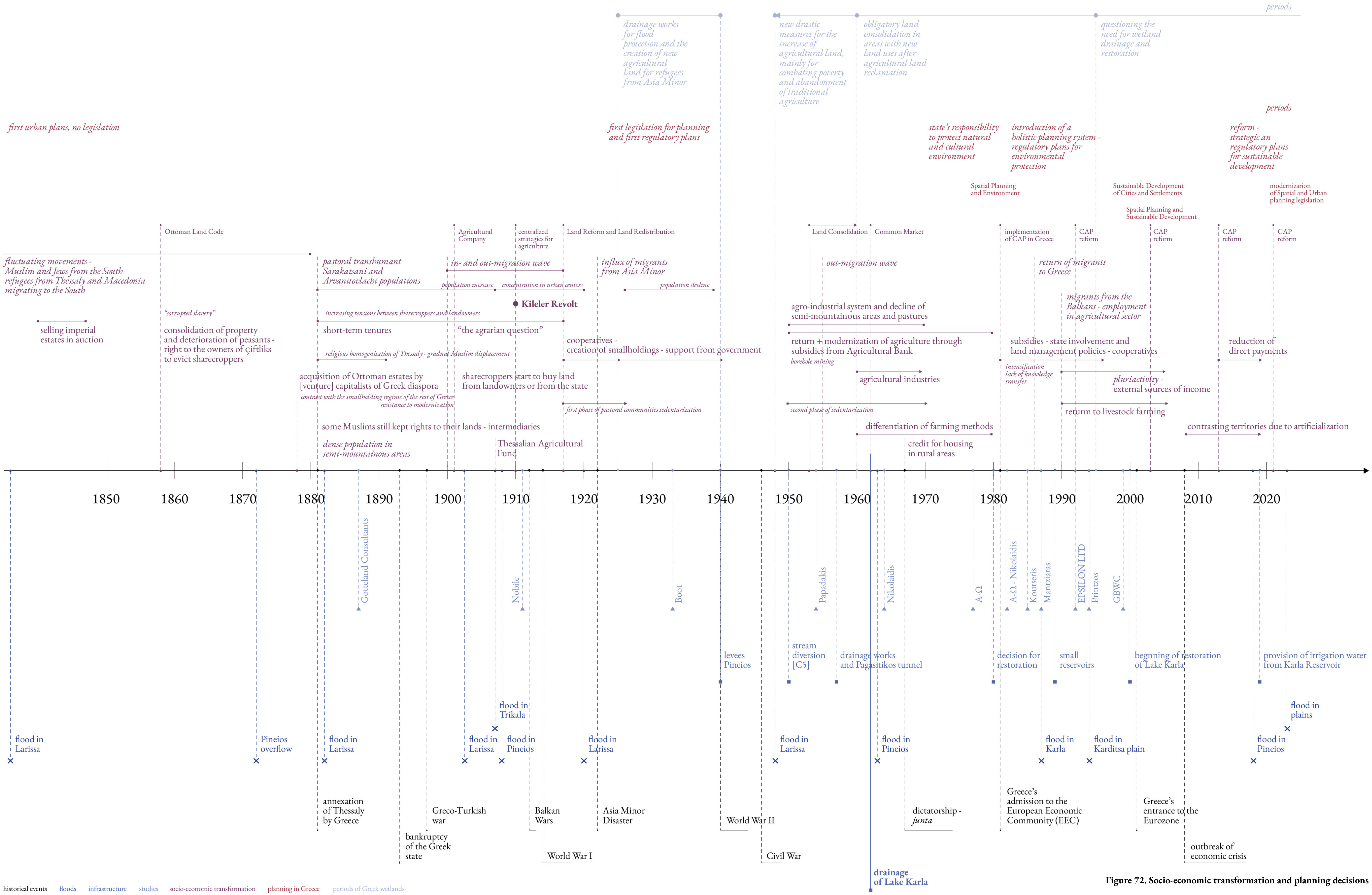


Figure 72. Socio-economic transformation and planning decisions

Current plans

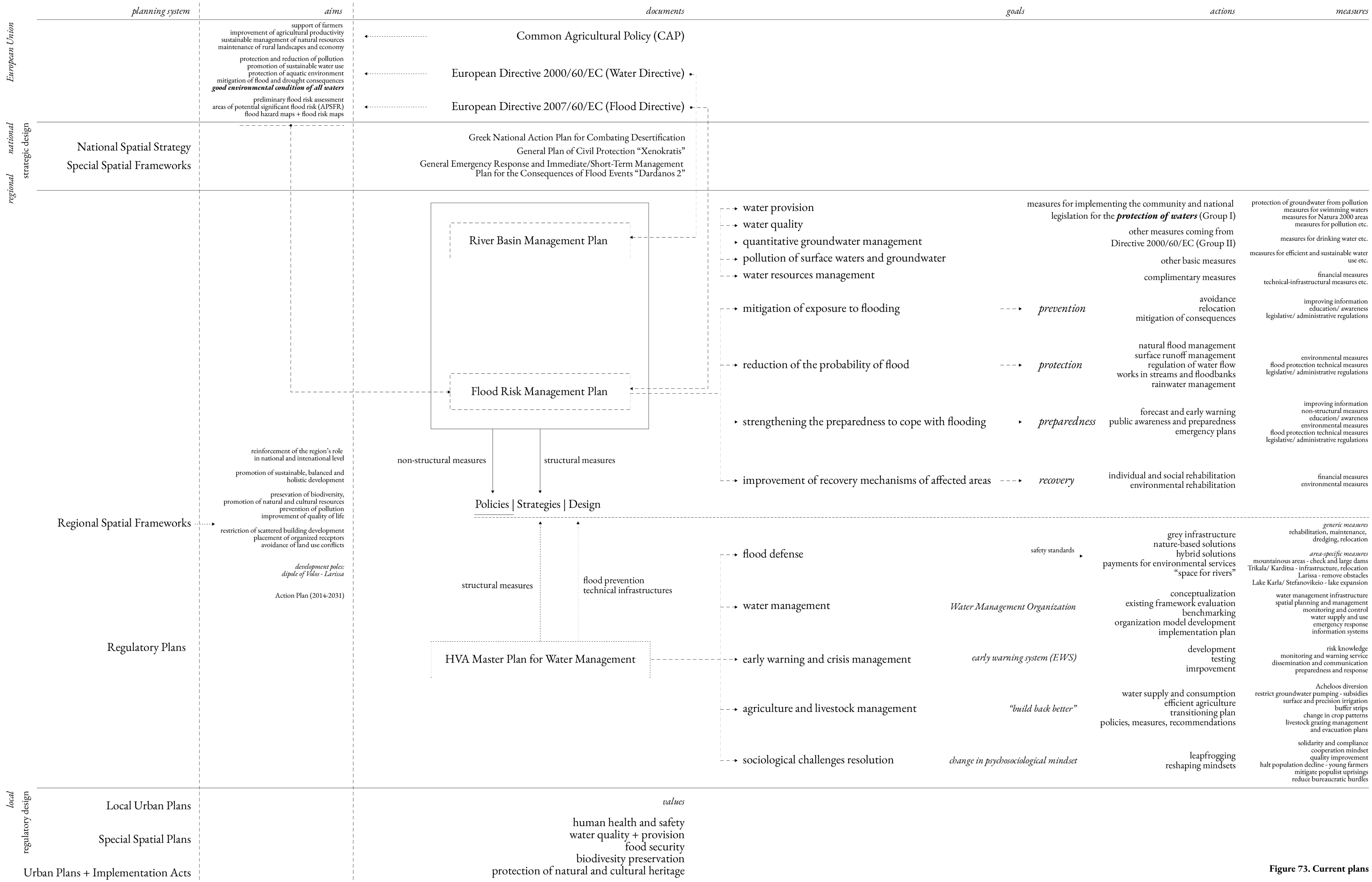
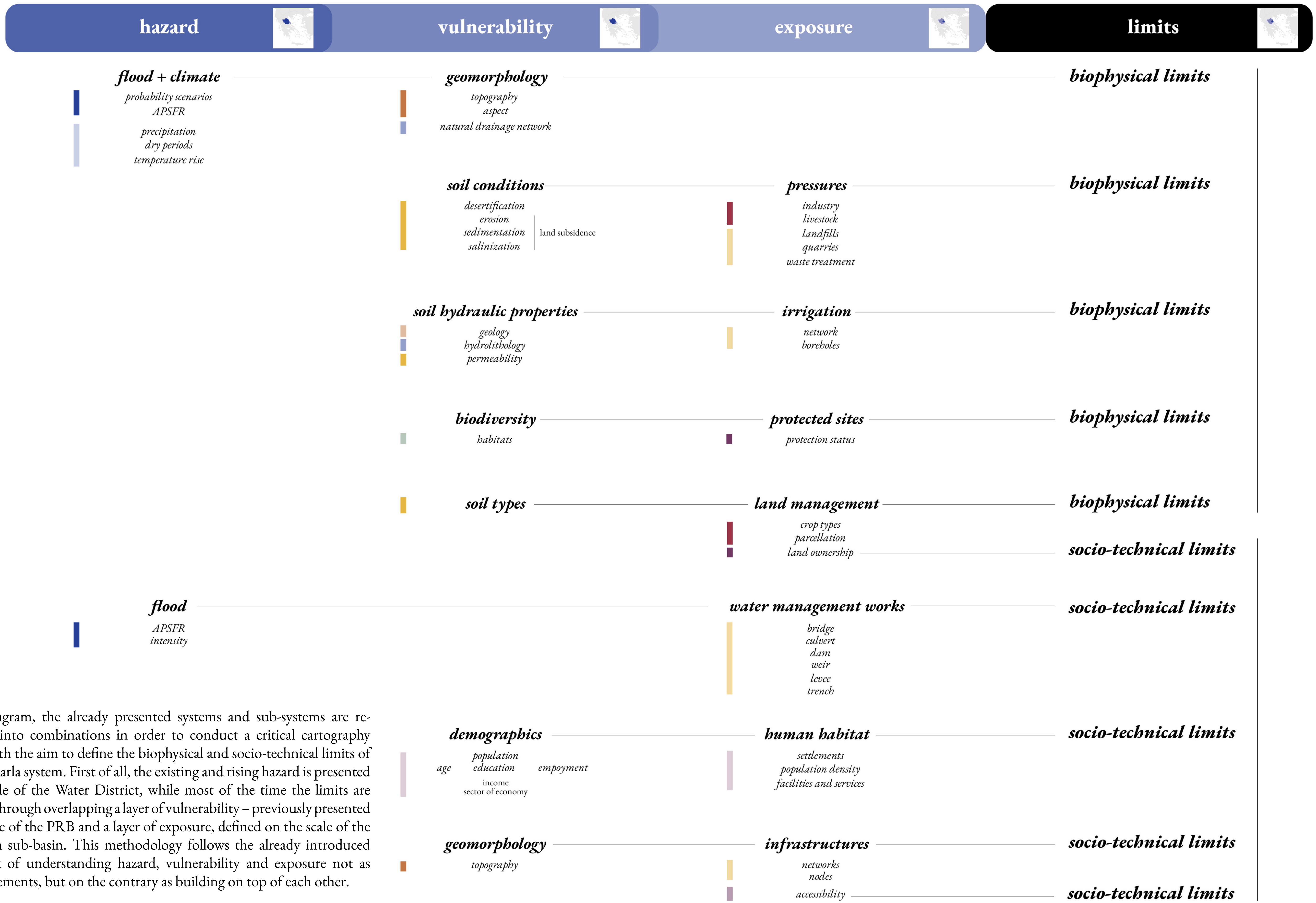


Figure 73. Current plans

Categorization of biophysical and socio-technical limits



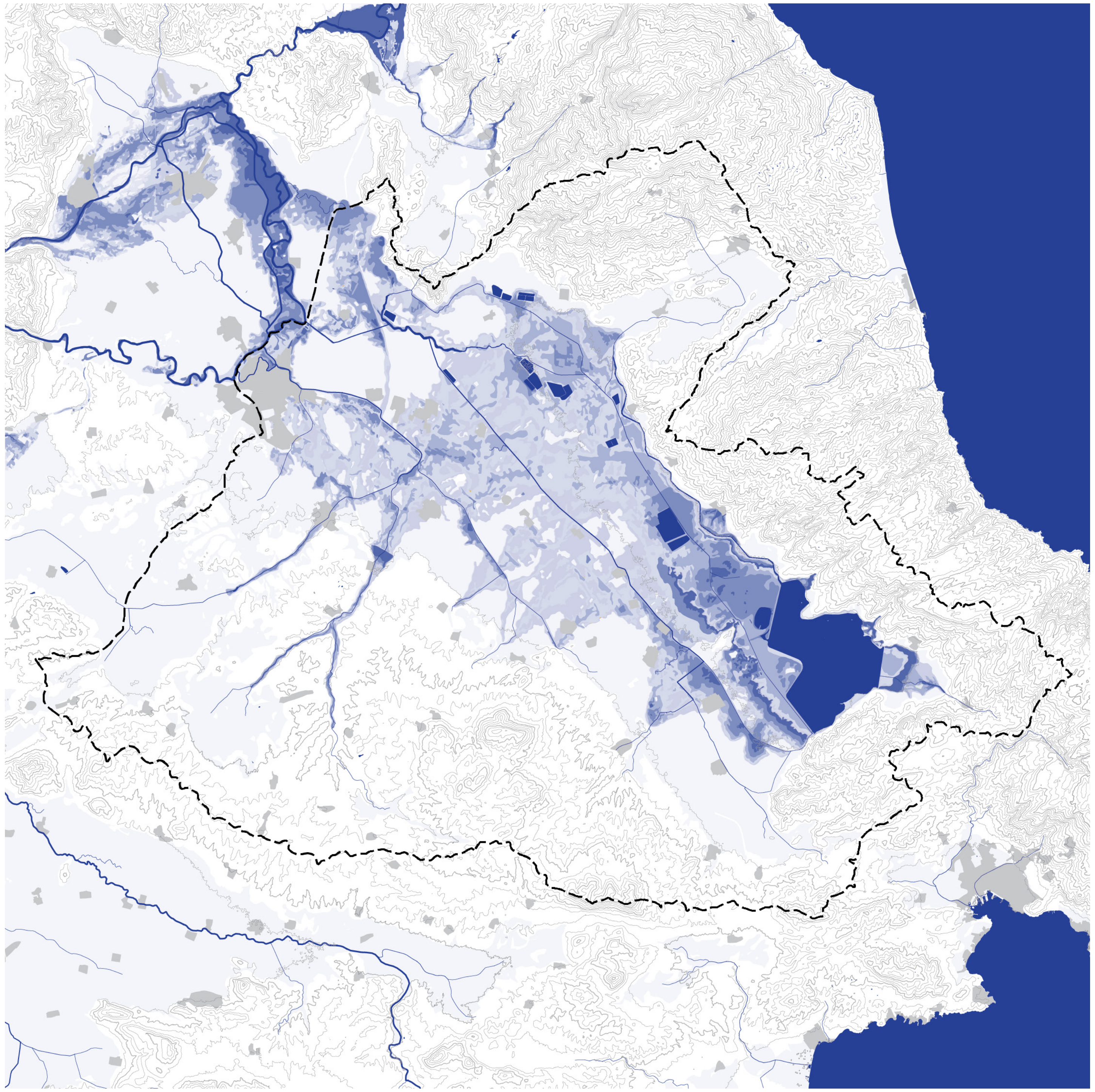
In this diagram, the already presented systems and sub-systems are re-organized into combinations in order to conduct a critical cartography exercise with the aim to define the biophysical and socio-technical limits of the Lake Karla system. First of all, the existing and rising hazard is presented on the scale of the Water District, while most of the time the limits are expressed through overlapping a layer of vulnerability – previously presented on the scale of the PRB and a layer of exposure, defined on the scale of the Lake Karla sub-basin. This methodology follows the already introduced framework of understanding hazard, vulnerability and exposure not as separate elements, but on the contrary as building on top of each other.

Figure 74. Categorization of biophysical and socio-technical limits

Biophysical limits

Composition

Flood hazard and geomorphology



From the three flood hazard scenarios (T=50 years for high probability, T=100 years for medium probability and T=1000 years for low probability), the T=1000 scenario was examined. Even though the return period of the rainfall event of September 2023 is estimated in 150 years (Dimitriou et al., 2024), some factors highlight the need to examine the worst case scenario. Those are the severity and persistence of the phenomenon, as well as the observed depth of water reaching 6m in some areas, combined with the overall weakening of the area's resilience to future flooding events, due to the failure of multiple flood protection infrastructures.

flood hazard depth, T=1000

<0.2m
0.2-0.5m
0.5-1m
1-2m
>2m
APSFR

water body
Strahler stream order

0 5km N

Figure 75. Flood hazard and geomorphology

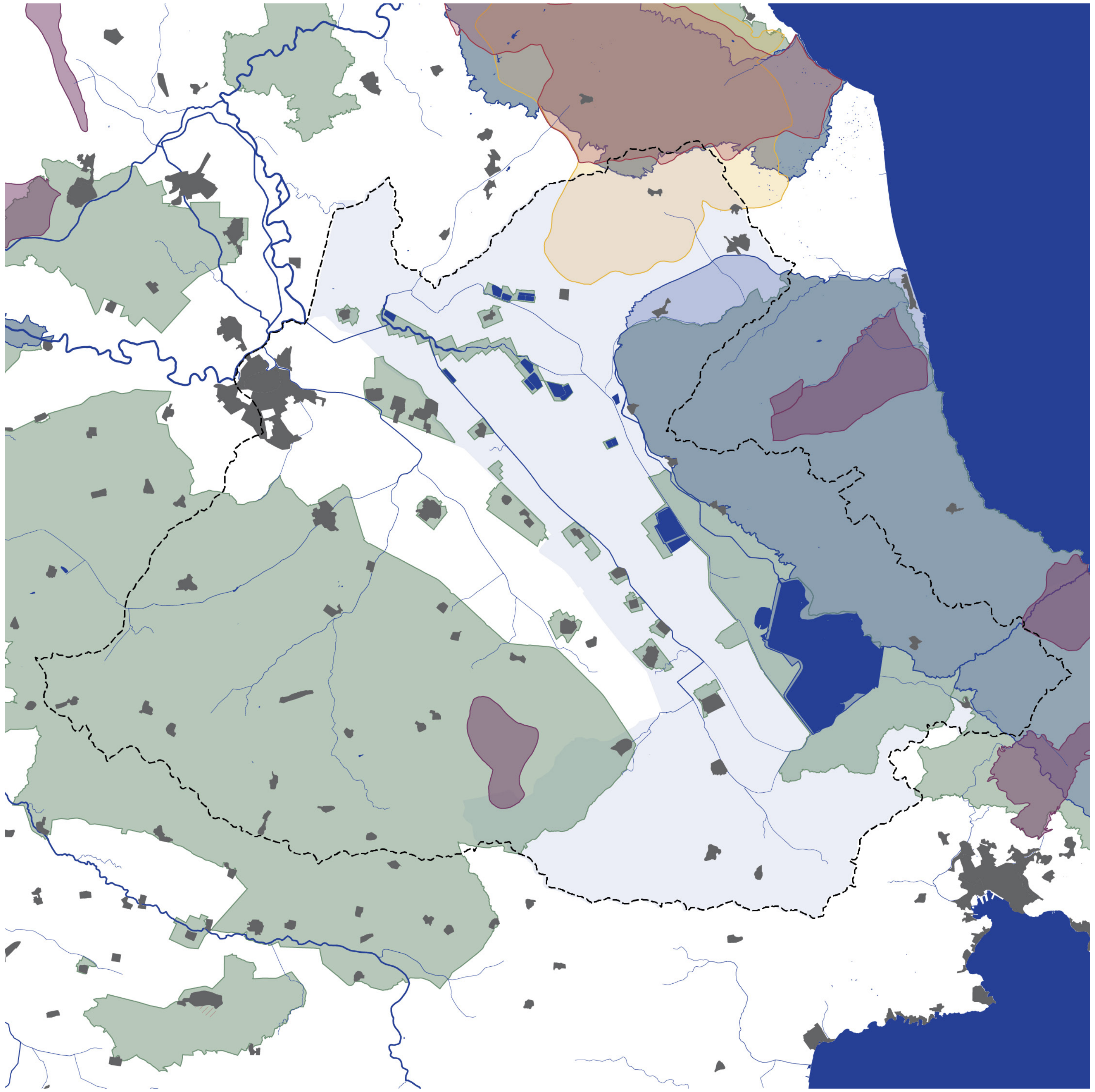


Figure 76. Biodiversity and protected sites

Lake Karla is a Natura 2000 site of community importance, specifically for the preservation of natural habitats of wild flora and fauna, with the code GR 1420004 "Karla-Mavrovouni-Kefalovriso-Velestino-Neochori". It has also been characterized as a special protection area for 75 permanent and 106 migratory bird species, such as the black-crowned night heron (*Nycticorax nycticorax*), squacco heron (*Ardeolla ralloides*) and little egret (*Egretta garzetta*), with the code GR1430007 "Reservoir area of former Lake Karla". It is a permanent wildlife refuge for habitat conservation, breeding, feeding, wild fauna wintering and fish spawning (Panagopoulos & Dimitriou, 2020). Since 2003, it is managed by the Thessaly Protected Area Management sub-unit for the area of "Karla-Mavrovouni-Kefalovriso-Velestino-Neochori".

Soil conditions and pressures

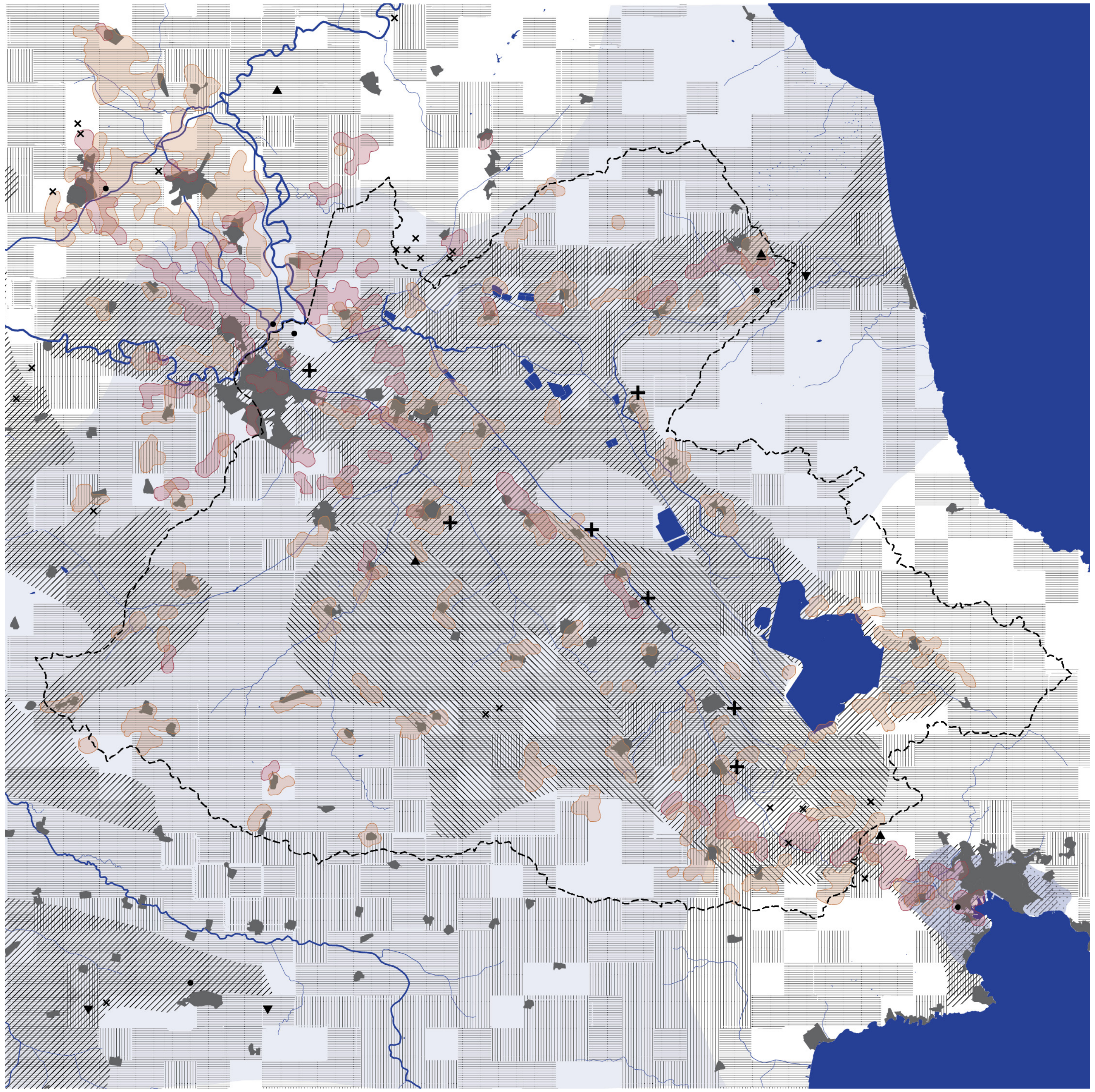


Figure 77. Soil conditions and pressures

The application of cotton monoculture has caused soil and land degradation, contributing to erosion and desertification (Arapostathis et al., n.d.). Anthropogenic land subsidence is also an issue, caused by over-pumping leading to extreme groundwater exploitation and subsequent drop of groundwater levels and aquifer reduction (Alexopoulos et al., 2024). The decline of the groundwater level reduces structural support, which causes volumetric contraction of fine-grained sediments such as the alluvial sediments of which the area mostly consists of, therefore resulting in land subsidence (Argyrakis et al., 2020). Other pressures regarding pollution result from the waste coming from industry and livestock units located in the area.

pressures

- livestock clusters
- industry clusters
- quarries
- wastewater treatment
- landfills
- unregulated waste disposal
- waste sorting center

- urban fabric
- water body
- Strahler stream order

soil conditions

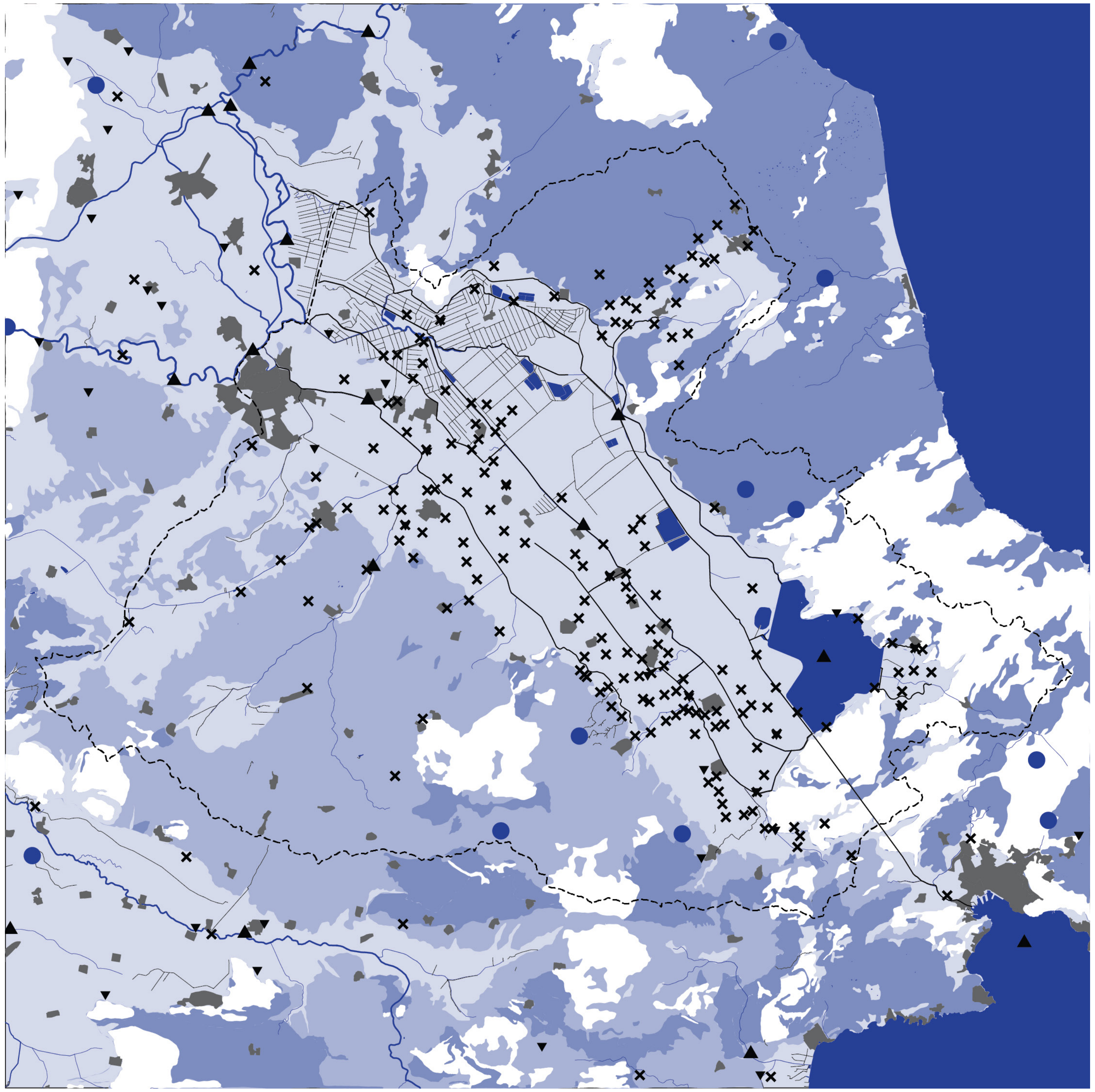
desertification risk

- fragile
- critical

saline soils

- >50%
- <50%

- seawater intrusion
- erodibility <0.023
- land subsidence



0 5km N

Figure 78. Soill hydraulic properties and irrigation

Only 40% of the irrigated land in the area is being irrigated through the existing collective system of boreholes which is under the jurisdiction of the Local Organizations of Land Reclamations (LOLRs). The rest is irrigated either from private boreholes (Panagopoulos & Dimitriou, 2020) or from using the drainage channels as irrigation channels. However, the extremely high costs of energy due to the now deep groundwater levels have discouraged farmers from abstracting water from the aquifer, making this practice nearly infeasible in the last years.

irrigation

boreholes

water monitoring stations

surface

groundwater

springs

irrigation network (surface)

drainage network

urban fabric

water body

Strahler stream order

soil hydraulic properties

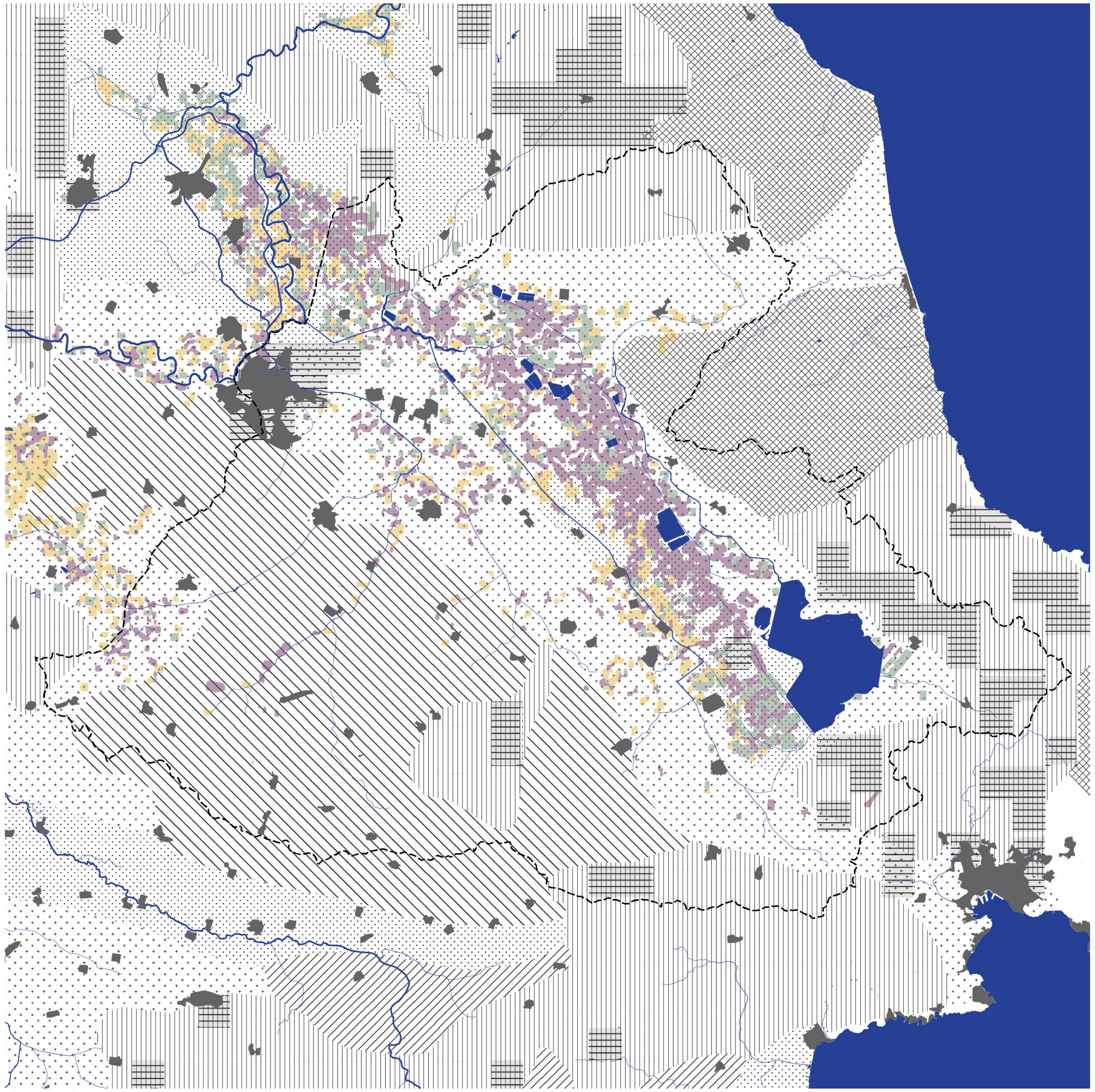
low to very low permeability, very high surface runoff

low to moderate permeability, relatively high surface runoff

flunctuating permeability, relatively high surface runoff

moderate to high permeability, low surface runoff

Soil types and crop types



0 5km N

Figure 79. Soil types and crop types

crop type

cotton
maize
alfalfa

urban fabric
water body
Strahler stream order

soil type

leptosols
fluvisols
regosols
luvisols
vertisols
cambisols

low soil quality index

Lake Karla sub-basin is the most intensely cultivated one in PRB, with 25% of the cotton that can be found in the Water District located there, due to the fertile clayey fluvisols as well as the presence of Lake Karla and the smaller artificial reservoirs that ensure water availability for its irrigation (Tsakmakis et al.,2020). As aforementioned, cotton was also the most affected crop from the flood of 2023. Specifically, 30.5% of the cotton area in the Thessalian plain was flooded (He et al., 2024).

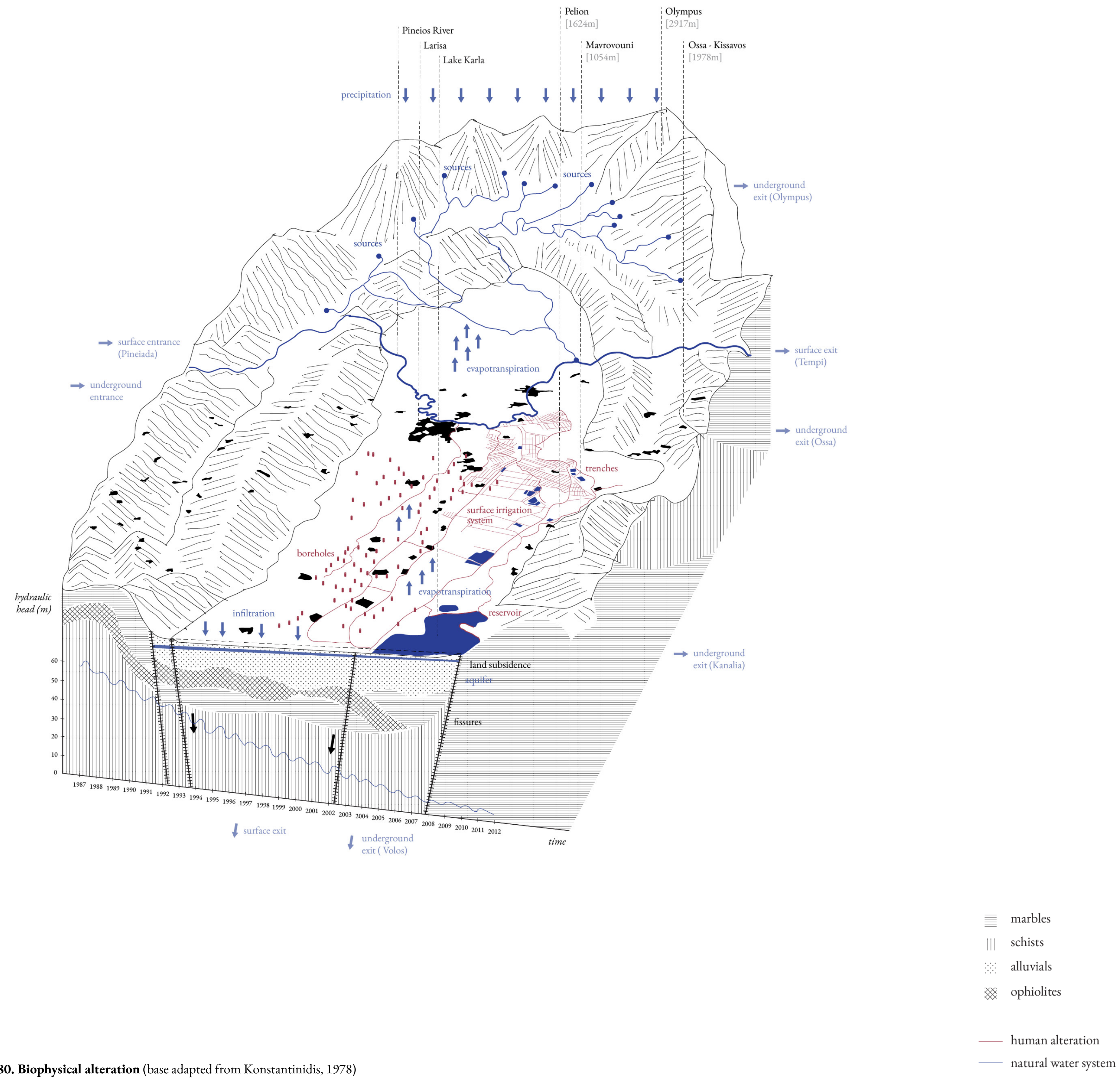


Figure 80. Biophysical alteration (base adapted from Konstantinidis, 1978)

In this drawing, it is evident how the natural hydrological system and water cycle stages (precipitation – surface runoff – evapotranspiration – infiltration) has been altered due to human manipulations. The unsustainable pumping of groundwater from the drillings and private boreholes, the lack of an official irrigation system and the subsequent fragmentation of overseeing and management from multiple authorities in combination with the obsolete and unmaintained earth canals system all contribute to groundwater degradation (Sidiropoulos, 2016). Specifically, the aquifer's hydraulic head has shown a significant drop during the last three decades, yet since the restoration of Lake Karla, this rapid decline has softened, showcasing the ecological benefits of the lake.

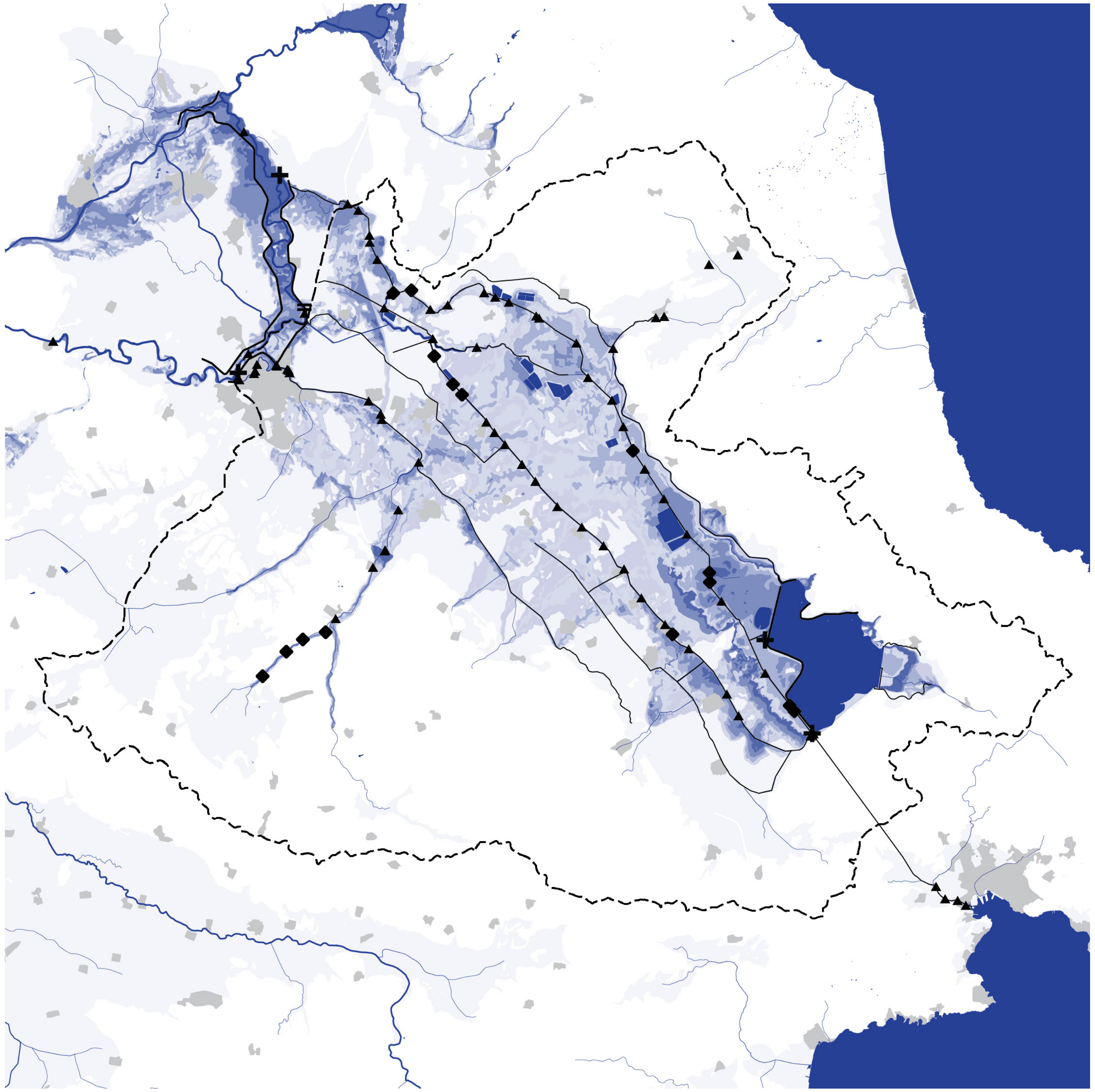
Figure 81. Discharge, February 2025

Figure 82. Cotton traces, February 2025

Socio-technical limits

Composition

Flood hazard and water management



With the construction of the flood protection system of Pineios, starting in 1940, and the drainage system consisting of the trenches and collectors, in 1957, an entire water management system, consisting of bridges, culverts, and dams had to be constructed. These sites can also prove points of tension in the event of flooding, as was the case of September 2023. Some incidents include culverts and dams that were blocked due to the transportation of sediment and flood waste, and embankments and levees experiencing structural failures, especially adjacent to Larissa city, Giannouli and Gyrtoni (Lekkas et al., 2024). Additionally, all the lowland smaller reservoirs (Dimitra, Eleutherio, Glayki, Kalamaki, Kastri, Niamata, Omorfochori, Platykampos) were affected by the flooding incident (Lekkas et al., 2024),

flood hazard depth, T=1000

<0.2m
0.2-0.5m
0.5-1m
1-2m
>2m
APSFR

water body
Strahler stream order

water management works

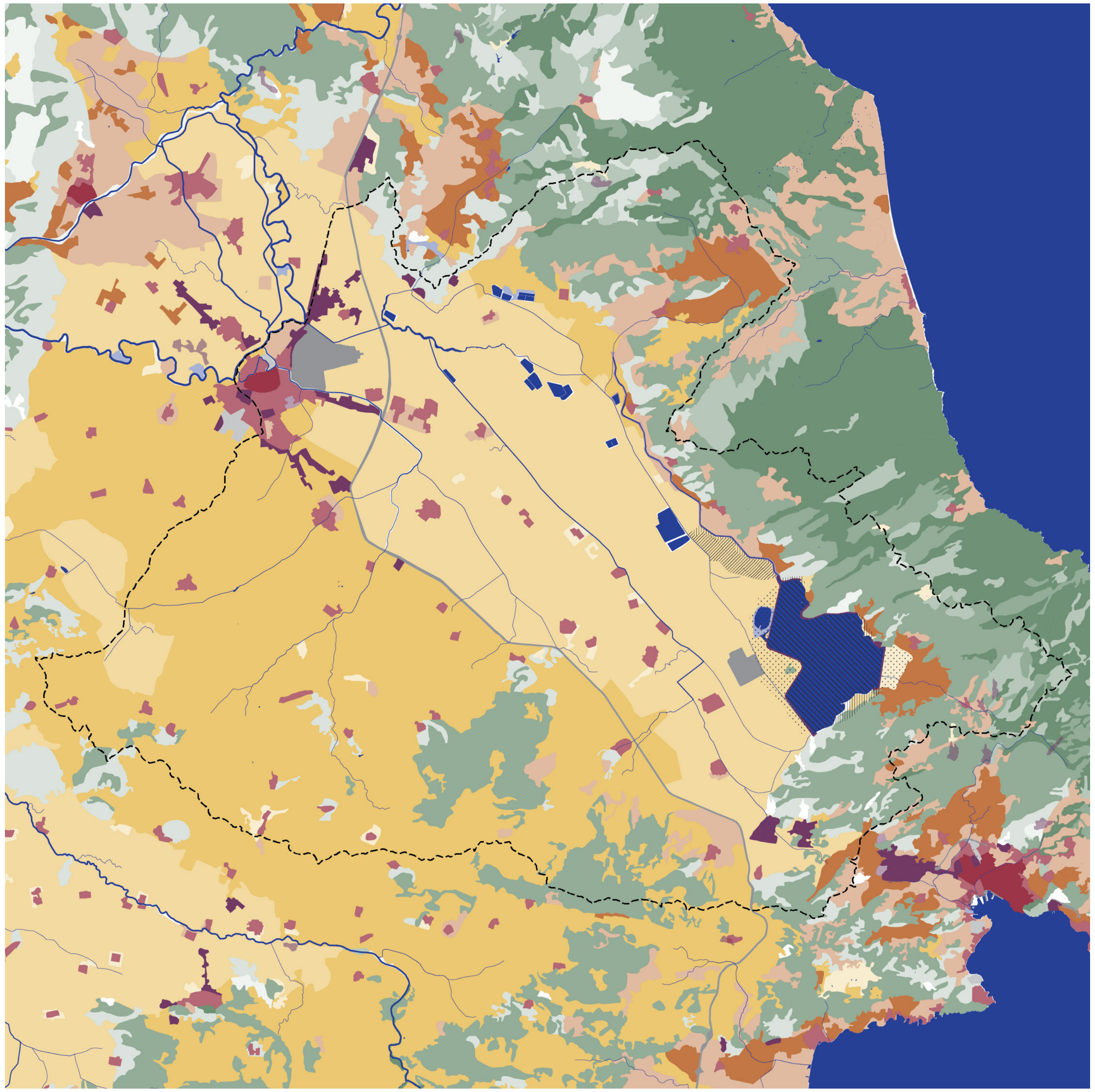
bridge
culvert
weir
dam
levee

ditch

0 5km N

Figure 83. Flood hazard and water management

Land cover and land ownership



0 5km N

Figure 84. Corine land cover 2018

When Lake Karla was drained, the uncovered land was either granted to landless farmers (46.000 acres), recognized as property of Plasia Farmstead (7.700 acres), granted to a union of "landless farmers" consisting of people who were previously fishermen (10.000 acres), turned into Kalamaki Reservoir (2.000) or granted to third parties who were required to ask for the ownership of this land (15.000 acres) (Kovani, 2002). In total, from the newly reclaimed agricultural land, approximately 70.000 acres belonged to private owners, while approximately 11.000 acres was – and still is – common property, leased to fishermen turned to "landless farmers" – farmers who does not own or is the owner of insignificant agricultural land, but their main employment remains within the primary sector and especially in agriculture, as well as being a resident of a lacustrine settlement (Kovani, 2002). This system created a lot of unrest and problems since everybody wanted to be in possession of a piece of land (Kovani, 2002).

Currently, those 11.000 acres still remain as common property, and is not attributed to farmers, while another 10-12.000 acres are attributed to agricultural and husbandry use, but the increased soil salinity and low productivity constitute it very vulnerable to floods (Arapostathis et al., n.d.). There is also a part of land that is expropriated for redevelopment purposes, such as an eco-museum. The possibility to utilize there areas should not be ignored.

Corine land cover 2018

artificial surfaces
- continuous urban fabric
- discontinuous urban fabric
- industry
- mine, dump, construction sites
- transport
- other artificial areas

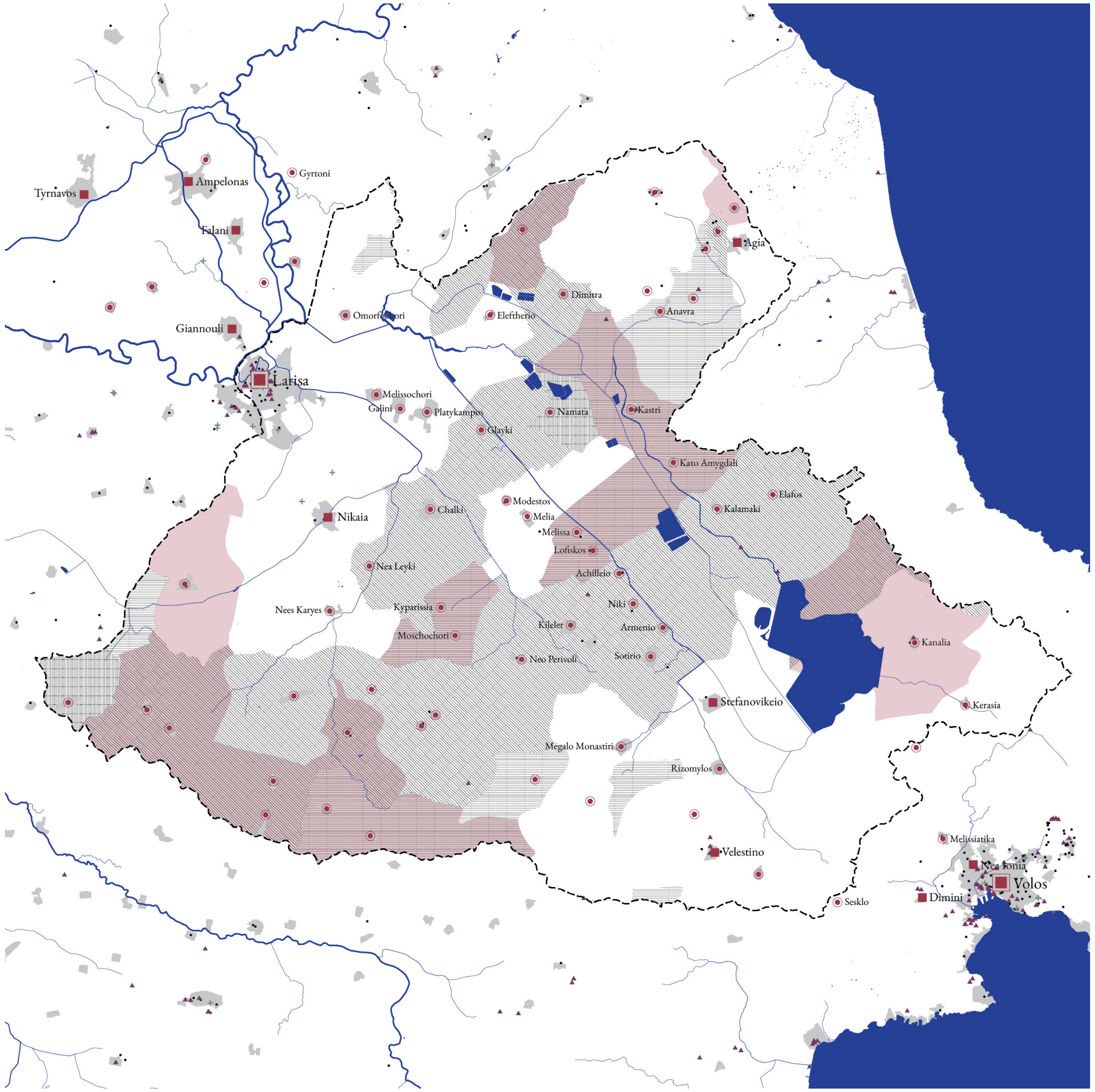
agriculture
- irrigated arable land
- non-irrigated arable land
- pastures
- permanent crops
- heterogeneous agriculture

natural
- forest
- sclerofyllous vegetation
- shrubs
- natural grassland
- other natural areas

- marshes

- water body
- Strahler stream order

public property
- Karla reservoir
- expropriated land for redevelopment purposes
- land for redevelopment purposes (ecomuseum)
- leased agricultural land



0 5km N

demohgraphics

- above 65 years old, elementary school >30%
- working in primary sector >40%

human habitat

- city
- town
- village
- church
- culture
- healthcare

- urban fabric
- water body
- Strahler stream order

Figure 85. Demographics and human habitat

A large percentage of the population in the area adjacent to Lake Karla – above 40% in most municipal and local communities located on the plain and in some cases, such as the Namata local community, even reaching numbers above 80% (Panorama Statistics). Additionally, the high number of people above 65 years old – in many municipal and local communities located mostly on the foothills of the surrounding mountains and hills, the percentage is above 30% (Panorama Statistics) – highlighting the problem of aging population and desertification of the countryside from the younger generations in favor of the bigger cities such as Athens, Thessaloniki, Volos and Larissa. Furthermore, in many municipal and local communities the percentage of people with only an elementary school degree is above 40% (Panorama Statistics). The very frequent overlapping of those factors highlights a very common profile of this area, senior farmers with only elementary school education. Finally, it is also very interesting to note that there are churches in almost every village and hamlet, yet the education and healthcare facilities are located either in the big cities or chief villages.

Geomorphology and infrastructures

There is a staggering development of solar parks in the agricultural plains of Thessaly, consisting either of smaller units that are gradually expanding, or new units with large power – competing with agricultural units – and even preferred in cases where the cost of agricultural production is much higher (Arapostathis et al., n.d.). In reality, the land with solar parks belongs either to absent landowners, pensioners or – most probably – to beneficiaries who live in larger cities and do not wish to practice agriculture (Arapostathis et al., n.d.). Another interesting point to consider is that the local railway line connecting Larissa to Volos is not functioning since the flood of 2023 due to the lack of proper maintenance, as the route is serviced by a replacement bus following the motorway. The intercity bus travels through the old national road, passing from every village on the way, fostering connections between them that are otherwise possible only with a car. There are also two airports in the area, the Larissa State Airport "Thessaly" and the Stefanovikeio military airport which was severely impacted from the September 2023 flood.

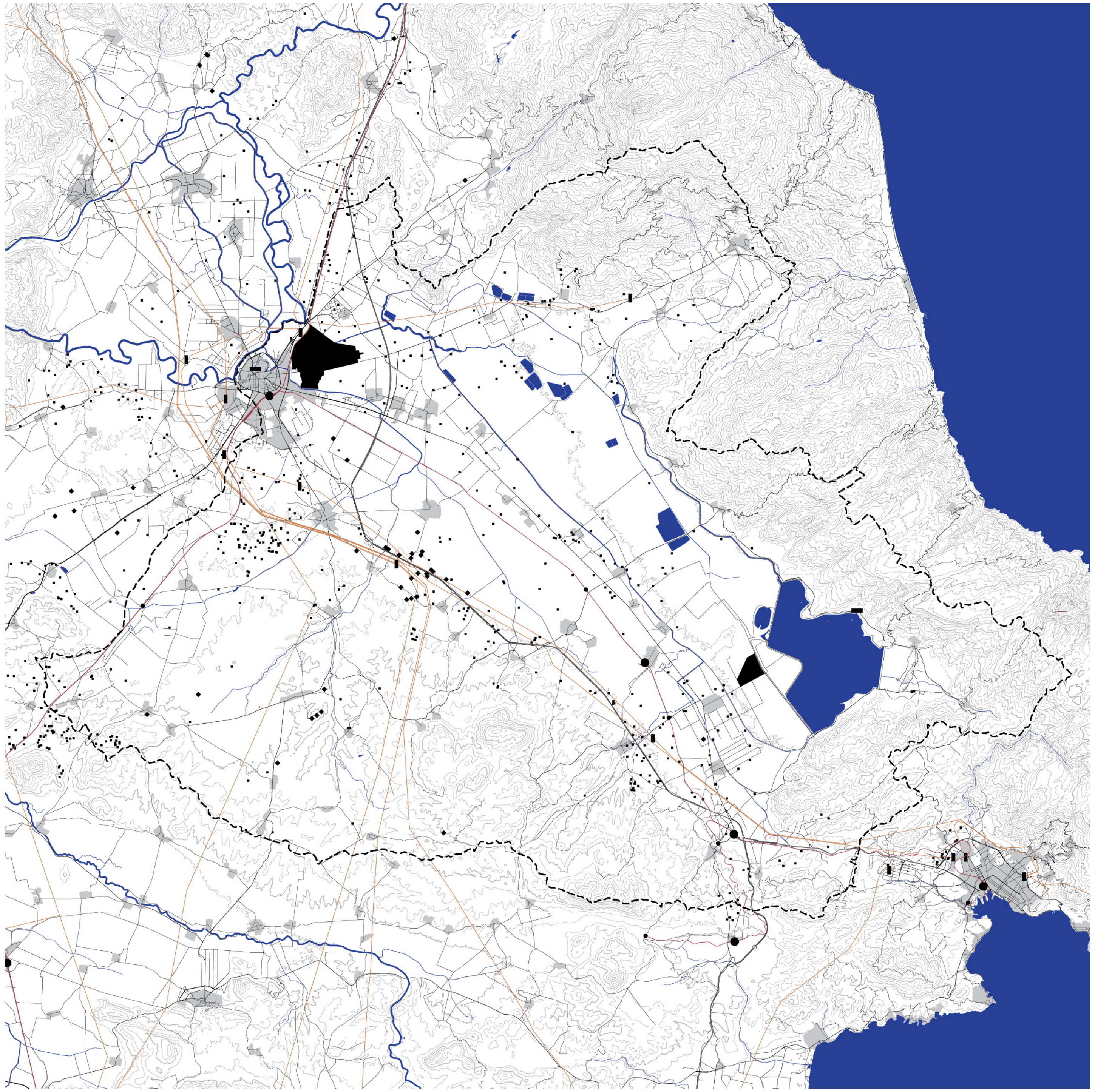
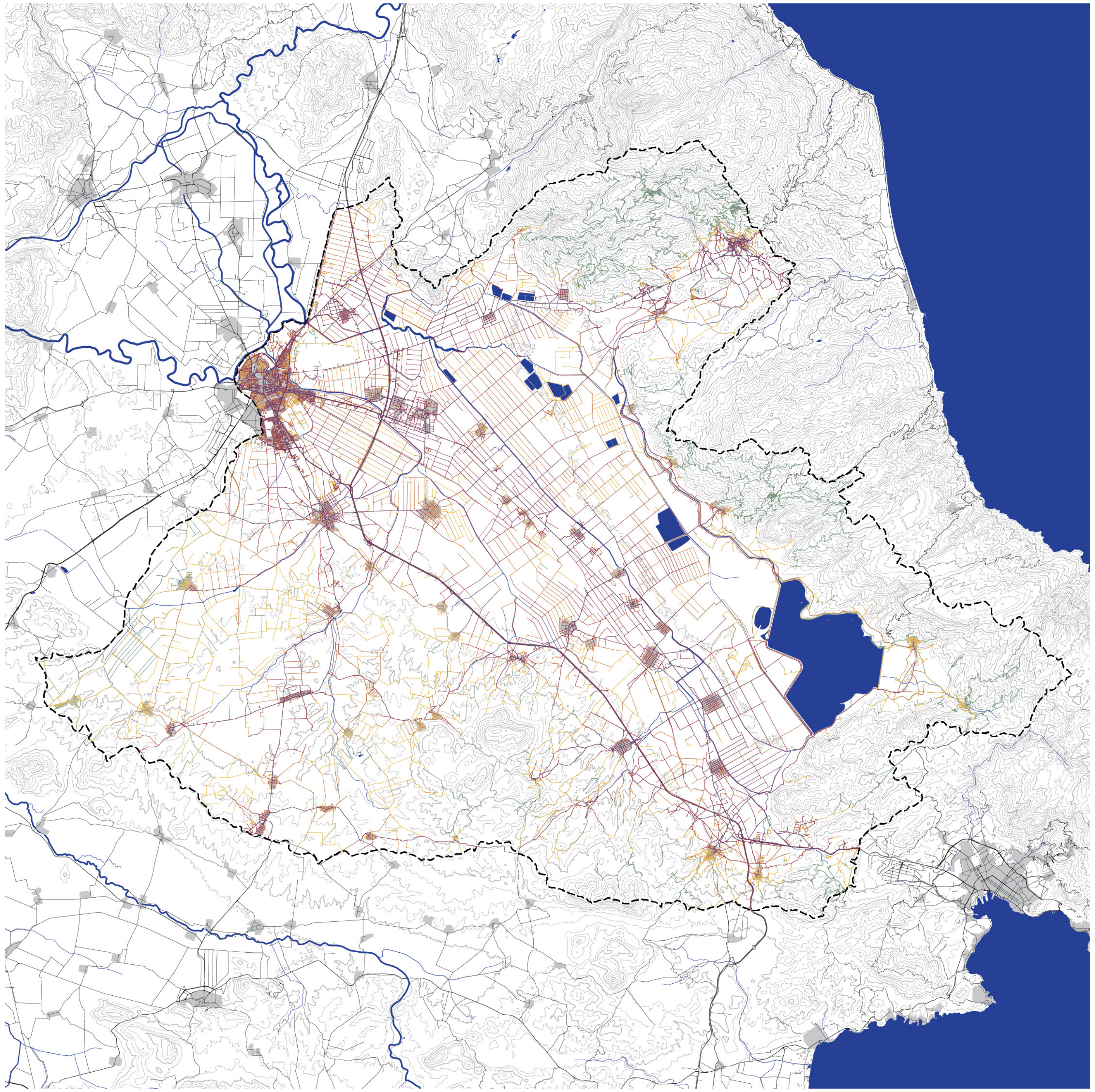


Figure 86. Geomorphology and infrastructures

Geomorphology and accessibility



To define how accessible the area is by car, a network analysis with a space syntax method using angular integration analysis, showing how easily a place can be reached, was conducted. As expected, the streets and places next to motorways and primary roads are easier accessible. However, the rural roads traversing the agricultural plain have very low accessibility, due to their unpaved and unmaintained nature, that make the use of a rural vehicle or tractor necessary to navigate the area. Finally, the areas harder to reach are up on the mountains, accessible only by narrow mountain roads, directly threatened by landslides caused by the cascading waters from streams.

car accessibility

very high

high

moderate

low

very low

urban fabric

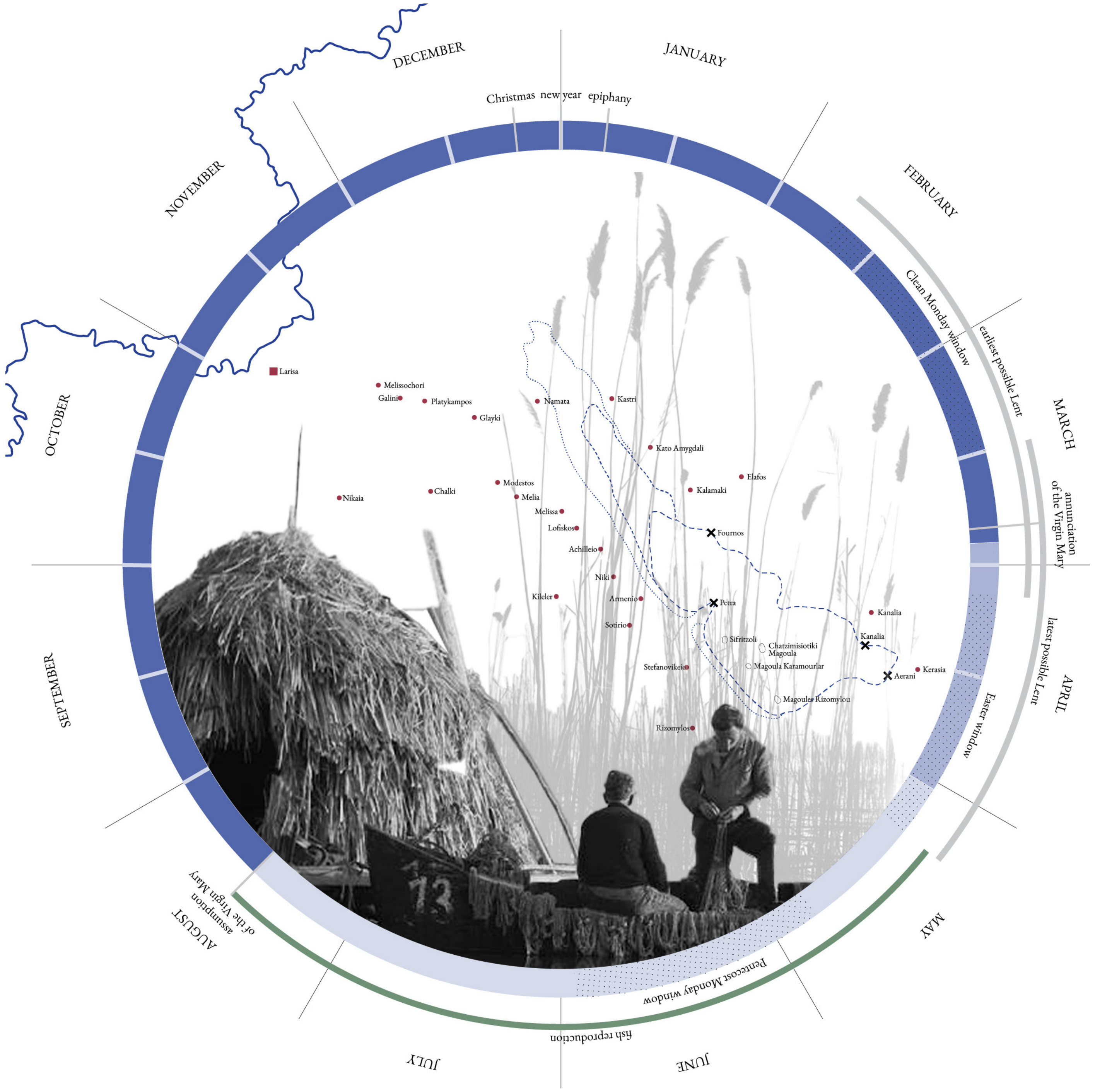
water body

Strahler stream order

0 5km N

Figure 87. Geomorhology and accessibility

Before drainage | cyclical



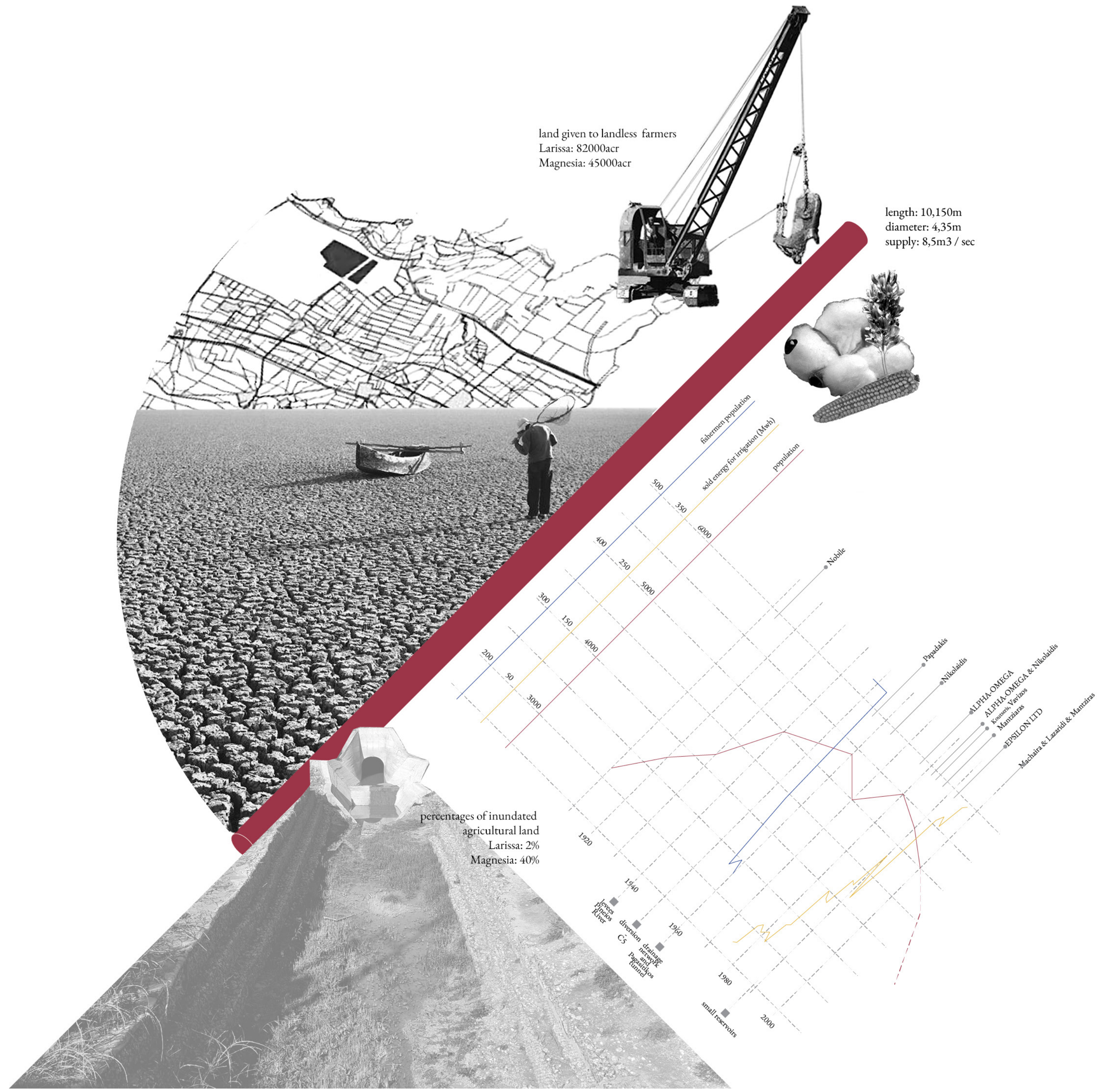
The cyclical way of life of the fishermen before the drainage of Lake Karla in 1962, which followed the cultural traditions and the reproductive rhythms of nature was abruptly transformed into a linear way of life following the productive rhythms of competitive economy, parcellating land that was once fluid and then reversing this decision when the consequences of the drainage negatively impacted the area.

fishing and now work period possible overlap
απεργία - no work period
movable holiday window
× fish market

low water level
normal water level
high water level

Figure 88. Socio-technical alteration. Before drainage (map adapted from Rouskas, 2001, photos by Takis Tloupas)

After drainage | linear



It is interesting to note that when the lake was restored, the farmers of the regional unit of Magnesia were disadvantaged in comparison to the farmers of Larissa, since the percentage of land that was inundated in Magnesia was 20 times more than that of Larissa (Kovani, 2002).

Figure 89. Socio-technical alteration. After drainage (photos by Takis Tloupas, Dimitris Letsios)

Figure 90. Trench 1, Kalamaki, February 2025

Figure 91. Solar energy landscape, Sotirio, February 2025

Criticality and transformability

Bodiversity and protected sites

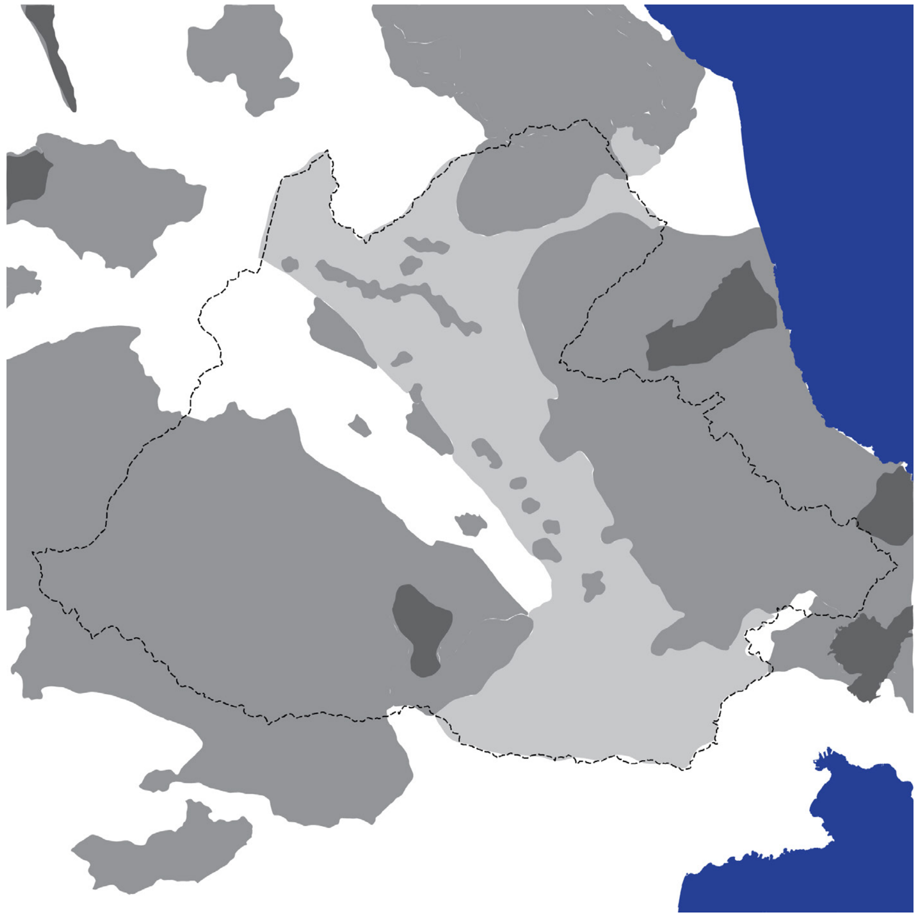


Figure 92. Criticality

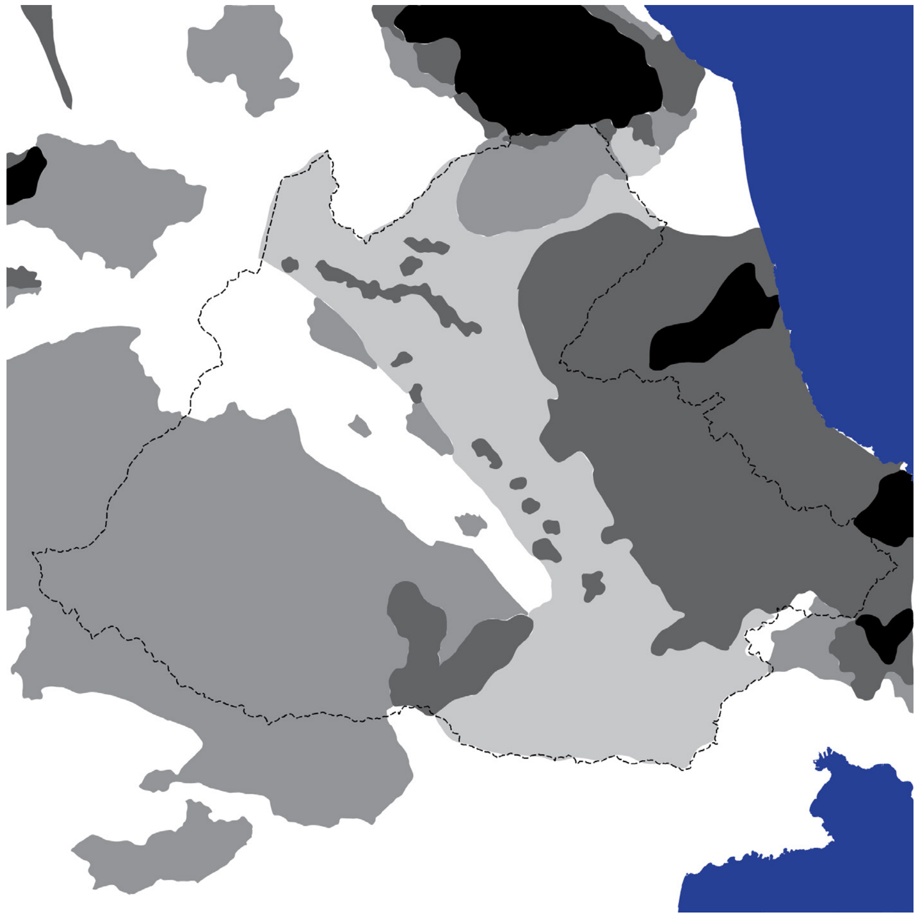


Figure 93. Transformability

Soil conditions and pressures

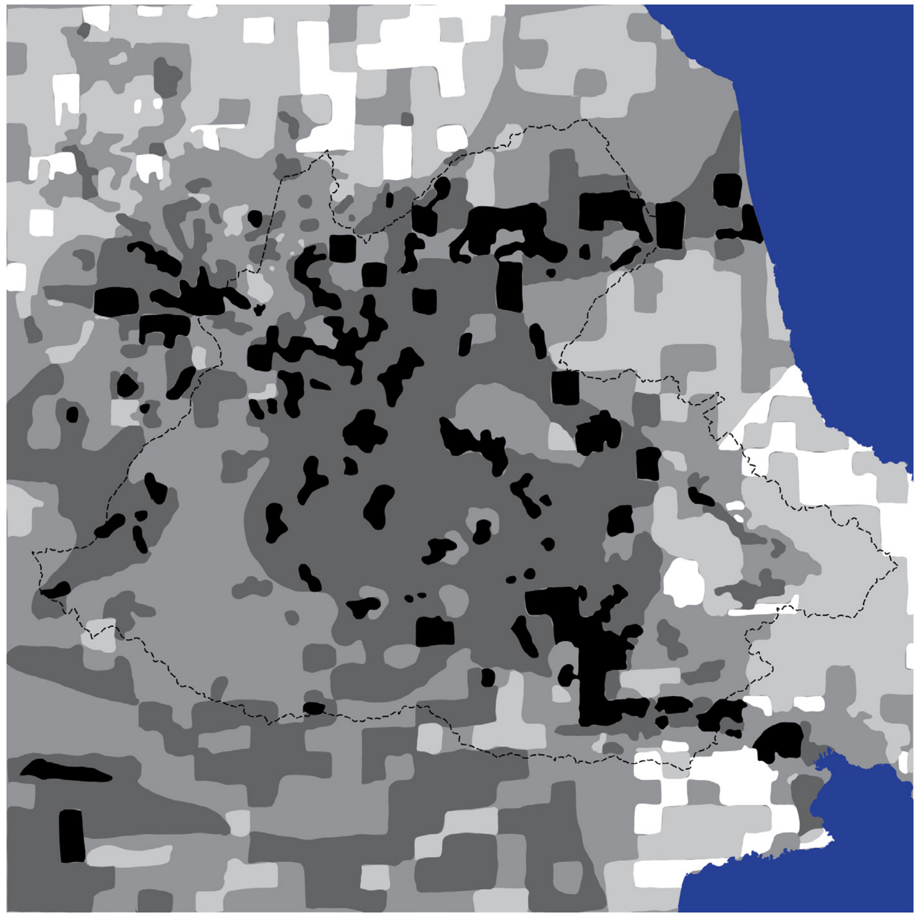


Figure 94. Criticality

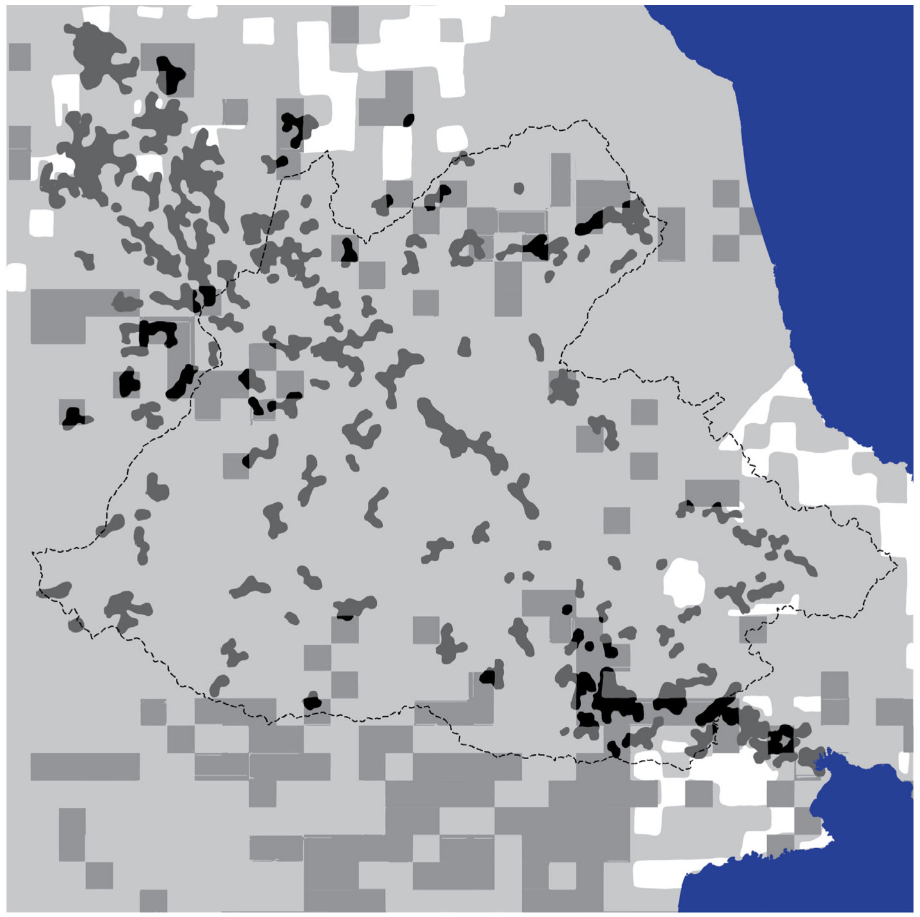


Figure 95. Transformability

Soil hydraulic properties and irrigation

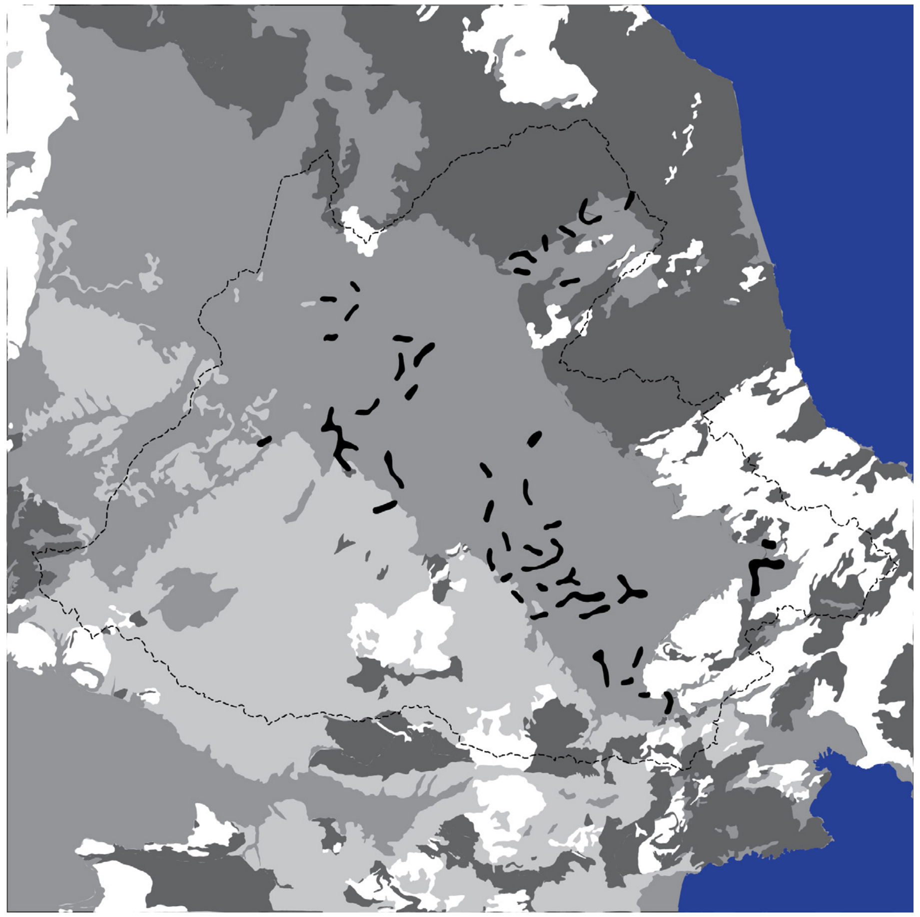


Figure 96. Criticality

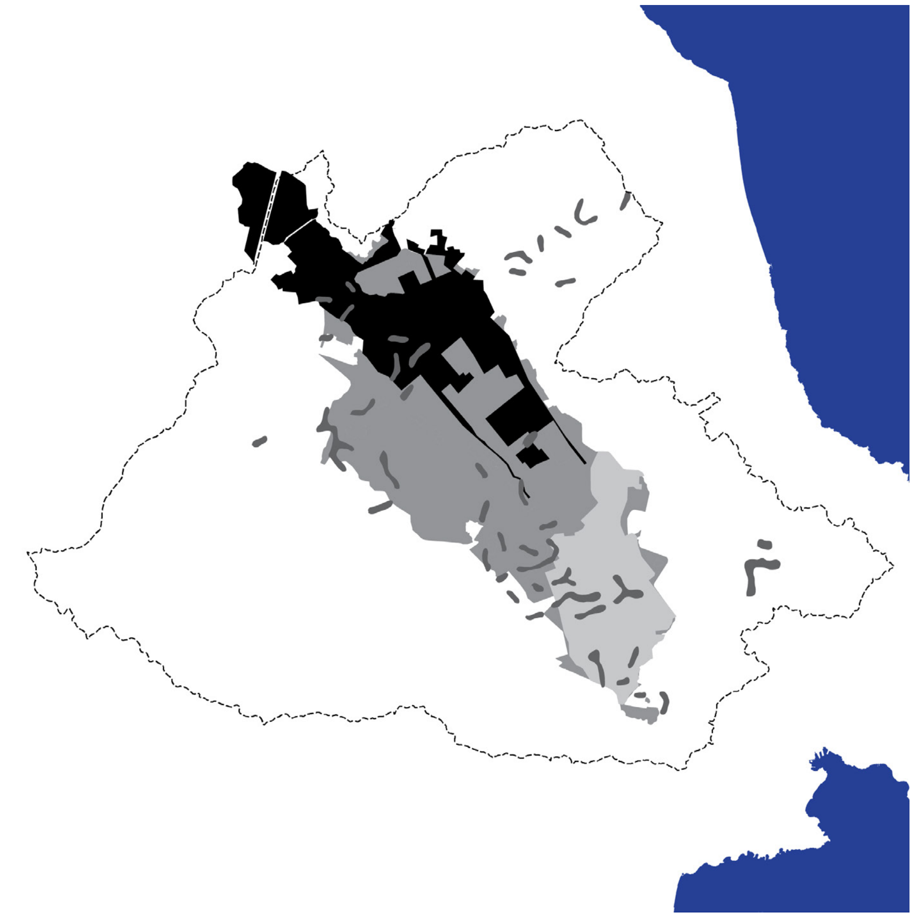


Figure 97. Transformability

Soil types and land management

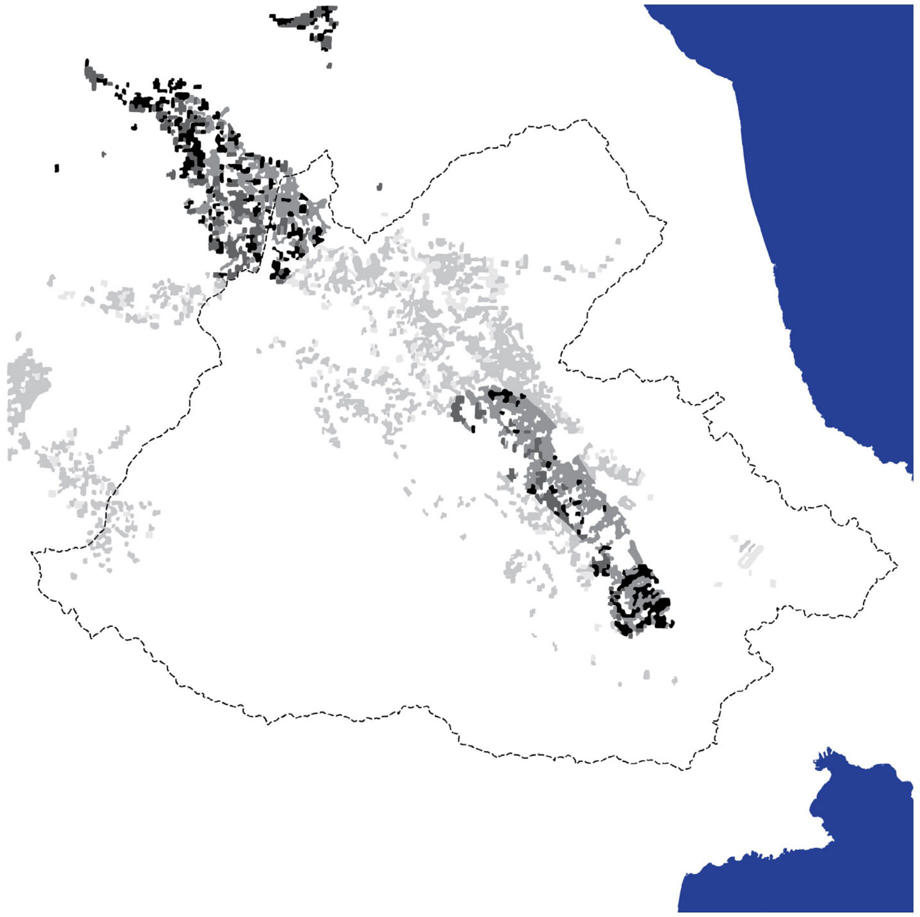


Figure 98. Criticality

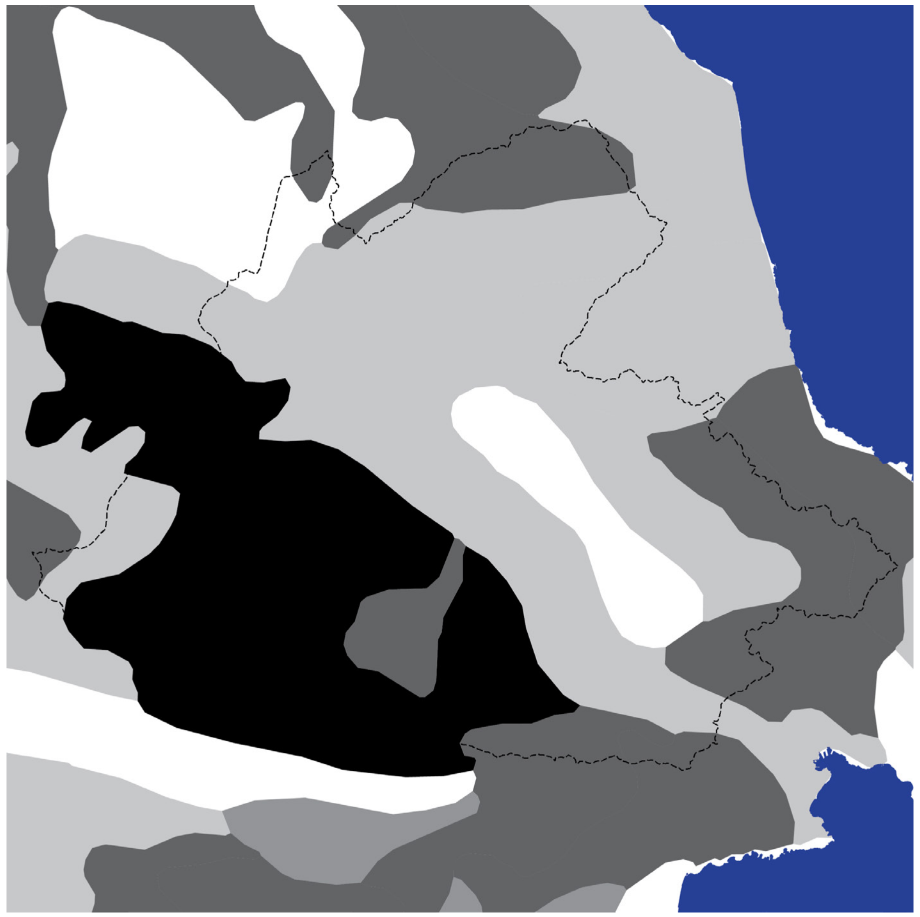
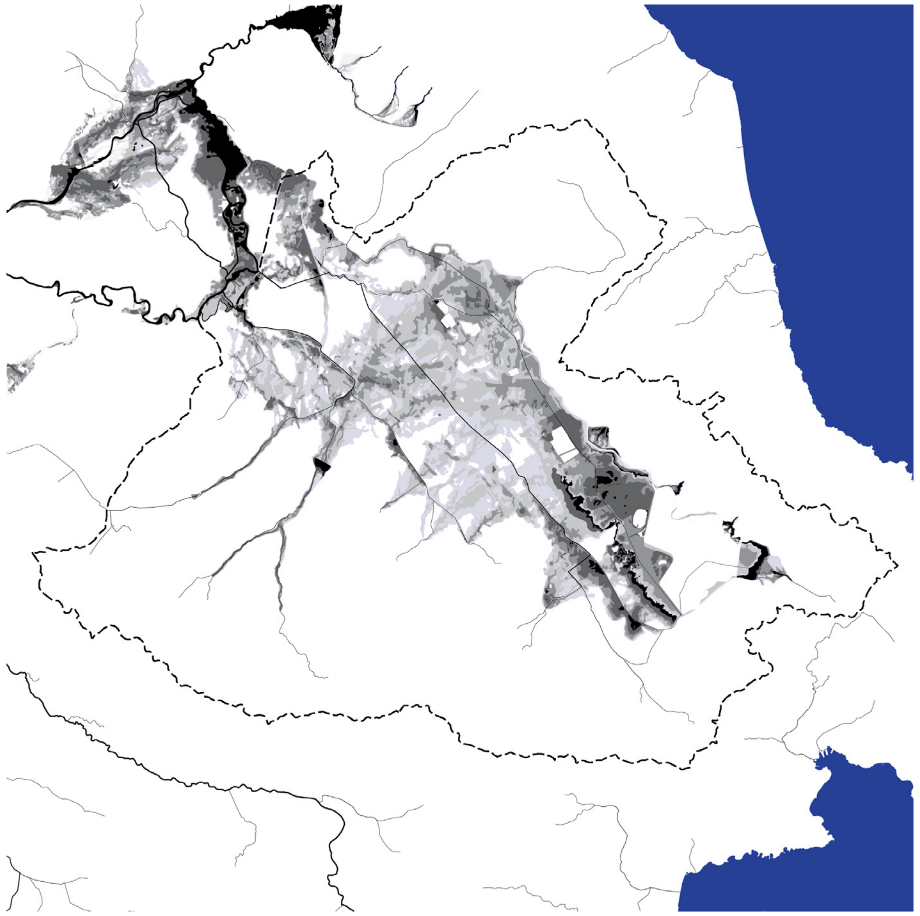


Figure 99. Transformability

Flood hazard and water management works



criticality

very high	>2m
high	1-2m
moderate	0.5-1m
low	0.2-05m
very low	0.2

water body

Figure 100. Criticality

transformability

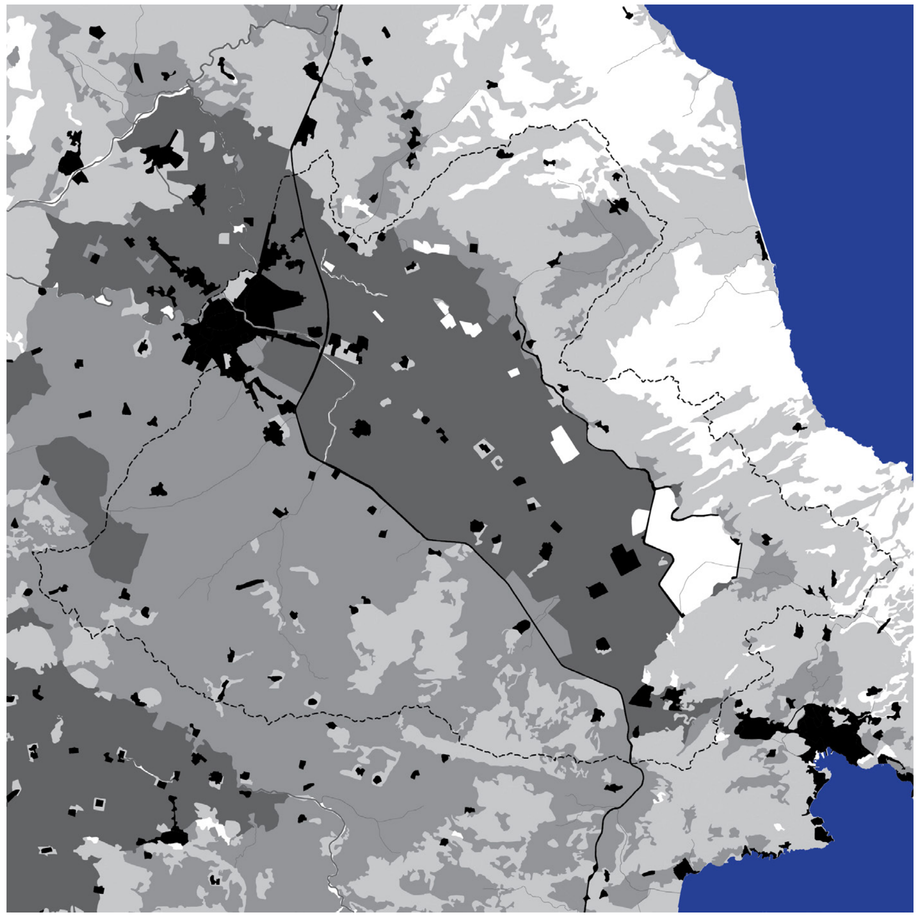
very high	
high	culverts
moderate	weir, pumping station
low	levees, bridges
very low	dams

water body

0 5km N

Figure 101. Transformability

Land cover and land ownership

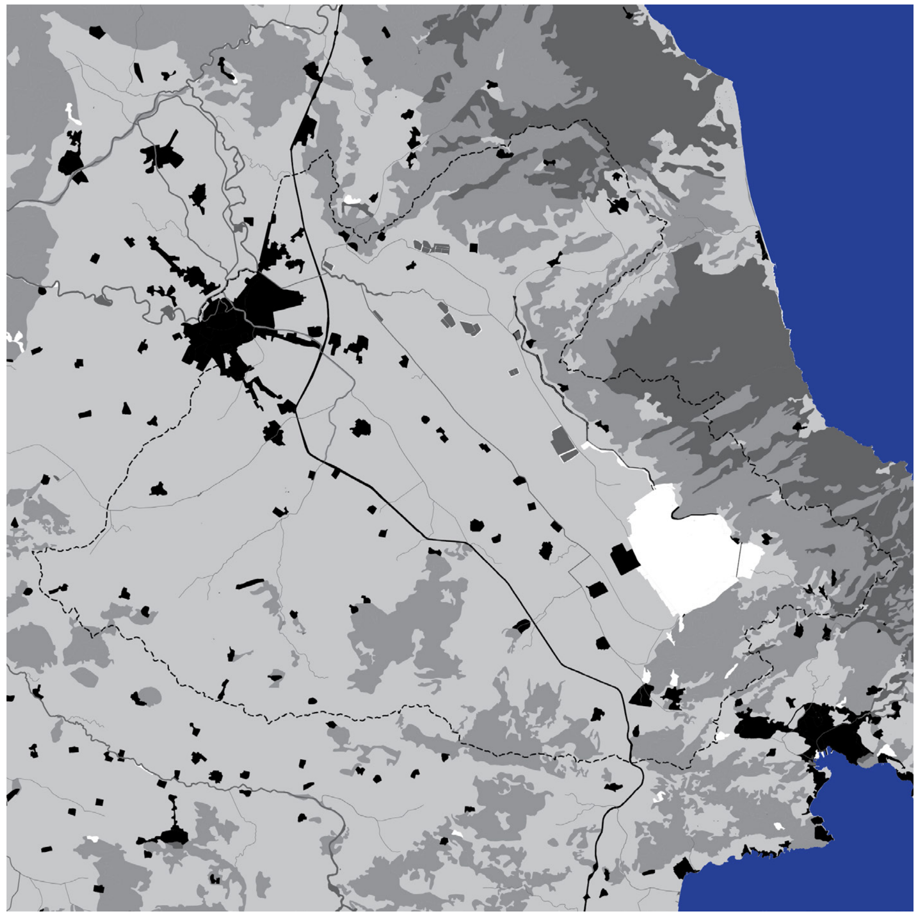


criticality

very high	artificial surfaces
high	irrigated agriculture
moderate	non-irrigated agriculture
low	pastures, shrubs, grassland
very low	forests and wetlands

water body

Figure 102. Criticality



transformability

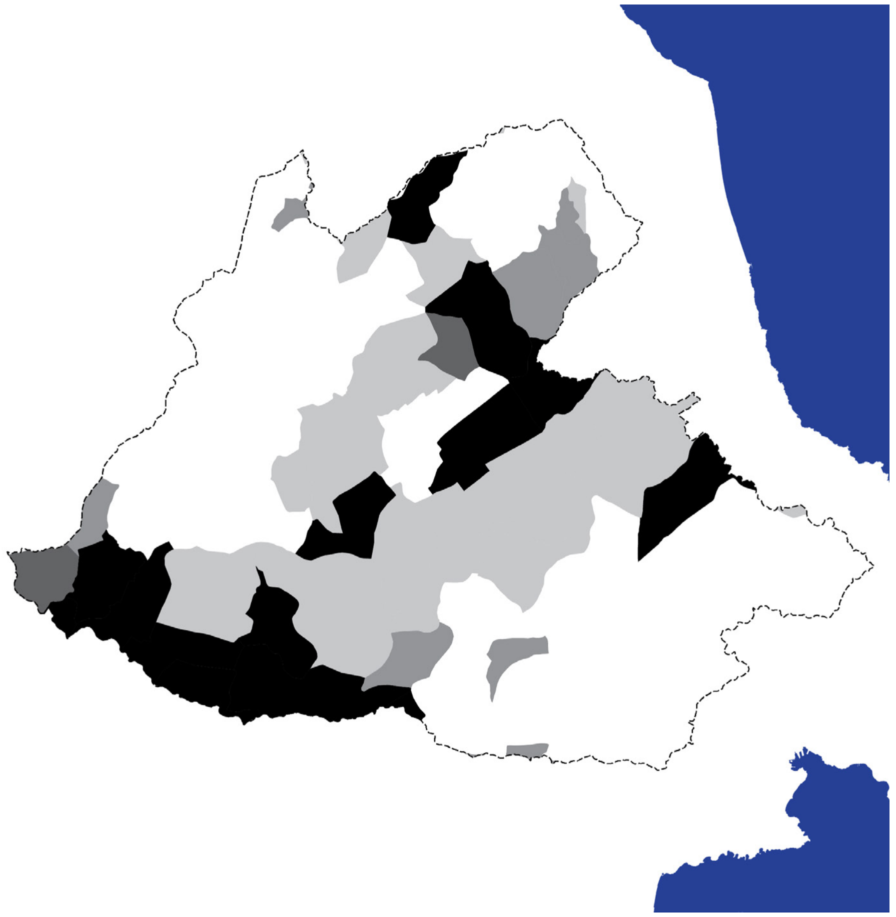
very high	state-owned lands
high	agriculture
moderate	shrubs and grasslad
low	forests, wetlands
very low	artificial surfaces

water body

0 5km N

Figure 103. Transformability

Demographics and human habitat

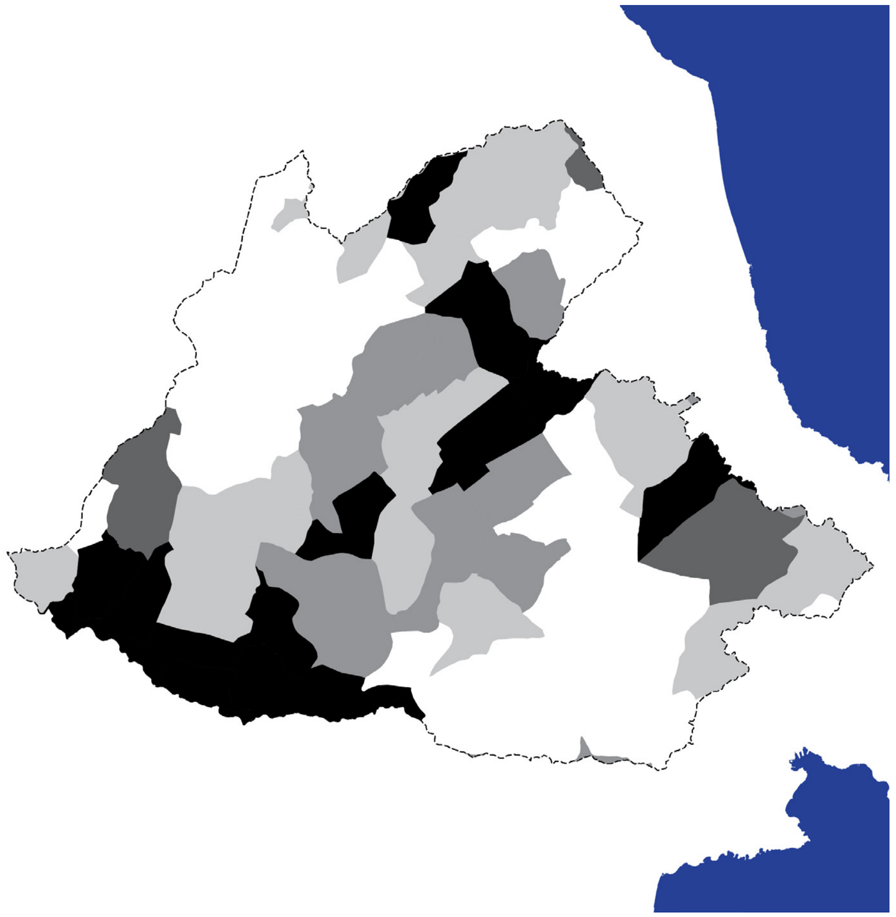


criticality

very high	above 65 + primary > 80%
high	primary > 80%
moderate	primary > 60%
low	primary > 40%
very low	none

water body

Figure 104. Criticality



transformability

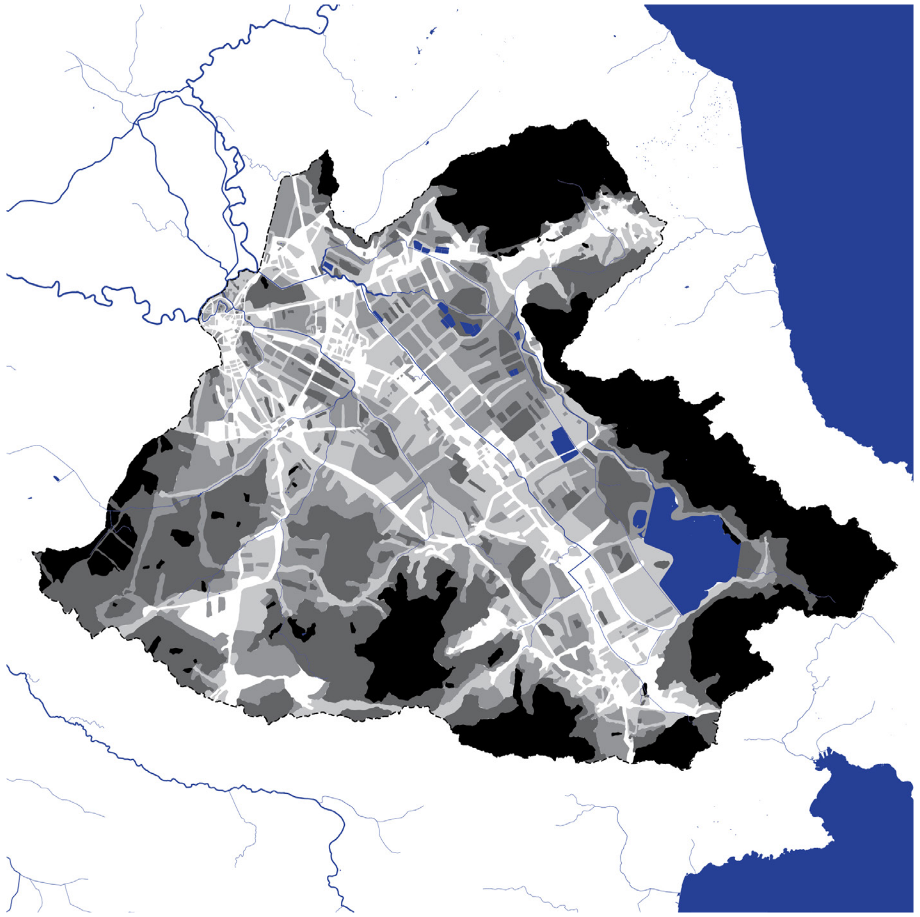
very high	none
high	above 65
moderate	elementary degree
low	above 65 + elementary
very low	+ primary > 80%

water body

0 5km N

Figure 105. Transformability

Geomorphology, infrastructures and accessibility



criticality

very high	very low accessibility
high	low accessibility
moderate	moderate accessibility
low	high accessibility
very low	very high accessibility

water body

Figure 106. Criticality

transformability

very high	none
high	plots with pv panels
moderate	other roads
low	motorway and power lines
very low	airports and railway

water body

0 5km N

Figure 107. Transformability

Fieldwork

Personal story

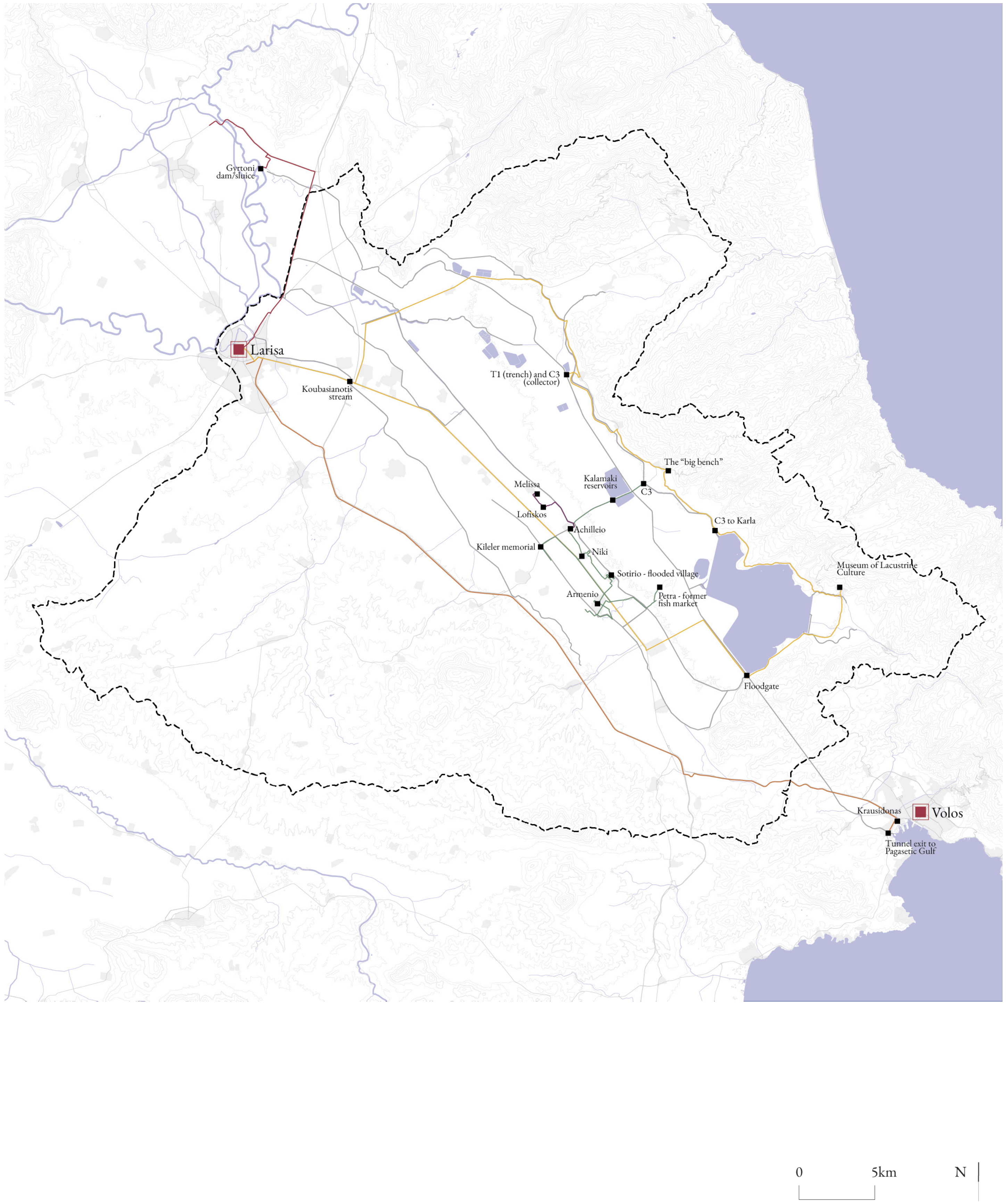


Figure 108. Routes

During my two site visits, one in December and one in February 2024, I followed different routes to make myself familiar with the Lake Karla system, and to understand how it works in the larger and smaller scales. In some of those explorations, I was accompanied by local people, who tried to transmit their knowledge to me about the functionality of the system.

Specifically, I visited the point where everything started for the eastern Thessalian plain, the Gyrtoni Dam. I was very surprised to see how difficult it was to reach this point, even by car – following unpaved roads after directions from the solitary people I encountered in the completely deserted village of Gyrtoni.

Next, I traversed along the C3 and T1, both with different characters – the C3 wide and vast with aquatic vegetation and in some places scarce of water, while the T1 was strict and defined by high embankments. I went to the point where the people of Kastri brought their own machines to create makeshift dams in the opposite direction, so the water would not overflow from T1 back towards their village. I saw the Acropolis of Kastri from afar, where a farmer I spoke with climbed when he was just a kid, and noticed how the older village of Amygdali is higher that Kato Amygdali, signifying a process of relocation of the people to the lower altitudes in order to come closed to the Lake and subsequently the plain, catapulting their transition into farmers from fishermen. In Kalamaki, I saw the "big bench", a solitary effort for a tourist attraction in the area. But the biggest revelation that day was how engineered landscape of Lake Karla appeared. There were no traces of the lacustrine civilization and environment that existed there until 60 years ago, no natural banks, no way to approach her but nearing the floodgates, the pumping stations, or walking on top of the 9m levees, which I was advised against due to the risk of landslides. However, the birds and the reeds did have the same limitations. Birds flew in abundance, reeds grew on the artificial islets. Herds of cows were grazing in the south-eastern side of the lake, where C6 and C7 are located. The floodgate is too small, too narrow, only 2m multiplied by 2.2m in diameter. I could not imagine that all this water that came all the way from the western Thessalian plain, along with all the transported sediment, travelled through this narrow hole until it found its exit in the Pagasetic Gulf. And then, one year later, the fish that died from the lack of oxygen due to the rapid evaporation of the floodwaters, also followed the same path.

The tunnel exit is also not easily accessible by foot or by car either. I struggled to get close to where the tunnel discharges the water coming from the lake to the stream Kaliakoudas,. The land was privately owned, and I was barked at by stray dogs, urging me to move away and stay on the main road. The only glimpse I could get of this protected wetland was from the national road, looking over at Xerias and in the distance at the Volos fish ladder.

Another day of revelation was in February, when I walked with my father along the T2, from Melissa to Lofiskos. These villages were not derelict like Gyrtoni, but charming and alive in their own way, a few children coming back from school, farmers on their tractors ploughing fields that were not destroyed by the flood, a dog searching for some company in the small market of Achilleio where the lady offered to make me and my father sandwiches to satiate our hunger. And the landscape of the plain was beautifully serene and uniform, framed by the mass of Mavrovouni, and only interrupted from tall cypress trees at a solitary graveyard, or by fields with PV panels owned by people that have left the plain for the cities and want to utilize this piece of land in some way.

Figure 109. Agricultural landscape, Melissa, February 2025

On my last day there I traveled through the fog, to the settlements of Niki, Armenio and Sotirio, in which only 12 people remain, the others having abandoned the place for a better future in Larissa or Volos when the cost of seeing their properties submerged in cracking mud was too much. The trace of water on the walls was still visible, even more than a meter high. Petra – a former fish ladder – is now only a hill and the drainage ditches and channels still remain unkempt and unmaintained, even almost 1.5 years after the flood. Near Armenio, a church stood unharmed during the disaster, "*something miraculous*" as the farmer with me said. He then took me to the memorial of Kileler, where farmers fought in union and died in 1910, demanding for the redistribution and expropriation of the land they considered theirs. Finally, my last glimpse was on top of an embankment, looking over at the two artificial reservoirs of Kalamaki, the smaller one deeper and filled with water while the northern and bigger one surrendered under aquatic vegetation. Rusted pipes and pumps drew water from T1, to divert it in the fields of the farmers of Niki.

Figure 110. Agricultural landscape, Lofiskos, February 2025

The profiles

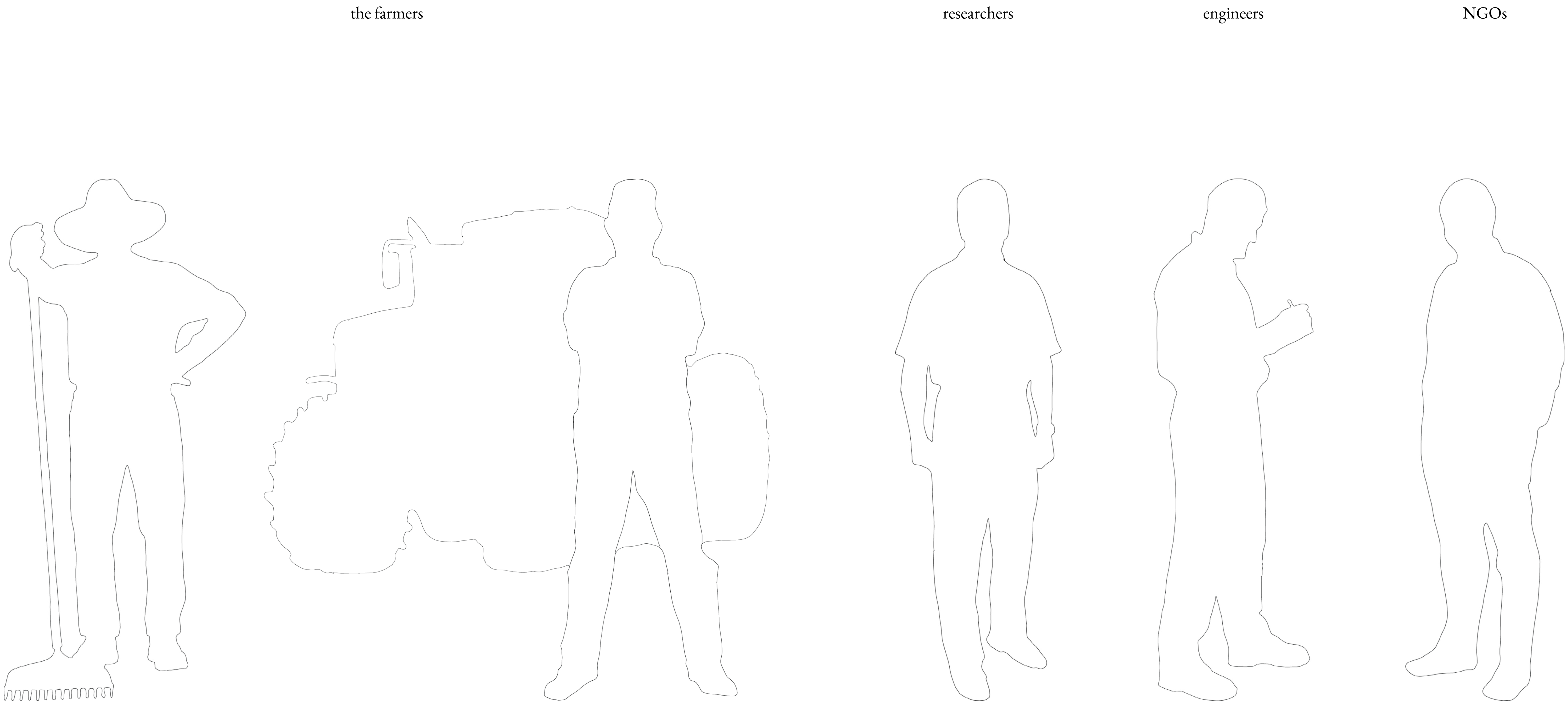
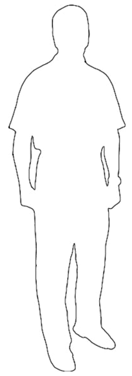
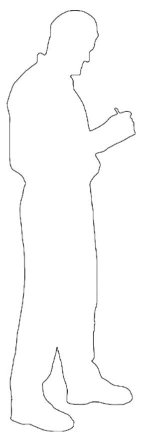


Figure 111. Profiles

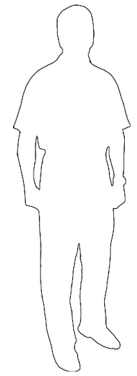


Water found its way in the old streams, meanders that were transformed into straight lines for irrigation purposes. However, the eastern Thessalian plain does not have an official irrigation system. Water is pumped from the drainage channels, not from the groundwater.

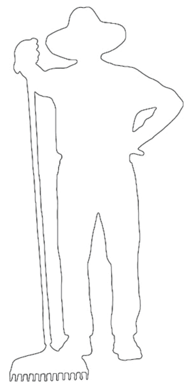


When Lake Karla was drained, the uncovered soil was the bottom of the lake. It was like planting seeds inside fertilizer, it was not suitable for cultivating crops. The land was left barren for years, ploughed again and again until the soil was productive for agriculture.

Figure 112. Irrigation channel, December 2024

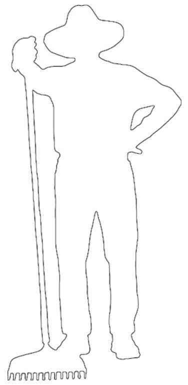


Water came also from the streams from the mountains, passed through the villages bringing sediments downstream and causing damages to the mountain settlements.

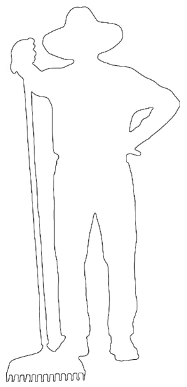


The water cannot be stopped at the plain, it has to be stopped at the mountains, with smaller dams.

Figure 113. Mountain stream, Kalamaki, December 2024

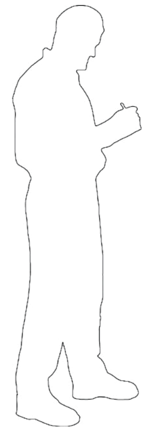


"The state did not help. The first days, it was absent. Whatever was trying to be done, it was done by the people themselves, to save what could be saved. To break down some dams, create rudimentary dams with hoes. You can never stop the water, we have known that for years. The water has memory. It remembers its route, even if it has been thousands of years. And it remembered it again in Daniel. This was the flow of water to Karla. This was the lake. This is where the water went. It could not have been stopped anywhere else."

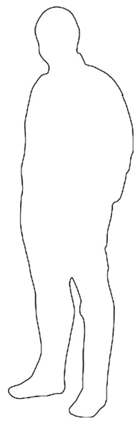


The people of Kastri brought with their own initiative earthmoving machinery and blocked the culvert in T1 that was overflowing, the pressure causing the water to go in the opposite direction towards the settlement of Kastri. The people of Niki broke a part of the T2 to let the water flow towards the plain instead of flooding their village.

Figure 114. Collector 3, Kato Amygdali, December 2024



Irrigation and drainage channels were created in order to irrigate the western Thessalian plain. This resulted in the decrease of the flow of Pineios, which was the source of Lake Karla. And so the decision to dry the Lake was made, and human exerted his power on the environment.



The common practice is to cover, trample, fill streams.

Figure 115. Levee and Trench 1, Lake Karla, December 2024

"There do not seem to be prospects. And unfortunately, most people are starting to accept it and this reduces the willingness to fight, to stay in the profession. The course is predetermined. The land will be consolidated. Farmers will be wiped out, the countryside will be deserted, and the urban centers will also be hit, because here in Larissa, it is a large urban center and it is the fourth in Greece, and many rely on agricultural income, even the commercial stores." For some people, it is even an opportunity to give up farming.

Their whole life was the fields, their families, their machinery, their cotton. This was their joy of life.

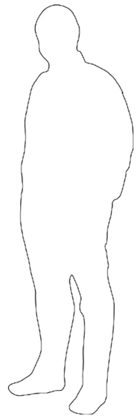
Figure 116. Agricultural landscape and Mavrovouni in the background, February 2025

The landless farmers were fishermen that very suddenly became farmers because the Lake was drained to combat malaria. Then the Lake was restored, as if there was no malaria anymore, yet they still remain landless.

If the whole area transforms back to a lake, then the people need to be properly compensated. This transition was made for several reasons, large funds were used, people built a living. How can this process be reversed?

Figure 117. Pasture, Kalamaki, February 2025

People were interested in the fish, and this is why they stayed there. The society of fishermen was a society of customs, where people had separated the Lake into different "fields"



Every 15 days one fisherman left the hut and went to the fish ladder – one of them was Petra – to sell the fish and bring back the money.

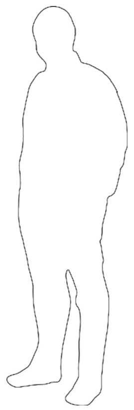
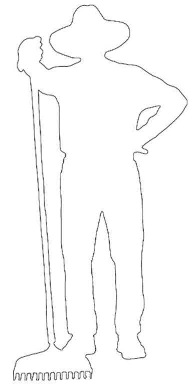
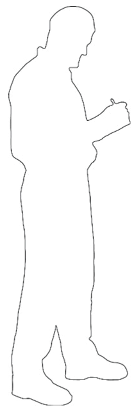


Figure 118. Petra fish ladder, February 2025



Nature showed itself that the extent of the Lake could be bigger. Even when it rains, the water reappears, trying to show that it's still there. *"The water doesn't forget. We are also Karla, are we not? Natured showed us."*



The area initially did not experience serious consequences from the flooding as the western Thessalian plain. The drainage system worked, even though the water levels were increased, and this was the reason the villages were saved. But the amount of the water was unimaginable, unthinkable, inconceivable. The situation was manageable until, at some point, it was not. The water was above their powers.

Figure 119. Kalamaki Reservoir, February 2025

The channels were not maintained for 30 years. *"At this moment, Thessaly is completely unfortified."*

"There will never be a gradual fortification. The dams, the levees that broke in the streams are not restored even 18 months later."

Figure 120. Gravel on the sides of the street for fortification, February 2025

Drainage works have been done in some settlements, like Niki, but in others, like Armenio, they have not

"The flood in Thessaly was not unexpected. It was bound to happen in an extreme precipitation event like this, not only because of the sheer volume of the volume but because of the lack of infrastructure and flood protection works for the area."

Figure 121. Debris in earthen irrigation channel, February 2025

Desires

smaller check dams
utilization of natural boreholes
large infrastructures – 3 dams (Skopia, Pyli, Mouzaki) and tunnel to the Aegean sea
no to greenhouses and land consolidation
maintenance of current infrastructure
just for something to happen – a need for guidance from people who know
a way to get back their life – stay within the profession and not have to abandon the land

regenerative agriculture/ agro-ecological transition – change in crop types
re-introduce water-loving animals
temporary floodable agricultural land
use surplus not reserve
regional motives for universities to engage in research

compensation for fishermen who became landless farmers
directions from the state in cases of emergency

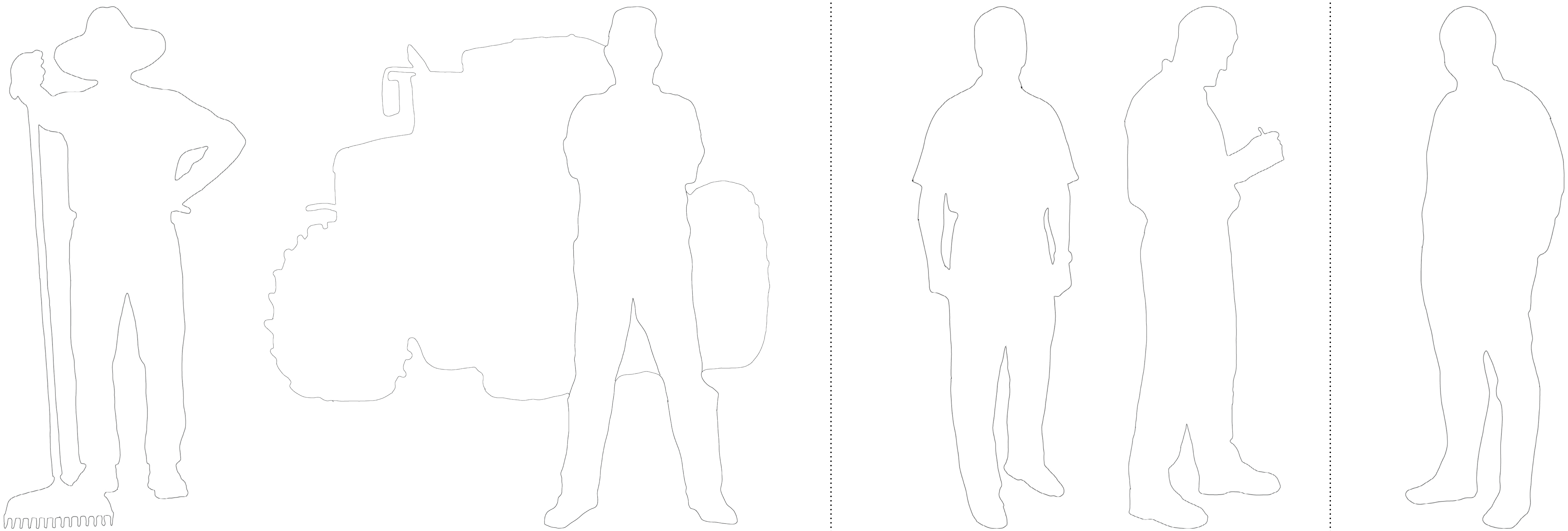


Figure 122. Desires

Current paradigm

Stakeholder analysis

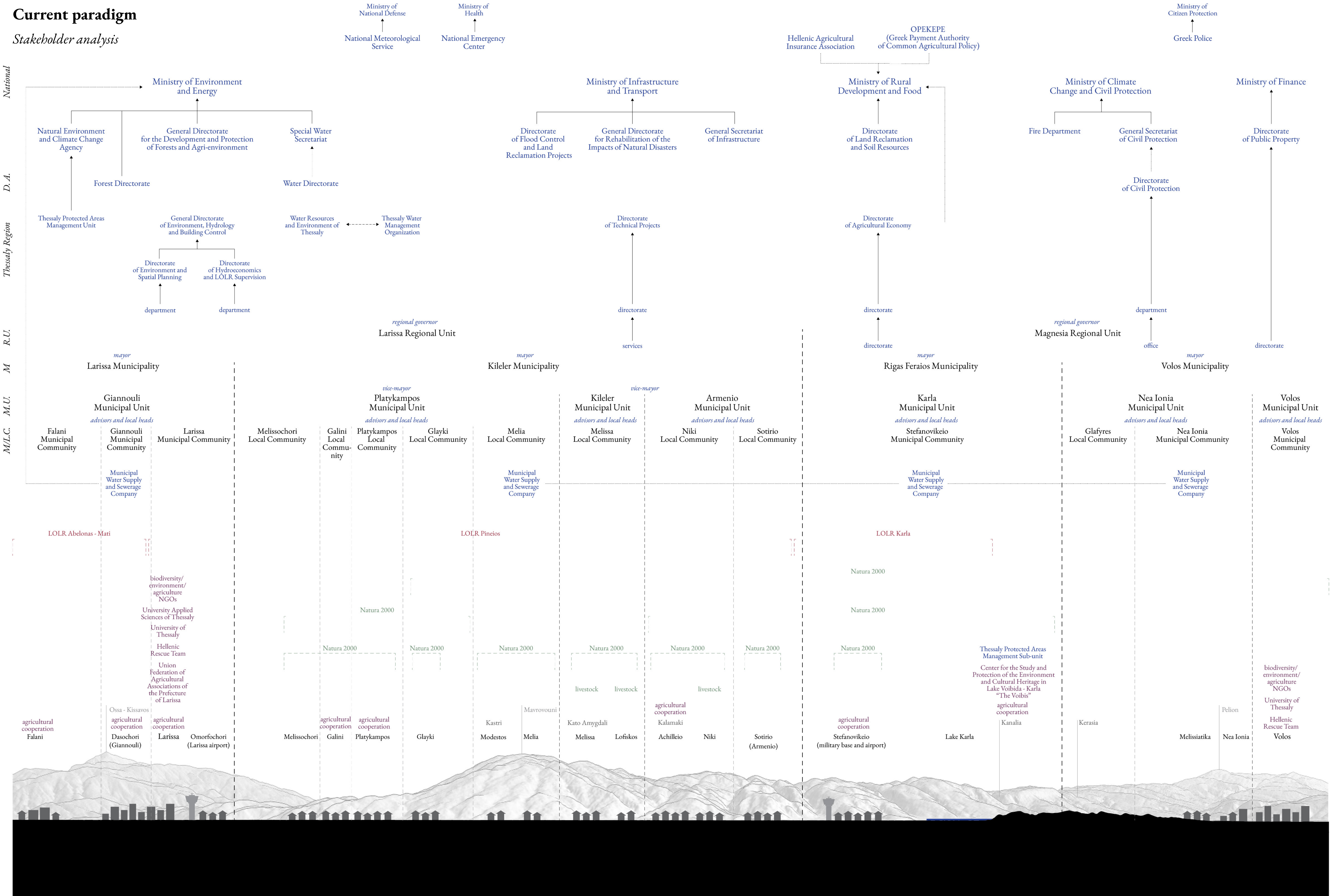
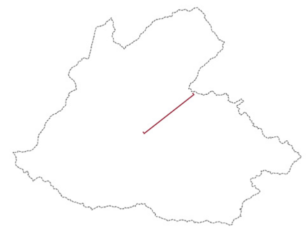
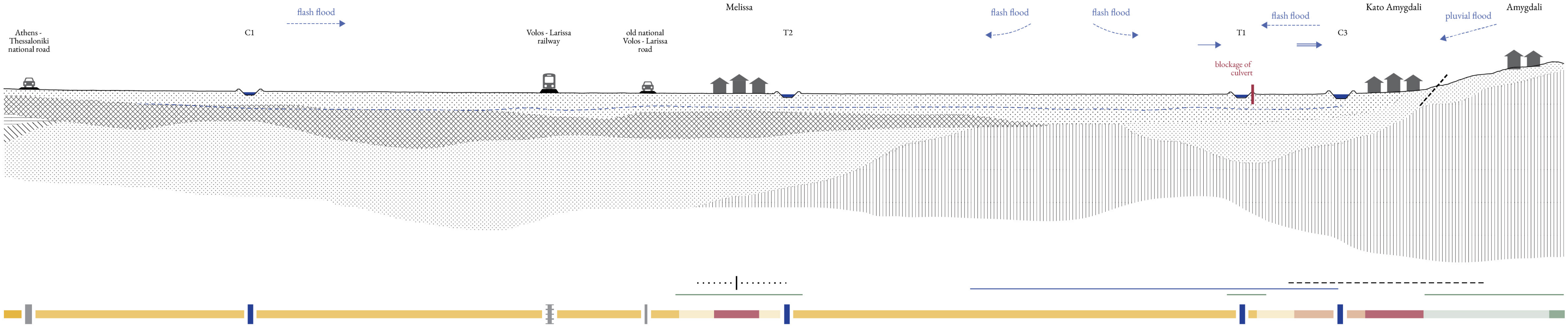


Figure 123. Stakeholder section

Local adaptation practices





geology

- quaternary alluvial deposits
- paleozoic triassic to middle jurassic mica-schists
- miocene and jurassic marls
- fluvio-terrestrial sediments
- neogene sedimentary deposits
- cretaceous limestones
- marls with travertine limestones
- jurassic schists phyllites
- flyschs
- paleozoic triassic to middle jurassic metamorphic gneiss-schists
- paleozoic gneiss-schists
- fault
- possible fault
- overthrust
- groundwater

land cover

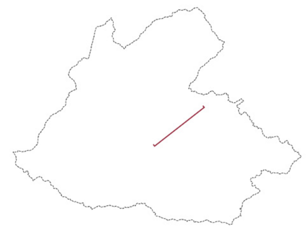
- dicontinuous urban fabric
- transport
- irrigated arable land
- non-irrigated arable land
- pastures
- permanent crops
- heterogeneous agriculture
- natural grassland
- sclerophyllous vegetation
- water

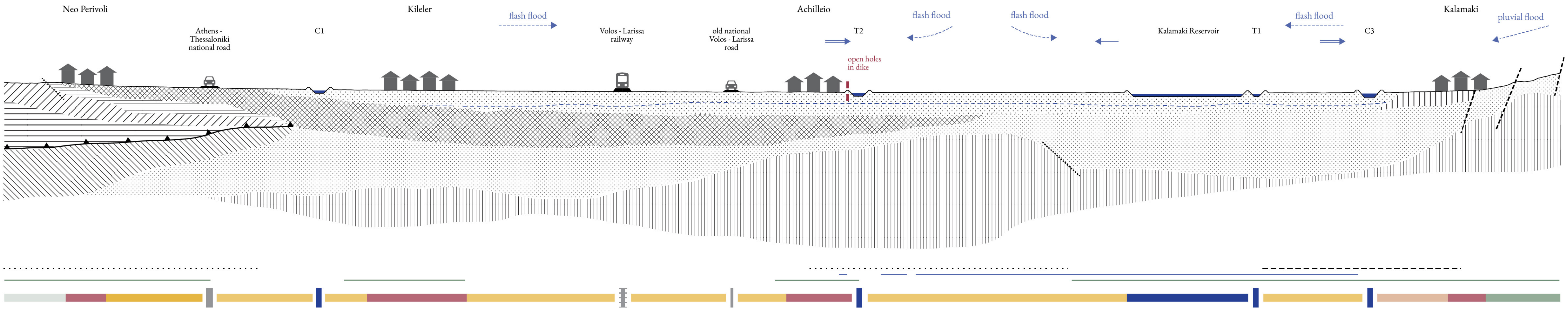
pressures - limitations

soil

- desertification
- salinization
- subsidence
- under protection status
- flooded 2023
- local adaptation urgencies
- flood water pressures

Figure 124. Section 1-1'





geology

- quaternary alluvial deposits
- paleozoic triassic to middle jurassic mica-schists
- miocene and jurassic marls
- fluvio-terrestrial sediments
- neogene sedimentary deposits
- cretaceous limestones
- marls with travertine limestones
- jurassic schists phyllites
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- paleozoic gneiss-schists
- fault
- possible fault
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- groundwater

land cover

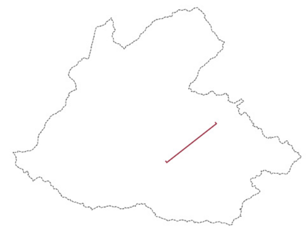
- dicontinuous urban fabric
- transport
- irrigated arable land
- non-irrigated arable land
- pastures
- permanent crops
- heterogeneous agriculture
- natural grassland
- sclerophyllous vegetation
- water

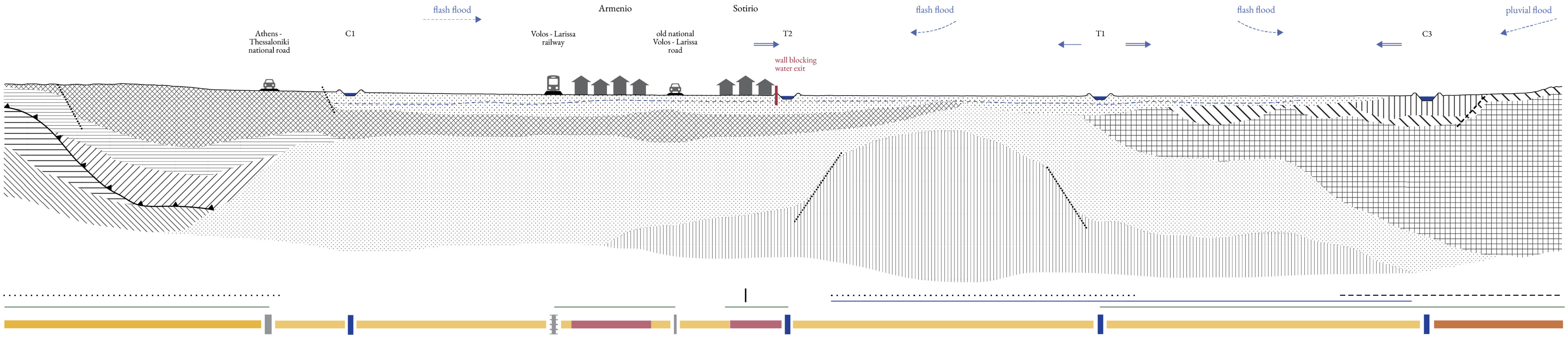
pressures - limitations

soil

- desertification
- salinization
- subsidence
- under protection status
- flooded 2023
- local adaptation urgencies
- flood water pressures

Figure 125. Section 2-2'





geology

- quaternary alluvial deposits
- paleozoic triassic to middle jurassic mica-schists
- miocene and jurassic marls
- fluvio-terrestrial sediments
- neogene sedimentary deposits
- cretaceous limestones
- marls with travertine limestones
- jurassic schists phyllites
- flyschs
- paleozoic triassic to middle jurassic metamorphic gneiss-schists
- paleozoic gneiss-schists
- fault
- possible fault
- overthrust
- groundwater

land cover

- dicontinuous urban fabric
- transport
- irrigated arable land
- non-irrigated arable land
- pastures
- permanent crops
- heterogeneous agriculture
- natural grassland
- sclerophyllous vegetation
- water

pressures - limitations

soil
- desertification
- salinization
- subsidence

- under protection status
- flooded 2023

- local adaptation urgencies
- flood water pressures

Figure 126. Section 3-3'

photo by Takis Tloupas

Figure 127. Thessalian plain close to Larissa, 1968

05| Propose

Project framing

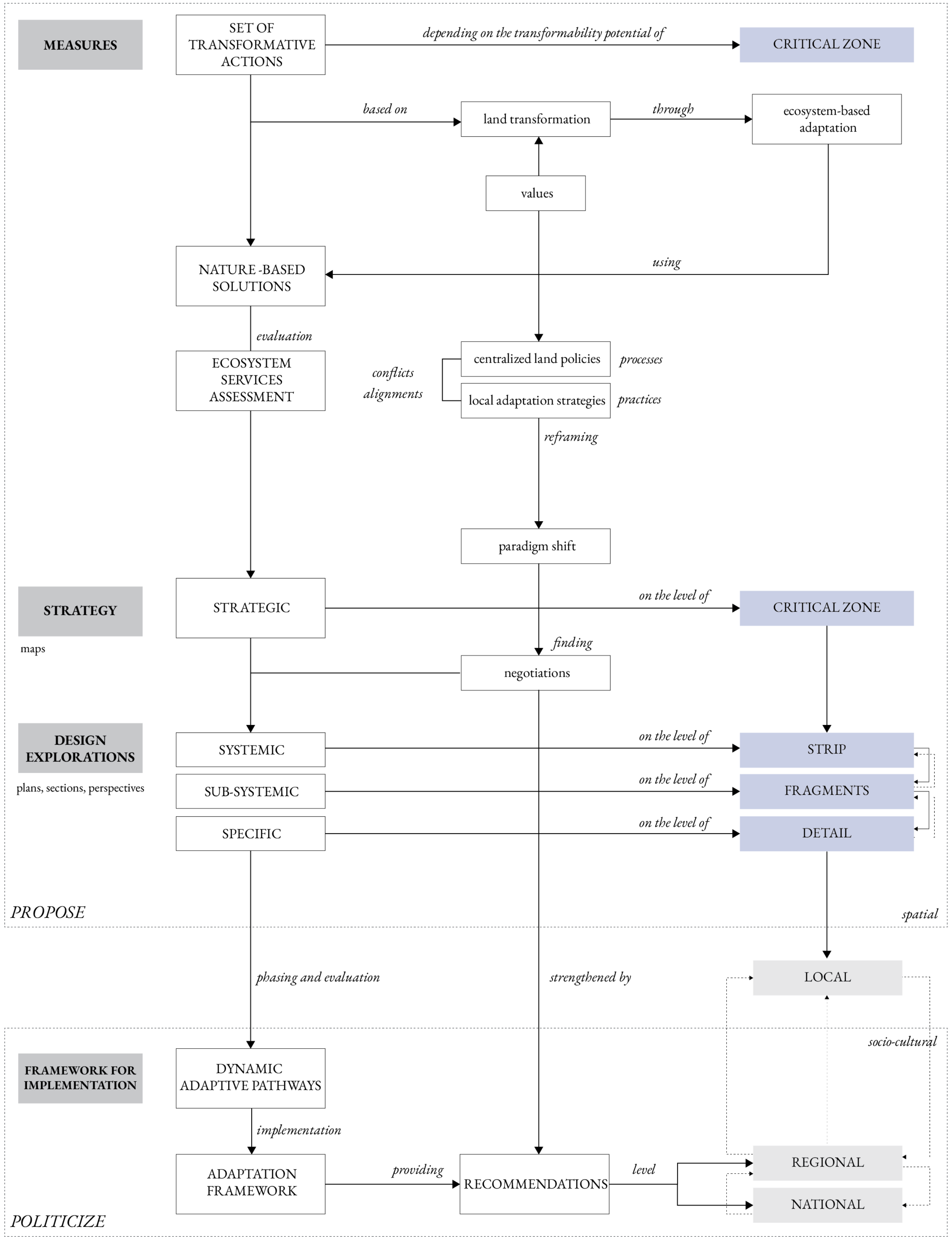
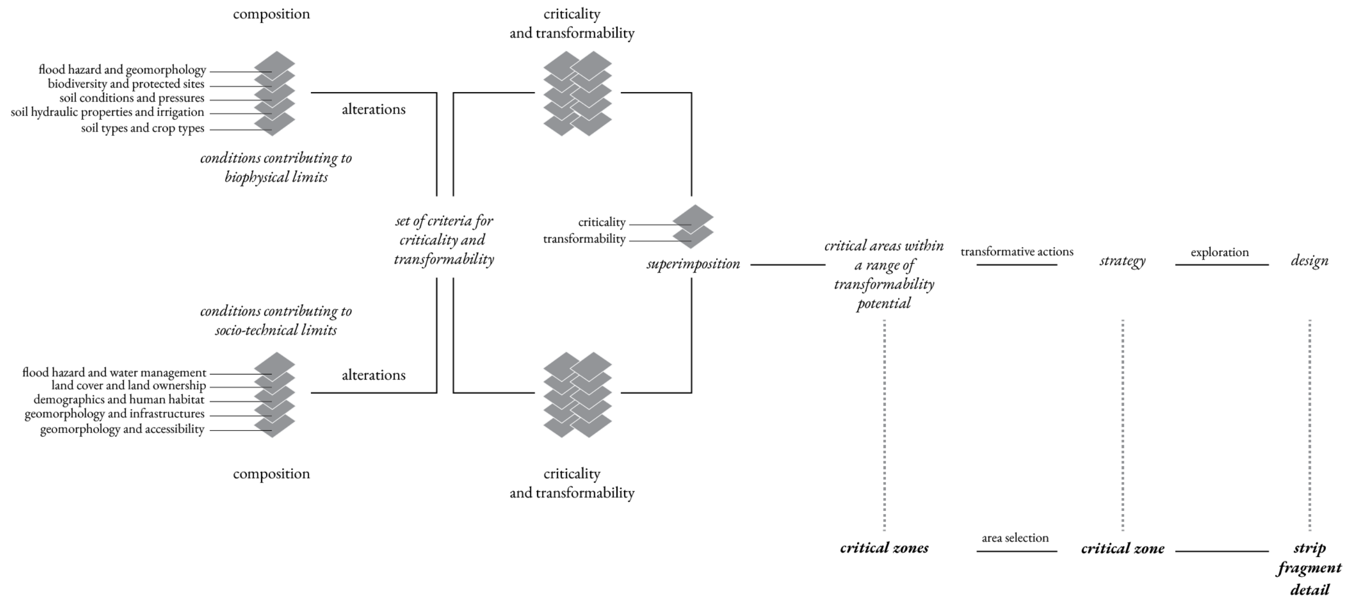


Figure 128. Project framing



After exposing the conditions of the related systems to hazard, vulnerability and exposure, and how they have been altered resulting in the current spatial and socio-economic organization, in order to evaluate the area's coping and recovery capacities to flooding, it is time to define how to make the jump towards activating adaptive capacity.

The project follows this methodology.

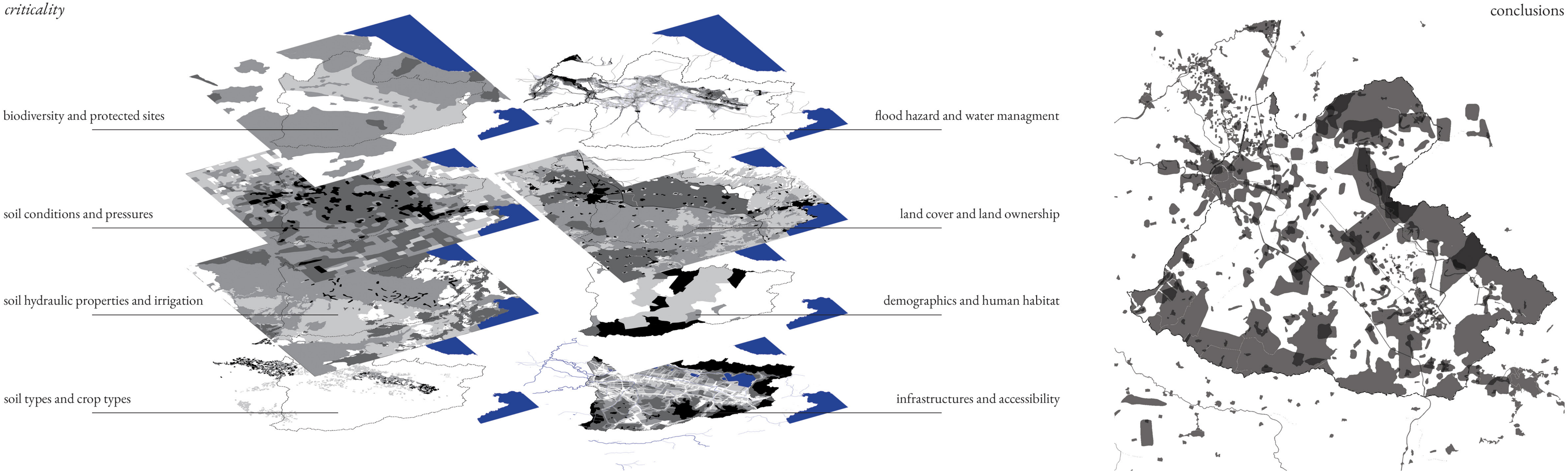
Firstly, the results of the cartographic investigation aiming to define the biophysical and socio-cultural limits are re-evaluated through a set of criteria for criticality and transformability. The outcomes of this process are then superimposed with each other, in order to determine critical areas within a range of potentiality for transformation (*critical zones*). A set of transformative actions of ecosystem-based adaptation using nature-based solutions is proposed and evaluated through an Ecosystem Services Assesment. By envisioning a desired future for the eastern Thessalian plain in a selected area for implementation (*the critical zone*), a strategy is developed. It is then further explored in a series of design explorations on strategic, systemic, sub-systemic and specific level on the scales of the "strip", "fragment" and "detail" respectively, aiming to come to possible negotiations between nature, water and agriculture, catapulting a paradigm shift. These are informed by the exposed centralized land policies (*processes*) and local adaptation strategies (*practices*), trying to reach an alignment of local and central values with the values of ecosystem-based adaptation. Finally, adaptive pathways are used as a phasing and implementation tool, and recommendations for the operation of this new system from the local to the regional and national scale are made though an adaptation framework.

This whole process can by itself be considered a research hypothesis, questioning whether this methodology – going through different scales and levels of design exploration – could be followed in order to achieve environmental co-management and activating a process of evolutionary resilience.

Figure 129. Project methodology

Defining critical zones

Conclusions



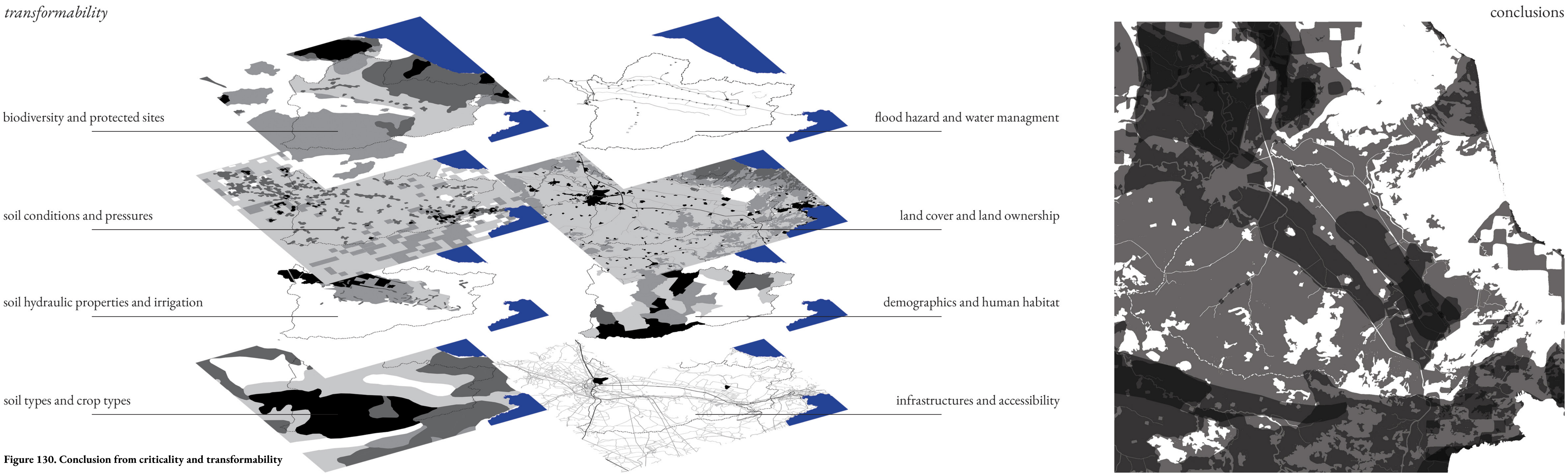


Figure 130. Conclusion from criticality and transformability

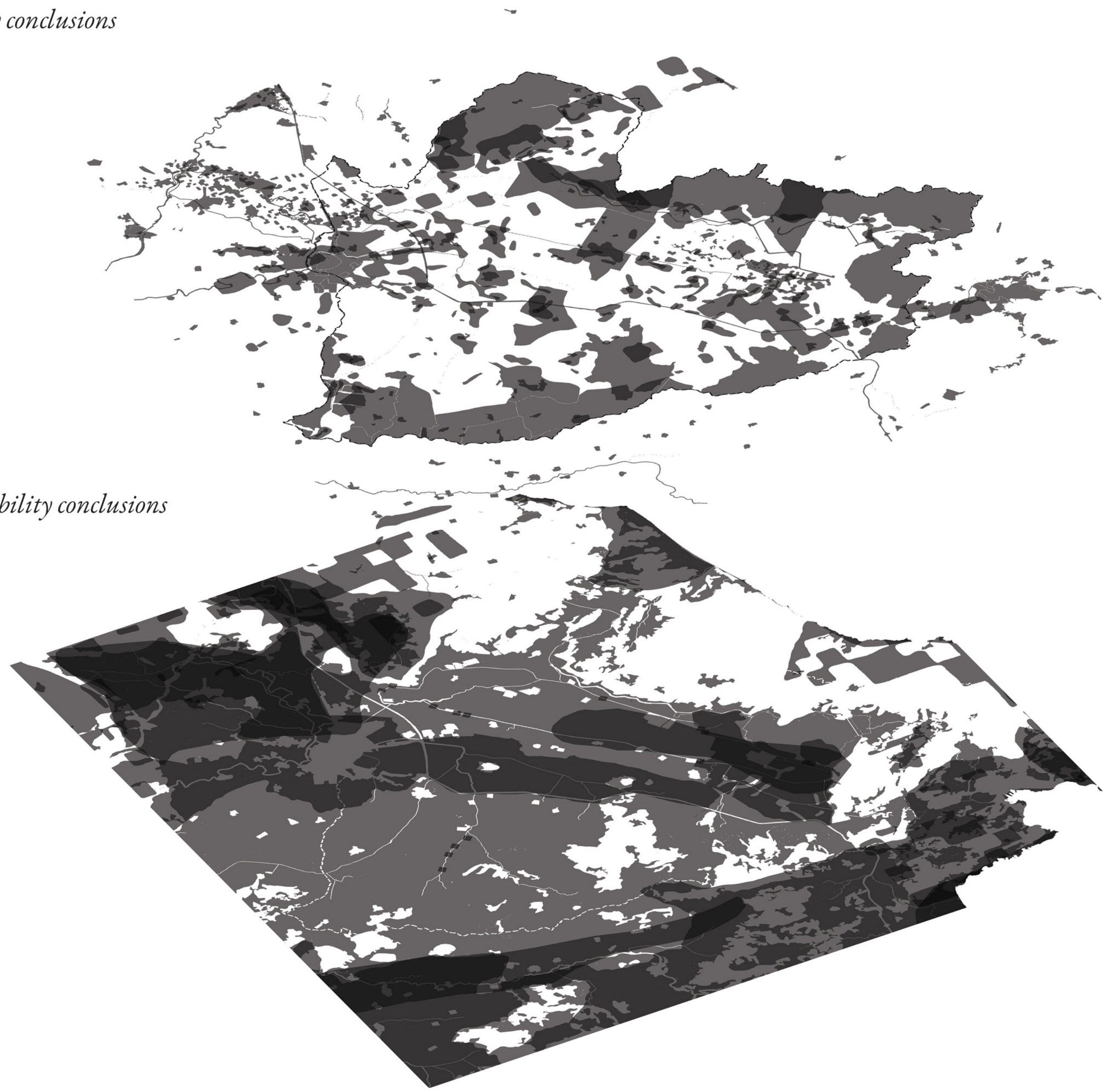


Figure 131. Superimposition

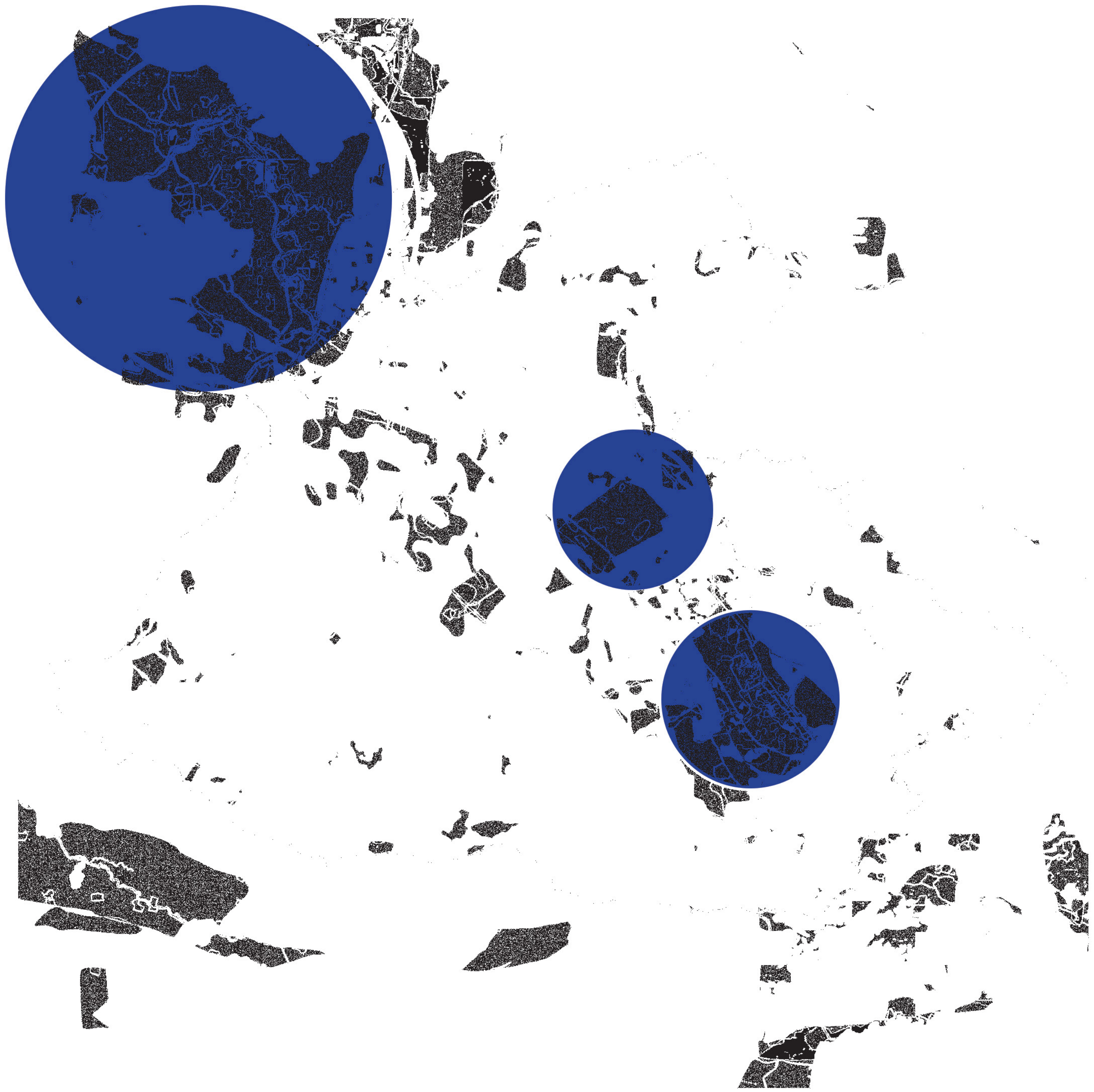
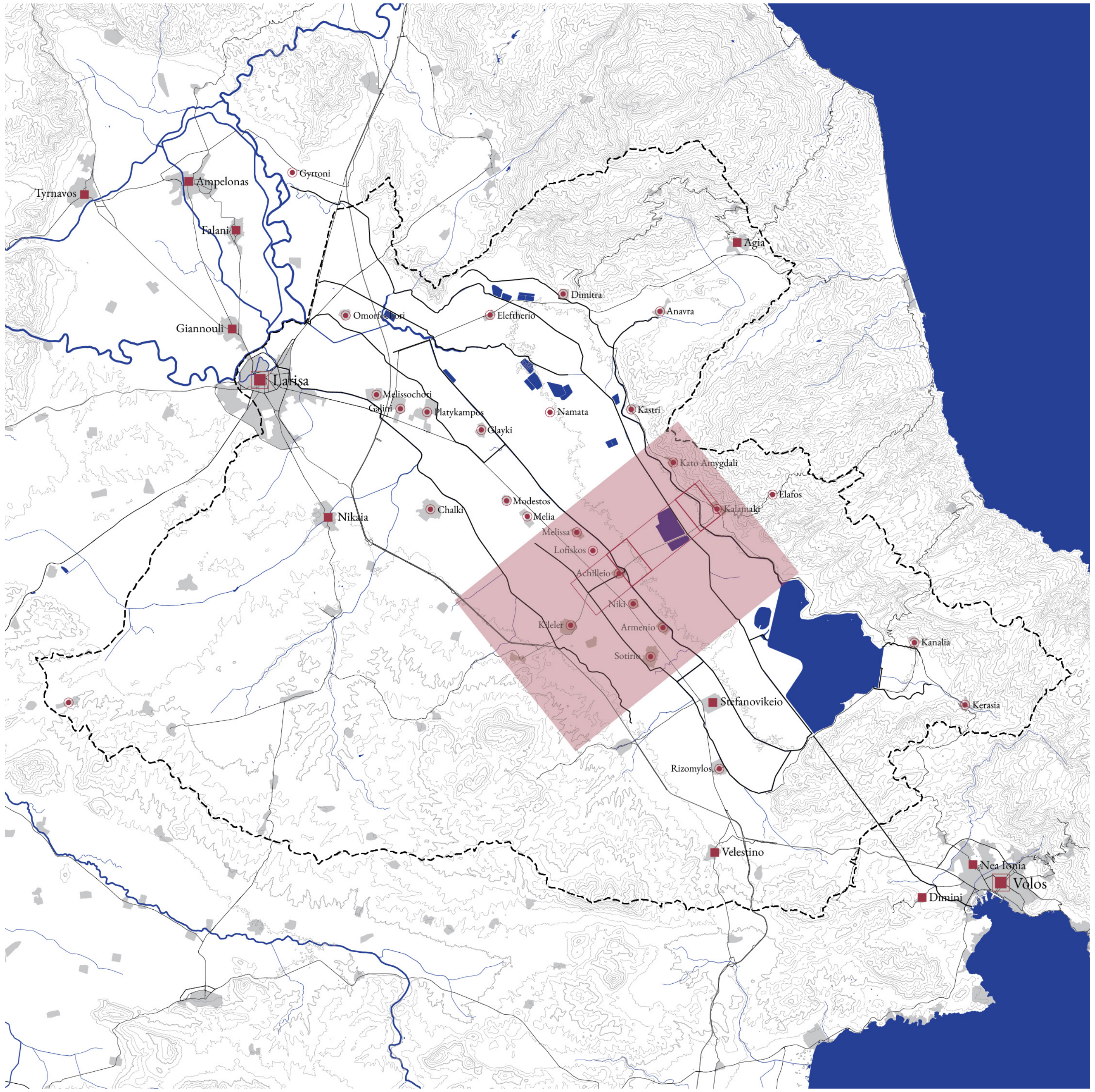
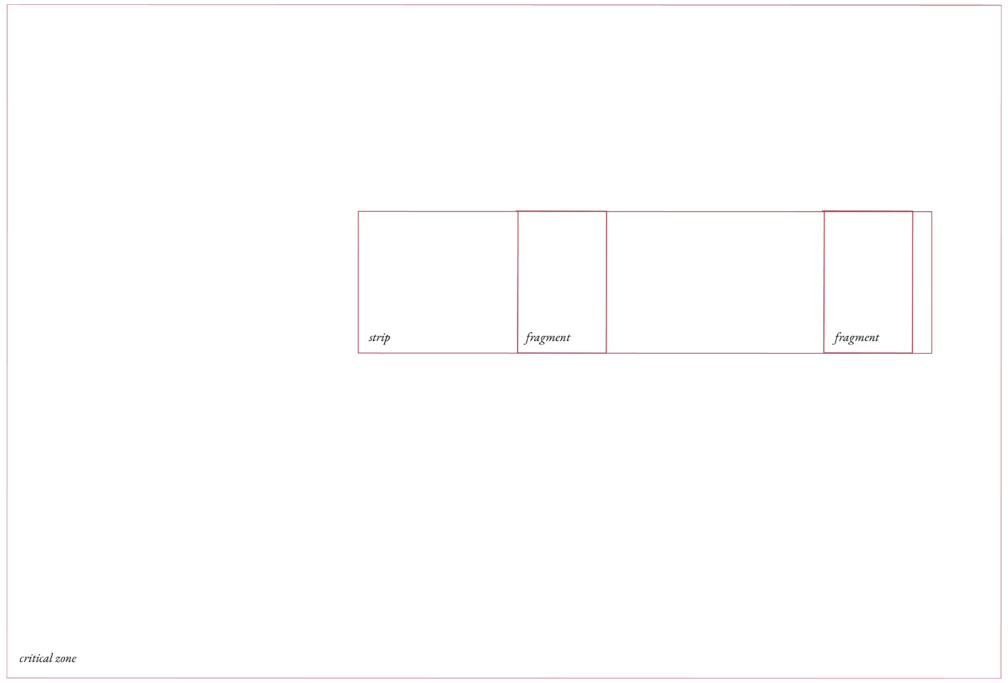


Figure 132. Critical zones





In order to define the area of intervention, the conclusion of the criticality and transformability exploration were superimposed, aiming to locate areas of high criticality and simultaneously within a range of transformability. Areas displaying these characteristics within the Lake Karla system are, firstly, the areas north of Larissa, starting from Gyrtoni Dam whose coping capacity was breached and including the severely affected settlements of Falani and Giannouli. The other two areas are located on the eastern Thessalian plain. The first one includes the settlements of Melissa, Lofiskos, Achilleio, Kato Amygdali and Kalamaki , along with the Kalamaki Reservoirs while the last one is the area west of where the current Karla Reservoir is located, including the settlements of Rizomylos and Stefanovikeio.

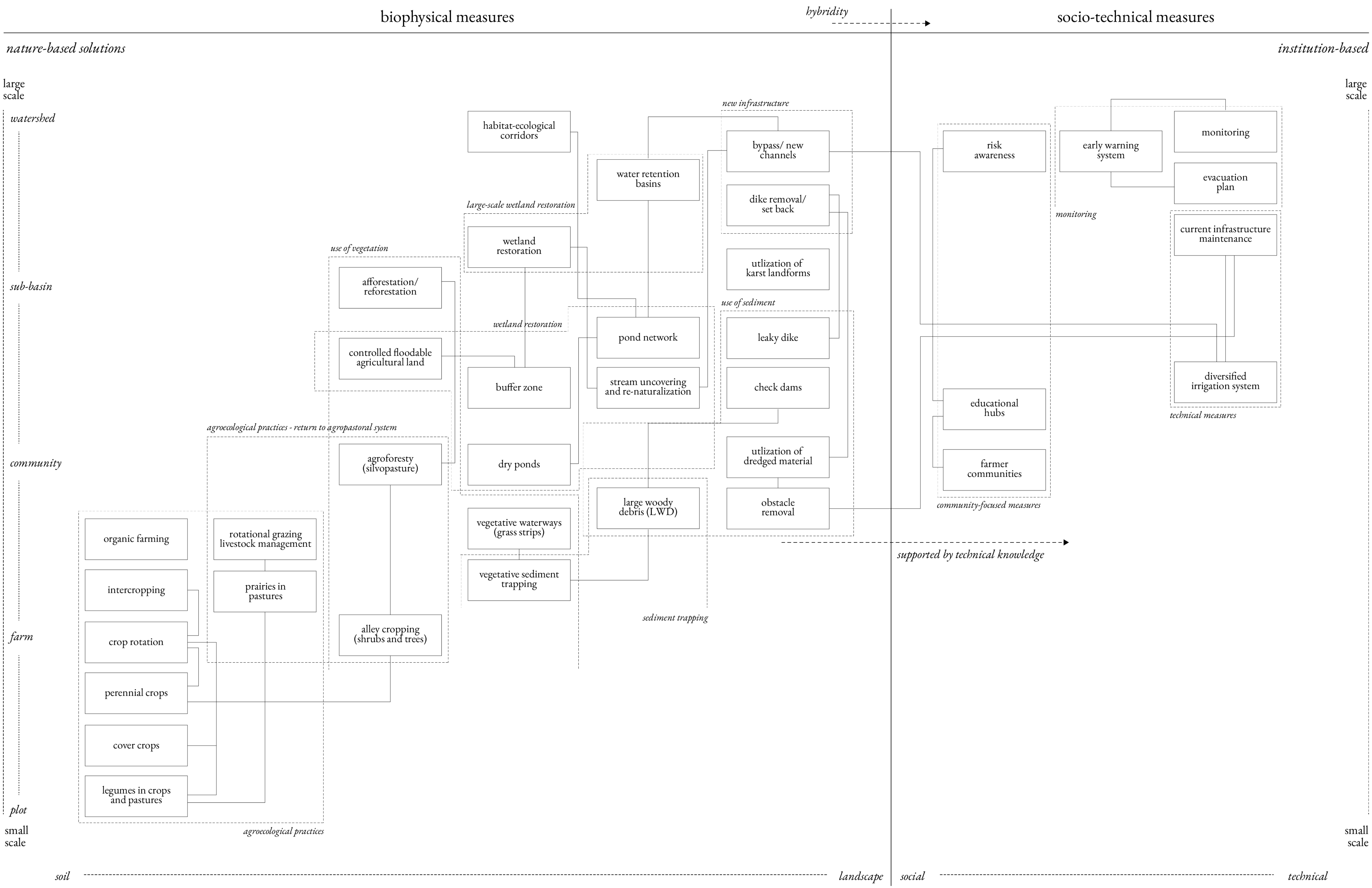
The area that was ultimately chosen was the one spanning from the settlement of Melissa to Sotirio on the vertical axis and from the national road to the foot of Mavrovouni delineated by the settlements of Amygdali and Kalamaki on the horizontal axis. The main reason for this is because this project identifies the operability of the eastern Thessalian plain as critical in the system's capacity to respond to flooding while also battling extreme water scarcity. Consequently, it recognizes a higher importance reconfiguring this specific system than the peri-urban area north of Larissa. Furthermore, the selected area is characterized by interesting relationships of vertical fragmentation from hard borders such as the national road, the railway line, the old national road as well as T2, T1 and C3. In addition, the area suffers from pressures on the soil such as erosion, subsidence, salinization and desertification, and experienced significant damage during the flooding of September 2023 – especially the settlement of Sotirio – conditions that are not as intense in the more southern area of Rizomylos and Stefanovikeio. All of this, combined with the high percentage of the population above 65 years of age with a low educational level (elementary school) that are working in the primary sector of the economy, make this specific area especially critical. Finally, this choice was influenced by the personal microstories that I was exposed to when talking to people from Kato Amygdali and Niki and during my critical walk from Melissa to Achilleio aiming to experience the Thessalian agricultural landscape. Therefore, I must recognize that this selection was not entirely objective, but following an intrinsic motivation to deal specifically with the flood affected area of the easter Thessalian plain which geared decisions of implicit design even during my research and analysis phase.

Figure 133. Area selection

Figure 134. Area explanation

Transformative actions

Matrix



The proposed transformative actions are divided into two categories – biophysical and socio-technical measures – responding to the predefined biophysical and socio-technical limits. More weight is given to the biophysical measures, which are in fact nature-based solutions, while the institutional socio-technical measures focus more on education and preparedness.

Technical measures such as grey infrastructure constitute the traditional response and they remain the preferred choice for flood risk protection (Vojinovic et al., 2021). Indeed, the desires and demands of the local people of Thessaly mostly focus on the construction of additional infrastructure such as larger and smaller dams in order to simultaneously store water that can be also used for irrigation purposes, responding to the problems of water scarcity in the area. However, the dependence on these engineered measures often creates a false sense of security (Vojinovic et al., 2021), which could lead to disastrous consequences in a time of crisis, as also clearly evident from the September 2023 flood, when the coping capacity of the existing technical flood protection measures (dams, levees, dykes, trenches, ditches, reservoir and drainage tunnel) was surpassed due to the large amount of water. Furthermore, the constant need for maintenance, which is not taking place, proves these measures to not be cost-effective and also failing to enhance the environmental sustainability of the area (Brink et al., 2016). Therefore, the answer *should not* be the construction of additional grey infrastructure, but a hybrid solution, utilizing the existing grey network in combination with ecosystem-based approaches. Nature-based solutions, besides enhancing the area's capacity to flooding with strengthening robustness and flexibility, also provide ecosystem functions and services. Examples of those services could be ecosystem restoration and soil formation, which contribute to protecting biodiversity and ameliorating soil health with benefits to agricultural production.

Figure 135. Transformative actions matrix

Consequently, this matrix of biophysical and socio-technical measures was created. Different measures are implemented on different scales, from a smaller one such as the scale of the plot, the farm and the community to a larger one such as the sub-basin and the regional watershed. The framework of Keestra et al. (2018), which offers a classification of nature-based solutions to soil and landscape solutions was followed. Soil solutions focus more on soil health, enhancing infiltration capacity and carbon sequestration, reducing runoff velocity and erosion, while improving soil structure, therefore contributing to the productive capacity of the soil (Keesstra et al., 2018). These consist mostly of the implementation of agro-ecological practices on the local scale, while landscape solutions tend to be integrated on a larger scale. Landscape solutions – or landscape transformations – on the other hand target the structural connectivity of a system, disconnecting and managing the cascade of processes related to it, while strengthening other types of connectivity such as hydrologic connectivity. Related benefits to these solutions are flood risk mitigation, erosion control groundwater recharge and enhancement of biodiversity (Keesstra et al., 2018). It is important to note that the distinction between soil and landscape solutions is not entirely defined. The combination of multiple nature-based solutions is far more effective than their singular implementation (Vojinovic et al., 2021). In addition to their main benefits, a strong point for nature-based solutions is that they provide secondary benefits such as aesthetic qualities and recreational opportunities. These are called co-benefits.

As for the socio-technical measures, they are again classified from the more social, which are geared towards education and opinion exchange, fostering active stakeholder engagement and participation, to the more technical, which are focused on monitoring, maintenance of current infrastructure and safety during the time of crisis, contributing to the preparedness to cope with risk. The aim of these measures is to enhance the learning capacity of the community, activating a process of evolutionary resilience.

Actions

Example sheet

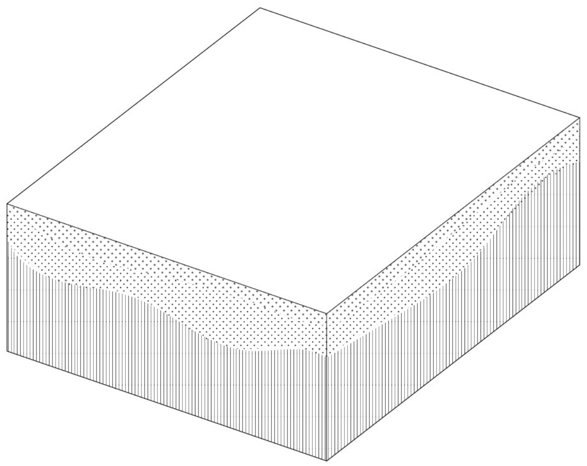
nature-based solution (NBS)

type of landscape

flood-affected arable land
non flood-affected arable land
uphill arable land
grassland
natural

contribution to capacity

coping
recovery
adaptive



pressures/ limitations

soil related
water related
level of flood risk

phase of implementation

short-term
mid-term
long-term

scale

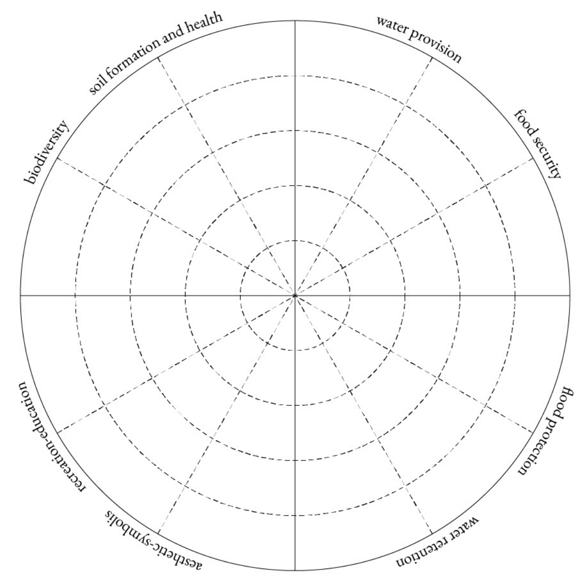
plot | farm | community | sub-basin | watershed

NBS evaluation

benefits

flood risk mitigation
soil health
groundwater recharge
biodiversity conservation

ecosystem services assessment



co-benefits

agricultural diversification
recreation | aesthetics
alternative tourism
local cooperation

cost
effort
maintenance
impact

Figure 136. Example tranformative action sheet

Current Ecosystem Services Assessment

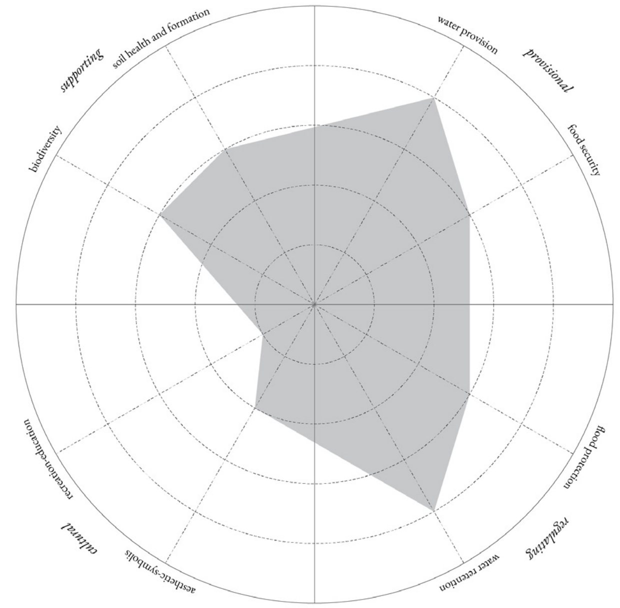
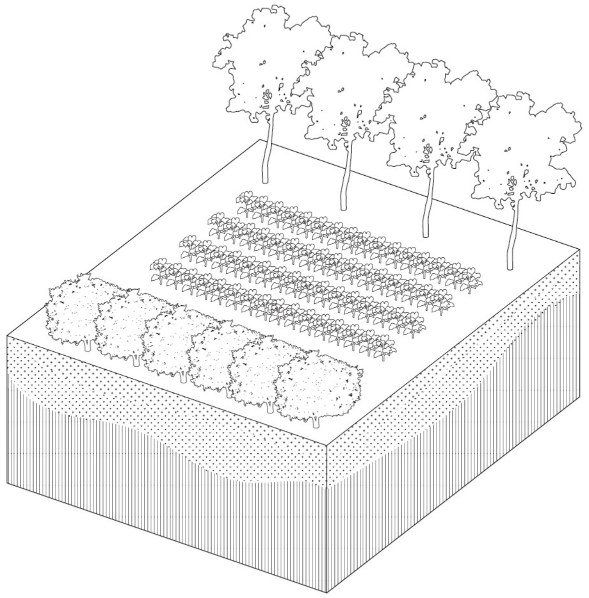


Figure 137. Current Ecosystem Services

Karla Reservoir itself was designed as a large-scale nature-based solution, a multi-purpose water resource consisting a vital aquatic ecosystem (Panagopoulos & Dimitriou, 2020). The benefits of the restoration of Lake Karla can be associated and expressed by Ecosystem Services.

Regarding provisioning services, the reservoir secures the water supply needs for drinking water for the city of Volos, as well as for irrigation, ensuring water availability even in dry years (Panagopoulos & Dimitriou, 2020). Higher water quantities directly correspond to higher agricultural productivity, increased crop yields and, therefore, a higher annual income for the farmers, highlighting the economic benefits of the restoration project. A related additional co-benefit is the sense of security associated with the absence of uncertainty regarding the available water quantity and quality. Subsequently, the increased agricultural production also contributes to ensuring local, regional and national food security, and the possibilities for new employment positions in agriculture could motivate people to return to the countryside, thus reducing unemployment and creating feelings of optimism (Panagopoulos & Dimitriou, 2020). Regulating services include benefits related to flood protection and water retention during heavy precipitation. The drainage channels trap flood waters and divert them to Karla Reservoir, shielding the adjacent floodplain areas from inundation. This system functioned as planned even during the flood of 2023, where the coping capacity was breached in another location and caused a cascade of consequences. Supporting services – often merged with regulating services – concern improved soil health as well as biodiversity preservation. Soil formation contributes to the fertility of the soil and its resistance to salinization and seawater intrusion in the sub-soil. The lake creates shelter for multiple bird and fish species and is used as a reproductive ground for habitats. Finally, another ecological benefit – also related to the increased water quantities is groundwater recharge (Panagopoulos & Dimitriou, 2020). Cultural services include aesthetic and symbolic values, but also recreational benefits associated with tourism activities.

alley cropping



type of landscape

flood-affected arable land
non flood-affected arable land
uphill arable land
grassland
natural

contribution to capacity

coping
recovery
adaptive

pressures/ limitations

erosion | sedimentation
water scarcity | flooding
medium | high flood risk

phase of implementation

short-term
mid-term
long-term

scale

plot | farm | community | sub-basin | watershed

NBS evaluation

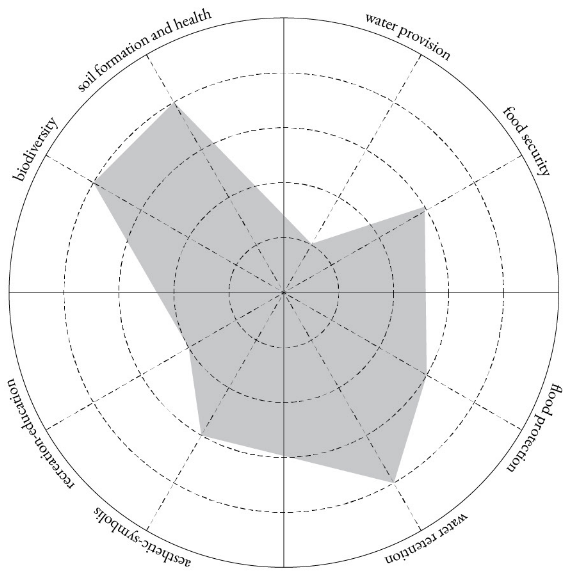
benefits

flood risk mitigation
soil health
groundwater recharge
biodiversity conservation

co-benefits

agricultural diversification
recreation | aesthetics
alternative tourism
local cooperation

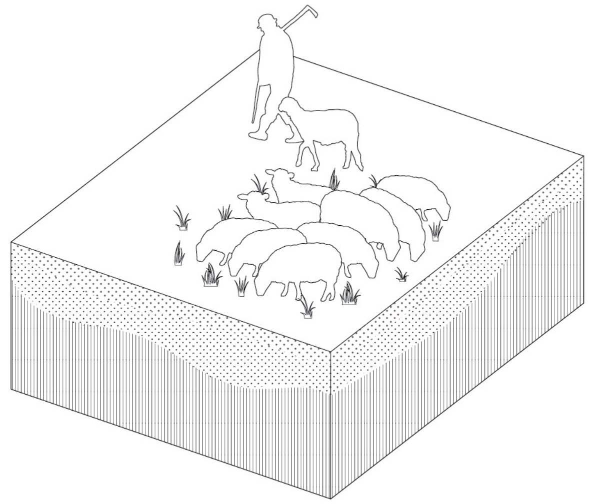
ecosystem services assessment



cost	●●○○○
effort	●●●○○
maintenance	●○○○○
impact	●●●○○

Figure 138. Alley cropping

rotational grazing livestock management



type of landscape

flood-affected arable land
non flood-affected arable land
uphill arable land
grassland
natural

contribution to capacity

coping
recovery
adaptive

pressures/ limitations

erosion | land degradation | desertification
water related
low flood risk

phase of implementation

short-term
mid-term
long-term

scale

plot | farm | community | sub-basin | watershed

NBS evaluation

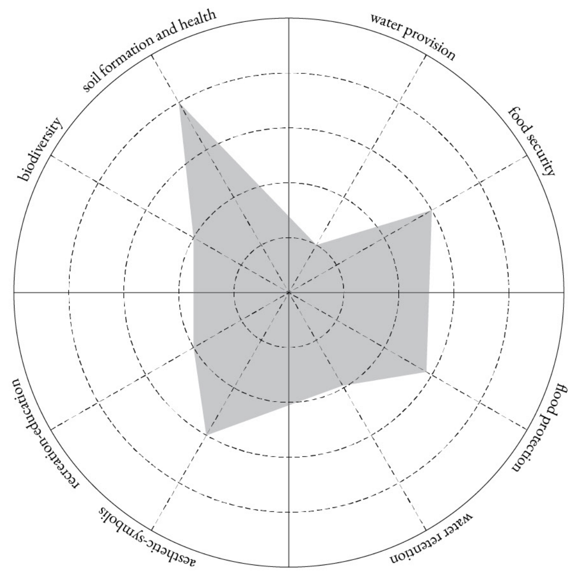
benefits

flood risk mitigation
soil health
groundwater recharge
biodiversity conservation

co-benefits

agricultural diversification
recreation | aesthetics
alternative tourism
local cooperation

ecosystem services assessment



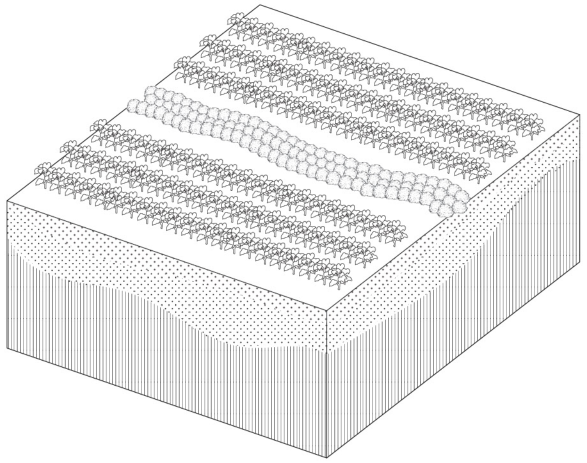
cost	●●○○○
effort	●●●○○
maintenance	●●●●○
impact	●●●○○

Figure 139. Rotational grazing livestock management

vegetated waterways

type of landscape

flood-affected arable land
non flood-affected arable land
uphill arable land
grassland
natural



contribution to capacity

coping
recovery
adaptive

pressures/ limitations

erosion | pollution | sedimentation
water scarcity | flooding
medium | high flood risk

phase of implementation

short-term
mid-term
long-term

scale

plot | farm | community | sub-basin | watershed

NBS evaluation

benefits

flood risk mitigation
soil health
groundwater recharge
biodiversity conservation

co-benefits

agricultural diversification
recreation | aesthetics
alternative tourism
local cooperation

cost ●●●○○
effort ●●●○○
maintenance ●●○○○
impact ●●●○○

ecosystem services assessment

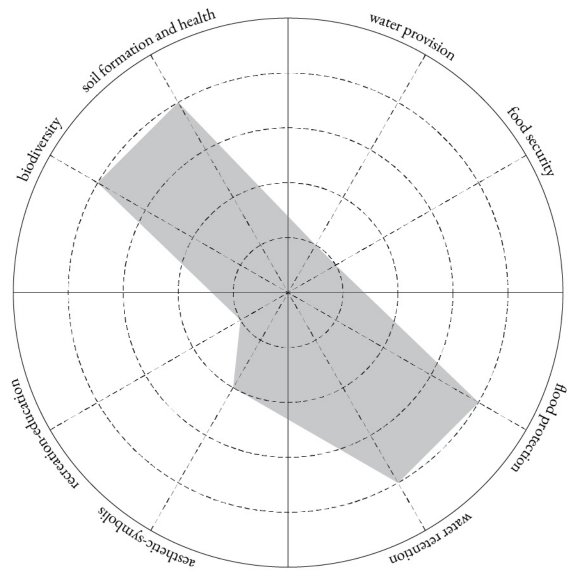
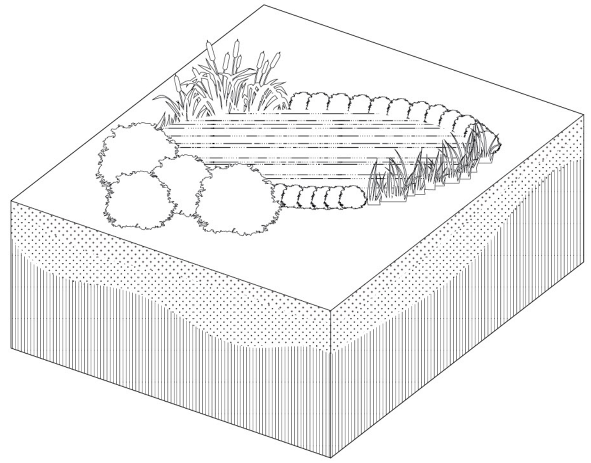


Figure 140. Vegetated waterways

dry ponds

type of landscape

flood-affected arable land
non flood-affected arable land
uphill arable land
grassland
natural



contribution to capacity

coping
recovery
adaptive

pressures/ limitations

erosion | land degradation
water scarcity | flooding
medium | high flood risk

phase of implementation

short-term
mid-term
long-term

scale

plot | farm | community | sub-basin | watershed

NBS evaluation

benefits

flood risk mitigation
soil health
groundwater recharge
biodiversity conservation

co-benefits

agricultural diversification
recreation | aesthetics
alternative tourism
local cooperation

cost ●●●○○
effort ●●●○○
maintenance ●●○○○
impact ●●●●○

ecosystem services assessment

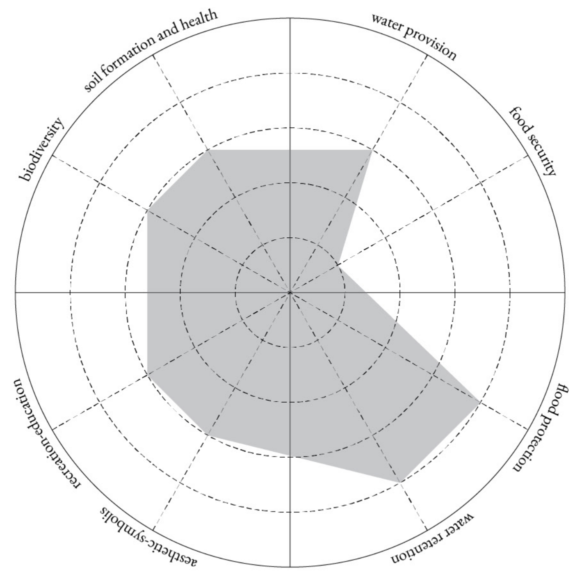
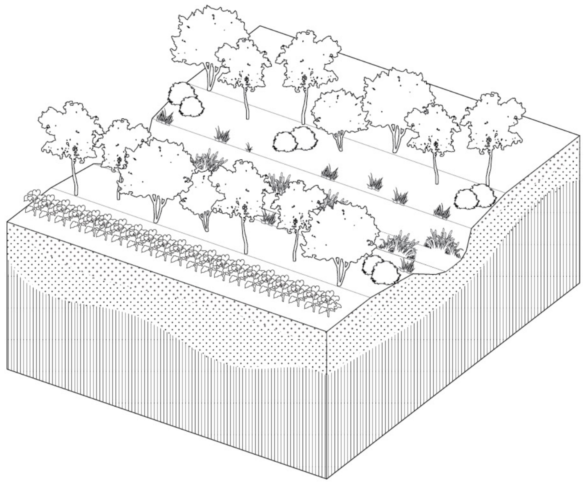


Figure 141. Dry pond

buffer zone

type of landscape

flood-affected arable land
non flood-affected arable land
uphill arable land
grassland
natural



contribution to capacity

coping
recovery
adaptive

pressures/ limitations

erosion | land degradation | sedimentation
water scarcity | flooding
high flood risk

phase of implementation

short-term
mid-term
long-term

scale

plot | farm | community | sub-basin | watershed

NBS evaluation

benefits

flood risk mitigation
soil health
groundwater recharge
biodiversity conservation

co-benefits

agricultural diversification
recreation | aesthetics
alternative tourism
local cooperation

cost	●●●●○
effort	●●●●●
maintenance	●●○○○
impact	●●●●○

ecosystem services assessment

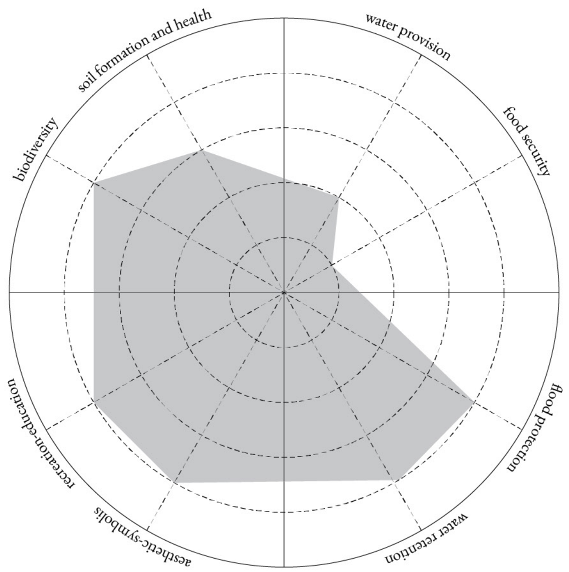
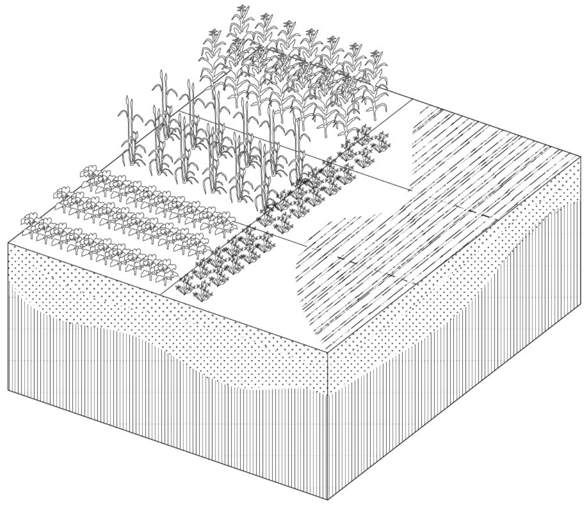


Figure 142. Buffer zone

controlled floodable agricultural land

type of landscape

flood-affected arable land
non flood-affected arable land
uphill arable land
grassland
natural



contribution to capacity

coping
recovery
adaptive

pressures/ limitations

erosion | salinization | desertification
flooding
high flood risk

phase of implementation

short-term
mid-term
long-term

scale

plot | farm | community | sub-basin | watershed

NBS evaluation

benefits

flood risk mitigation
soil health
groundwater recharge
biodiversity conservation

co-benefits

agricultural diversification
recreation | aesthetics
alternative tourism
local cooperation

cost	●●●○○
effort	●●○○○
maintenance	●●○○○
impact	●●●●●

ecosystem services assessment

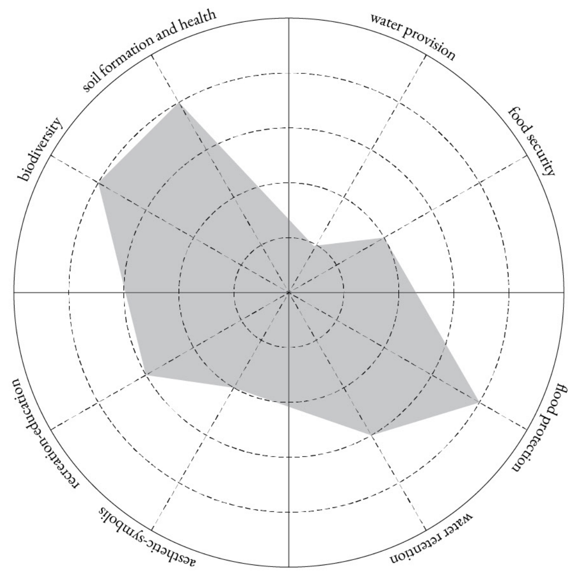
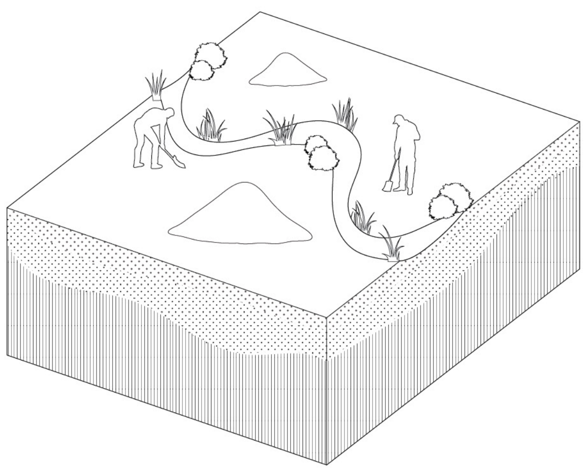


Figure 143. Controlled floodable agricultural land

stream uncovering and re-naturalization



type of landscape

flood-affected arable land
non flood-affected arable land
uphill arable land
grassland
natural

contribution to capacity

coping
recovery
adaptive

pressures/ limitations

erosion | land degradation | sedimentation
water scarcity | flooding
low | medium | high flood risk

phase of implementation

short-term
mid-term
long-term

scale

plot farm community sub-basin watershed

NBS evaluation

benefits

flood risk mitigation
soil health
groundwater recharge
biodiversity conservation

co-benefits

agricultural diversification
recreation | aesthetics
alternative tourism
local cooperation

cost ●●●●●
effort ●●●●●
maintenance ●●●●○
impact ●●●●●

ecosystem services assessment

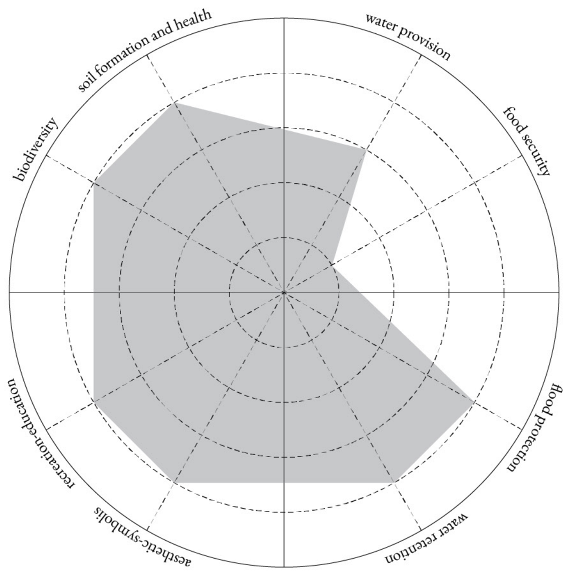
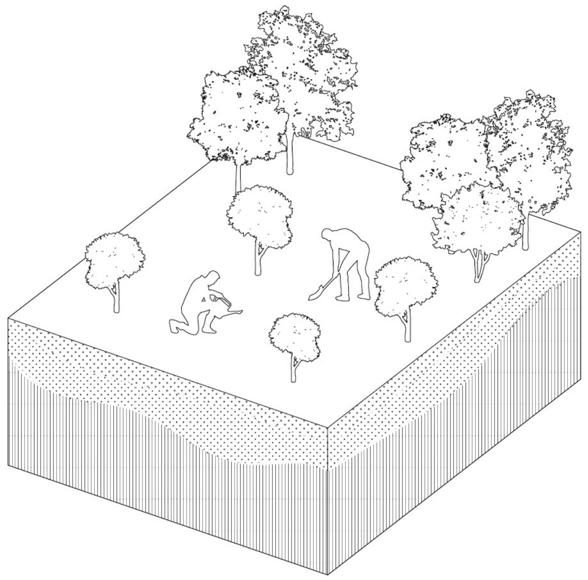


Figure 144. Stream uncovering and re-naturalization

afforestation | reforestation



type of landscape

flood-affected arable land
non flood-affected arable land
uphill arable land
grassland
natural

contribution to capacity

coping
recovery
adaptive

pressures/ limitations

erosion | desertification
water scarcity
no flood risk

phase of implementation

short-term
mid-term
long-term

scale

plot farm community sub-basin watershed

NBS evaluation

benefits

flood risk mitigation
soil health
groundwater recharge
biodiversity conservation

co-benefits

agricultural diversification
recreation | aesthetics
alternative tourism
local cooperation

cost ●●●○○
effort ●●●●○
maintenance ●○○○○
impact ●●●○○

ecosystem services assessment

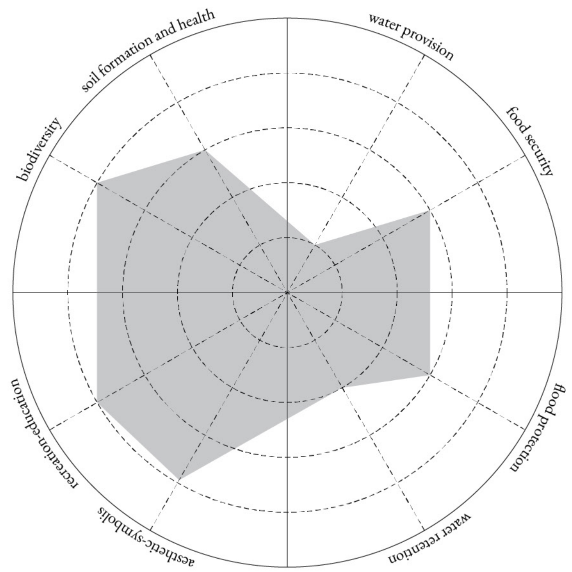
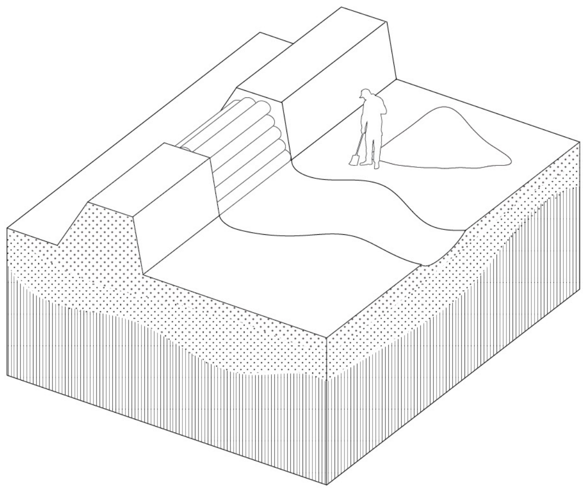


Figure 145. Afforestation and reforestation

leaky dike

type of landscape

flood-affected arable land
non flood-affected arable land
uphill arable land
grassland
natural



contribution to capacity

coping
recovery
adaptive

pressures/ limitations

erosion
water scarcity | flooding
low | medium flood risk

phase of implementation

short-term
mid-term
long-term

scale

plot | farm | community | sub-basin | watershed

NBS evaluation

benefits

flood risk mitigation
soil health
groundwater recharge
biodiversity conservation

co-benefits

agricultural diversification
recreation | aesthetics
alternative tourism
local cooperation

cost	●●●○○
effort	●●●○○
maintenance	●●○○○
impact	●●●○○

ecosystem services assessment

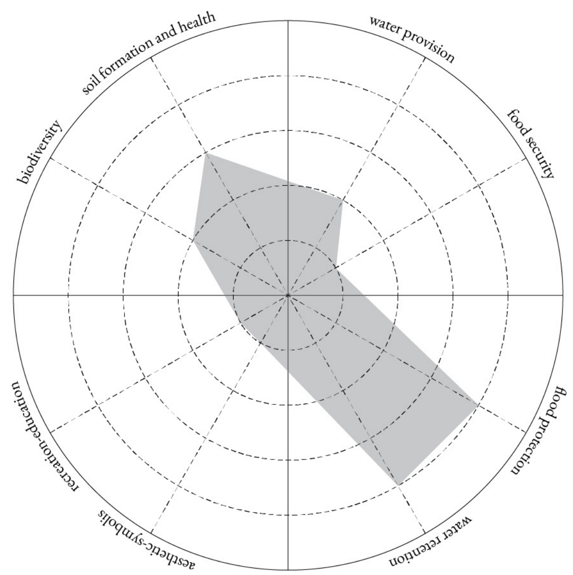
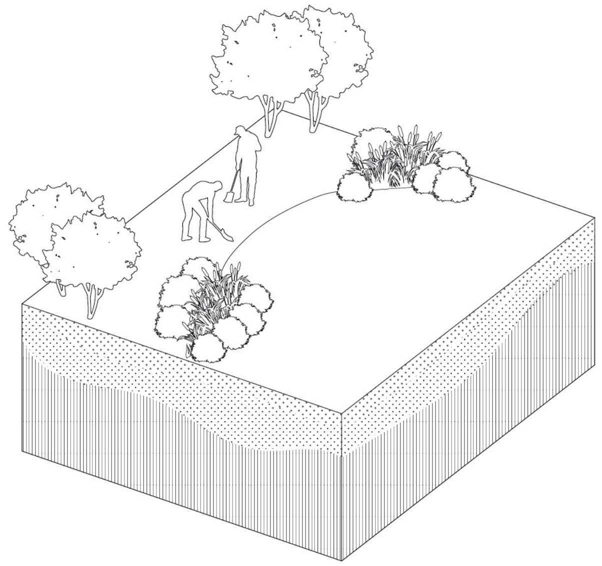


Figure 146. Leaky dike

wetland restoration

type of landscape

flood-affected arable land
non flood-affected arable land
uphill arable land
grassland
natural



contribution to capacity

coping
recovery
adaptive

pressures/ limitations

erosion | salinization | sedimentation
water scarcity | flooding
high flood risk

phase of implementation

short-term
mid-term
long-term

scale

plot | farm | community | sub-basin | watershed

NBS evaluation

benefits

flood risk mitigation
soil health
groundwater recharge
biodiversity conservation

co-benefits

agricultural diversification
recreation | aesthetics
alternative tourism
local cooperation

cost	●●●●●
effort	●●●●●
maintenance	●●●○○
impact	●●●●●

ecosystem services assessment

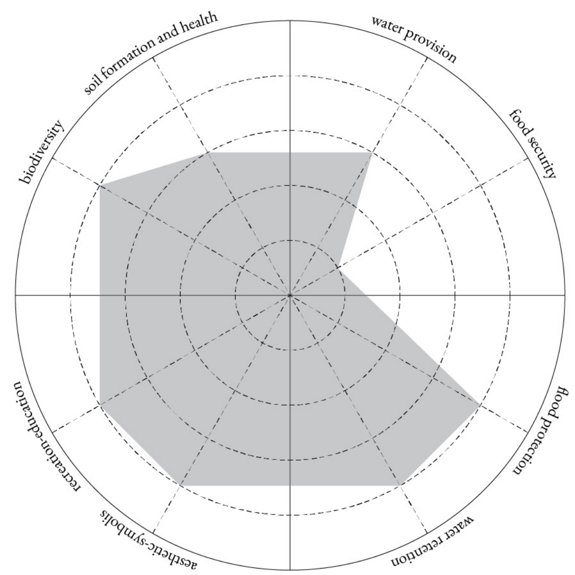


Figure 147. Wetland restoration

Vision

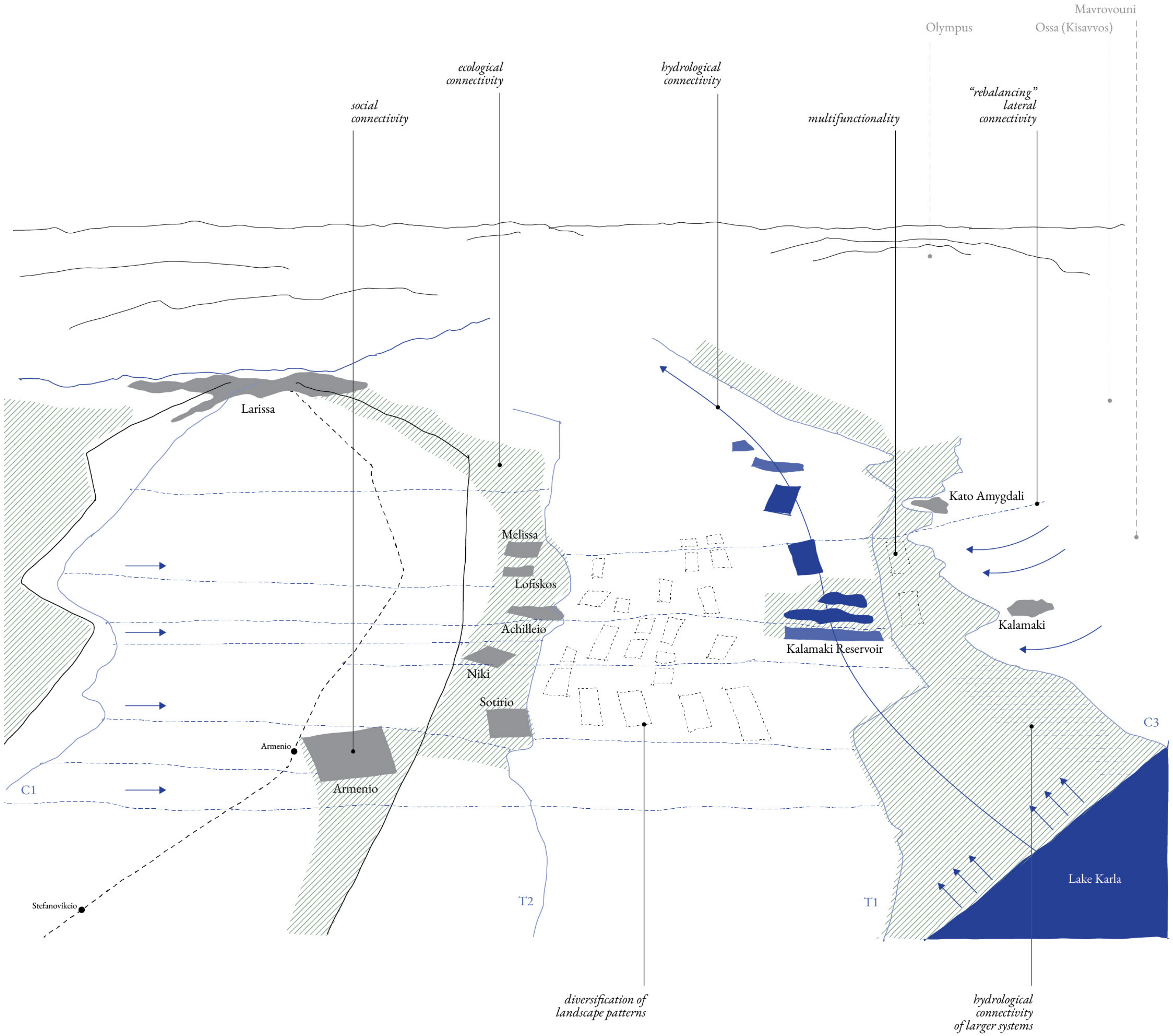


Figure 148. Vision

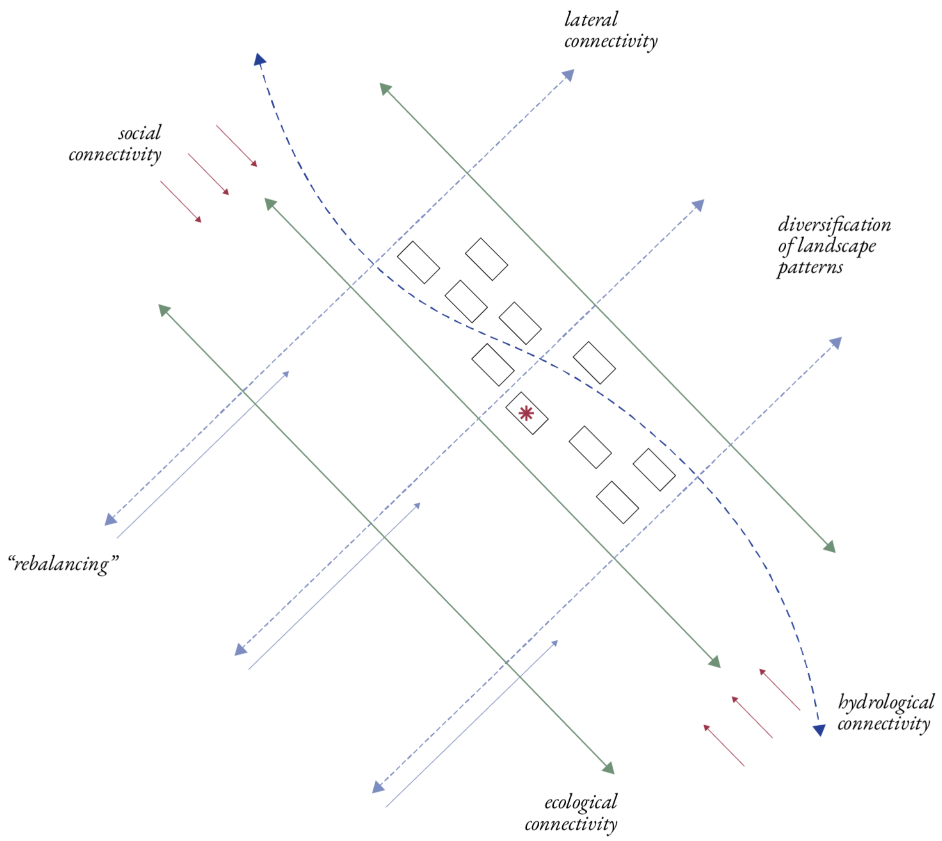


Figure 149. Principles

The proposed vision is based on the principle of connectivity, either by redefining it or interrupting it. Firstly, one of the aims of the proposal is to improve hydrologic connectivity, by "rebalancing" lateral connectivity (Mason et al., 2025), either between streams or larger water systems consisting of wetlands and floodplains. Furthermore, ecological connectivity should also be achieved, by recognizing the protected areas from the Birds and Habitats Directive and reinforcing them through the creation of ecological corridors. This happens mostly through landscape solutions based on landscape transformations. At the same time, the uniformity of the current agricultural landscape needs to be disrupted, through soil solutions based on agroecological practices, resulting in a multifunctional and heterogeneous landscape. This facilitates the disconnection of cascading processes resulting in high flood risk on different spatial levels (Keesstra et al., 2018). Through the diversification of landscape patterns and patches, the fragmentation of the natural systems and ecosystems is reversed. Finally, another aim is to strengthen social connectivity, creating new hubs for knowledge and alternative production, consequently supporting rural development through processes of decentralization.

Figure 150. Critical zone recognition

Important elements

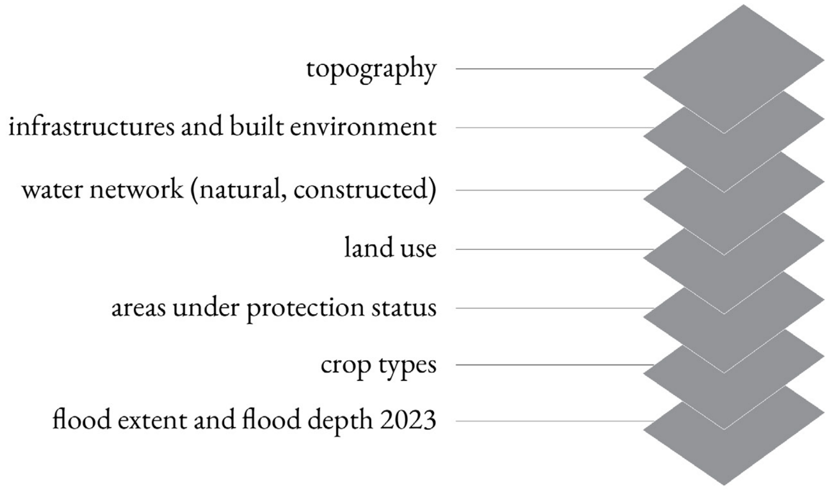


Figure 151. Important elements

A similar methodology as the definition of areas within a range of criticality and transformability was followed, with examining and overlaying important elements. Those are the topography, infrastructures and the built environment, the water network – whether it is natural or constructed, latent or existing – land use, protection status, crop types, as well as the observed flood extent and depth during the September 2023 event.

Figure 153. Infrastructures and built environment

Figure 152. Topography

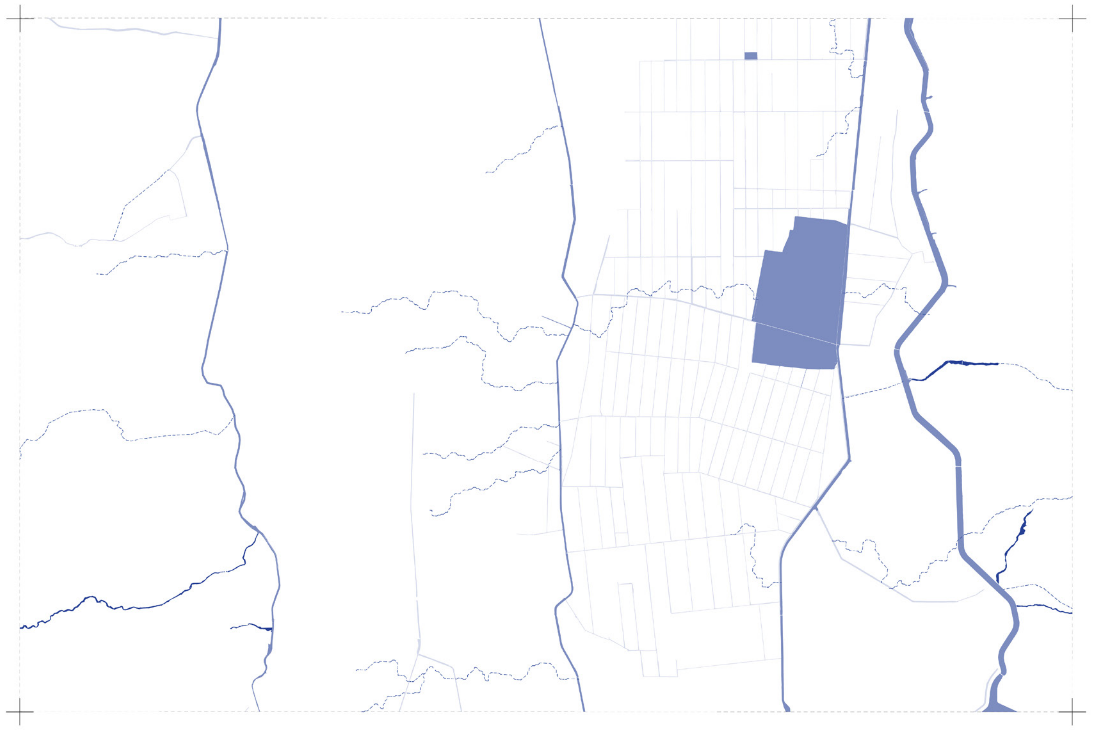


Figure 154. Water system

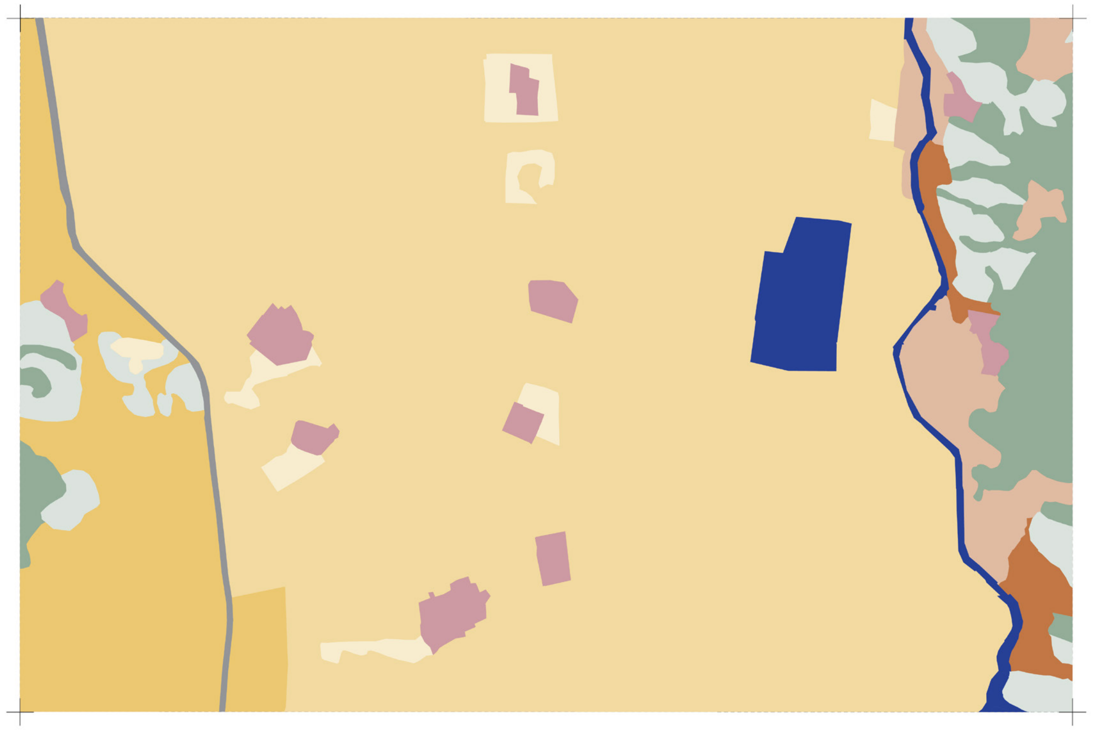


Figure 155. Land cover

Figure 157. Crop types

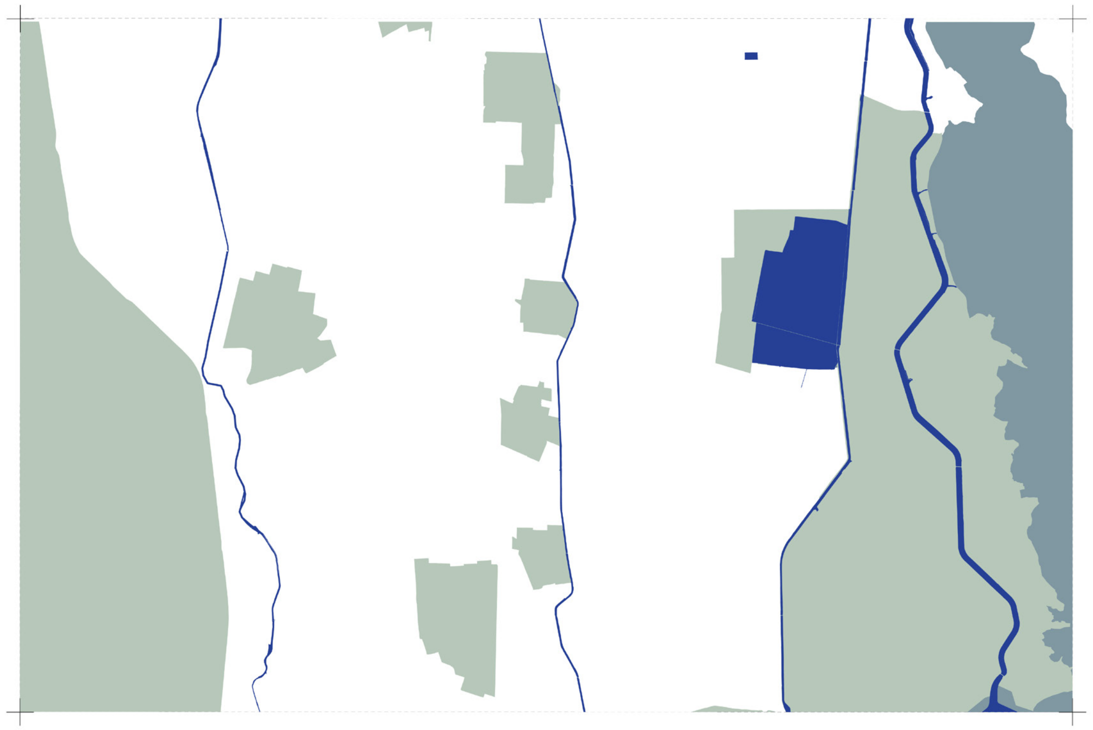


Figure 156. Areas under protection status

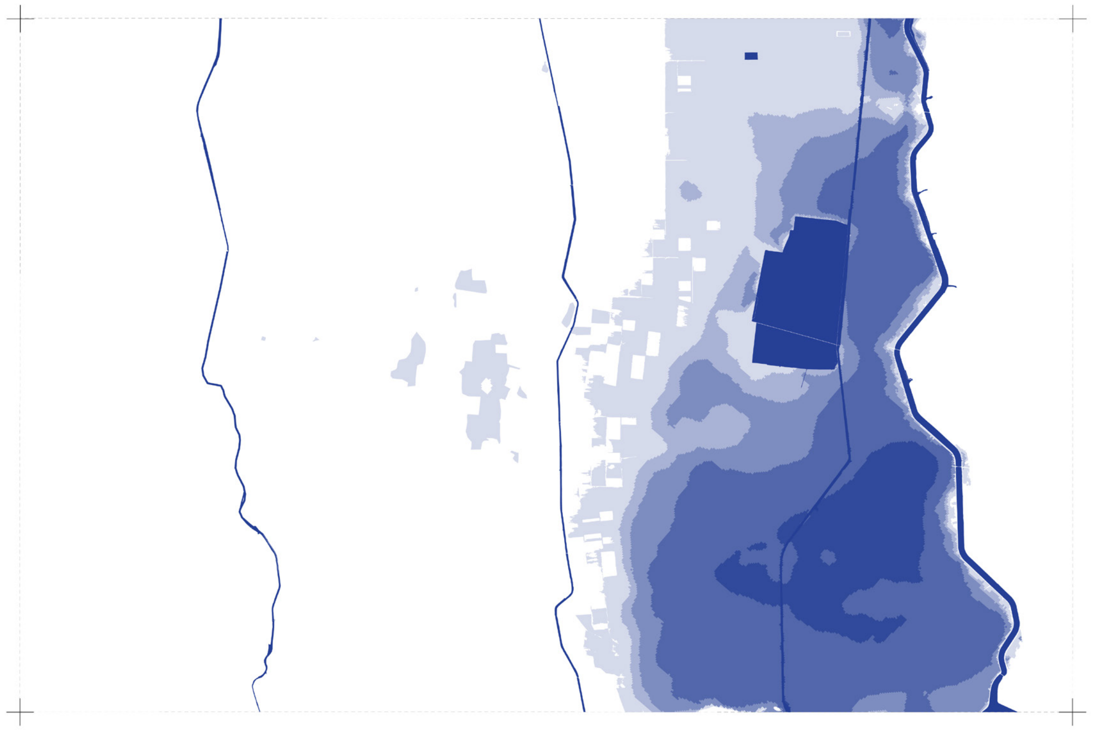
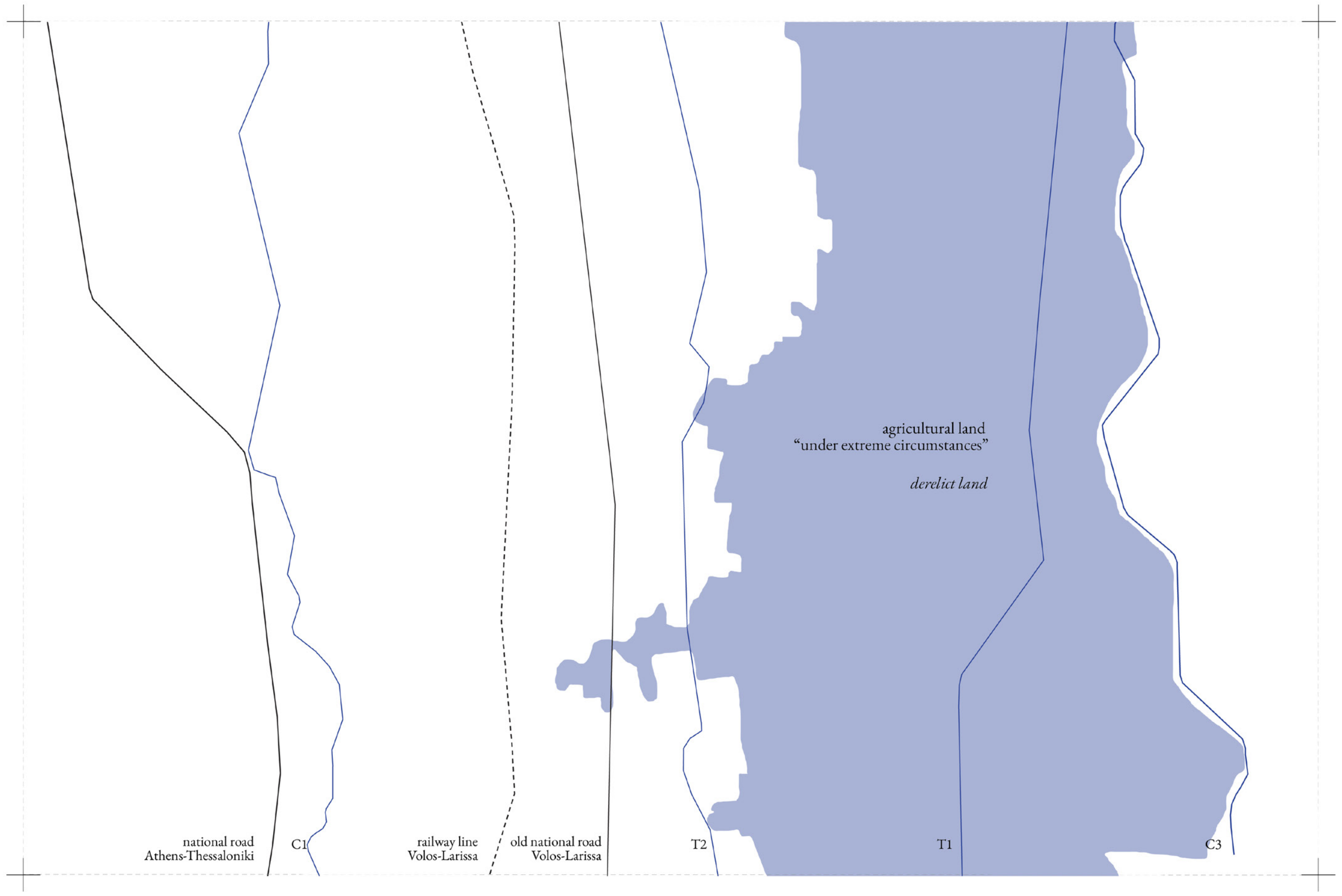


Figure 158. Flood extent and flood depth 2023

fragmentation and dereliction



0 1km N

Figure 159. Fragmentation and derelict land

old streams

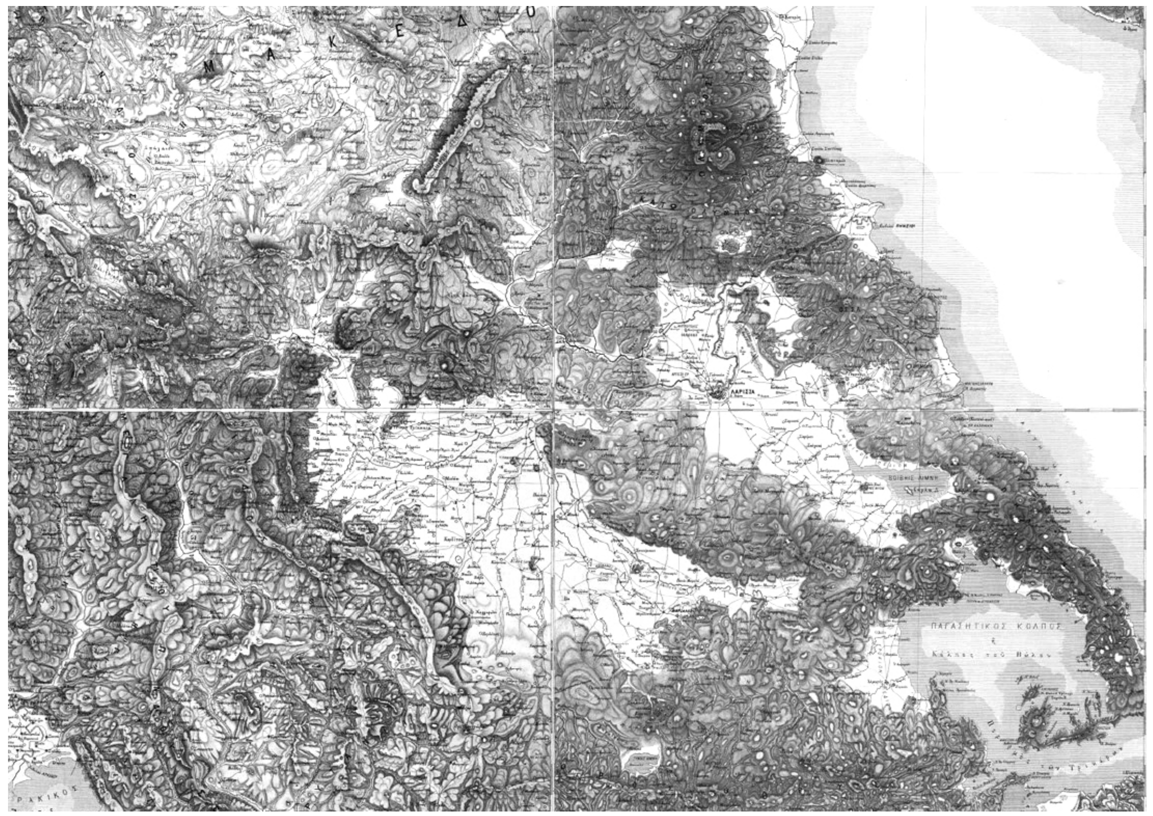
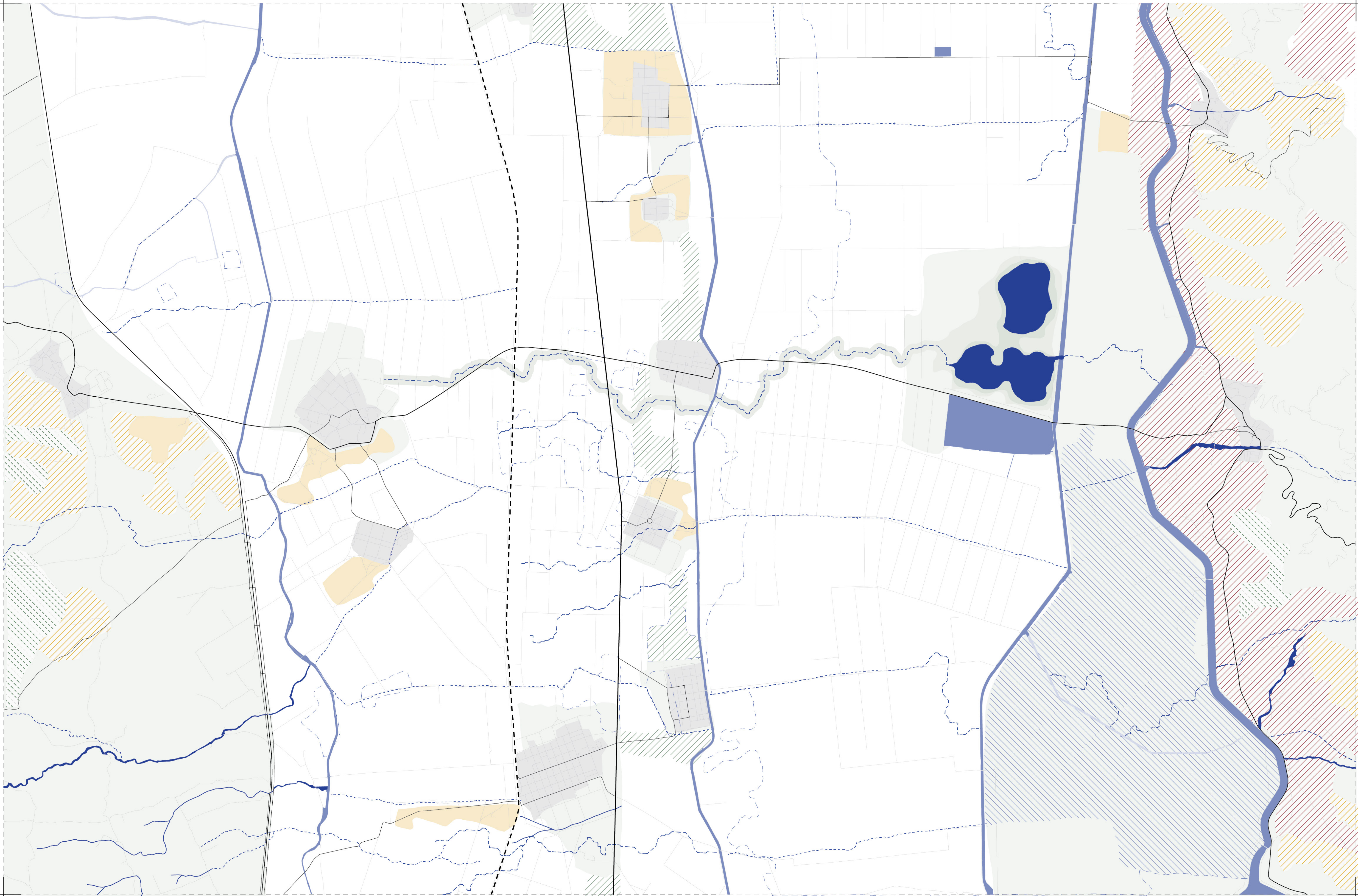


Figure 160. Topographic map, 1881



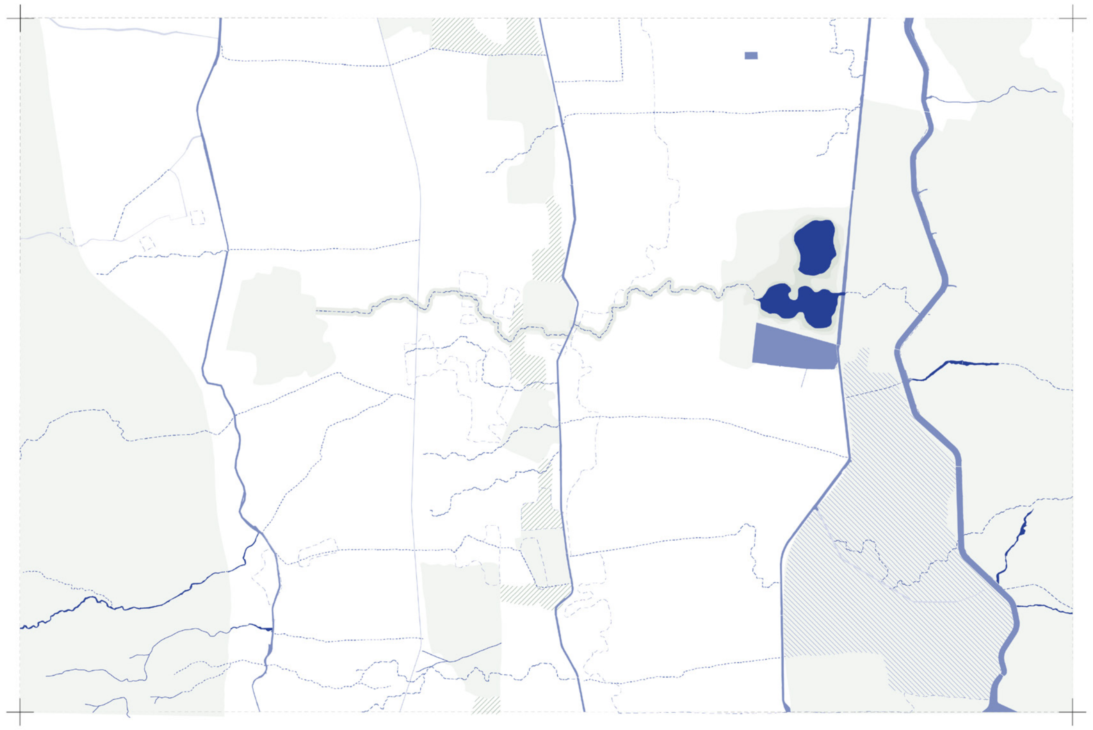


Figure 162. Biophysical layer

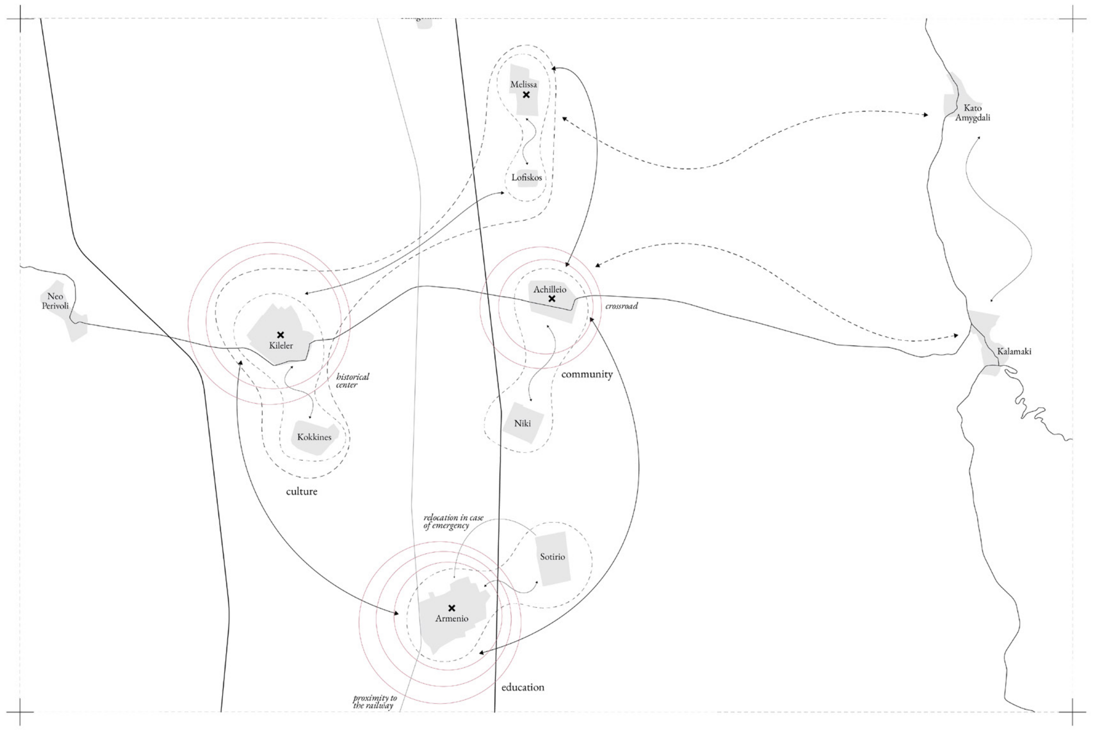


Figure 163. Socio-technical layer

The strategy, applied on the critical zone defined by the area selection, is loosely based on the concept landscape mosaic (Vogt, 2024), recognizing patches of land that create a spatial mosaic with specific biophysical and socio-technical conditions. Then, following the principle of landscape ecology, it utilizes this concept, by understanding the importance of enhancing the relationship between these complex spatial pattens and ecological processes.

The first thing was to depict the water system, whether it is constructed (trenches, collectors, irrigation channels and artificial reservoirs), or natural (existing and latent). The latent natural system is defined from the drainage network of Copernicus derived from a DEM as well as historical maps of Thessaly depicting the water system before the subsequent processes of human-induced alteration. Proposed lateral connections between those streams are made, following the topography.

Additionally, the outline of the maximum extent of the flooded area during September 2023 is highlighted, along with the outline of the agricultural land that has been categorized as "under extreme circumstances" by the Greek Payment Authority of Common Agricultural Policy (C.A.P.) Aid Schemes (OPEKEPE) and has remained uncultivated in the last two years – a *derelict* land. These outlines signify agricultural land that has the biggest potential to be transformed, either on the local scale with the implementation of agroecological practices to the level of the plot and farm, or by activating larger landscape transformations, especially on the land that is owned by the state where no land consolidation is needed.

Furthermore, the areas under protection status, whether it is the Birds or Habitats Directive are outlined, and proposed connections between them are explored, in order to create larger ecological corridors. The two vertical ecological corridors are connected laterally through the new hydrological links created by uncovering or re-naturalizing the old streams, establishing a wider ecological green-blue network which fosters and supports biodiversity.

Finally, the pastures surrounding agricultural settlements, and existing within the Natura 2000 protected areas are recognized as areas that can be used as a management tool to contribute to biodiversity conservation and enhance ecological connectivity. However, overgrazing should be avoided, as well as their conversion into cropland. Natural grasslands located uphill also have the potential to be used as pastures, with the proper livestock management and re-introduction of traditional low-intensity grazing.

All of these proposed strategic transformations belong to the biophysical layer, with the main aim being the creation of lateral connectivity between these strong vertical axes. For the socio-technical layer, partnerships between settlements and communities are introduced, coming from the already existing administrative organization, as well as their geographical proximity to one another. For example, pairs of villages such as Sotirio and Armenio, Achilleio and Niki, and Melissa and Lofiskos are created, which in turn foster lines of communication with the uphill settlements on the other side of the floodplain, Kalamaki and Kato Amygdali.

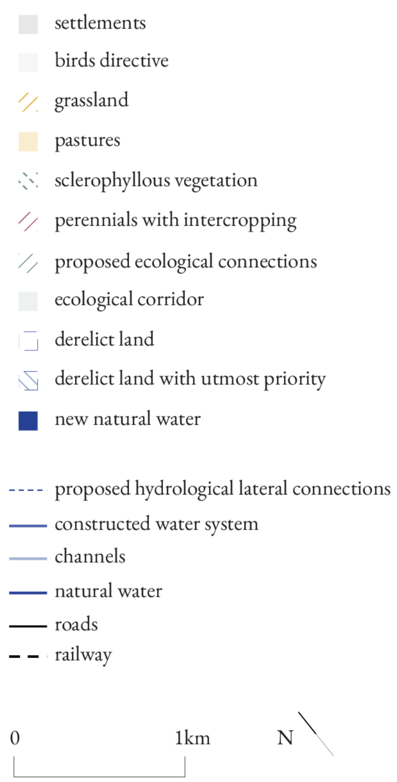


Figure 161. Strategy

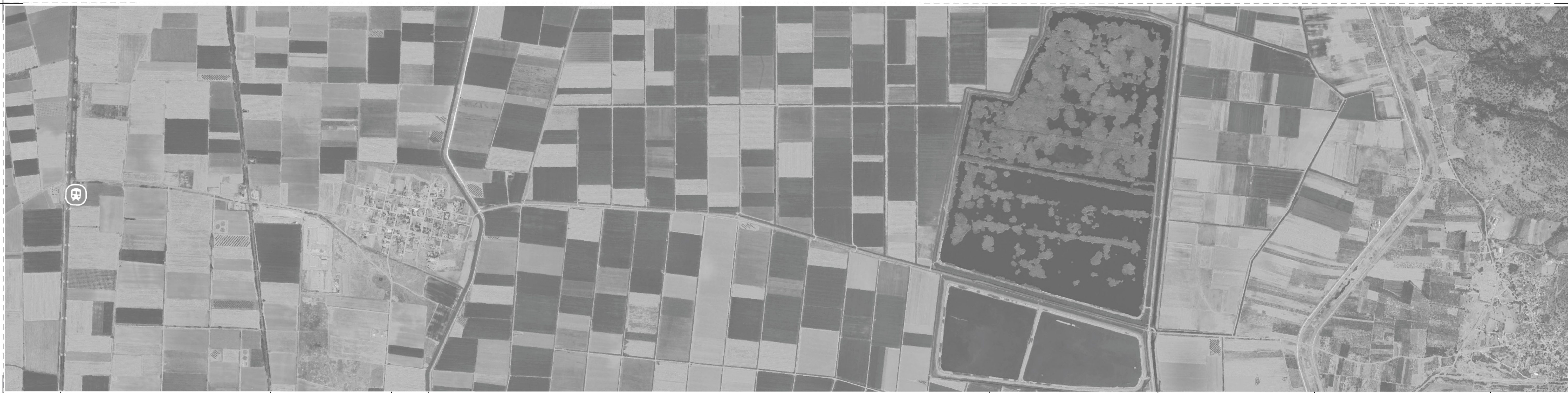


Figure 164. Strip recognition

Figure 165. Topography, infrastructures and built environment

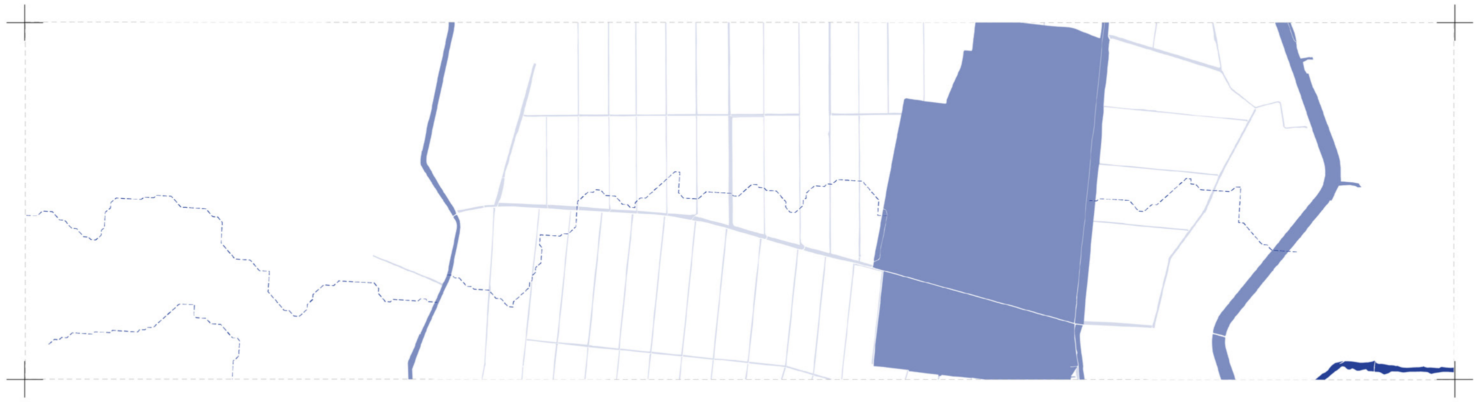


Figure 167. Water system

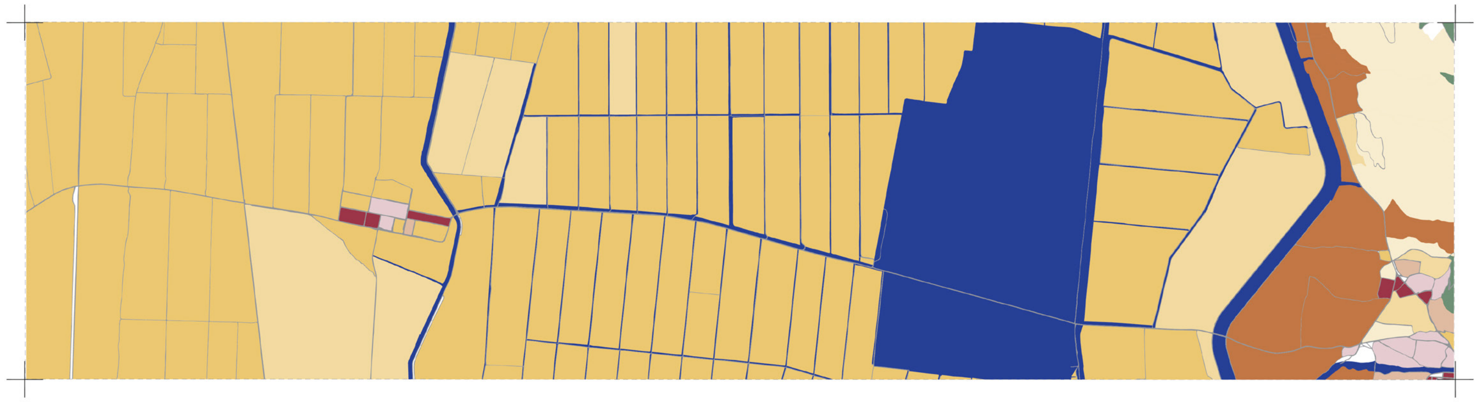


Figure 166. Suitable land cover

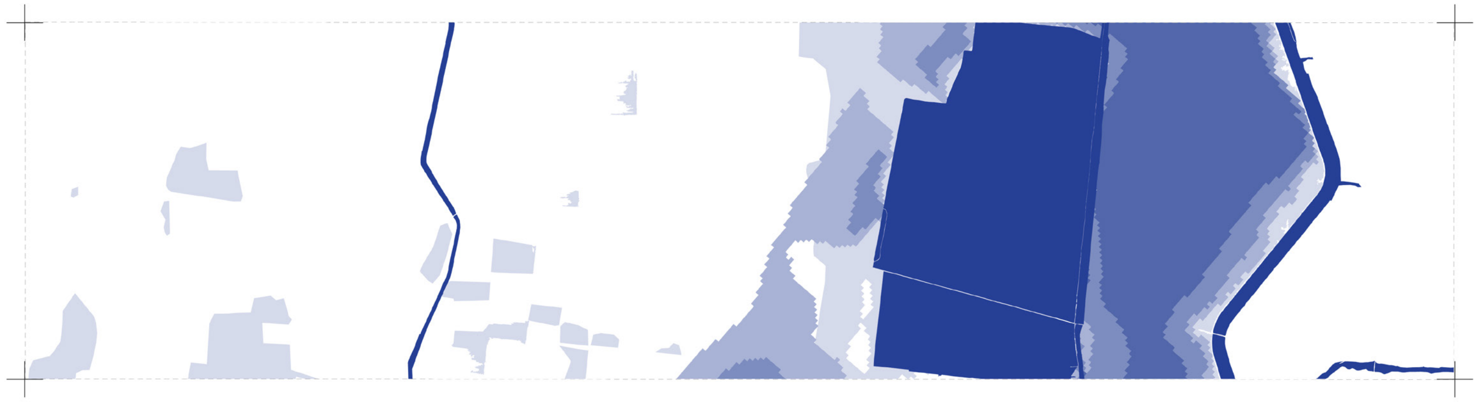
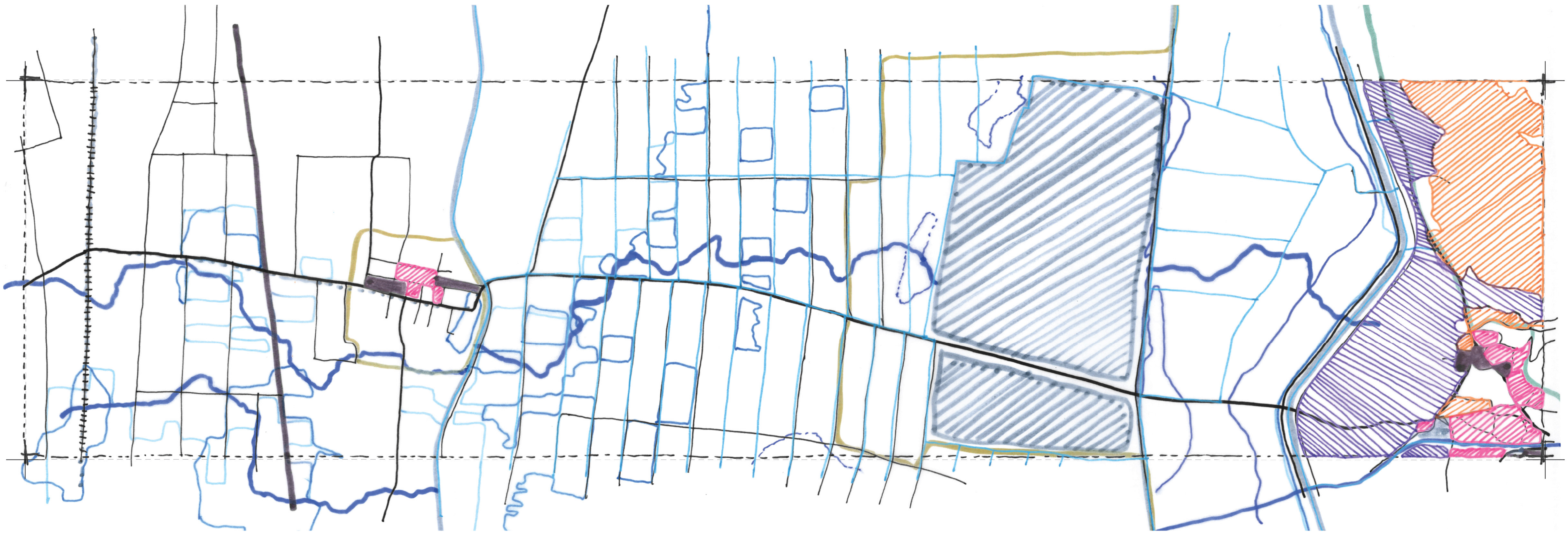


Figure 168. Flood extent and depth 2023



perennial cultivation
natural grasslands suitable for grazing
vineyards
built environment
Birds Directive
Habitats Directive

roads
railway
latent natural water system
constructed water system
channels
flooded land 2023
derelict land

0 1km N

Figure 169. Conclusions

Main concept

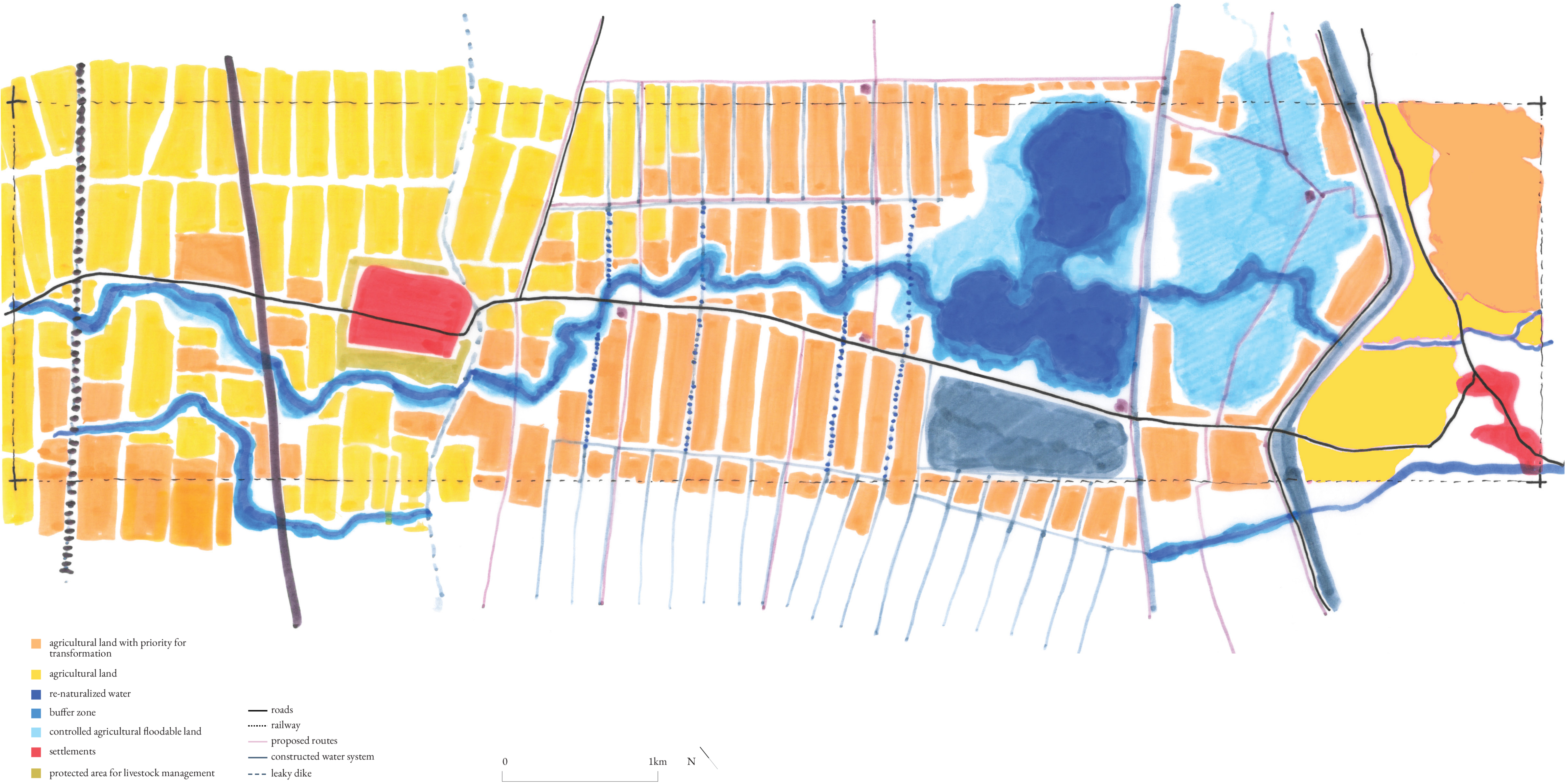


Figure 170. Main concept

A "focus strip" was chosen within the critical zone, in order to locate the proposed transformative actions into a specific spatial context. This area that was chosen spans from the railway line connecting Larissa and Volos to the foot of Mavrovouni, where Kalamaki is located. The reason for this selection is that the secondary road connecting the settlements of Kileler, Achilleio and Kalamaki already functions as an element of social connectivity, as well as an underlying stream that is now expressed as an irrigation channel connecting to the artificial reservoir of Kalamaki. Therefore, the landscapes separated from the strong axes of the railway line, the old national road, the T2, T1 and C3 already possess the underlying potential to be reorganized, re-connected and diversified.

A similar methodology to the strategy was followed. Firstly, the constructed and natural elements of the water system were showcased in greater detail, along with the outlines of the *derelict land*. Then the same was done for the land use, differentiating between arable and land with perennial cultivation, pastures and settlements.

The main concept of the design exploration constitutes a "*maximized vision*" for the area, imagining a future where water, nature and agriculture co-exist, introducing a resilient model for water and land management. The old stream traversing the eastern Thessalian plain is uncovered, re-naturalizing the existing irrigation channel. A buffer zone with vegetation is created on the sides of the stream, delineated from the topography and the flooding that was observed in September 2023. Following the same principles, on offset from this buffer zone, there is an outlined area for floodable agricultural land, its size fluctuating according to the criticality of the area during the recent flooding. The northern reservoir of Kalamaki is restored as a wetland, while some of the existing irrigation channels are transformed into vegetated waterways with small buffer zones. These would decrease the water runoff speed in case of another unprecedented flooding event that would result in water coming from the Gyrtoni Dam through the old Asmaki Stream towards the lowlands of the easter Thessalian plain, providing routes for the water to travel.

The agricultural land is either categorized as higher or lower priority for the implementation of agroecological practices for the restoration of an agro-silvopastoral system. Examples of these practices are cover cropping and crop rotations using alterations between cotton, wheat and legumes or fallow, agroforestry implementing afforestation as well as alley cropping using trees and shrubs, re-establishing pastures on the plain and on natural grasslands following rotational grazing regulations, and finally intercropping.

A network of walking and biking routes with stop points is also implemented, following the existing network of paths and channelization.

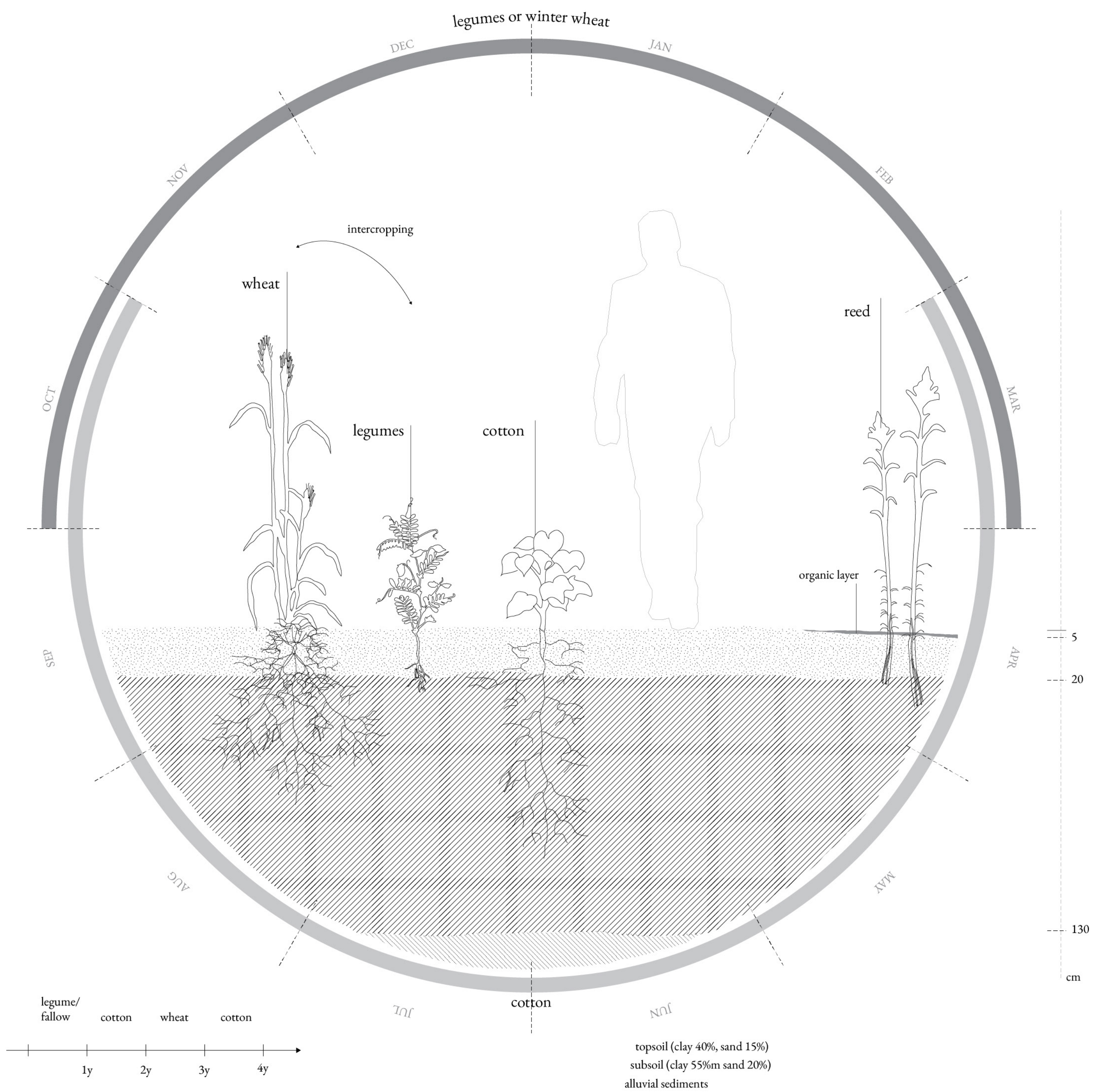
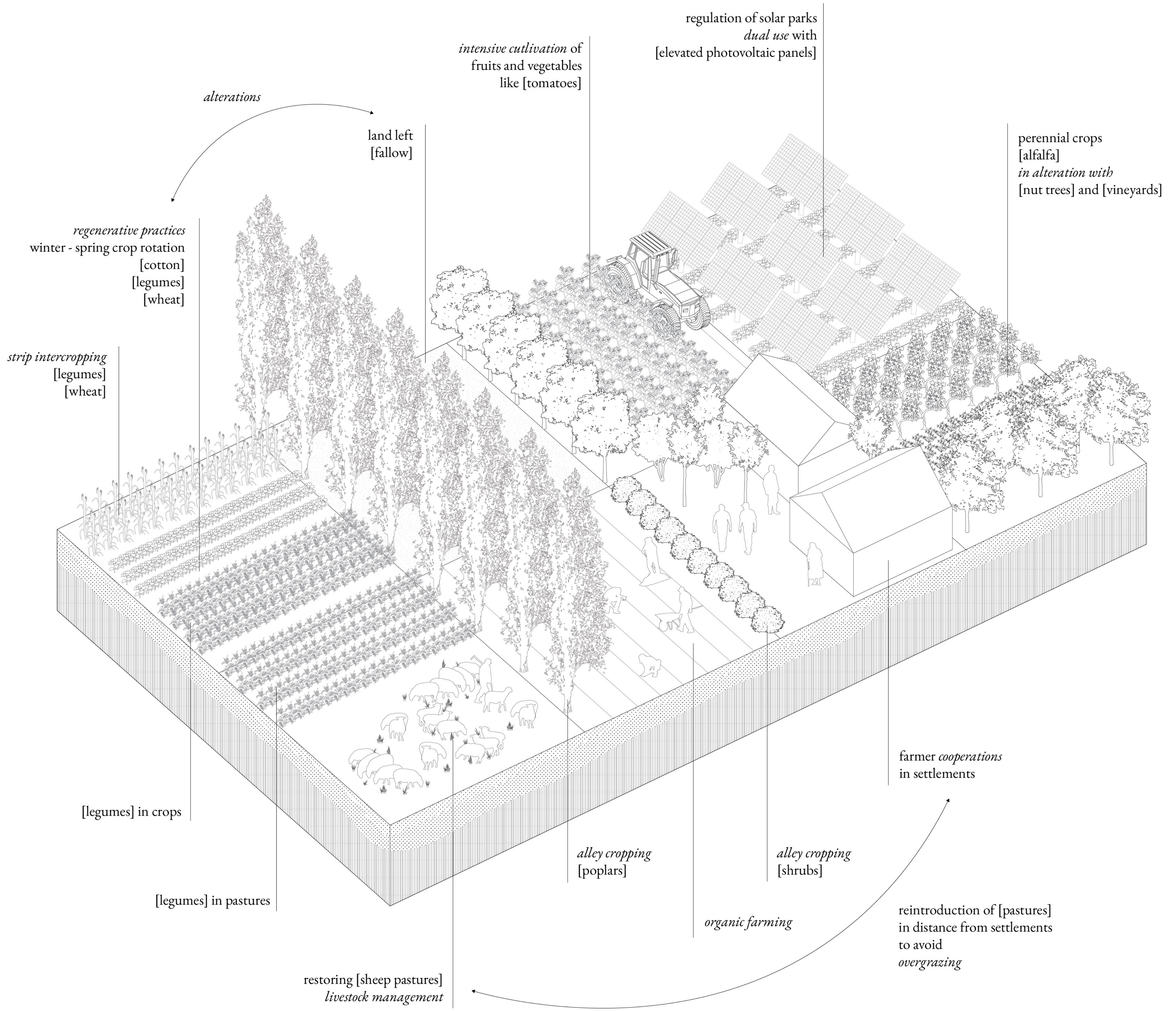


Figure 171. Proposed crop rotations

Systemic

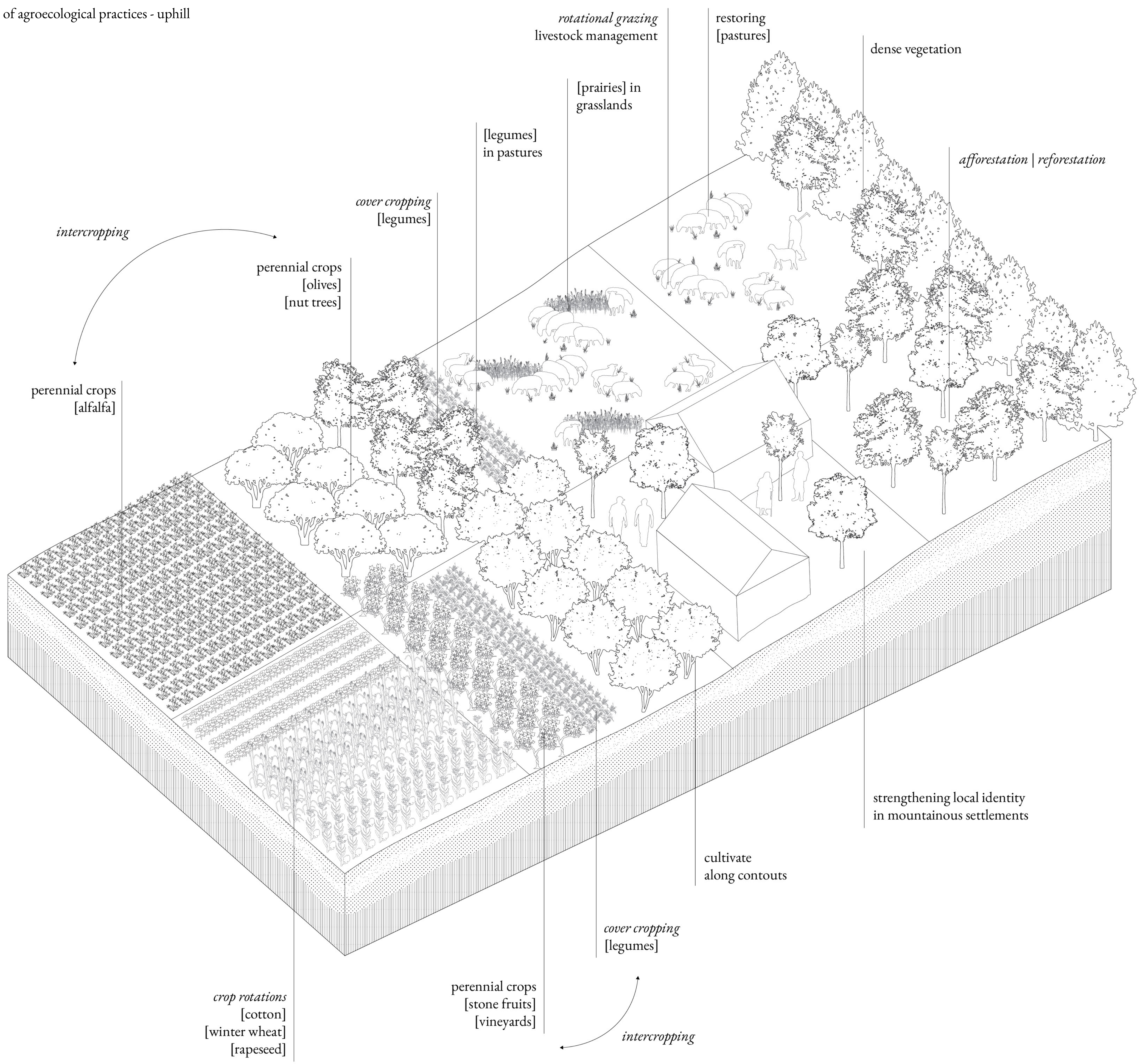
Patchwork system of agroecological practices - plain



Cotton has been the one crop type facing the most intense pressure to disappear from the Thessalian plain. However, it is the best crop type regarding water use efficiency among the rest of the cultivated crop types in the area and is of great financial importance (Arapostathis et al., n.d.). Therefore, it should not disappear in favor of other non-irrigated agriculture. On the contrary, its cultivation should be supported through the proposed series of agroecological transitions, such as crop rotations with wheat and legumes. Maize and alfalfa cultivations should also be supported, entering a rotation cycle as well. In some areas with low risk, perennial crops like vineyards and nut trees – specifically pistachios – can be also introduced. The re-introduction of pastures should also happen in areas of low risk. The already existing plots with PV panels can be transformed into dual-use, elevating the PV panels above the ground so that the area can also be cultivated.

Figure 172. Patchwork system of agroecological practices - plain

Patchwork system of agroecological practices - uphill



Perennial crops, especially nut trees and vineyards on uphill environments, should be supported by a series of best agroecological practices. Cultivating along the contour lines improves the structure of the soil. Additionally, intercropping between nut trees and winter wheat, as well as between vineyards and legumes is another possible solution. Legumes are also introduced in pastures for sheep farming located on natural grasslands, along with prairies. Aromatics can also be integrated into cultivation patterns. Fallow land and uncultivated land is also important to disrupt the homogeneity of monoculture, as well as creating interruptions with rows of trees and bushes (Arapostathis et al., n.d.).

Figure 173. Patchwork system of agroecological practices - uphill

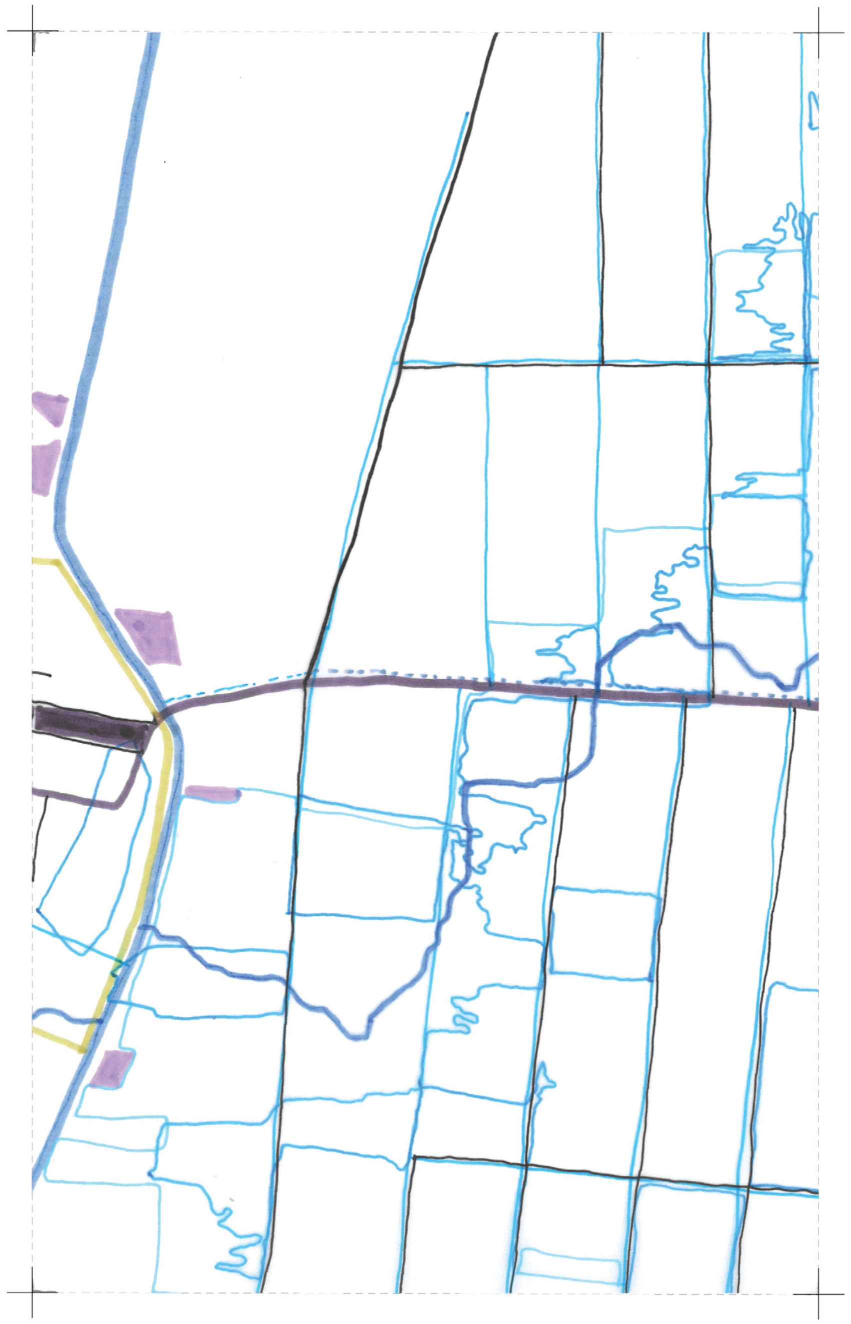


Figure 174. Land use and regulations, fragment 1

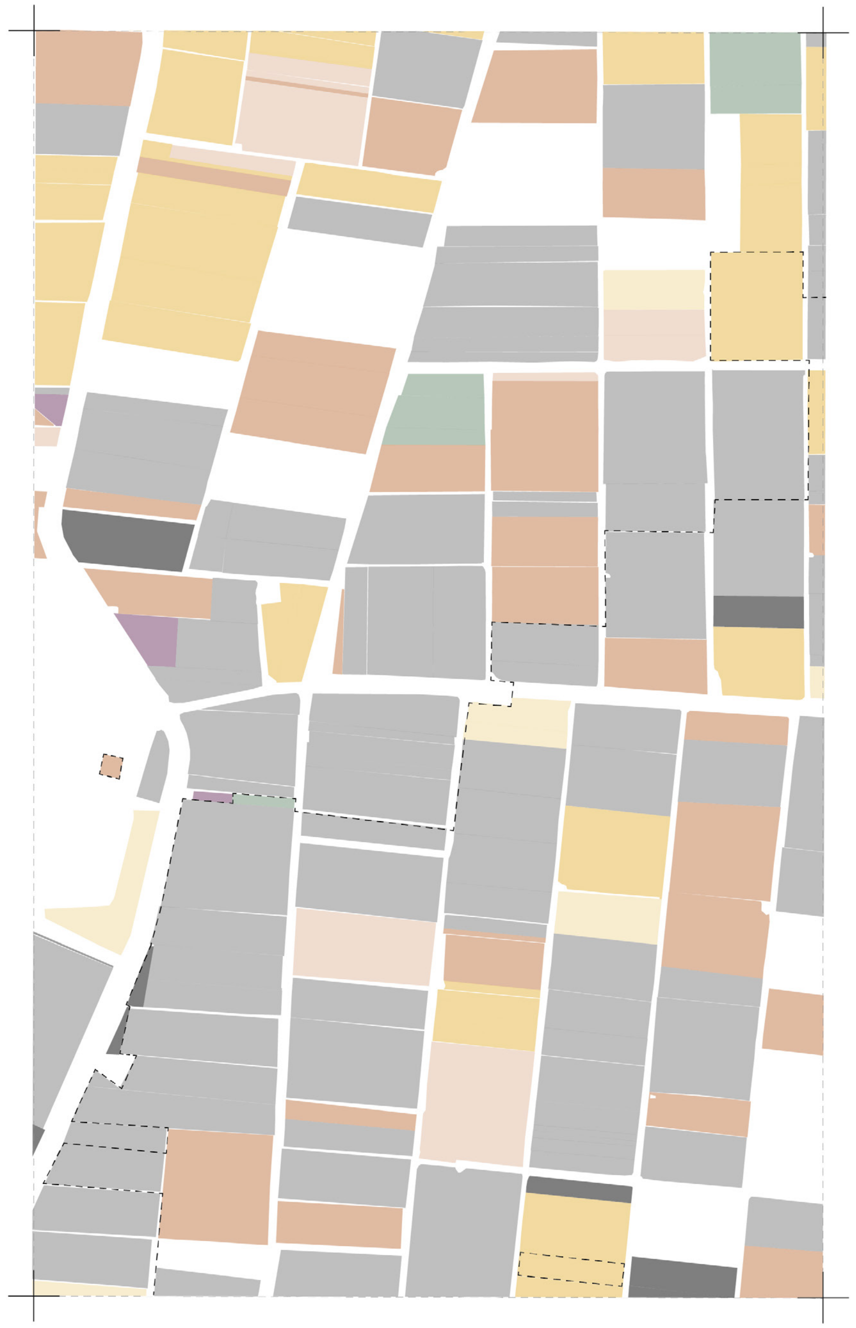


Figure 175. Land management, fragment 1

From the systemic design proposal of the "strip", two "slices" were chosen to be further explored through a sub-systemic design. These two areas are located near the edges of the strip, one on the transition from the settlement of Achilleio and the T2 to the agricultural area that was inundated in September 2023 and one on the transition from the aforementioned agricultural area to the foots of Mavrovouni and the settlement of Kalamaki. The same process followed during the strategy and the systemic design was followed in greater detail here as well, even focusing on the type of crop per plot, categorizing them according to the priority that should be given to the specific plots during the agroecological transition.

<u>Achilleio</u>

This area is located on the plain on top of alluvial deposits, specifically fluvisol. The main crop type cultivated before the flood was in its majority cotton, followed by wheat and then maize and alfalfa. There are also some plots with PV panels adjacent to the village.

The old stream is uncovered and re-naturalized, a buffer zone with hydrophilous vegetation like reeds and poplar trees created along its course. In larger offset, an floodable agricultural area is delineated. T2 functions as a leaky dike, allowing the water to pass through and continue its course in the eastern Thessalian plain. It is important to note that the buffer zone and floodable area before the crossing of the leaky dike is located only on the south, in order to protect the settlement from floodwaters. Furthermore, some of the existing irrigation channels are transformed into vegetated waterways with small buffer zones, leading the water naturally to the stream. The agricultural areas located firstly within the delineated floodable agricultural zone and secondly in the outlined *derelict* land need to transition first, following a series of agroecological practices.

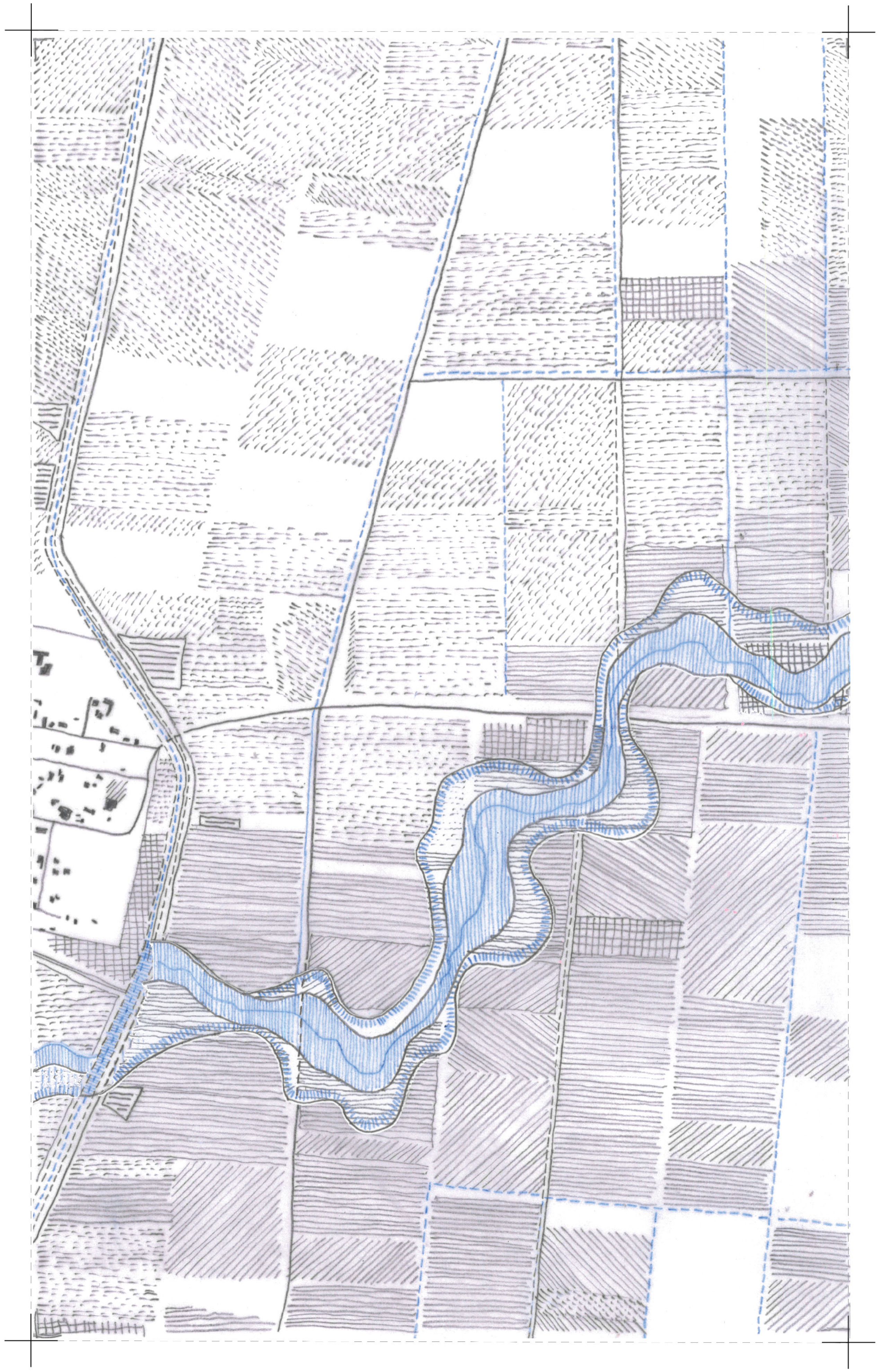
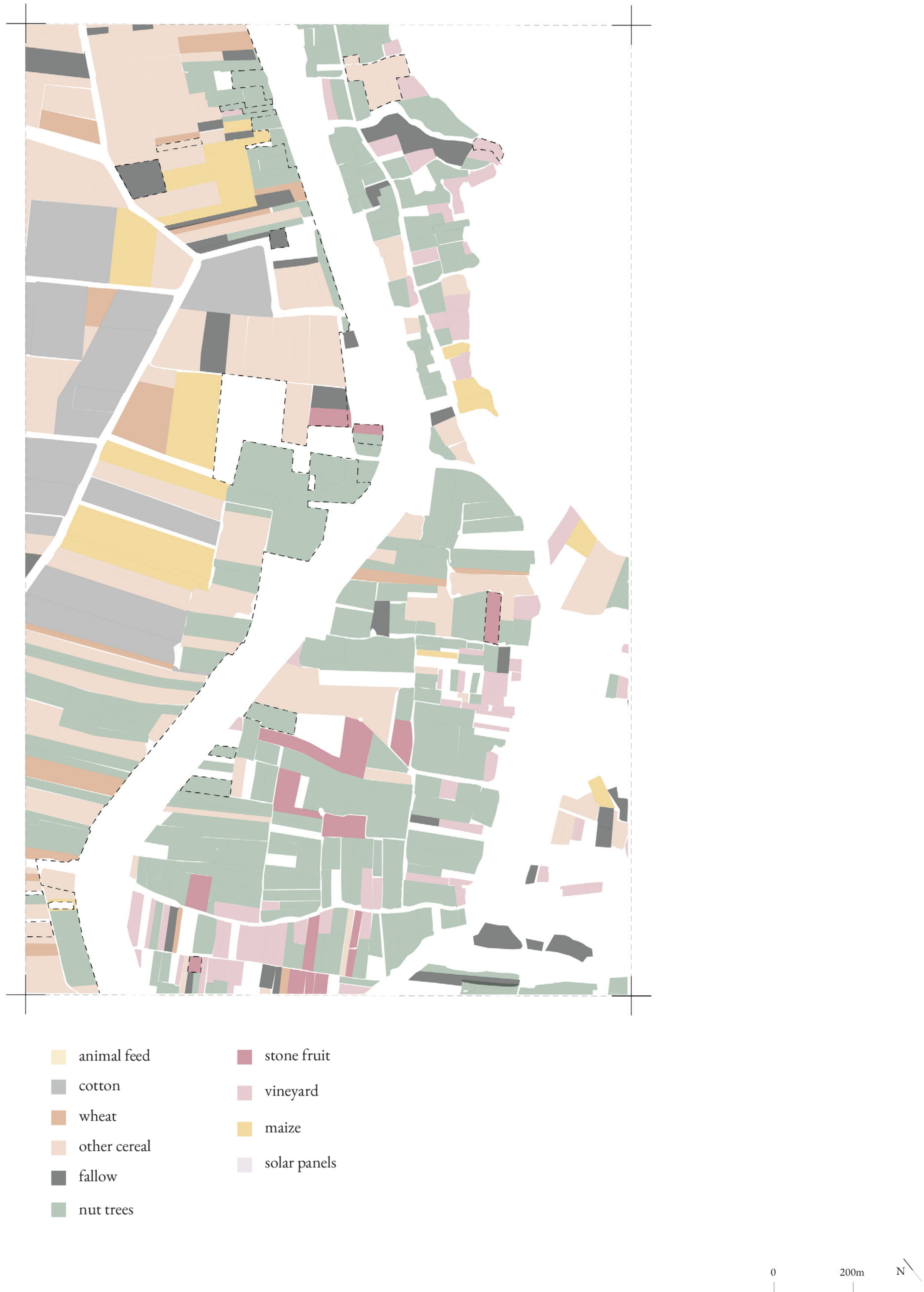


Figure 176. Sub-systemic design, fragment 1

perennial cultivation
natural grasslands suitable for grazing
vineyards
built environment
Birds Directive
Habitats Directive
roads
railway
latent natural water system
constructed water system
channels
flooded land 2023
derelict land

Figure 177. Land use and regulations, fragment 2



animal feed
cotton
wheat
other cereal
fallow
nut trees
stone fruit
vineyard
maize
solar panels

Figure 178. Land management, fragment 2

Kalamaki

This area is located on the transition between the agricultural plain and the foot of Mavrovouni. Therefore, a change in character is observed, divided by the C3. The soil type of the area is cambisol, and is under critical desertification risk. The main crop types are cotton and wheat on the plain and nut trees uphill. There is also a large area of natural grassland, which has been categorized as selectable for pastures.

The old stream here connects with the stream coming down from the mountain, north of the settlement of Kalamaki. The buffer zone ends upon its intersection with the C3, while the floodable agricultural zone is much larger, since this area was inundated under 5m of water, making it an especially critical area for flood protection. Again, the agricultural areas within the delineated and derelict zones should be the first ones to transition, while the areas east to the C3 should remain perennial crops. The natural grasslands uphill can be restored as pastures, following a livestock management scheme which will support rotational grazing.

buffer zone
cotton with priority for transition
cotton
wheat with priority for transition
wheat
alfalfa with priority for transition
maize with priority for transition
nut trees with priority for transition
stone fruits and vineyarwith priority for transition
natural grasslands suitable for grazing
built environment

roads
controlled agricultural floodable land
uncovered stream
leaky dike
agriculture dual use with PV panels

0 200m

N

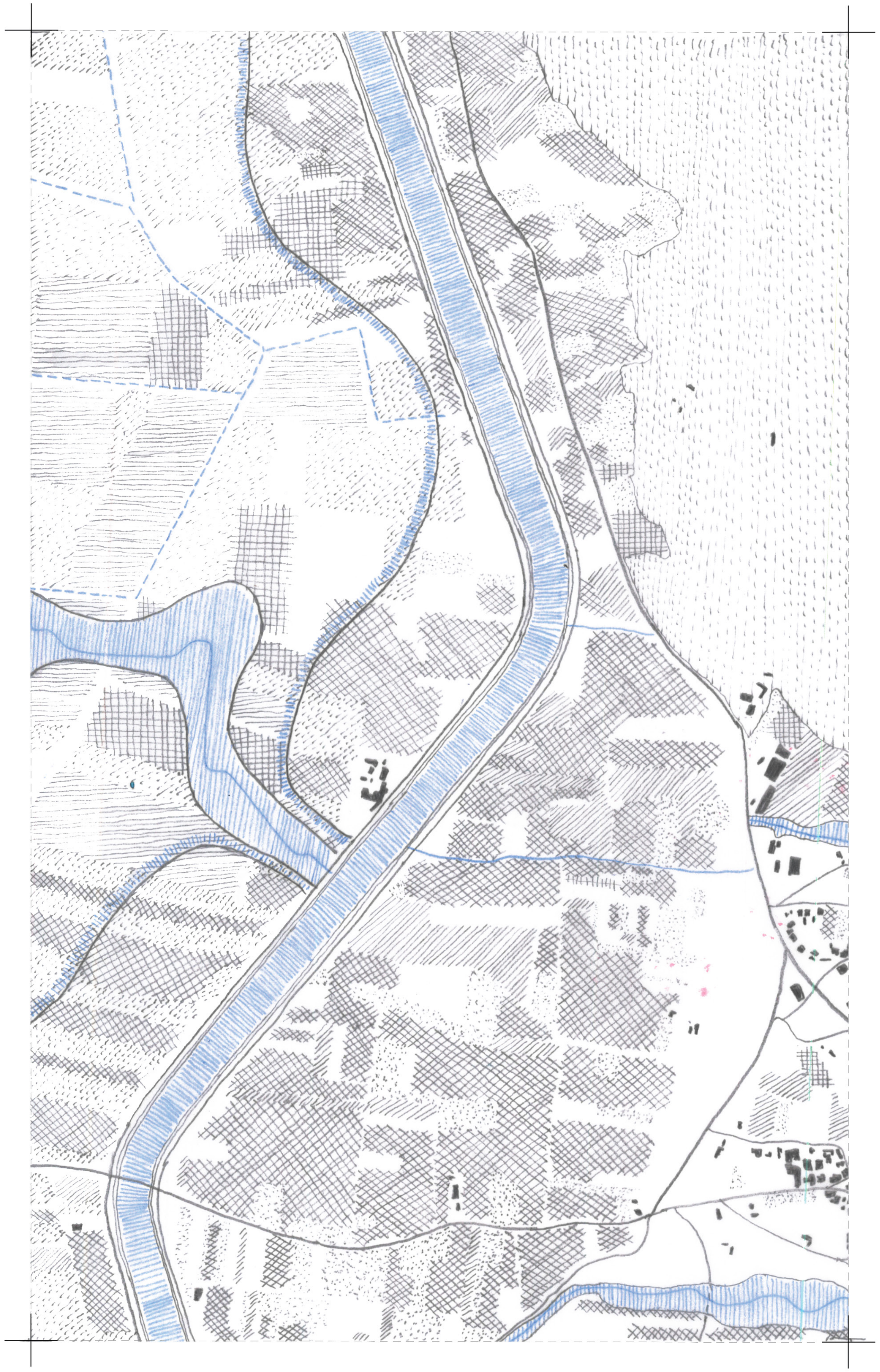
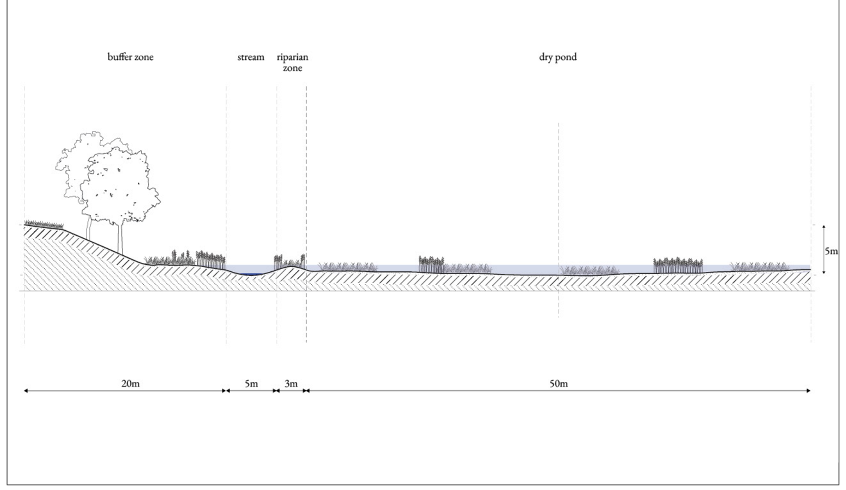
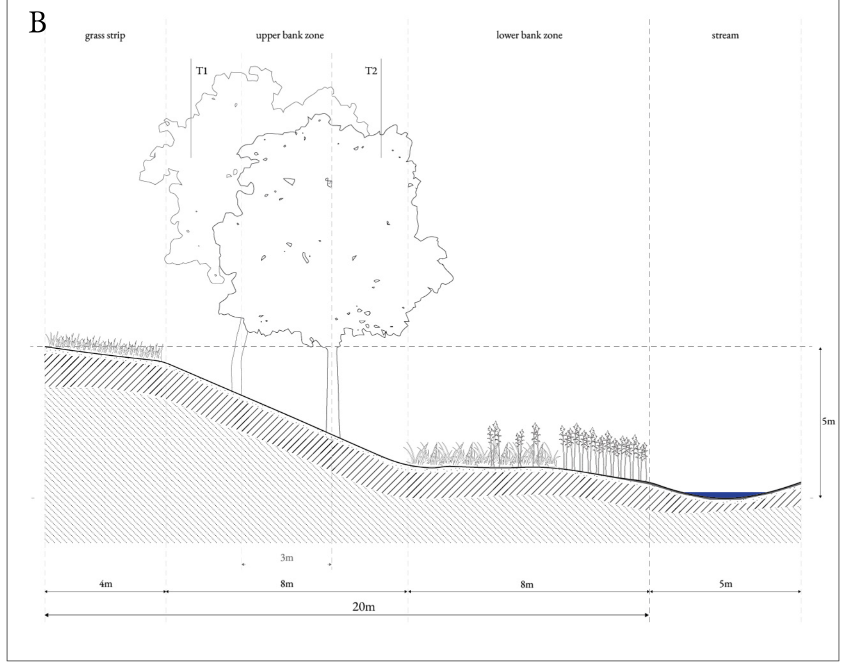
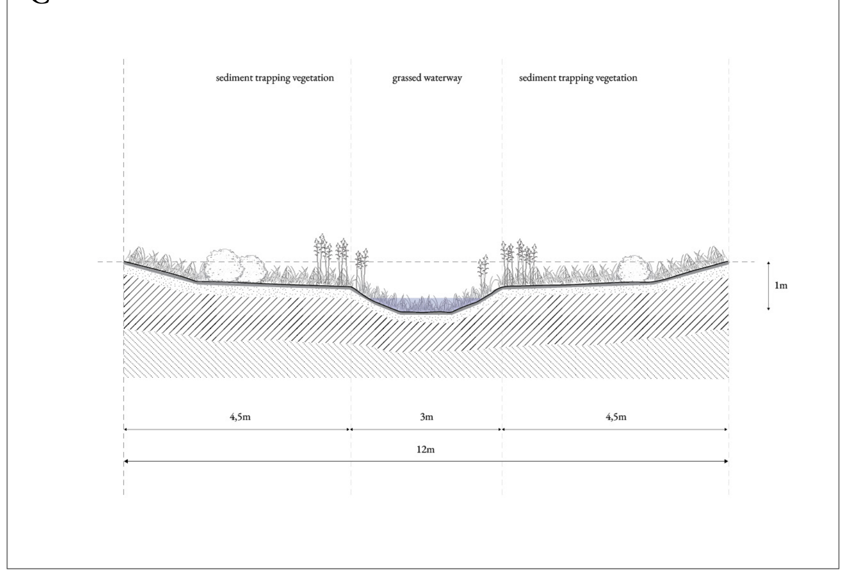


Figure 179. Sub-systemic design, fragment 2







Point of entrance

The intersection of the stream and its buffer zone with the road connecting Achilleio and Kalamaki is explored further through a process of specific design. The width of the stream, the buffer zone and the delineated floodable area are defined from the topography of the area, as well as the inundated area during September 2023. This intersection signifies a crucial point that needs to be highlighted with a landscape design intervention. Furthermore, smaller corridors and pathways are created by vegetation, and the former channels are transformed into vegetated waterways, with their own small buffer zones, directing the water to the stream. The points where the agricultural fields intersect with the delineated area and the buffer zone are spaces of negotiation, a negotiation between the productive agricultural landscape, water and nature.

LEGEND

1	dense vegetation	KAEK 311140431008
2	participating field (wheat)	KAEK 311140432007
3α	aromatics garden	KAEK 311140432008
3β	aromatics garden	
4α	participating field (wheat)	KAEK: 311140433004
4β	aromatics garden	
4γ	dense vegetation	
4δ	aromatics garden	
4ε	dense vegetation	
5	dense vegetation	KAEK 311140541001
6α	dense vegetation	KAEK 311140541002
6β	participating field (alfalfa)	
7α	dense vegetation	KAEK 311140541003
7β	participating field (alfalfa)	
8	participating field (wheat)	KAEK: 311140444002
9α	dense vegetation	KAEK: 311140444003
9β	aromatics garden	
10α	dense vegetation	KAEK: 311140444004
10β	participating field (alfalfa)	
11α	dense vegetation	KAEK: 311140444005
11β	participating field (alfalfa)	
12α	participating field (wheat)	KAEK: 311140431005
12β	dense vegetation	
13α	dense vegetation	KAEK: 311140444006
13β	participating field (alfalfa)	
14	dense vegetation	KAEK: 311140431006
15α	dense vegetation	KAEK: 311140444007
15β	participating field (alfalfa)	
16α	dense vegetation	KAEK: 311140444008
16β	participating field (alfalfa)	
17α	dense vegetation	KAEK: 311140444009
17β	participating field (alfalfa)	

tree

T1 - *salix alba, alnus glutinosa*
T2 - *quercus robur, coryllus avellana*

stream
pond
constructed water
participating fields
wood

location	Achilleio (country road Agriosykies - Kalamakiou)
estimated area	375.000m²
title of drawing	stream uncovering and buffer zone
scale	1:5.000
time of study	June 2025

N

Figure 180. Specific design

photo by Fotis Natsioulis

06| Politicize

Phasing and adaptive pathways
Adaptation framework and recommendations

Figure 181. Layers

Phasing and adaptive pathways

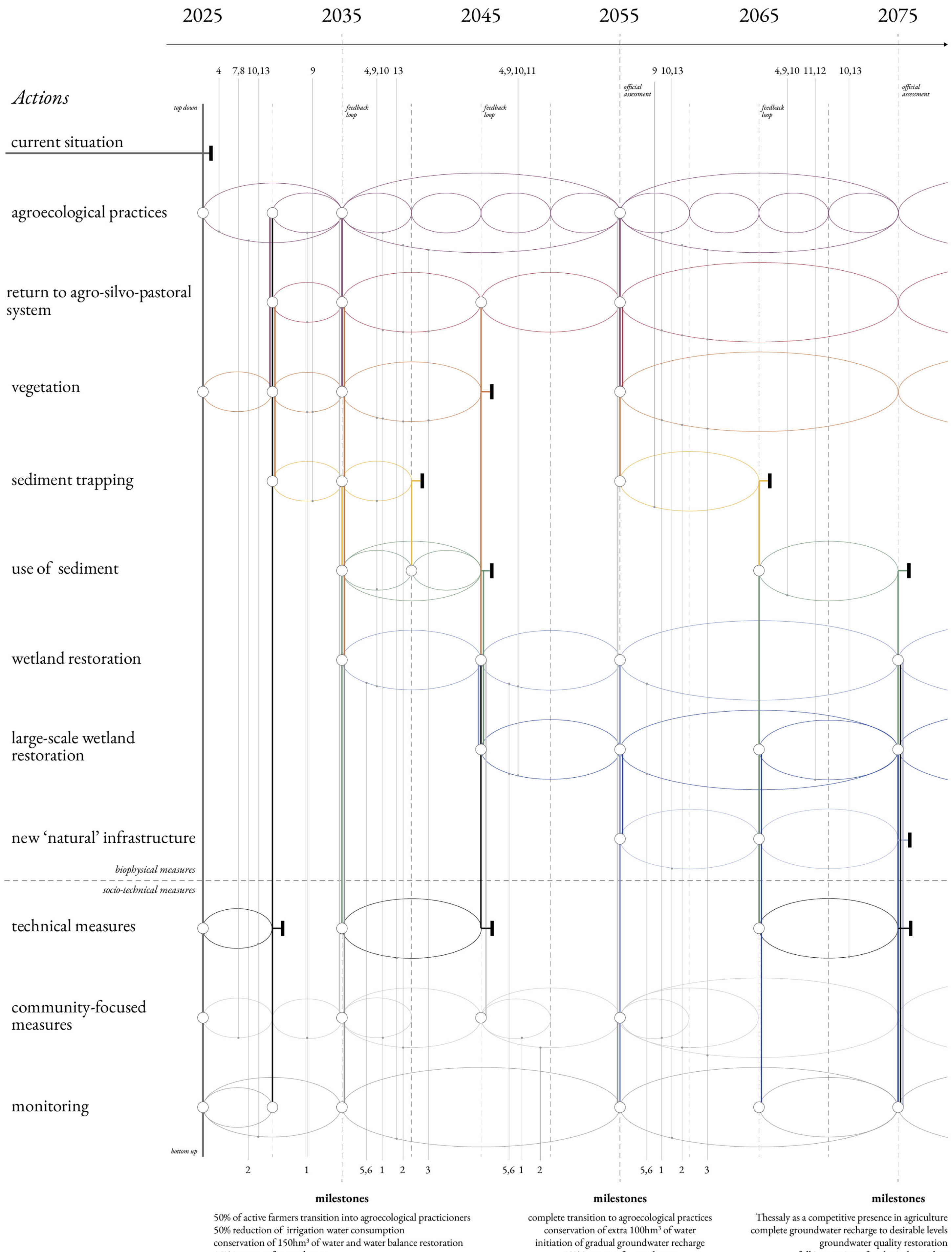


Figure 182. Adaptive pathways

The cycle

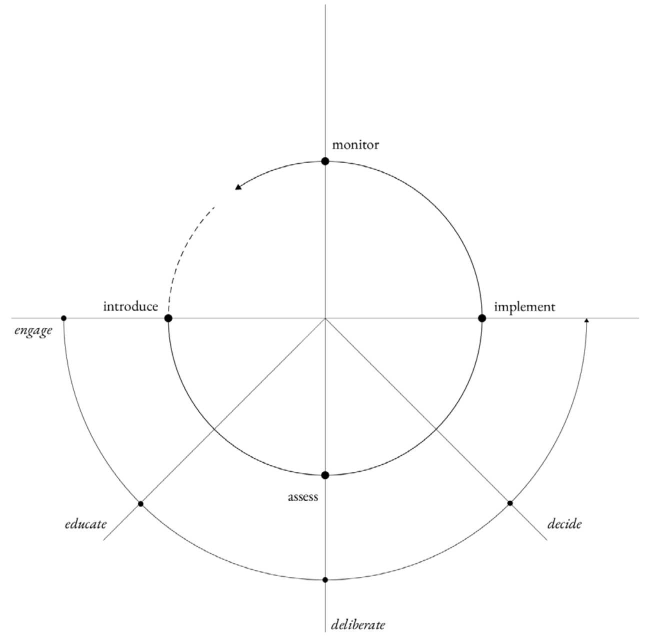


Figure 183. Explanation of cycle

○ tranfer station to new action

⊣ adaptation tipping point of action (terminal)

1 farmers
2 agricultural cooperations
3 agricultural unions
4 research institutions
5 NGOs
6 cultural center
7 local heads
8 local administration
9 ***local land and water management organisation***
10 **Thessaly water management organisation**
11 Thessaly Protected area management sub-unit
12 Thessaly protected area management unit
13 national government

The proposed transformative actions, comprised of biophysical and socio-technical measures, were systematically and spatially explored in the previous chapter, through the visualization of a "*maximized vision*" for the area through different scales and levels. However, in order for the desired transformation to be properly operationalized, it is necessary for these actions to be evaluated and phased within a specific timeframe. For this purpose, the tool of adaptive pathways was chosen, based on the Adaptation Pathways (AP) approach, adopted by the Dutch Delta Programme (Haasnoot et al., 2019). Adaptive pathways, consisting of a series of short-term and long-term actions, provide space for flexibility and adaptability within uncertainty and changing conditions, while also aiming to achieve set objectives (milestones). Consequently, a pathway map was created, showcasing possible routes and the complex relationships between different action groups (as elaborated in the *Transformative actions matrix*), as well as their timing of implementation. When an action reaches an adaptation tipping point and is no longer effective, it terminates and transfers to another action.

The originality of this diagram lies in the fact that the shape of a *circle* (or more correctly an ellipse) is adopted during the configuration of the pathways, instead of a simple line, henceforth described as *the cycle*. The cycle represents two things – a *cyclical process* for the implementation of a specific action, based on the Dynamic Adaptive Policy Pathways (DAPP) approach and steps (Walker et al., 2013) as well as its duration, depending on the length of the shape's horizontal axis. The process described is divided into four main steps – first the identification and *introduction* of the proposed action, followed by its *assessment* and subsequent *implementation* and finally though *monitoring* it is evaluated, initiating the next cycle of this process. Within the first semi-circle, another process involving local stakeholder integration takes place simultaneously, based on the "engage, deliberate, decide" approach (Daly et al., 2015 in Anderson et al., 2023), with the added step of "educate" between engage and deliberate. This approach recognizes the importance of relying on the local actors and understanding their perspective, in order to secure their trust and participation in the ongoing transition. Consequently, the public acceptance of the proposed transformative actions is enhanced, facilitating the *implementation* of the actions.

The chosen timeframe spans until the year 2075, the year 2025 marking the termination of the current condition and the implementation of the initial transformative actions. The pathways between action groups are expressed as "*cycles*" (as analyzed above), in order to highlight the duration of the process associated with their implementation. The related actors to those action groups – either bottom-up or top-down – are also showcased, along with which level of the integration process they correspond to. Therefore, some cycles are smaller and are located within other cycles, since some processes of implementation involving different stakeholders should take less time than others, but are still part of a longer integration process.

For example, a process for the implementation of agroecological practices is introduced immediately, involving larger-scale stakeholders such as research institutions, as well as engaging and educating people in agricultural cooperations, who will then translate and deliberate the proposed transformations with the affected farmers, for a decision to be made. Consequently, a series of smaller cycles starts then, highlighting the farmers' agency and control over the actions' immediate implementation, but also provides a shorter and longer timeframe for the evaluation of the related (co-)benefits to the specific measures, such as water conservation and soil health improvement, in order to transition to different practices if necessary. At the same time, during this process, other action groups are triggered – such as practices related to agro-pastoralism and planting vegetation.

Feedback loops between actors evaluating the results of the implemented actions happen every 10 years, while the first moment of official assessment will take place after 10 years, so in 2035, and then will continue with 20-year intervals. These moments of assessment function as a test to see how effective the proposed measures were in order to achieve the set objectives.

Figure 184. Agroecological practices - plain

Adaptation framework and recommendations

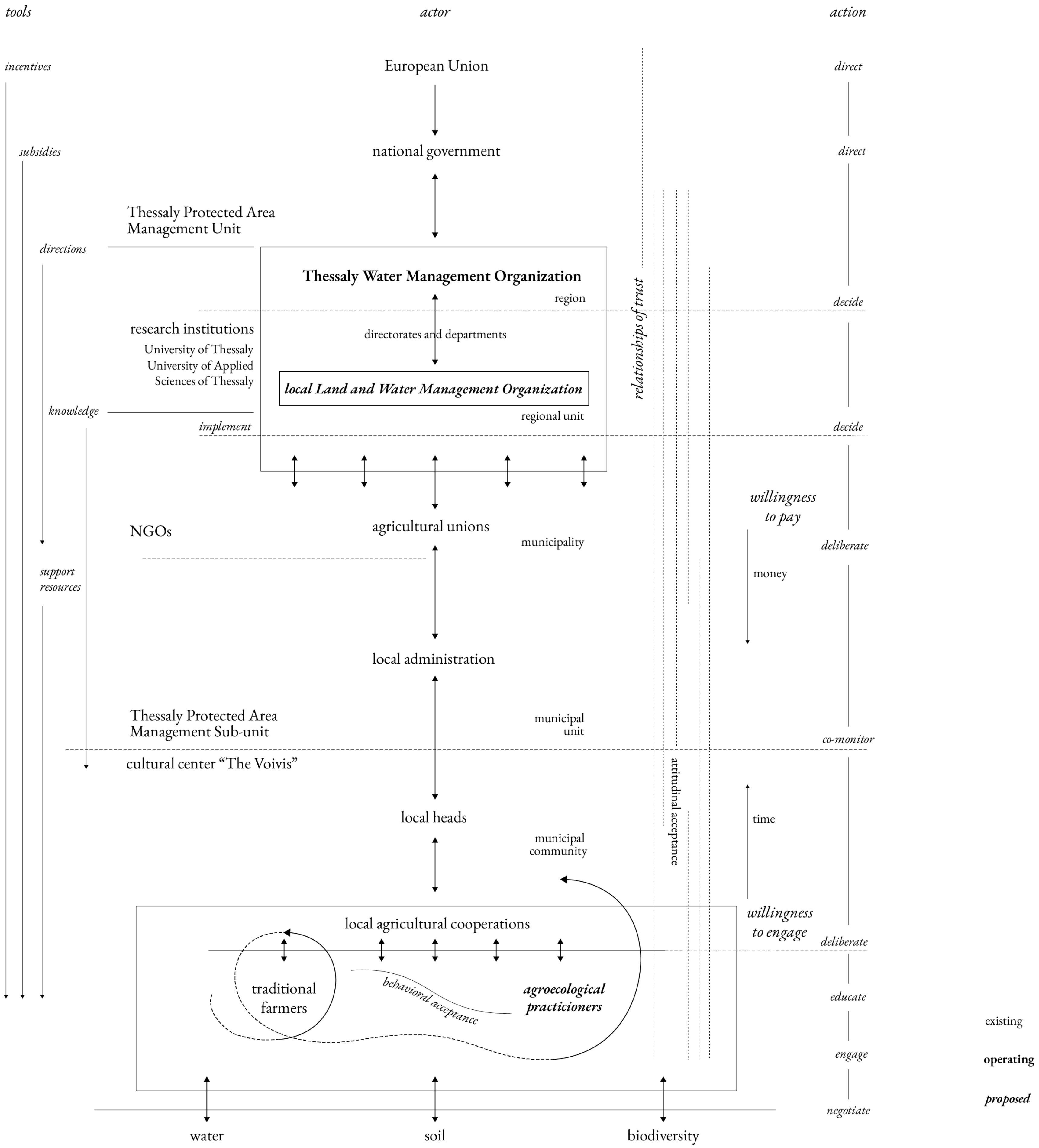


Figure 185. Adaptation framework

The adaptive pathways provide insights into the timing of each action group as well as the complex relations between them and the stakeholders directly related to each action. However, a very important component that is missing from this framework is the developing relationships between the different actors and the tools and actions facilitating the communication and alignment between the various governance levels. Therefore, the aim of this adaptation framework is to provide recommendations on how to achieve an effective governance system, bringing the agency of the local human and non-human actors in the forefront, while nurturing relationships of trust between them and higher-standing actors and ensuring the public acceptance and participation in the proposed transformation (Anderson et al., 2023).

Recognizing the connectedness existing farmers feel for the agricultural landscape is crucial. Promoting positive images of agroecology and regenerative agriculture, in relation to their benefits in enhancing the area's adaptive capacity to flooding – building upon the negative risk perception and intolerance, especially after the floods of 2023 – contributes to developing *behavioral acceptance*. This, in turn, increases the farmers' *willingness to engage* and educate themselves in agroecological practices.

For more effective communication and engagement, the use of existing community groups and actors is necessary (Daly et al., 2015). Therefore, the role of the local agricultural cooperations is amplified, promoting constant dialogue and deliberation between them and the transitioning farmers. The cooperations can voice the farmers' concerns and share their perspectives with the local heads within the community and the local administration within the municipal unit. On a larger scale, the agricultural unions deliberate with the respective Local Land and Water Management Organization, facilitating the communication between the directly affected stakeholders with the newly formed Thessaly Water Management Organization. This organization was formed after directions provided by the Dutch consultancy company HVA, and its main aim is to coordinate the water management activities for the Water District in order to ensure water safety, availability and sustainable use while taking into consideration social, economic and environmental circumstances of all related stakeholders (Draft Master Plan Water Management in Thessaly, 2024). However, the development of another intermediary actor that connects agricultural communities, cooperations and unions with the Water Management Organization is necessary. These are the *Local Land and Water Management Organizations*, functioning at the level of the regional unit. A similar scheme was proposed in the Plan for the Agricultural Development of Thessaly (Arapostathis et al., n.d.), named Agri-Food Transition Governance Center, with its main objective being ensuring the holistic constitution of an agri-food system for Thessaly. These two actors, working in unison and integrating knowledge, support and resources coming from research institutions and NGOs, as well as directions from the Thessaly Protected Areas Management Unit are tasked with making decisions on the implementation of the proposed transformative actions. The various developing relationships of trust between the actors operating on different levels contribute to the increase of public *attitudinal acceptance* (Anderson et al., 2023) and the *willingness to pay*. Therefore, the process of co-monitoring the transition with actors such as the Thessaly Protected Area Management sub-unit and the cultural center "The Voivis" is facilitated. Commitment to nature (soil, water, biodiversity), risk perception and intolerance, connectedness with the place and cultivating relationships of trust are the factors building behavioral and attitudinal acceptance (Anderson et al., 2023) in order to embrace this model of environmental co-management.

Initiating transitions on a local level, as well as creating communication and connecting processes with higher organizational levels can support a long-term transformation facilitating policy alignments. In this way then the local actors can *demand* action from larger institutions and governance bodies such as the European Union and the national government, in the form of financial incentives and subsidies.

Figure 186. Socio-technical measures

Figure 187. Agroecological practices - uphill

Figure 188. Wetland restoration

Figure 189. Trench 1, Kastri, December 2024

07| Conclusions

Conclusion
Reflection

Conclusion

This project proposes a methodological approach on how to utilize and enhance the operability of the water scarce eastern Thessalian plain in the event of flooding in the uncertain times of climate change, towards an evolutionary resilient future. The case study where this methodology is applied is Lake Karla.

The flood of September 2023 in Thessaly initiated my problematization about the topic of flooding, under the lens of water and land management, and how human-induced processes of alteration have rendered the system incapable of adapting to flooding. Then, following a thorough process, I defined the components of flood risk, which are hazard, vulnerability and exposure, and what they mean in the Thessalian context. Moreover, different systems and sub-systems related to these notions are examined and organized depending on their interrelations to determine whether they contribute to the biophysical or the socio-technical limits of Lake Karla's system, in the effort to identify the current coping and recovery capacities to flooding. Finally, a research methodology in how to utilize those limits to locate areas of criticality and transformability is proposed, with their superimposition outlining critical areas with a potentiality for transformation. Then, in order to expand the coping and recovery capacity of the system, a set of biophysical and socio-technical measures activating adaptive capacity is proposed, forming a strategy. The former are founded in ecosystem-based adaptation and expressed through soil and landscape-related nature-based solutions, and the latter focusing more on enhancing preparedness and learning capacity. Systemic and specific design explorations investigate the possible negotiations between agriculture, water and nature and a recommendation is made on the implementation and phasing of the proposed solutions. The overall aim of the project is to initiate a process of evolutionary resilience through environmental co-management.

Overall, the methodology introduced by the project brings together elements of risk and environmental management, performed through the lens of water and land management, as well as landscape ecology and design. Enhancing the adaptive capacity to flooding while simultaneously battling water scarcity with the implementation of nature-based solutions could be a widely transferable concept. Nevertheless, there needs to be contextual research which will inform the biophysical measures applied, as well as the necessary trade-offs that need to happen between natural and agricultural landscapes. A balance should be found between protecting people's livelihoods and avoiding compromising food security, while giving the necessary space to natural elements aiming to enhance resilience to flooding. Therefore, recommendations on their implementation through an adaptive framework which creates communication channels between the related actors are always necessary.

It should be recognized that the choices made throughout the project, especially when defining criteria for criticality and transformability – even though informed by the existing literature – they were set with the specific context of the eastern Thessalian plain and my knowledge about the Lake Karla system in mind. Consequently, this was a very contextual and intrinsic study, which should be taken into consideration when attempting to upscale the proposed implementations to the scale of the watershed and even transferring the results to other places with similar conditions.

Reflection

The project

The preliminary results of the graduation project showcase a new water and land management framework for an area battling flooding as well as water scarcity. This framework is guided by the values of Ecosystem-based Adaptation, utilizing nature-based solutions specifically regarding agroecological practices focused on soil health and landscape transformations focusing on water ecosystem restoration. The aim of the project is to develop the area's adaptive capacity to flooding upon its coping and recovery capacity, in order to enhance the system's evolutionary resilience to water extremes.

The process of the project emphasizes a proposed methodology for understanding risk and its components, as well as their systemic interrelation, and using this understanding to define biophysical and socio-technical limits of a specific area, which contribute to an identification of critical zones. Theoretical research, critical cartography as well as empirical research through site visits were utilized during the project. This approach draws on the expertise of environmental management, landscape design and landscape ecology. It was very interesting for me to discover that in both my bachelor's and master thesis, I gravitated towards marginal agricultural and peri-urban spaces, exploring how they can be transformed through the principles of landscape design.

The planning of the project focuses on adaptability, specifically proposing an implementation framework for the proposed transformative actions, starting from the local scale and moving towards the scale of the sub-basin and eventually the watershed. Necessary trade-offs need to happen between the different actors in order to reach a successful negotiation between nature, water and agriculture.

The final part of my graduation period will consist of finalizing the design explorations on the systemic, sub-systemic and specific scale, including visualizations that transmit the sense of the place created by the proposed transformative actions. Additionally, the adaptation framework and recommendations need to be further clarified, and the phasing and adaptive design pathways which is a part that is so far missing need to be developed. Finally, the expression of the visual material, as well as the remaining text need to be refined.

Mentoring and feedback integration

During my graduation year, I had the pleasure to work with two very inspiring mentors, who I had not worked before during my first year in the Urbanism master track. The insights and feedback provided were valuable and crucial to the development of my project. In their own different way, they both challenged me to think on different levels and embrace different perspectives, from the systemic to the specific, from the methodological to the intuitive, from the adaptive implementation to the actual experience of the place. All of this stimulated and triggered my mind into more complex patterns of thinking, which I am very grateful for. However, a struggle I had during the beginning stages of the project was to differentiate my expectations and desires from my mentors' expectations. I had to find the confidence to make my own decisions, but both of my mentors were empowering me and supporting me in this process, urging me to explore and expand my capabilities.

Furthermore, the presentation moments were also very important to me since they were the opportunities to come together with both of my mentors, present my project in a comprehensive manner, receive constructive criticism and identify alignments, leading to a meaningful discussion. Every time after a presentation, I reflected upon the feedback received, which then made me more capable of understanding it, digesting it and move forward implementing it in my line of work.

Consequently, this mentoring experience contributed immensely to the quality of my project yet also played a vital role in my independence and confidence as a designer.

Way of working, approach, methods and methodology

Throughout my graduation year, I reflected upon my way of working multiple times, also in regard to the approach of the project. It was a process of discovery and acceptance, finding a balance between exploring new methodologies and visual expression techniques as well as utilizing my already existing skills and abilities.

In retrospect, I recognize that setting a rigid research framework and project framing before properly delving into the "analyze" and "expose" – as well as "propose" and "politicize" – phases of my project was not entirely helpful for my progress. The setting up of the methodology should have been more balanced with the actual execution. However, I learned to identify where the direction of my project was not aligning anymore with the framework that I had set, especially during the "propose" and "politicize" stage, and accepted that it was constantly evolving and changing, which is part of the learning process. It was validating nevertheless to come back to my problem statement and research questions during my P3 and preparation for P4 moments and see that the core, values and theories the project was based on remained the same, only the framing of the project had changed drastically, following a more intuitive process that a strict methodology of scenario making and adaptive pathways, as originally planned.

In any case, I believe that it would have been more useful for me to start "executing" sooner, yet this mental block was caused also from thinking too much about the reality of the situation, the current plans and proposals, as well as the stance of the various actors. It was when I allowed myself to envision and imagine an alternate desirable future for the area – *a negotiation between water, nature and agriculture through agroecological practices and landscape transformations leading to sustainable water and land managemen*t – no matter how unrealistic, that I managed to "unlock" myself and come to a proposal that is made from the position of an urbanist, a designer expressing my personal values.

As for the methods used, literature and policy review as well as historical and spatial analysis proved vital to understand the current site-specific and contextual conditions, and the way they had been altered. Critical mapping was an important part of my project, bringing seemingly unrelated elements together that explored the overlay of the different components of flood risk (hazard, vulnerability, exposure) in order to define the biophysical and socio-technical limits of the system. Informal interviews and ethnographic fieldwork during my site visit helped me discover the local sensitivities as well as make implicit decisions for the possible adaptive transformations proposed. Research by design played a big role during my project, the one constantly informing and evaluating the other, a process that was enhanced by the constant back-and-forth between the different scales. This in itself was a process of discovery – exploring the design implementation on a smaller scale informed my decisions on a bigger scale, regional and systemic. The Dynamic Adaptation Pathways were used as a tool for phasing and evaluation, along with Ecosystem Services Assessment for the proposed nature-based solutions.

Research and design

One of the most important personal achievements of working on this project was the fact that I was able to combine research and design, with the research informing my design decisions and then, during the design process, discovering elements that needed further investigation.

In particular, my initial theoretical research and analysis of the components of flood risk guided the critical mapping exercise of criticality and transformability, where an implicit design decision was made about the most important elements, thus validating the site selection. It was at this point that I realised that I had already made unconscious design decisions that influenced the scope of my analysis. Then, during the fieldwork, I had the opportunity to visit the selected area, where additional information about local knowledge and current practices was revealed to me, leading me to reflect on the knowledge I had gained from the literature review and to go back and extend my research. Research on nature-based solutions was also conducted when deciding on the most appropriate transformative actions for the area, which were then implemented when designing through the scales. Throughout this process I kept discovering things that needed to be explored further, whether through research or reference projects.

Therefore, there was a constant back and forth between the two disciplines of research and design, with research initially guiding the design, then implicit design guiding the analysis in search of validation or rejection of my choices, and finally research and design coming together at the stage of my proposal, with design taking the lead in shaping the desired spatial qualities and research supporting and testing the applicability of the solutions.

Relation to studio topic

The Transitional Territories studio focuses on the topic of "Altered Nature: Poetics of Change", specifically dealing with the dynamic interplay between altered landscapes and the projected future of territories, highlighting how human-induced development and exhaustive consumption of resources are unsustainable in the long run, during times of climate change.

My graduation project topic can be directly linked to those themes since the former floodplains of Thessaly function as large operational landscapes of the primary sector, providing not just for the region but are of national importance. The intensification of agriculture in the Thessalian plain in order to increase production has led to processes of terraforming, specifically the drainage and subsequent restoration of Lake Karla, which result in extreme consequences in cases of natural disasters, specifically flooding. Often, these processes are not a product of ignorance, but of deliberate manipulation of natural systems. The plains have been reclaimed and reconfigured and the water system and water cycle have been manipulated and appropriated by human actors in the Thessalian plain in order to support the productive agricultural landscapes. Nature has been constructed and deconstructed, often ignoring the local knowledge and "site-specific histories of more-than human ecologies" (Muñoz Sanz and Katsikis, 2023). Consequently, the saturation of the natural ecosystem has led to the loss of the landscape's generative capacities, which combined with the rapidly changing climate patterns are resulting in the increase of the flooding risk in the area.

The goal of my project aligns with the overall aim of the studio to imagine alternative futures through transformative actions that demand a paradigm shift in mentalities, reaching a state of environmental co-management. Specifically, my project thoroughly focuses on the examination of conditions (spatial, material, socio-environmental) defining limits that define spaces of potentiality for transformation – the critical zones – and then uses those spaces to test transformative actions guided by nature-based solutions that enhance the area's resilience to flooding while preserving the local values of human and natural ecosystems.

Relation to Urbanism master track and MSc AUBS master programme

My project is also related to the Urbanism master track since it examines the situated conditions of the area of Thessaly, and how their alterations has resulted in this form of spatial organization. These conditions concern systems such as – among others – geomorphology, hydrology, land and water management and the human habitat. It is true that this is not an urban project, but my reasoning for this is founded in the notion that these agricultural – formerly floodplains and wetlands – landscapes are part of an urbanization process. Finally, the relation to the MSc AUBS master programme is that this project deals with the human and "built" (specifically constructed and de-constructed) environment, adopting a multi-disciplinary approach, while incorporating elements of agroecology and landscape design that aim for a more sustainable future of the region of Thessaly.

Societal relevance

This project's societal relevance lies in the way local sensitivities are recognized within a flood risk and water resource management framework. Specifically, it aims to protect the livelihood of the local communities which rely heavily on agriculture; therefore, also contributing to Greece's food security. Furthermore, the societal relevance is also highlighted with the effort to align local adaptation practices with centralized land management policies, through an explorative design proposal that is informed by both, yet also aims to reframe them, catapulting a paradigm shift that will lead to a more sustainable and evolutionary resilient future to water extremes, addressing short term and long-term challenges. All of this is calibrated under the lens of an ecosystem-based adaptation, recognizing and supporting the dynamic relationship between human and natural ecosystems. Finally, achieving environmental co-management is directly contributing to the survival and well-being of both human and non-human actors.

Scientific and professional relevance

This project's scientific relevance is expressed through the effort to provide a new understanding of risk literature, analysing the disciplines of hazard, vulnerability and exposure. Specifically, this project is trying to assess Thessaly's flood risk through the examination of physical, environmental, social and economic conditions and alteration processes they have undergone, in order to define the system's limits (biophysical and socio-technical). The proposed methodology of overlaying the spatial manifestations of those limits with the aim to define the potentialities for transformation and then testing possible nature-based solutions with site-specific design implementations in various scales could provide a contribution to the current research for climate change adaptation from the lens of urban planning and could also inform resilient models for integrated water resource management, which simultaneously contributes to soil health and ecosystem restoration. Consequently, this methodology tested through this case study could provide a future reference for urban planners of an innovative framework for adaptive planning.

Limitations

Even though this project aims to provide a meaningful contribution to climate adaptation studies, it does not come without limitations. Firstly, it is a complex project conducted within a year by only one person, so it is only natural that not all its aspects are examined completely, and some assumptions are made by default. Furthermore, a significant aspect that I need to consider is that data available are not always up to date or correct, which might lead to some misleading results of the analysis. Additionally, it is impossible to exactly predict and evaluate the needs and desires of such diverse groups of actors, and it is reasonable that not all the societal nuances are able to be considered and translated into the project. Finally, this project, however thorough the research and analysis that has been conducted to support it, remains a subjective interpretation and iteration upon the theme of adaptation to flood risk and water scarcity.

Ethical considerations

There is also a number of ethical considerations regarding this proposed graduation project. Firstly, it is necessary to take into account the affected communities and ensure that the outlined strategies are just and equitable, with a specific focus on the local cultural sensitivities and their position within the land and water management policy frameworks. It is imperative to make sure that the trade-offs and negotiations are evenly distributed among stakeholder groups, but it is impossible to make everyone satisfied. Furthermore, it is important to preserve the integrity of non-human actors and make sure that they are treated with the same care as human actors, in order to avoid the further exhaustion and degradation of the natural systems, fostering environmental justice and biodiversity protection.

Transferability

Even though this project is site-specific, there are multiple overexploited agricultural areas worldwide combating extended periods of water scarcity with extreme events of flooding. Therefore, even though the specific design interventions are not directly transferable, the methodology of defining the biophysical and socio-technical limits and identifying the critical zones through a set of criteria of criticality and transformability is. Furthermore, the implementation of nature-based solutions in order to enhance the resilience of a natural system to climate change is also not something new, or unheard of. The key lies in identifying which solutions are applicable in which location, a decision made after research and examination of the current conditions and the risks each specific area faces.

Personal development

Besides my development as an urbanist, this graduation year played a crucial role in my personal development as an individual. Throughout the whole year I struggled with managing stress and perfectionism, which caused mental blocks that hindered my progress, especially in the beginning. As the year went on, I started to recognize the patterns within myself that led me in these stagnant situations and how to get out of them. Understanding the importance of mental health, rest and interpreting the learning process not as a straight but a fluctuating line, helped me disengage from harmful patterns that I had adopted in the past. Recognizing personal limitations, accepting them, and eliminating guilt was what actually contributed to my productivity, moved me forward, and helped me expand my abilities and knowledge. Completing this degree, I have not only matured as a designer, but as a person as well, and it is only fair to say that I am equally proud of my academic accomplishments and my personal growth.

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Geodata.gov (http://geodata.gov.gr/dataset/)
Global ML Building Footprints (https://github.com/microsoft/GlobalMLBuildingFootprints?tab=readme-ov-file&fbclid=IwY2xjawLDr9VleHRuA2FlbQIxMABicmlkETBMRW9MYXNYcEFvbnNpSDhNAR6DrrEGLgyejD6Vq9AtDxL6qe9phSjUKz9zuQvF35oggW6i-Rlfs4c4psK8aw_aem_PixySqoEBF2C2VsdS7QbNw)
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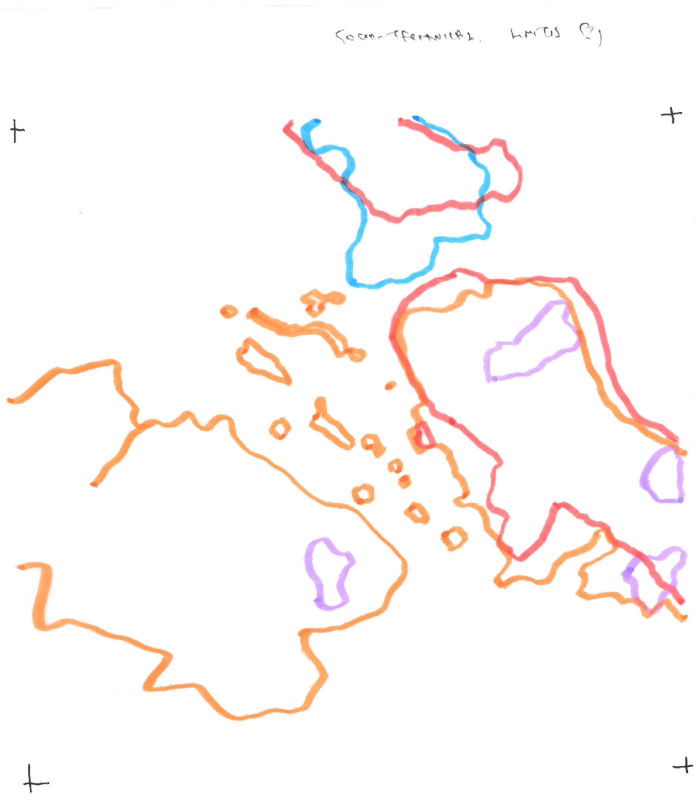
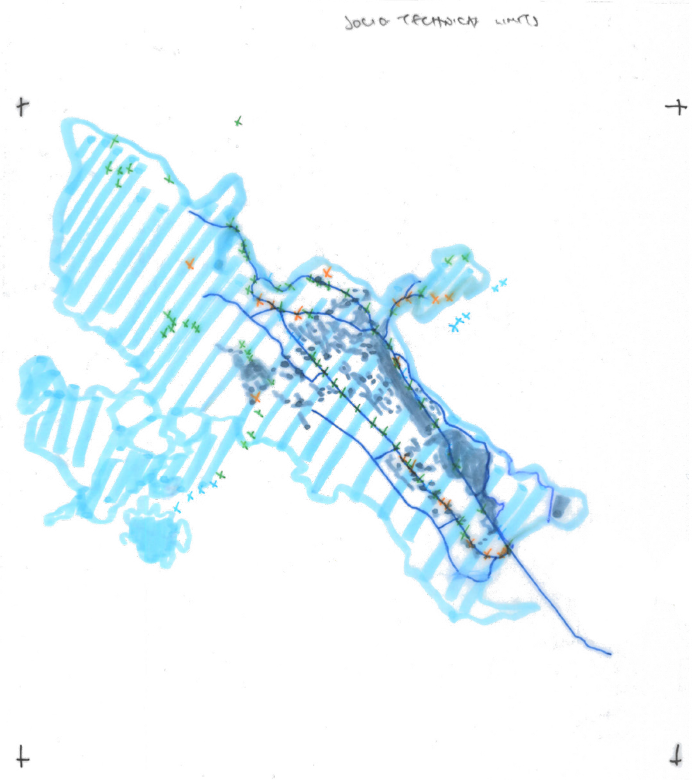
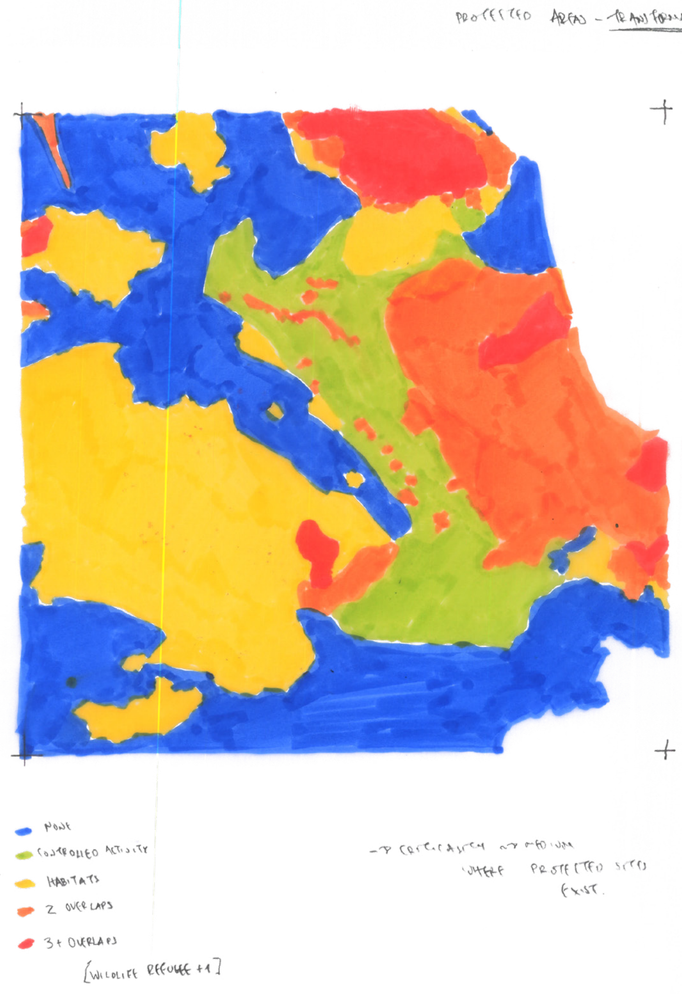
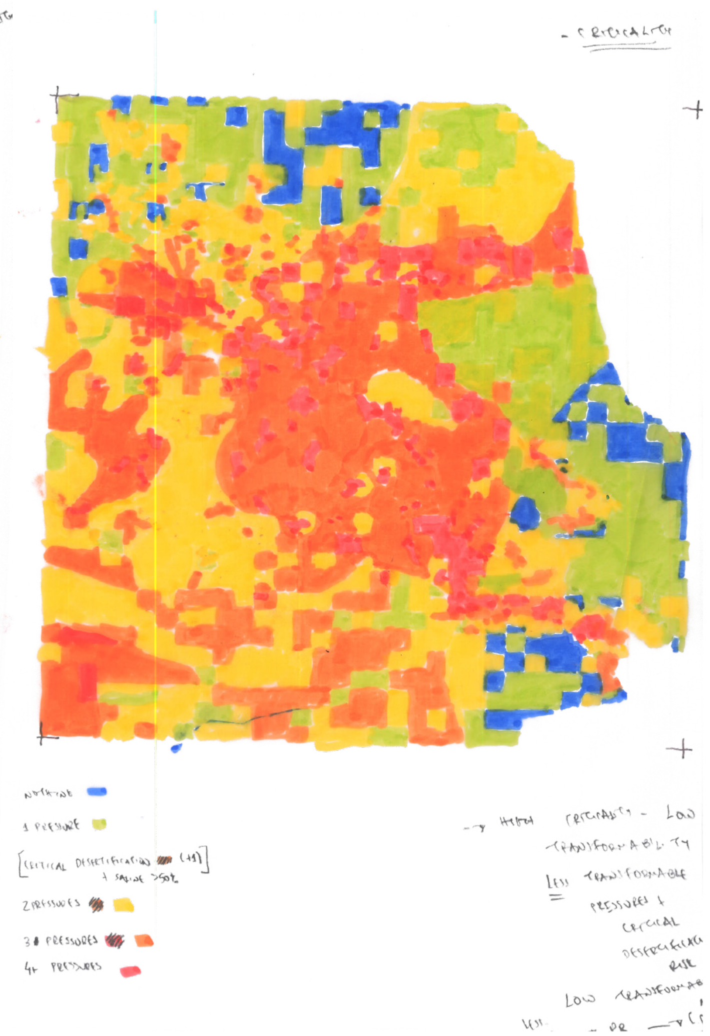
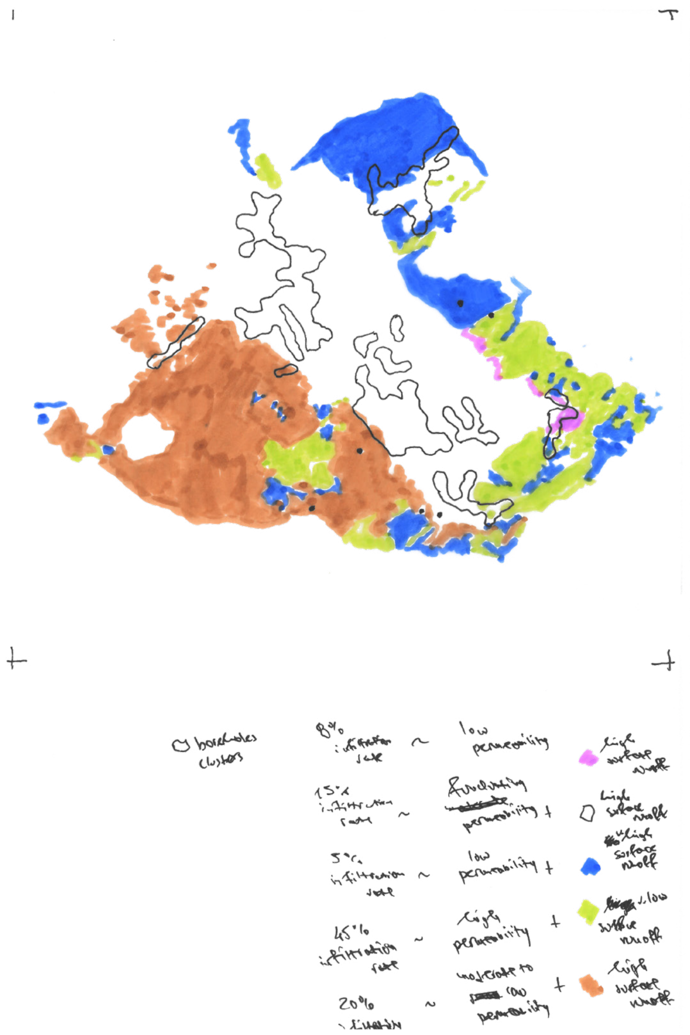
Appendix

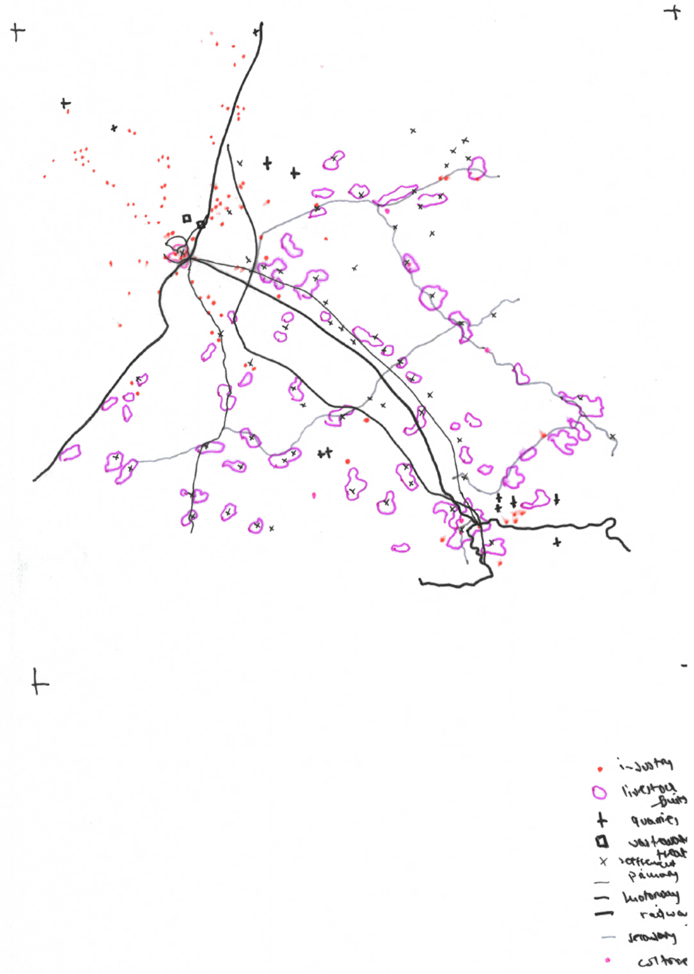


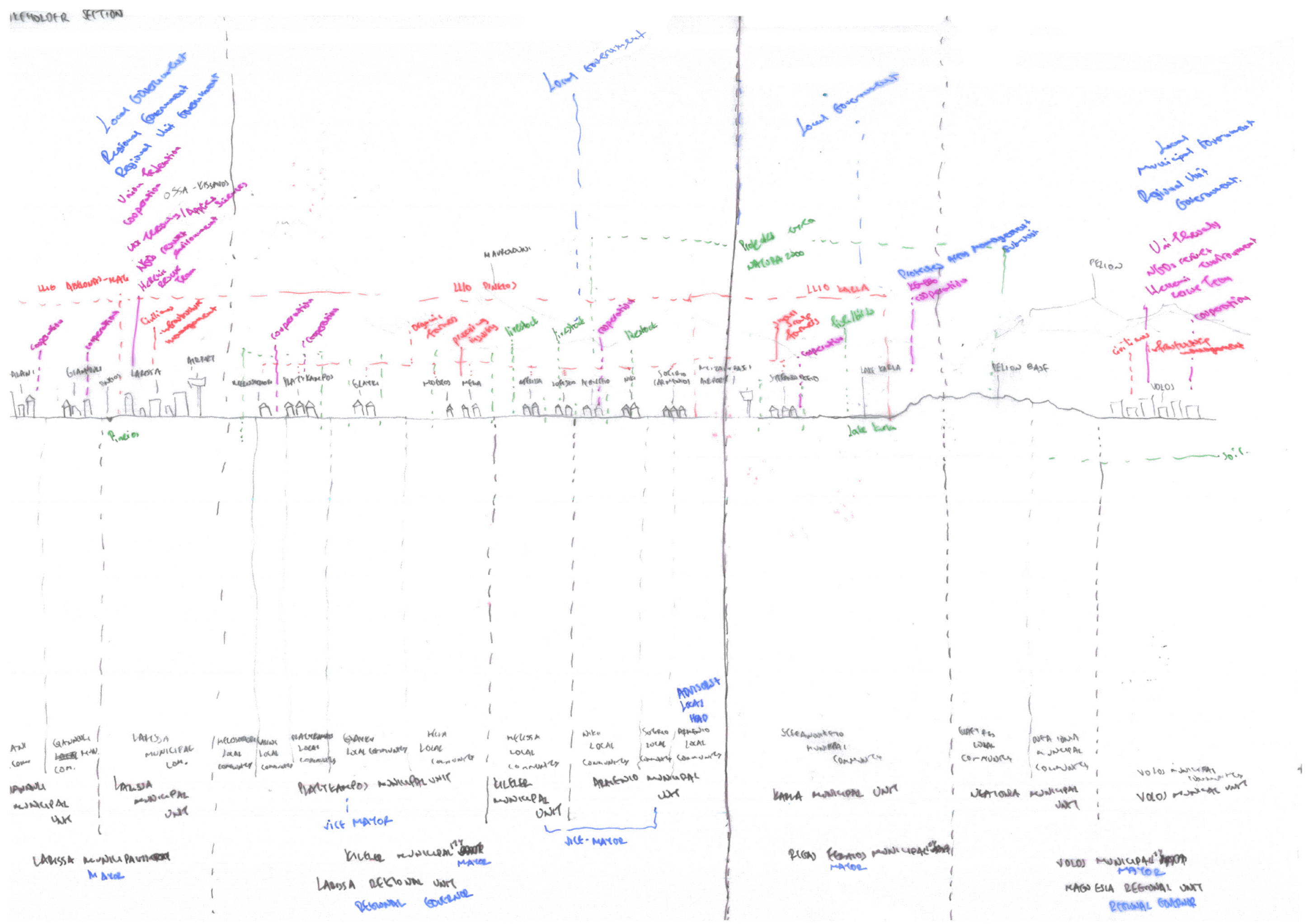


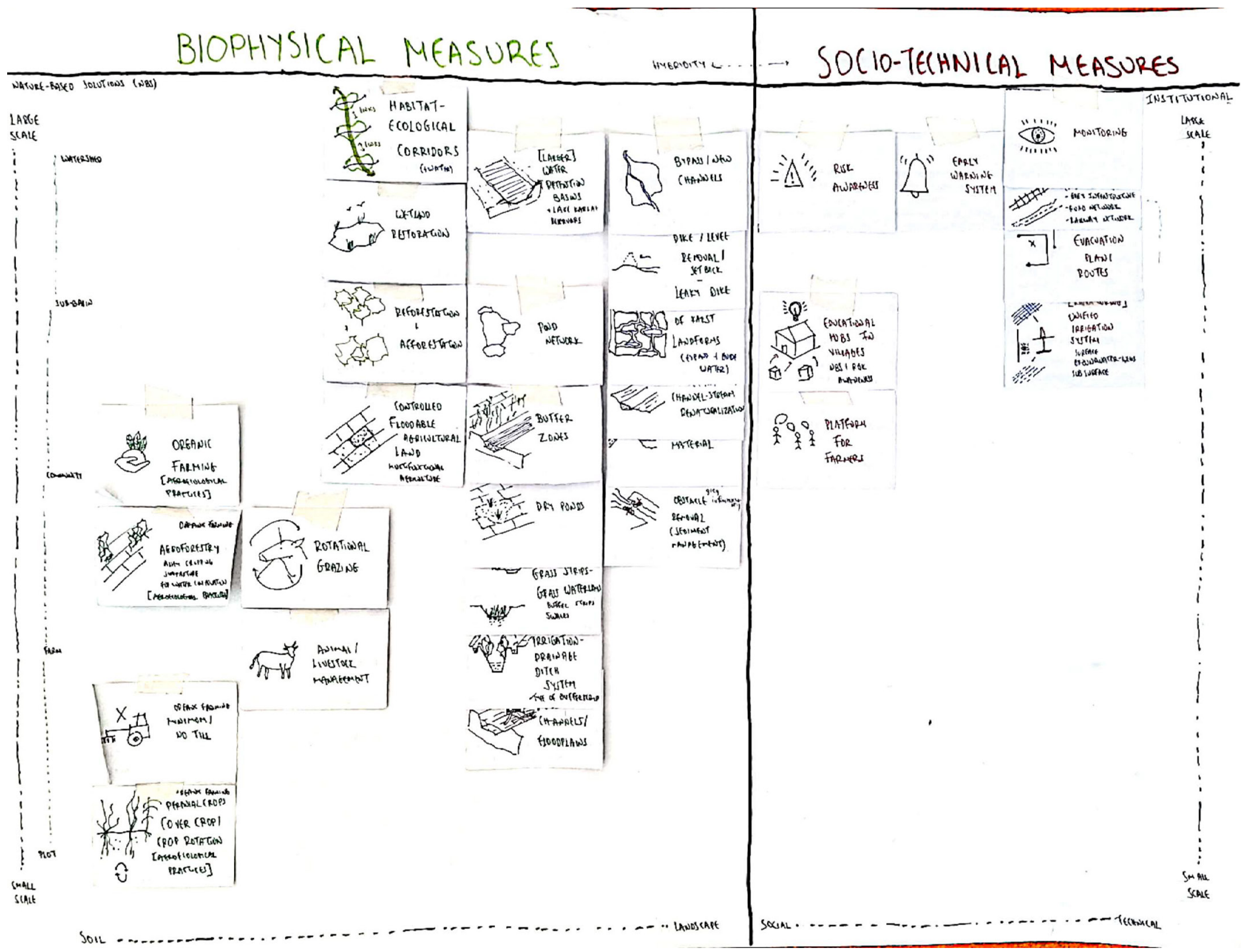

NONE
CONTROLLED ACTIVITY
HABITATS
2 OVERLAPS
3+ OVERLAPS
[WILDLIFE REFUGE +1]
PROTECTED SITES
EXIST.


NOTHING
1 PRESSURE
2 PRESSURES
3 PRESSURES
4+ PRESSURES
HIGH CRITICALITY - LOW TRANSFORMABILITY
LESS TRANSFORMABLE
PRESSURES +
CRITICAL
DESERTIFICATION
RISK
LOW TRANSFORMAB

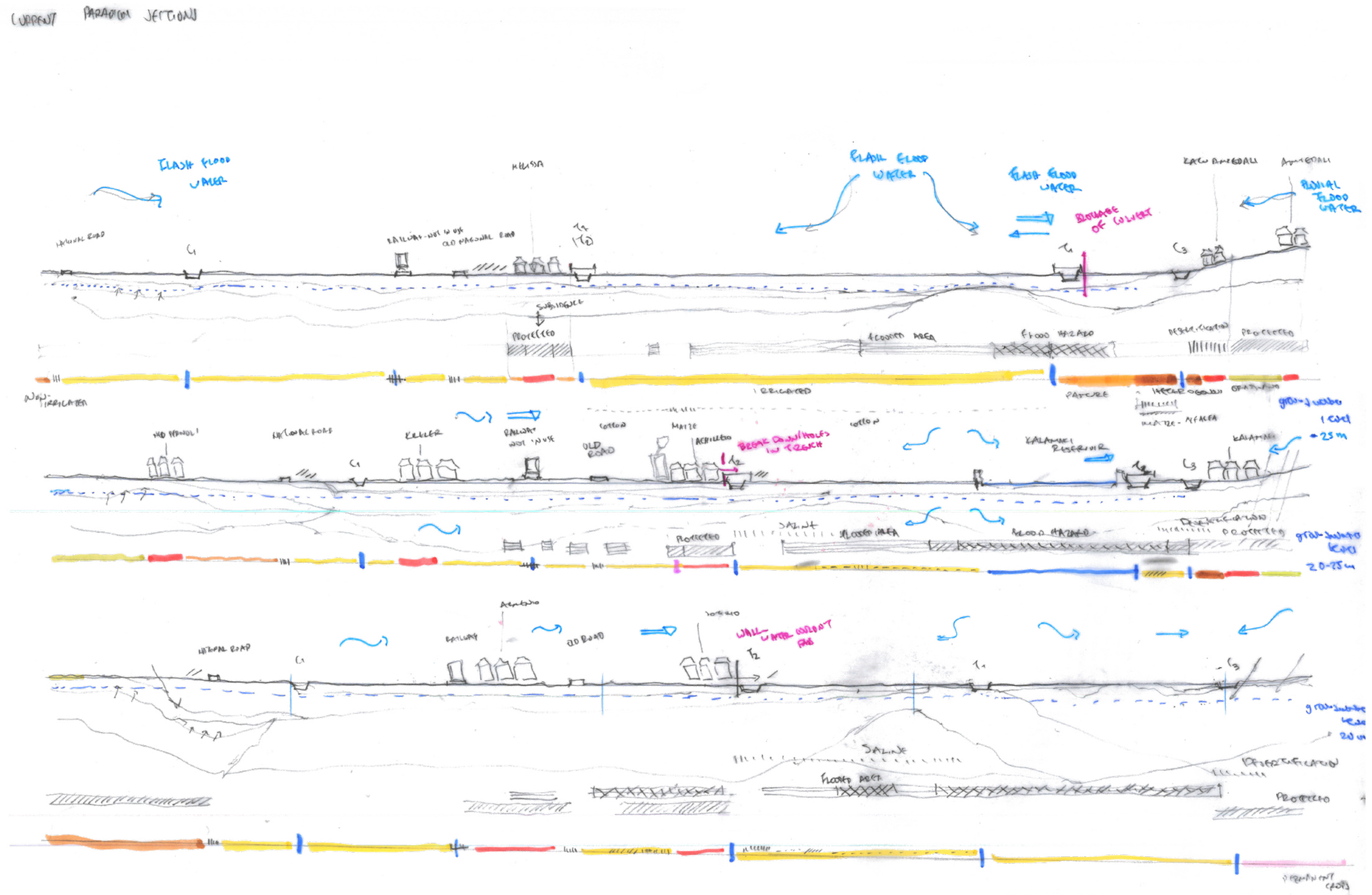

boreholes clusters
8% infiltration rate ~ low permeability
high surface runoff
15% infiltration rate ~ fluctuating permeability +
high surface runoff
5% infiltration rate ~ low permeability +
high surface runoff
45% infiltration rate ~ high permeability +
low surface runoff
20% ~ moderate to low permeability +
high surface runoff

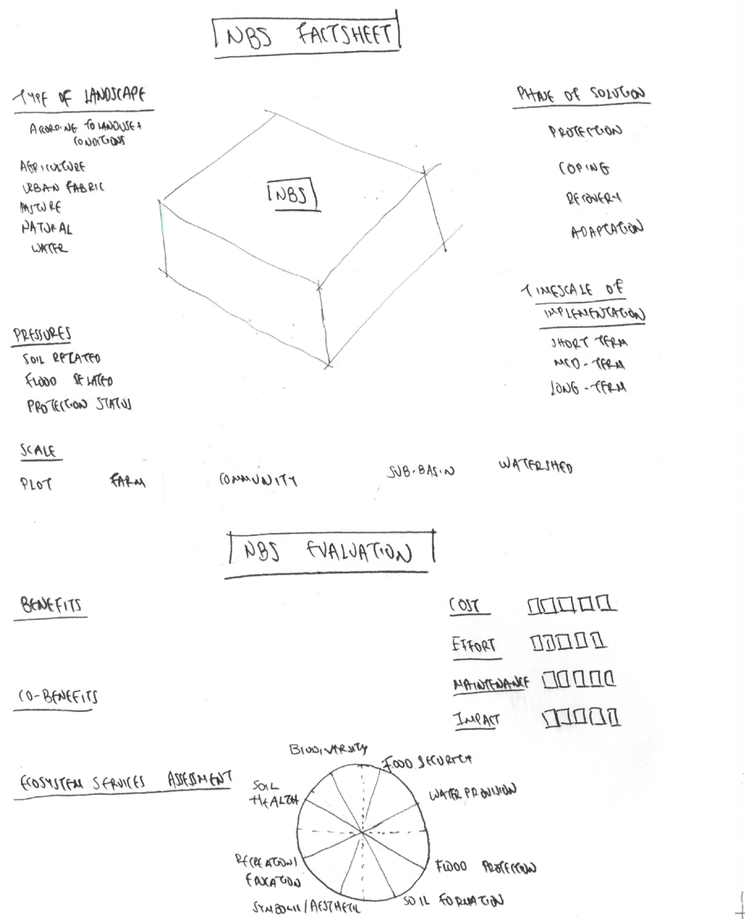

industry
livestock
quarries
settlement
primary
motorway
railway
secondary



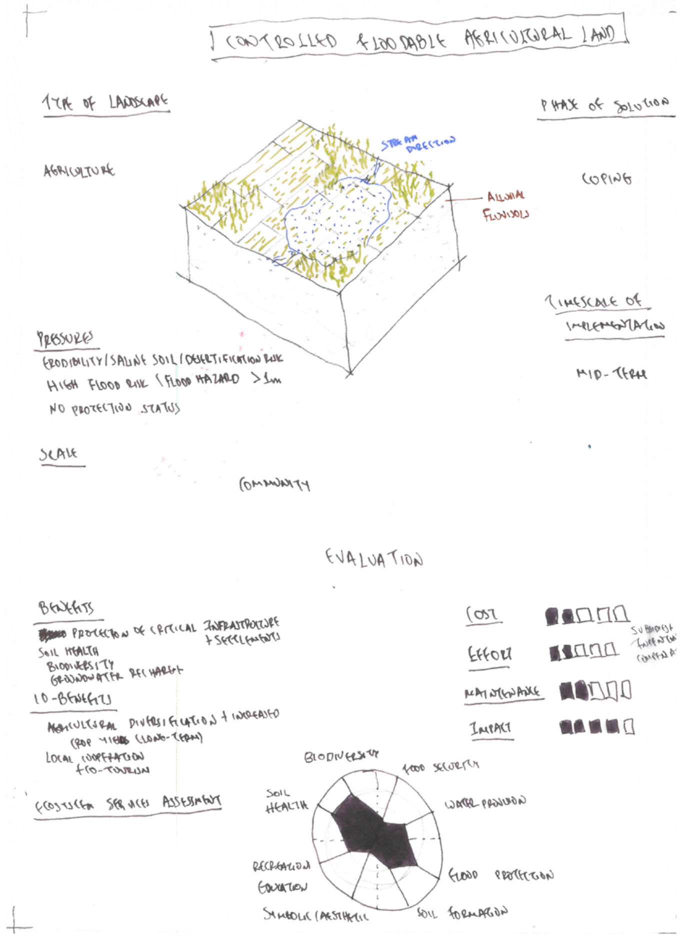


BIOPHYSICAL MEASURES
SOCIO-TECHNICAL MEASURES

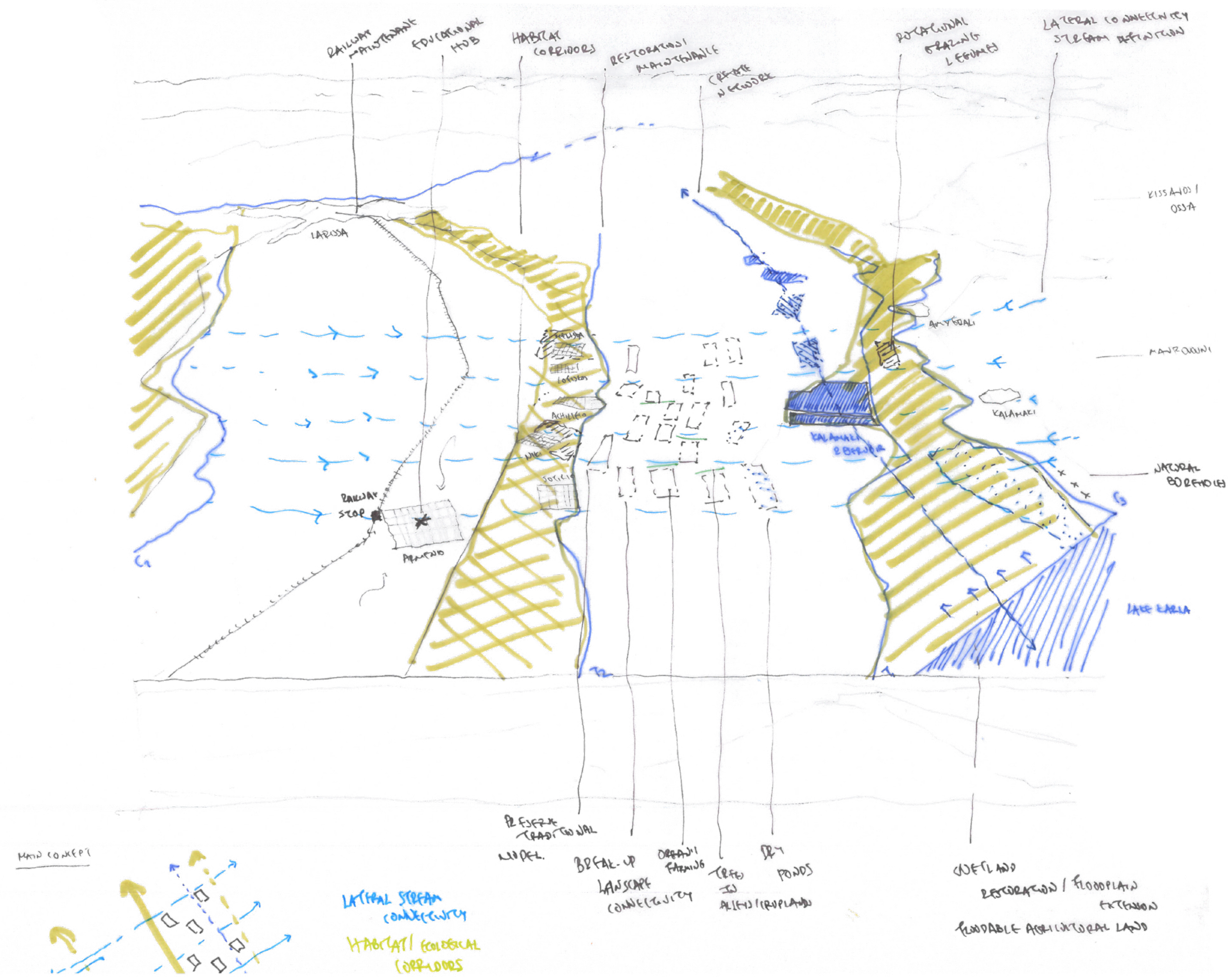


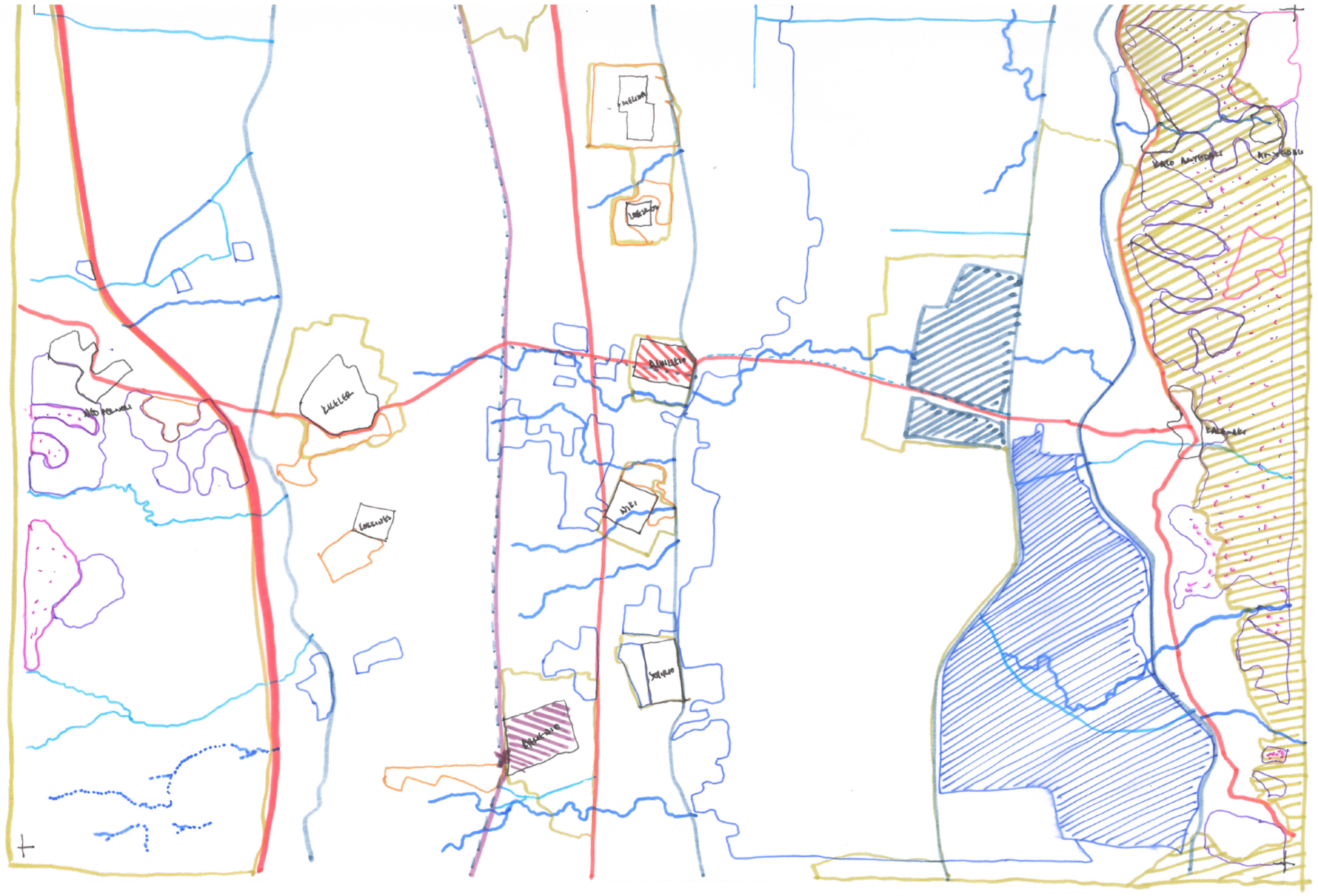


NBS FACTSHEET
NBS EVALUATION



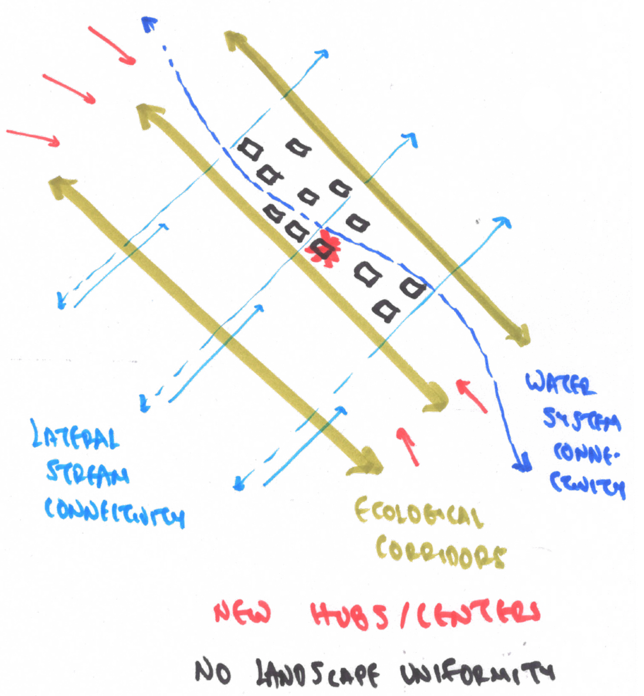
CONTROLLED FLOODABLE AGRICULTURAL LAND
EVALUATION





CONCEPT

OF VISION



PRINCIPLES

→ TWO PRODUCTION MODELS (OF AGRICULTURE)

PRESERVATION OF CURRENT TRADITIONAL MODEL — SLOWLY TRANSITION OUT

TRANSITION IN → AGROECOLOGICAL PRACTICES + ORGANIC FARMING ⇒ SOIL-RELATED NBS

PRODUCTIVE BUT NOT INTENSIVE ······→ POST-PRODUCTIVE

SUSTAIN → INTRODUCE

MONITOR → STRENGTHEN

* AVOID LAND CONSOLIDATION

[* NO LARGE-SCALE GREY INFRASTRUCTURE]

→ CONNECTIVITY

HABITAT - ECOLOGICAL CONNECTIVITY

STREAM LATERAL CONNECTIVITY

WATER SYSTEM CONNECTIVITY

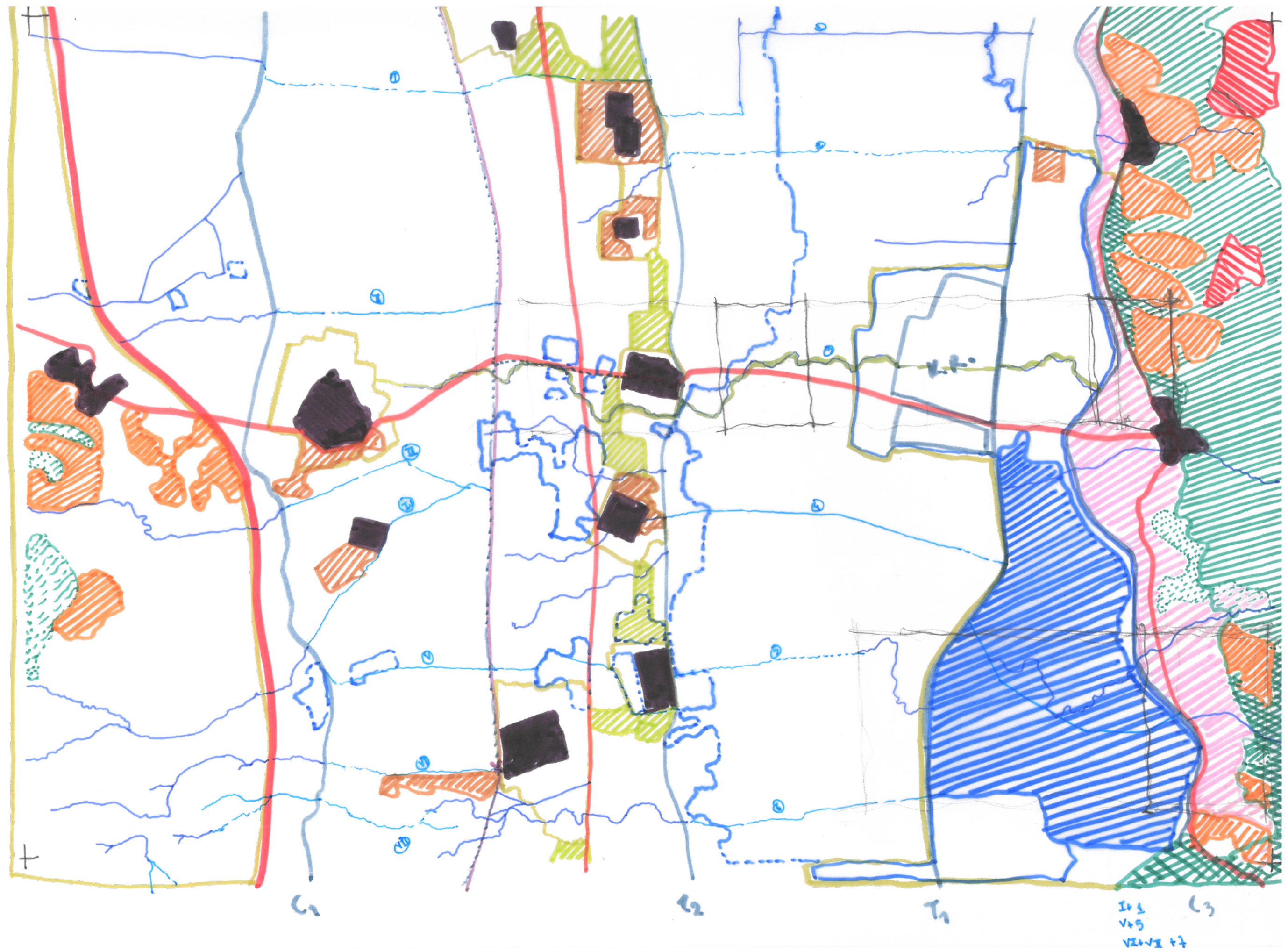
⇒ LANDSCAPE-RELATED NBS

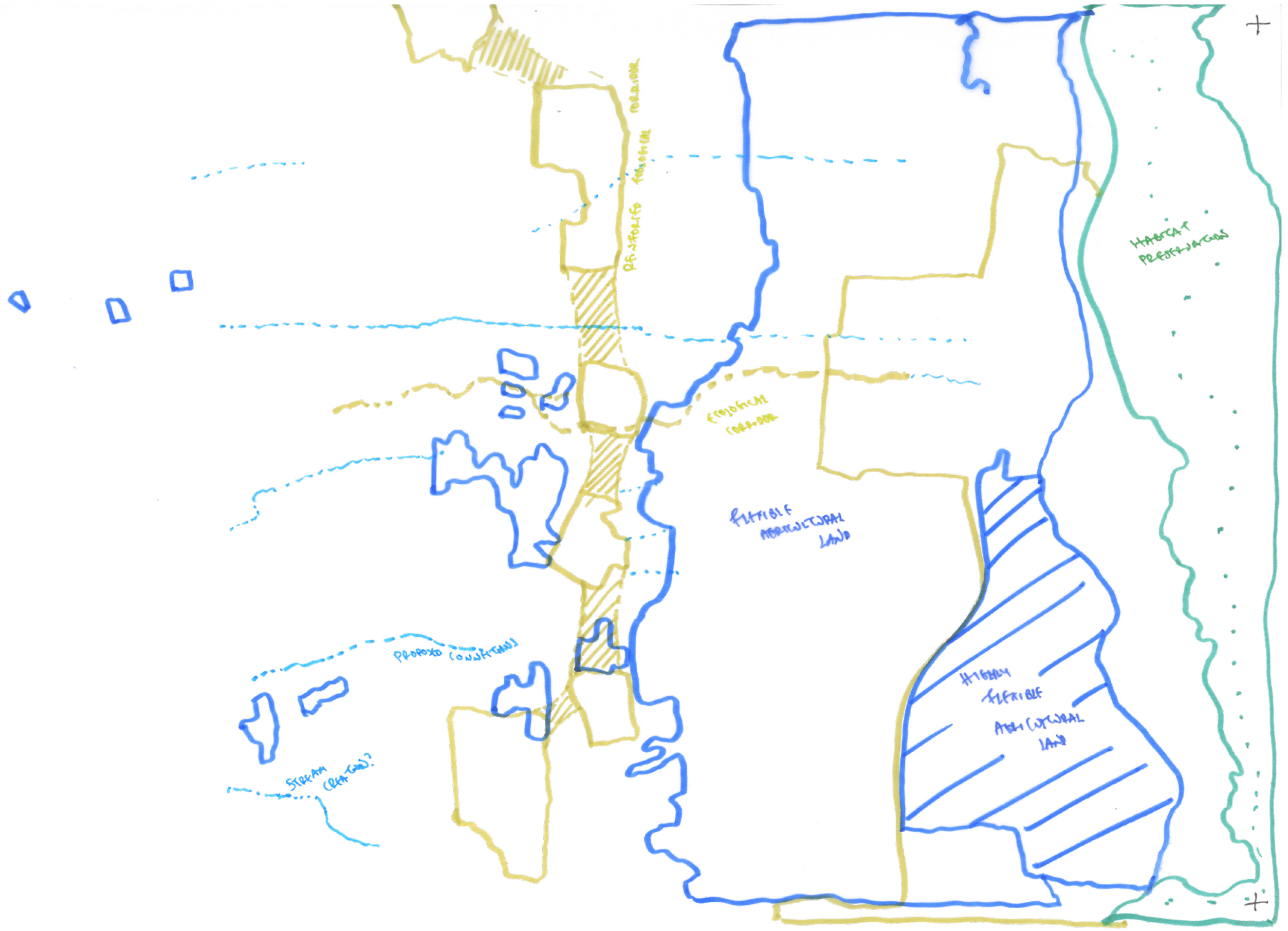
→ LANDSCAPE DIVERSIFICATION

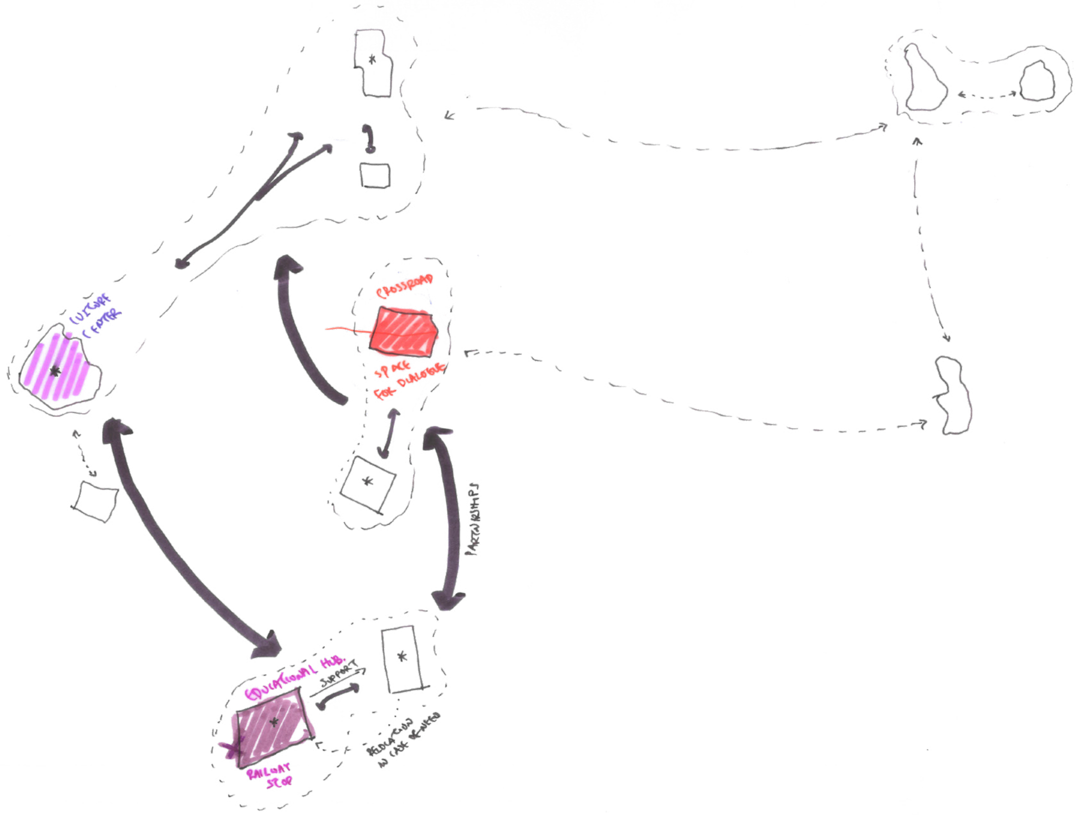
BREAK-UP LANDSCAPE UNIFORMITY + CONNECTIVITY

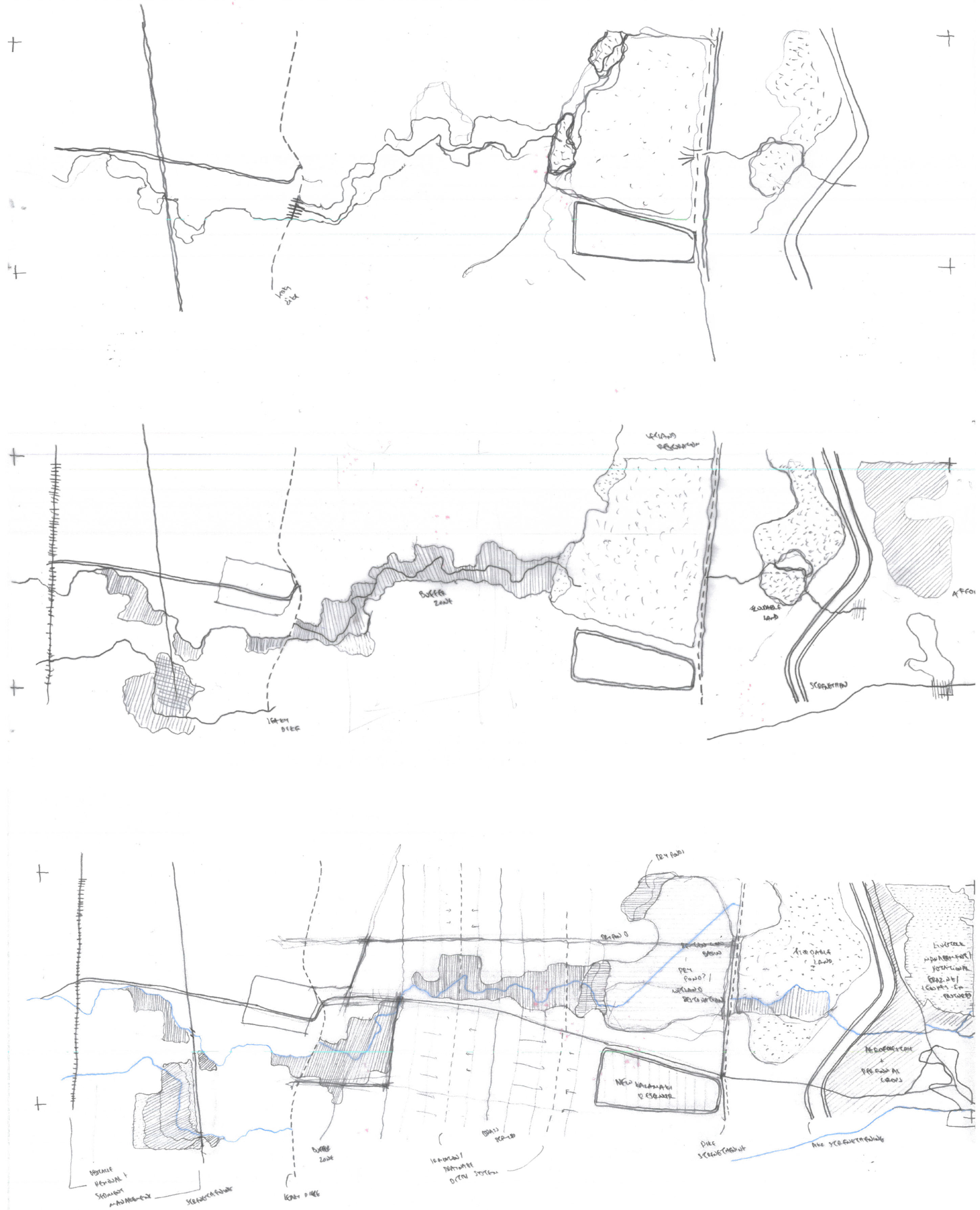
→ DECENTRALISATION + RURAL DEVELOPMENT

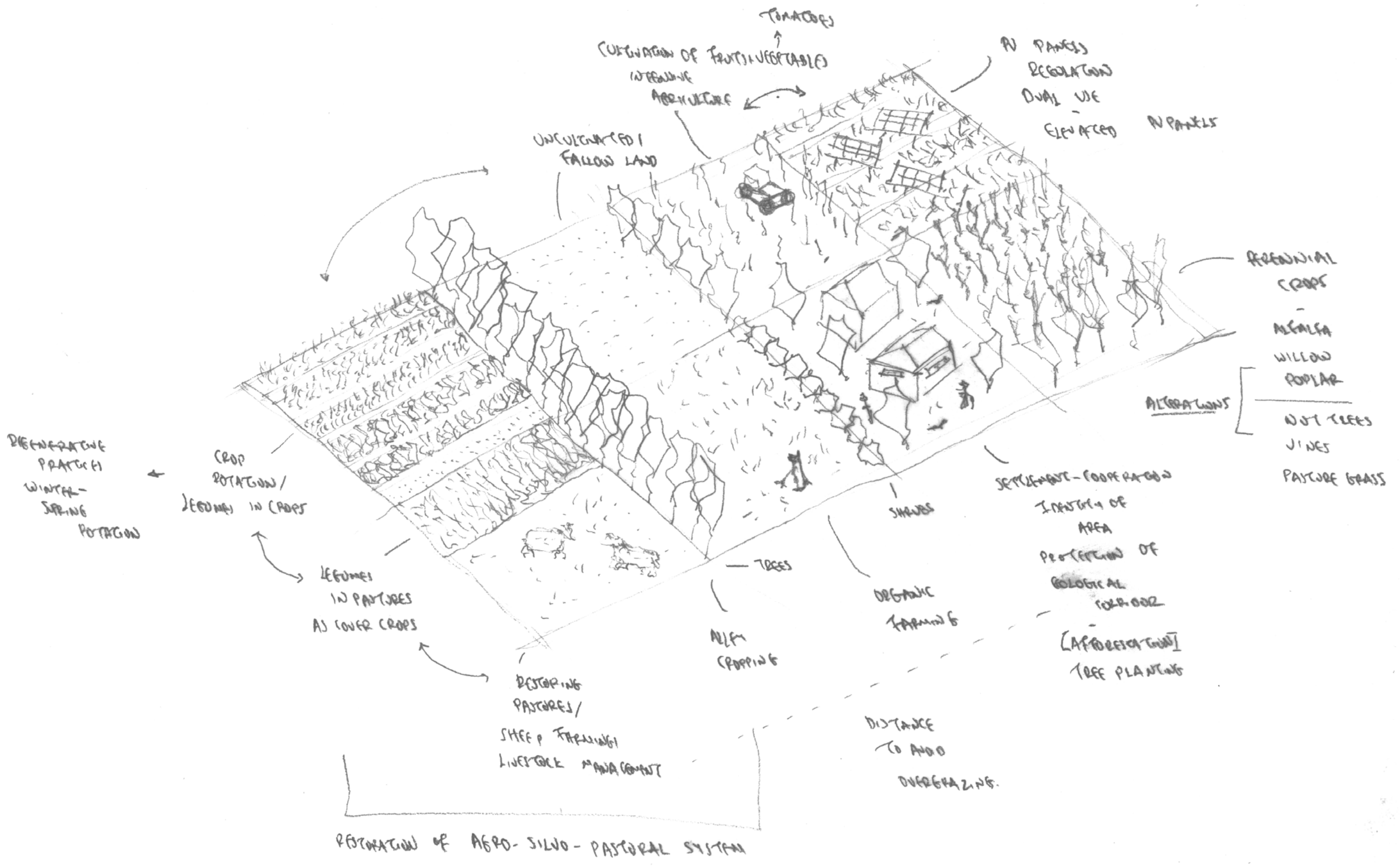
CREATE NEW CENTERS + HUBS

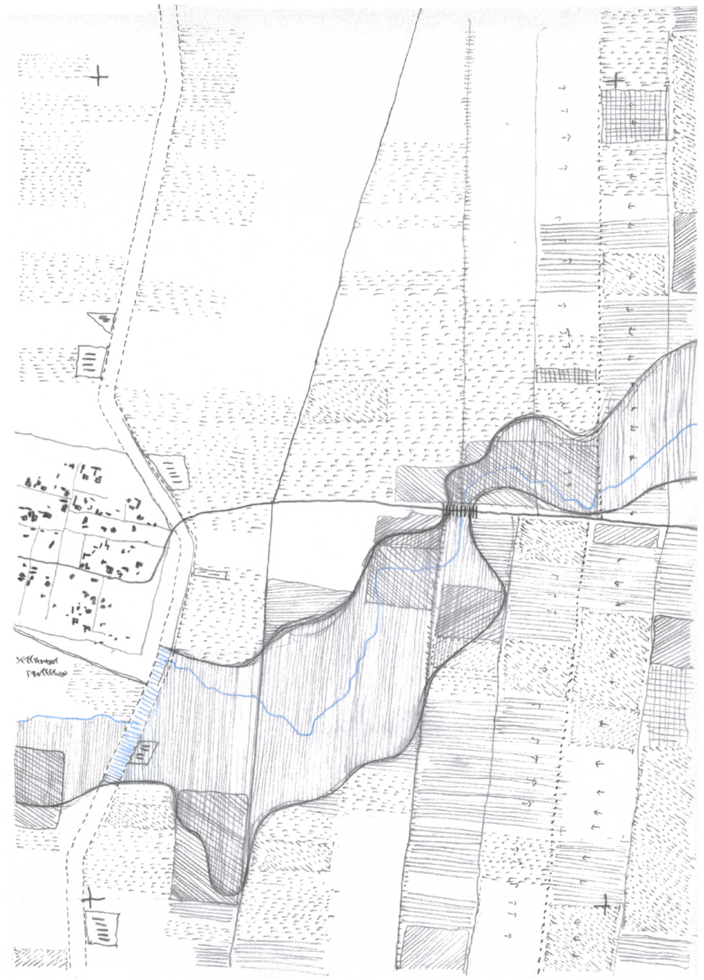


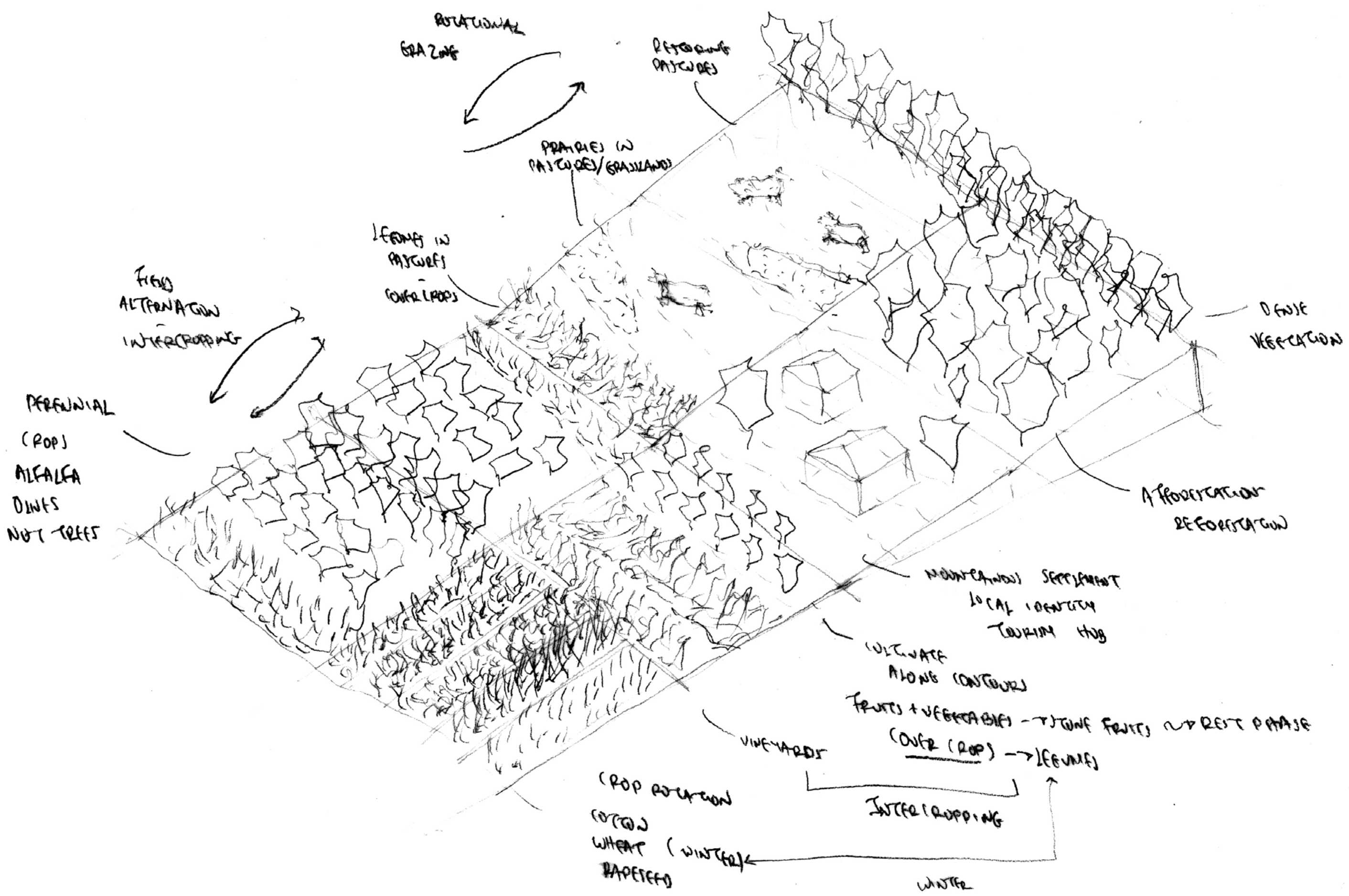

ECOLOGICAL CORRIDOR
HABITAT PRESERVATION
FLEXIBLE AGRICULTURAL LAND
HIGHLY FLEXIBLE AGRICULTURAL LAND
PROPOSED CONNECTIONS
STREAM (CREATION)?

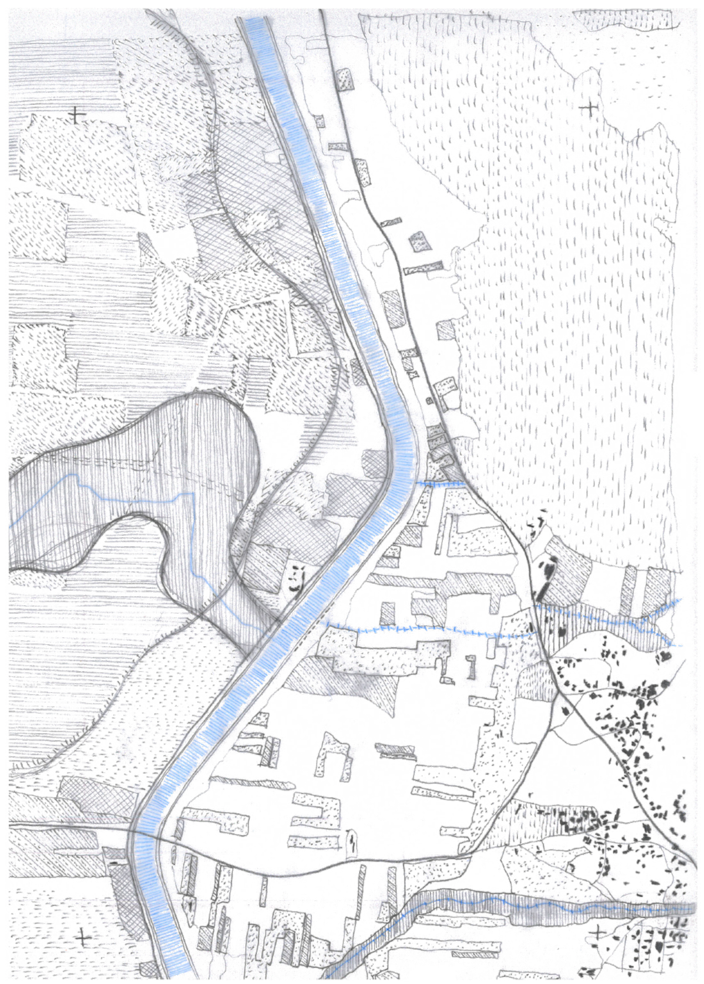

CULTURE CENTER
CROSSROAD
SPACE FOR DIALOGUE
PARTNERSHIPS
EDUCATIONAL HUB.
SUPPORT
RAILWAY STOP
RELOCATION IN CASE OF NEED

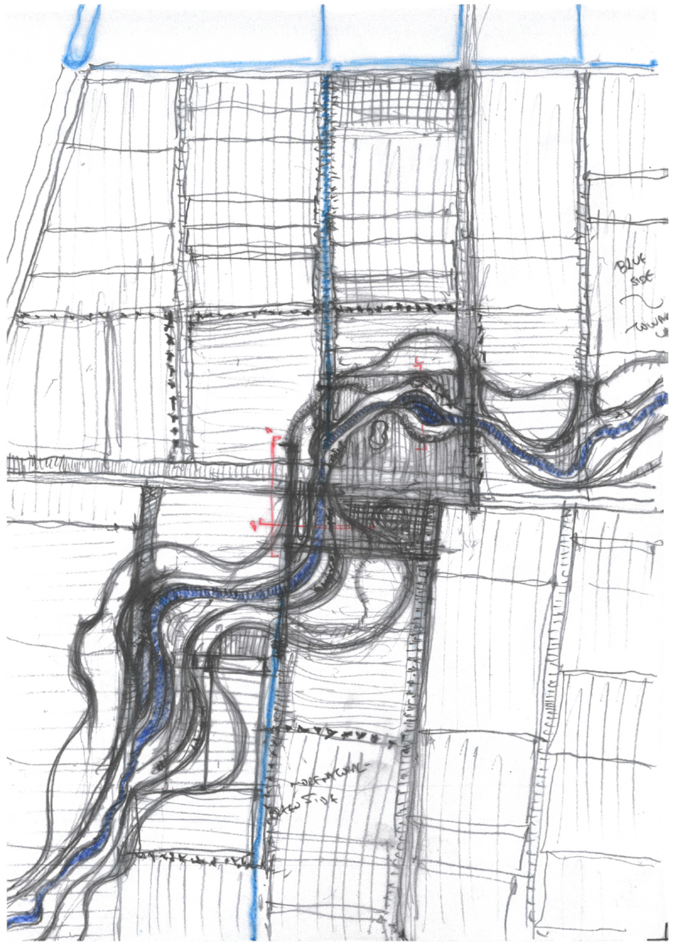


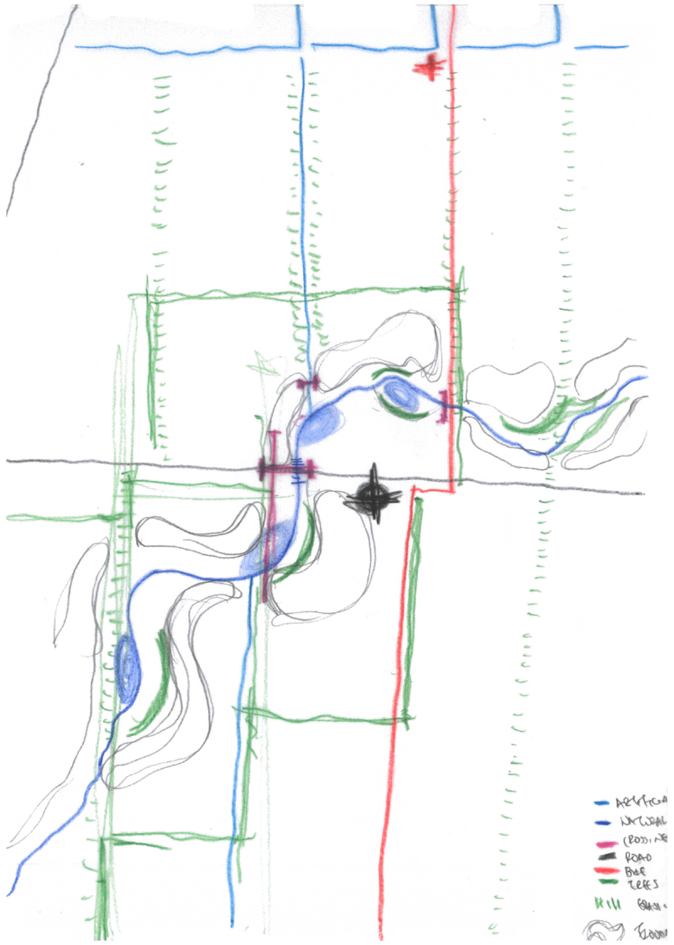

Tomatoes
Cultivation of fruits/vegetables
Intensive agriculture
PV panels
Regulation
Dual use
Elevated PV panels
Uncultivated / fallow land
Perennial crops
Alfalfa
Willow
Poplar
Alterations
Nut trees
Vines
Pasture grass
Regenerative practices
Winter-spring rotation
Crop rotation / legumes in crops
Legumes in pastures as cover crops
Shrubs
Settlement - cooperation
Identity of area
Protection of ecological corridor
[Afforestation]
Tree planting
Trees
Organic farming
Alley cropping
Restoring pastures /
Sheep farming /
Livestock management
Distance to avoid overgrazing.
Restoration of agro-silvo-pastoral system

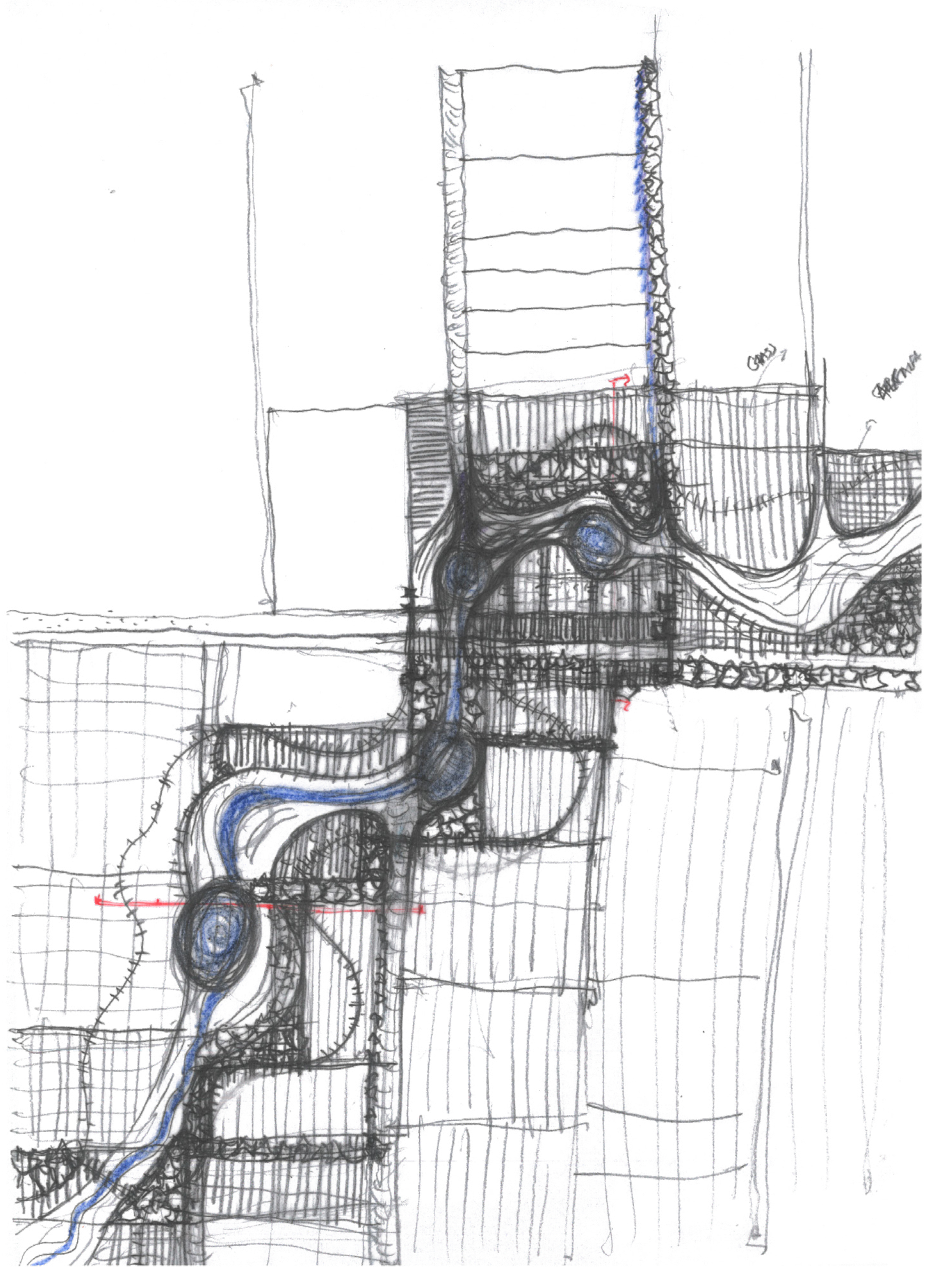


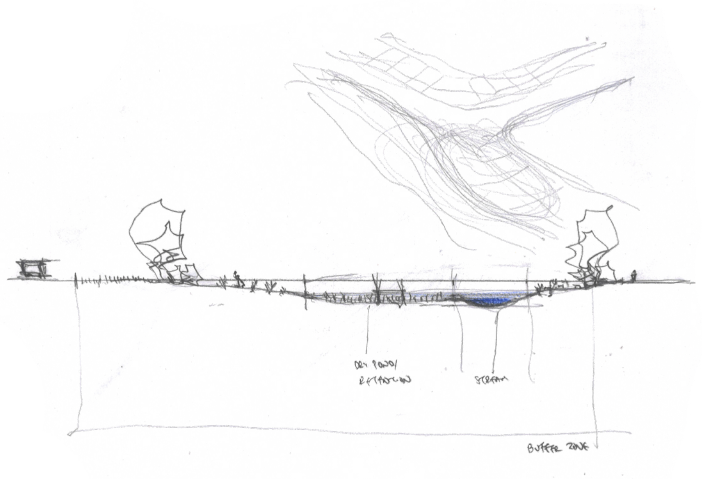

Rotational grazing
Restoring pastures
Prairies in pastures/grasslands
Legumes in pastures
Cover crops
Field alternation
Intercropping
Perennial crops
Alfalfa
Vines
Nut trees
Dense vegetation
Afforestation
Reforestation
Mountainous settlement
Local identity
Tourism hub
Cultivate along contours
Fruits + vegetables - stone fruits → rest phase
Cover crops → legumes
Vineyards
Intercropping
Crop rotation
Cotton
Wheat (winter)
Rapeseed
Winter

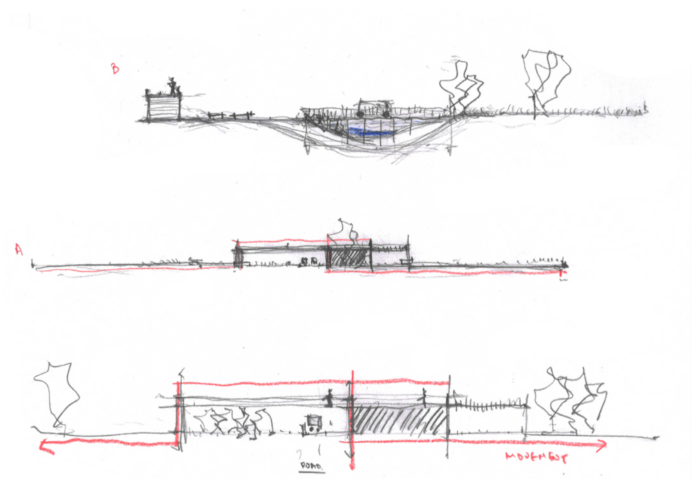


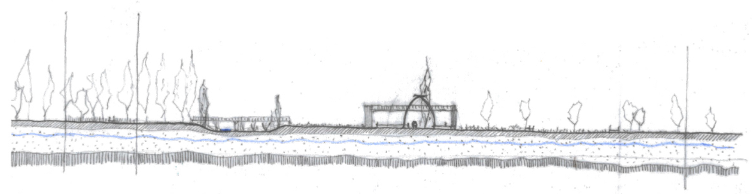


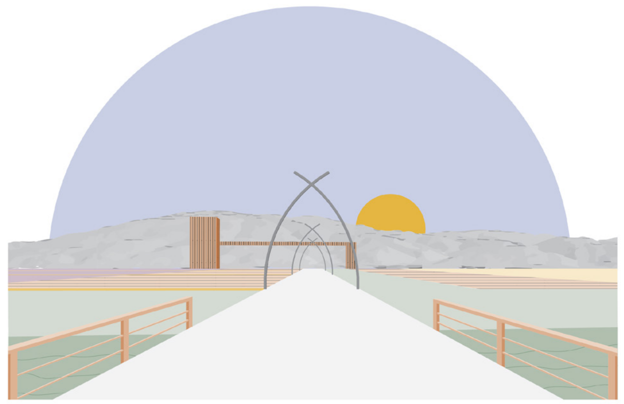


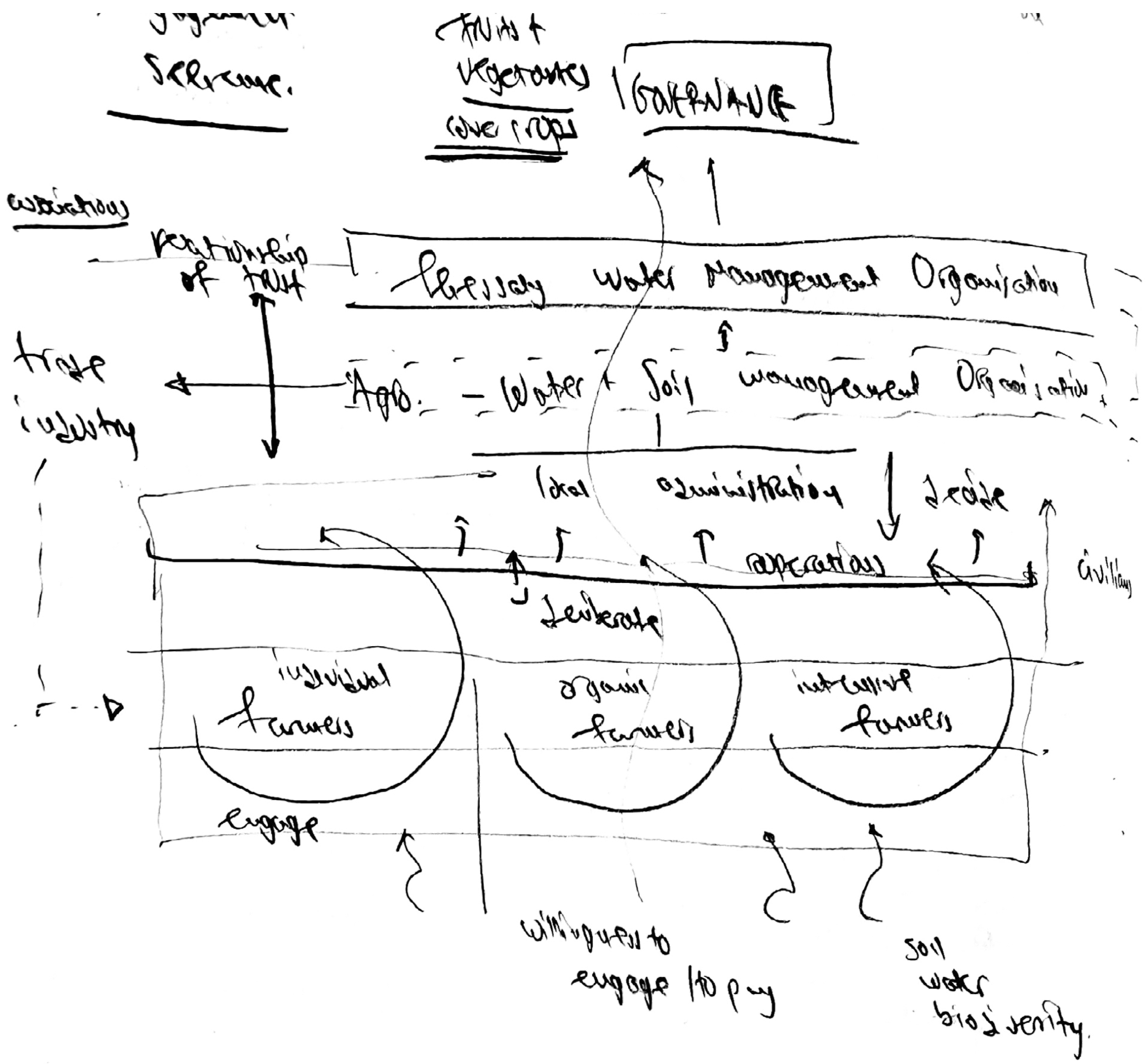











GOVERNANCE
Regional Water Management Organisation
Agri - Water + Soil Management Organisation
Local administration
individual farmers
organic farmers
intensive farmers
engage
unwilling to engage / to pay
soil
water
biodiversity