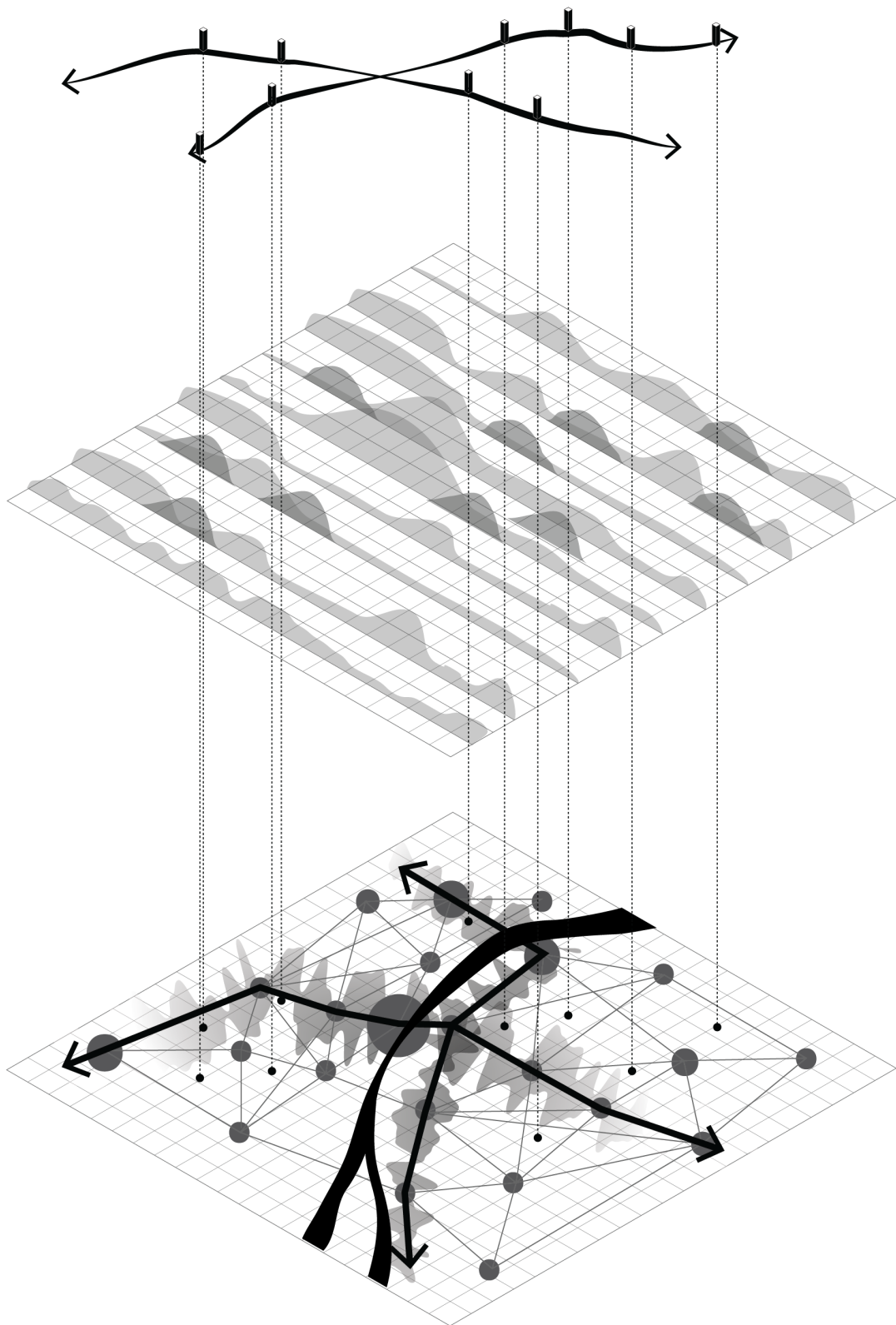




VISIONING INDIAN AGRO-URBANISM

Futuring Indian agricultural system paradigms for food sovereignty, security, and justice

Aparnaa Chandrasekaran

Graduation Project Report
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COLOPHON

VISIONING INDIAN AGRO-URBANISM

Futuring Indian agricultural system paradigms for food sovereignty, security, and justice

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Critical Environments: Material Ecologies of Care

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*Appa (Chandrasekaran), Amma (Laxmi), and Prashant
thank you for always supporting me and making me an achiever..!*

GLOSSARY

Agro-climatic zone: Region defined by climate, soils, and agricultural conditions.

Agro-ecological urbanism: Planning approach integrating ecological processes and agriculture into urban development.

Agro-park: Cluster combining farming, processing, research, and agricultural logistics.

Agro-urbanism: Planning paradigm positioning agriculture at the centre of urban futures.

Agriculture 4.0: Digital farming using automation, sensors, AI, and data technologies.

APMC mandi: Regulated wholesale market linking farmers, traders, and agricultural buyers.

Automation commons: Shared technological infrastructure collectively owned and managed by farmers.

Biodynamic farming: Holistic farming system emphasising ecological balance and natural cycles.

Capitalocene: Framework attributing ecological crisis to capitalist accumulation and expansion.

Cold chain infrastructure: Temperature-controlled systems for storing and transporting perishables.

Critical cartography: Mapping practice revealing power relations and spatial inequalities.

Degrowth: Approach advocating reduced consumption within ecological and social limits.

Double-burden: Simultaneous presence of malnutrition and obesity within populations.

Ecological corridor: Connected habitat supporting species movement and ecological processes.

Ecological justice: Fair distribution of environmental benefits, burdens, and responsibilities.

Food sovereignty: Communities' right to control food systems and production.

Green Revolution: Agricultural transformation driven by improved seeds, irrigation, and inputs.

Groundwater mining: Unsustainable groundwater extraction exceeding natural recharge rates.

High-yielding varieties (HYV): Crop varieties bred for maximum productivity under intensive cultivation.

Kharif season: Monsoon cropping season from June to October in India.

Metropolitan food cluster: Urban agricultural zone integrated within metropolitan economies, developed by Wageningen Metropolitan Food Clusters.

Minimum support price (MSP): Government-guaranteed minimum price for selected agricultural commodities.

Monoculture: Cultivation of a single crop across large areas.

Multi-criteria decision analysis (MCDA): Method evaluating alternatives using multiple decision criteria.

Pareto-front: Optimisation method balancing performance across competing objectives.

Permaculture: Agricultural design system modelled on natural ecological processes.

Planetary urbanisation: Theory describing urbanisation extending beyond traditional city boundaries.

Public distribution system (PDS): Government programme distributing subsidised food to households.

Riparian buffer: Vegetated strip protecting waterways from runoff and erosion.

Saltwater intrusion: Seawater encroachment into freshwater aquifers due to over-extraction.

Scenario mapping: Method exploring multiple plausible future territorial developments.

Smallholder farmer: Farmer operating a small landholding with limited resources.

Soil salinisation: Build-up of salts reducing soil fertility and productivity.

Systemic resilience: Capacity of systems to adapt, recover, and transform.

The Stack: Model of interconnected layers enabling planetary-scale computation and automation.

ABSTRACT

The 21st century presents India with an unprecedented convergence of crises: a growing population projected to reach 1.515 billion by 2030 (United Nations Population Fund, 2025), accelerating urbanisation encroaching upon productive rural landscapes, and a food system caught between ecological exhaustion and deepening spatial inequality. India's double burden of malnutrition and obesity, distributed asymmetrically between rural and urban populations (Dutta et al., 2019), is not merely a nutritional challenge but a territorial one, embedded in the infrastructure, governance, and political economy of the agricultural system. Historical ratchets, from the Green Revolution's ecological hatchets of soil salinisation and groundwater depletion (Aditya et al., 2020) to the emerging Agriculture 4.0 trajectory of precision farming and drone-based agriculture (Barman et al., 2025), risk reproducing structural inequities unless decoupled from questions of access, justice, and place-based ecological knowledge. This project, thus, examines how India's food production system can achieve resilience in a just manner, improving agricultural productivity to meet nutritional security, while simultaneously ensuring the livelihoods of producers and the ecological balance of the landscapes that sustain them.

This project focuses on the tri-state region of Gujarat, Madhya Pradesh, and Maharashtra, linked by the Narmada and Tapi river systems and a transboundary basalt aquifer as an exemplary agro-climatic territory where these overlapping crises manifest. The region's agricultural significance, shaped by large-scale hydrological infrastructure, the Sardar Sarovar Project, reveals how technocratic water governance simultaneously enables production and produces territorial inequalities in which surplus and scarcity coexist.

This project employs critical and narrative cartography, multi-criteria decision analysis, geospatial synthesis, and scenario mapping as tools to classify agricultural landscape typologies across the study region and evaluate their biophysical feasibility, governance constraints, and socio-ecological vulnerabilities. Four scenarios, developed

along axes of scale and technology, are evaluated against criteria of producer justice, ecological balance, food sovereignty, and systemic resilience.

The project concludes that India's agricultural crisis demands a decisive departure from siloed technological and economic interventions toward integrated, justice-oriented spatial strategies. The proposed Indian Agro-Urbanism Operational Framework, tested through Surat district, repositions agriculture as an urbanisation issue, embedding agro-climatic zone-based planning, participatory governance, and ecological balance into territorial planning. Investment in adaptive, resilient public and commons infrastructure is indispensable for navigating the Ratchet–Hatchet–Pivot cycle (DeFries, 2014) justly, providing conservation grounds, experimental testing spaces, and deployment commons accessible to farmers, consumers, and ecosystems alike, rather than captured by private capital. Reinstating agro-climatic zone differentiation provides a scientifically grounded basis for cropping strategies and resource allocation. Ultimately, achieving just and resilient food production requires abandoning the dichotomy between conventional and automated farming, rural and urban, and production and ecology, co-producing the spatial imaginaries that India's food system crisis urgently demands.

Keywords

Agro-urbanism, food security, regionalisation, commons infrastructure

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I am profoundly grateful to my mentors, Victor Muñoz Sanz and Daniele Cannatella, for their unwavering guidance throughout this graduation process. Victor's intellectual rigour challenged me to be simultaneously analytical and creative, to question every decision, interrogate every assumption, and pursue design with the same precision demanded of research. His scrutiny of perspectives beyond the field and incredible references in each discussion opened avenues I would not have found alone. Daniele's methodological clarity helped me navigate the considerable challenge of scope, grounding the research in technically sound frameworks without sacrificing its ambition. His critical questioning sharpened the project at precisely the moments

it needed sharpening. I am especially grateful to both of them for their support during what was, personally, the most difficult period of my life. That this project exists in its current form is, in no small part, a result of their patient and principled mentorship, and their enthusiasm that carried me forward when momentum was difficult to sustain.

I extend sincere appreciation to all studio and elective tutors of the MSc Urbanism programme, whose collective teachings have shaped my growth as an urban designer in ways both visible and difficult to trace. A particular thank you to Mohit Kapoor for facilitating connections with practitioners Dr Mukta Naik and Aditi Mali, whose conversations helped me ask better questions at a critical stage of the research.

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MOTIVATION

Growing up in India, many of us are taught to say, in whichever language we speak at home, *annadata sukhino bhavantu*, a Sanskrit phrase that translates simply and profoundly as *may those who provide us food be blessed*. This gratitude extends to everyone in the chain that brings food to the table: the farmers who endure extraordinary hardship to grow it, the vendors who make it accessible, and those who cook it with care. It is not a ritual phrase but a lived orientation, one that my family practised with sincerity and warmth, and that shaped, long before I had the language to articulate it, my understanding of food as a deeply political and deeply human act.

During my undergraduate years at CEPT University, I had the opportunity to take electives that were at the intersection of food and the city, a combination that felt almost designed for someone who loves both urbanism and food. But it was not the studio that first made the question urgent. It was the daily encounter with the news: a drought, a price collapse, a farmer's protest. I would notice how low the prices of vegetables could be at the market and find myself wondering, if I am paying this little, what is the farmer receiving? That question never left me.

My undergraduate and early professional years were spent building expertise in urban areas, their systems, their failures, and their spatial logic. So when I arrived at TU Delft to pursue my master's, I made a deliberate choice to move in the opposite direction: to understand what lies beyond the city and the systems that make the functioning of cities possible. The Netherlands offered an extraordinary vantage point for this, a country that, despite its modest

scale, is the second-largest exporter of agricultural products in the world. I immersed myself in the technical dimensions of soil science and water systems, disciplines I had not formally encountered before, and found in them a rigour and a beauty that deepened my spatial thinking considerably.

It was the convergence of these threads, a childhood gratitude for farmers, a growing technical understanding of agro-ecological systems, and the spatial sensibility cultivated across years of urban practice, that drew me toward the question this project seeks to answer. My conversations with Dr Mukta Naik and Aditi Mali made me conclude what I had begun to suspect: that food planning in India, despite the scale and complexity of its agricultural system, does not exist as a coherent, integrated discipline. Research, legislation, and practice address different stages of the food system as separate workflows, rarely synthesised into a framework capable of confronting the full territorial and social reality of feeding the largest population on the planet. That gap, urgent, consequential, and deeply personal, is where this project begins.



Figure 1: Vegetable farming near Kalol, Gujarat, India.
Photo by the author (2025).

1.

INTRODUCTION

This chapter covers the problems related to the food production system to address the double-burden that India faces, the research purpose, and the scope of the project.

PROBLEMATISATION

India, with a population of approximately 1.46 billion people (Figure 2), is currently the most populous country in the world and is estimated to reach 1.515 billion by 2030 (India Population 2025 - United Nations Population Fund, n.d.). The country is witnessing rapid urbanisation to accommodate this population growth (Kouamé, 2024). By 2036, it is estimated that the urban population will be around 40%, compared to 31% in 2011. Urban areas account for approximately 70% of the country's total GDP (Figure 3). This rapid urbanisation, driven by efforts to increase the country's GDP, poses challenges to food security, which is already affected by overlapping crises and land and resource scarcity (Aditya et al., 2020).

Addressing the double-burden spatially

The need for urbanisation has resulted in the infringement on rural landscapes in the country, which are primarily production landscapes to suffice the population's sustenance needs (Figure 4). Urbanisation-led food production is impacting the affordability and accessibility of food, let alone healthy and nutritious food. As per the study by Dutta et al. (2019), India faces a double burden of malnutrition and obesity prevalent across the country. Trends suggest that malnutrition is predominantly present in rural areas, and obesity is prevalent mainly in urban areas. This dichotomy presents a food insecurity crisis that requires land for agricultural intensification to meet the growing demand for a healthy, accessible, and affordable food supply. This raises critical questions: What is the future of agriculture in India? Can the food production processes meet the desired nutritional quantity and quality for its population?

Agricultural productivity needs to be addressed spatially

The future of Indian agriculture is influenced by the current deeply layered landscape of overlapping crises, intersecting infrastructure, ecology, politics, and culture, which is shaping agriculture in India (Pandey & Seto, 2015). From an urbanism lens, this challenge is not only about agricultural productivity but also about territorial organisation. Urbanisation does not merely consume agricultural land; it reorganises flows of labour, water, energy, capital, and governance across regions (de Bruin & Holleman, 2023). These arise from the dual pressures of efficient production and economic growth, which have transformed them into capitalised operational landscapes (Muñoz Sanz & Katsikis, 2024). Food insecurity stemming from the current agricultural system cannot be read as purely rural or sectoral issues; they are embedded within urbanisation processes, state-building projects, and spatial inequalities that link cities, hinterlands, and ecosystems, and must be accounted for as such.

Water geopolitics governs food production

In the Indian context, large-scale water infrastructure, particularly inter-state river treaties and major irrigation projects such as post-independence dams catering to farming and everyday use, has been central to India's development imagination (Sikka, 2020). Water began to be considered a political and economic asset, mobilised to consolidate state power, support agricultural intensification, and fuel urban and industrial growth. Gujarat's Sardar Sarovar Project is one such example: canal networks, subsidised electricity for

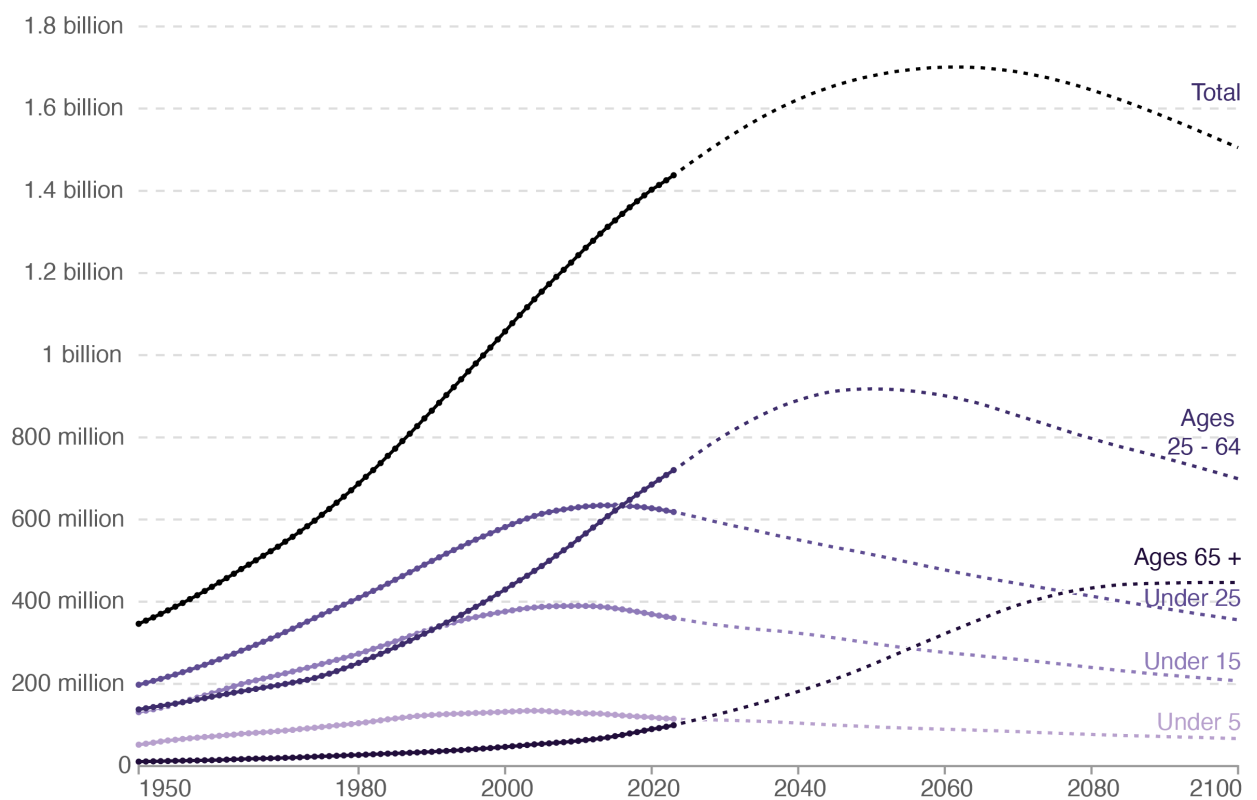


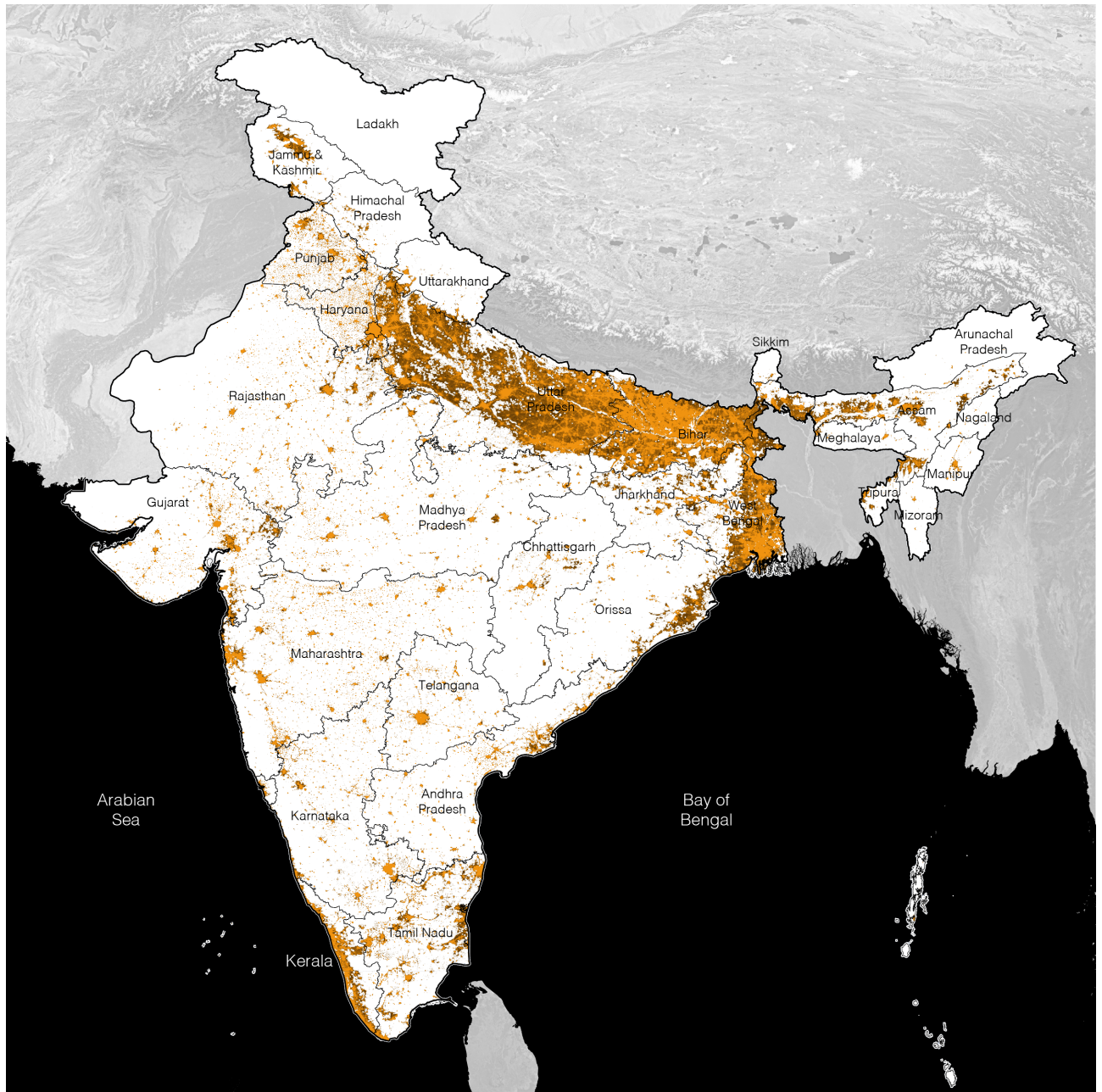
Figure 2: Timeline and estimate of population growth by age group for India.
Image source: Ritchie (2019).

groundwater pumping, and technocratic water governance increased production but also locked regions into water-intensive cropping systems (Mollinga & Deekshit, 2025). These interventions, while framed as progress, have contributed to groundwater over-extraction, ecological degradation, and uneven regional development, revealing a crisis produced by the very infrastructures meant to solve scarcity. Regions favoured by canal irrigation and proximity to political power, such as Punjab, Haryana, and parts of western India, became centres of agrarian growth. In contrast, rainfed and tribal regions remained marginalised (Abdeen et al., 2025). This uneven geography is reinforced by land-use change and plantation expansion, particularly in ecologically sensitive areas like the Western Ghats, where agricultural intensification intersects with biodiversity loss and climate vulnerability (Gupta & Rowan, 2025). Consequently, these historical infrastructural decisions have resulted in contemporary governance path dependencies. River basin management, agricultural policy, and urban development are administered through fragmented institutional silos that rarely align with ecological systems or regional food needs. As a result, infrastructure, initially conceived as a unifying development tool, now produces territorial inequalities in which surplus and scarcity coexist within the same regional systems. Agencies such as the Narmada Control Authority, specifically set up to address regional ecological boundaries rather than administrative boundaries, are unable to address the misalignment, particularly concerning the upstream and downstream impacts of dam projects on agriculture and people's lives, which becomes a central constraint on food system resilience.

Need for justice for the producers

These further expose how power operates unevenly across bodies and communities. Farmers, engineers, policymakers, and urbanists occupy unequal positions within decision-making systems. Farmers, the producers, bear the brunt of climate change in production and in returns. There is a significant increase in farmers leaving the profession and moving to urban areas to work in secondary and tertiary sectors. At the same time, trends also suggest a reversal of migration to agriculture in light of developments in agriculture and the post-pandemic period (Saini et al., 2025). However, the problems of unequal compensation and the unpredictable nature of yields to barely make a living persists for the farmers. Legislation pertaining to agriculture primarily supports the capitalised operational landscapes framework, aggravating the impacts on the farmers. There is a need to challenge dominant planning paradigms by highlighting interdependence between humans, non-humans, and infrastructures, and by questioning growth-centric narratives that externalise ecological and social harm.

Concurrently, debates around automation, planetary urbanisation, and rights of nature signal emerging responses to the crisis that remain deeply contested. While there is a need for agricultural intensification to meet food demand, the natural ecosystem has reached a saturation point in terms of nutrient replenishment, water-holding capacity, and soil erosion, with subsequent carbon release (Mandal et al., 2020). At the same time, framing rivers and ecosystems as rights-bearing entities opens alternative imaginaries for spatial planning that prioritise ecological



Population Density 2020

Population density per sq. km

0 40 80 120 km



Figure 3: India's population density map
 Image source: WorldPop (2020), Population density for India.

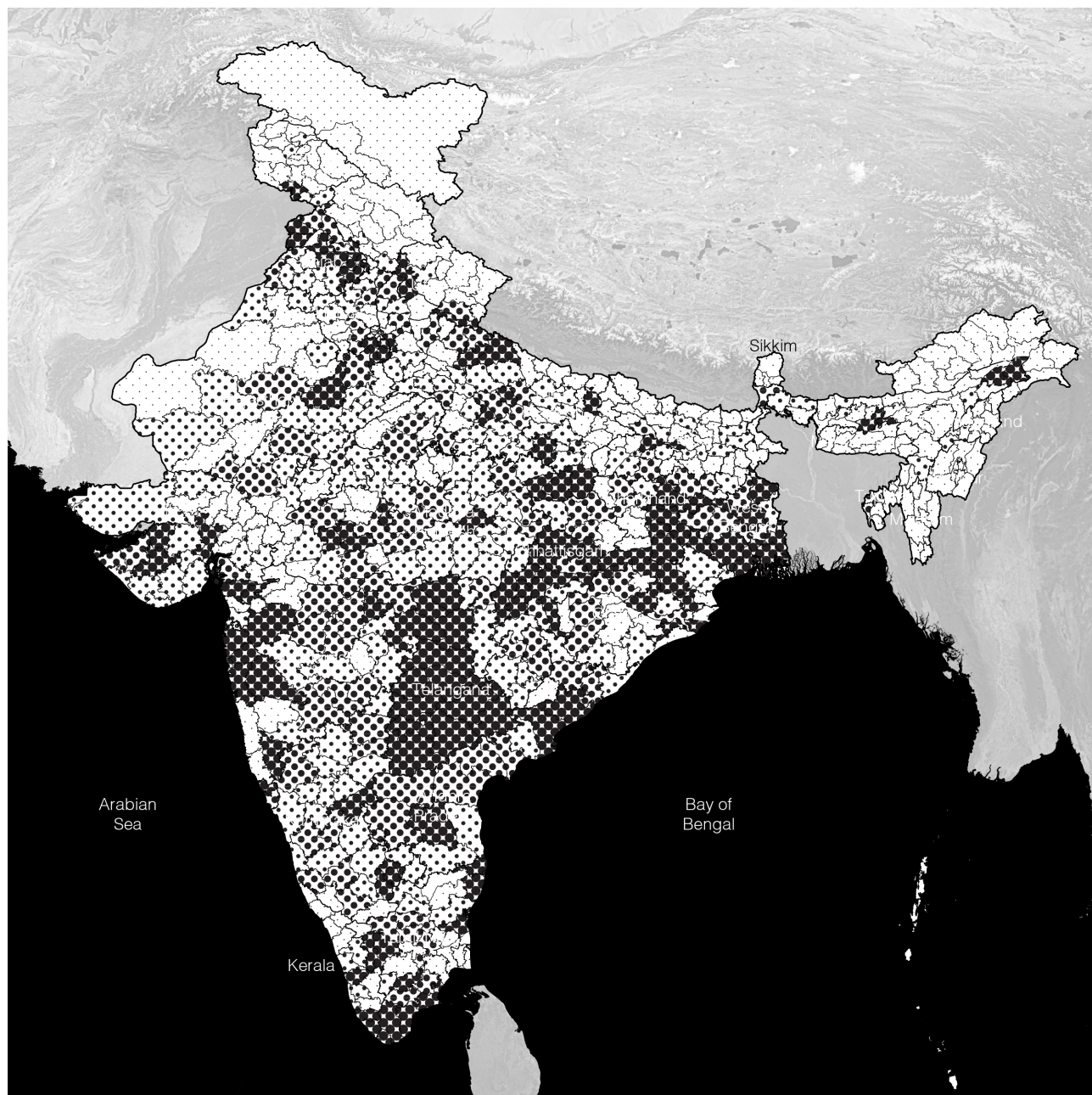
thresholds and long-term resilience. The introduction of precision farming, IoT, and drone-based farming aims to reduce the environmental impact of agriculture (Barman et al., 2025). However, these technologies also bear the risk of reproducing inequalities if detached from questions of access and governance. Currently, the farms are small, and deploying automation on such small plots is highly expensive for individual farmers to bear.

Thus, for urbanists, the overlapping crises impacting Indian agriculture demand a shift from siloed solutions toward integrated, justice-oriented spatial strategies that recognise agriculture as central to urban futures, ecological survival, and social equity, and a consideration for an agro-urbanism model contextualised to the complex interrelationships that India faces.

Relevance

In the agricultural scheme of things, as per the book *The Big Ratchet* (DeFries, 2014), there is a constant cycle of ratchet, hatchet, and pivot: raising food production with new means, encountering issues in tandem with limited resources due to the increased production, and inventing new technologies to tackle these issues. In the Indian context, as in many other parts of the world, the technological advancements perpetuate this cycle (Figure 5 on the next page). It began with the Green Revolution in the 1960s, followed by the introduction and global availability of fertilisers, and the widespread adoption of techniques such as High-Yielding Varieties (HYV) crops, which helped tackle food insecurity in India through agricultural intensification. However, its repercussions presented challenges at the nexus of agriculture, water, and governance from the beginning of the 2000s. This intensive agriculture, along with the use of external inputs, resulted in the loss of arable land, accompanied by soil salinisation due to saltwater intrusion from climate change, land desertification, and subsequent greenfield development (Aditya et al., 2020). The extensive homogenisation of land has led to biodiversity loss, impacting the natural ecosystem and water cycle, especially in coastal regions such as Gujarat, Maharashtra, and Karnataka, and in forested landscapes such as the Western Ghats.

Significantly, the agricultural realm in India is defined mainly by legislative amendments to primarily proliferate economic growth. Historically, they have manifested as key agricultural revolutions, resulting in ecological contestations in the form of protests or spatial



Agricultural land lost to urbanisation

Area in hectares

- 1,550 - 27,756
- 531 - 1,519
- 106 - 519
- 0 - 100

0 40 80 120 km



Figure 4: Total agricultural land area lost to urbanisation
 Image adapted from source: Pandey & Seto (2015).

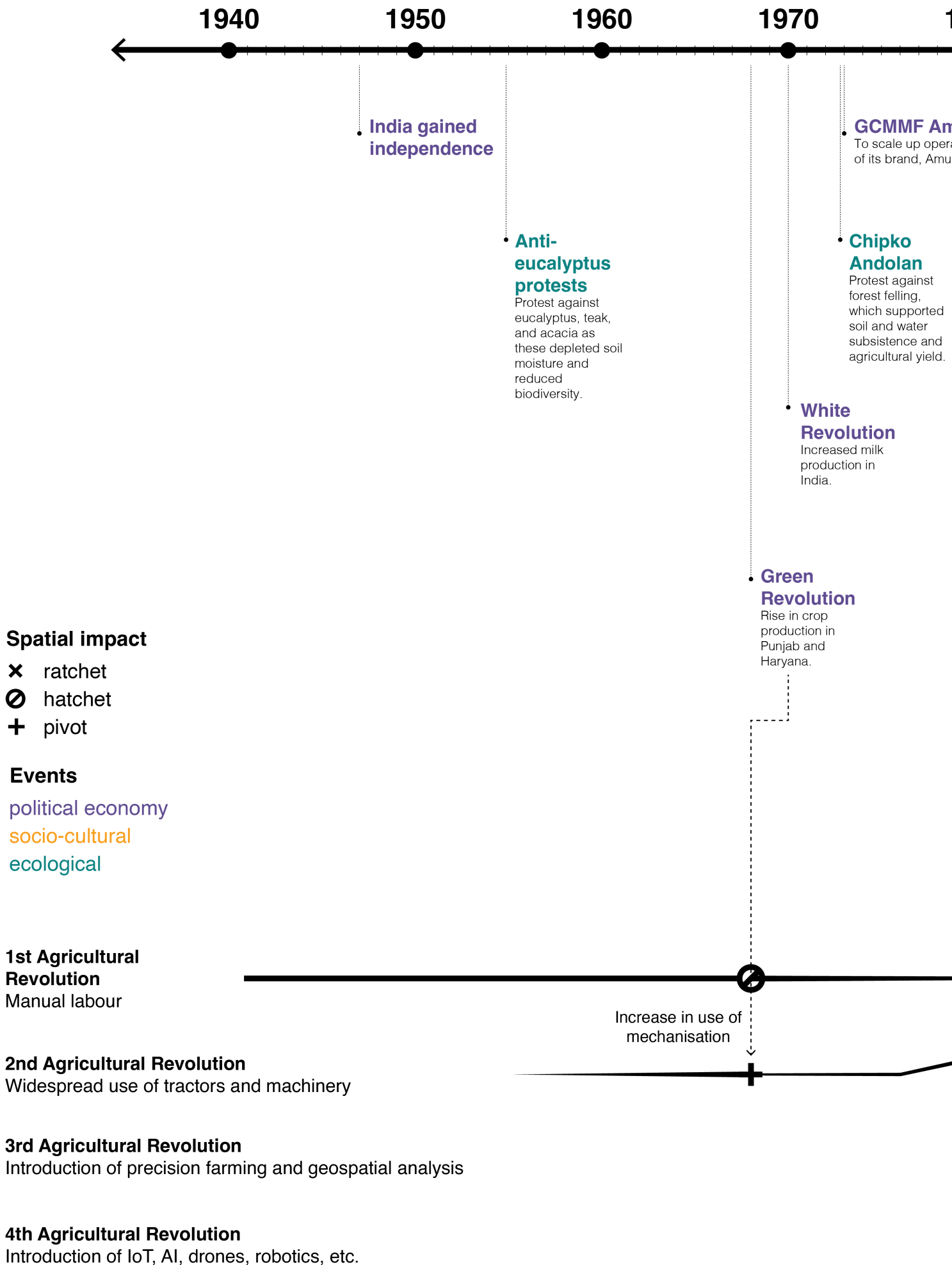
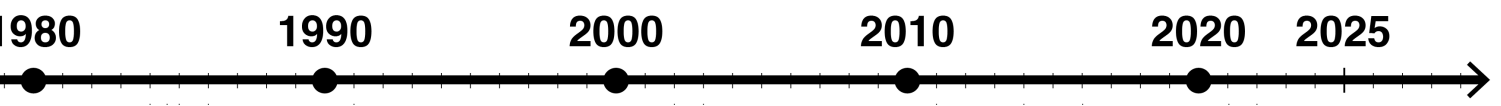


Figure 5: Timeline of key events related to agricultural revolutions in India
Source of information for image: Mahajan, 2022; Barman et al., 2025



mul
ations
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Yellow Revolution
Production of edible oilseeds.

Liberalisation
Shift in focus to high crop value agriculture.

Blue Revolution
Redefining structure for the fishing industries.

Narmada Bachao Andolan
Protest against dam construction flooding agricultural land and impacting ecology.

Stubble burning
Quickest and cheapest method to clear fields of crop residue before next plantation.

APMC Law
Farmers can trade directly with the consumers.

Anti - BT Cotton Mobilisations
Protest against high cost GM cotton with drastic ecological impacts.

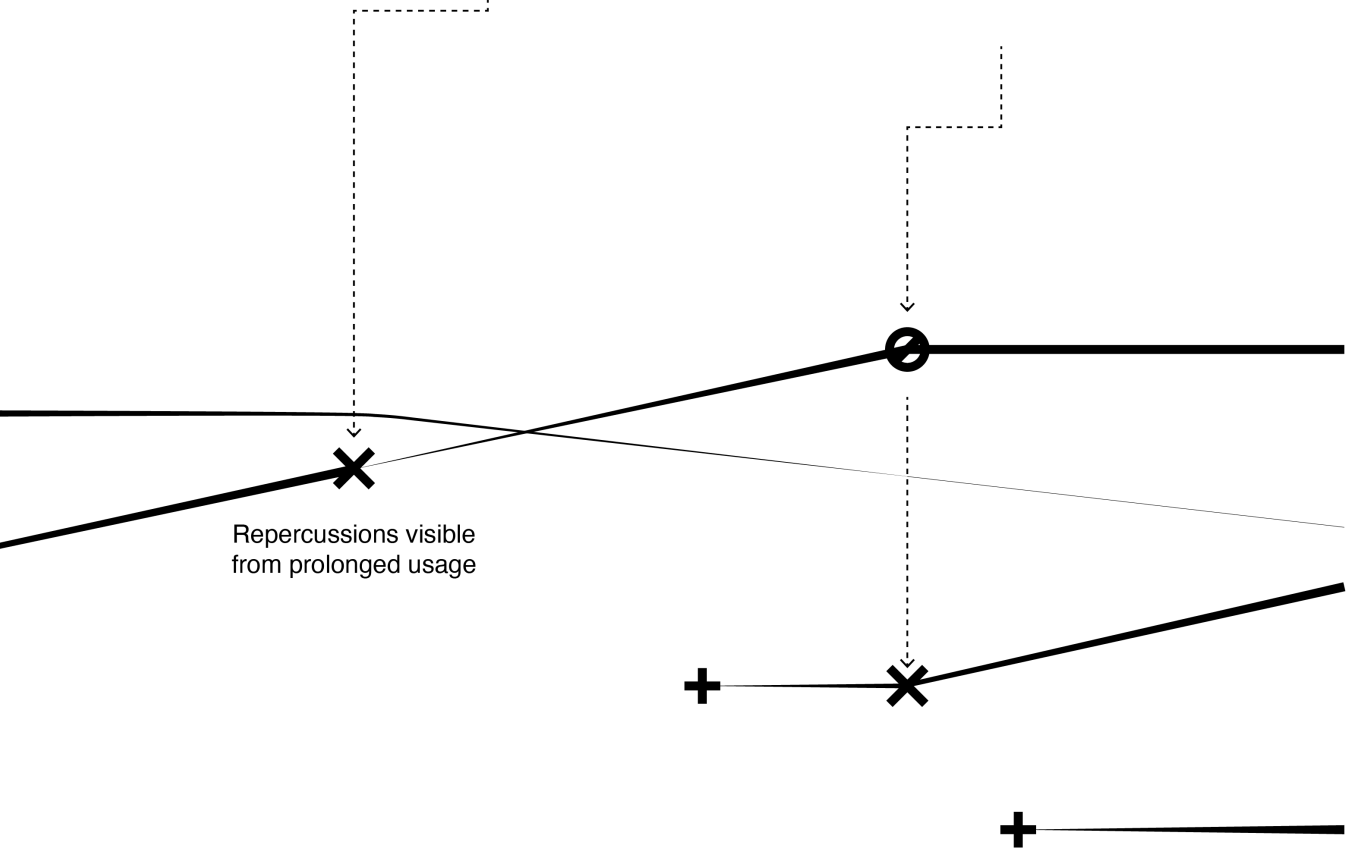
Anti-GM Mustard Protests
Impact on biodiversity, especially bee pollination.

Farmers protests led to farm bill repealing
Fear in farmers of being suppressed by corporate pricing.

Draft IoT Policy
Setting up Centre of Excellence for integration in various sectors.

Draft Farm Bill
Three acts initiated to allow farmers to exercise free trade beyond markets.

Cancer Roko Jagriti Manch
Protests in Malwa, Punjab on cancer spread due to pesticide and fertiliser overuse contaminating water bodies.



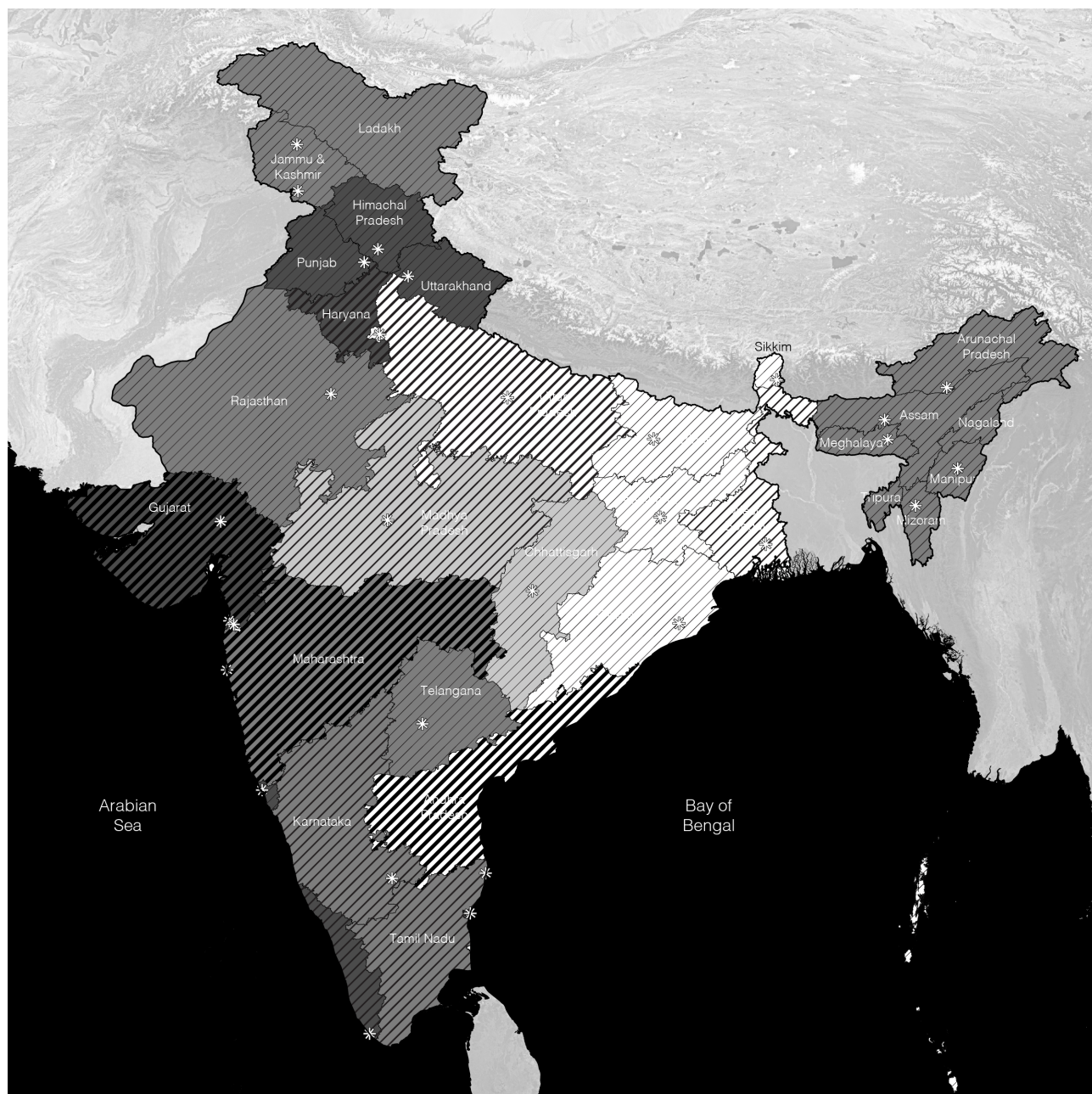
Repercussions visible from prolonged usage

hatchets, in which territories are altered, and soil and water reach saturation points on various grounds. These also have socio-cultural impacts, such as displacements caused by significant water infrastructure projects to fuel irrigation for farming (Sikka, 2020), and the omnipresent health risks, both directly from the food produce consumed and from the influence of agricultural practices on soil and water systems. Automated farming in the form of greenhouses, precision farming, and the use of drones to increase yields have been the most recent ratchets. While automation is scaling up in the Indian context, the land currently used for conventional agriculture is a testing ground for it. Given the impact of both conventional and automated farming practices, exacerbated by the climate crisis, what is the balance between conventional farming methods, indigenous practices, and automation in agriculture? How do they spatially manifest to bring about the integral changes required in the food production processes?

As Jens Beckert (2013) argues, it is the future that shapes the present. It is imperative to envision the future of agriculture and the key steps we need to take now to achieve it. It relies on understanding and addressing intensively the problems related to conventional farming and its aftermath, while simultaneously evaluating the extent to which the transition to automation is required. Historical events, current trends and patterns, and the state of the food production system inform these visions.

Conventional farming has achieved the hatchet stage

Due to various economic, governance, and socio-cultural reasons, along with integral environmental characteristics, the Western and Northern areas in India are faring better in export values and average monthly income of farmers in the country (Figure 6). Despite that, at present, the rapidly changing land cover poses a limitation on and for resources used in conventional agriculture. This is exacerbated by competing interests in resource production, extraction, and transportation, which primarily contend for land allocation (Figure 7). Simultaneously, water bodies and associated catchment areas are integral natural resources that require space, the presence of which defines the intensity, efficiency, and spatialisation of farmlands and other systemic requirements (Figure 8). Furthermore, the presence of cities and towns in proximity and their clustering establishes rural-urban integration. The integration of labour as a resource through labour mobility anchors urbanisation, which, in turn, promotes agricultural intensification in the hinterlands to meet the population's food needs (Figure 9). The overlapping territories for this material, natural, and labour resources create agricultural powerhouses in the country, evident in the farmers' incomes (Figure 10).



Agricultural Production System

□ State

* Capital city

Farmer's Average
Monthly Income (INR)

□ 6,000 - 7,878

■ 7,878 - 8,931

■ 8,931 - 10,624

■ 10,624 - 23,133

Agricultural Export Value
2022-23 (USD Million)

■ 0 - 1,000

■ 1,000 - 2,000

■ 2,000 - 3,000

■ > 4,000

0 40 80 120
km



Figure 6: State-wise agricultural export value and farmers' average monthly incomes
Source of information for image: Gulati et al., 2021.

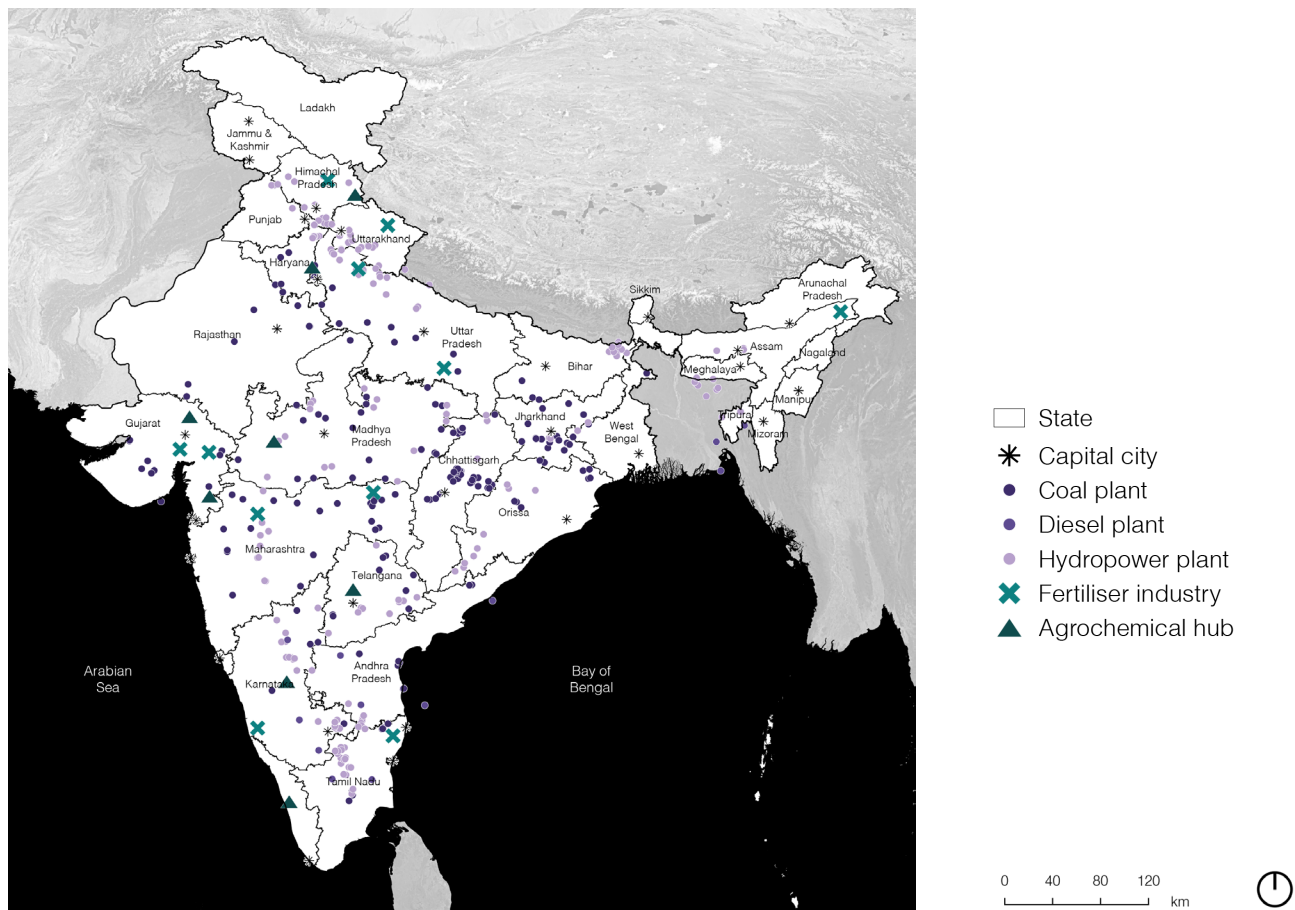


Figure 7: Key industries for resource input production

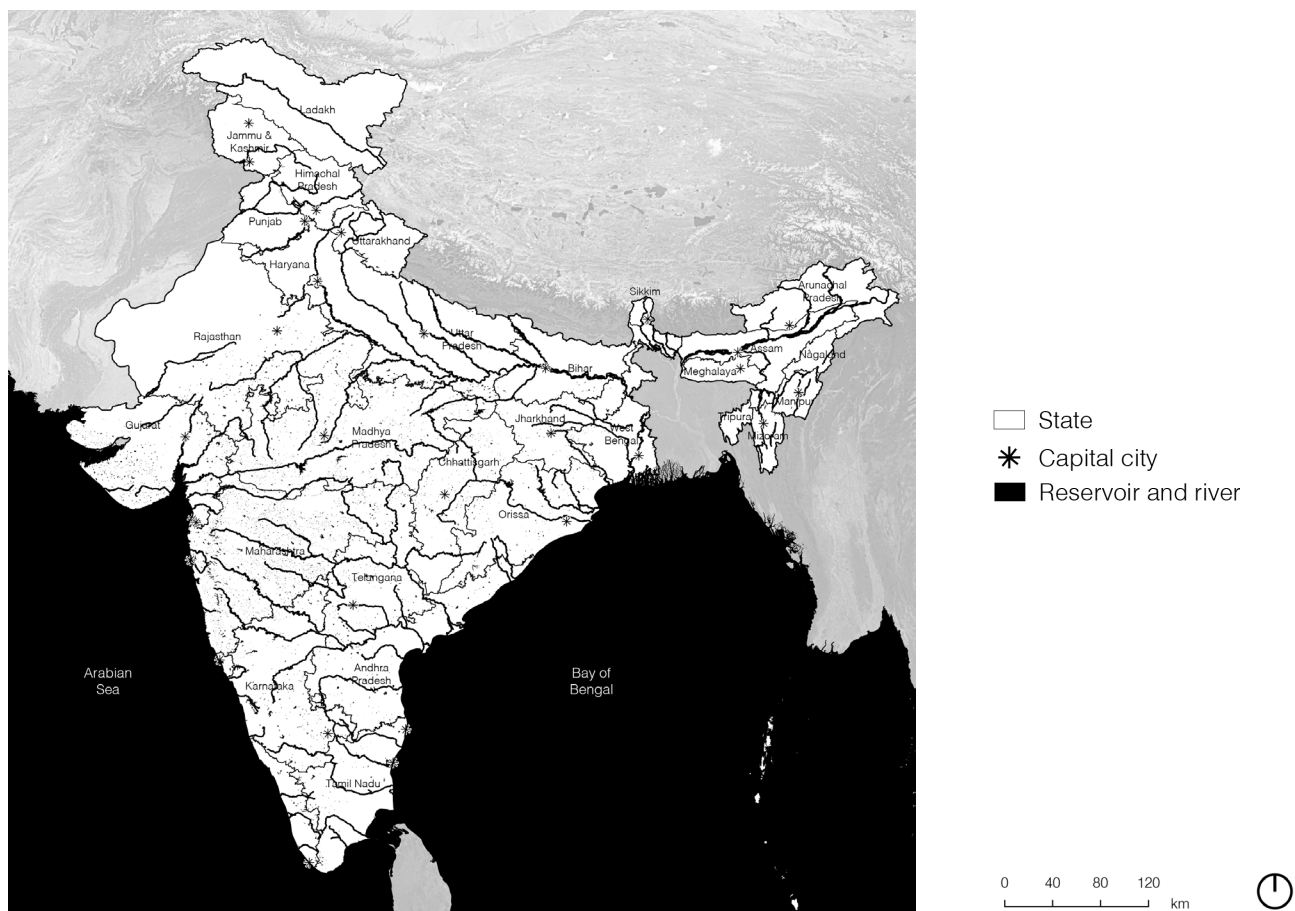


Figure 8: Water as a resource

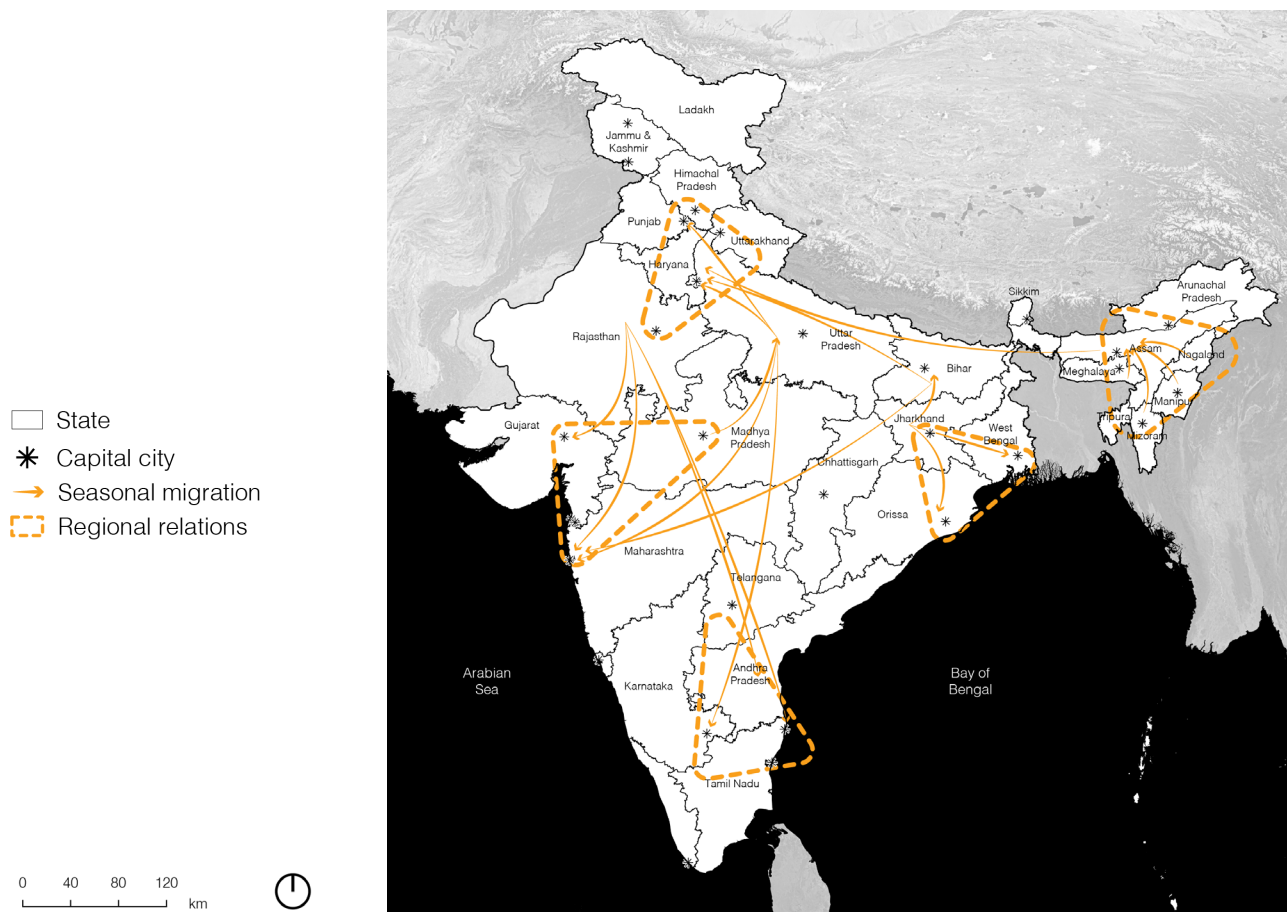


Figure 9: Rural-urban integration through cluster of cities as power hubs

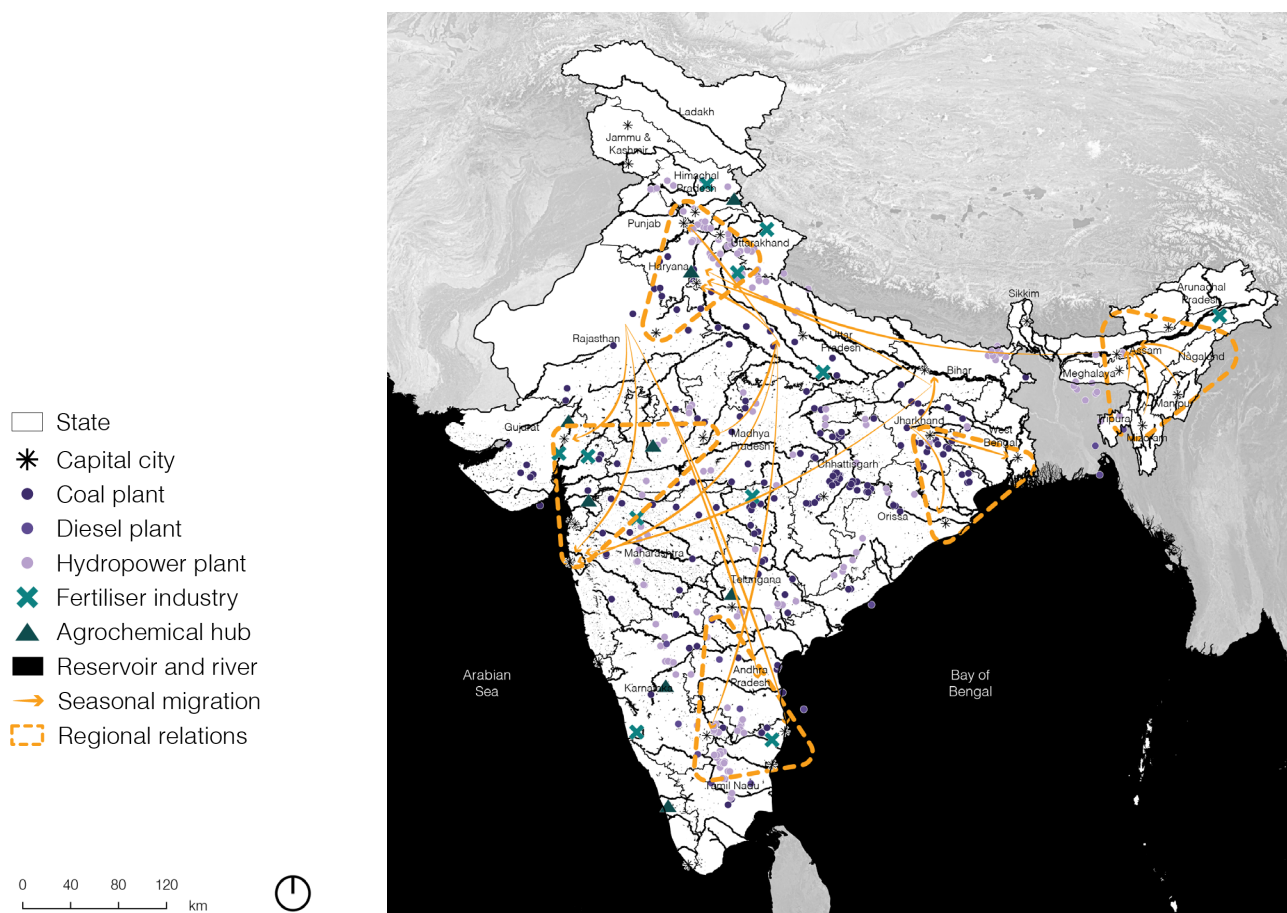


Figure 10: Agricultural power houses in India

Is automation in agriculture the desired pivot?

The recent work on Agriculture 4.0 (Barman et al., 2025) in India highlights a further dimension: the uptake of digital technologies, big data, sensors, and AI in Indian agriculture to address concerns about India's farmlands having reached the hatchet stage once again. The authors show how technologies (Precision Ag, IoT, drones) are being framed as the 4th Green Revolution. However, they also caution that such technological transitions neglect regional heterogeneity, infrastructure bottlenecks, small-holder constraints, and governance readiness. Thus, there is a dual limitation: technology-led research often assumes uniform farm conditions and ignores institutional and spatial diversity. In contrast, governance and socio-cultural research often neglect the implications of agro-technological change.

Benjamin Bratton addresses this regional heterogeneity through the model of The Stack (Bratton, 2014). It represents the interconnected layers that enable automation in this age. However, it also unravels a hidden infrastructure of extraction, computation, waste, and material-ecological transformation, which it calls The Black Stack. This is evident in the flows and distribution of primary, secondary, and tertiary resources to support digitisation in agriculture, asserting that the infrastructure for all these resources has become more important than the production lands (Figure 11).

These further present challenges from the lens of political economy, socio-cultural grounds, and ecological processes (Figure 12). The food system is constrained by uneven infrastructure, capital intensity, and social exclusion. Weak rural connectivity, fragmented landholdings, high-tech costs, and institutional bias favouring large conglomerates while marginalising smallholders, women, and caste-oppressed groups. These constraints generate cascading impacts: groundwater depletion, soil degradation, ecological contamination, and uneven technological benefits. Agriculture becomes embedded in energy, data, and industrial networks, producing spatial and environmental externalities that extend far beyond the farm into planetary systems.

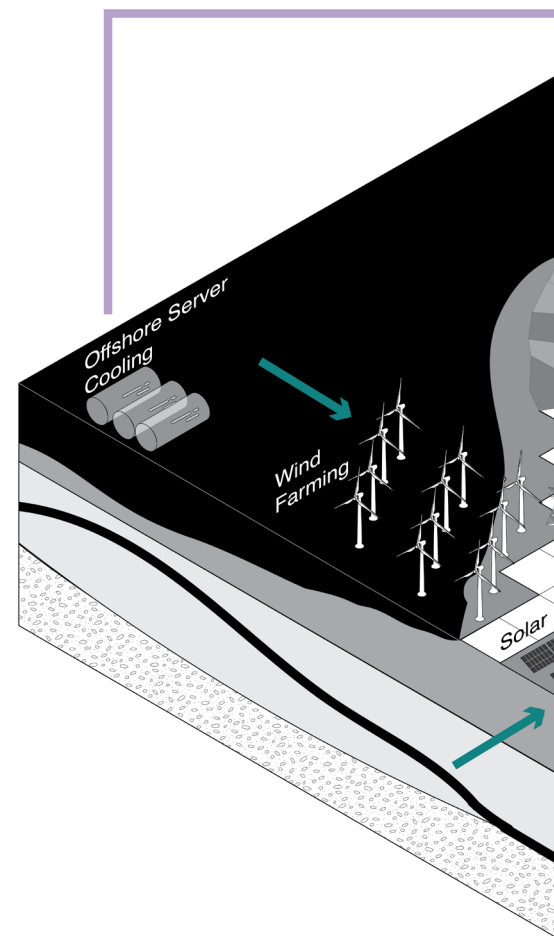
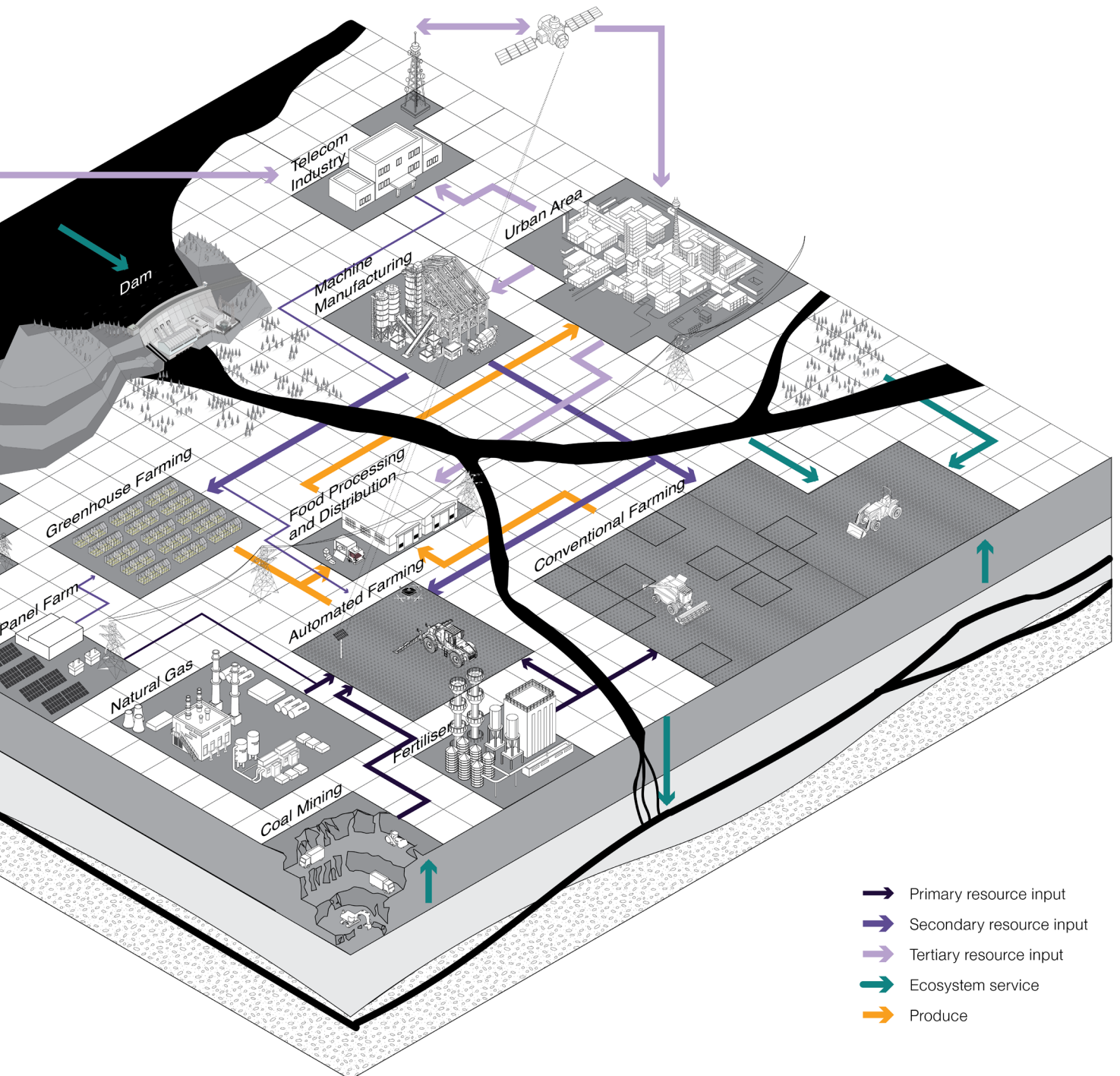


Figure 11: Resource input and land allocation in the food system of India
Source of information for image: Barman et al., 2025.



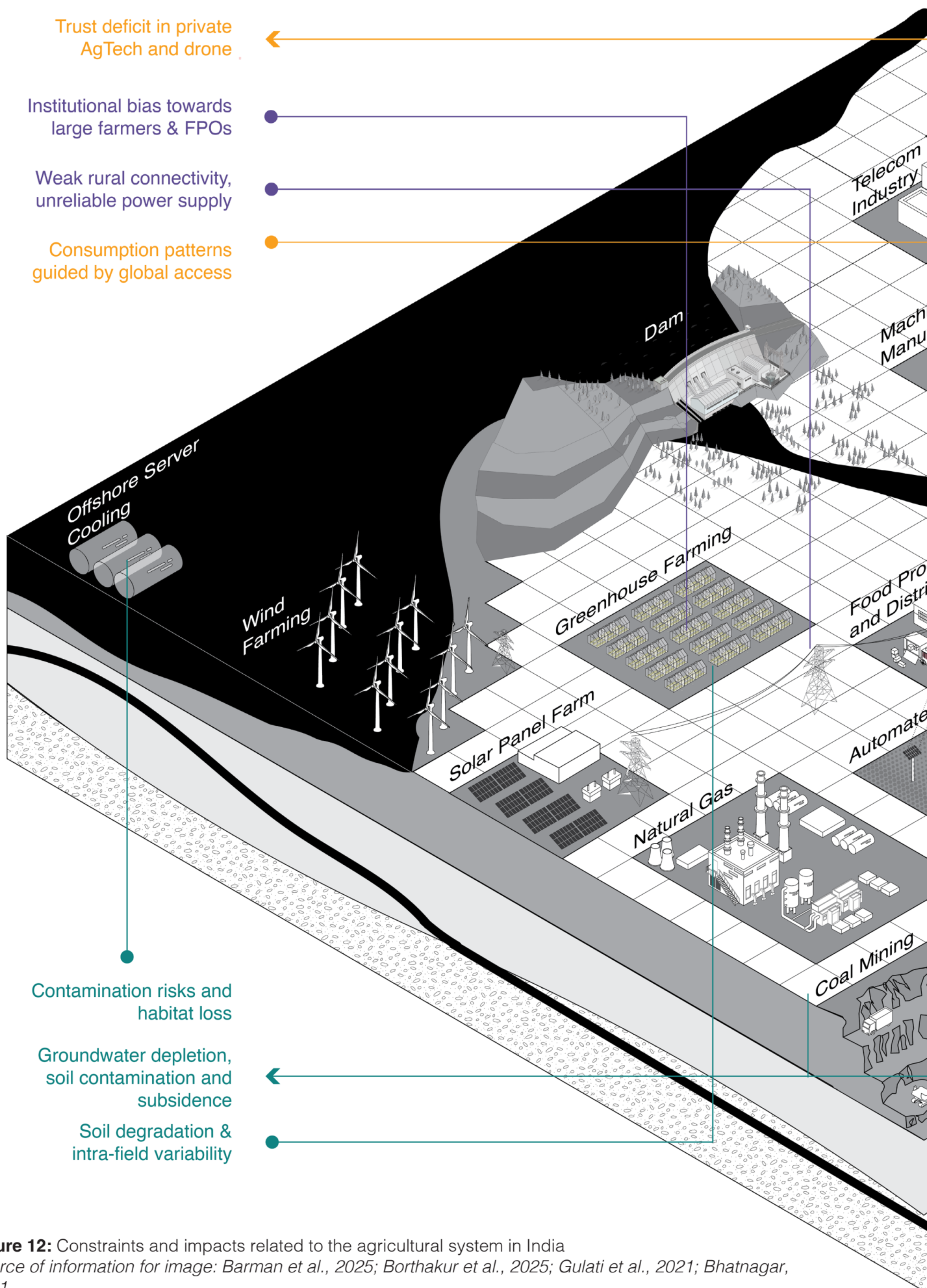
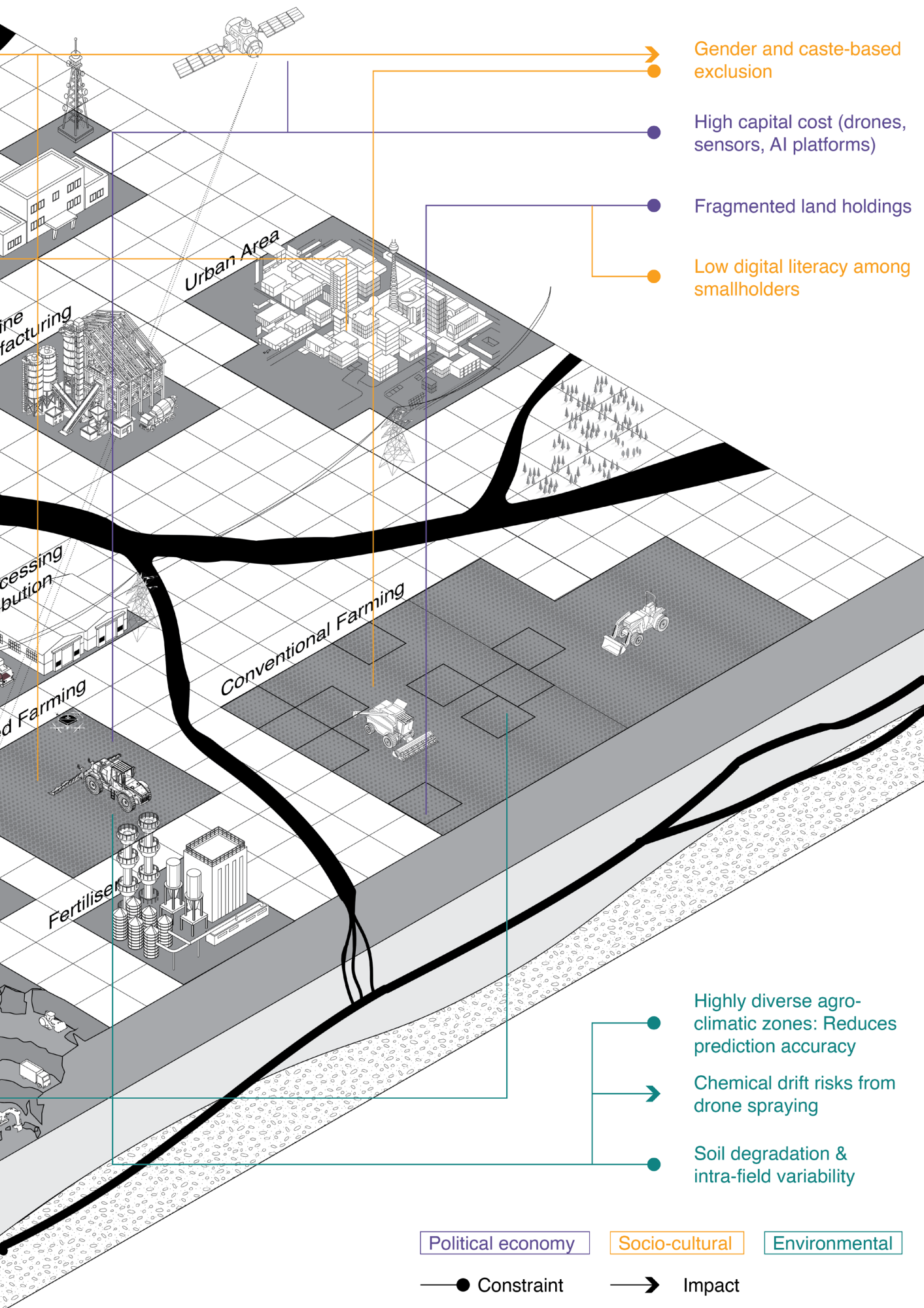


Figure 12: Constraints and impacts related to the agricultural system in India

Source of information for image: Barman et al., 2025; Borthakur et al., 2025; Gulati et al., 2021; Bhatnagar, 2021.



Research gap

With the complex system of resource inputs and contested territories, the need of the hour is to achieve just and accessible food production today and, in the future, to address these challenges in an interconnected manner. Existing research is fragmented in nature. There is substantial research on advancing agricultural practices across the economic, socio-cultural, hydro-geological, and governance scales. However, it remains siloed, rarely integrating these perspectives into a holistic understanding of how infrastructures, power dynamics, cultural values, and ecological processes intersect. Methodologically, much research focuses on either macro-level policy or micro-level social impacts, with limited spatial cross-scalar or interdisciplinary synthesis. An in-between spatially differentiated framework that links agricultural typologies, governance mechanisms, biophysical constraints, and urban-rural interactions to enhance food system resilience in India is dire. This can be addressed by introducing a regional layer within The Big Stack model, between the City, Cloud, and Earth layers, to enable symbiotic urbanism (Figure 13). It needs to account for regional natural landscape considerations rather than follow intangible governance borders that shape spatial characteristics across regions.

Architects, urbanists, and planners across the world have been creating models and visions of what a regional agro-eco-urbanism model could look like. Pronounced visions include The Garden City by Ebenezer Howard (1902), which examines the Town-Country model and identifies spaces for production, consumption, and nature. Its implementation, however, stemmed from a misunderstanding of the original ideas, resulting in more elite, gated societies. In recent times, there has been a growing interest in agro-urbanism models, exemplified by projects such as Oosterwolde in Flevoland, The Netherlands, by MVRDV, Andrea Branzi's Agronica, and the Tirana Master Plan by Stefano Boeri Architetti. These models are rooted in the historical and contextual spatial, ecological, and governance characteristics of the regions. This raises the question: What is a contextualised agro-eco-urbanism model for regions in India? Can it address the challenges of rural-urban integration to achieve just food production?

inserting a regional layer

Position as an urbanist to use the regional scale as a transition between the city and cloud to ensure food sovereignty.

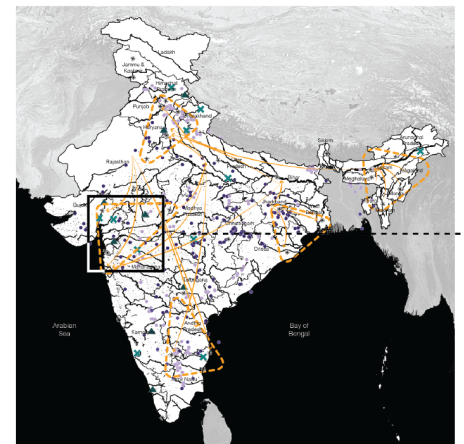
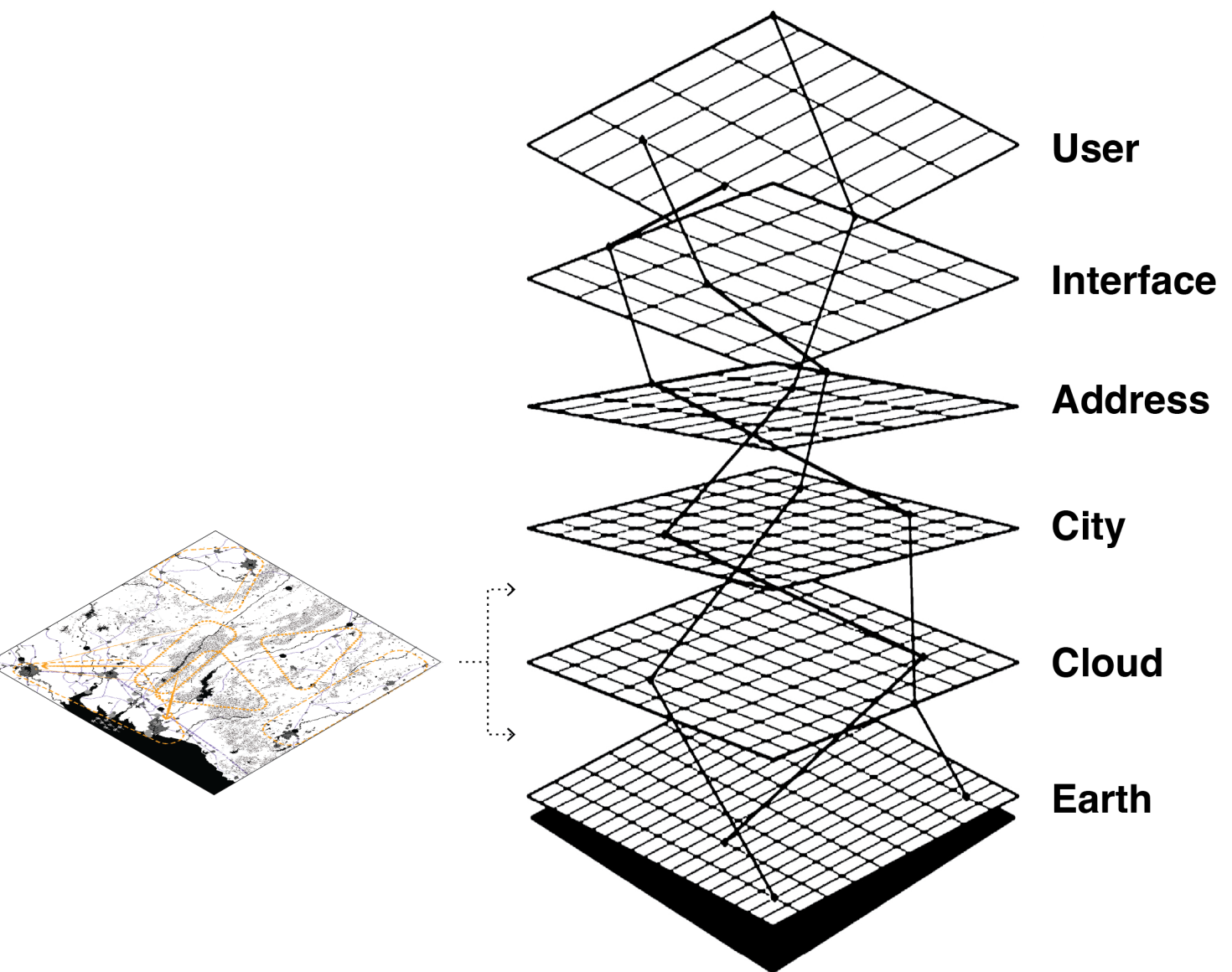


Figure 13: Position as an urbanist to address the agricultural issues
Image source for 'The Stack': Bratton, 2014.



RESEARCH PURPOSE

If this issue is not resolved, people will face health challenges, as evidenced by the persisting double burden, exacerbated by the loss of agricultural land productivity amid the worsening climate crisis. The most precious resource, land, is almost saturated, aggravating the biggest hatchet of the 21st Century: feeding a population of 1.46 billion people while also ensuring the ability to feed future generations. Simultaneously, the recent advocacy for increasing organic produce through biodiverse, indigenous practices is difficult to scale up to meet consumer demand. On the other side, the expansion of automation is opposed by small-scale farmers, who fear being taken over by large-scale industries. Research on the balance between both methodologies for resilience is almost unavailable in the Indian context and thus constitutes the most integral starting point.

The pressing questions of the time are: How can the agricultural system cope with the challenges presented by the overlap of multiple crises to be more resilient? Is the current path of the 4th Green Revolution in India the pivot we require? Or is there a need to redefine what the 4th Green Revolution can be to balance both automated and biodynamic forms of agriculture? This research thus focuses on developing an integrated, spatially differentiated framework that strengthens the resilience of India's food systems by aligning biophysical requirements, governance structures, and urban–rural relationships across diverse agricultural typologies.

The following research question aims to address the problem of who feeds the city, in what ways, and where and how the various facets of the food system function:

How can India's food production achieve resilience in a just manner, improving agricultural productivity to meet the nutritional security, while also ensuring the producers' liveability and ecological balance?

WHAT: Review

- What are the systems and subsystems related to agricultural practices and food systems in India?
- What is the current global discourse on agro-urbanism models aimed at achieving food system resilience?

WHY: Reason

- What are the current environmental, spatial, hydrological, social, and economic characteristics that impact food production in India?
- What are the complexities within the current spatial governance framework that impede food production resilience?

WHERE: Region

- What are the various agricultural spatial typologies in India?
- What are the biophysical considerations for the typologies to make the transformation process of the food production practices across seasons and scales feasible?

HOW: Redefine

- What agro-ecotechnological solutions can enhance food production resilience to meet food demand?
- What are the actions required in urbanised spaces of consumption to establish a symbiotic nature with spaces of production?
- Why are the key actors to be introduced and/or empowered in the governance framework?
- What is a context-sensitive Indian agrarian urbanism model?

Objectives

This research thus aims to develop a systemic understanding of India's food production processes by mapping its interconnected agricultural practices, supply chains, governance structures, and consumption networks. It aims to investigate the spatial, environmental, hydro-geological, socio-cultural, and politically oriented economic drivers shaping food production and their uneven impacts across regions. The study examines governance and institutional constraints affecting resilience while classifying India's major agricultural spatial typologies. It evaluates the biophysical feasibility of transforming farming practices and identifies context-specific agro-ecological and technological interventions. Finally, it aims to analyse urban–rural linkages and clarify the roles of key actors in enabling a more resilient, just, and integrated food system.

Scope

As evident in Figure 14, the region encompassing the borders of Gujarat, Maharashtra, and Madhya Pradesh serves as an exemplary site for this research and design endeavour. Statistics show that these three states are faring better than other states in agriculture in terms of export values and average farmers' monthly incomes, and could offer engaging lessons for other regions. The presence of the Narmada River catchment is important to the region's food production practices. At the same time, the presence of the Sardar Sarovar Project poses a regional planning challenge: addressing intangible governance boundaries and tangible barriers, such as forests and elevated landscapes, that are crucial to this agro-climatic region. Upon evaluation and the creation of an operational framework, the Surat district will be used as an exemplary mesoscale to test and represent the operational framework. Furthermore, the district will be zoomed into for testing design interventions as part of the toolkit.

Scale L

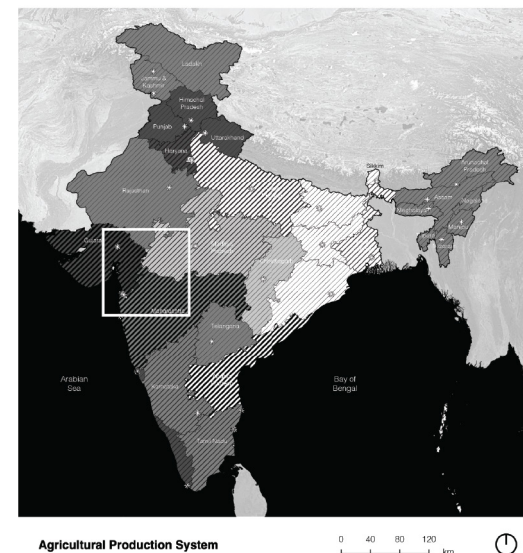
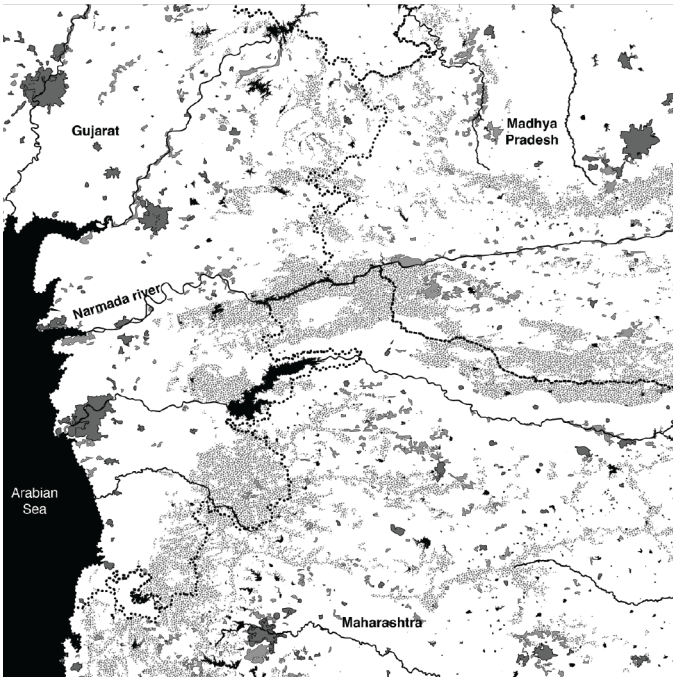


Figure 14: Scope definition depicting the chosen region for study and its characteristics
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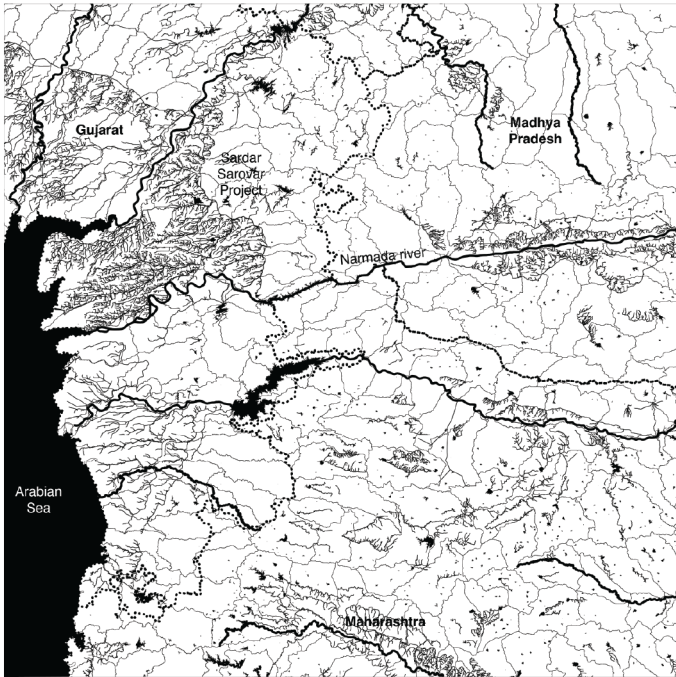
Scale M



Land use

- State boundary
- Urban area
- Farmland
- Forest
- Wasteland
- Water body

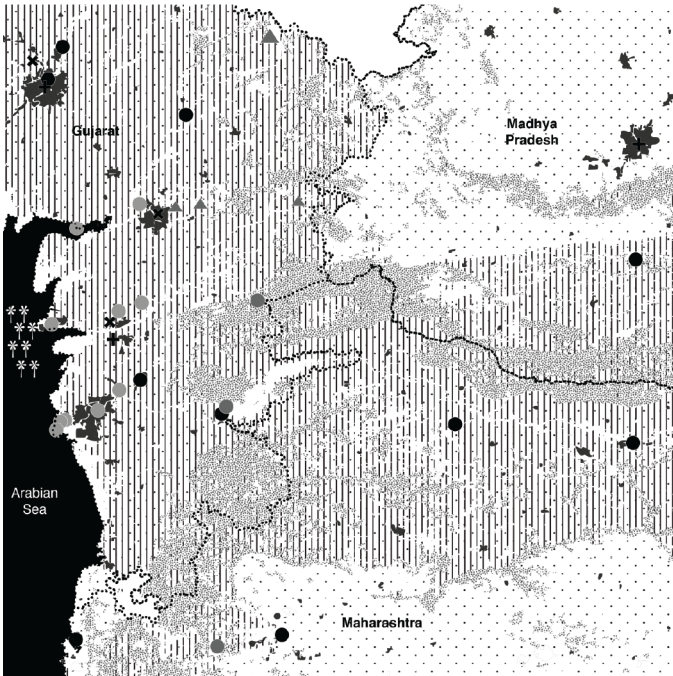
0 20 40 60 km



Catchment

- State boundary
- Water body
- Watershed
- River
- Canal

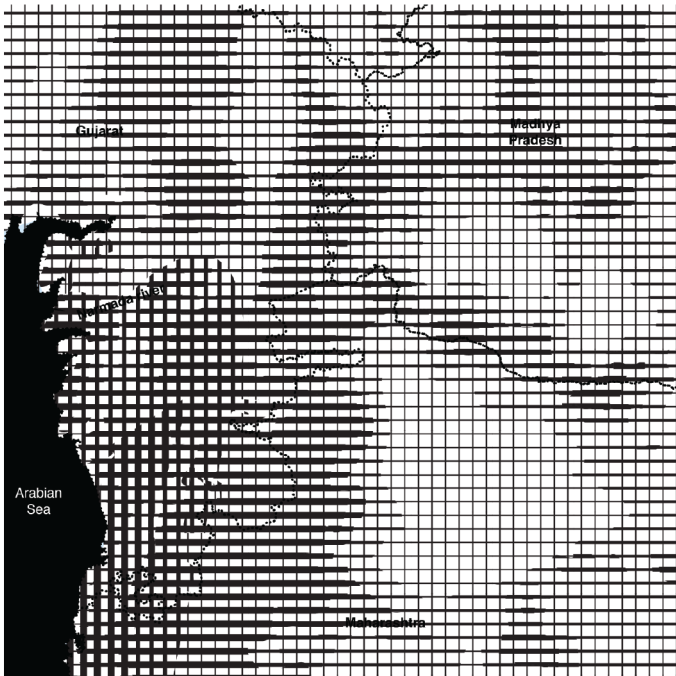
0 20 40 60 km



Anthropogenic challenges

- State
- Industries
 - Fertiliser industry
 - Agrochemical hub
 - Coal plant
 - Diesel plant
 - Hydropower plant
- Human Activities
 - Tilling
 - Overgrazing
 - Forest area decrease
 - Urbanisation

0 20 40 60 km



Climatic challenges

- State
- Mean Wind Speed at 100m
 - > 5.5 m/s
 - 5 - 5.5 m/s
 - 4.5 - 5 m/s
 - 4 - 4.5 m/s
 - < 4 m/s
- Annual average rainfall
 - 100 - 150 cm
 - 80 - 100 cm
 - 40 - 60 cm

0 20 40 60 km





Figure 15: An image of a peri-urban farm near Gandhinagar, Gujarat.
Photo by the author (2019).

2.

APPROACH

This chapter covers discourses from various disciplines and the key theories underpinning the project, their placement within the conceptual framework, and the associated methodologies used to address the research question and sub-research questions.

THEORETICAL FRAMEWORK



Figure 16: Theoretical framework

main authors

Fera et al., 2025I Marot, 2022

Tornaghi and Dehaene, 2020

Bratton, 2015

Brenner and Schmid, 2017

DeFries, 2014

Steel, 2020

Arenes et al., 2022; Ungar 2018

McHarg, 1969

Shiva, 2016

Escobar 2018; Sanz and Katsikis, 2023

Williams and Sharp, 2023

Chandra et al., 2017

Crane, 2014

Barman et al., 2025

Peschard, 2014



KEY THEORIES

Various perspectives inform this research, some of which are or need to be adapted and contextualised. The challenges associated with food production are yet to be addressed as an urbanisation problem in the region of study. This theoretical framework (Figure 16) assembles a set of interdisciplinary theories that allow the agricultural system to be understood as a socio-cultural, ecological, and governance system embedded within spatial development processes. Rather than treating food production as a rural or sectoral concern, the framework situates it within regional territories shaped by infrastructure, markets, computation, ecological limits, and social relations. Together, these theories support the main research question (Figure 17).

Key Theory 1: Justice for the producers, the environment, and the consumers

Justice-oriented theories ensure that resilience is pursued without compromising equity. Socio-ecological justice, advocated by prominent Indian scholar and activist Vandana Shiva, argues that environmental planning must respect ecological limits while addressing historical exploitation of land and communities (Shiva, 2017). The Seed Act has been supporting IPRs and patent monopolies created by large conglomerates, while deeming locally grown, open-pollinated seeds produced by small-scale farmers illegal. This is evident in the rise of the Bt cotton variety, a high-yielding variety that cannot be reused and is costlier, and in the clever advertising strategies that resulted in debt traps for farmers, leading to 3000 farmer suicides in the years 2012-15. This GMO's use is pronounced in Gujarat, Maharashtra, and Andhra Pradesh, with over 80% of cotton cultivation under Bt cotton. Notably, these states also record soil degradation and loss of soil biodiversity due to monoculture and increased pest resistance. This can be addressed by spraying broad-spectrum pesticides, which rid all crops except the GMOs. This diverts prime productive land from food production, aggravating the country's persistent food insecurity. This drives the need for social justice and, further, the need for ecological justice.

Concomitantly, ecological justice needs to be achieved spatially by examining how resources, risks, and opportunities are unevenly distributed across territories and how this uneven distribution reproduces social injustices. The agricultural system is extraction-intensive, particularly in the resources required to support the different stages of production. The current food production hegemony

perpetuates the extraction-intensive nature of production through infrastructures for fuel generation, predominantly natural gas from coal mining; large-scale water infrastructure (i.e., dams); the redefinition of the natural course of water bodies; and the replenishment of soil with nutrients solely to avoid productivity loss. The growing climate urgency demands inclusive food production practices, which can be learnt from agro-climatic zone considerations and the indigenous practices of tribes across the country. As advocated by Arturo Escobar, designing for the pluriverse requires inculcating regenerative practices for abundance in extractive territories for coexistence rather than the current, harmful Anthropocene undertakings (Escobar, 2018; Muñoz Sanz & Katsikis, 2024). These need to be in tandem with procedural justice, which focuses on who participates in decision-making processes. The need to empower farmers in decision-making and to ensure equitable returns becomes crucial.

Technological advancements heighten these socio-ecological injustices. Benjamin Bratton's (2014) concept of the Stack provides a framework for understanding how digital platforms, data infrastructures, and planetary-scale computation restructure governance and regional territory. In Indian agriculture, this is evident in precision farming technologies, AgTech platforms, satellite monitoring, and algorithmic market access. Automated landscapes extend this idea by examining how agricultural spaces are increasingly governed through sensors, drones, AI-driven inputs, and remote decision-making systems. It further explains that environmental and socio-economic drivers are increasingly mediated by technological systems that often privilege capital-intensive actors. The stakeholder

analysis reveals the significant power of companies and institutions serving agro-tech models over farmers practising conventional farming. Designing the pluriverse should serve as a tool for unpacking the power asymmetries embedded in technological transitions.

These theories are integral to understanding how to facilitate governance reforms and actor empowerment. Methodologically, they justify governance model analysis and the development of policy recommendations that prioritise inclusion, decentralisation, and cross-scalar coordination through a critical cartographic analysis and the identification of the region's potential through scenario mapping. As a design experiment to identify forensic interventions in the identified S scale zones, it is integral to ensure that regional integration does not reproduce existing inequalities between urban consumers, decision-makers with a politically driven economic-growth outlook, and rural producers.

Key Theory 2: Agrarian urbanism and agro-ecological urbanism

Agrarian urbanism and agro-ecological urbanism provide the conceptual foundation for reframing agriculture as an integral component of urban and regional design. Contemporary agrarian urbanism models such as Andrea Branzi's Agronica, Kisho Kurokawa's Agricultural City, and Frank Lloyd Wright's Broadacre City have critically envisioned models that blur the distinction between the rural and the urban areas (Fera et al., 2025). Cases such as Almere Oosterwolde in the Netherlands further the notion of employing disruptive modes of city-making to balance and integrate production and conviviality. Agro-ecological urbanism extends this position by grounding spatial design in ecological processes, emphasising soil health, water cycles, biodiversity, and climate responsiveness as structuring elements of territorial planning (Tornaghi & Dehaene, 2020). However, these models are feasible only in regions with large swaths of unaltered or minimally altered land to support the implementation of visions in a tabula rasa manner. Planning and designing with constraints require multiscalar, multidisciplinary collaboration to minimise the impacts of the human quest for sustenance. DeFries' (2014) concept of productive landscapes complements this by focusing on how land systems need to be reorganised to meet growing food demand under ecological constraints.

The theory of planetary urbanisation, coined by Henri Lefebvre and further developed by Neil Brenner along with his colleagues (Brenner & Schmid, 2012), advocates that we transcend the dichotomous differentiation between the city and the hinterlands. This shift in outlook

can help examine agriculture across regions that encompass a spectrum of urbanisation and address the interrelations that persist more effectively. This is complemented by the 'integration' direction outlined in the book *Taking the Country's Side: Agriculture and Architecture* (Marot, 2022). Marot created a framework identifying four directions for envisaging agrarian-urban reforms, each producing spatial imaginaries that vary according to the scope and approaches to agricultural practices. The 'integration' direction proposes hybrid spaces that cater to the best interests of the urban realm and agriculture. Simultaneously, as advocated in the book *Sitopia* (Steel, 2020), addressing the power structures that govern food is imperative to reach a symbiotic relationship between the spaces of production and consumption, and a 'sitopia' would include strong links between the urban and the hinterland. Notably, the fourth direction, 'secession', in Marot's framework aligns with Steel's first recommendation of radical imaginaries to respond to the status quo. The way forward to achieve a more coherent planetary urbanisation that identifies food production as an integral component of urbanisation is hitherto a hybrid of 'integration' and 'secession' directions.

In conjunction, these theories justify identifying agricultural spatial typologies not as isolated rural zones but as differentiated components of an urbanised regional system. They also reinforce the need for geospatial analysis and critical cartography within the methodology to reveal uneven development patterns across India. Marot's framework also sets a precedent for using scenario mapping as a methodology to examine and propose a contextualised agro-ecological urbanism model for the Indian context.

Key Theory 3: Food sovereignty and resilience

Given agriculture's vulnerability to climate change, systemic resilience theory provides a critical counterpoint to productivity-driven approaches to system planning (Ungar, 2018). As per the second principle, resilience is a process which can be primarily categorised into the following components: persistence, resistance, recovery, adaptation, and transformation. The key idea is to identify, within the food system, which components fall into these categories. Furthermore, it is integral to identify and bridge across these components, disciplines, and principles to facilitate design interventions that can absorb shocks, adapt to changing circumstances, and transform when existing structures become untenable. Intergenerational resilience extends this thinking by emphasising that decisions made today, regarding land use distribution, water extraction, and agricultural inputs, shape the possibilities available to future generations (Steel, 2020). Spatially, this calls for regional design strategies that consider, yet also go beyond, market fluctuations and governance borders, and embed the rights of nature in the form of soil fertility, aquifer recharge, and the continuity of socio-cultural identities.

Political ecology offers a critical way to uncover how policies, legislative power, and economic structures shape socio-environmental contexts in agricultural lands, especially for smallholder farmers (Chandra et al., 2017). Urbanists can draw on theories and understandings from the political ecology of climate-smart agriculture to reposition resilience as a geopolitical question that accounts for technological pivots. Agricultural anthropology complements this by highlighting cultural practices, indigenous knowledge, and everyday farming decisions that are often overlooked in technocratic

planning approaches (Crane, 2014). Robert Rhoades and Robert Booth's proposal of farmer-back-to-farmer (FB2F), while sounding simple and obvious, is the outlook required to tackle the challenges. However, the Green Revolution subverted this paradigm and shifted to a high-modernist scientific strategy to deal with the ratchets of overconsumption and trade liberalisation at a global scale. Going forward, urbanism models that address urban-rural integration and farming as a hybrid space component, as well as formal sciences contriving better ways to deploy automated farming, should instil an agricultural anthropological perspective to reinforce FB2F's consideration of the lived realities of smallholder farmers and avoid their marginalisation. Together, these disciplines can be bridged to anchor regionally adaptive solutions that engage farmers as co-producers of knowledge rather than passive recipients of innovation.

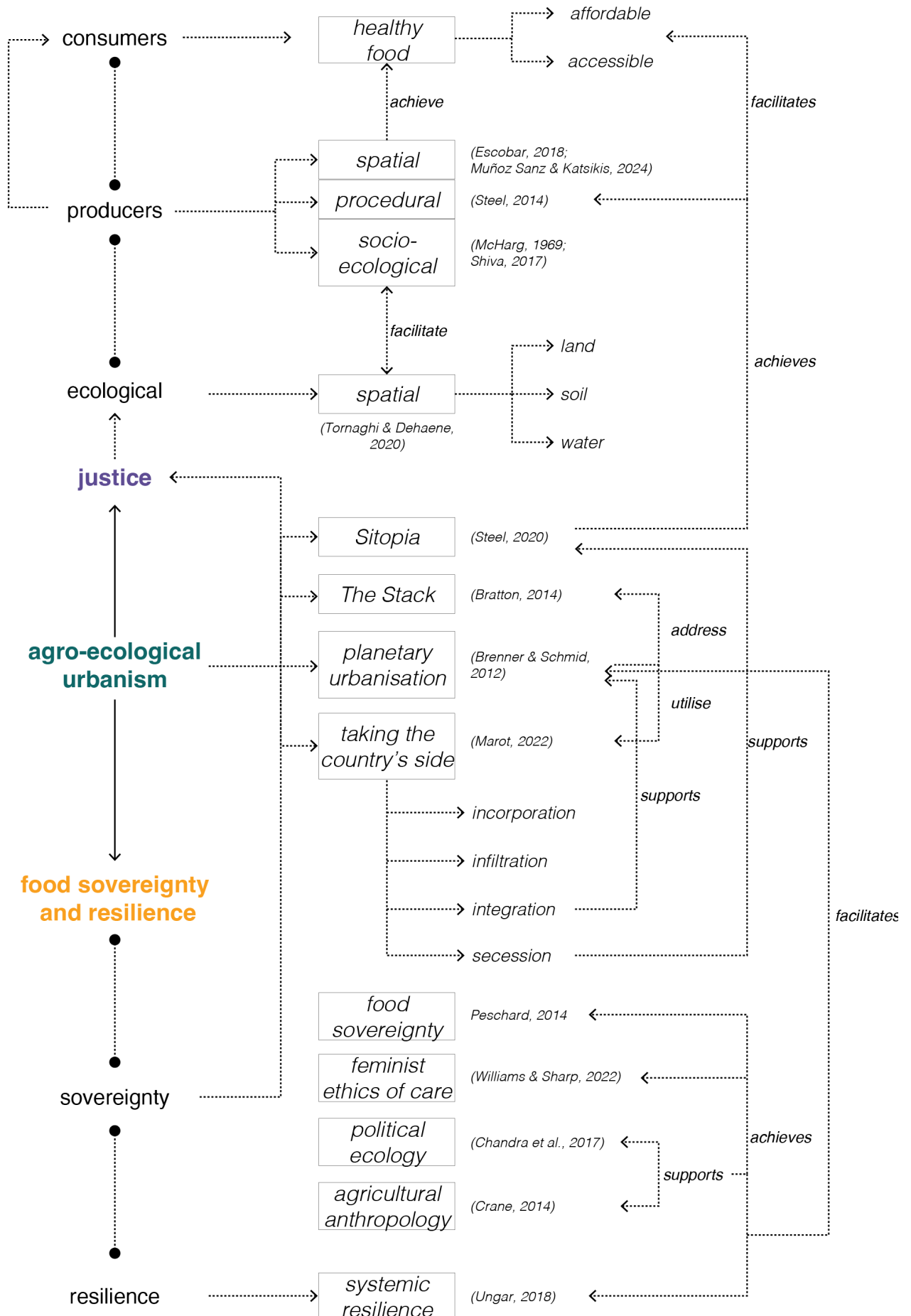
Feminist ethics of care also emphasises the importance of considering beyond the Anthropocene actors to achieve food sovereignty through redefining urban food governance (Williams & Sharp, 2022). The authors highlight that care extends beyond personal spaces; it permeates the establishment of markets and infrastructures. In India's food governance, farmers sell to mandis, wholesale hubs regulated by the Agricultural Produce Market Committee (APMC). The buyers/sellers at mandis are intermediaries who take a larger cut than the farmers and have been noted to instil trust issues among farmers due to their deceptive practices and unfair compensation. In this capitalocene (Muñoz Sanz & Katsikis, 2024) and the introduction of automation with big conglomerates and other industries driving the market, there is a need to introduce

the ethics of care to address the viability of local production and consumption that can do justice to the producers and consumers. Additionally, feminist ethics of care is needed for the gendered politics within the mainstream Indian agricultural undertakings. Beyond the farming realm, there is an invisible social cost of food production borne mainly by women in farmer households. With male farmers seasonal migrating to nearby urban areas after the plantation and harvest seasons, household females carry on farm responsibilities, without any legal entitlement to the land, while managing household responsibilities. While the government has introduced schemes to empower female farmers, such as the Nano Didi Scheme, which provides female farmers with drones at an 80% subsidy, they rarely have any entitlement to land and any kind of skill development to learn how to utilise technology in farming, leaving them to do all labour predominantly manually. Incorporating feminist ethics of care through the three domains of care connections, care as a stance on geopolitical and gender politics, and materialities of care into regional design challenges, extractive, growth-oriented paradigms and advocates for spatial practices that support well-being, reciprocity, and collective resilience of all groups, advocating food sovereignty's core ideas to shift to a local production and consumption.

An analysis of food sovereignty through the lens of India's Protection of Plant Varieties and Farmers' Rights Act demonstrates how the politics of farmers' rights are deeply entangled with broader struggles over knowledge, power, and governance in food systems (Peschard, 2014). At its core, food sovereignty asserts the collective right of communities to define agricultural and food policies, emphasising

access to, and control over, seeds, land, and cultural food practices as essential pillars of democratic food governance. This normative claim resonates with resilience theory by shifting the focus from short-term productivity to long-term adaptive capacity, highlighting the ability of food systems to withstand environmental and socio-economic shocks precisely because they decentralise authority and embed decision-making within the lived realities of the producers.

Figure 17: Analytical framework

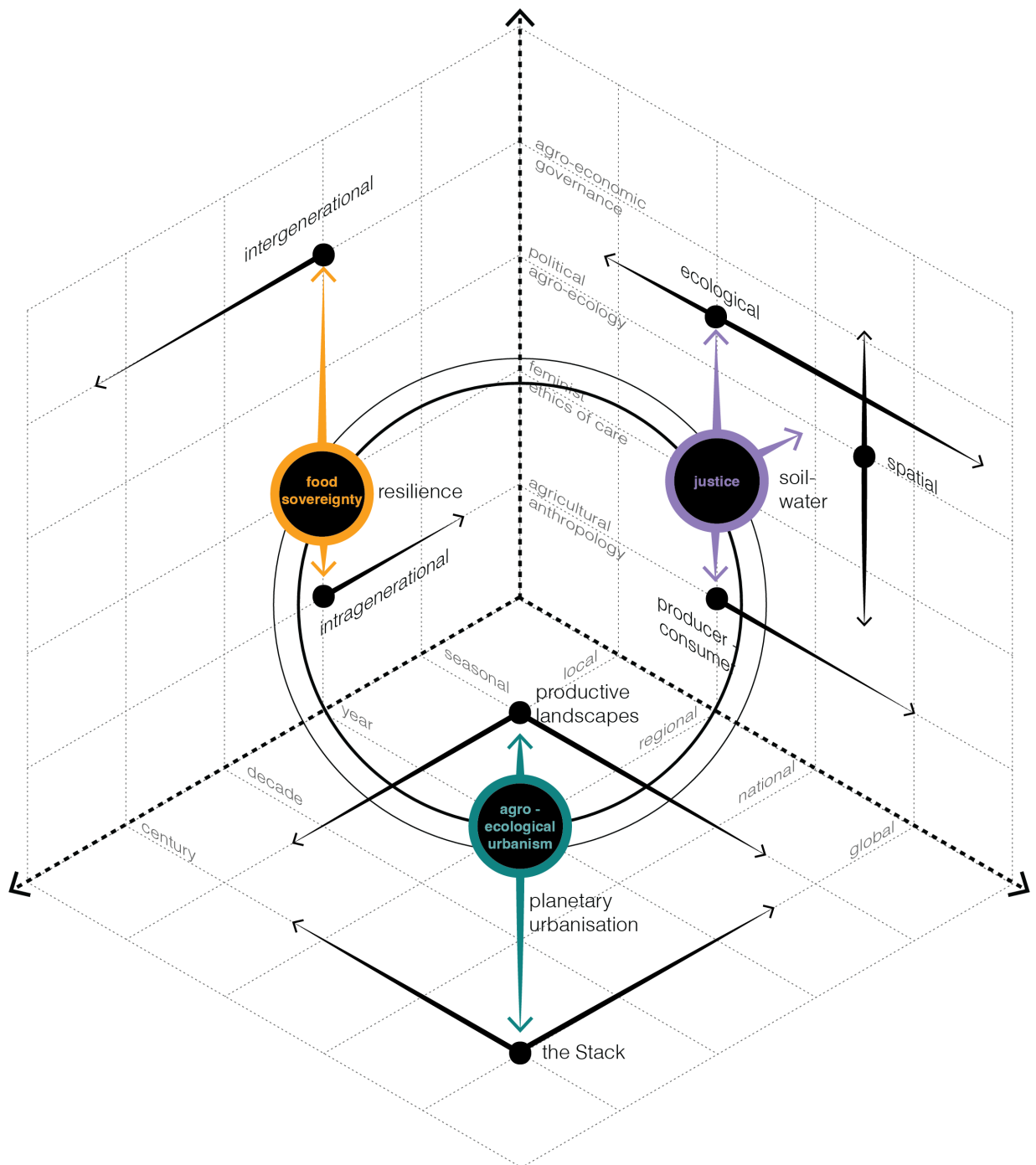


CONCEPTUAL FRAMEWORK

The Conceptual Framework (Figure 18) draws on theories delineated in the Theoretical Framework to situate the key theories, along with interconnected disciplines and principles, as goals for urbanists to address the food production crisis and facilitate the necessary paradigm shifts. The urbanist's role in directing spatial development must include interventions that facilitate achieving justice, food sovereignty, and resilience through multiscale agro-urbanism models. In the space-time continuum of events, the varying perspectives, disciplines, and theories can facilitate the adaptation of India's food production across regional agricultural typologies to improve resilience in a just manner.

The need for food sovereignty drives multiscale interventions for intra- and intergenerational systemic resilience. The idea of food sovereignty binds the theories and disciplines of resilience, political ecology, agricultural anthropology, and the feminist ethics of care to a spatially and socially grounded governance paradigm. This governance paradigm needs to carefully address the soil-water-land nexus to support regional strategies and biophysical design interventions that advance justice for producers, the environment, and consumers, ensuring food security. The agro-urbanism models proposed should utilise aspects of planetary urbanisation at the regional scale to mediate between the concerns of productive landscapes at a local scale for local consumption and The Stack's global outlook for production for global consumption and resilience. It can facilitate navigating between top-down and bottom-up approaches to spatial planning, governance, food production and consumption, and the rights of nature to achieve food sovereignty, resilience, and justice.

Figure 18: Conceptual framework



METHODOLOGICAL FRAMEWORK

To achieve the research aims, objectives, and questions, the project follows the timeline and methods (Figure 19) structured across four principal phases: Problematisation, Defining the Approach, Decoding Indian Agro-Urbanism, and Futuring Indian Agro-Urbanism, operating under four overarching sub-research question phases: Review, Reason, Region, and Redefine.

The project begins with the Problematisation phase, drawing on an extensive literature review supported by media analysis, informal discussions, historical analysis, stakeholder analysis, and oral history review. Together, these methodologies situate India's agricultural crisis within broader global debates on food security, climate adaptation, and urban-rural interdependence, while simultaneously revealing how current environmental, hydrological, social, and economic conditions are not accidental but the accumulated outcome of long-term governance choices and development trajectories.

The second phase, Defining the Approach, translates the findings of the review phase into frameworks. Framework development, encompassing scope definition, the identification of key theories, and the construction of both an analytical and a conceptual framework, establishes the interrelationships between existing domains and theories and how they can address the complexity of India's food system. This phase is critical for ensuring that the subsequent spatial and design work remains theoretically grounded rather than procedurally opportunistic.

The third phase, Decoding Indian Agro-Urbanism, constitutes the empirical and spatial core of the project. Research conducted through policy review, ethnographic study, and governance model analysis uncovers why structural vulnerabilities, groundwater depletion, spatial inequality, and farmer precarity persist, and how overlapping institutional jurisdictions constrain systemic resilience. This research is spatialised and depicted using critical and narrative cartography. The research is then used to define layers for multi-criteria decision analysis and the classification of landscape system typologies. Geospatial data is transformed into interpretive spatial representations that articulate the diverse agro-climatic, biophysical, and socio-ecological conditions across the study region. The MCDA and landscape typologies are carried forward as foundational inputs into the Futuring phase, ensuring analytical continuity across the project's progression.

The fourth and final phase, Futuring Indian Agro-Urbanism, reframes food production as a design problem demanding spatial imagination as much as technical resolution. Research-by-design methods anchor this phase, using scenario mapping exercises that explore how agro-eco-technological solutions can cultivate resilience under conditions of climatic uncertainty. The scenario mapping, in turn, informs and defines the vision plan, which is iteratively developed alongside the operational framework. Toolkit development translates the operational framework's spatial logic into actionable context-specific yet replicable interventions. The research and design ultimately inform the articulation of a contextualised agro-urbanism model.

Throughout this phase, the feedback loops of refinement, between scenario mapping and the vision plan, and between the vision plan and the operational framework, are as methodologically significant as the outputs themselves, ensuring that proposals remain responsive to contradictory evidence rather than fixed to prior assumptions.

Intended Output

The intended output of this methodological progression is an operational framework to establish a just food planning system and a contextualised Indian agro-urbanism model capable of facilitating food sovereignty, security, and justice across diverse agro-climatic conditions. The classification of landscape typologies within the Narmada basin region, encompassing the borders of Gujarat, Madhya Pradesh, and Maharashtra, based on agro-climatic conditions, biophysical characteristics, vulnerabilities, and adaptive capacity, provides the spatial foundation upon which scenario mapping and research-by-design methods test long-term resilience pathways. Each scenario embeds regional strategies specific to the stakeholders that guide them and their interests.

From the contesting priorities surfaced across these scenarios, zoomed-in zones with varying landscape systems are identified as exemplary sites to evaluate the minimum set of design interventions capable of driving sustainable and resilient food production development. These interventions constitute a suite of agro-eco-technological solutions, combined with interventions to enhance liveability and ecological balance, each calibrated to the

specific landscape typology and scenario conditions of its zone and collectively exploring how food production resilience can be enhanced under shifting climatic, hydrological, and socio-economic pressures. Given the multiscale nature of India's food system, these interventions are explicitly designed to begin at the local scale and progressively scale upward into regional strategies and national-level governance mechanisms, demonstrating that spatially coherent, ecologically grounded, and socially just planning is not an aspirational abstraction but an operationally achievable condition.

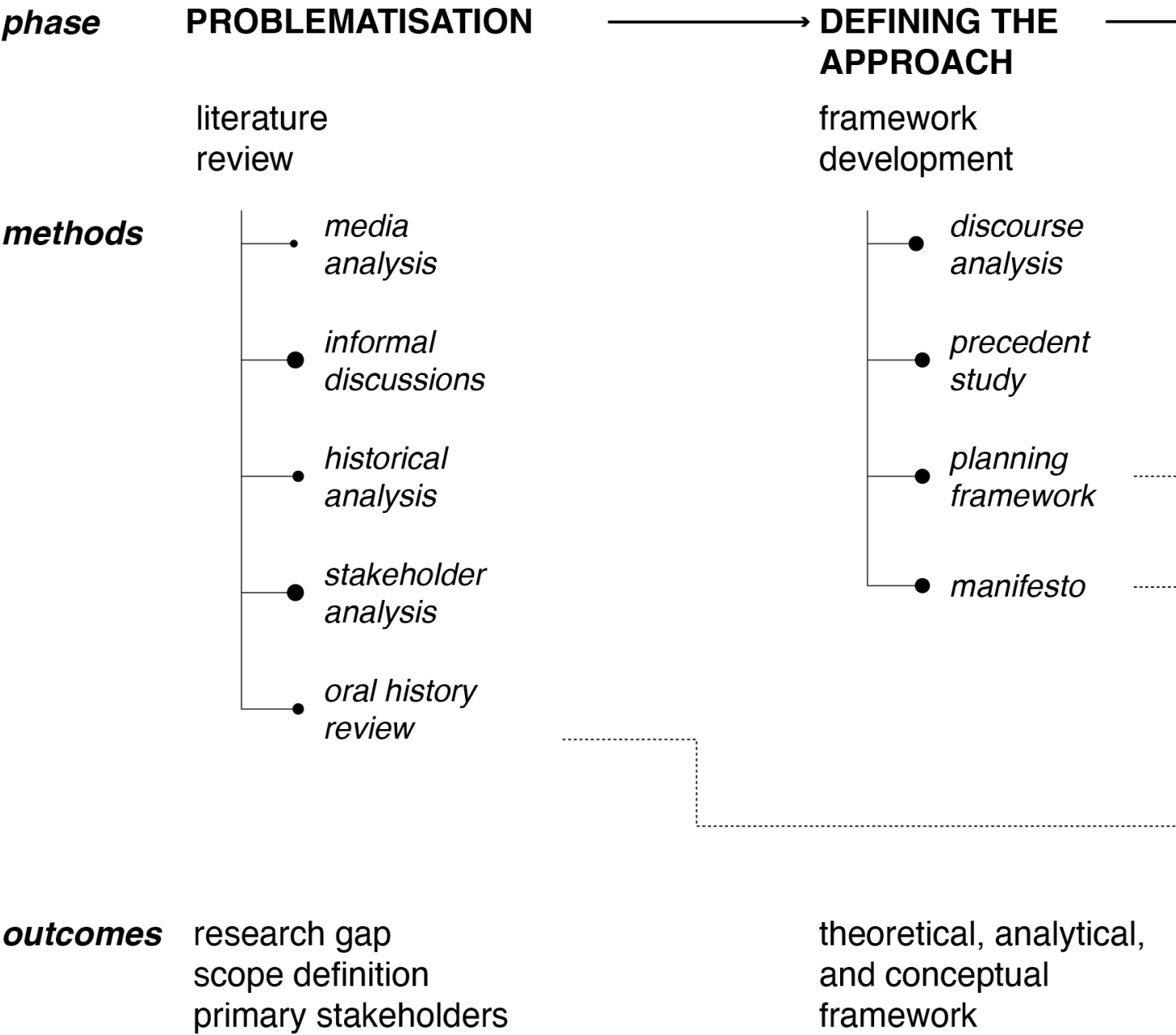
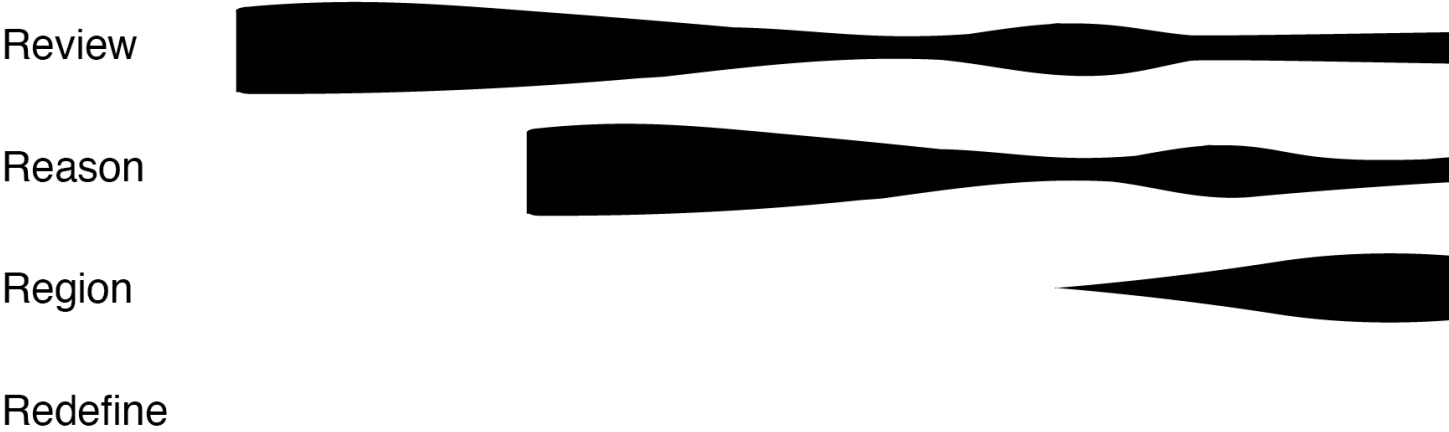
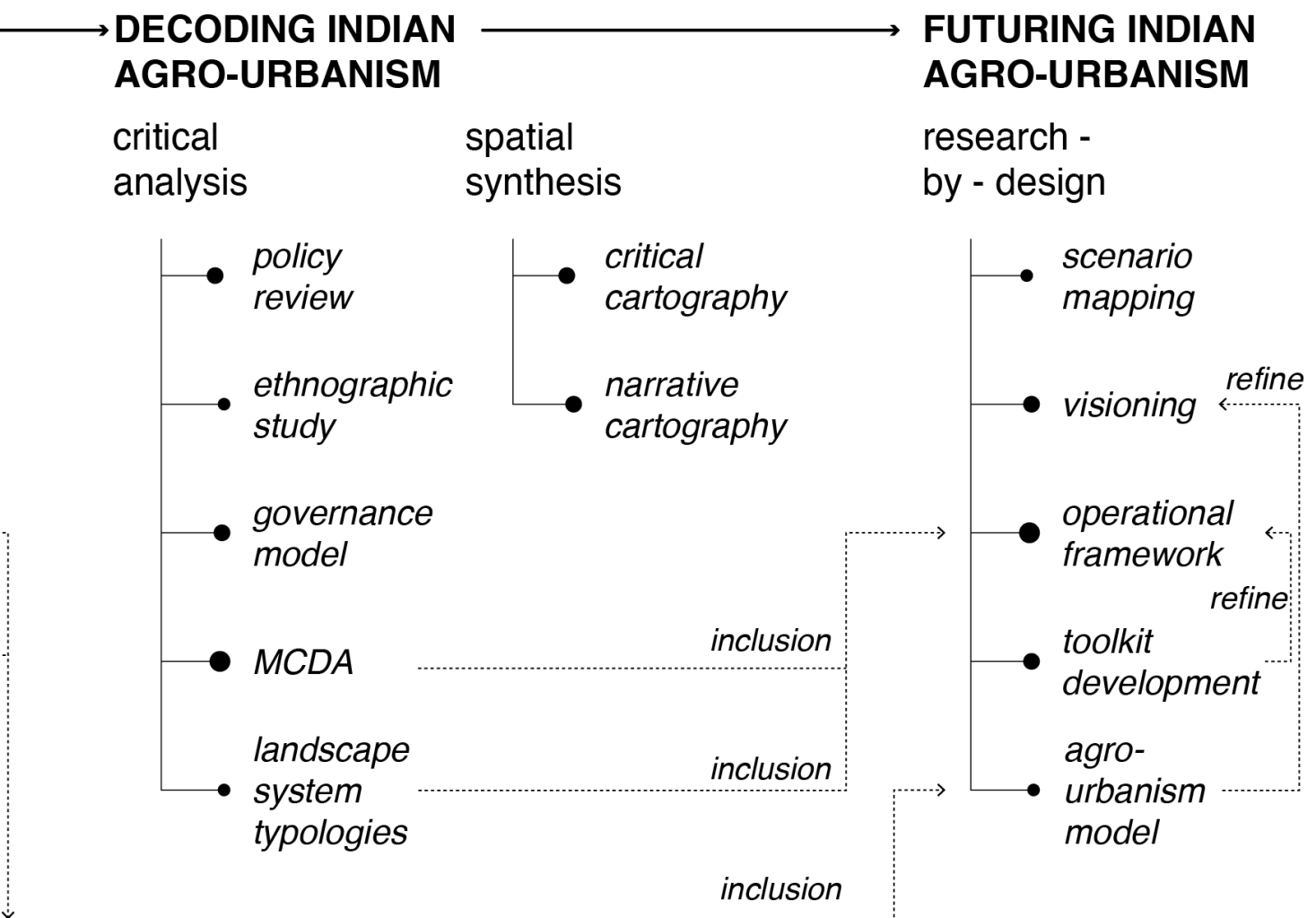
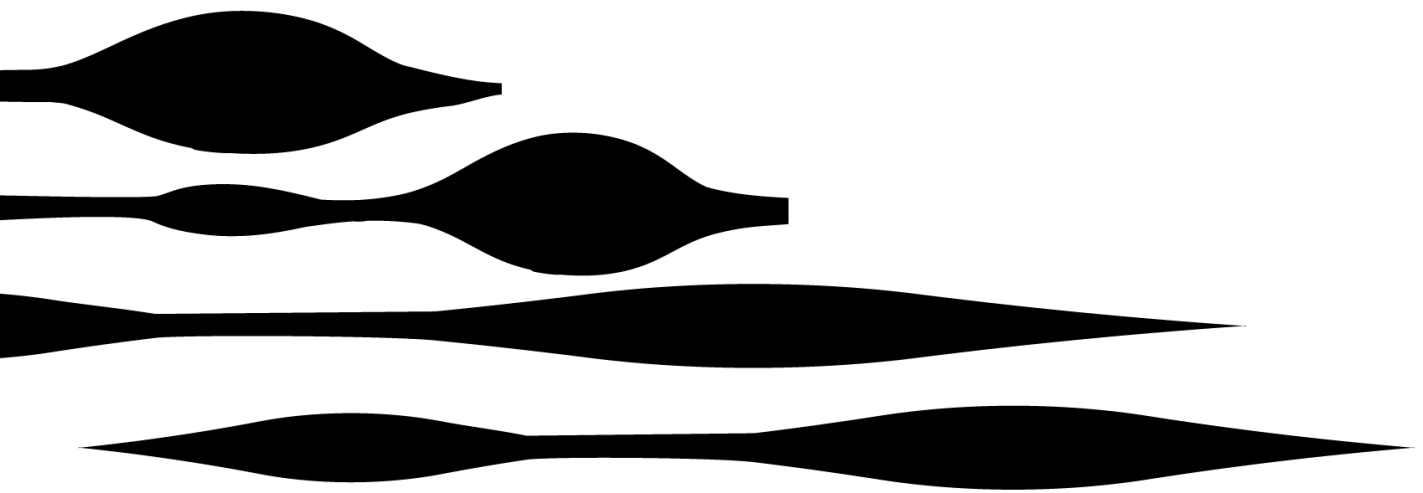


Figure 19: Methodological framework, timeline, and expected output



Seasonal production and migration atlas
Sovereignty territoriality diagrams

4 scenario manifestos
Regional vision plan
Stakeholder involvement plan
Indian Agro-Urbanism Model



Figure 20: Monocropping of wheat captured at a farmland near Kalol
Photo by the author (2025).

3.

DECODING INDIAN AGRO - URBANISM

This chapter covers the WHAT, WHERE, and WHY sub-research questions; an inquiry into the systems and subsystems, biophysical characteristics, socio-ecological conditions, and the governance system that enables or impedes food production processes.

DEMOGRAPHICS

The selected region includes parts of three states in western and central India: Gujarat, Madhya Pradesh, and Maharashtra, each presenting its own opportunities and constraints. These states are closely interconnected through shared natural resources, particularly the Narmada and Tapi river systems and the underlying basalt aquifer that spans across state boundaries (Dhiman, 2012). This landscape connectivity creates a symbiotic relationship among the states as well as the uneven distribution of burdens, as water availability, agricultural activity, and resource management in one area often influence conditions in neighbouring regions.

Gujarat

Gujarat functions as a highly legible example of infrastructure-led spatial transformation. The buildout of large-scale hydraulic infrastructure, anchored by the Sardar Sarovar Project and complemented by distributed interventions such as check dams and farm ponds, has fundamentally boosted agricultural productivity. This is reinforced by an improved network of energy distribution and an all-weather rural road network, which has catalysed a decisive land-use transition: from subsistence grain cultivation toward export-oriented cash cropping in cotton, oilseeds, and horticulture. The dairy economy, organised around the Amul cooperative network, represents a parallel spatial logic of dispersed production aggregated through supply-chain corridors. The presence of industrial development initiatives led by the Gujarat Industrial Development Corporation (GIDC) has also contributed to the growth of industrial corridors throughout the

region, mainly including chemicals and petrochemicals, textiles, pharmaceuticals, engineering, automobiles, gems and jewellery, and ceramics. Fertiliser industries and agro-based parks are also present, including township settlements associated with the Indian Farmers Fertiliser Cooperative (IFFCO). Despite this apparent dynamism, the territory exhibits extreme climatic vulnerabilities: erratic monsoon variability, recurring drought-induced production shocks, and accelerating groundwater depletion in semi-arid zones driven by water-intensive monocultures undermine long-term resilience (Gulati, Roy, & Hussain, 2021).

Madhya Pradesh

Madhya Pradesh presents a comparable trajectory of agrarian intensification, driven by expanded irrigation coverage strengthened by state subsidies and growing private investment in tube-well infrastructure, particularly across its western districts. Improved wheat procurement systems, rural electrification for agriculture, and enhanced road connectivity have progressively integrated previously peripheral rural hinterlands into regional market systems. The state's economic base has diversified beyond its historic grain identity: while wheat and soybeans are predominantly grown, horticulture is emerging as a significant land-use category, with MP repositioning itself as a net exporter of fruits and vegetables to urban markets in northern and western India. However, the territorial development model faces persistent systemic constraints, low per capita income, fragmented smallholder landholdings, and inadequate cold chain and post-harvest processing infrastructure, which

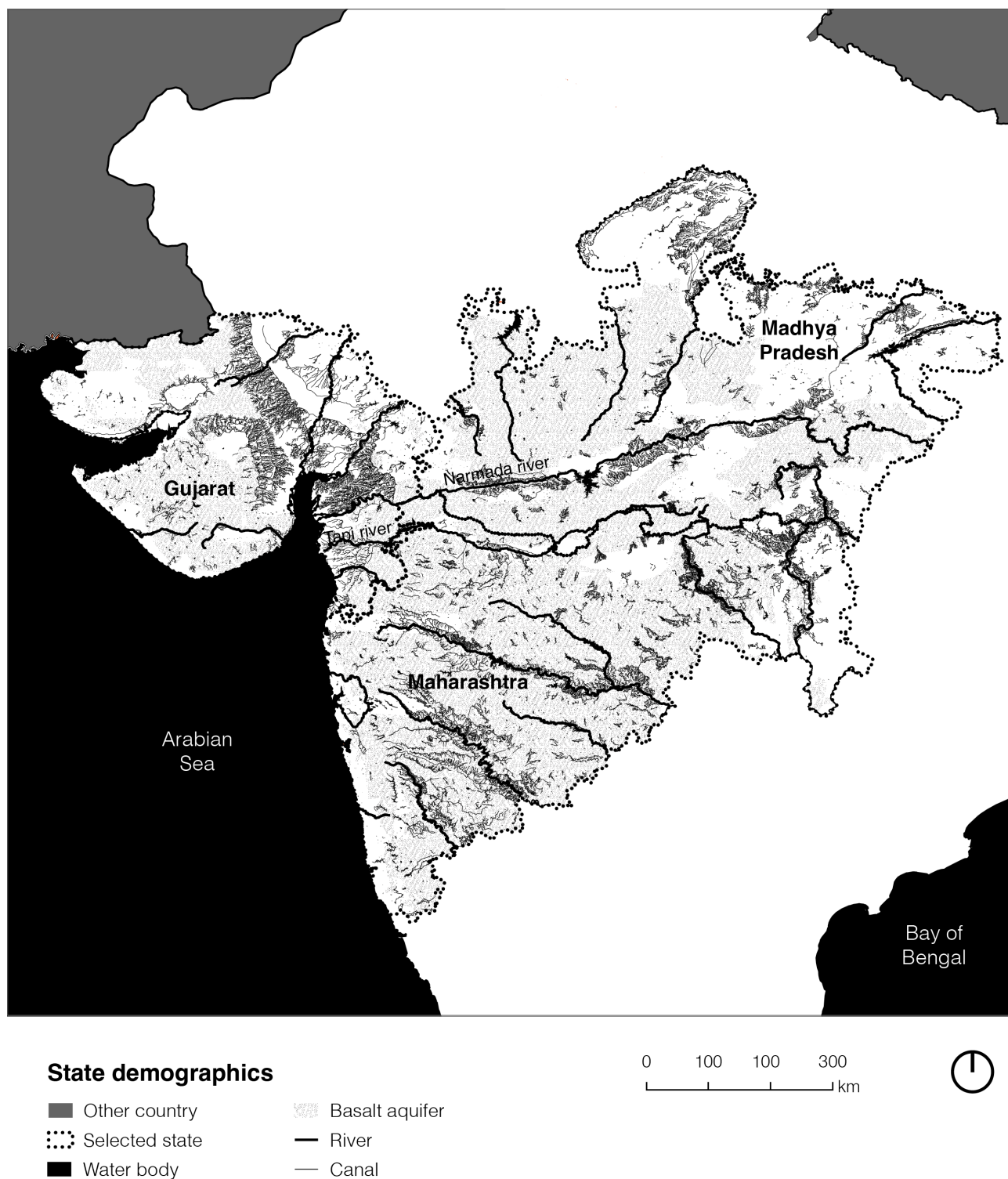


Figure 21: Map depicting shared water resources between the three selected states
 Source of information for image: Central Ground Water Board (2012); (Ministry of Electronics and Information Technology (MeitY), 2021)

limit value capture along agro-commodity chains. In rainfed upland districts, climatic variability and asymmetric access to irrigation infrastructure continue to reproduce spatial inequalities (Gulati, Rajkhowa, Roy, et al., 2021)

Maharashtra

Maharashtra's border districts, Nashik, Dhule, Nandurbar, and Jalgaon, exhibit a dense, polycentric agro-industrial landscape. Sugarcane belts sustain cooperative sugar mill clusters that anchor peri-urban economies; Nashik's Sahyadri foothills support internationally linked grape and onion export nodes connected to Gujarat's port infrastructure by highway corridors. Cotton cultivation in the Deccan black-soil zone feeds raw fibre into the textile manufacturing hubs of Surat and Ahmedabad. Double-cropping systems along the Tapi and Girna canal networks and emerging agro-processing clusters in Jalgaon reflect intensifying land-use pressure. Yet groundwater overexploitation, sugarcane monocultures straining water equity, inadequate cold-chain infrastructure, and erratic monsoon exposure in upland Nandurbar reveal the fragility embedded within this productive landscape (Gulati et al., 2023).

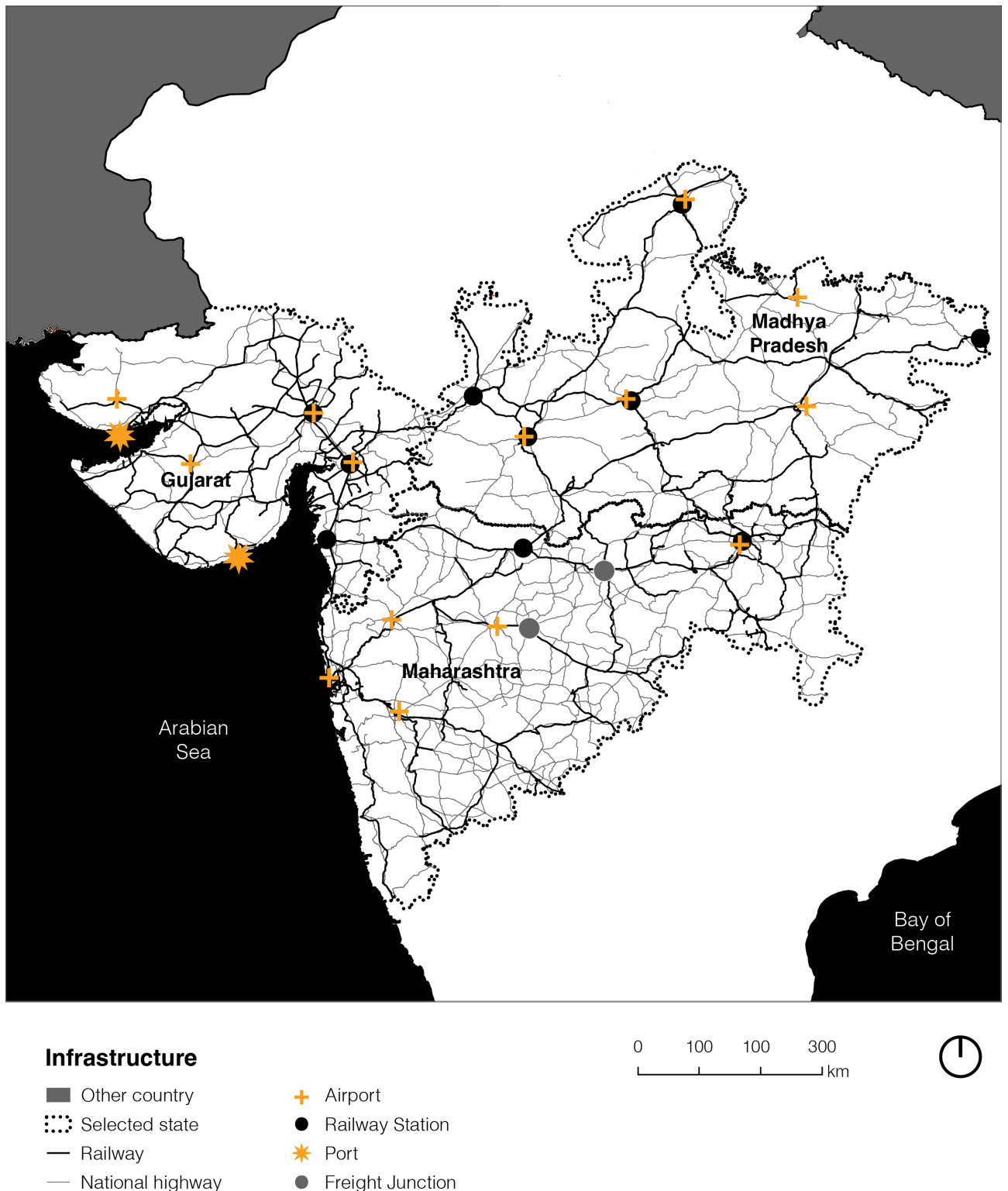


Figure 22: Map depicting the infrastructural connectivity within and between the three states
Source of information for image: Central Ground Water Board (2012); (Ministry of Electronics and Information Technology (MeitY), 2021)

AGRO-CLIMATIC ZONES

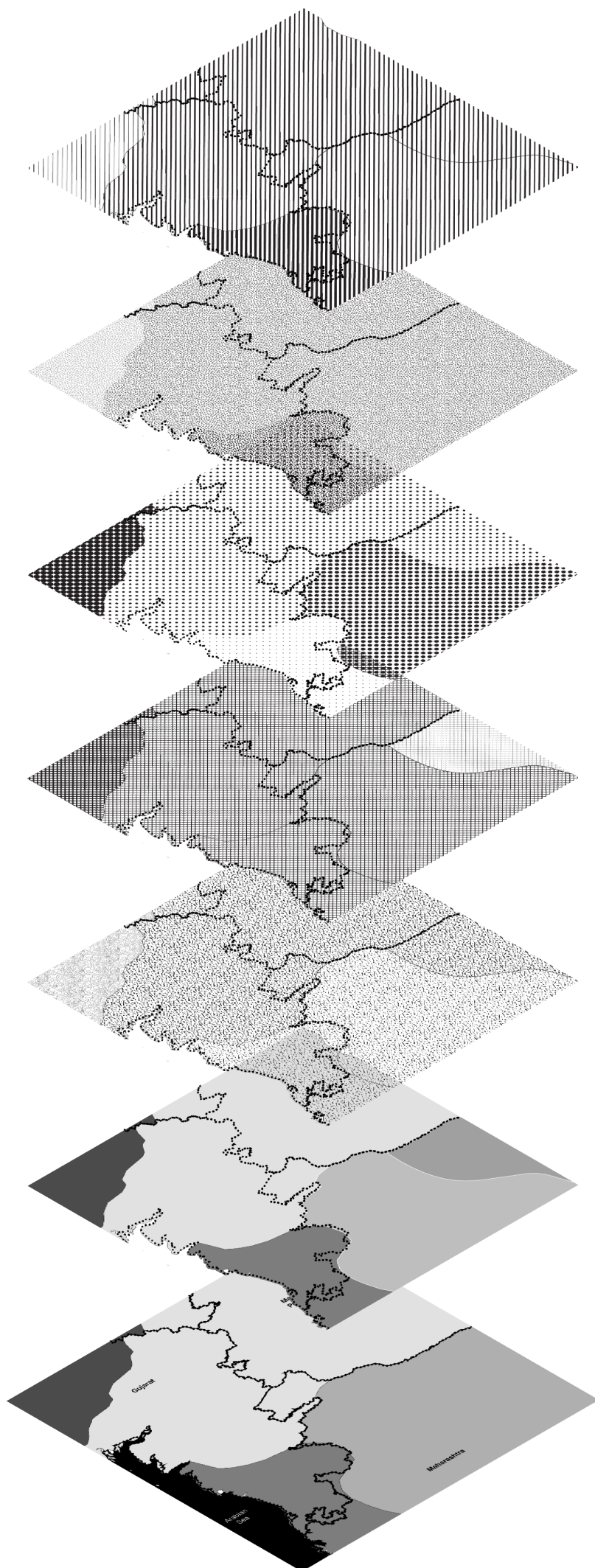
In the late 1980s, the Planning Commission of India (established in 1950 and subsequently replaced by NITI Aayog in 2015) delineated the Indian subcontinent into 15 agro-climatic zones and 72 sub-zones, establishing a biophysical basis for spatially differentiated agricultural planning. The study region spans four of these zones across five sub-zones (Ahmad et al., 2017). The tripoint area, covering districts in Madhya Pradesh and eastern Gujarat, is characterised by hot, moist semi-arid conditions, medium-to-deep black clayey soils, and a growing period of 120–150 days. Northeastern Gujarat, by contrast, presents a drier semi-arid profile with alluvium-derived loamy soils and a shorter growing period of 90–120 days; conditions that limit agricultural productivity and have historically steered this sub-zone toward urbanisation. Maharashtra's portion of the region encompasses three sub-zones: a humid coastal plain shared with southern Gujarat, supporting high agricultural intensity with a growing period of 210–240 days; and two inland semi-arid zones with black clayey soils and medium growing periods, primarily supporting rainfed cultivation of wheat, millets, cotton, pulses, and oilseeds. Irrigated areas are predominantly focused on water-intensive crops such as sugarcane, rice, and wheat.

The Planning Commission assigned each zone a Zonal Planning Team (ZPT), comprising central departments, state governments, and agricultural research institutions, tasked with producing territorial diagnostic frameworks mapping land-use constraints, cropping options, and irrigation infrastructure (Guha, 1995). These teams were tasked with formulating zone-specific strategies intended to bridge national policy and district-level implementation. However, neoliberal agricultural policies prioritising high-value crops and Minimum Support Price mechanisms

undermined locally contextualised cropping recommendations. Furthermore, the discontinuation of the committees established by the Planning Commission (Arunachalam & Misra, 2020), even if agro-climatic zonal considerations are reflected in local body strategies today, remains a missed opportunity that can be revived.

Figure 23: Agro-climatic zone characteristics in the selected region

Source of information for image: Sehgal et al. (1996), European Digital Archive of Soil Maps (EuDASM)



Length of Growth Period (LGP)

- 210 - 240 days
- 120 - 150 days
- 90 - 120 days

Weather type

- Hot moist subhumid
- Hot moist semi arid
- Hot dry semi-arid

Soil type

- Loamy grey brown and alluvium-derived soil
- Loamy to clayey black soil
- Clayey black soil
- Loamy to clayey mixed red and black soils

Soil depth

- Deep
- Medium to deep
- Shallow to medium

Available water content (AWC)

- Medium to high
- Medium

Agro-climatic sub-zones

- Western Ghats and Coastal Plain
- Central Highlands (Malwa)
- Northern Plain (and Central Highlands)
- Deccan Plateau: Central and Western Maharashtra
- Deccan Plateau: Eastern Maharashtra Plateau

Agro-climatic zones

- State boundary
- Western Ghats and Coastal Plain
- Central Highlands (Malwa)
- Northern Plain (and Central Highlands)
- Deccan Plateau

SYSTEMS AND SUBSYSTEMS

A myriad of processes and systems are interlinked before they reach the consumers. The following subsystems, however, are key to the food planning system to ensure food security. Anchored by cities such as Ahmedabad, Surat, Vadodara (Baroda), Nashik, and Indore, this region functions as both an agricultural hinterland and an industrial-logistics corridor. Here, rural livelihoods, peri-urban expansion.

Seasonality of Production Processes

There are primarily two cropping seasons. Kharif season, driven by the southwest monsoon from June to October, anchors rainfed production across Madhya Pradesh, Maharashtra, and Gujarat. Key crops include soybean, where Madhya Pradesh and Maharashtra contribute 53% and 34% of national output respectively, alongside cotton in Gujarat (28%) and Maharashtra (21%), plus rice, maize, sorghum, and pulses. While early monsoon rains accelerate planting, waterlogging in the deep black soils of Madhya Pradesh and districts such as Surat poses productive risks. Rabi season, extending from October to April under irrigated conditions, supports wheat, barley, gram, and mustard cultivation, climatically the most stable and predictable window in the agricultural calendar. A third season, Zaid (March–June), supports subsistence and commercial horticulture but remains climatically precarious, with farmer participation contingent on prior harvests, weather forecasts, and urban wage-labour opportunities.

The need for income diversification instigates local and regional migration corresponding to the type of farmer and the farming season, which is further defined by the biophysical characteristics of their farming region (see Figure 24). Farmer typologies, as shown in the figure, correspond to distinct spatial

strategies (Ministry of Agriculture & Farmers Welfare, 2019). Tribal and landless farmers concentrate production during kharif while seasonally migrating as agricultural labourers (Ministry of Tribal Affairs, 2018). Marginal and small farmers circulate to nearby urban construction sites during crop periods, leaving spouses to manage cultivation (Jethmalani & Katiyar, 2023). Semi-medium and medium farmers increasingly relocate permanently to urban centres, while large landholdings, often absentee-owned, rely on hired seasonal labour, with owners present only during sowing and harvest (Food and Agriculture Organization, 1989).

Input subsystem

The region's shared hydrological infrastructure of river basins, groundwater systems, and the transboundary basalt aquifer means that anthropogenic pressures in one territorial unit generate cascading effects across state boundaries. Intensive upstream irrigation in Madhya Pradesh and Maharashtra has historically driven agricultural productivity, but at a significant systemic cost downstream in Gujarat. Studies on Indian groundwater use document a persistent imbalance between aquifer recharge and extraction rates, producing conditions of “water mining” and declining water tables, particularly across semi-arid western territories where groundwater constitutes the primary irrigation source (Balaji et al., 2025). The westward flow of the Narmada and Tapi river systems amplifies this dynamic; upstream abstraction for agriculture or industrial use directly diminishes downstream availability critically during dry seasons when natural recharge is already constrained (Figure 25).

A second transboundary challenge concerns the downstream migration of agricultural

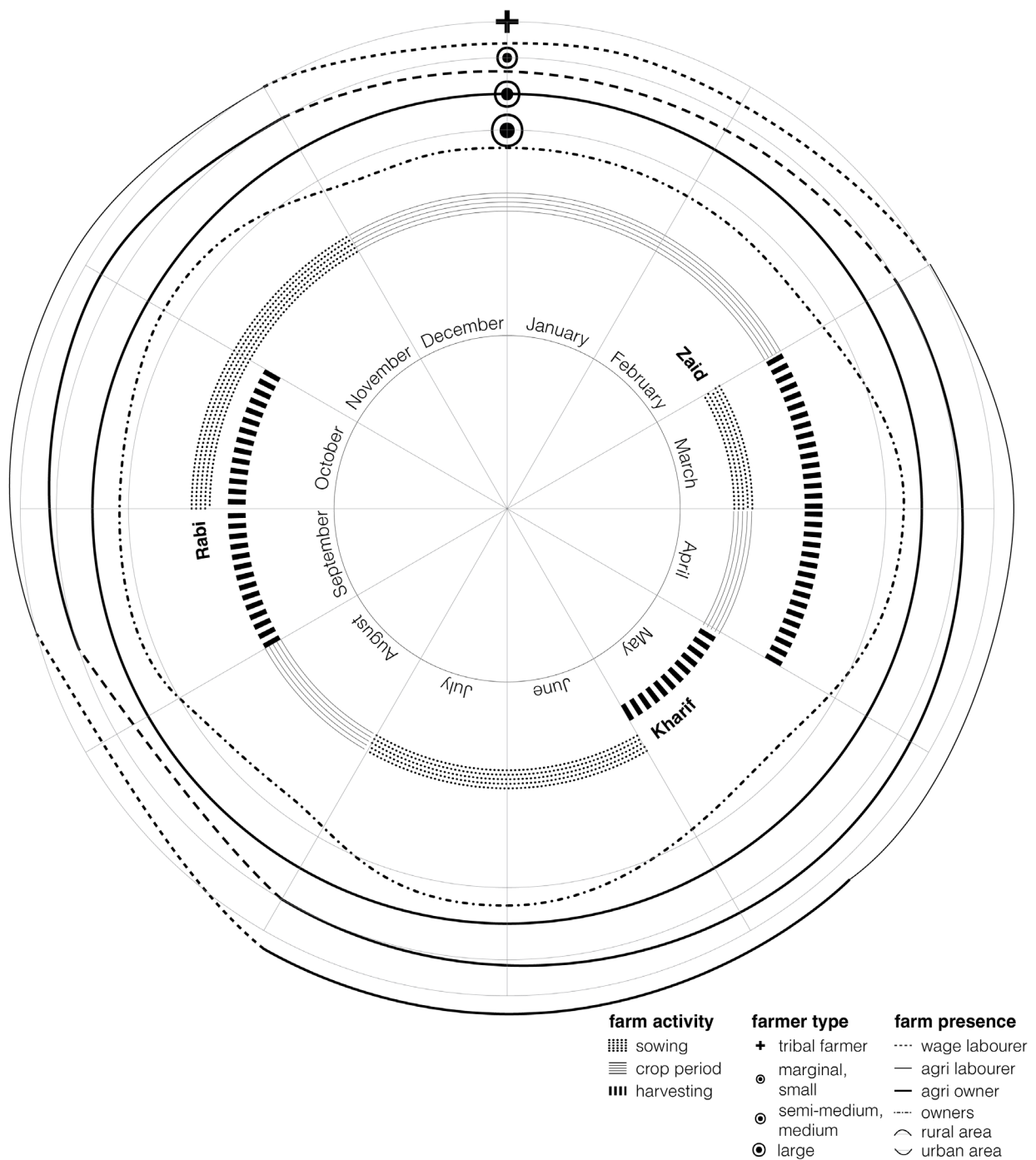


Figure 24: Farming seasons, farmer types, and the associated migration patterns.
Source of information: Sehgal et al. (1996).

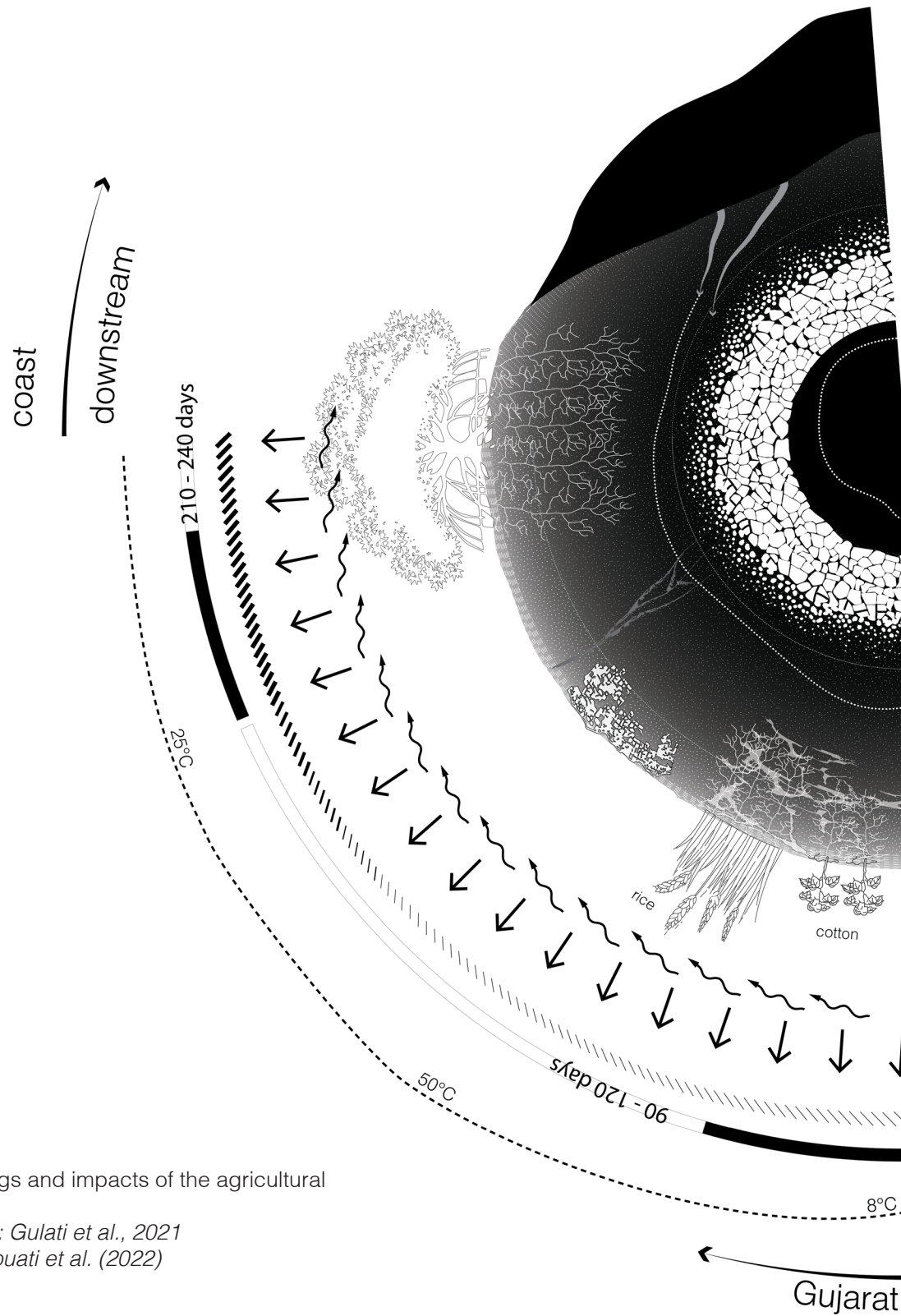
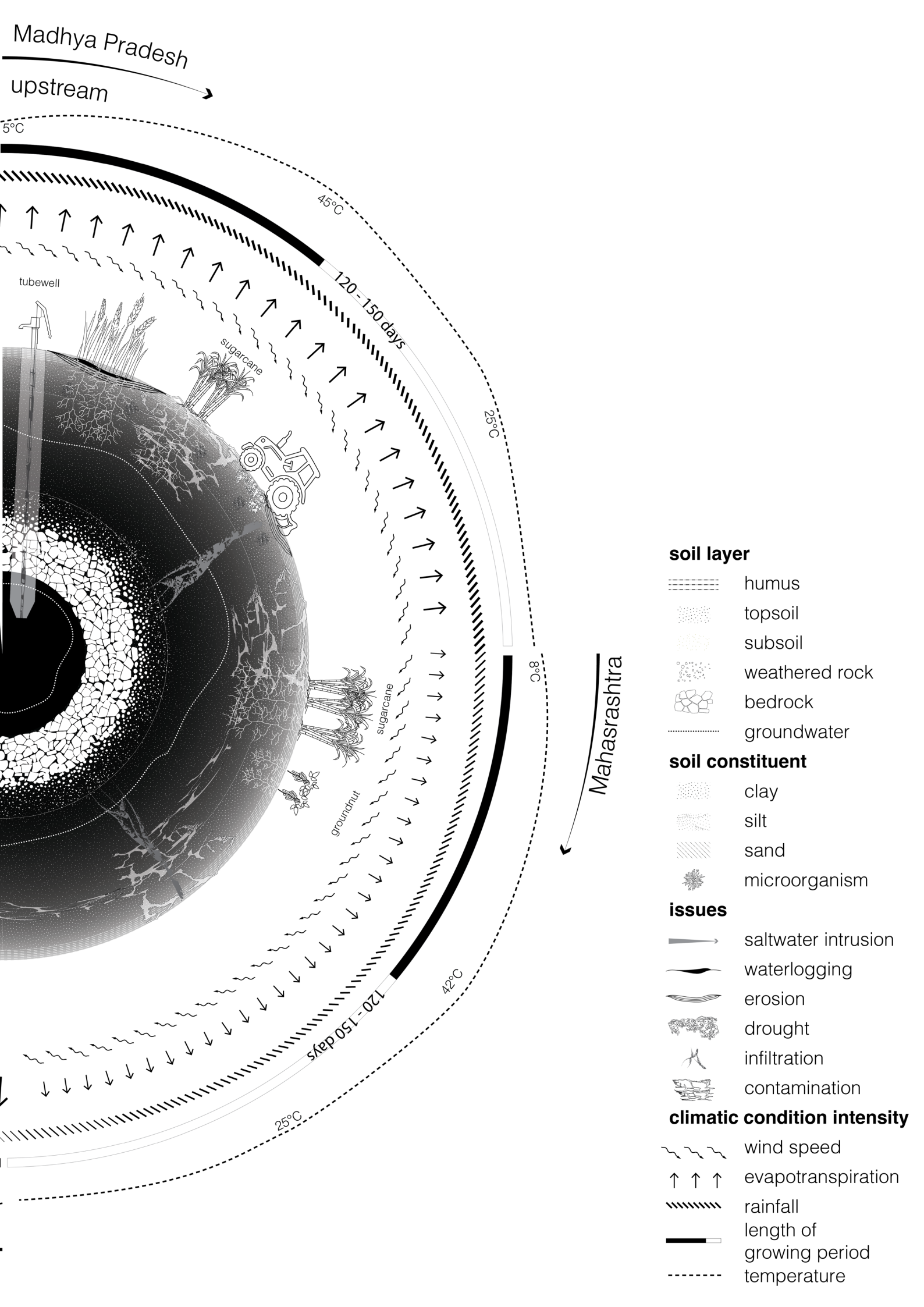


Figure 25: Regional undertakings and impacts of the agricultural system in the study region.

Source of information for image: Gulati et al., 2021

Representation reference: At-Touati et al. (2022)



pollutants. Fertilisers and pesticides applied across upstream cultivated landscapes get carried with surface runoff and river systems into downstream soils and aquifer recharge regions. Reviews of groundwater quality in Gujarat identify chemical agricultural inputs as a significant driver of aquifer degradation and water quality deterioration, particularly where intensive irrigation and poor agrochemical management compound one another (Chaudhari et al., 2024). The cumulative territorial implication is significant: contaminants originating in the upland agricultural systems of Madhya Pradesh and Maharashtra may ultimately undermine water safety and soil productivity across downstream Gujarat, a transregional dynamic well-documented in river-basin environmental studies.

Along Gujarat's coastal edge, these pressures exacerbate with a further hydrological vulnerability: saltwater intrusion. Inland groundwater over-extraction reduces freshwater hydraulic pressure, enabling seawater to infiltrate into coastal aquifer systems. Hydrogeological reviews confirm groundwater over-exploitation as the dominant driver of coastal salinity intrusion in Gujarat, directly threatening irrigation water quality and soil productivity in coastal agricultural zones (Siddha & Sahu, 2020).

Climatic stressors, elevated temperatures, high evapotranspiration rates, and wind erosion compound the aforementioned vulnerabilities across all three states. Semi-arid districts experience intensified soil moisture loss and heightened irrigation demand, reinforcing groundwater depletion cycles. In sparsely vegetated dryland landscapes, wind and water erosion strip productive topsoil, with documented evidence of significant runoff-driven sediment loss from western Indian

agricultural systems (Meena et al., 2023). The interaction between drought stress and soil degradation produces self-reinforcing feedback loops, progressively eroding the long-term productive carrying capacity of marginal agricultural lands.

Post-Harvest Processing and Storage

A structural disconnect between agricultural output and post-harvest infrastructure intensifies the region's agrarian challenges. Despite high production volumes of cash crops, particularly backed by Minimum Support Price (MSP), formal storage capacity remains critically underprovided. Farmers across Gujarat and neighbouring states default to informal household storage for grains, pulses, and oilseeds, where inadequate ventilation and moisture exposure generate pest infestations and fungal contamination (Figure 26). Aflatoxin contamination of groundnuts presents a particular risk in Gujarat, where improper drying and storage conditions compromise both crop quality and export viability (Gulati, Roy, & Hussain, 2021). This infrastructural gap has produced operational failures in government procurement systems. Groundnut procurement in Gujarat was shortly suspended a decade ago due to storage saturation (Dave, 2014), revealing the mismatch between bulk monoculture production strategies and institutional absorptive capacity.

Central Warehousing Corporation (Figure 27) and APMC mandi-linked facilities remain inadequate relative to production volumes, with rural zones disproportionately underserved and storage capacity unevenly concentrated around specific commodities and urban nodes (Mukarji & Ranjan, 2026). Cold chain infrastructure, essential for horticultural clusters in Nashik and Indore, is both scarce and financially inaccessible for smallholders.



Figure 26: Farmers storing grains in their houses in farm near Kalol, Gujarat.
Image source: Photo by author (December 2025).



Figure 27: A place to store and trade agricultural produce, APMC Surat
Image source: Tallati (2021).



Figure 28: Central warehouses for non-perishable items such as potatoes, Nashik
Image source: AgroSpectrum India (2022).

Existing cold storage capacity is predominantly configured for single commodities such as potatoes (Figure 28), leaving perishables inadequately served ('Gujarat Leads the Country in Cold Storage', 2023).

While logistics corridors connecting Surat, Nashik, and Indore function as significant inter-state agricultural arteries, they consolidate economic power within large procurement systems. The transition towards diversified, perishable, and nutritionally dense crop production demands a complementary shift toward decentralised processing units, cold chain networks, and distributed storage infrastructure embedded within production landscapes.

Market and Trade

Post-harvest infrastructure deficits are further aggravated by structural market inequities that simultaneously impact farmer income and ecological sustainability. The regional trading system remains substantially organised around APMC mandis, where intermediaries historically monopolised agricultural exchange (Figure 29). Recent reforms across Gujarat, Madhya Pradesh, and bordering states have now partially liberalised this system. Gujarat's 2020 Ordinance unified market areas, enabling private yards, direct sales, and e-trading platforms with capped fees, while the e-NAM platform has improved price discovery for millets, pulses, and organic produce. Nevertheless, intermediaries continue to capture a disproportionate share of consumer prices. Producer price shares for perishables range from only 32–68%, with the remainder absorbed by commissions, transport costs, and trader margins (Saha et al., 2024). Licensing structures facilitate cartel-like behaviour that suppresses competitive bidding and systematically disadvantages

smallholders (Agriculture Institute, 2025).

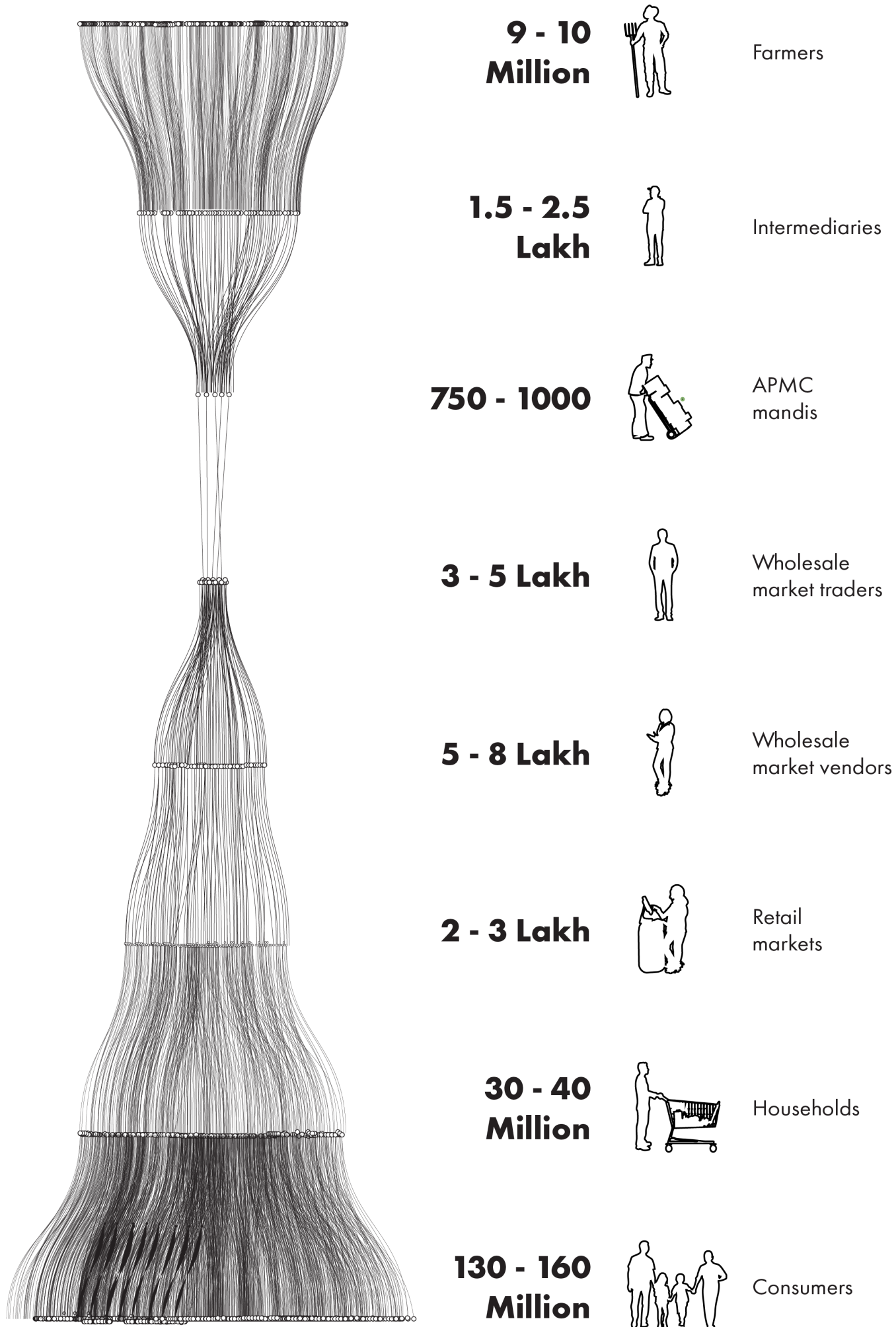
Price volatility across horticultural commodities, particularly onions, soybeans, and groundnuts, constitutes a further destabilising force. Seasonal supply fluctuations, perishability, and inadequate storage compress farmers' selling windows, generating chronic uncertainty and eroding trust between producers and mandi traders. Empirical studies confirm that dependence on a limited pool of licensed traders restricts bargaining power and breeds widespread scepticism around grading and price determination (Bhatnagar, 2021). These market dynamics directly shape cropping decisions at the territorial scale. Farmers adjust production in response to export demand and anticipated price signals, particularly for cotton, onions, and oilseeds, reinforcing monoculture patterns that carry both ecological and financial risks for farming communities (Villacis et al., 2024).

Distribution and consumption

India's post-independence food system was organised around caloric sufficiency, with the Green Revolution embedding large-scale rice and wheat production as the territorial backbone of national food policy. The Public Distribution System (PDS) institutionalised this logic, channelling subsidised staple grains to below-poverty-line households (Public Distribution System (PDS), n.d.), while the Food Corporation of India (FCI) managed procurement at Minimum Support Prices, operating grain reserves across an extensive fair-price shop network. In many rural territories, these distribution nodes have progressively expanded into Common Service Centres (CSCs), functioning as integrated rural access points for seeds, fertilisers, and digital services, reflecting policy ambitions to embed last-mile agricultural support within the rural spatial fabric (MeitY, 2015).

Figure 29: Production and consumption statistics.

Source of information for image: Saha et al., 2024; Bhatnagar, 2021.



FAO and NITI Aayog assessments confirm that this procurement-led distribution model substantially improved national food availability and eliminated large-scale famine risk, repositioning India from food deficit to a major staple exporter. However, the ecological costs embedded in this success are significant: intensive rice and wheat cultivation has driven disproportionate irrigation demand and accelerated groundwater depletion across production territories, leading to alterations in the ecosystem of water bodies (Balaji et al., 2025). Institutional discourse is crucial to reframe food security beyond caloric metrics toward nutritional security, advocating diversification into pulses, millets, fruits, and vegetables to simultaneously address dietary deficiencies and reduce soil and water stress. Reconciling the structural incentives of MSP-driven monoculture with ecologically sustainable and nutritionally diverse production systems remains a central territorial planning challenge across the region.

Governance Systems

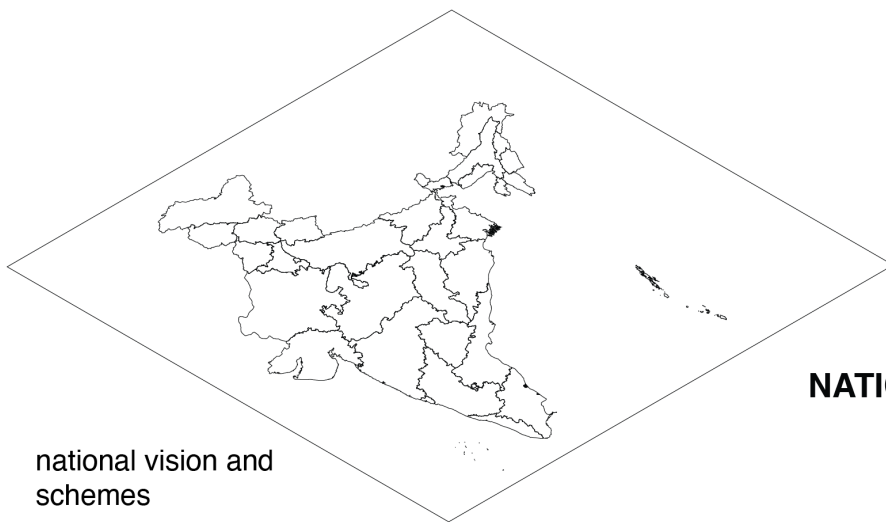
In peri-urban territories surrounding India's expanding metropolitan centres, non-farm wage labour, particularly urban construction work, has become structurally embedded within agrarian household economies. Studies on rural-urban linkages document construction and infrastructure labour contributing up to 40% of total household earnings in peri-urban regions, reflecting how urban expansion economies directly subsidise rural livelihoods (Gulati et al., 2023). This dependence is driven by progressive landholding fragmentation and declining per-capita agricultural viability, pushing governance frameworks toward resource-efficient intensification, producing greater output from diminishing land and water endowments. These pressures are accelerating interest in precision irrigation,

sensor-based monitoring, and mechanised harvesting systems that reduce labour dependency while maintaining productivity.

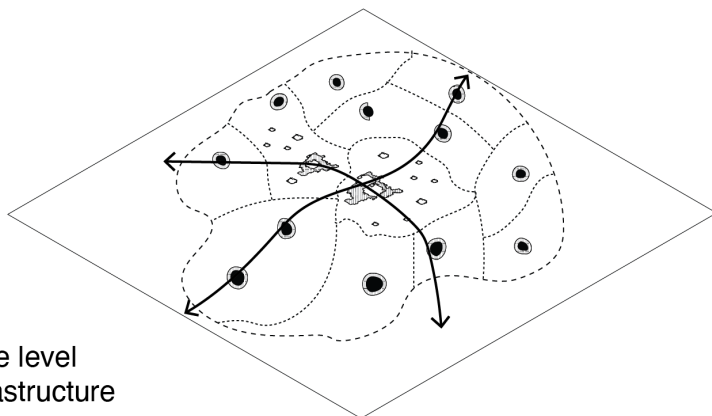
Yet technological transitions remain structurally constrained by inadequate credit access. Small and marginal farmers continue to depend on informal lending networks due to complex documentation requirements and insufficient rural banking penetration, limiting investment in crop diversification, storage infrastructure, and value-addition facilities (Gulati et al., 2023). This credit gap reproduces regional trade imbalances, where territories export raw commodities while remaining dependent on external imports of processed goods.

India's decentralised governance model compounds these challenges. Although Panchayati Raj institutions were designed to enable bottom-up territorial planning, centralised fund allocation effectively reproduces top-down planning logic, aligning local priorities with nationally defined schemes rather than place-based needs. Historically, planning investment has concentrated in metropolitan and industrial corridors, leaving rural extension services, infrastructure delivery, and localised implementation mechanisms chronically underfunded, reinforcing spatial inequalities between urban & industrial development and agrarian hinterlands (Figure 30).

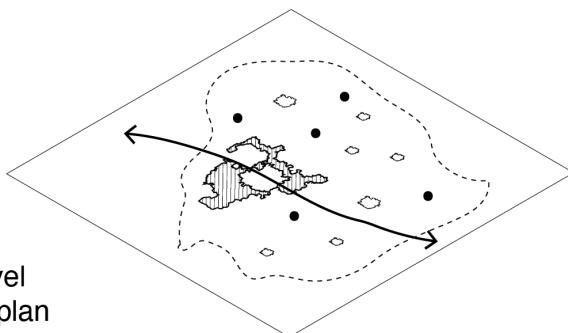
Figure 30: Multiscalar interdependent spatial planning framework in India.



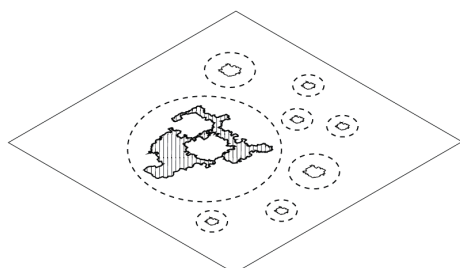
national vision and schemes



state level infrastructure



district level coherent plan



NATIONAL

*national interest
in GDP growth*

STATE

DISTRICT

LOCAL

urbanisation

infrastructural
projects

industrial
projects

taxation and
subsidies

land
economics

land
consolidation

land use
zoning

urban
development
plan

urban
development

tokenism
rural plan
updates

rural
development

—→ actual

- - - → perceived

LIVED REALITIES

Justice to Farmers

Despite constituting nearly half of India's workforce, farmers contribute only approximately 15% of the national GDP, a structural disparity that concentrates economic precarity within the agrarian sector (Ahluwalia, 2016). Oral testimonies from communities displaced by the Sardar Sarovar Project highlight a deeper dimension of this precarity: tribal farmers, whose subsistence practices were historically embedded within forest ecosystem knowledge, describe forced adoption of chemical-intensive agriculture on nutrient-depleted soils disconnected from their accumulated understanding of ecological crop cycles (Oral History Narmada, n.d.). The urbanisation-oriented development sever place-based ecological knowledge from productive landscapes. Additionally, while many farmers demonstrate awareness of eco-sensitive and potentially cost-efficient farming practices, collective action barriers inhibit adoption, as individual farmers remain reluctant to absorb the risks of sustainable transition while peers continue extracting short-term economic gains through conventional methods.

Furthermore, farmers in rural areas consistently articulate aspirations toward urbanisation, seeking better educational infrastructure and income diversification, yet structural cost barriers confine most of them to seasonal migration strategies. Farming frequently persists as an inherited practice rather than a chosen vocation, sustained by limited access to education, skill development, and affordable financial services. The absence of credit histories and collateral places formal lending structurally out of reach for smallholders,

compounding income constraints. The territorial planning frameworks must, thus, extend beyond agricultural productivity metrics to address enhanced liveability index, ecological literacy, financial inclusion, and livelihood diversification as foundational dimensions of agrarian urbanism.

Justice to Nature

Across the urbanising corridor connecting Ahmedabad, Surat, Vadodara, Nashik, and Indore, ecological justice emerges as a foundational planning imperative, demanding recognition of watersheds, soils, forests, and biodiversity networks as legitimate spatial actors rather than resource inputs for urban expansion. IPCC assessments confirm that semi-arid territories of western and central India face rising temperatures, increasingly erratic monsoon patterns, and intensifying extreme weather events, with climate pressures disproportionately concentrating vulnerability in peri-urban and rural communities whose livelihoods remain ecologically embedded (Pörtner et al., 2022). Shifting rainfall variability documented by the India Meteorological Department, producing simultaneous flash flooding and prolonged dry spells, destabilises agro-urban territories and renders climate-responsive spatial design non-negotiable.

Furthermore, the maritime infrastructure anchored by Surat Port exemplifies the territorial contradictions embedded in the current development model. Gujarat's coastal ports handle a significant share of India's maritime trade, facilitating flows of agricultural commodities, edible oils, fertilisers, and livestock products. Yet the spatial footprint

of port expansion, land reclamation, and industrial effluents has systematically degraded estuarine habitats, disrupted mangrove ecosystems, and undermined coastal fishery livelihoods. UNEP research highlights that coastal industrialisation accelerates biodiversity loss and amplifies flood vulnerability in deltaic zones where mangroves function as critical buffers against storm surge and saltwater intrusion (UNEP, 2026).

Livestock systems add a further layer of ecological complexity. Mixed crop-livestock economies provide critical livelihood resilience for peri-urban smallholders around Ahmedabad and Nashik, with dairy networks functioning as financial stabilisers against crop income volatility, a model the FAO identifies among the most climate-resilient agricultural configurations (Gulati, Roy, & Saini, 2021). However, livestock intensification generates competing pressures: escalating fodder and water demands accelerate land contestation and deforestation in marginal landscapes, while inadequately managed animal waste drives soil contamination and methane emissions. IPCC reporting confirms livestock production as a significant contributor to global greenhouse gas emissions, foregrounding the need for integrated waste management and sustainable grazing strategies within peri-urban territorial planning frameworks.

India's prevailing development paradigm has historically treated rivers, floodplains, and agricultural soils as extractable infrastructure for urban growth, a logic that has progressively impacted watershed integrity, disrupted biodiversity corridors, and accelerated

dependence on artificial irrigation. The loss of agro-climatic regionalisation as a governing framework has compounded this deterioration, promoting uniform cropping practices across ecologically diverse territories. Ecological balance requires watershed protection, wetland restoration, and the reintegration of agro-ecological landscapes within urban planning frameworks.

Urban planners and designers for justice to all

In contemporary Indian planning, urban professionals occupy an ambivalent yet influential position, simultaneously acting as mediators of spatial equity and as convenient targets for political and institutional failures (Chakravarty & Prakash, 2024). Governance structures frequently subject planners to political pressures that favour immediate infrastructural outcomes over sustained resilience, rendering their professional judgment secondary to electoral and economic imperatives. This structural misalignment impacts institutional credibility and impedes resilient planning. Despite NITI Aayog's consistent advocacy for integrated frameworks reconciling national development with regional ecological realities, implementation remains fragmented.

Contemporary urbanism increasingly acknowledges that conventional land-use paradigms inadequately address agro-urban complexity. The modernist zoning inheritance, segregating land into residential, commercial, industrial, and agricultural categories, proves insufficient for territories where these distinctions blur. Agro-urbanism models around the world challenge this compartmentalisation, as exemplified by

“Agriculture should not be viewed merely as subsistence but as an enterprise requiring knowledge, skill, and innovation.”

“Limited access to institutional credit remains one of the most critical constraints to agricultural investment among smallholder farmers.”

Agriculture continues to employ nearly half of India’s workforce while contributing a much smaller share to GDP, reflecting low productivity and persistent rural income challenges.

“Improving farm incomes alone is insufficient; rural well-being depends equally on education, healthcare, infrastructure, and access to markets.”

“Limited access to institutional credit remains one of the most critical constraints to agricultural investment among smallholder farmers.”

“Planning practice is deeply rooted in local knowledge and must operate within constraints.”

“Mixed crop-livestock systems are among the most resilient agricultural models, particularly in regions exposed to climate variability.”

“Farmers’ knowledge systems are deeply rooted in ecological understanding and must be recognised as valuable forms of expertise.”

“Loss of biodiversity in agricultural landscapes reduces resilience to pests, climate variability, and soil degradation.”

Figure 31: Important quotes and conclusions that define
Source of information for image: Oral History Narmada, n.d.; Chakravarty & Prakash, 2024.

“Large infrastructure projects often transform riverine and forest ecosystems, affecting livelihoods that depend on these landscapes.”

“Watershed degradation undermines both ecological sustainability and human resilience in rainfed agricultural systems.”

“Cities cannot be understood in isolation from the rural regions that sustain them; food systems connect urban consumption to rural production.”

Well-being
re, and

“Rural and peri-urban communities are among the most vulnerable to climate variability because their livelihoods depend directly on ecological systems.”

**deeply embedded in political processes, and planners frequently
constraints imposed by short-term political priorities rather than long-
term spatial strategies.”**

“Climate change is expected to reduce water availability and increase the frequency of extreme weather events in semi-arid regions.”

“Rural households increasingly rely on non-farm income sources, including construction labour, as agriculture alone cannot sustain household aspirations.

Migration is often not a choice but a compulsion driven by limited local opportunities and inadequate rural services.”

“Modernist land-use zoning often fails to address the complexity of contemporary landscapes, particularly where rural and urban functions overlap.”

“Planners are often positioned between competing interests and are expected to mediate conflicts, even when the underlying decisions are shaped by political authority.”

the Netherlands' metropolitan food clusters, which reclassify intensive agriculture as industrial land (Wageningen MFC, n.d.). Current advocacy in India, however, disproportionately centres on introducing agriculture within urban boundaries through forensic interventions or mixed-use typologies. While valuable, such approaches cannot fulfil large cities' food demands without regional operational landscapes. Meanwhile, conventional agricultural practices similarly fall short, making automation, despite its contradictions, a pragmatic necessity.

Urbanisation processes must, therefore, be reconceived as a comprehensive system wherein food planning, encompassing production, distribution, consumption, and waste, is foundational. A shift from rigid zoning toward landscape-based planning would reframe rural-urban interfaces as dynamic ecological and economic corridors. Reinstating the Planning Commission's agro-climatic regionalisation could restore coherence across fragmented landscapes, enabling diversified cropping and localised food systems. Most importantly, **advancing agricultural productivity must proceed in tandem with improving liveability and preserving ecological balance, ensuring that spatial planning serves both human sustenance and environmental continuity across generations.**

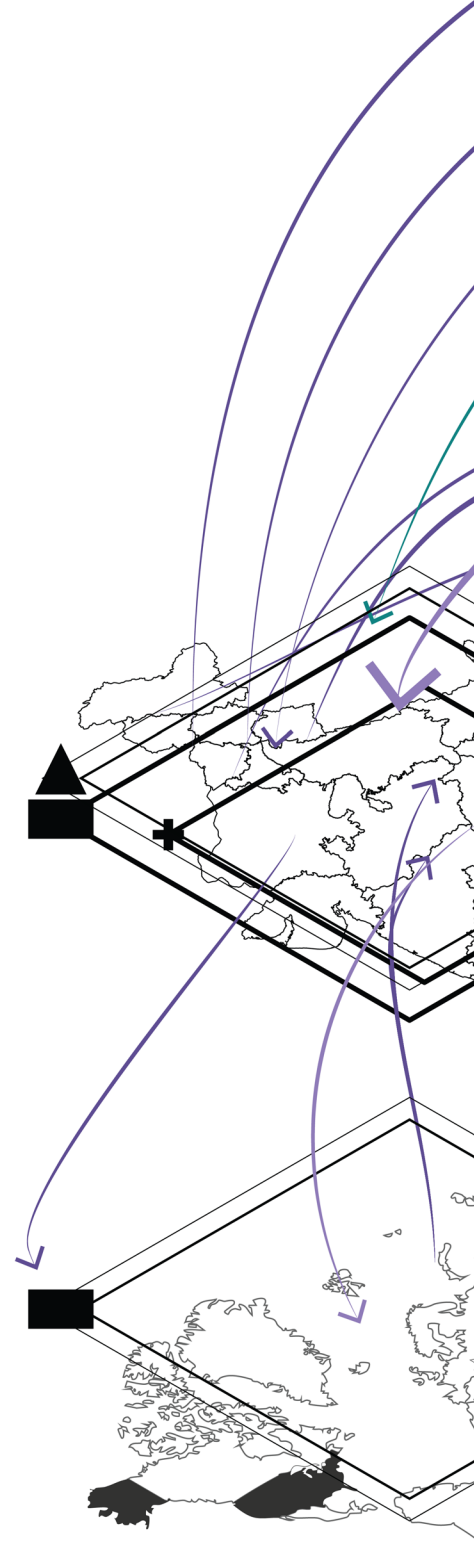


Figure 32: Diagram showing territoriality of sovereignties in The Stack model.

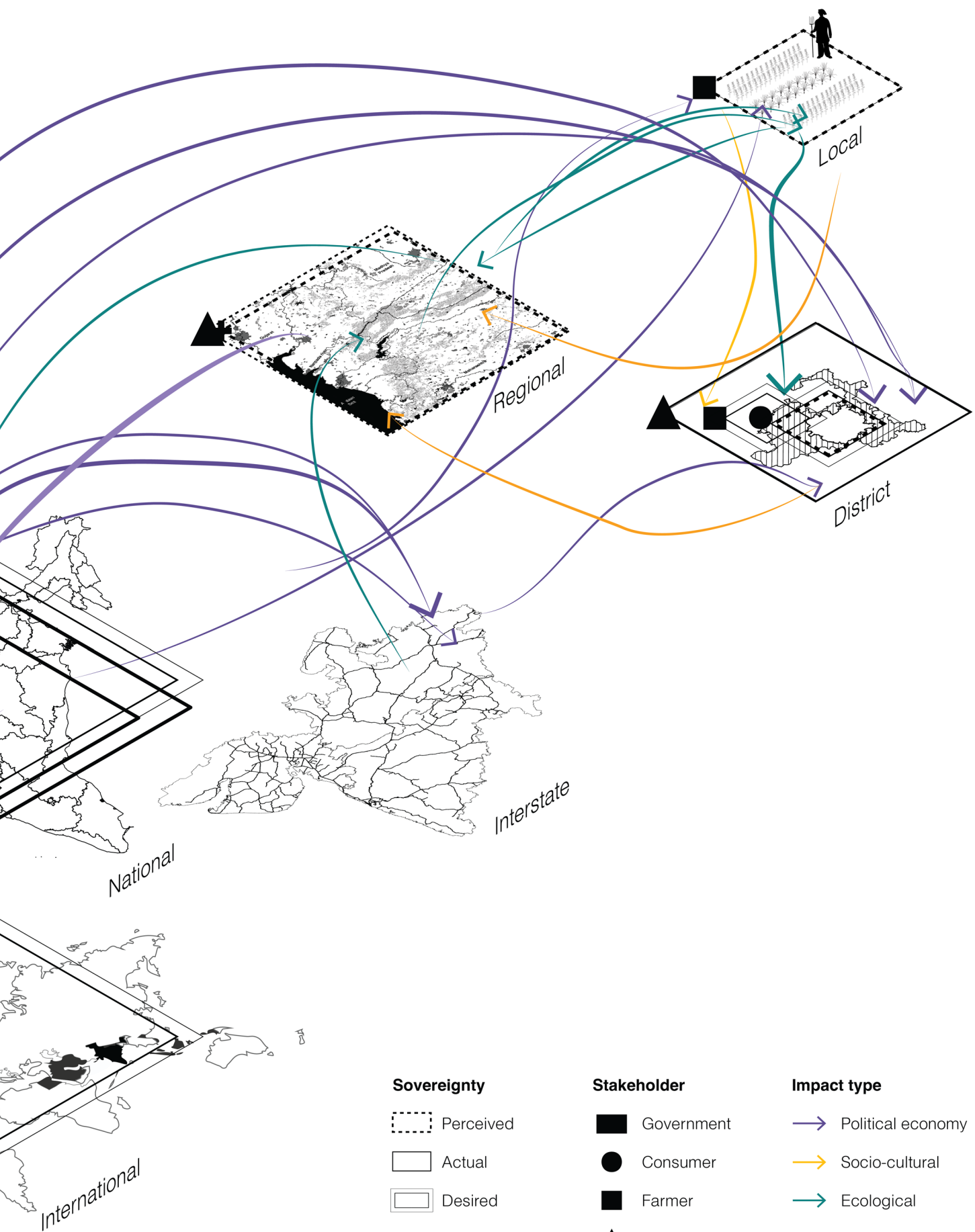




Figure 33: Machinery used for farming and harvesting by farmers in a farm near Kalol, Gujarat.
Photo by the author (2025).

4.

FUTURING INDIAN AGRO - URBANISM

This chapter delineates scenario mapping as tools to identify potentials, a vision plan for the region, an operational framework to realise vision plans, and an exemplary case to represent how the operational framework can be utilised and scaled.

SCENARIO MAPPING

India's food governance landscape is characterised by a complex interplay of competing structural approaches. At the national level, central institutions such as NITI Aayog have developed toolkits encouraging farmers to transition toward natural farming practices (Patel et al., 2026). Simultaneously, emerging draft legislation centred on IoT expansion signals the government's intent to position technology-driven enterprises, both startups and established conglomerates, as architects of India's agricultural future, through the development of AI-driven playbooks for automated farming (Borthakur et al., 2025). This consistent back-and-forth between top-down and bottom-up approaches, and between natural and automated agricultural modes, reflects a deeper tension in reconciling national food security imperatives with localised production and consumption needs. To critically examine how each trajectory might unfold and the potential benefits they can have towards a just and resilient agricultural production, two axes are established: scale, ranging from local to regional, and technology, spanning low-tech to high-tech.

The scenario mapping diagram (Figure 34) positions each of the four scenarios across these two axes, with each quadrant populated by potential spatial measures categorised according to their contributions to political economy, socio-cultural conditions, and ecological resilience. These measures represent actionable spatial measures that collectively operationalise the ethos of their respective scenarios, each responding differently to questions of equity, autonomy, and ecological stewardship across India's agro-urban territories. The preservation of

ecologically sensitive areas is treated as a foundational premise across all scenarios; ecological corridors linking existing sensitive zones and riparian buffers along river systems are therefore considered a non-negotiable constant rather than a variable intervention (Figures 35 and 36). The section that follows elaborates on the distinctive anchors and ethos that differentiate each scenario.

The four scenarios created are further evaluated against a multi-dimensional framework encompassing criteria that are defined based on the key theories considered in the Conceptual and Analytical Framework, ensuring that the evaluation remains theoretically grounded. Each scenario is assessed across all criteria, enabling a comparative reading of trade-offs and synergies.

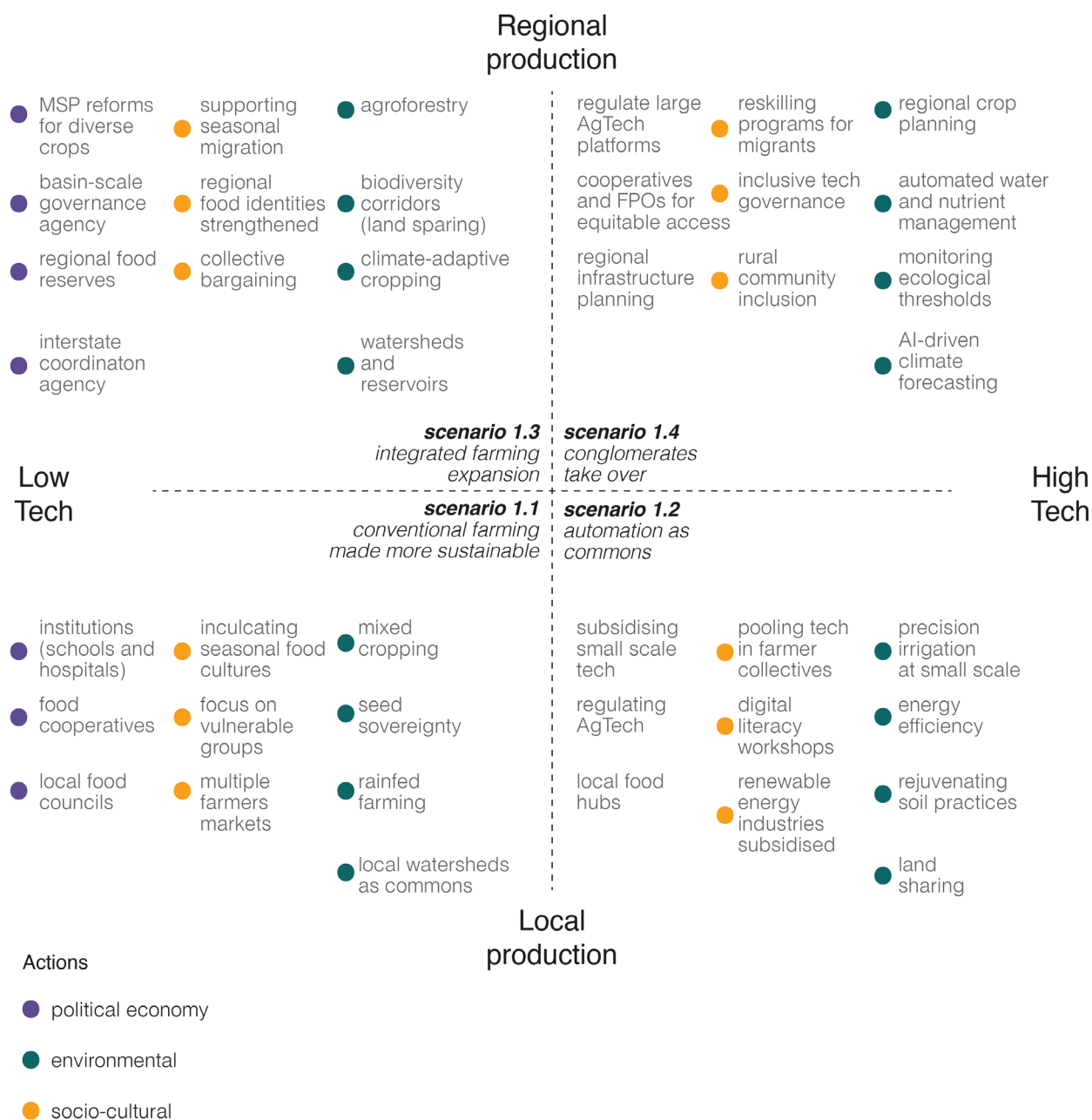
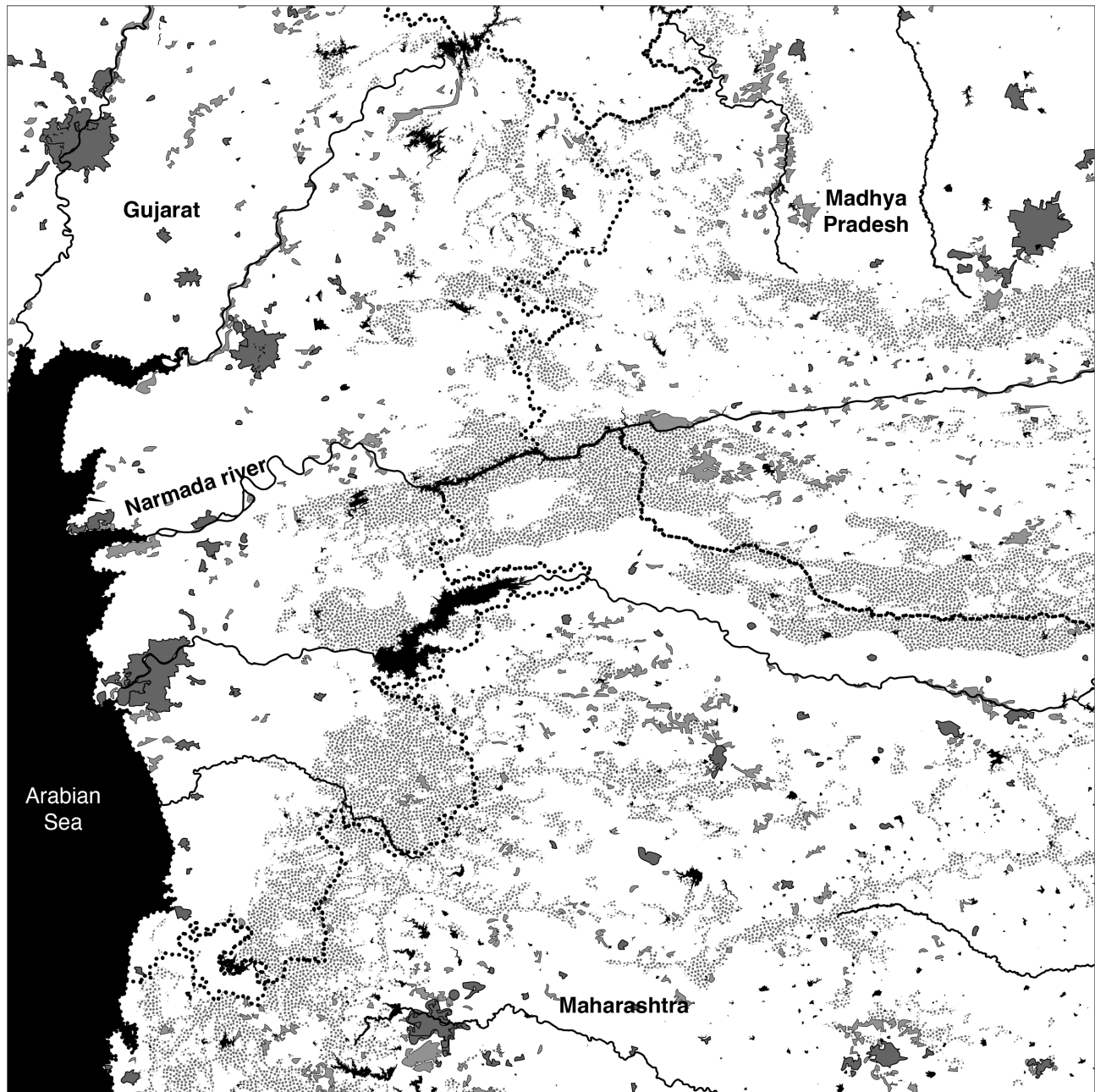


Figure 34: Ideation of spatial characteristics required for Scenario Mapping 1, using the Technology and Scale as axes



Land use

- State boundary
- Urban area
- Farmland
- Forest
- Wasteland
- Water body

0 20 40 60
km



Figure 35: Existing land use. NRSC & ISRO, 2016.

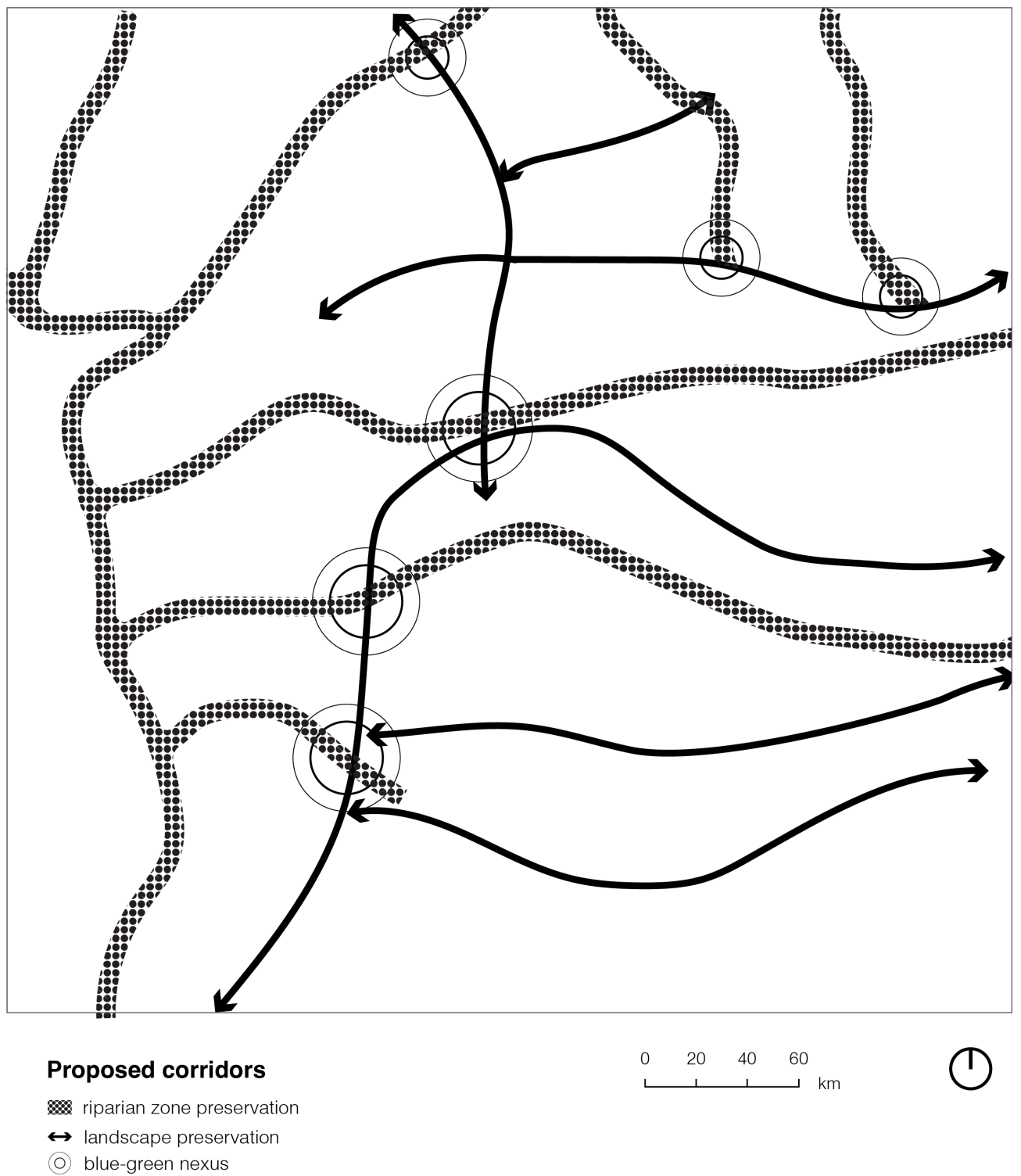


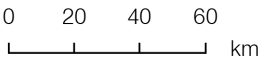
Figure 36: Proposed ecological corridors to be considered as a non-negotiable constant.

SCENARIO 1

Sustainable conventional farming

This scenario is centred on and anchored by smallholder farmers and tribal communities who rely on the indigenous knowledge of their ancestors and a deep understanding of holistic ecological food systems. Their approach combines traditional wisdom with sustainable technologies, emphasising agro-ecological farming methods such as biodynamic farming and permaculture. Rather than allowing urbanisation to dictate food demand, this scenario seeks to subvert the trend by placing food production at the core of the system, where supply shapes demand instead of the other way around. In this vision, small villages regain importance as hubs of agricultural activity, becoming places where farmers live and work while urban populations actively invest in and support their production. Collaboration plays a key role, with institutions partnering closely with farmers and local communities to adopt and maintain sustainable practices. This scenario embraces principles of degrowth and decentralisation, promoting smaller-scale, locally managed networks that reduce dependency on large centralised systems while strengthening resilience, ecological balance, and community well-being.

-  state boundary
-  local production
-  local consumption
-  mixed-cropping
-  contour trench
-  green belt
-  wetland
-  cow shed + biogas plant
-  seed bank + storage + distribution shop



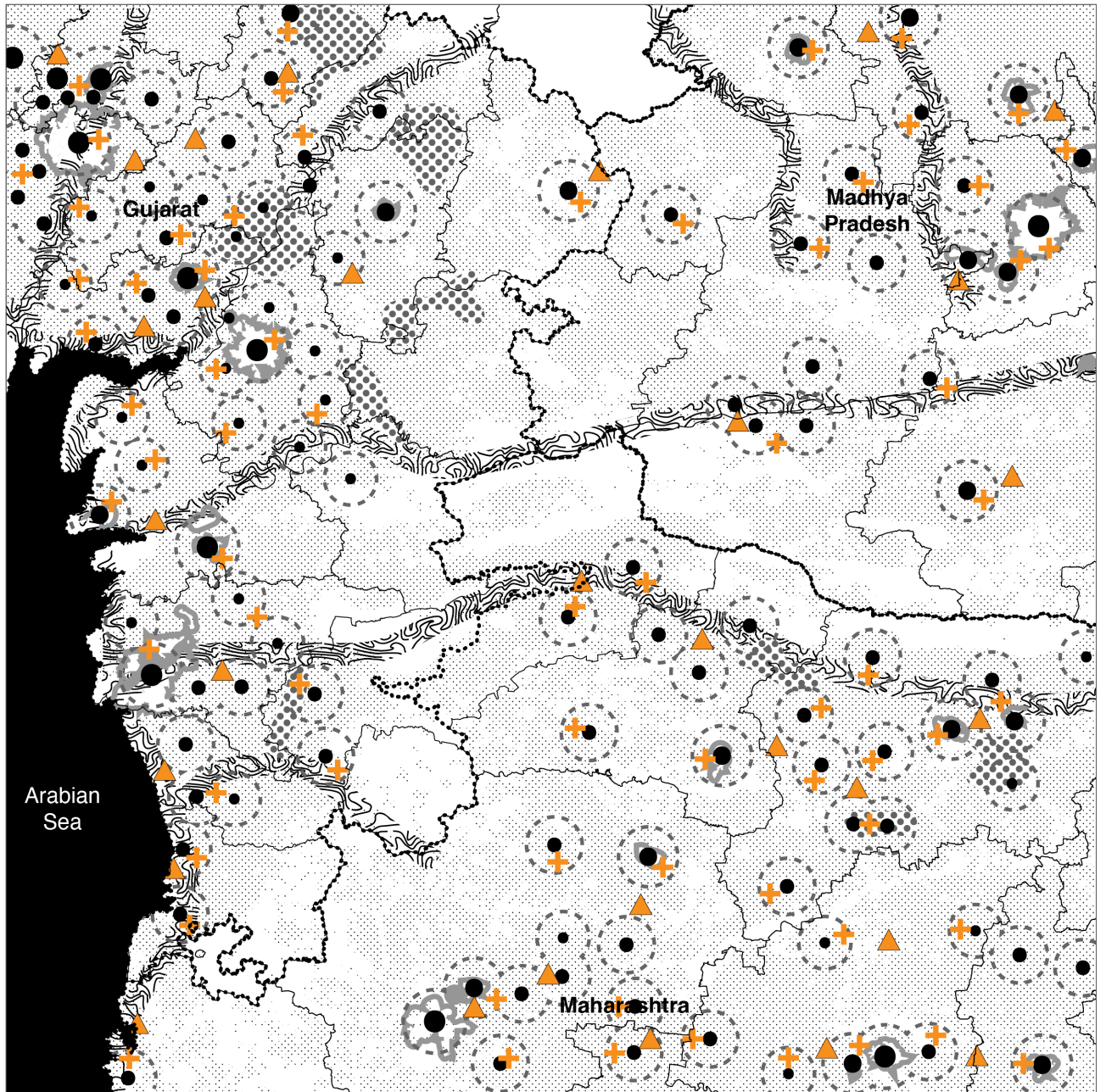


Figure 37: Scenario 1 spatialisation and vision plan

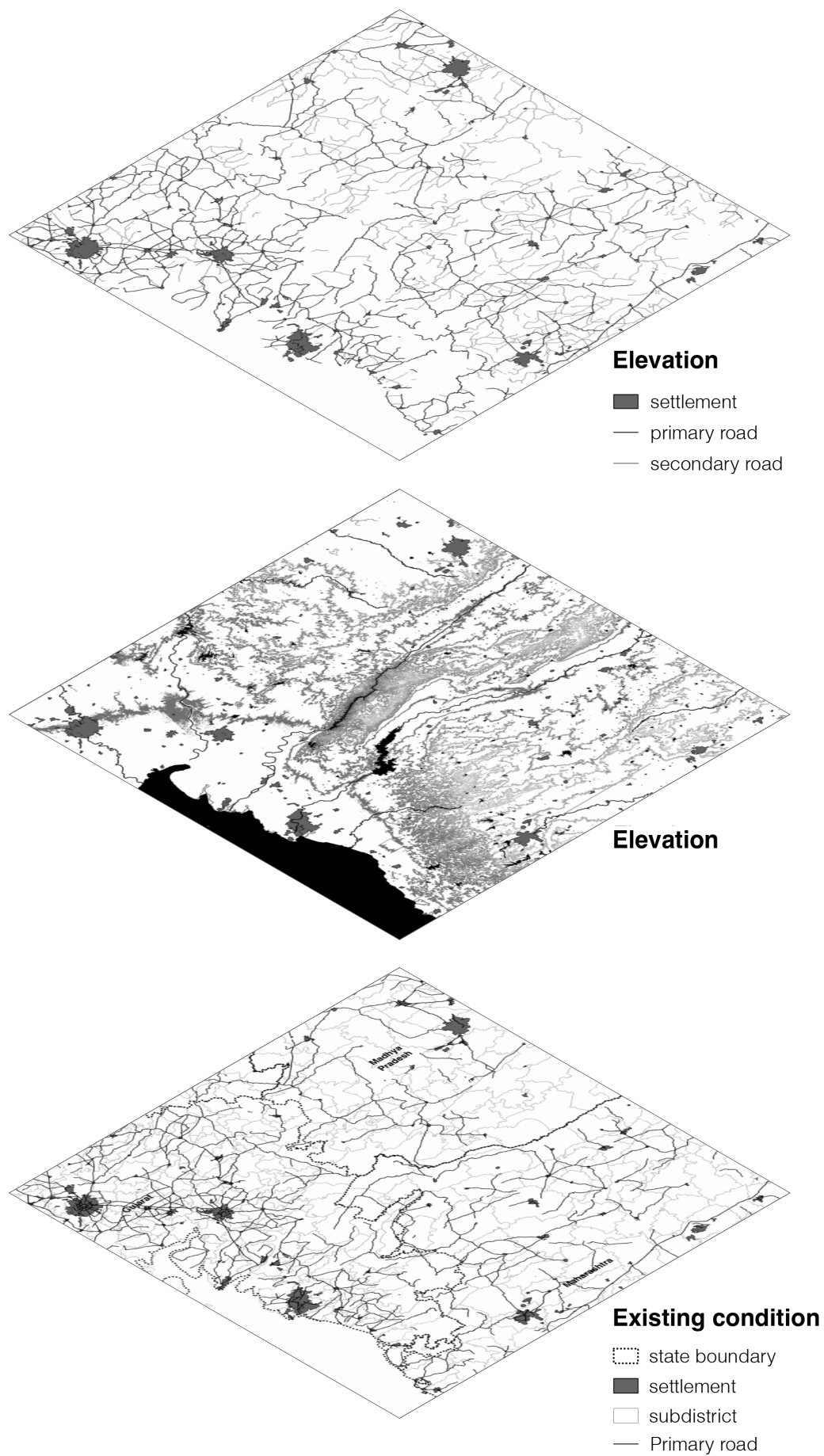
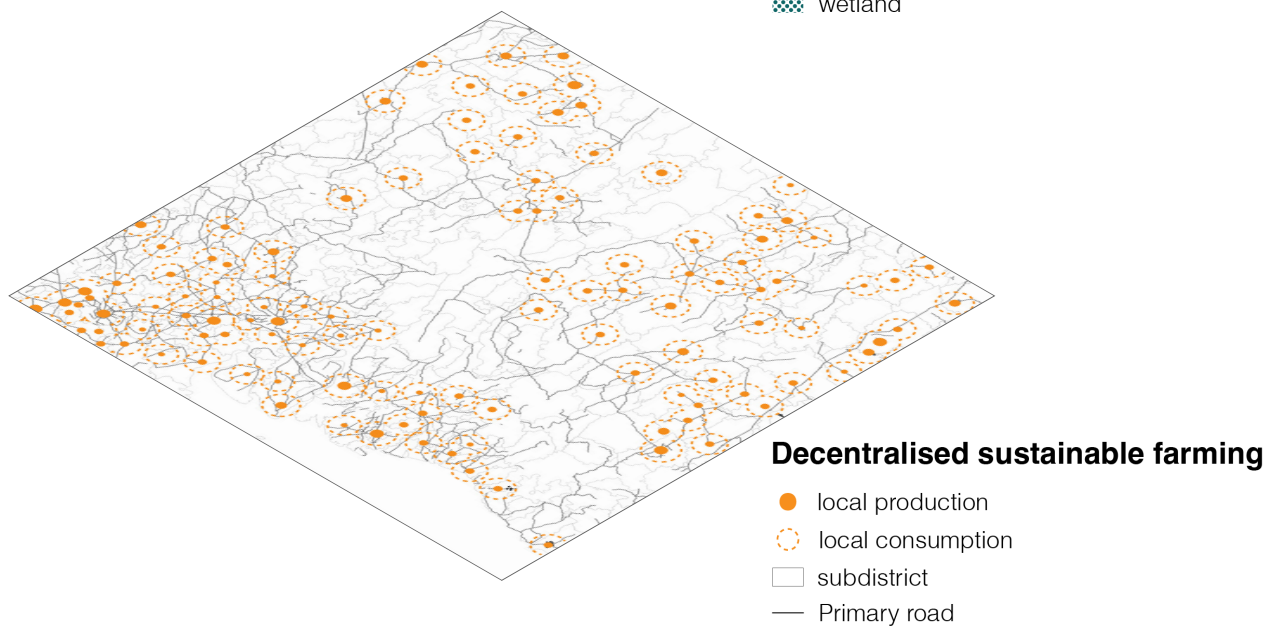
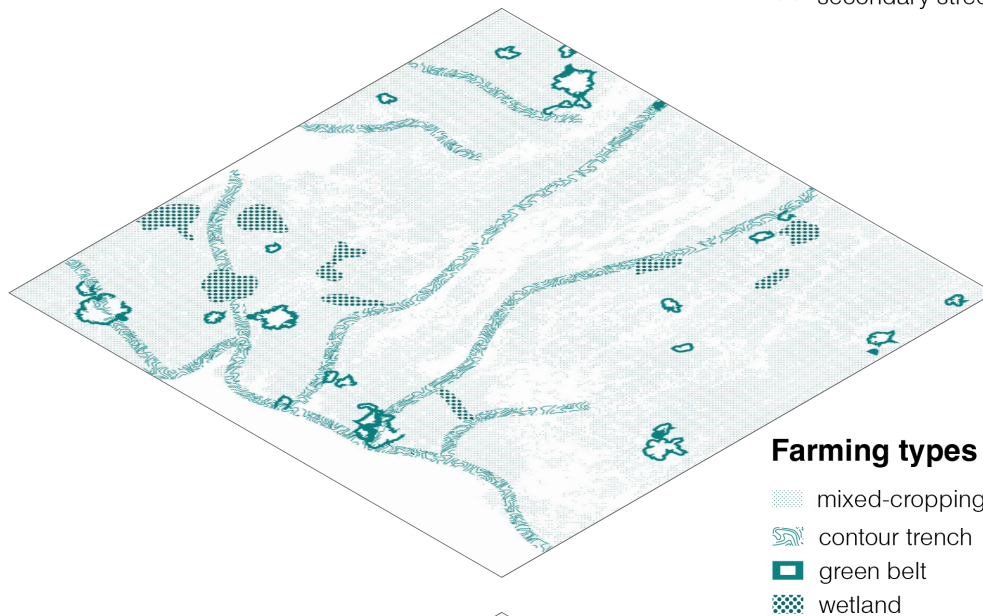
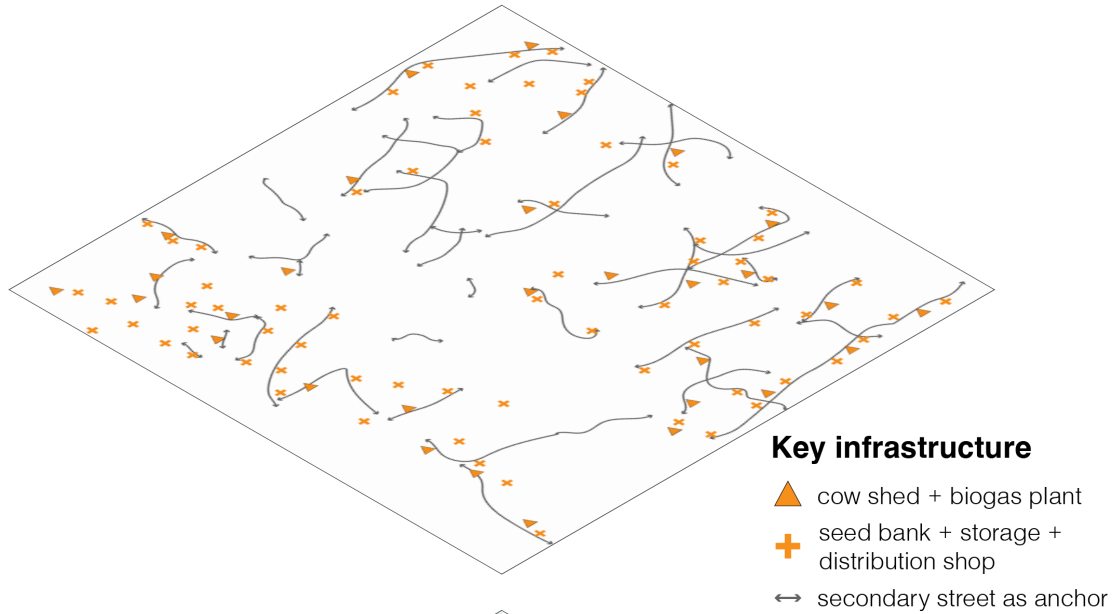


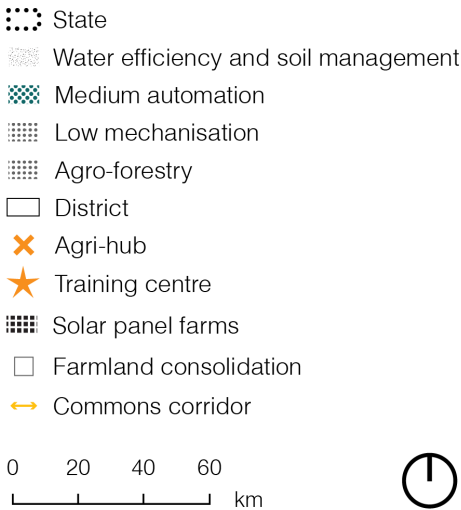
Figure 38: Defining factors and proposed spatial strategies for Scenario 1



SCENARIO 2

Automation as commons

This scenario is driven by smallholder farmers who understand that automation can help them advance their business, and they can do so collectively in ways that serve their shared interests rather than private corporations. By working collectively, these farmers consolidate fragmented farmland across hinterland regions to create meso-scale agricultural systems that are large enough to benefit from advanced technologies while remaining locally managed. The core idea is the establishment of automation commons corridors and hubs, including machinery, data systems, and technical tools that are jointly owned, shared, and maintained through farmer cooperatives. This prevents the privatisation of critical technologies and helps smallholder farmers remain economically viable while adapting to the technical transformation needed to sustain a growing population. In this scenario, hinterland regions become the nucleus of subdistrict economies, where food production and consumption are closely linked to local needs. The corridors are along the junction of primary and secondary street networks to create multiple subdistrict nuclei. The scenario also integrates contingency planning to address climate variability, using shared data platforms, cooperative decision-making, and climate-resilient farming practices. Through collective ownership, coordinated land use, and decentralised infrastructure, this scenario enables efficient production while strengthening local autonomy and markets.



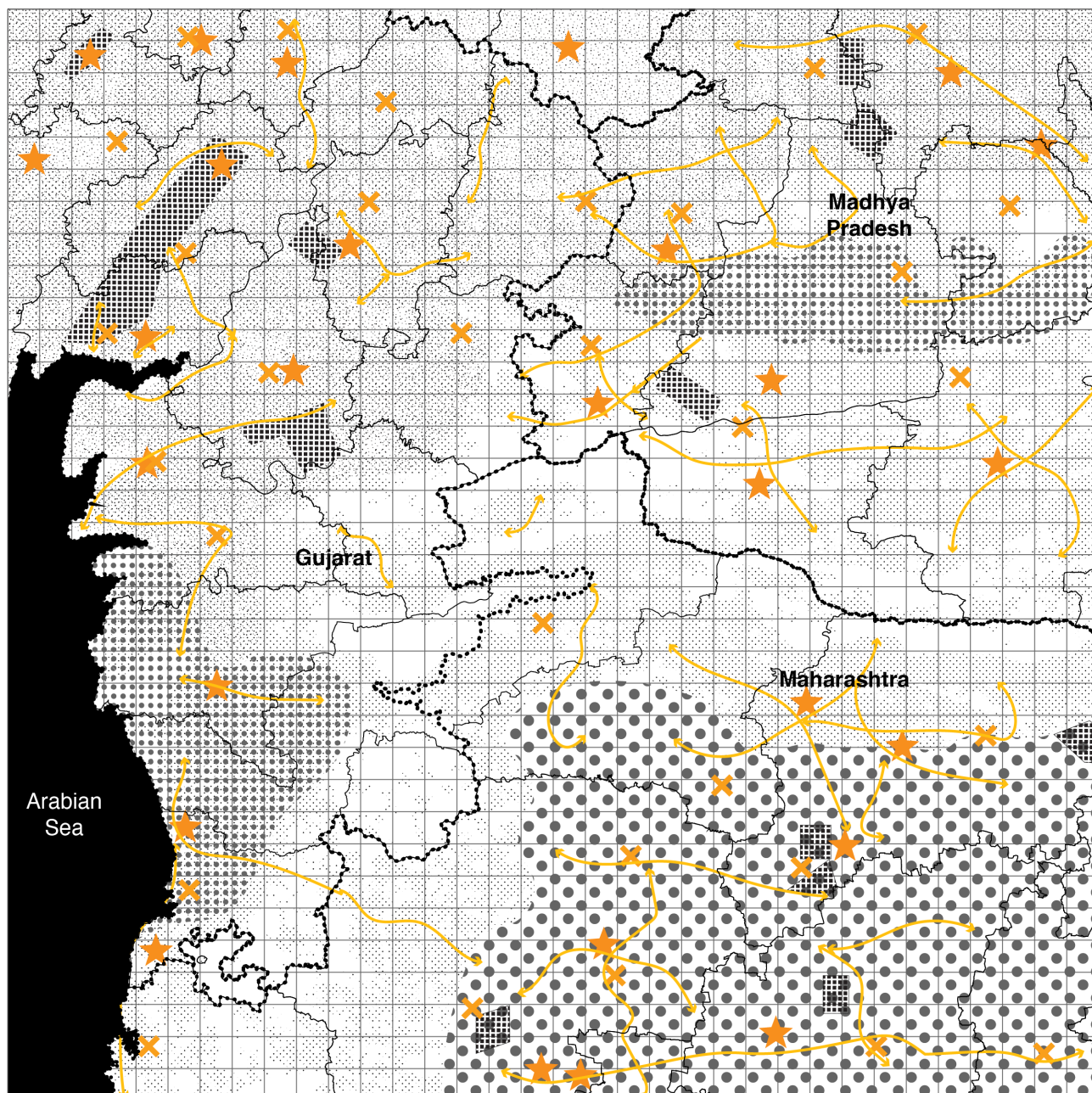


Figure 39: Scenario 2 spatialisation and vision plan

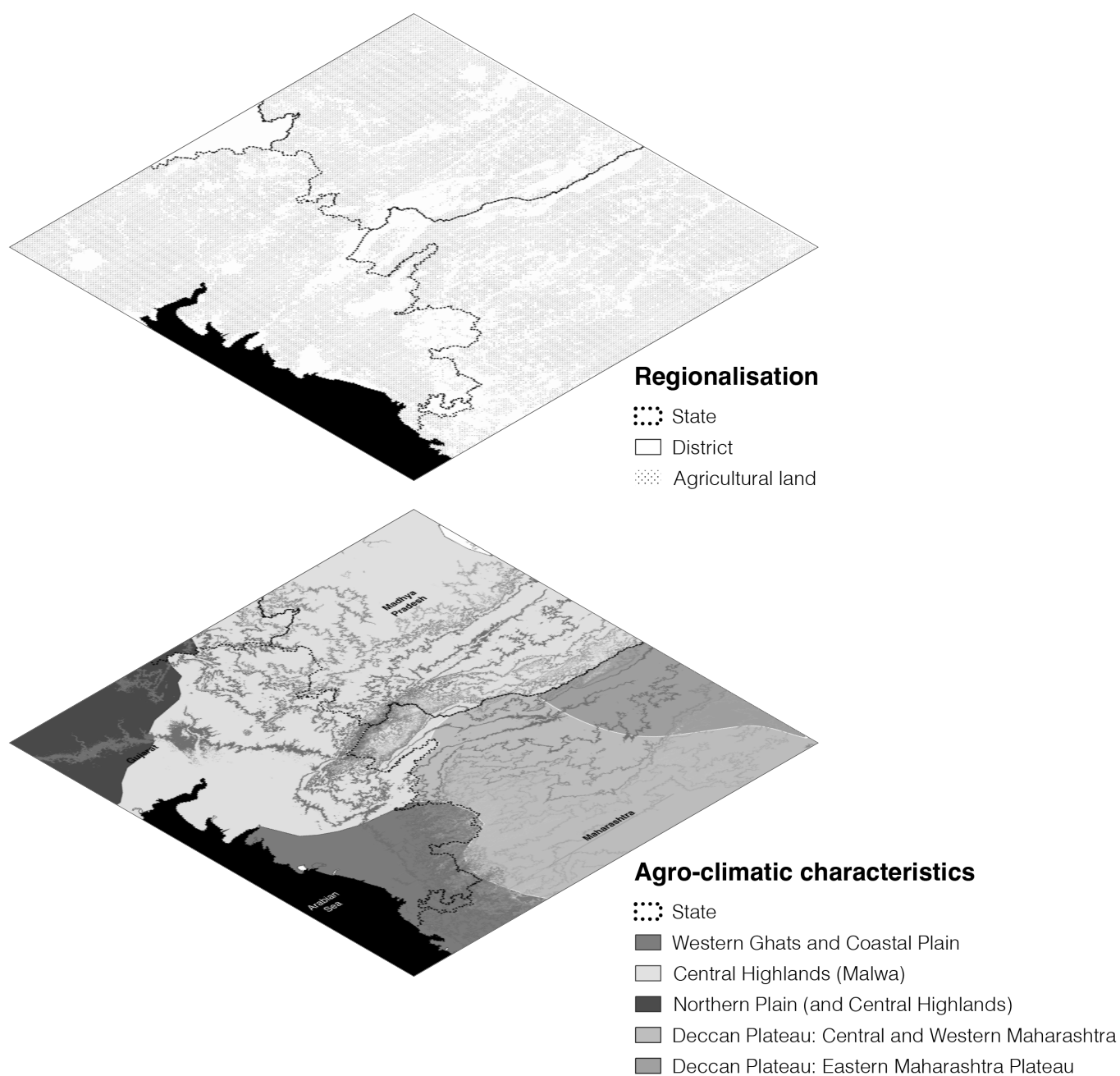
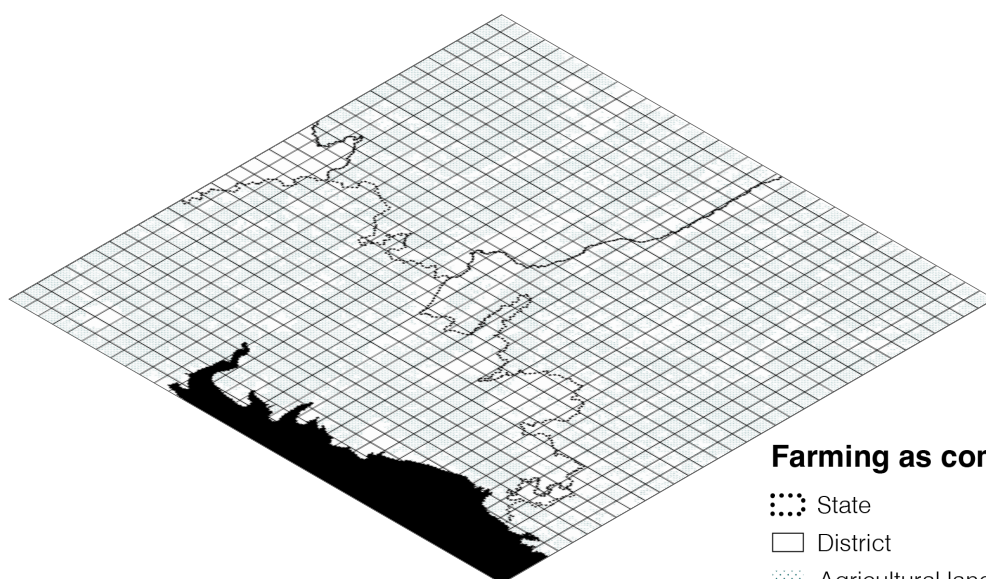
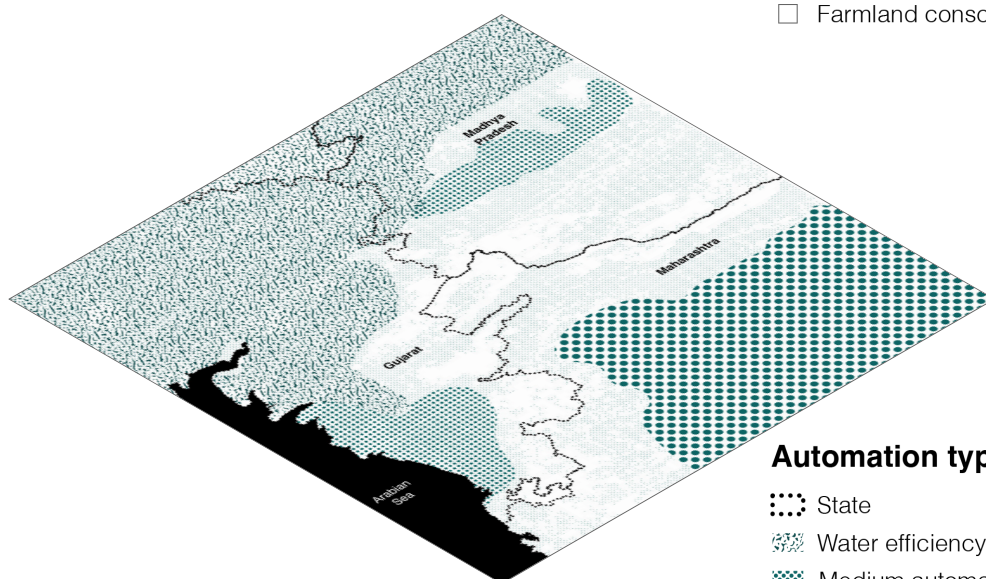


Figure 40.1: Defining factors and proposed spatial strategies for Scenario 2



Farming as commons

- State
- District
- Agricultural land
- Farmland consolidation



Automation type and focus

- State
- Water efficiency and soil management
- Medium automation
- Low mechanisation
- Agro-forestry

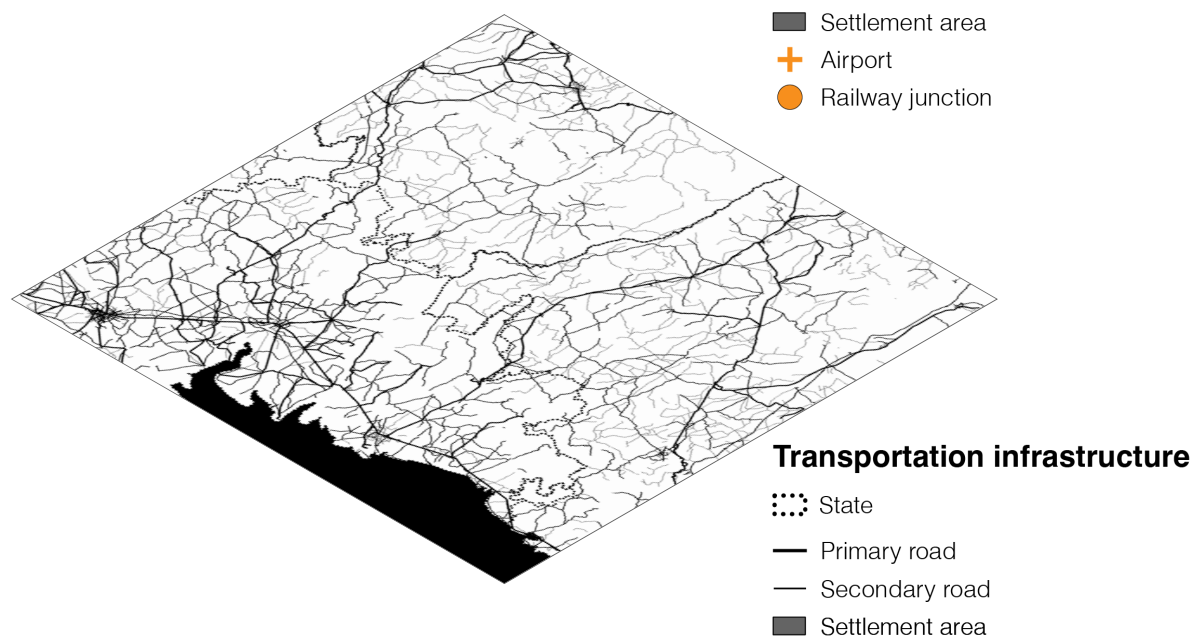
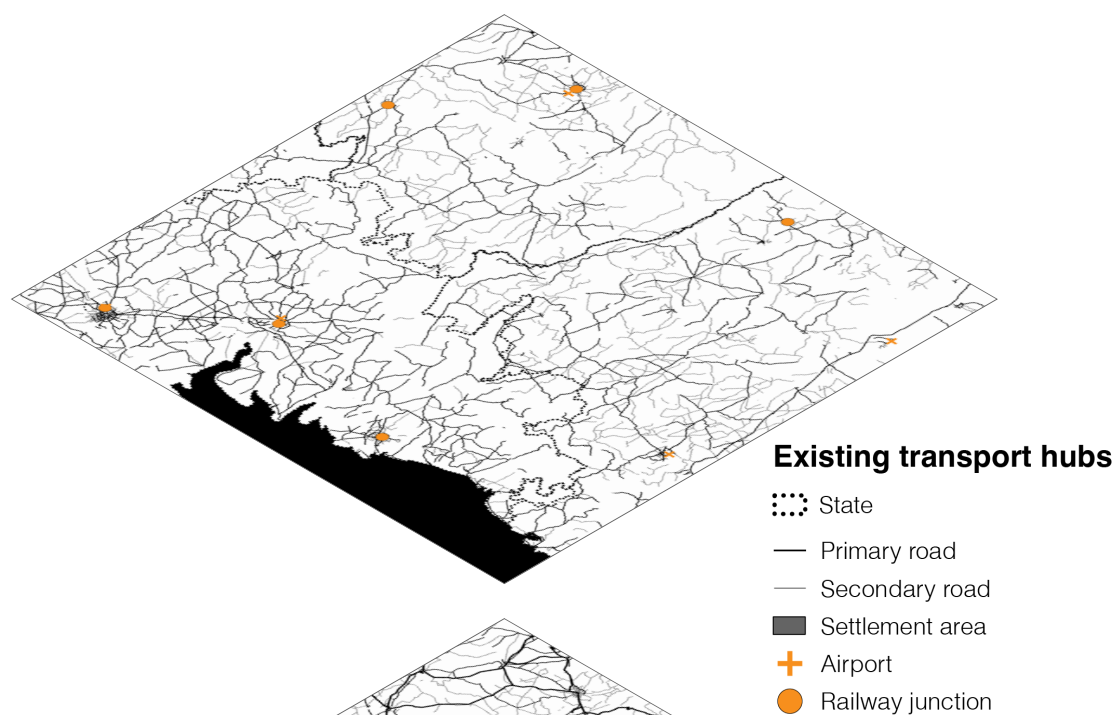
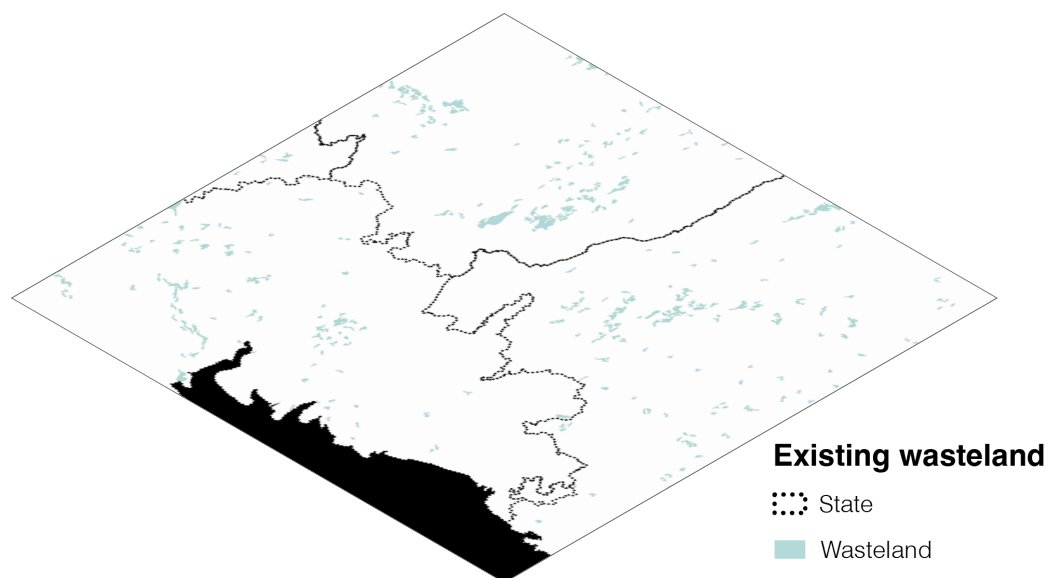
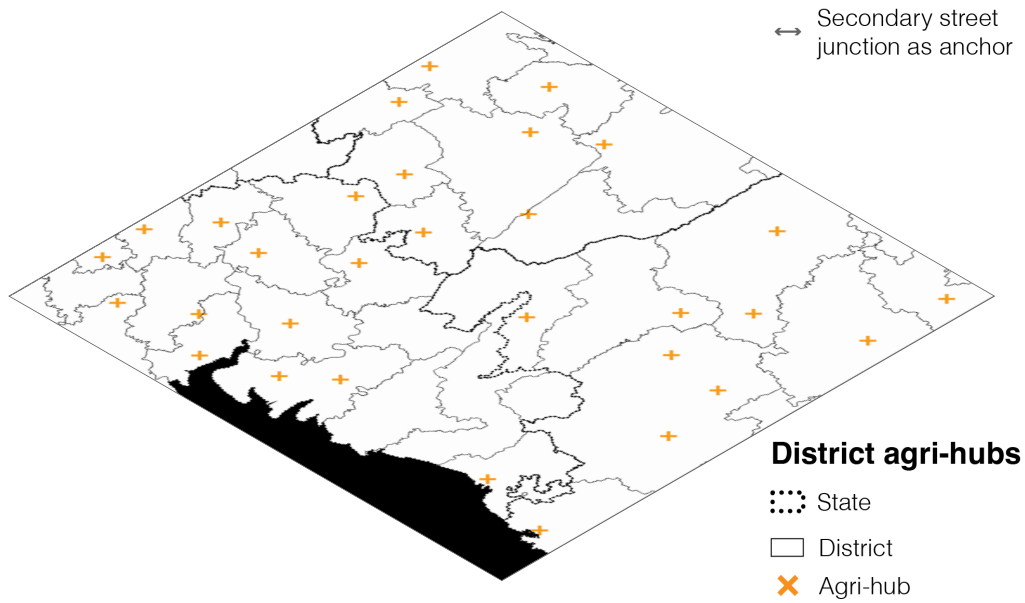
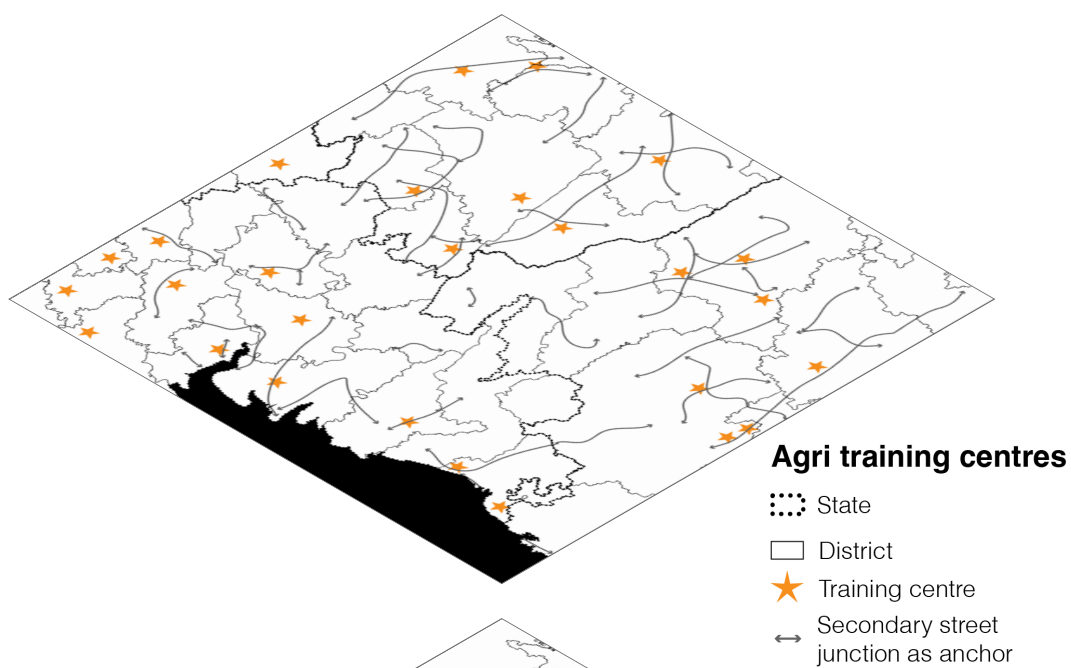
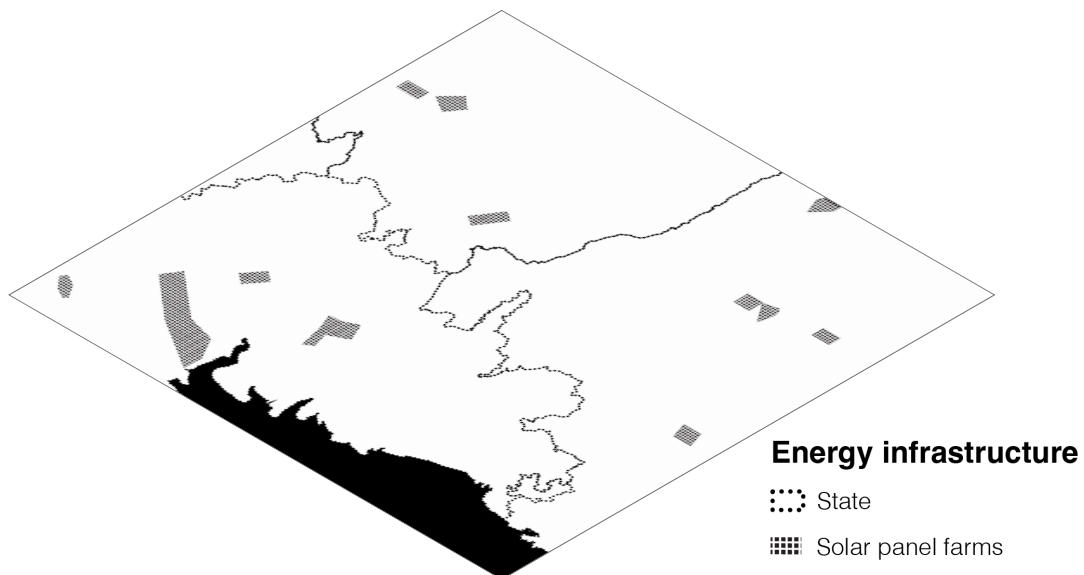


Figure 40.2: Defining factors and proposed spatial strategies for Scenario 2

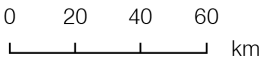


SCENARIO 3

Balancing and scaling all farmin types

This scenario is driven collaboratively by the national and state governments that seek to balance local food security with participation in the global food economy. Their goal is to support domestic populations while also maintaining influence over international trade networks, spatialising the ideology “Think global, act local”. The focus is primarily on peri-urban regions and corridors connecting the cities, where governments encourage coordination between smallholder farmers and large agricultural conglomerates to meet demand at local, regional, and global scales. In this vision, agriculture in the hinterlands becomes closely tied to urban development, transforming rural production into an extension of metropolitan growth. This scenario operates by establishing large-scale agro-parks that bring together farming, logistics, research, and processing facilities in centralised hubs. These agro-parks use advanced infrastructure, data-driven management, and coordinated supply chains to improve efficiency, reduce waste, and strengthen connections between rural producers and urban markets, enabling a highly organised and globally competitive food system.

- State
- District
- ★ Training centre
- ✕ Agri-hub
- Zonal agricultural hub
- Automated agriculture
- Agroforestry
- Hydroponics



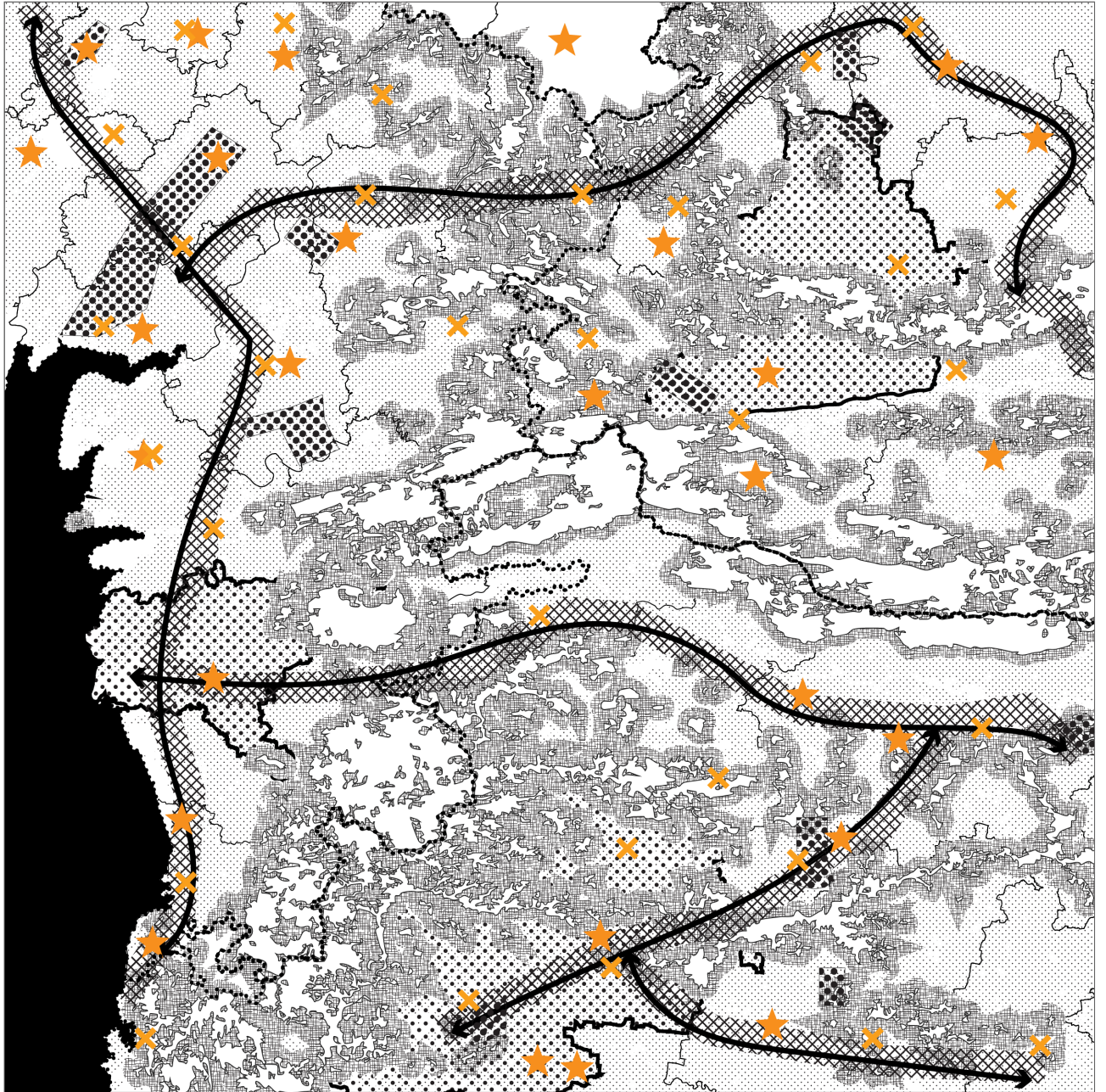


Figure 41: Scenario 3 spatialisation and vision plan

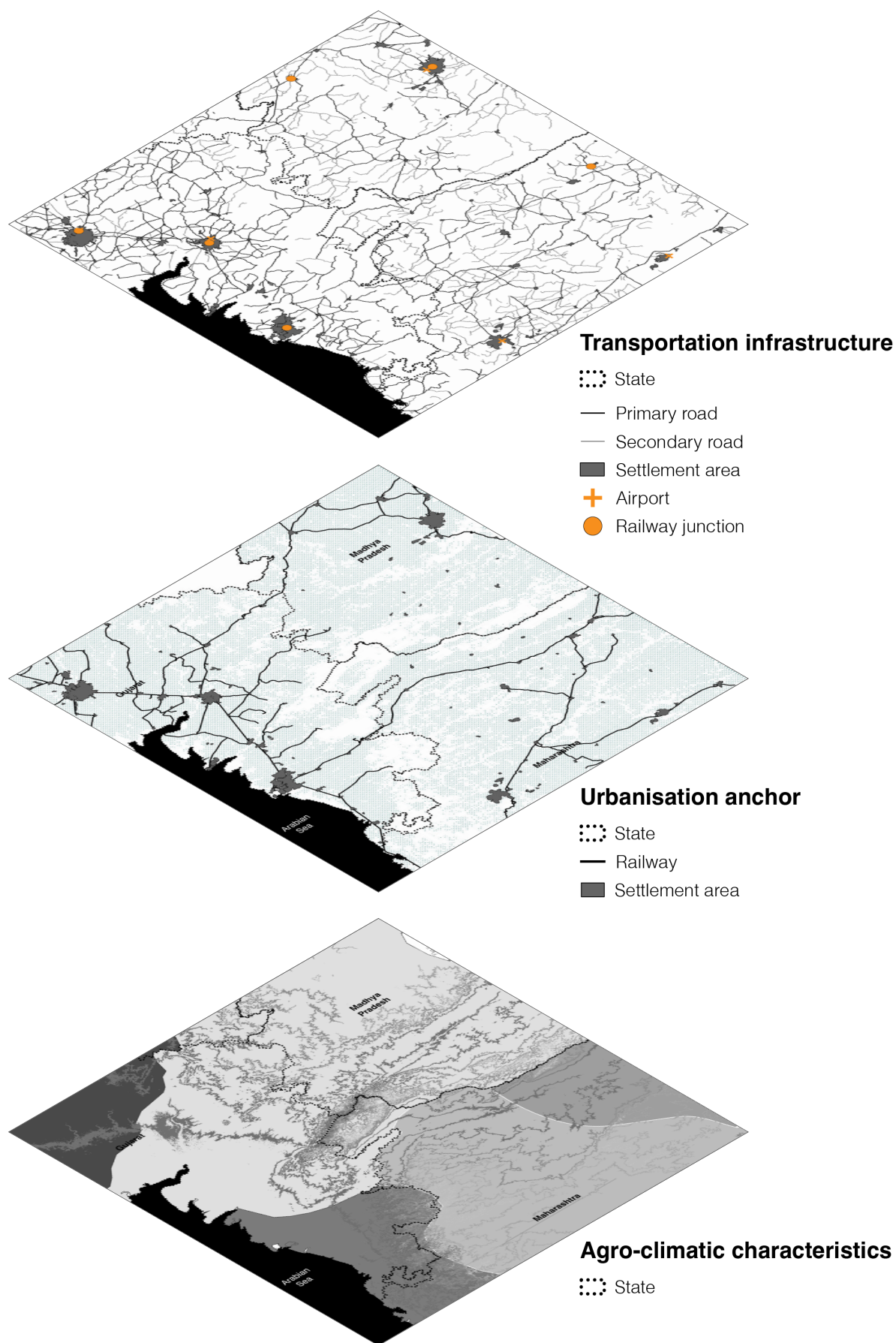
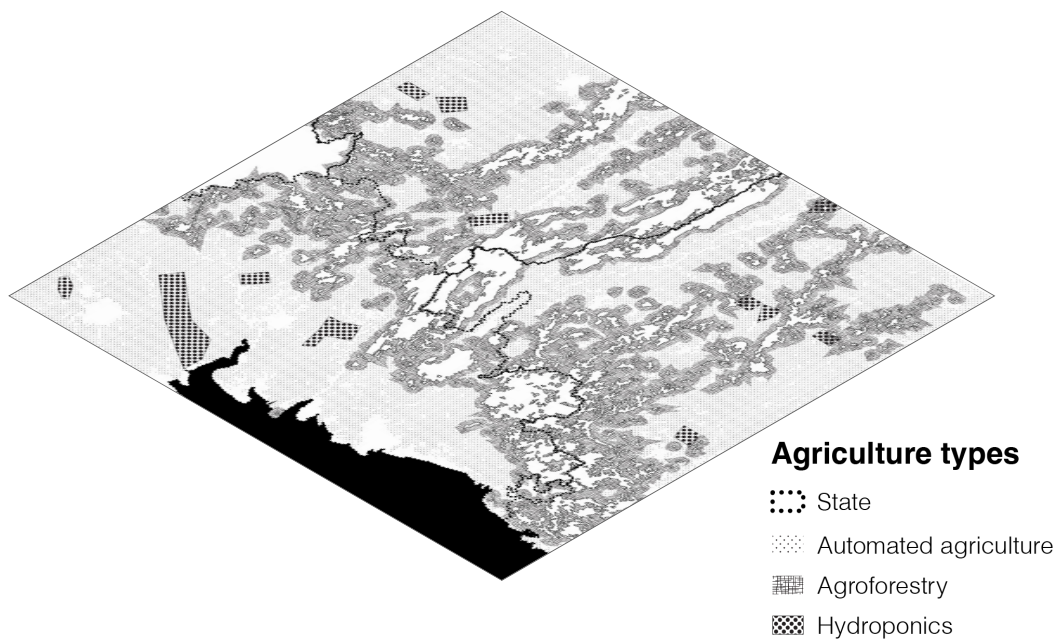
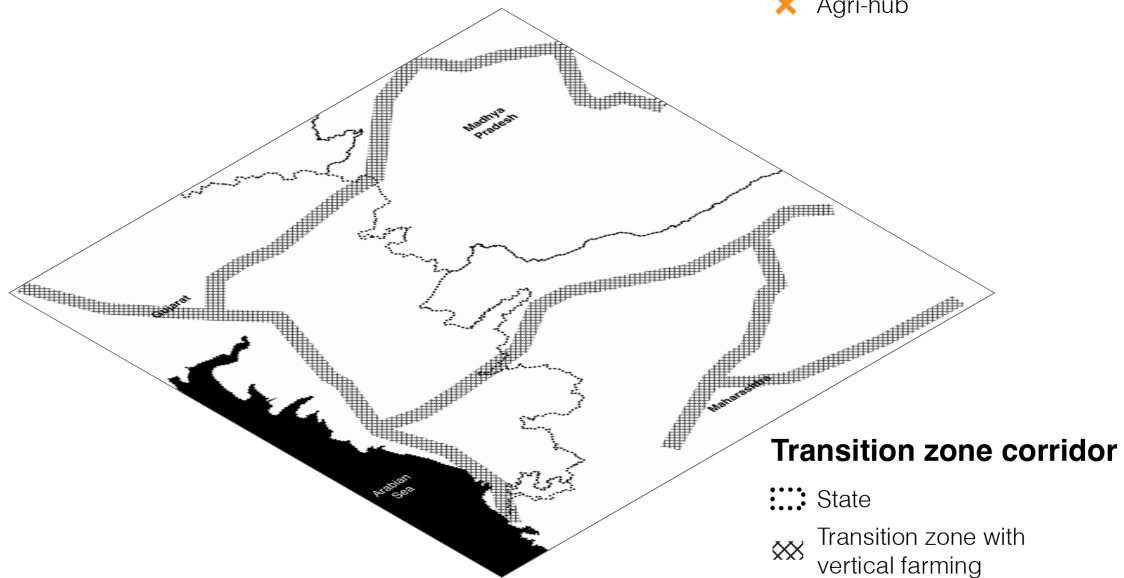


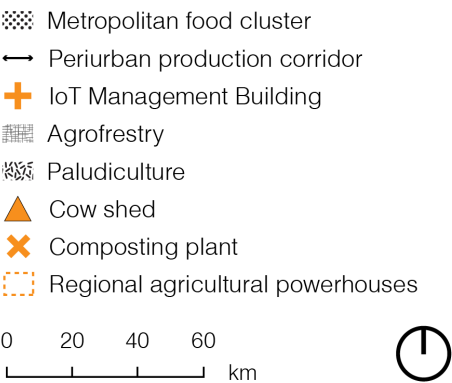
Figure 42: Defining factors and proposed spatial strategies for Scenario 3



SCENARIO 4

Conglomerates take over

This scenario positions industries as frontrunners, transforming conventional agriculture into a highly industrialised operation focused on efficiency and scale. It operates primarily in agriculturally rich hinterlands adjacent to industrialising urban and peri-urban regions, where fragmented farmlands are strategically reorganised into categorised industrial zones, such as precision crop modules, automated livestock units, and agro-processing clusters, to optimise land use and output. Industries achieve this through the creation of expansive metropolitan food clusters (Wageningen MFC, n.d.) that integrate cutting-edge technologies like AI-driven precision farming, vertical hydroponics, robotics for planting and harvesting, and blockchain-tracked supply chains. These hubs centralise operations, converting smallholder plots into standardised production units managed by corporate consortia, while enforcing uniform inputs and data analytics for yield prediction and pest control. By doing so, the model minimises seasonal variability and aligns rural production directly with urban-industrial demand, while ensuring the transition of smallholder farmers into skilled farmers.



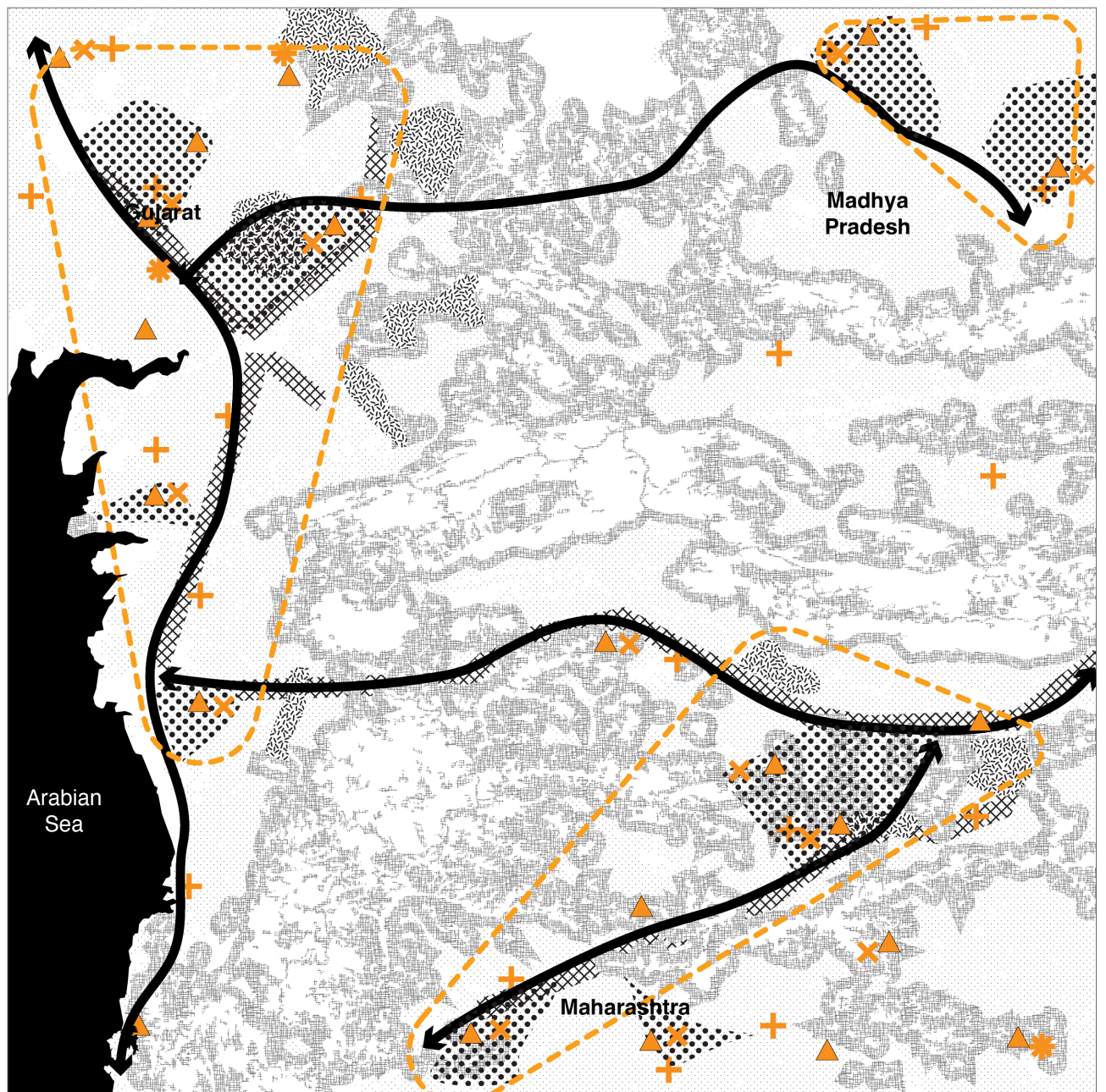


Figure 43: Scenario 4 spatialisation and vision plan

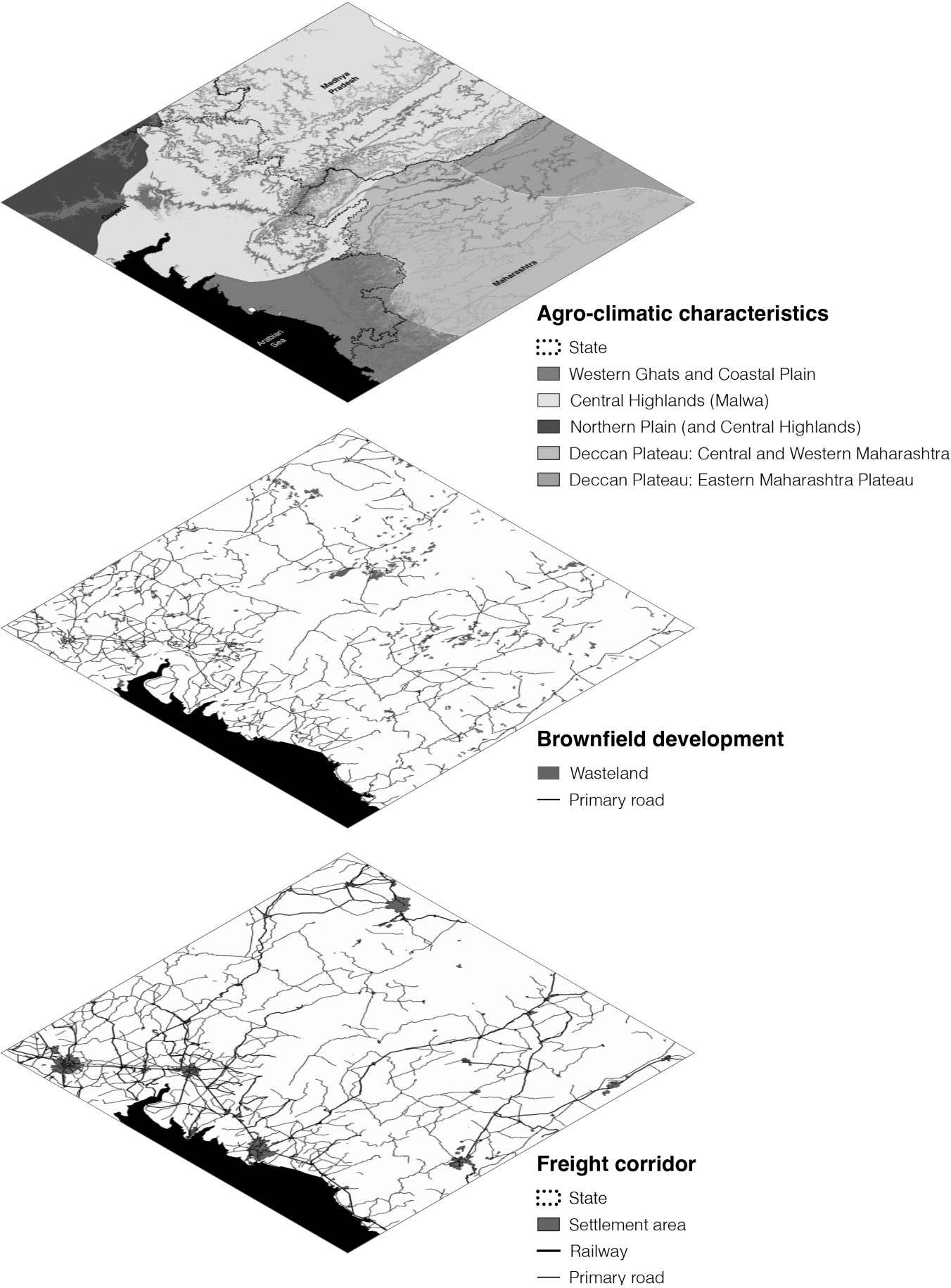
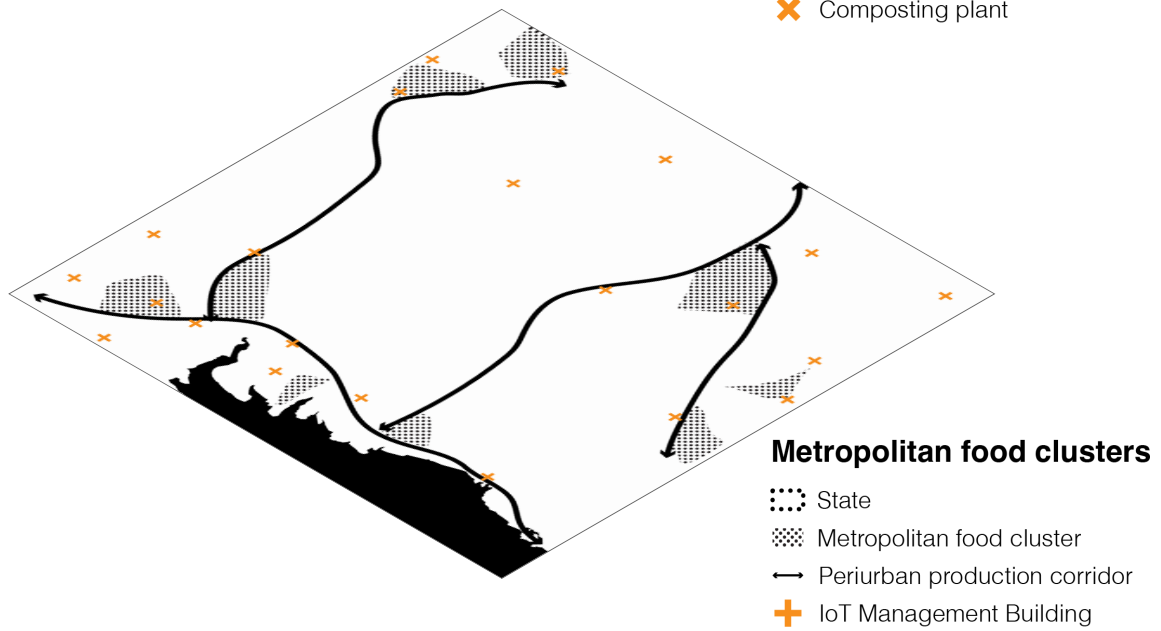
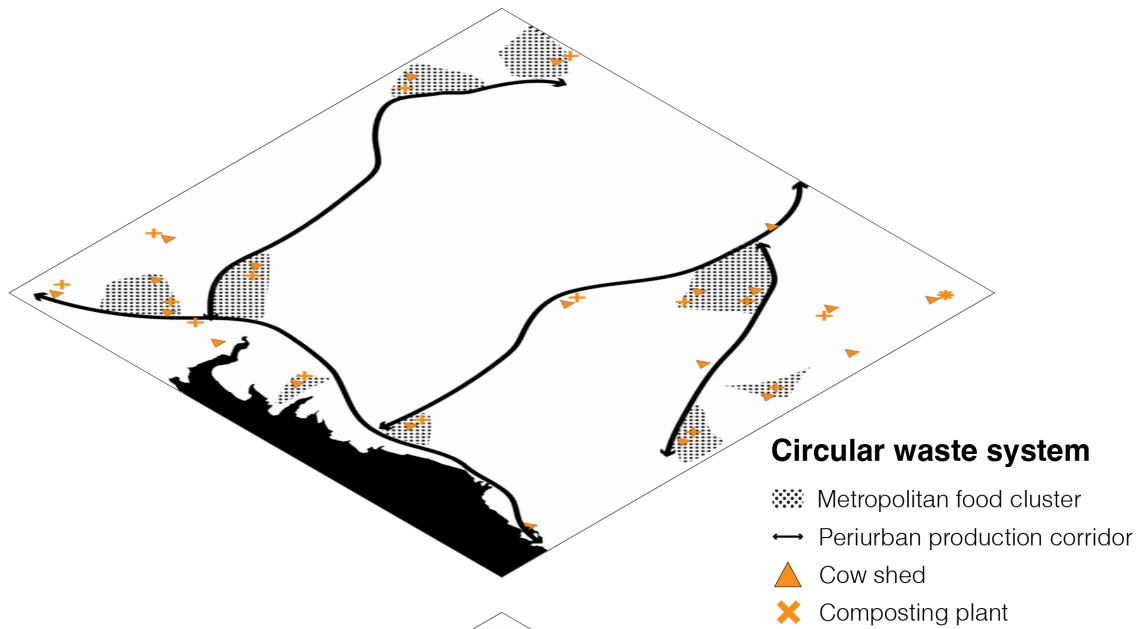
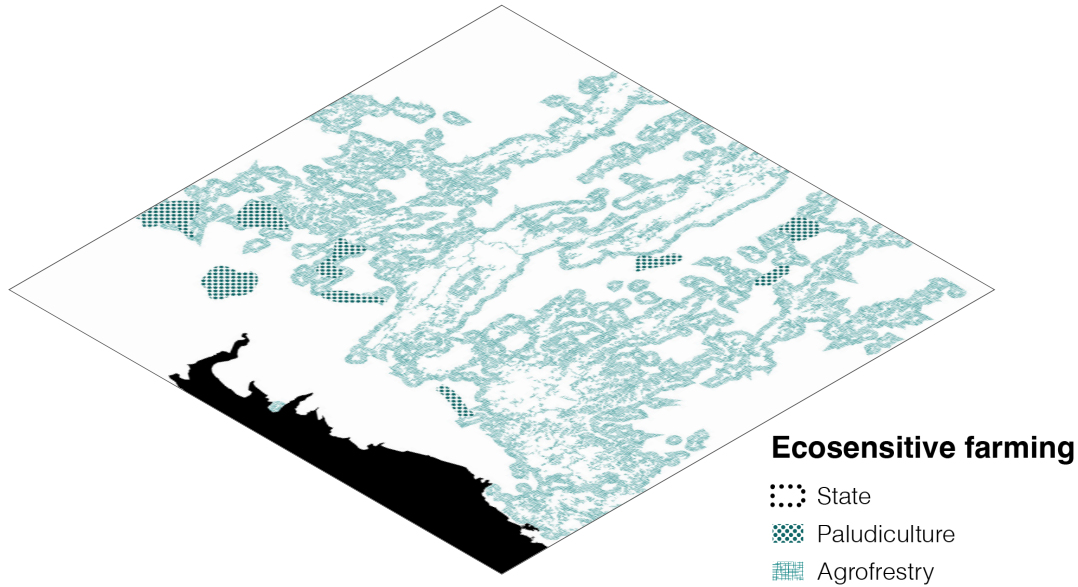


Figure 44: Defining factors and proposed spatial strategies for Scenario 4



Evaluation criteria

Assessed through the defining factors established in the research question and analytical framework, each scenario yields a distinct spatial logic and performance profile. Scenario 1 demonstrates considerable potential in achieving producer and ecological justice, with its localised production-consumption model enhancing systemic resilience by containing shocks at manageable scales. Strong circular metabolism due to high input reduction, recycling, and adaptive capacity is consistent with decentralised, locally embedded infrastructures. However, limited yield and constrained land-use diversification may prove insufficient against climatic and market volatility, compromising long-term productivity and spatial efficiency.

Scenario 2 advances systemic and ecological integration, with improved biodiversity outcomes and reduced input dependency, signalling a more circular territorial metabolism. Yet spatial justice and socio-cultural dimensions remain uneven, and ecological performance marginally declines relative to Scenario 1, indicating that governance improvements alone cannot substitute for deeper spatial implementation for social and ecological balance.

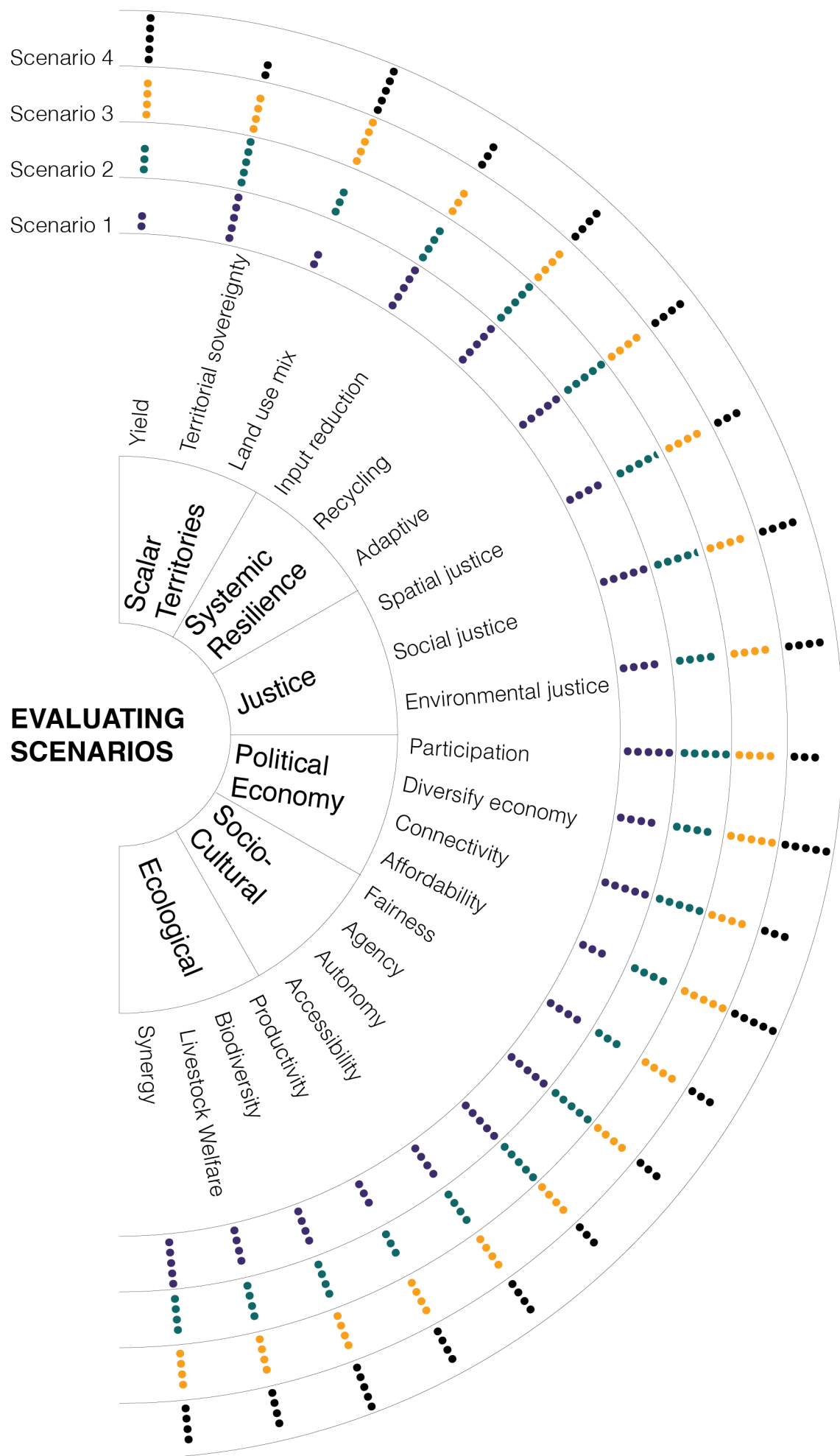
Scenario 3 emerges as the most spatially coherent and future-oriented proposition, balancing productivity, justice, and landscape diversity through multifunctional territorial structures and strong economic diversification.

Scenario 4 excels in yield, connectivity, and systemic adaptability, projecting a highly optimised territorial network.

However, the intensity of its interventions risks over-centralisation and socio-spatial homogenisation, potentially impeding local autonomy and cultural specificity, qualities indispensable to resilient place-making.

Upon evaluating the four scenarios and the needs identified in the analysis of the prevailing Indian agro-urbanism trends, the need of the hour is to move from the dichotomous thinking and to bring forth a balance in various initiatives: to incorporate the idea of a Pareto front of combining good aspects from all scenarios as part of the ideologies of Scenario 3.

Figure 45: Criteria and subcriteria for evaluating the impacts of the scenarios



VISION PLAN: DECENTRALISED FOOD CLUSTERS

Upon evaluating the four scenarios based on the criteria outlined in the research question and the conceptual framework, the need of the hour is to move from the dichotomous thinking and to bring forth a balance in various initiatives: to follow the idea of a Pareto front of all criteria and good aspects from all scenarios. The vision for this region is thus a balanced food system where diverse agricultural typologies, smallholder agroecology (Scenario 1), cooperative automation commons (Scenario 2), government-led agro-parks (Scenario 3), and industrial hubs (Scenario 4), coexist harmoniously, guided by regional to bridge local resilience with global competitiveness. Anchored in peri-urban corridors, this manifesto prioritises ecological corridors as vital green spines: linear agroforestry buffers, restored wetlands, and biodiversity-rich riparian zones along rivers like Narmada-Tapi, linking hinterland farms to urban hubs while preserving soil health, pollinators, and water cycles.

Scenario 3's large-scale agro parks serve as integrative nodes, promoting nutritional security through diversified clusters, millets/pulses for micronutrients, veggies/livestock for proteins, fed by short chains to urban consumers, cutting down on waste and imports. Smallholder farmers practice and impart their indigenous and permaculture wisdom, while cooperatives simultaneously expand automated operations through shared AI/drones for precision, upscaling processing without dominating. National policy enforces equity: subsidies for corridor zoning, FPOs in parks, and degrowth incentives for villages.

-  state boundary
-  settlement area
-  IoT management building
-  cow shed
-  composting plant
-  agri-rurban areas
-  agri-corridor
-  ecological corridor
-  agro-park
-  agro-forestry
-  sustainable farming with medium automation

0 20 40 60
km



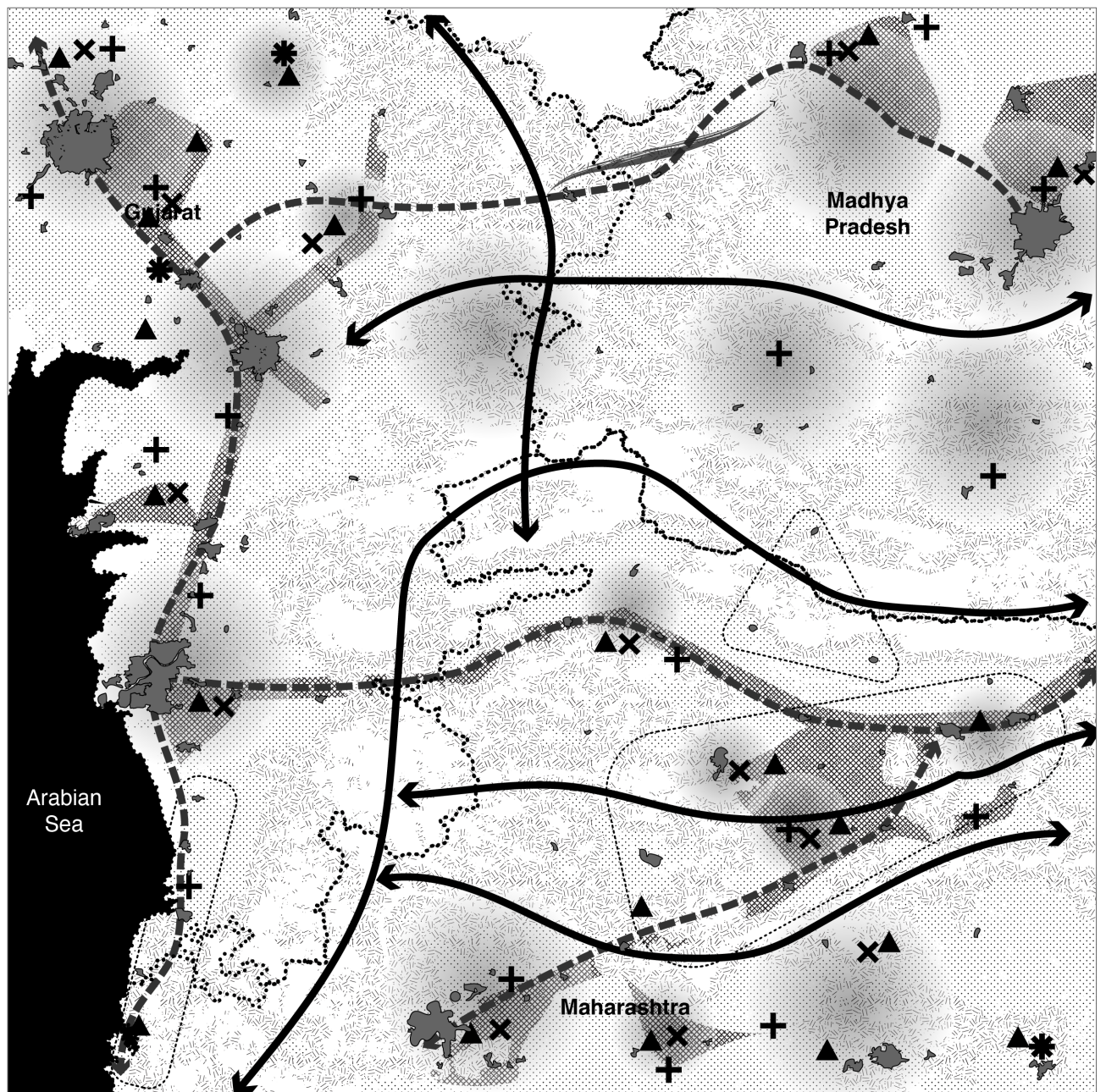
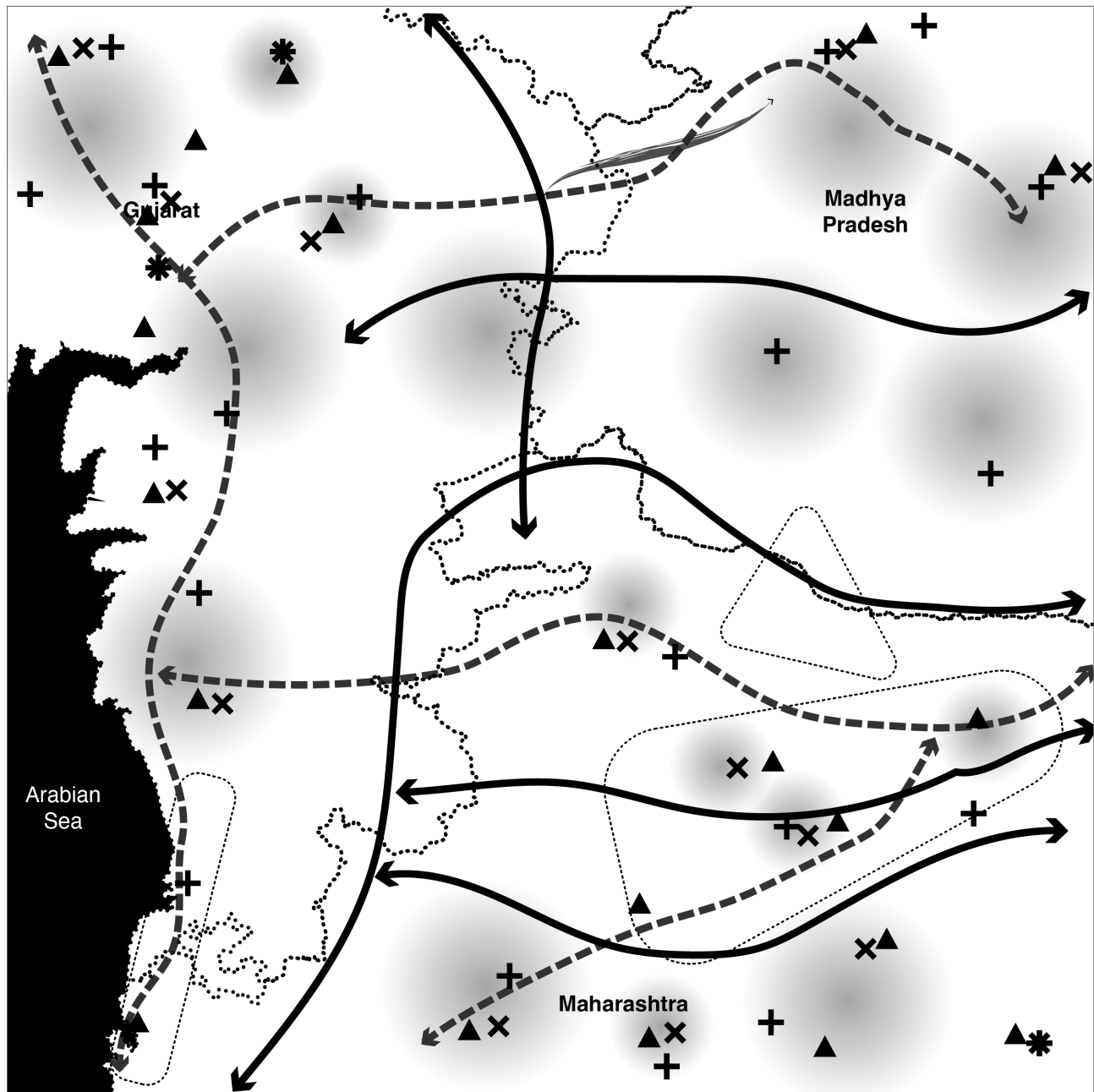


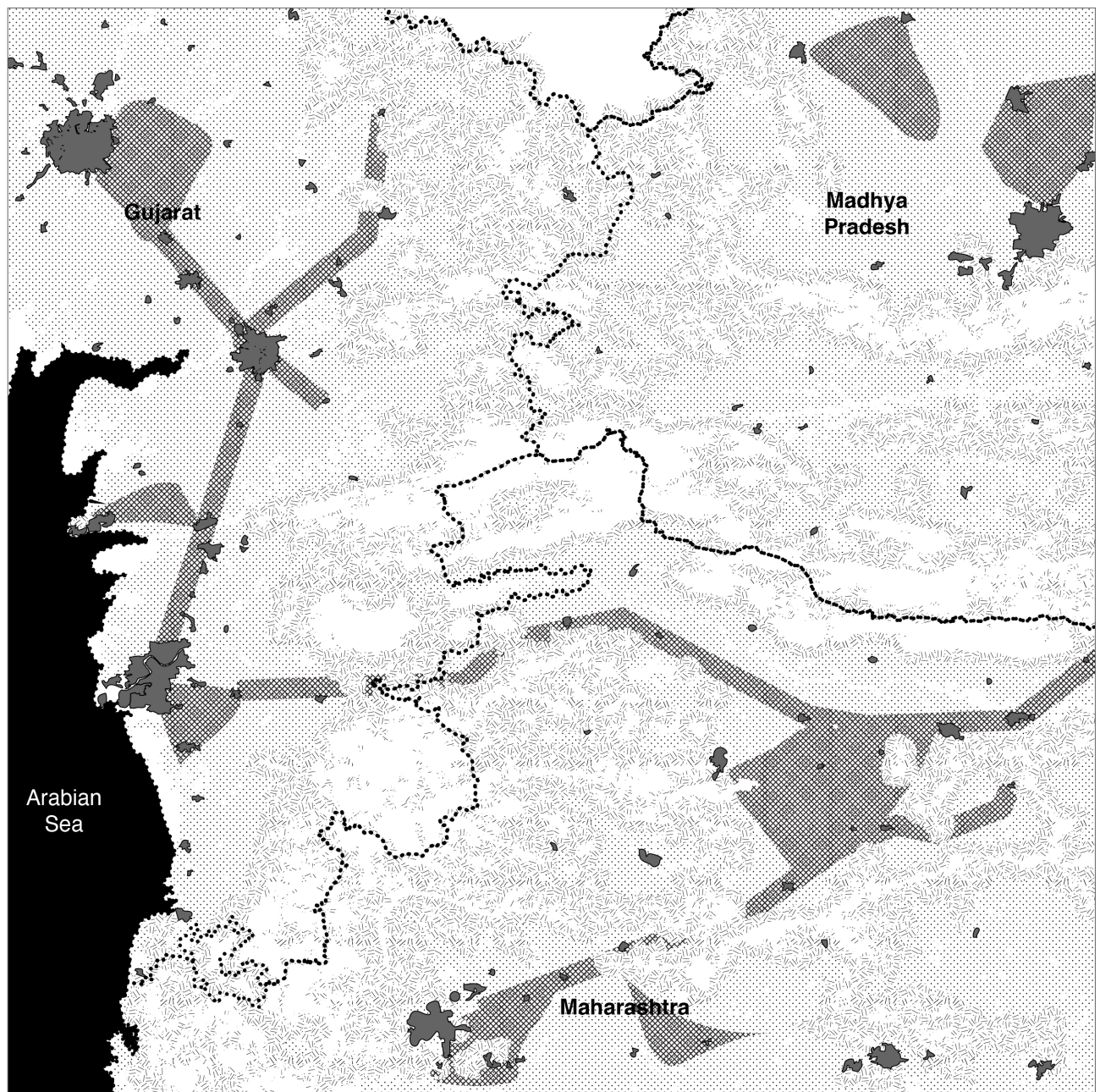
Figure 46: Vision plan for the region



Proposed corridors

- state boundary
- settlement area
- IoT management building
- cow shed
- composting plant
- agri-corridor
- ecological corridor
- agri-rurban areas

Figure 47: Proposed corridors and anchors



Agricultural typologies

- state boundary
- settlement area
- agro-park
- agro-forestry
- sustainable farming with medium automation

0 20 40 60
km



Figure 48: Proposed agricultural typologies

AN OPERATIONAL FRAMEWORK FOR INDIAN AGRO-URBANISM

In the absence of an established food planning framework in India, urban planners require a structured yet flexible operational apparatus, one that cultivates critical thinking and advocacy rather than rendering them instruments of misaligned political agendas (Chakravarty & Prakash, 2024). Planners and designers must position themselves as system architects, actively mediating the symbiosis between urban consumption and rural production spaces. The impediment is rarely one of local knowledge; rather, it is the structural complexity of governing agencies and decision-making hierarchies that systematically marginalises farmer practices, citizen responses, and social justice considerations at scale. Large-scale master plans consistently fail to integrate human relationships with spatial dynamics, overlooking the lived realities of producers and perpetuating fragmented interventions that deepen existing inequities.

To address this, an Indian Agro-Urbanism Operational Framework is proposed, one that streamlines the planning process for both decision-makers and practitioners while embedding participatory methodologies at every stage. The framework progresses through six iterative phases: consult, identify, analyse, demarcate, intervene, and envision, functioning across local, meso, and regional scales and sustained by a continuous feedback loop. It is designed to actively empower three stakeholder groups that the power-interest matrix identifies as currently underrepresented despite their high stakes: the environment, farmers, and consumers (Figure 49). The framework dictates the roles of the stakeholders in each of the planning and implementation stages in Figure 50.

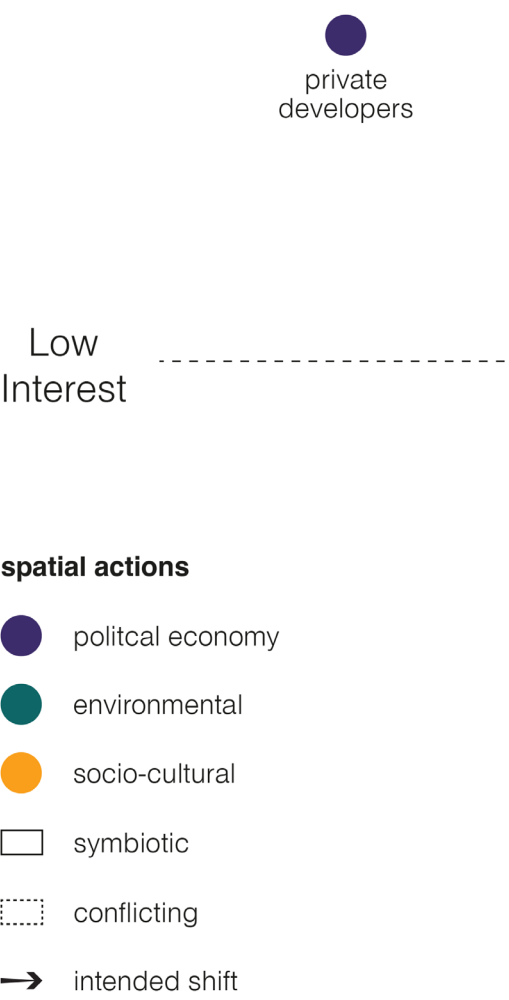
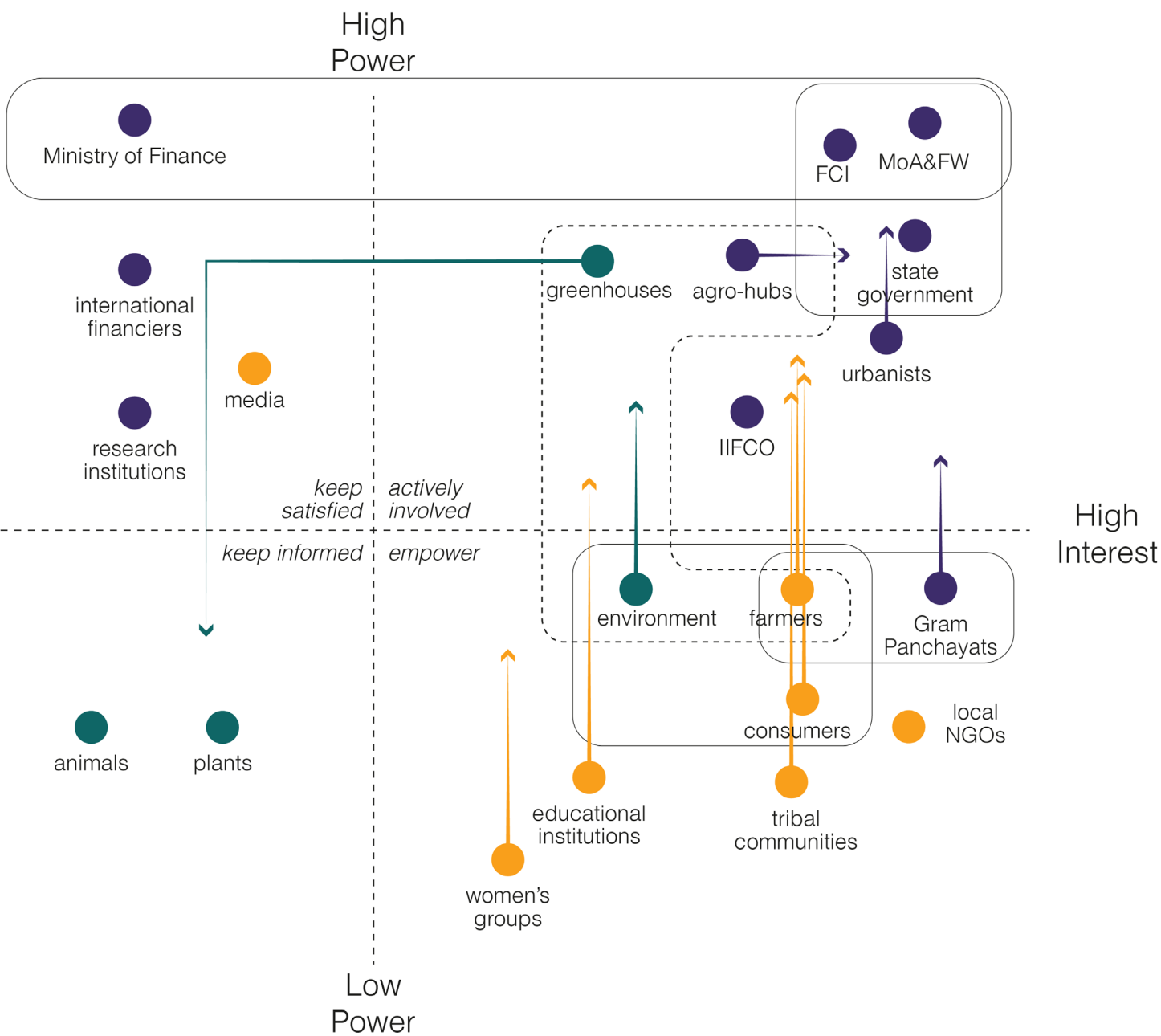


Figure 49: Intended shift in the positions of different stakeholders with the proposed operational framework



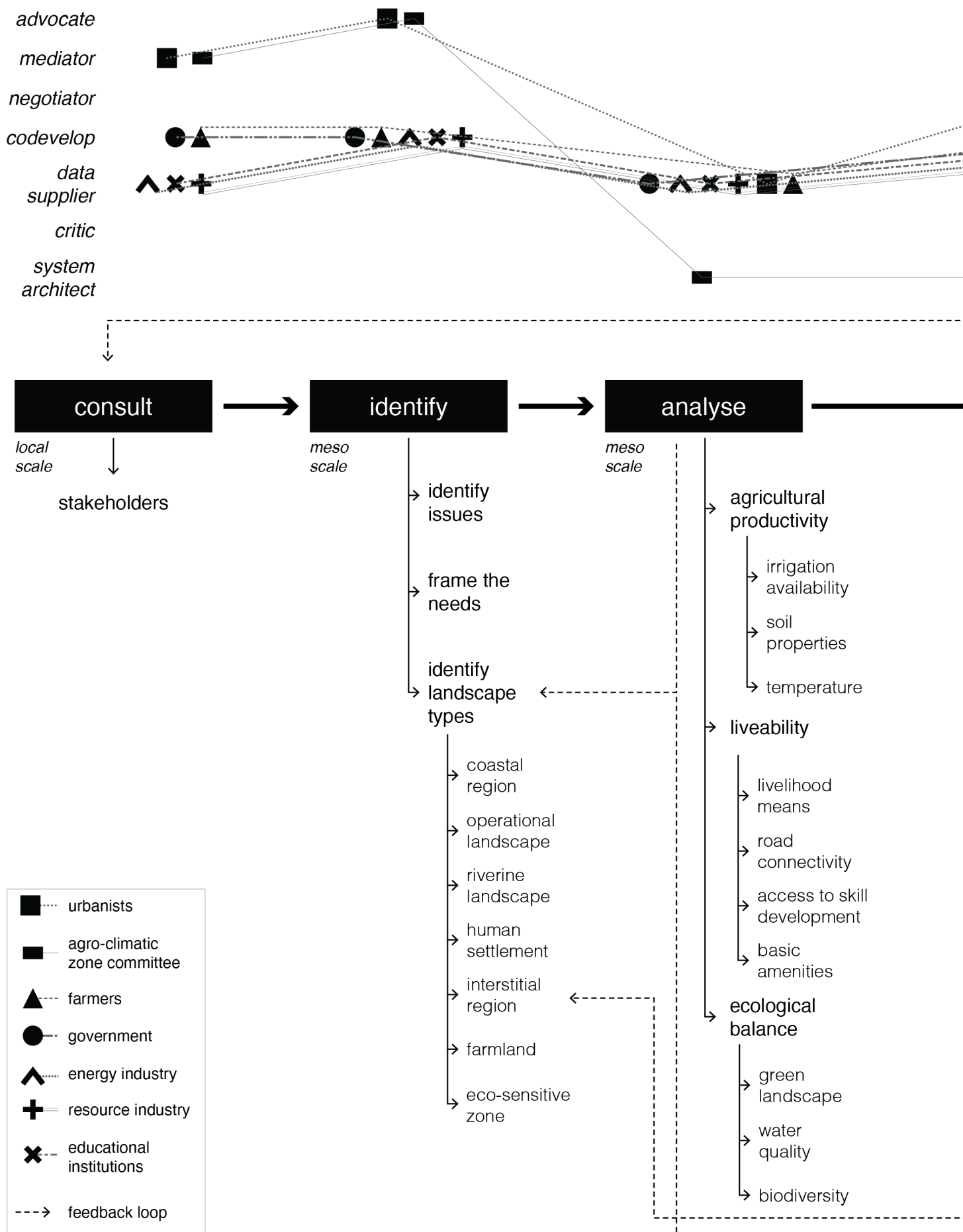


Figure 50: Proposed operational framework for urban planners and other stakeholders

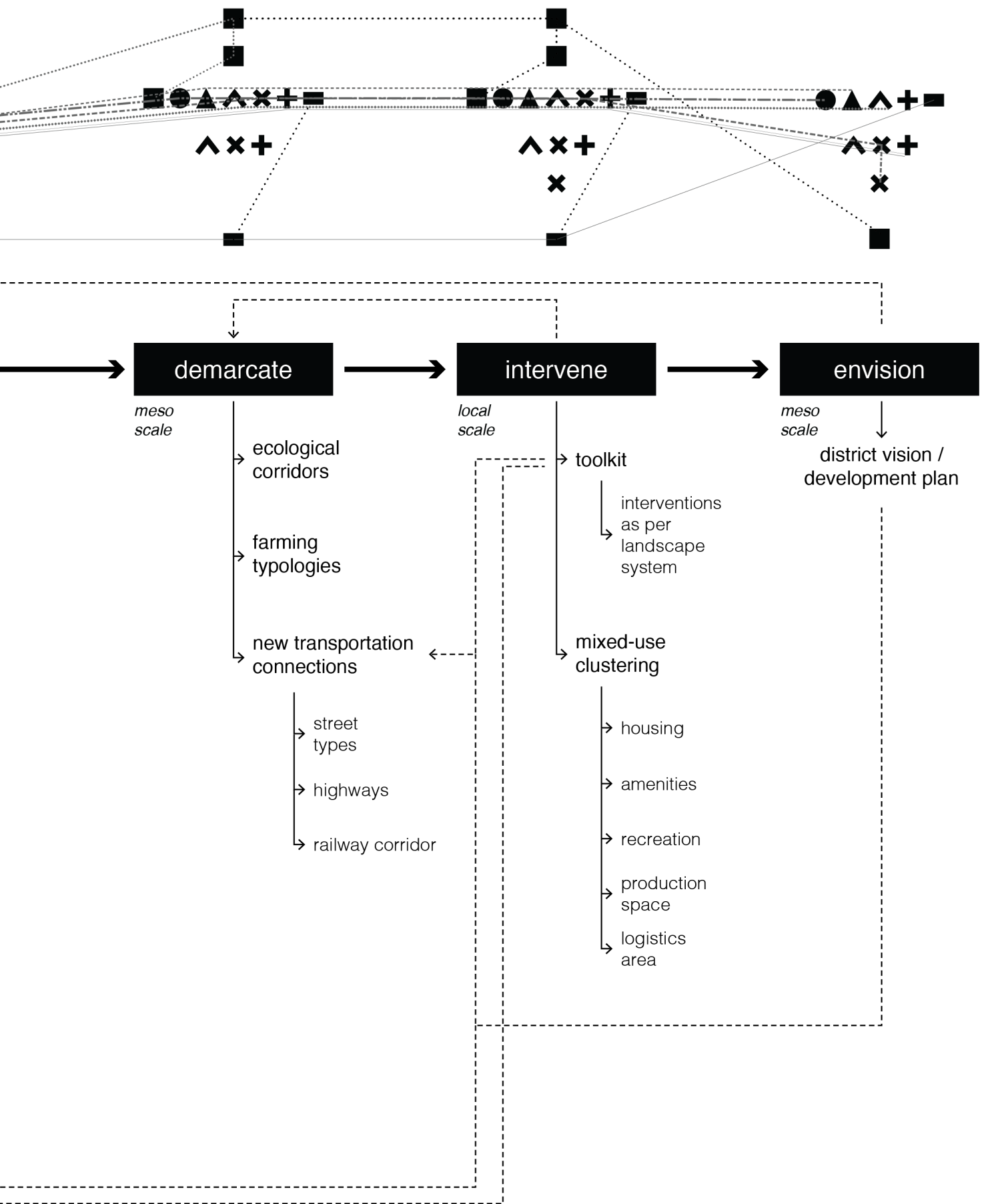




Figure 51: Sugarcane fields in Surat, Gujarat.
Image source: Express Archives (2026).

5.

TESTING GROUNDS: SURAT DISTRICT

This chapter represents the use of the operational framework to envision the future of an exemplary case: Surat district, Gujarat, India.

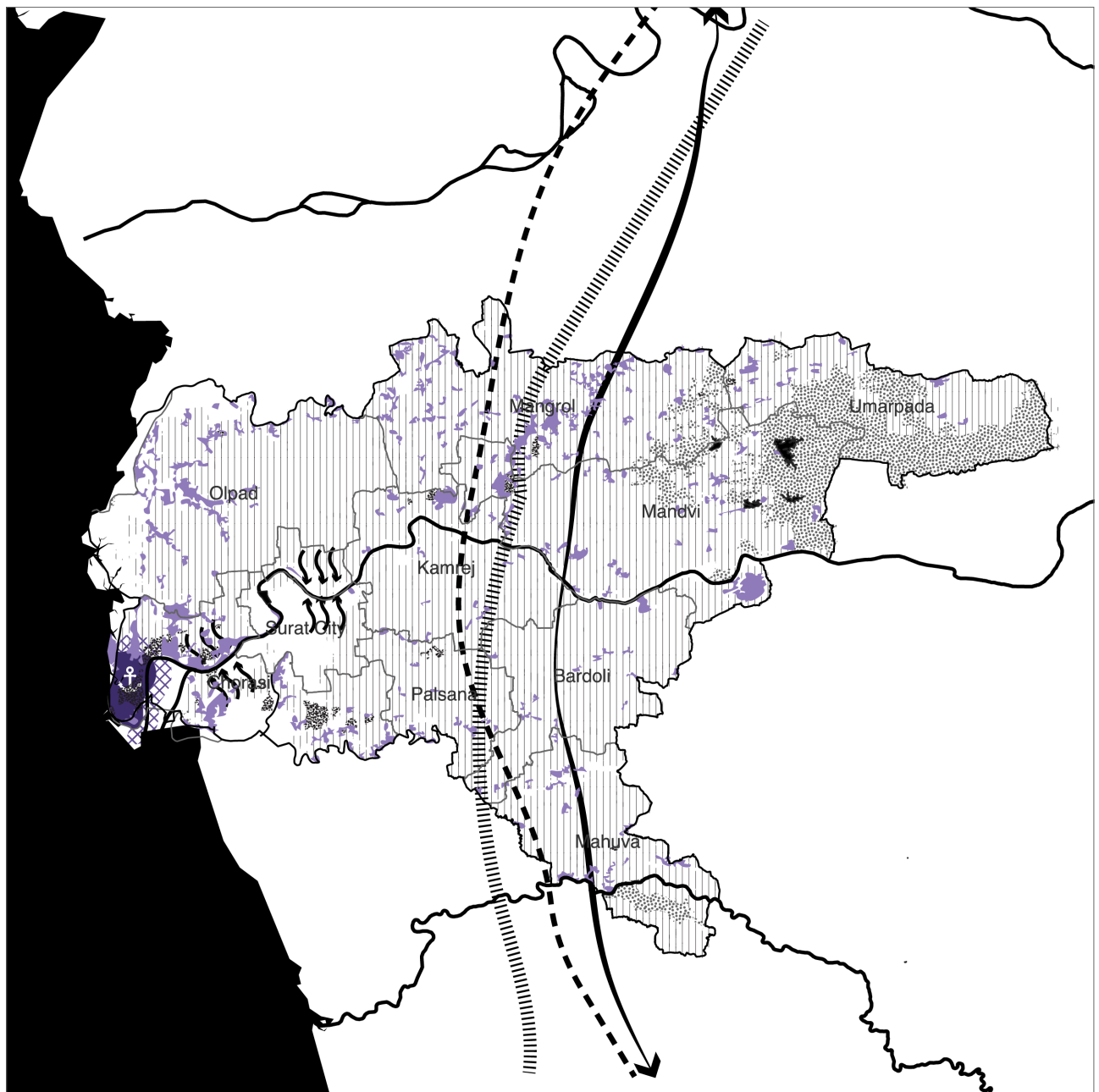
STEPS 1 & 2: CONSULT AND IDENTIFY

Framing the needs

Surat district, situated in southern Gujarat along the Tapi River and the Gulf of Cambay, represents one of India's most economically vibrant yet ecologically strained territories. Despite nearly 80% urban residency, Scheduled Tribes constitute 14.1% of the population, with subdistricts such as Mandvi, Mangrol, and Umarpada remaining predominantly tribal, necessitating targeted interventions for equitable development. The agricultural landscape is dominated by sugarcane and paddy, with approximately 66% of holdings belonging to small and marginal farmers averaging just 1.86 hectares, placing smallholders in chronic vulnerability. Erratic rainfall, as witnessed in late 2025, has severely disrupted harvests and deepened agrarian distress. Rapid industrialisation has progressively degraded surface water quality through effluent discharge, while industrial reclamation around Hazira has constricted the Tapi's natural drainage, intensifying flood exposure across low-elevation coastal zones. Emerging initiatives such as the Gujarat Agro Infrastructure Mega Food Park at Mangrol, developed collaboratively by the Ministry of Food Processing Industries, NABARD, and Panchayati Raj, signal growing institutional recognition of the imperative to integrate food processing, rural livelihoods, and tribal inclusion into the district's agricultural trajectory (Government of Gujarat & NABCONS, 2016).

Identifying the landscape systems

Surat district encompasses a remarkably diverse gradient of landscape systems that directly border and interact with its agricultural lands (Figure 53). From the coastal salt marshes, beach towns, and port areas in the west, impacted by tidal dynamics and saline intrusion, along with the landscape transitions through energy infrastructure, mining areas, and GIDC industrial zones. The river Tapi and the canal networks spread across the subdistricts and pass through urban and rural settlements. Peri-urban and rural areas are consistently growing besides the urban areas, creating a friction between expanding settlements and farmland. There is an eco-sensitive zone in the eastern part of the district, comprising inland wetlands, forests, and reservoirs. This spectrum of adjacencies (Figure 55) means agricultural lands in Surat are simultaneously pressured by industrialisation, urbanisation, and ecological fragility, yet also potentially enriched by proximate water bodies, transport corridors like the MAHSR and national highways, and agro-food infrastructure such as the Mangrol food park.



Surat District Local Plan

state

water body

Opportunities

bullet train corridor

dedicated freight corridor

Delhi-Mumbai expressway

wastelands

Challenges

water intensive agriculture

river narrowing

forest area depletion

mining

0 10 20 30 km



Figure 52: Opportunities and challenges of the Surat district, Gujarat, India.



Villages and farmland



Urbanised riverfront



Beach town



Energy infrastructure



Natural ecosystem and industries



Port area



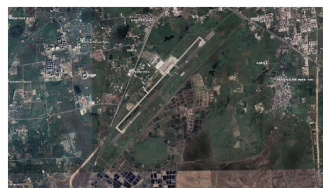
Mining area



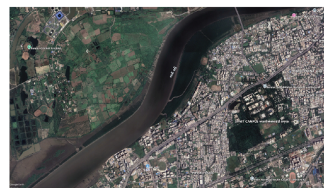
Floodplain



Salt marshes



Airport



Urban and farmland



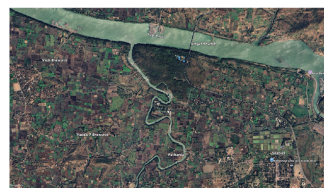
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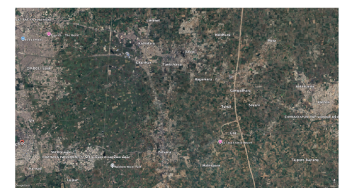
Industrial



Agro food park



River and canal



Cities

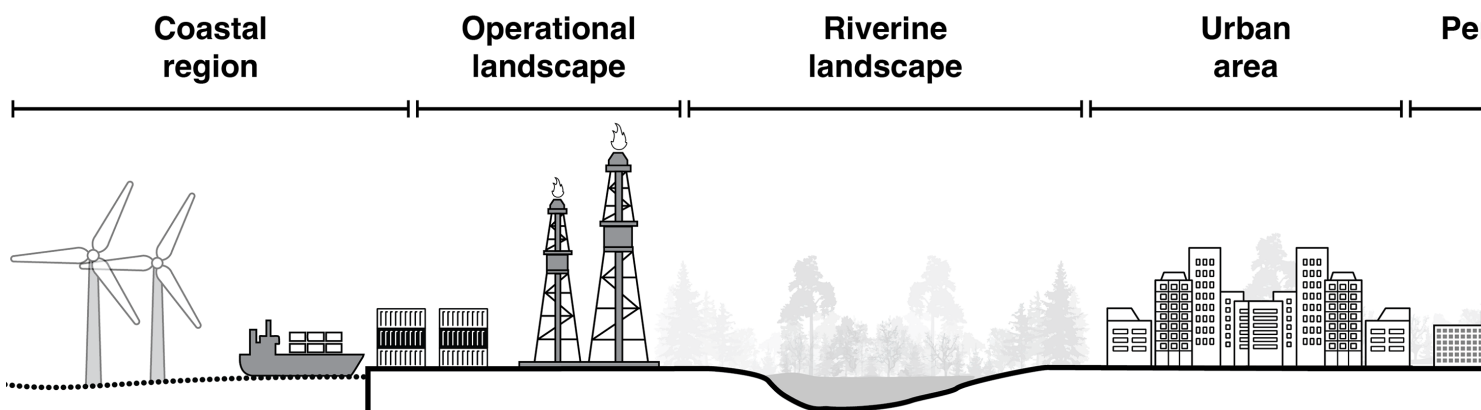


Figure 53: Landscape type categorisation for Surat district, Gujarat, India.



Railway through settlement areas



MAHSR and Railway corridor



Junctions



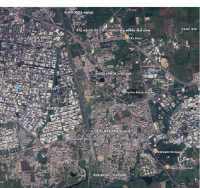
National highway



Inland wetland



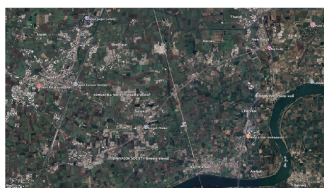
Industries near reservoir



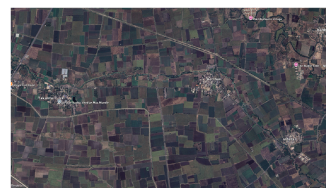
DC areas



Forest and reservoir



Urbanised rural areas



Villages



STEP 3: ANALYSE

To assess the needs of the Surat district, MCDA metrics were defined to evaluate the impact of interventions across planning stages, structured around three thematic pillars derived from the regional analysis in Chapter 3: Agricultural productivity, liveability, and ecological balance. Sub-subcriteria relevant to the agro-climatic zone were identified through a systematic literature review (see Figure A.1 in Appendix A). A 1 km × 1 km grid was applied across the district, aggregating multiple smallholder parcels into a landscape-scale unit while remaining compatible with key spatial datasets, including NDVI, soil classifications, groundwater depth, and rainfall data from ISRO Bhuvan, FAO SoilGrids, and IMD, ensuring analytical consistency. The rationale for selecting MCDA, sub-subcriteria ranking, spatial attributes, score normalisation, and data sources is detailed in Appendix A.1. The analysis yielded the following conclusions (Figure 54).

Agricultural productivity

Soil suitability is predominantly codependent on riverbank conditions, meaning that the quality and viability of agricultural land are closely tied to the health of nearby water bodies such as rivers and canals (Figure 55). Downstream areas in the coast present water recharge challenges due to the limited infiltration capacity of the soil, limiting their productive potential. Productivity tends to be highest in peri-urban areas surrounding major cities, as well as rural settlements near water bodies, suggesting that proximity to settlement supports agricultural output. This is the result of the importance of urban development being a key consideration for canal system establishment, as compared to the need for water for agricultural irrigation. Please refer to Figure A.2.1 in Appendix A for the normalised scoring in each sub-subcriteria.

Liveability

Liveability is the highest in peri-urban areas due to a key focus on infrastructural development near the major city in the district, Surat (Figure 56). These areas offer the best of both urban and rural worlds. These transitional spaces benefit from urban services while retaining rural qualities, making them desirable for communities. In contrast, tribal communities recorded the lowest liveability index scores, indicating that remoteness and limited access to services significantly diminish quality of life in those areas. This is corroborated by the interviews as part of the Narmada Oral Histories archive. Please refer to Figure A.2.2 in Appendix A for the normalised scoring in each sub-subcriteria.

Ecological balance

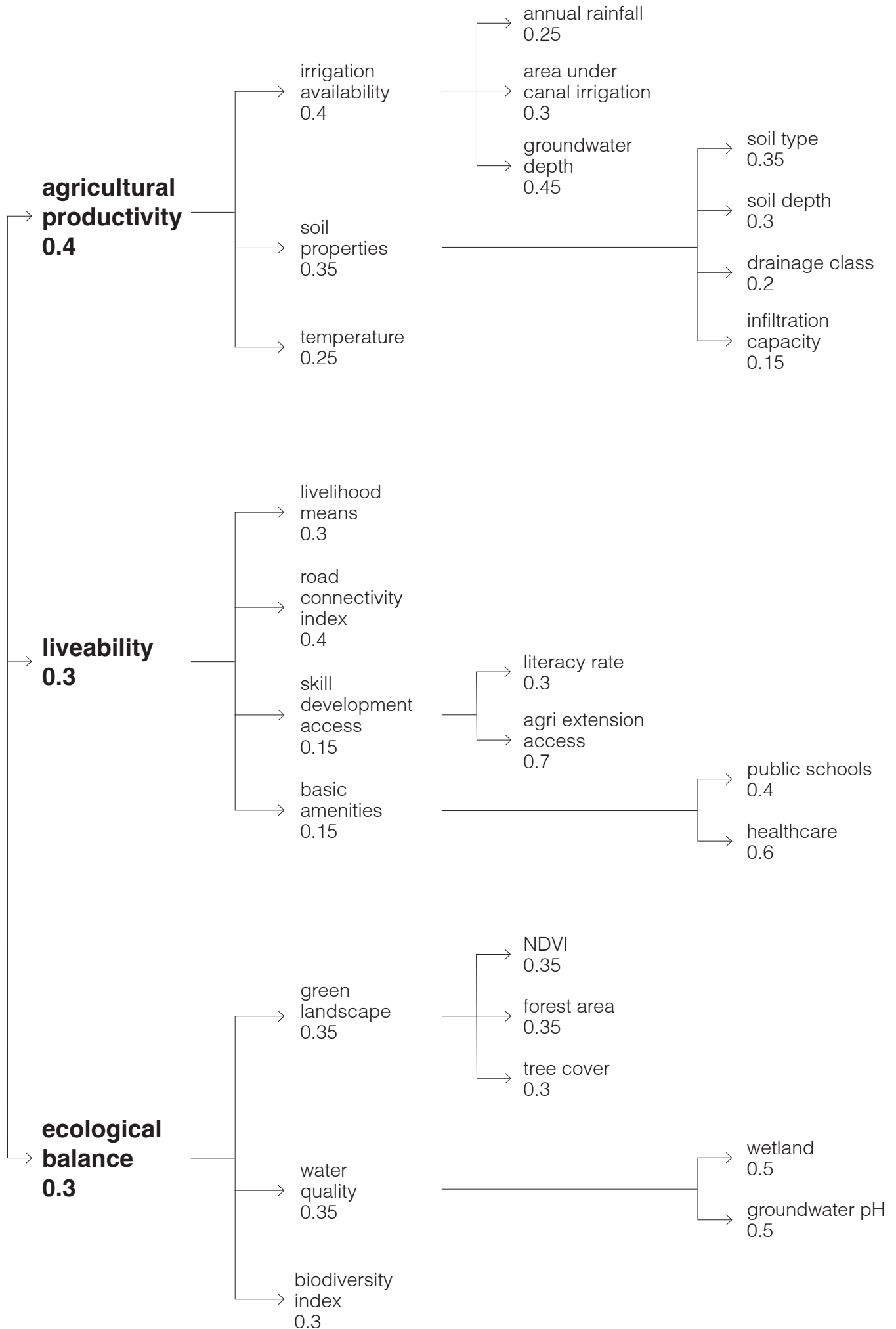
The analysis found that biodiversity is strongly forest-dependent and consistently located in non-urban areas (Figure 57). This presents a critical tension in patch selection: large urban areas can act as pollination barriers, fragmenting ecosystems and disrupting the movement of pollinators across the landscape. These findings highlight the need to carefully consider the spatial relationship between urban expansion and ecological connectivity. Please refer to Figure A.2.3 in Appendix A for the normalised scoring in each sub-subcriteria.

Just Agro-Urbanism

Patches near forests perform strongly in the final output primarily due to their high normalised ecological balance scores (Figure 58). Whereas the other patches have very low ecological balance, while simultaneously scoring low to average across agricultural productivity and liveability. Thus, these three categories highlight the trade-offs involved in patch selection, where maximising agricultural output or urban liveability must be balanced with integration of biodiversity in and around all the identified landscape types in the district.

Figure 54: Layers for analysis and their assigned weights.

JUST AGRICULTURAL URBANISM



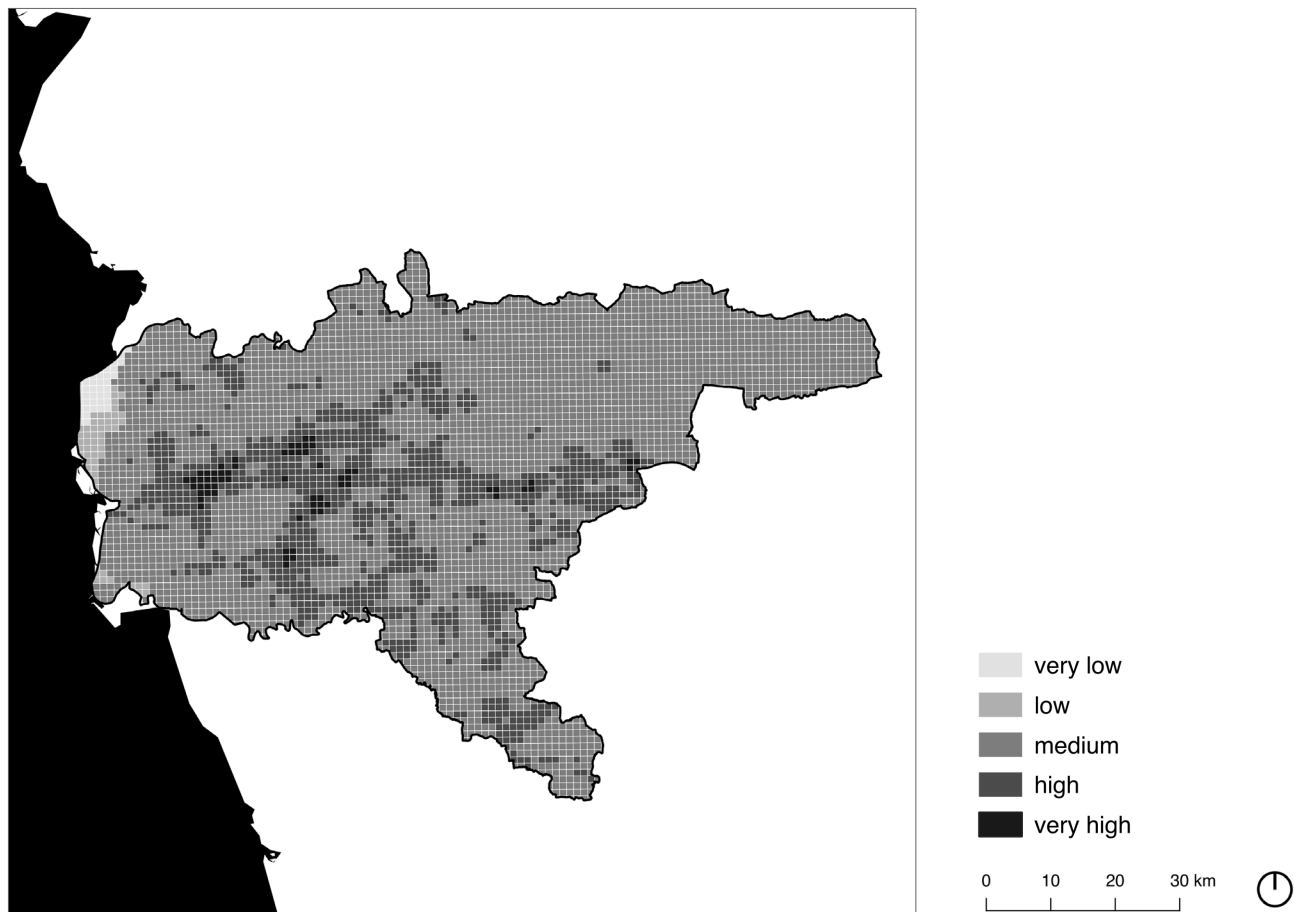


Figure 55: Normalised agricultural productivity of Surat district, Gujarat, India.

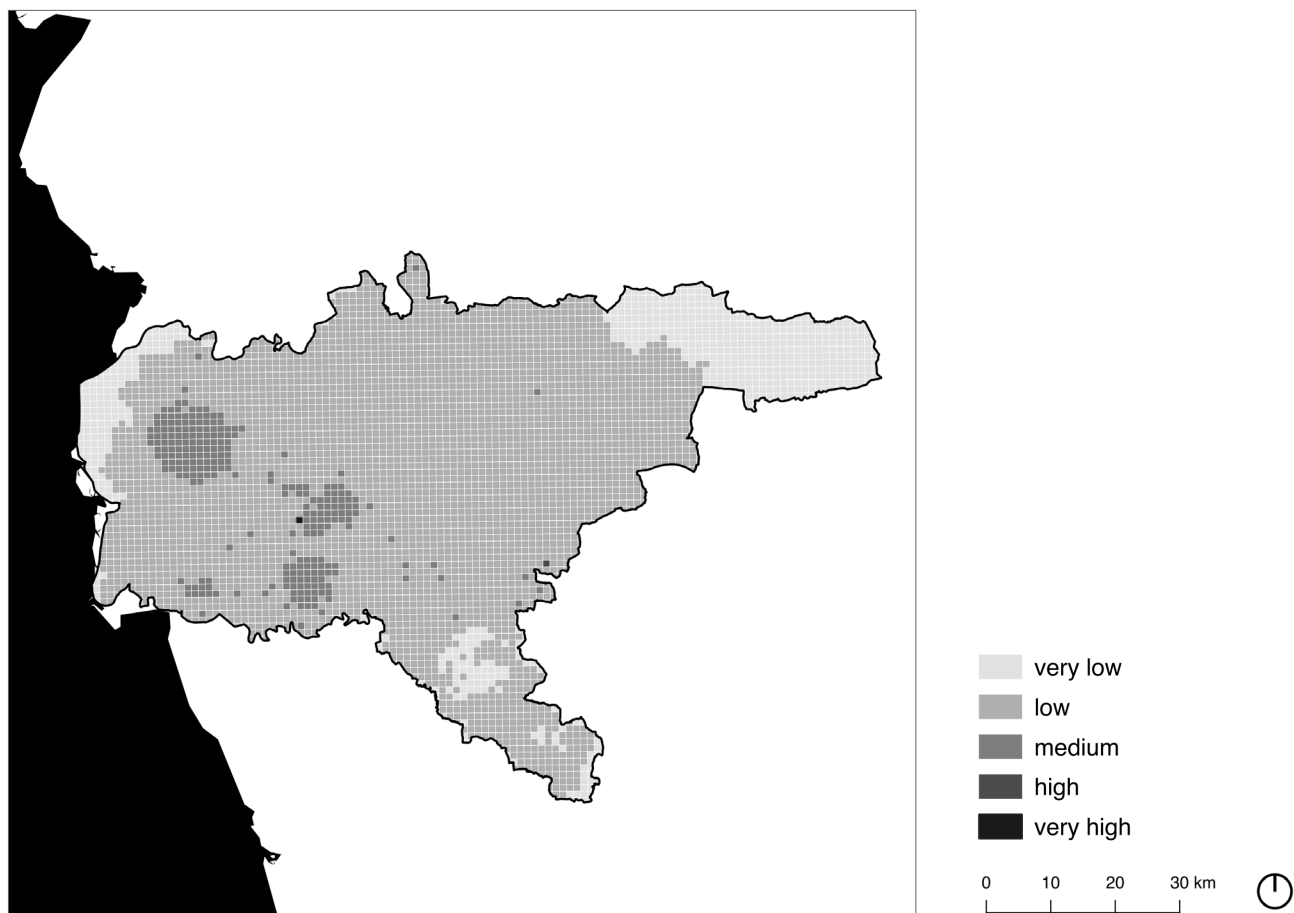


Figure 56: Normalised liveability of Surat district, Gujarat, India.

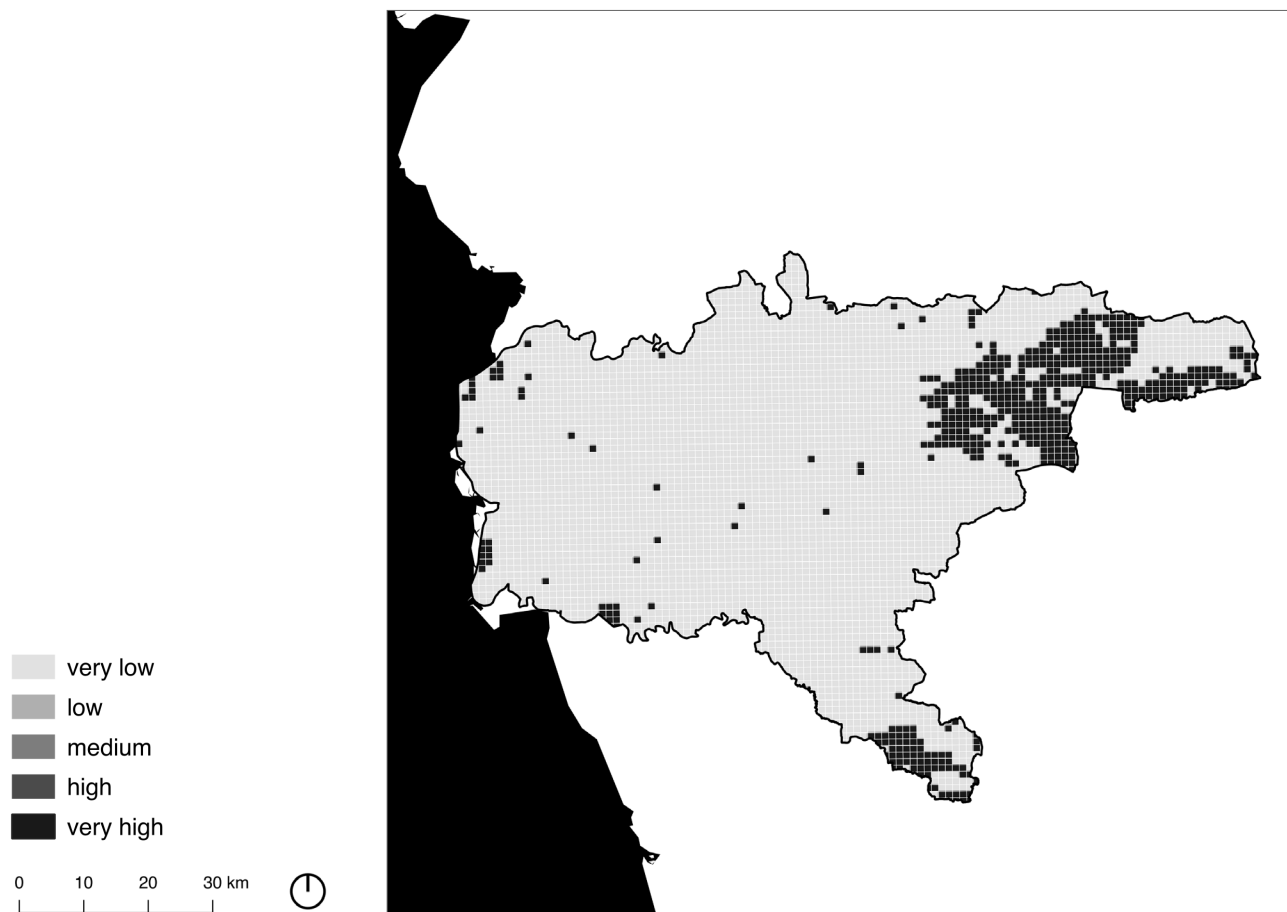


Figure 57: Normalised ecological balance of Surat district, Gujarat, India.

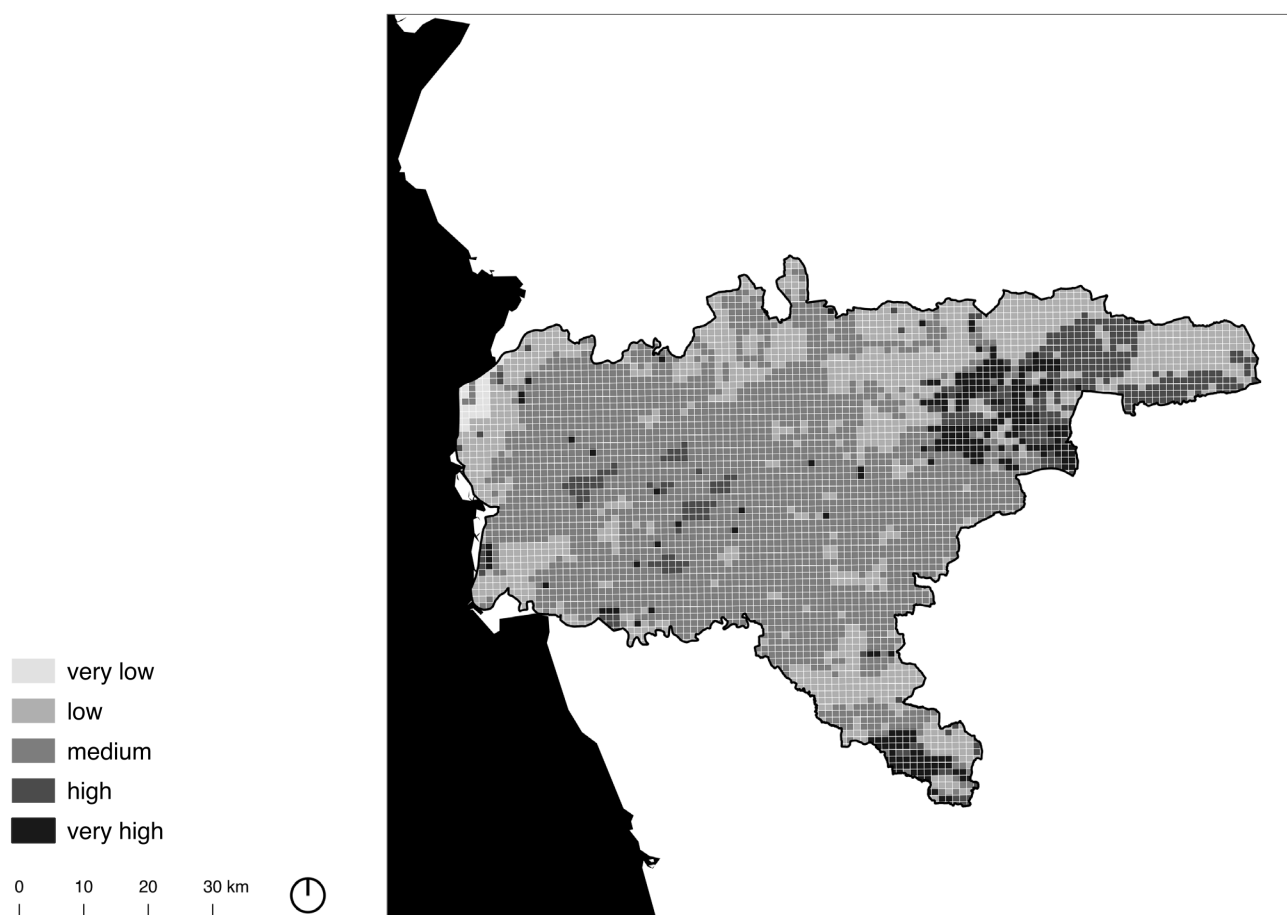


Figure 58: Normalised ecological balance of Surat district, Gujarat, India.

STEP 4: DEMARCATATE

Building on the multi-criteria decision analysis, several non-negotiables have been established to guide the conservation of ecologically sensitive areas, define appropriate agricultural typologies, and propose new spatial connections between these zones. Furthermore, these demarcations can be planned collaboratively with the farmers, the tribal communities, and industries focused on energy infrastructure and automation to ensure a consensus amongst the various stakeholders mediated by urbanists and the agro-climatic zone committee.

Ecological Corridors

Ecological corridors are proposed to link existing ecologically sensitive areas through the transitional spaces between human settlement areas and water bodies such as rivers and canals (Figure 59). These corridors serve a dual purpose: buffering settlement areas from environmental pressures while simultaneously reinforcing and supporting riverine landscapes.

Agricultural Typologies

Based on the identified normalised agricultural productivity scores, transition zone patches, located between high-productivity agricultural areas and primary street networks, can be designated as agro-parks or metropolitan food clusters, depending on the density of the proximate settlements (Figure 60). Patches already demonstrating strong agricultural productivity should adopt sustainable and organic farming methods to maintain ecological balance. The patches comprising water bodies and broader ecosystem services are suited to

agroforestry practices. Remaining areas with growth potential can be gradually phased into higher productivity through medium-level automation. Coastal regions, in turn, would apply halophyte and aquaculture-integrated farming techniques.

New Spatial Connections

Drawing from the normalised liveability index, existing rural-urban settlement patterns, and current street network configurations, areas requiring new connections are identified (Figure 61). These linkages should align with both the demarcated ecological corridors and the proposed agricultural typologies, ensuring spatial coherence between ecological, productive, and inhabited landscapes.

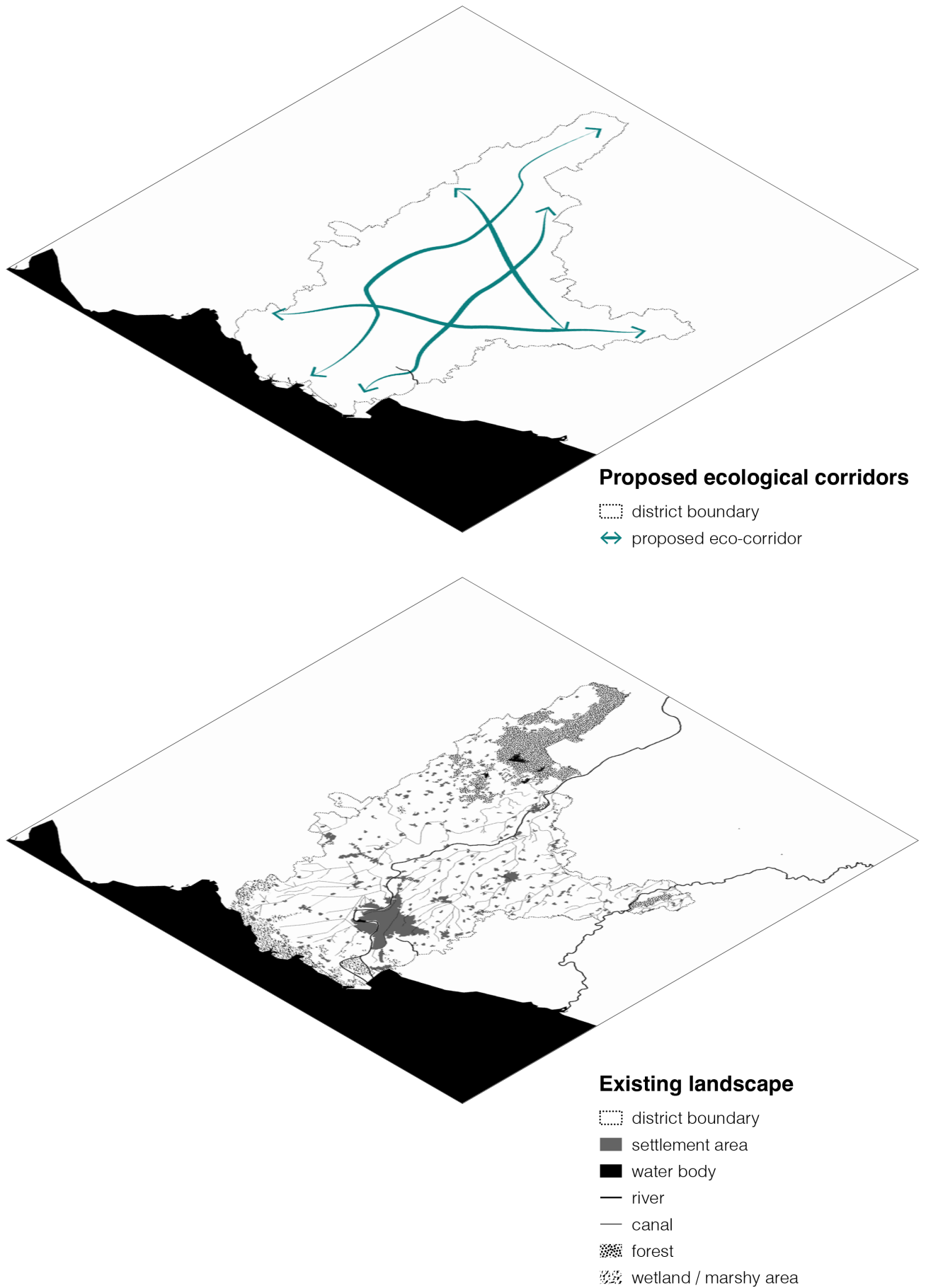


Figure 59: Proposed ecological corridors as per existing landscape condition.

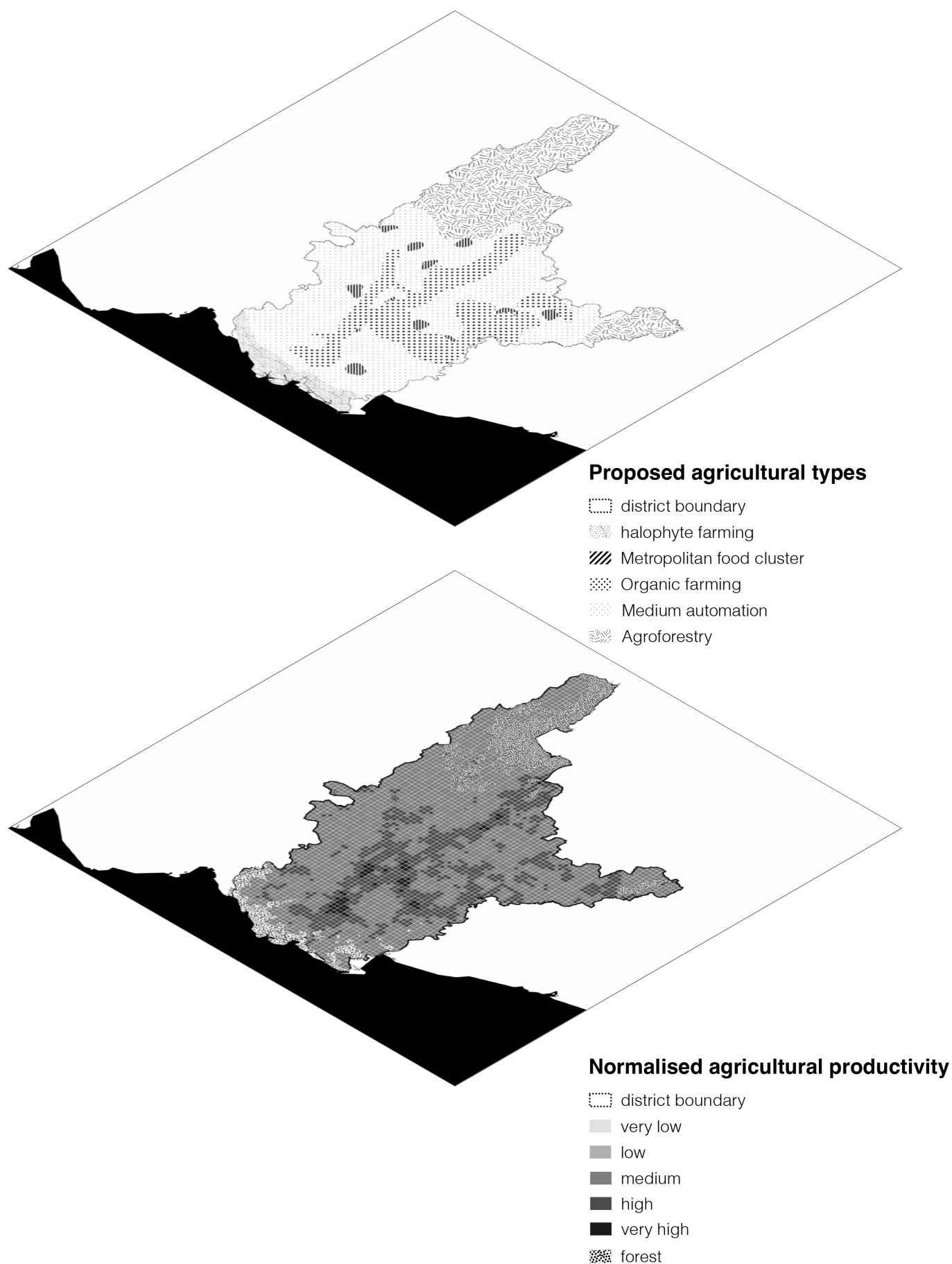


Figure 60: Proposed agricultural types as per existing landscape condition.

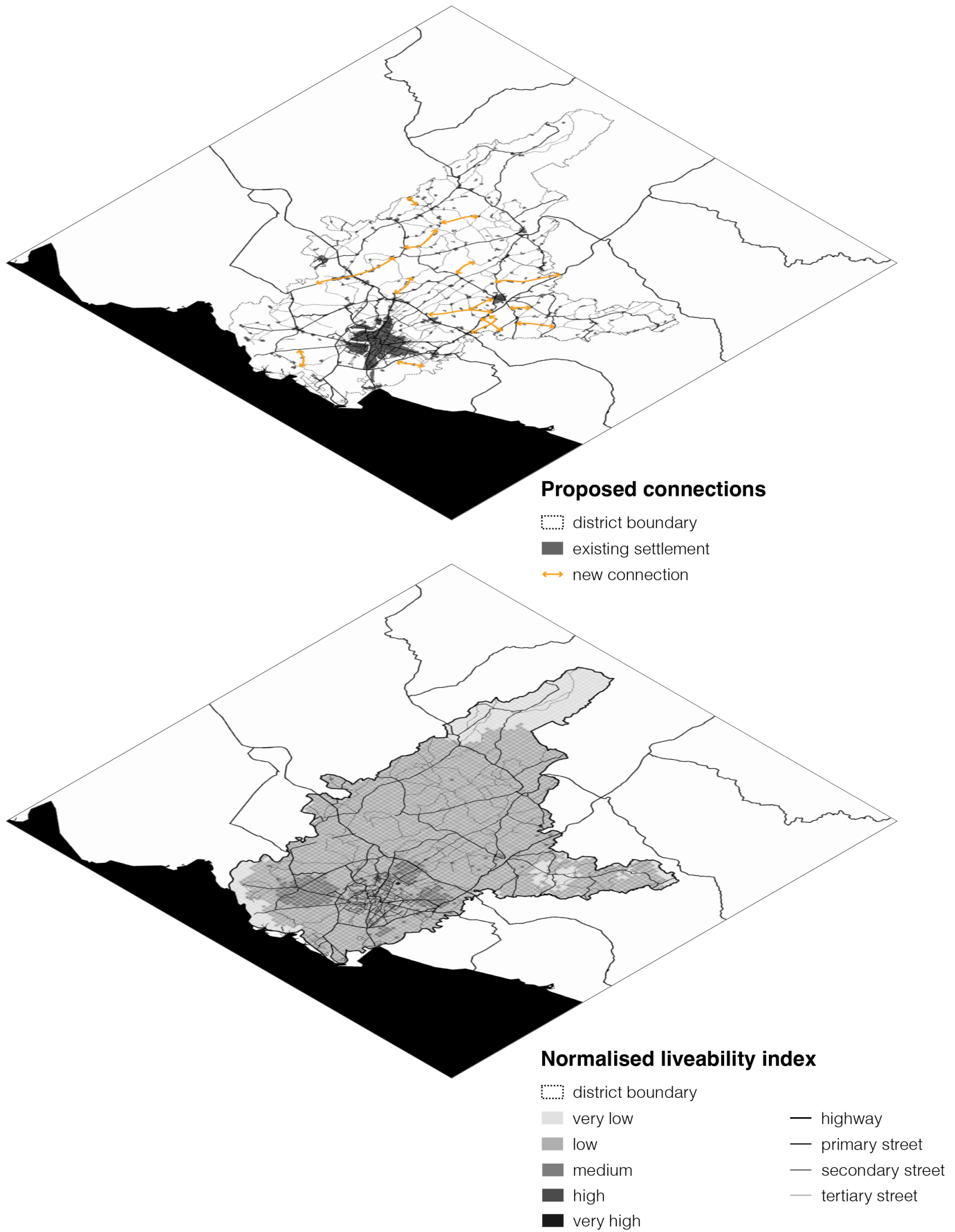


Figure 61: Proposed connections as per existing landscape condition.

STEP 5: INTERVENE

Drawing from the analysis conducted across the three criteria, agricultural productivity, liveability, and ecological balance, patches scoring low across multiple sub-criteria can be prioritised for targeted interventions aimed at improving overall conditions. For each such patch, the underlying landscape system and the nature of its transition zones would first be identified. A contextually responsive toolkit could then be co-designed in collaboration with the agro-climatic zone committee, urban farmers, tribal communities, educational institutions, and other stakeholders with vested interests, to address the specific sub-criteria underperforming within that region. This toolkit would subsequently serve as a reference for planners working within similar agro-climatic zones and comparable conditions, while urbanists could further refine site-specific forensic interventions based on local context.

In the exemplary case of Surat district, the following section outlines seven landscape systems alongside their identified interventions and the key stakeholders involved in co-designing and implementing them (Figures 62-68). While certain intervention types may recur across multiple landscape transition systems, their application would differ meaningfully by context. For instance, a green buffer around an urban area would primarily serve carbon sequestration purposes, whereas one adjacent to a mining zone would focus on soil stabilisation, thus varying in plantation species, density, and methodology. Please refer to Figure A.3 (Appendix A) for the detailed table delineating measures required per sub-criterion identified based on the analysis conducted for the region.

Additionally, recognising seasonality as an integral dimension of agricultural production, automation corridors could be established in primary production landscapes, enabling farmers to pool land and resources to reduce seasonal volatility while ensuring portions of land remain fallow for soil regeneration (Figures 69 and 70). Concurrently, housing and essential amenities, including healthcare, banking, public schools, and recreational infrastructure, should be planned and co-created with residents to ensure good liveability. Based on preliminary calculations, urbanists can propose indicative land-use allocations across categories such as agriculture, industrial agriculture, commons corridors, infrastructure, and water retention over the years.

ecosensitive areas with forest

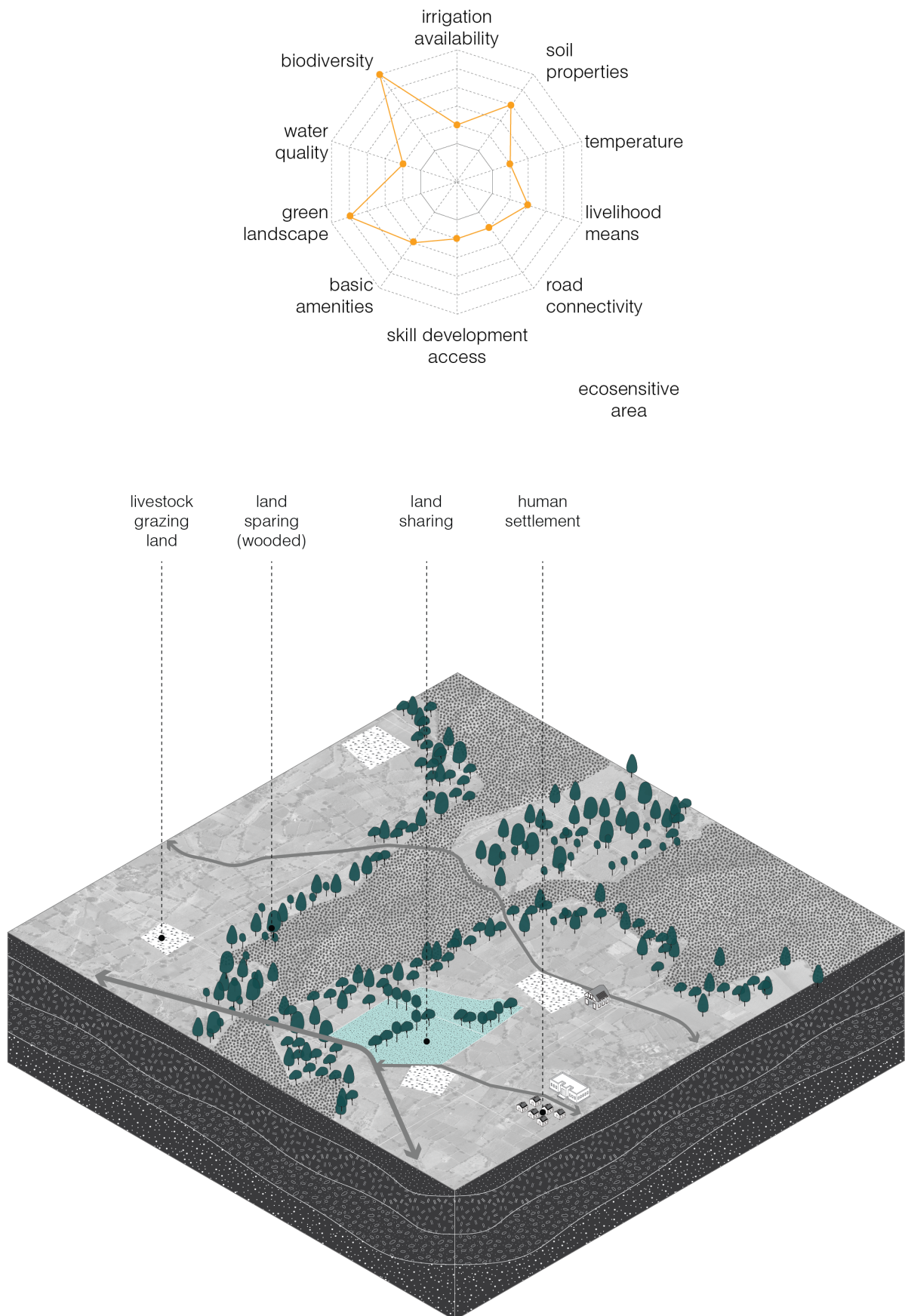


Figure 62: Subcriteria scores and patialisation of proposed interventions for an eco-sensitive area with a forest as per the toolkit.

coastal areas

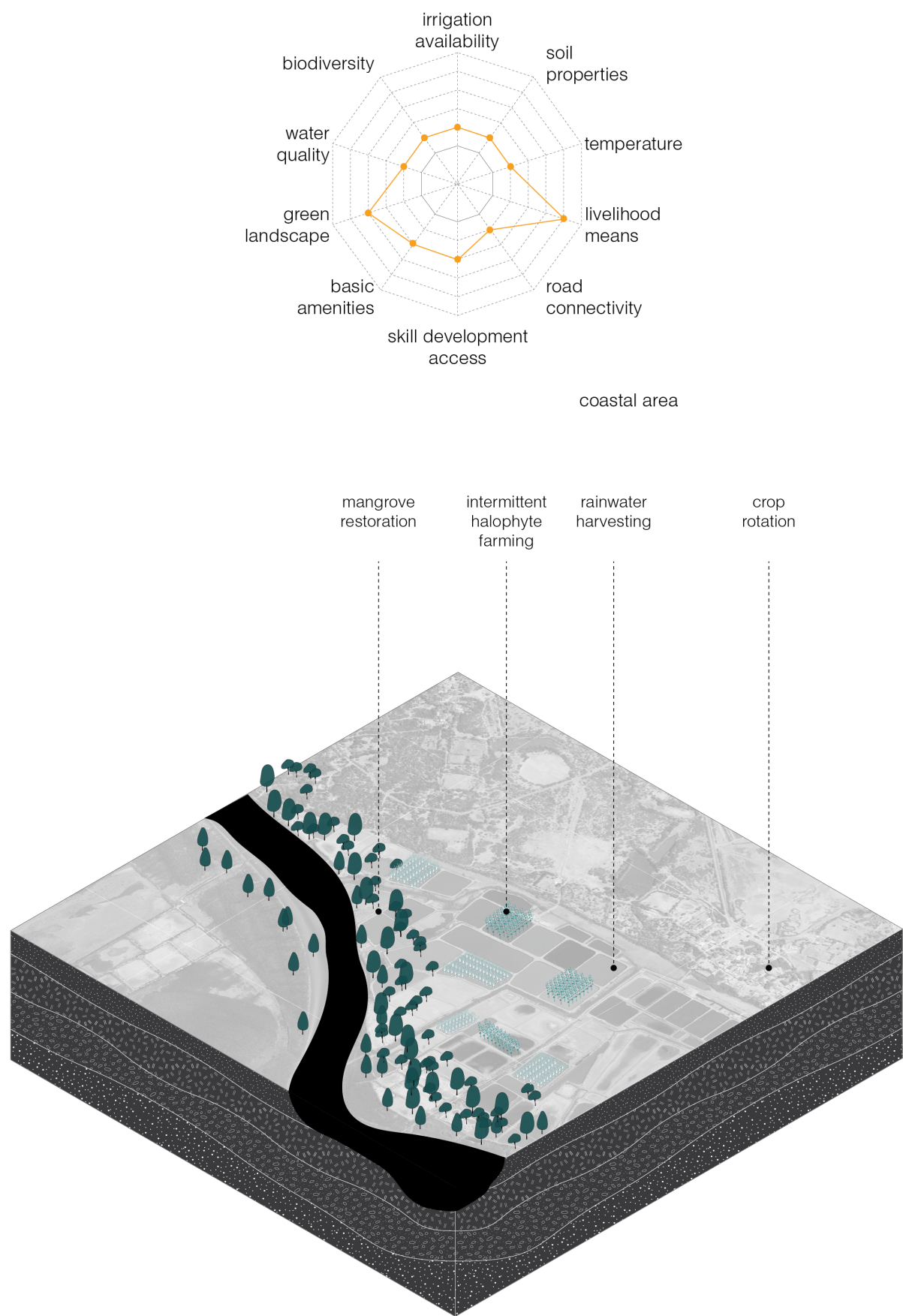


Figure 63: Subcriteria scores and patialisation of proposed interventions for coastal area as per the toolkit.

floodplain

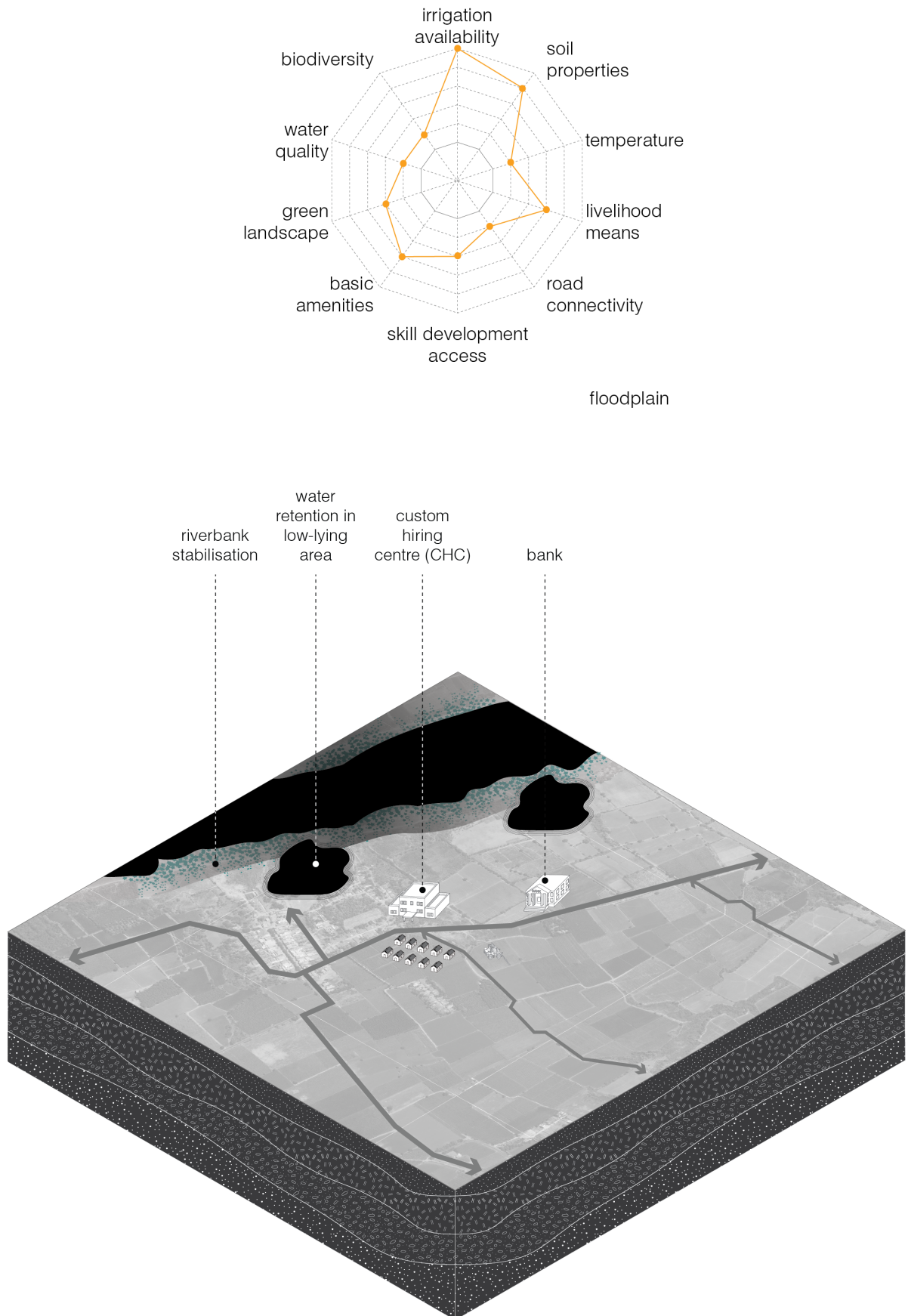


Figure 64: Subcriteria scores and spatialisation of proposed interventions for floodplain in a rural area as per the toolkit.

mining area

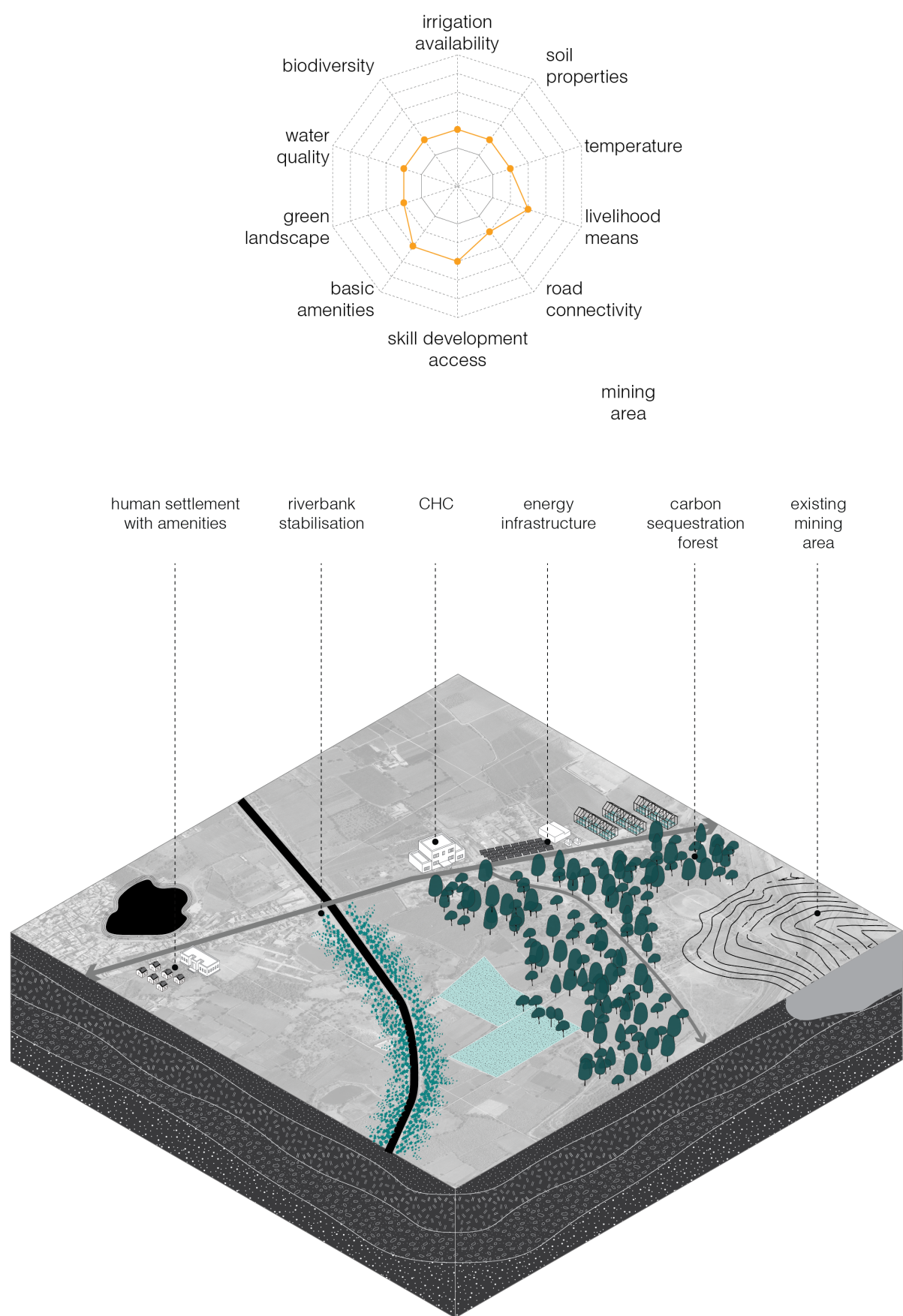


Figure 65: Subcriteria scores and patialisation of proposed interventions for a mining area as per the toolkit.

interstitial region

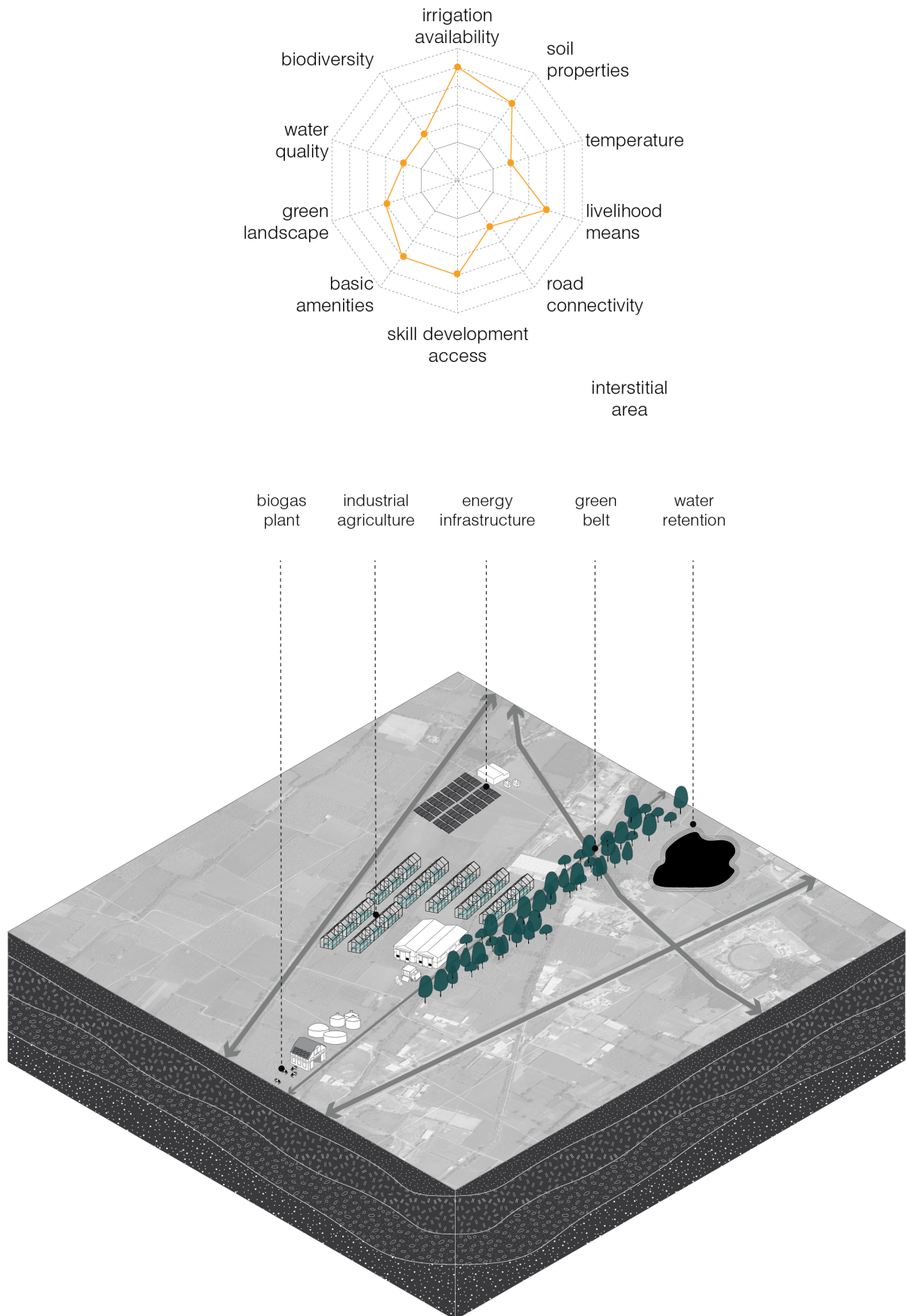


Figure 66: Subcriteria scores and patialisation of proposed interventions for an interstitial region with transport infrastructure as per the toolkit.

urban area

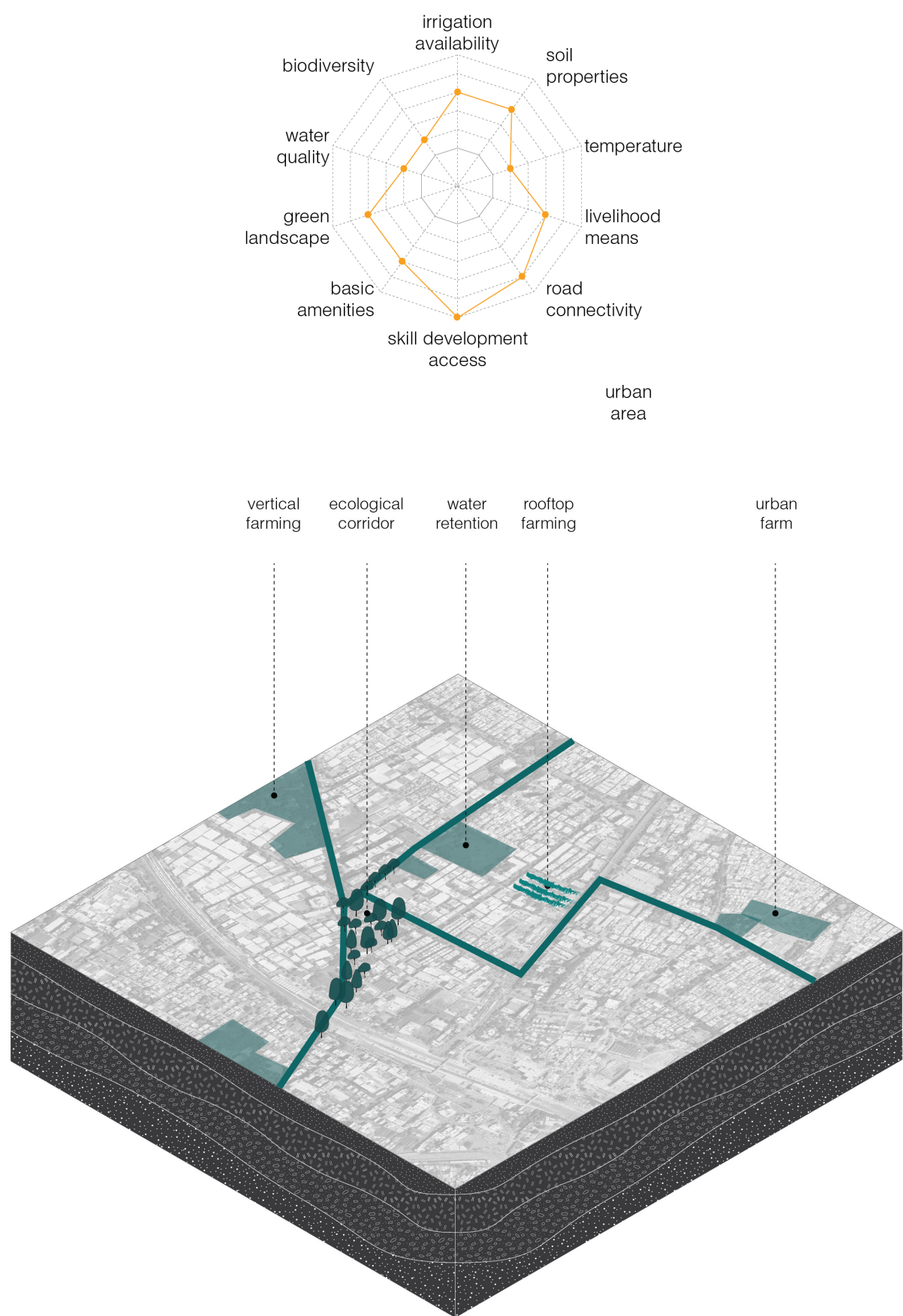


Figure 67: Subcriteria scores and patialisation of proposed interventions for an urban area as per the toolkit.

peri-urban area

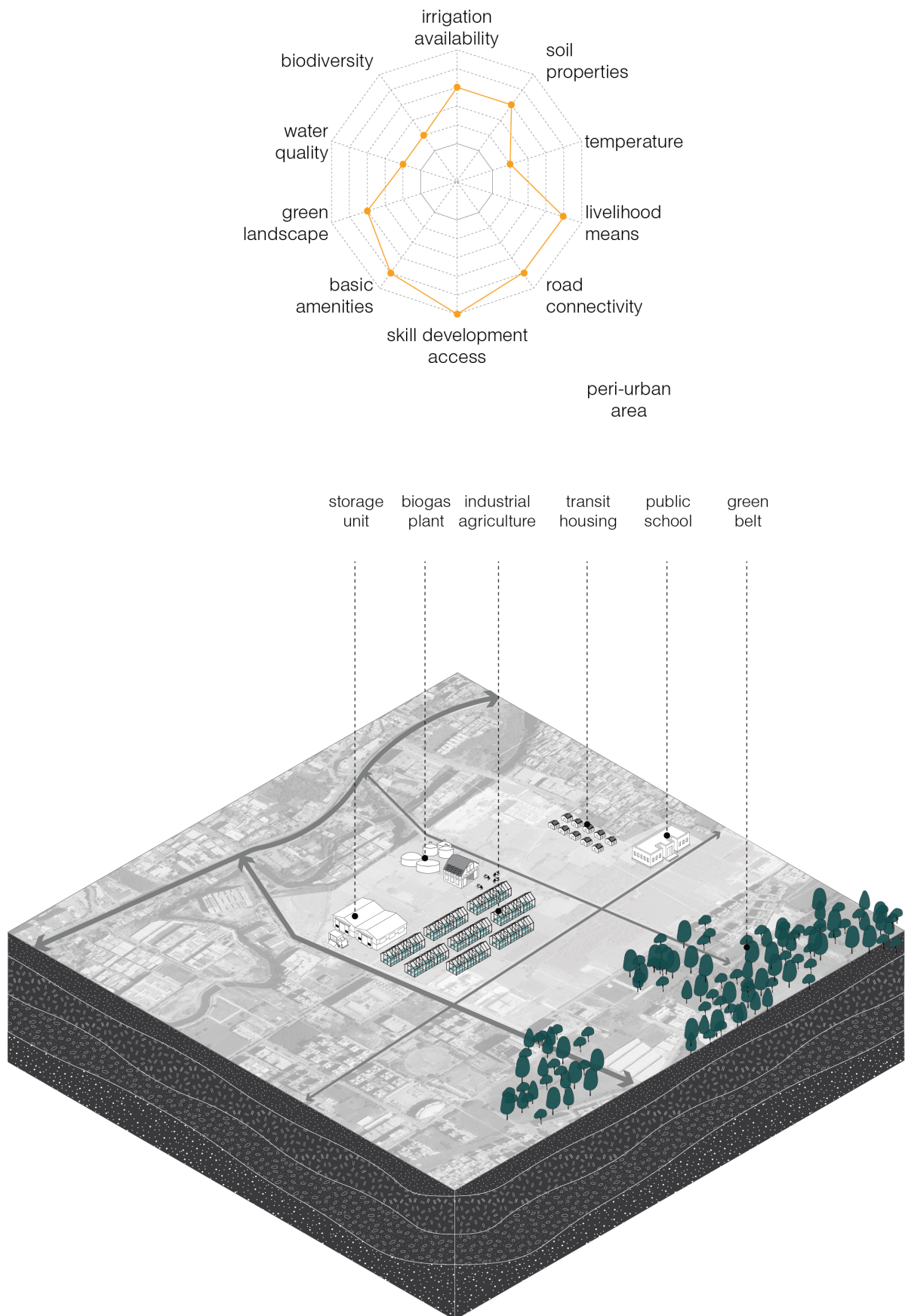


Figure 68: Subcriteria scores and spatialisation of proposed interventions for a peri-urban area as per the toolkit.

seasonality

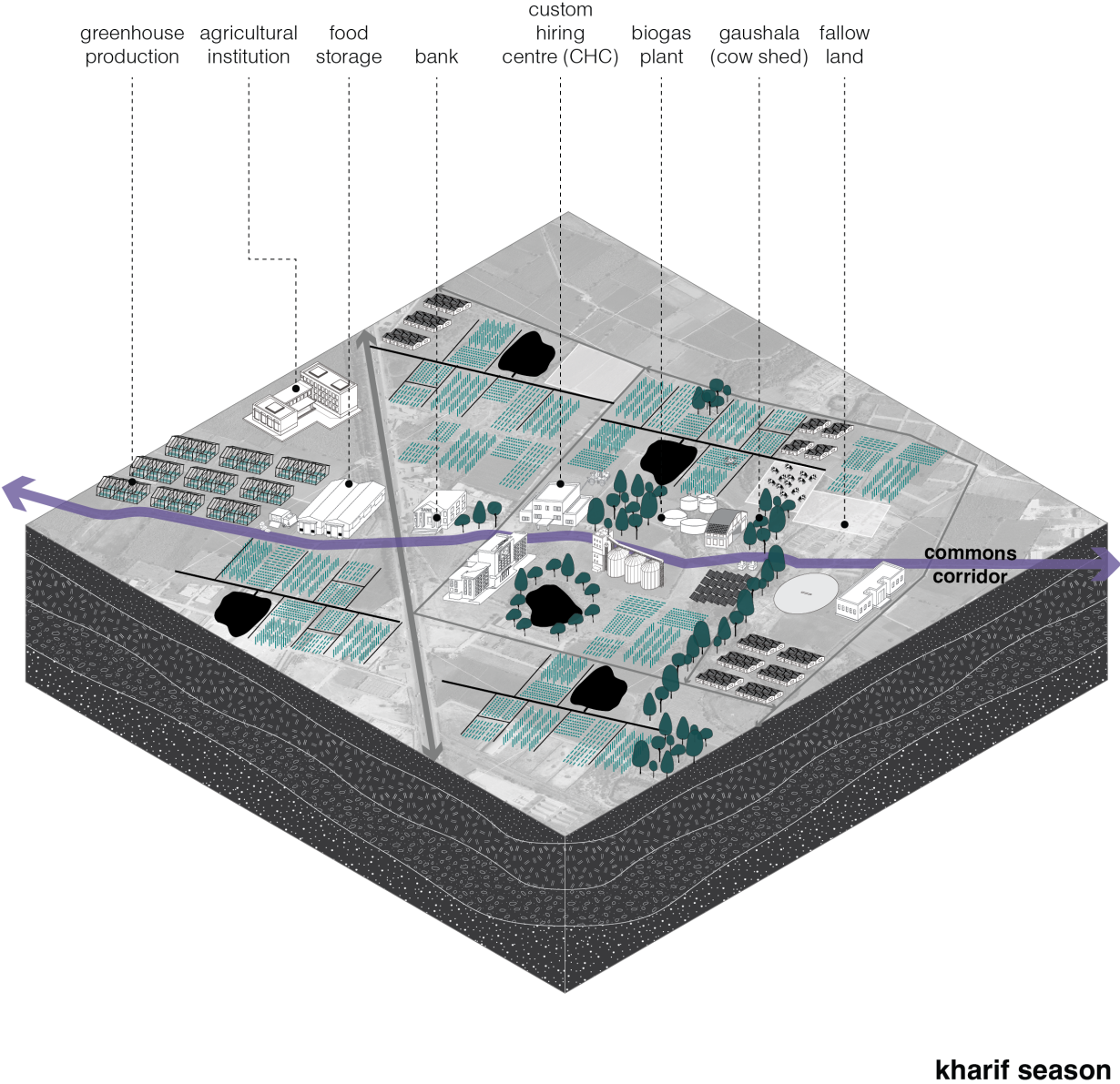


Figure 69: Proposed interventions for a rural area during kharif season in a year.

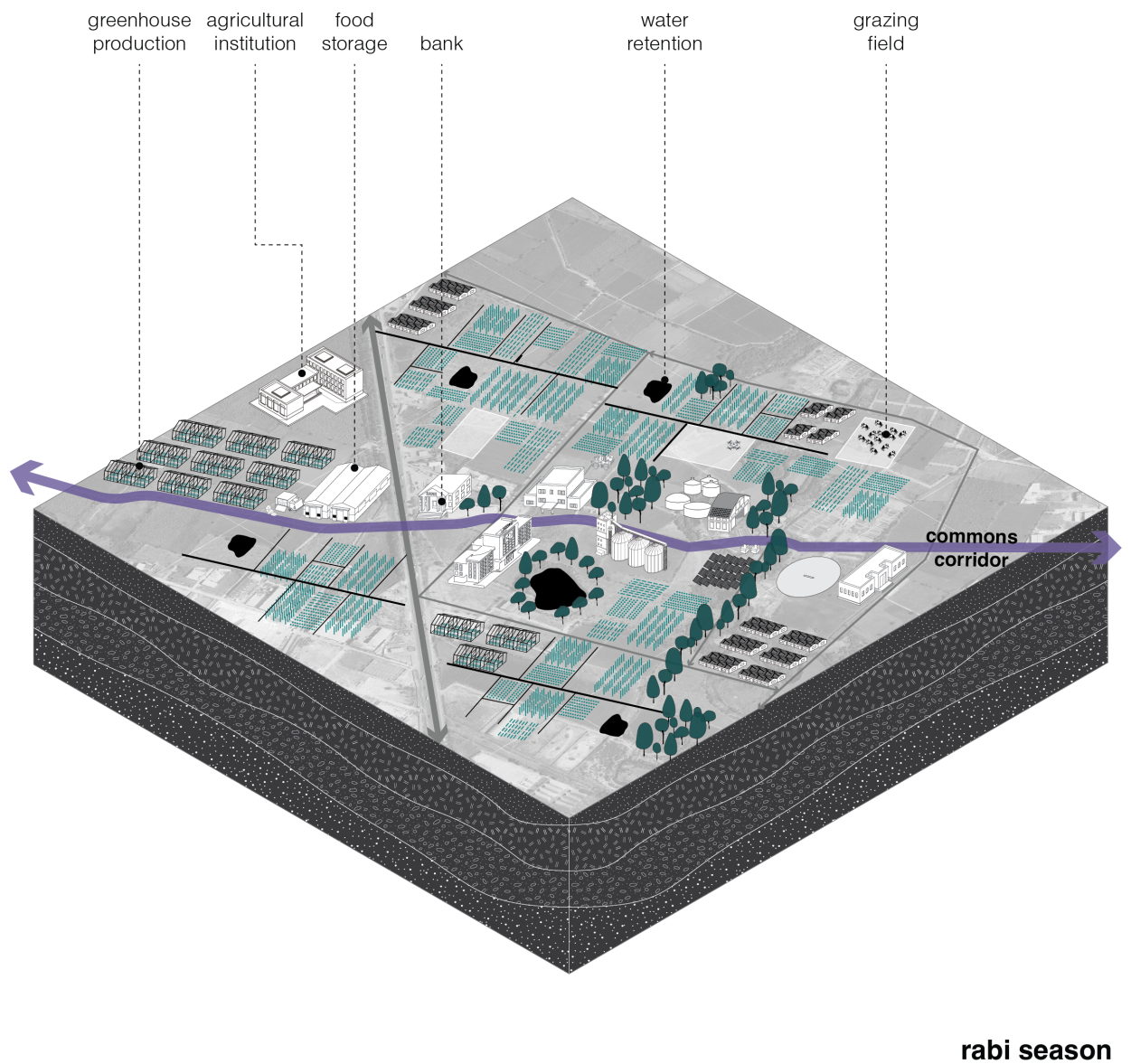


Figure 70: Proposed interventions for a rural area during rabi season in a year.

timeline

Aligning with India's five-year development planning cycles, the proposed timeline is structured to align interventions with institutional collaboration rather than operating in tension with them. The first cycle is directed toward establishing the commons corridor as the foundational spatial and relational infrastructure of the framework, cultivating the institutional trust, stakeholder collaborations, and capacity-building processes upon which all subsequent development depends. By the tenth year, with governance structures consolidated and farming communities having acquired the technical and organisational competencies the transition demands, expanded settlement provisions can be introduced alongside a proportional extension of the commons as conditions require. Concurrently, emerging agro-ecological and automation technologies enter iterative testing cycles, such that by the fifteenth year, the methodologies governing agricultural production may be substantially transformed from those currently in operation. Throughout this progression, the commons corridor functions not as a transitional instrument but as the permanent spatial anchor and organisational backbone of the evolving development framework.

The proportional distribution of land uses is understood as a dynamic rather than fixed condition. Agricultural land may progressively transition toward more intensive productive configurations where biophysical conditions and market structures warrant, while ecological preservation imperatives simultaneously reshape the spatial logic of water retention zones, seasonal cropping areas, and dedicated pollinator corridors — the latter serving the dual function of soil nutrient replenishment and the sustenance of pollination systems upon which long-term agricultural productivity depends.

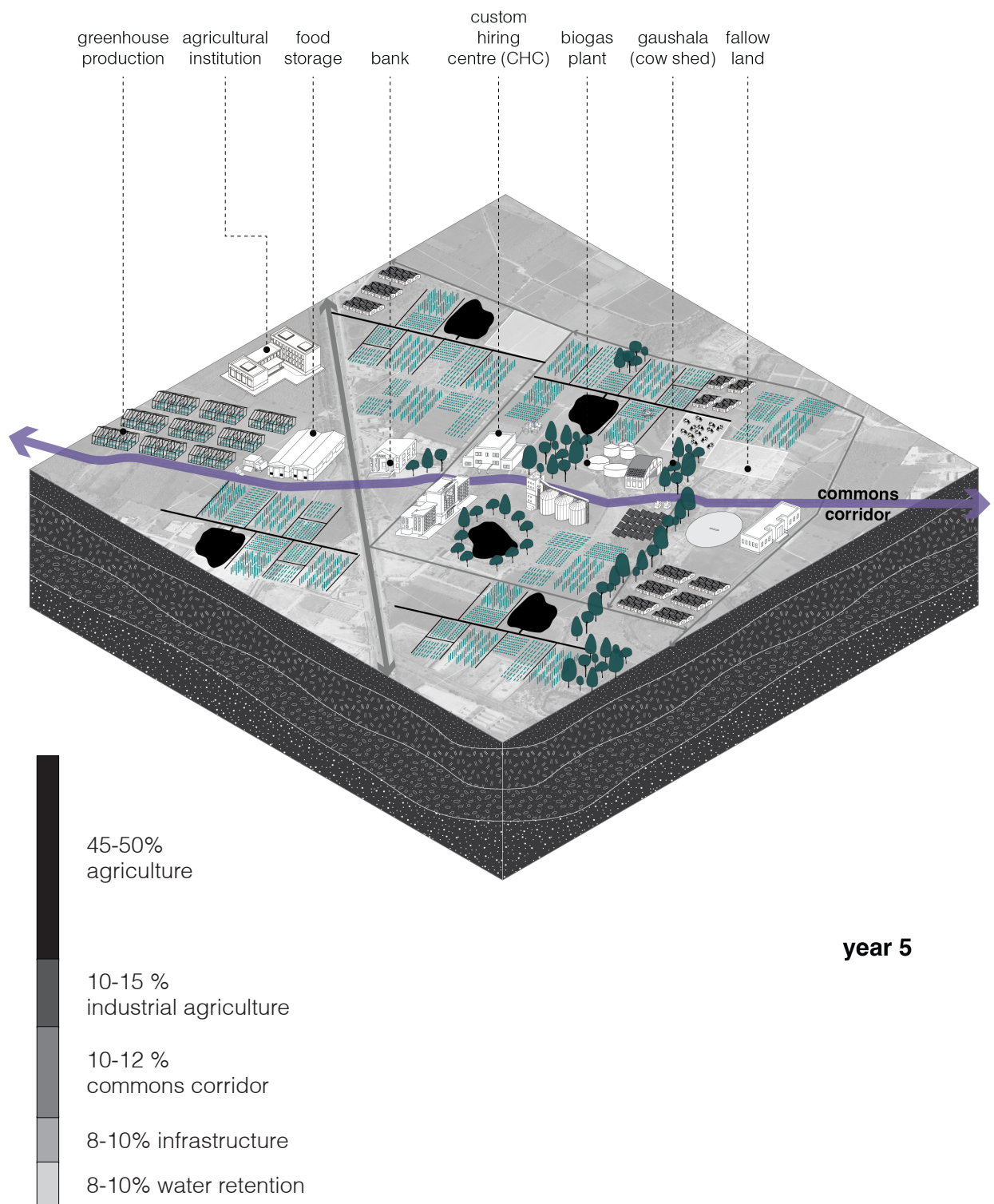


Figure 71: Proposed interventions for a rural area in five years.

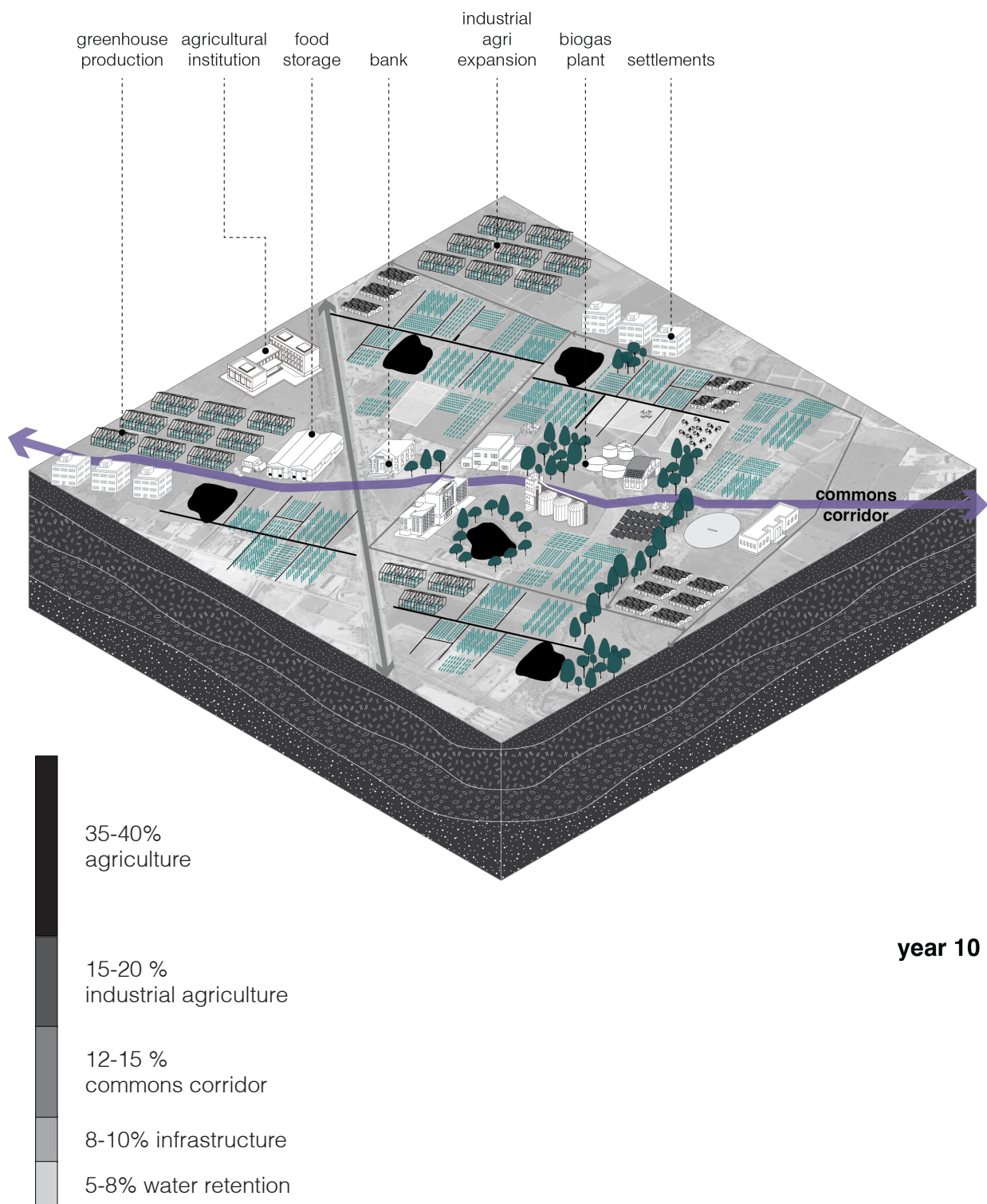


Figure 72: Proposed interventions for a rural area in ten years.

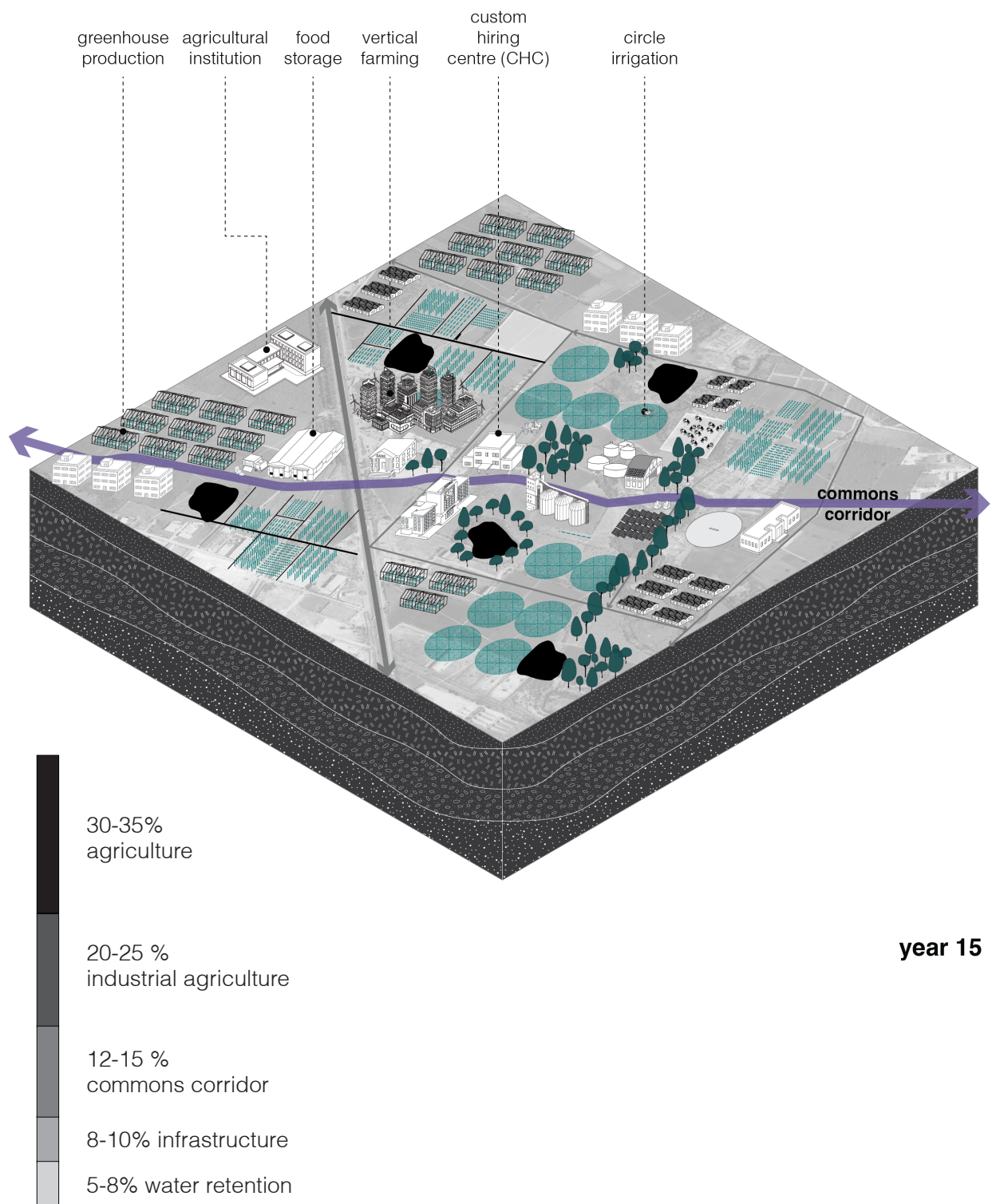


Figure 73: Proposed interventions for a rural area in fifteen years.

STEP 6: ENVISION

Having established non-negotiable parameters, including ecological corridors, agricultural typologies, and new spatial connections, and having identified forensic interventions tailored to specific patches, urbanists and stakeholders can collectively co-create a development plan, typically revised on a five-year cycle. Such a plan would be implemented in close collaboration with residents, particularly within production landscapes where community engagement is integral to long-term success.

Beyond interventions identified from the toolkit, the vision plan can demarcate projected urbanisation trajectories alongside industrial and energy infrastructure areas, ensuring these are guided by and remain consistent with the established parameters. This layered approach ensures that growth is not only managed but actively shaped toward ecological resilience, agricultural sustainability, and equitable liveability while including the stakeholders. Figure 74 depicts the vision plan developed for the exemplary case of Surat district, Gujarat, India, illustrating how these principles translate into a spatially coherent and actionable planning framework.



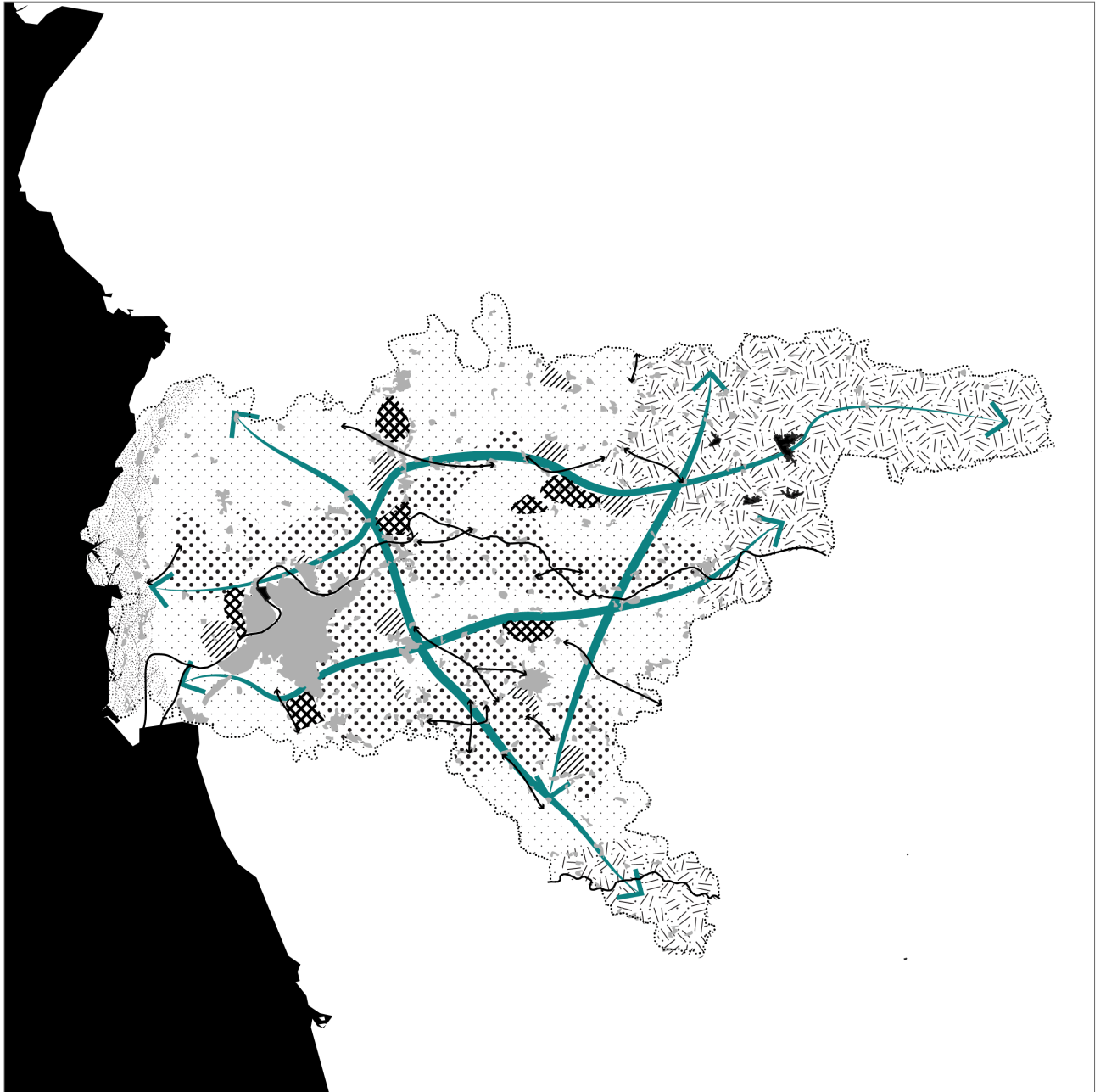


Figure 74: Vision plan for Surat district, Gujarat, India.



Figure 75: Aerial view of the selected region
Photo by the author (2025).

6.

INDIAN AGRO- URBANISM MODEL

This chapter attempts to envision a schematic agro-urbanism model for India, delineating the interrelationship between various factors that direct the built environment development and, in turn, the agricultural production processes.

COMMONING THE NEGOTIATED FIELD

Human settlements have always been organised by proximity. From the earliest riverine civilisations to the ridge-top fortifications of medieval territories, access to water defined advantage. As settlements expanded, road infrastructure connected these territorial hierarchies; prominent routes anchored prominent settlements, and newer developments clustered along these arteries in self-reinforcing cycles of inhabitation. Over centuries, this logic has reproduced itself with remarkable consistency. Industrialisation, however, began to dissolve these inherited hierarchies, blurring the boundaries between the urban and the rural and rendering operational landscapes, the fields, watersheds, and production territories that sustain human life in a state of tension. This tension is not new to urbanism. It was acknowledged in Ebenezer Howard's Garden City model (Howard, 2003) and in Andrea Branzi's Agronica (Lueder, 2013), both of which recognised agriculture not as the residue of urbanisation, but as its necessary counterpart. Yet across every iteration and misinterpreted execution of these visions, agricultural fields have remained the negotiated field: the surface upon which urban ambitions are repeatedly inflicted.

This project situates itself within that long arc of negotiation and demands a paradigm shift. As Ruth DeFries (2014) correctly identifies, humanity is perpetually driving the Ratchet–Hatchet–Pivot cycle: each technological pivot raises production, generates unforeseen ecological and social hatchets, and demands yet another pivot to avert collapse. History has provided sufficient evidence of this cycle, and yet the dominant response remains curative rather than precautionary. Pivots continue to

treat symptoms rather than structural causes. What this project insists upon is that food systems must be designed to adapt at every stage of this cycle, not merely to survive the hatchet, but to anticipate its prevalence in different forms.

This demands a rethinking of the infrastructures that mediate agricultural transition. As the cycle moves from Ratchet to Hatchet, conservation practices are required to prevent irreversible ecological thresholds from being breached, as evident in the lived realities of farmers and tribal communities. As it moves from Hatchet to Pivot, experimental testing grounds are needed to absorb risk and enable innovation. And as pivots mature into practice, learning and deployment spaces must exist to enable broad and equitable uptake. Without such infrastructures, innovations remain inaccessible to those who need them most, captured by private capital, large conglomerates, or energy industries whose interests are extractive rather than regenerative.

Hence, these infrastructures cannot be privately owned. They must function as public commons, adaptive, multi-scalar, and governed in the interest of farmers, consumers, and ecological systems alike. The Indian Agro-Urbanism model precisely needs such an infrastructure: a planning mechanism designed to activate the agency of agricultural landscapes, moving them from the background of urban development to its foreground. Agriculture is not what remains after the city is built. It is the condition upon which all urban futures depend, and should be addressed in that manner.

Figure 76: Proposed Indian agro-urbanism model.

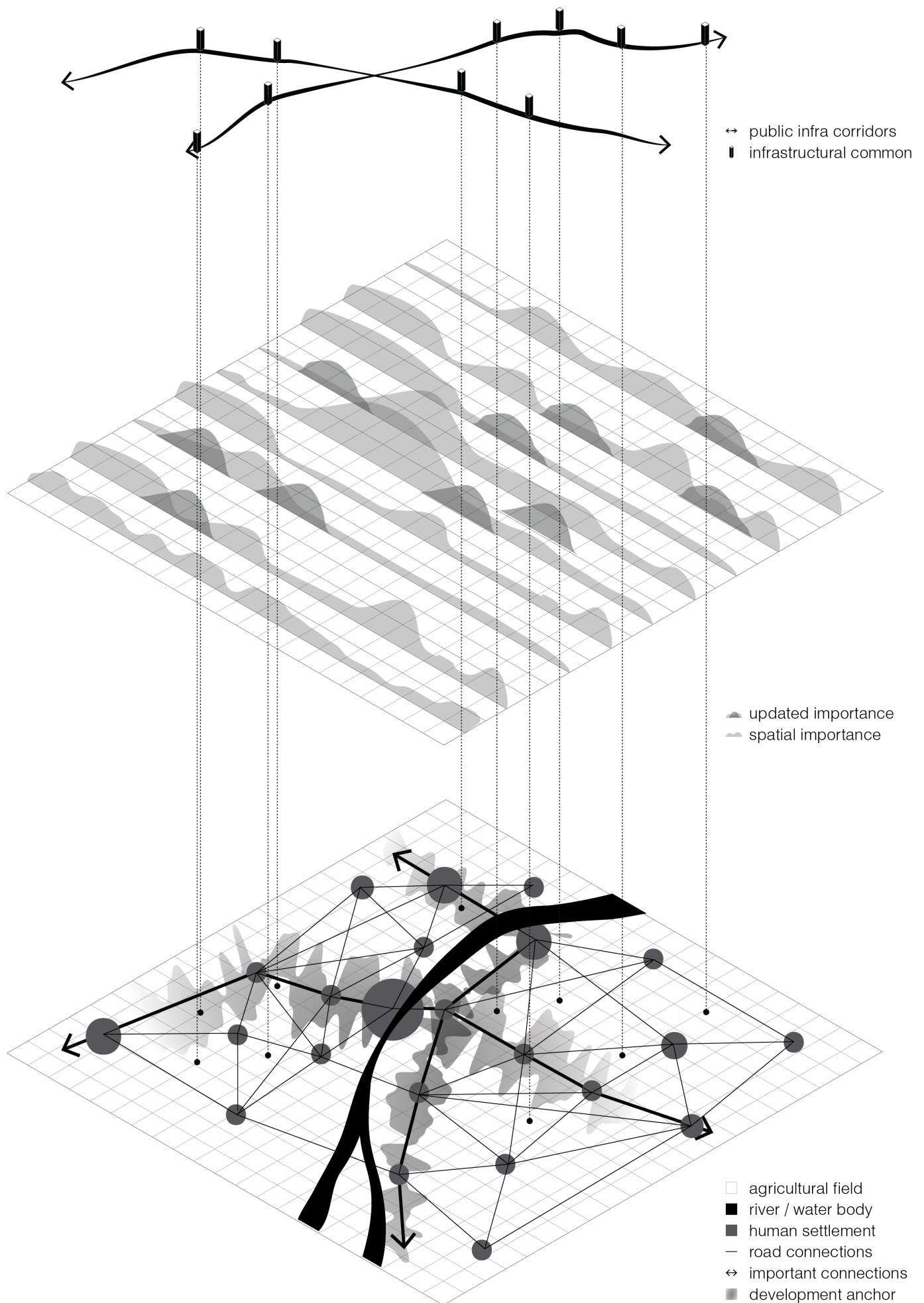




Figure 77: An image of a peri-urban farm near Gandhinagar, Gujarat.
Photo by the author (2019).

7.

CONCLUSION AND REFLECTION

CONCLUSION AND IMPLICATIONS

The crises afflicting Indian agriculture are not the product of isolated failures but of a deeply layered, historically produced system in which the pursuit of economic growth has systematically externalised ecological and social costs onto farmers, ecosystems, and future generations. This research set out to examine how India's food production system can achieve resilience in a just manner, improving agricultural productivity to meet nutritional security, while simultaneously ensuring the livelihoods of producers and the ecological balance of the landscapes that sustain them. The analysis reveals a consistent finding that a singular technological fix, be it the intensification of sustainable agriculture or the wholesale adoption of Agriculture 4.0 platforms, cannot address the multidimensional nature of India's food system crisis.

The selected region comprising Gujarat, Madhya Pradesh, and Maharashtra illustrates the spatial dimensions of this systemic failure with particular clarity. Shared water resources, governed through fragmented institutional silos, have been mobilised to fuel export-oriented cash cropping and urban-industrial growth, producing groundwater depletion, soil degradation, and coastal saltwater intrusion that undermine the very productive capacity upon which both rural and urban populations depend. Structural market inequities trap smallholder farmers in cycles of debt and price volatility, while inadequate post-harvest and cold chain infrastructure generates significant losses even from existing production volumes. The lived realities of farming communities, as documented through the Narmada Oral History Archive and fieldwork, confirm that these systemic failures are not abstract: they are experienced as forced displacement, inherited precarity, and the slow disappearance of place-based ecological knowledge.

While there are toolkit provisions, all of them imbue onus on the farmers to drive the sustainable and technological advancement in agriculture but fail to realise that capacity building is the second step in the cycle. The first one is to identify the trajectory of agricultural

expansion and simultaneous urbanisation. To foresee the potentials, four scenarios developed in this project illustrate, through comparative evaluation, that each trajectory entails distinct trade-offs between producer justice, ecological balance, spatial efficiency, and food sovereignty. The Pareto-front vision that synthesises the most productive elements of all four scenarios points toward a necessary but challenging path: towards decentralisation of food clusters with the simultaneous cultivation of smallholder agroecology, cooperative automation commons, government-led agroparks, and selective industrial intensification, held together by ecological corridors as non-negotiable spatial constants and guided by a governance framework that places farmers, consumers, and the environment at the centre of decision-making. The Surat district exemplary case confirms that the Indian Agro-Urbanism Operational Framework is a workable planning instrument at this scale. The multi-criteria decision analysis, integrating agricultural productivity, liveability, and ecological balance across a 1 km × 1 km grid, reveals the spatial heterogeneity within a single district that national-level policies routinely homogenise.

The findings carry significant implications for spatial planning practice, governance reform, and food systems policy across India. At the most immediate level, food production processes need to move beyond being addressed solely through economic instruments and instead be treated spatially, with agriculture recognised not merely as a rural development concern, but as an urbanisation issue. Agricultural land has long been treated as whatever remains after urban development priorities are satisfied, producing a hierarchical system that widens structural gaps and reinforces extractive morphologies. Urban planners and designers must reposition themselves as system architects, actively mediating the symbiosis between spaces of production and consumption, rather than functioning as instruments of urban growth-centric agendas. This reorientation requires a shift from rigid, modernist land-use zoning toward landscape-based territorial planning

that recognises the rural-urban interface as a robust ecological continuum.

The reinstatement of agro-climatic zone-based planning, as originally conceived by the Planning Commission's Zonal Planning Teams, represents a particularly urgent policy recommendation. The discontinuation of these committees was a missed institutional opportunity to embed ecological differentiation into territorial governance. Reviving and periodically updating this framework, followed by layered spatial analysis and future climate projections as defined within the operational framework, would provide a scientifically grounded basis for differentiated cropping strategies, resource allocation, and infrastructure investment. This is especially critical in shared hydrological systems that demand coordination across administrative boundaries, and in the context of unchecked greenhouse emissions that rapidly alter future projections. The proposed Indian Agro-Urbanism Operational Framework offers a transferable planning instrument adaptable across diverse agro-climatic contexts. Its six iterative phases, consult, identify, analyse, demarcate, intervene, and envision, provide planners and stakeholders with clearly defined roles in a structured yet flexible toolkit that integrates participatory design, multi-criteria spatial analysis, and scenario planning within a single governance architecture.

In the current economically driven Indian governance model, Paul Samuelson's Public Goods and Market Failures theory (Thompson, 2015) dictates how market failure is tackled through mechanisms such as calorific security certifications in the Indian context. In the absence of critical infrastructures, governing agencies have deployed economic and legal instruments, such as nitrogen emission regulations, carbon taxation, and subsidies such as the Minimum Support Price, to address production and distribution-related failures. However, the farmers bear the brunt of it as their owned land undergoes extractive intensification to support their needs. They adopt practices that maximise individual

income. The project views this phenomenon as a moral particularist (Dancy, 2001), understanding that in the socio-economic context of India, farmers cannot perceive the cumulative regional consequences of those choices. It is therefore the responsibility of urbanists to bring to light and assume the roles of advocate, mediator, and negotiator to bridge the structural gap that persists between individual agricultural decisions and their collective territorial impacts. Investment in public infrastructure for production processes is an indispensable mechanism for ensuring that supply drives demand and for improving systemic resilience over time.

Finally, this graduation project has addressed the production dimension of the food system. As Amartya Sen argues, food security is not solely a production issue but equally a matter of equitable distribution (Thompson, 2015). While India's public distribution system has extended significant reach, it remains calorie-oriented rather than nutrition-oriented. Further inquiry into distribution systems and infrastructure, followed by waste systems reconfigured as circular economies, is equally integral to closing the loop of a food production system. Without these structural supports, even the most spatially sophisticated agro-ecological models risk being captured by the same capitalised logics they seek to transform (Muñoz Sanz & Katsikis, 2024). Ultimately, feeding India's 1.46 billion people, and its future generations, requires abandoning the dichotomous thinking that has historically pitted conventional against automated farming, rural against urban, and production against ecology. The contextualised Indian agro-urbanism model proposed here is not definitive, but a beginning: an invitation to planners, policymakers, farmers, and communities to co-produce the spatial imaginaries that India's agricultural crisis urgently demands.

REFLECTION

Relation between the graduation project topic, Urbanism track, and the master's programme

The graduation project occupies the intersection of urbanism, food systems, and spatial justice, a positioning that is not coincidental but foundational to what the MSc Architecture, Urbanism and Building Sciences programme at TU Delft asks of its graduates. The Urbanism track, in particular, directs its inquiry toward the territorial and systemic scales at which cities, landscapes, and infrastructures converge, calling on the graduate to function concurrently as analyst, designer, and critical theorist. By approaching agricultural territory not as the inert backdrop against which urbanisation unfolds, but as an active, contested, and ecologically constituted space with trans-scalar and interdisciplinary ramifications, the research foregrounds precisely the category of complex spatial problem that urbanism, as a discipline, is distinctively positioned to engage. The MSc programme's grounding in research-by-design, multi-scalar analysis, and socially embedded planning practice supplied both the conceptual architecture and the methodological latitude to pursue a project that actively resists the separation of the technical from the political, and the spatial from the systemic.

How research influenced design/recommendations and vice-versa

The relationship between research and design across this project was neither sequential nor unidirectional, but iterative and mutually generative, the essence of research-by-design as a mode of inquiry. The initial research phase, which charted the structural conditions of Indian agriculture across ecological, economic, and social registers, established the diagnostic foundation from which the scenario framework was built. The scenario mapping exercise functioned as a design instrument for identifying latent potential, with each scenario's manifesto prompting investigation into spatial expression, biophysical and socio-cultural systems, economic configurations, and institutional dissonance. Each scenario crystallised from a distinct reading of what the

system might become under a specific set of planning and governance conditions, and it was through their comparative evaluation that the Pareto-front vision emerged, not as a singular optimal trajectory but as a constellation of non-negotiable spatial constants and complementary typological interventions. The design work, most concretely realised in the Surat district exemplary case, subsequently fed back into the research by exposing the analytical insufficiency of national-scale framing, necessitating local investigation through a 1 km × 1 km multi-criteria grid to apprehend the degrees of intra-district spatial heterogeneity that the prior research had not fully anticipated. This in turn sharpened the theoretical argument that homogenising national policy instruments are structurally ill-equipped to address the diversity of India's agro-climatic and socio-economic landscape. The process was one of constant oscillation between research-by-design and design-by-research. At the outset, there was a degree of scepticism toward research-by-design, having encountered instances of practitioners deploying design ideologies to retrospectively validate predetermined conclusions. However, a firm ethical grounding ensured that when research findings contradicted the initial design framework, the designs were reworked rather than the evidence rationalised away.

Assessing the methodology

The methodological approach assembled for this project draws on a range of established disciplinary instruments, deployed within a research-by-design framework: spatial analysis, scenario planning, multi-criteria decision analysis, secondary and tertiary source analysis, and co-design. The value of this combinatory approach resides in its principled rejection of methodological monism, no single analytical instrument was accorded singular sufficiency. The integration of quantitative spatial analysis with qualitative fieldwork and archival sources allowed the project to hold in productive tension registers of evidence that are too often artificially segregated. The Narmada Oral History

Archive, for instance, furnished testimony that statistical datasets are structurally incapable of yielding: the lived temporality of displacement, the gradual dissolution of ecological memory, and the embodied knowledge of landscape systems accumulated and transmitted across generations.

The methodological framework was itself a recursive undertaking, continuously adapting in the manner of research-by-design. In the problematisation stage, for instance, the intended output was a standalone toolkit. As research and design progressed in tandem, it became evident that existing toolkits required embedding within a broader operational framework capable of structuring agricultural urbanism planning processes coherently. Similarly, the inclusion of multi-criteria decision analysis as a pivotal methodological stage only became apparent after analysing the scenario mapping exercise, which generated a set of spatial layers specific to the agro-climatic zone that required systematic ranking. In this way, components of the graduation project's own methodology became constitutive stages within the proposed operational framework, enabling continuous cross-evaluation between the rigour of the project's process and the quality of its outputs.

The limitations of the approach are equally worth registering. The operational framework's six phases are methodologically coherent at the district scale but have not yet been subjected to empirical testing across the full range of India's agro-climatic zones; the claim of transferability therefore rests on structural logic rather than demonstrated replication. The scenario evaluation, while anchored in multi-criteria analysis, inevitably incorporates value judgements regarding the relative weight assigned to ecological, productive, and social criteria, judgements that technical procedure alone cannot fully neutralise. These are not disqualifying constraints but productive ones: they delineate the current boundaries of the inquiry and chart the directions in which it may be extended.

Values of the graduation project: academic, societal, ethics

The academic contribution of the project lies in its engagement with an emerging body of scholarship on agro-urbanism and territorial food systems planning in the Global South. By advancing the Indian Agro-Urbanism Operational Framework as a transferable planning instrument, the project offers not merely a regional case study but a conceptual and methodological prototype adaptable not only across the Indian subcontinent but across other contexts in the Global South where agricultural territory faces analogous pressures from urbanisation, climatic instability, and market restructuring. The societal value of the project is inseparable from its ethical orientation: it explicitly refuses to reduce food system resilience to a technocratic optimisation problem, insisting instead on the centrality of producer justice, ecological sovereignty, and community agency in any credible planning response, a commitment reflected in the operational framework's explicit articulation of stakeholder roles at each phase. The ethical stakes are considerable. India's 1.46 billion people depend on a food system that currently displaces its costs most harshly onto those least positioned to absorb them: smallholder farmers, displaced communities, and ecologically degraded landscapes. A planning framework that fails to reckon with this structural injustice risks inadvertently reproducing the very conditions it professes to contest. The project's insistence on co-designed interventions, participatory governance, and the positioning of farmers and communities as agents rather than objects of planning is therefore not a methodological stylistic choice but an ethical commitment structurally embedded in the research design. Simultaneously, the project remained clear-eyed about India's complex negotiations between historical legacies of colonialism and contemporary ambitions of global economic positioning, proposing mechanisms that support financial resilience and enable a gradual, rather than abrupt, transition toward more equitable productive models.

Transferability of the graduation project

The transferability of the project's results operates across several dimensions. The Indian Agro-Urbanism Operational Framework is transferable as a planning methodology: its six iterative phases can be operationalised across diverse agro-climatic and governance contexts, calibrated to local spatial datasets, institutional configurations, and participatory processes. The scenario typologies, smallholder agroecology, cooperative automation commons, agro-parks, and selective intensification, carry transferability precisely because they are technically grounded while preserving space for context-sensitive, forensic interventions at the urbanist's discretion, responsive to the socio-cultural specificities of each operating context. The analytical logic of ecologically inviolable corridors as spatial constants, combined with context-specific productive typologies, constitutes a transferable design rationale applicable wherever the tension between agricultural productivity and ecological preservation demands territorial resolution. What requires substantive adaptation across contexts is the configuration of interventions specific to each region. The framework's value lies in its capacity to generate contextually differentiated responses while simultaneously establishing replicable presets across agro-climatic zones, balancing structural consistency with local responsiveness.

Limitations

The graduation project is cognizant of the limitations posed by time constraints and data accessibility. Considering the Indian subcontinent has diverse resource sets, the availability and editability of those data sets are still limited. The analysis, such as multi-criteria decision analysis, was constrained from including additional criteria, such as crop pollination models and aquatic health. In the absence of readily available spatialised data, I have utilised statistics and numerical data and spatialised them to the best of my capabilities. However, in actually carrying out the operational framework, extensive field work

and interdepartmental collaborations for data collection would be integral.

The graduation project begins with advocacy and has attempted to be prescriptive in nature to a certain extent. The methodologies applied were largely ones with which the author was already familiar in the interest of time. For instance, the multi-criteria decision analysis utilised the analytical hierarchical process within brackets HP over other methodologies, such as the best worst method and Electre/Promethee (Outranking methods), due to familiarity. However, the AHP method is widely relevant and simpler to use and hence chosen for its transferable and replicable nature.

In the interest of time, associated fields within urbanism, such as industrial development, energy infrastructure, political science and so on, have been briefly touched upon but not elaborated intensively. However, the graduation project recognises the importance of each of these fields and advocates for further research to address the complexities and challenges associated. Furthermore, the graduation project is also cognizant of the intrinsic negotiations that follow when these development plans are actually made. Stakeholder collaborations are easier to talk about than to execute. At the same time, it is imperative to make visible these negotiations and challenges that may come about not only for the stakeholders but also for the future urban planners and designers in the making to inculcate thought processes that would be required as a professional.

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APPENDIX

APPENDIX A: OPERATIONAL FRAMEWORK STAGES FOR SURAT DISTRICT

Criteria	Sub-criteria	Sub-subcriteria	Spatial attributes mapped
Agricultural productivity	Irrigation availability	Annual rainfall	Mean annual rainfall
		'% area under canal irrigation'	Agricultural land within 200 m buff of water bodies
		Groundwater depth (m bgl)	Decadal groundwater depth post monsoon
	Soil type	Texture class	Soil type
		Soil depth	Topsoil + Subsoil depth
		Drainage class	Soil type
		Infiltration capacity	Soil type
	Temperature	Temperature	Temperature

Figure A.1.1: MCDA criteria, normalised score reasoning, and data sources.

	Normalised rating	Dataset sources
	900 mm to 1800 mm normalised between 0 and 1. Mean value calculated in the grid cell.	CGWB, 2022
er	Distance from river and/or canal normalised between 0 and 1, where <200m is 1. Mean value calculated in the grid cell.	MeitY, 2021 KGIS KRSRAC, 2021
	Less than 2 m is 1 and more than 20 m is 0. Mean value calculated in the grid cell.	CGWB, 2022
	Deep black soil = 1 Riverbank sandy soil or medium sandy soil = 0.8 Goradu sandy loam = 0.6 Coastal alluvium = 0.4 Mean value calculated in the grid cell.	Sehgal et al., 1996
	>150 cm = 1 100-150 cm = 0.8 75-100 cm = 0.6 50-75cm = 0.4 25-50 cm = 0.2 Mean value calculated in the grid cell.	Government of Gujarat & NABCONS, 2016
	Riverbank sandy soil = 1 Goradu sandy loam = 0.8 Coastal alluvium = 0.6 Coastal alluvium (saline) = 0.4 Medium sandy soil = 0.2 Deep black soil = 0.2 Mean value calculated in the grid cell.	Sehgal et al., 1996
	Riverbank sandy soil = 1 Goradu sandy loam = 0.8 Coastal alluvium = 0.6 Coastal alluvium (saline) = 0.4 Medium sandy soil = 0.2 Deep black soil = 0.2 Mean value calculated in the grid cell.	Sehgal et al., 1996
	0 = >40°C max/<10°C min, GDD<3000 1 = 25-35°C, GDD 3500-4500 Mean value calculated in the grid cell.	Government of Gujarat & NABCONS, 2016

Criteria	Sub-criteria	Sub-subcriteria	Spatial attributes mapped
Liveability	Livelihood means (agricultural income)	Agricultural income per household (₹/year)	Normalised value of net sown area in agricultural land, livestock (number of small and large animals), wage labour at a sub-district level.
	Market access & infrastructure	Road connectivity index	Distance of settlements from existing mandis and storage units
	Educational access & skills	Literacy rate (%)	Literacy rate at a village level.
		Agricultural extension access	Distance from agri extension infrastructure
	Access to healthcare and housing	Public schools	Education facility access (distance from school). Information available at a village level.
		Healthcare facilities	Distance to healthcare

Figure A.1.2: MCDA criteria, normalised score reasoning, and data sources.

	Normalised rating	Dataset sources
a	High net sown area and livestock and low wage labour = 1 Low net sown area and livestock and high wage labour = 0 Mean value calculated in the grid cell.	Government of Gujarat & NABCONS, 2016
	2 - 4 km = 1 > 10 km = 0 Mean value calculated in the grid cell.	CWC, n.d. NaPanta, n.d. Director of Agriculture Marketing & Rural Finance, Government of Gujarat, n.d.
	As shown in the legend. Mean value calculated in the grid cell.	Directorate of Census Operations, 2011
t	As shown in the legend. Mean value calculated in the grid cell.	Krishi Vigyan Kendra, 2026
e e	Distance of anganwadis categorised as $a \leq 5$ km, $b \leq 10$ km, and $c > 10$ km. Mean value calculated in the grid cell. The normalised ratings are as follows ≤ 2 km = 1 2-4 km = 0.8 4-6 km = 0.6 6-8 km = 0.4 8-10 km = 0.2 >10 km = 0	Directorate of Census Operations, 2011
	Distance of government hospitals categorised as $a \leq 5$ km, $b \leq 10$ km, and $c > 10$ km. Mean value calculated in the grid cell. The normalised ratings are as follows ≤ 2 km = 1 2-4 km = 0.8 4-6 km = 0.6 6-8 km = 0.4 8-10 km = 0.2 >10 km = 0	Directorate of Census Operations, 2011

Criteria	Sub-criteria	Sub-subcriteria	Spatial attributes mapped
Ecological condition	Green landscape (vegetation cover)	NDVI (Normalized Difference Vegetation Index)	NDVI
		Forest/green area (% of taluka)	Forest vs built areas
		Tree cover (%)	Tree cover
	Water body quality	Wetland area (ha)	Wetland area, averaged at a village level.
		Groundwater pH	Well pH level
	Biodiversity	Biodiversity	Flora and fauna data available, filtered to include species that help crop growth and pollination.

Figure A.1.3: MCDA criteria, normalised score reasoning, and data sources.

	Normalised rating	Dataset sources
	As per available data, normalised between highest and lowest values. Mean value calculated in the grid cell.	Indian Space Research Organisation (ISRO), 2015
	As per available data, normalised between highest and lowest values. Mean value calculated in the grid cell.	NRSC & ISRO, 2016
	As per available data, normalised between highest and lowest values. Mean value calculated in the grid cell.	Hansen et al., 2013
ge	As per available data, normalised between highest and lowest values. Mean value calculated in the grid cell.	Gujarat Forest Department, n.d. Gujarat State Forest Department & Gujarat Ecological Education and Research Foundation, 2012
	As per available data, normalised between highest and lowest values. Mean value calculated in the grid cell.	CGWB, 2022
p	As per available data, normalised between highest and lowest values. Mean value calculated in the grid cell.	Global Biodiversity Information Facility, 2024 India Biodiversity Portal, n.d. Surat Municipal Corporation, n.d.

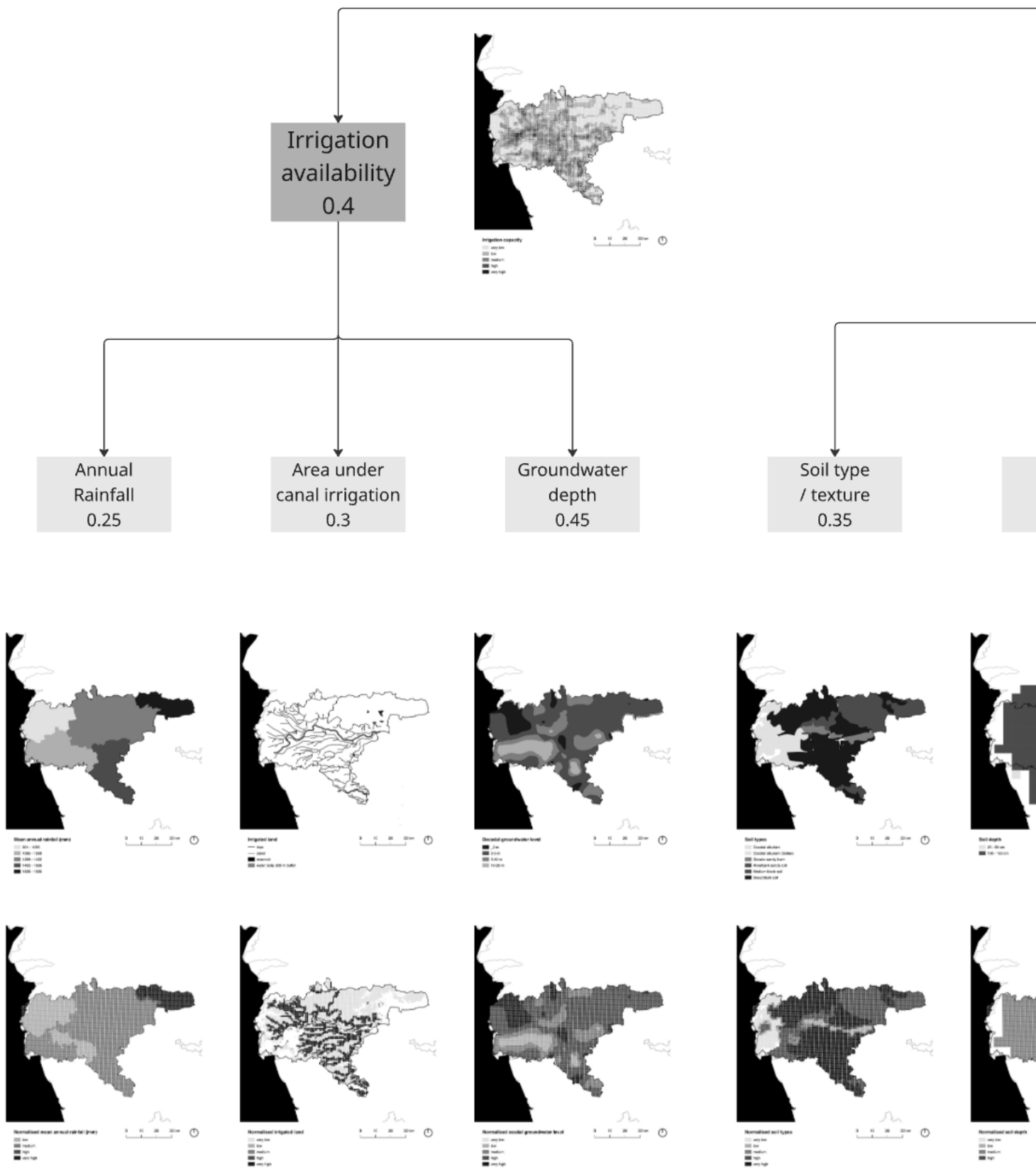
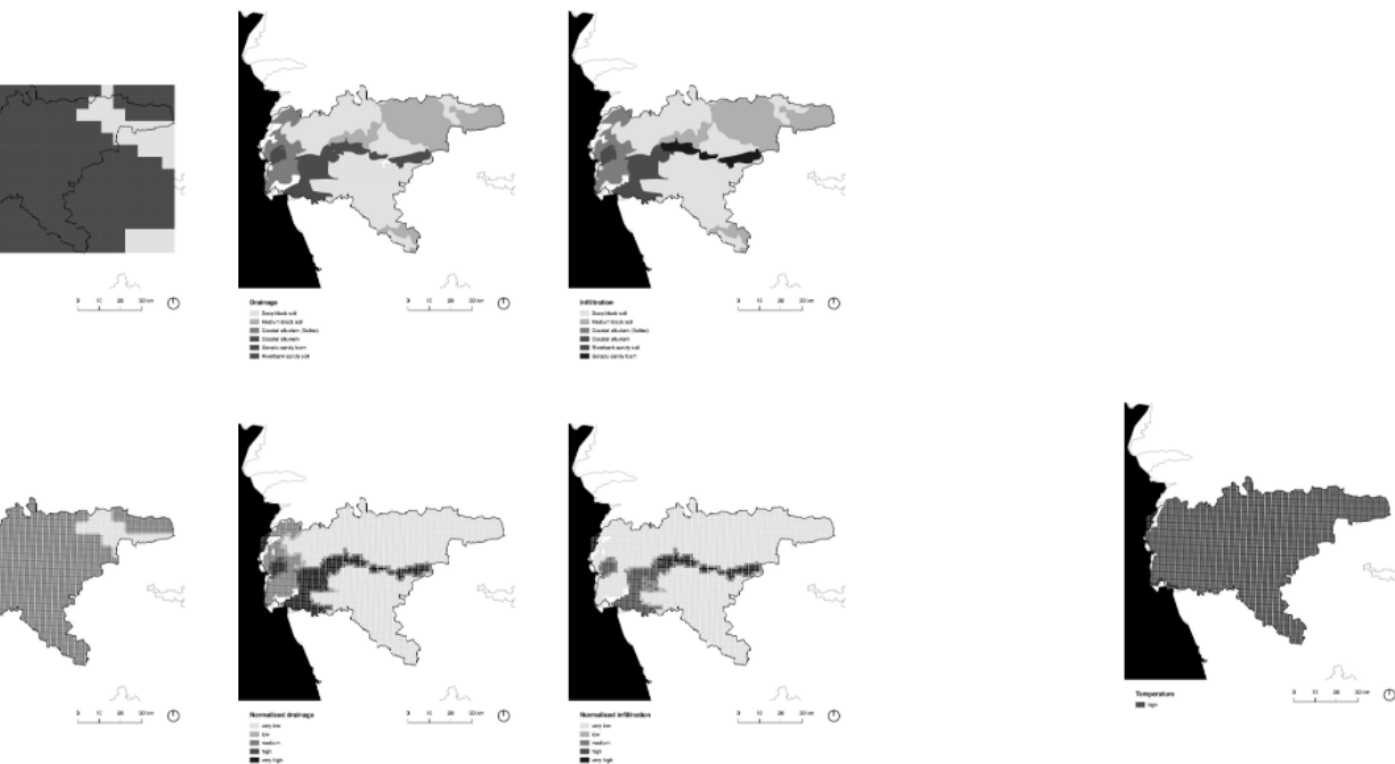
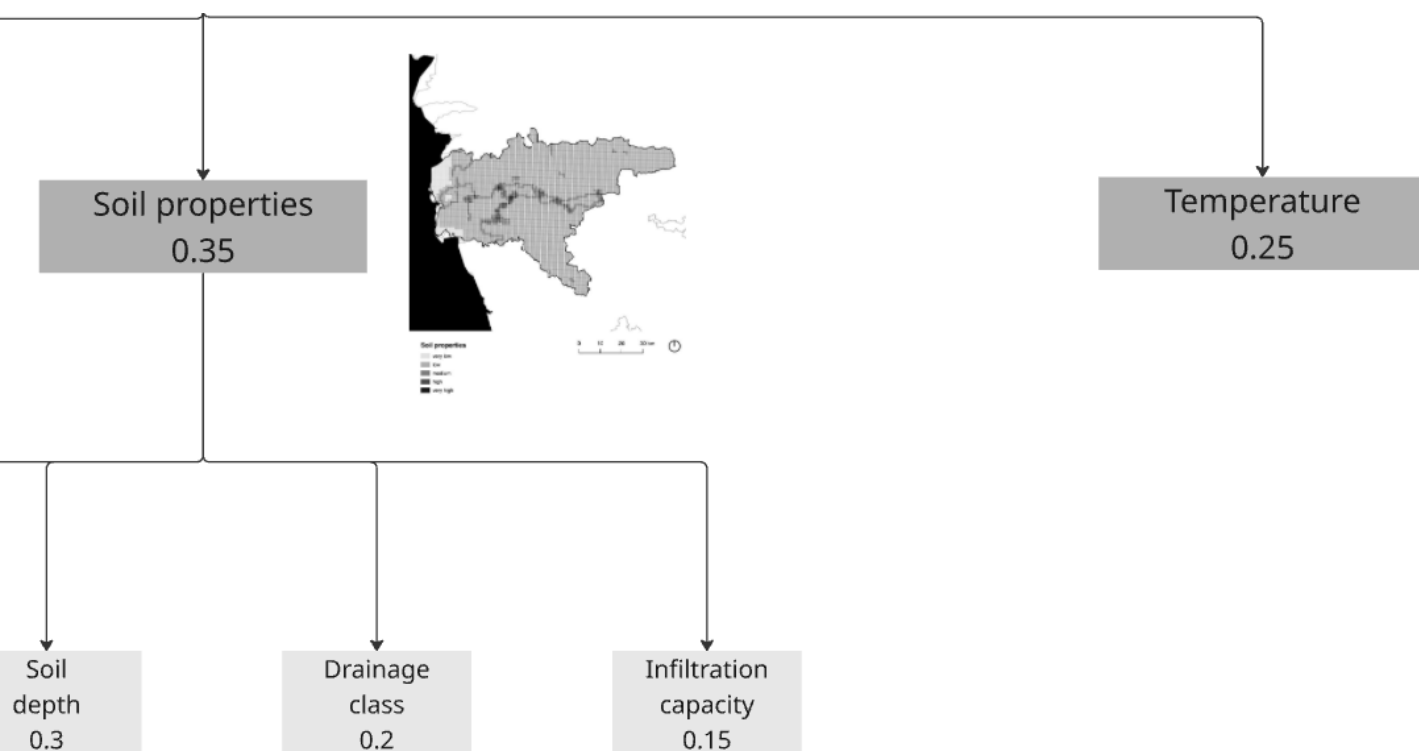


Figure A.2.1: Normalised rating spatialised for sub-subcriteria in the criteria 'Agricultural Productivity'



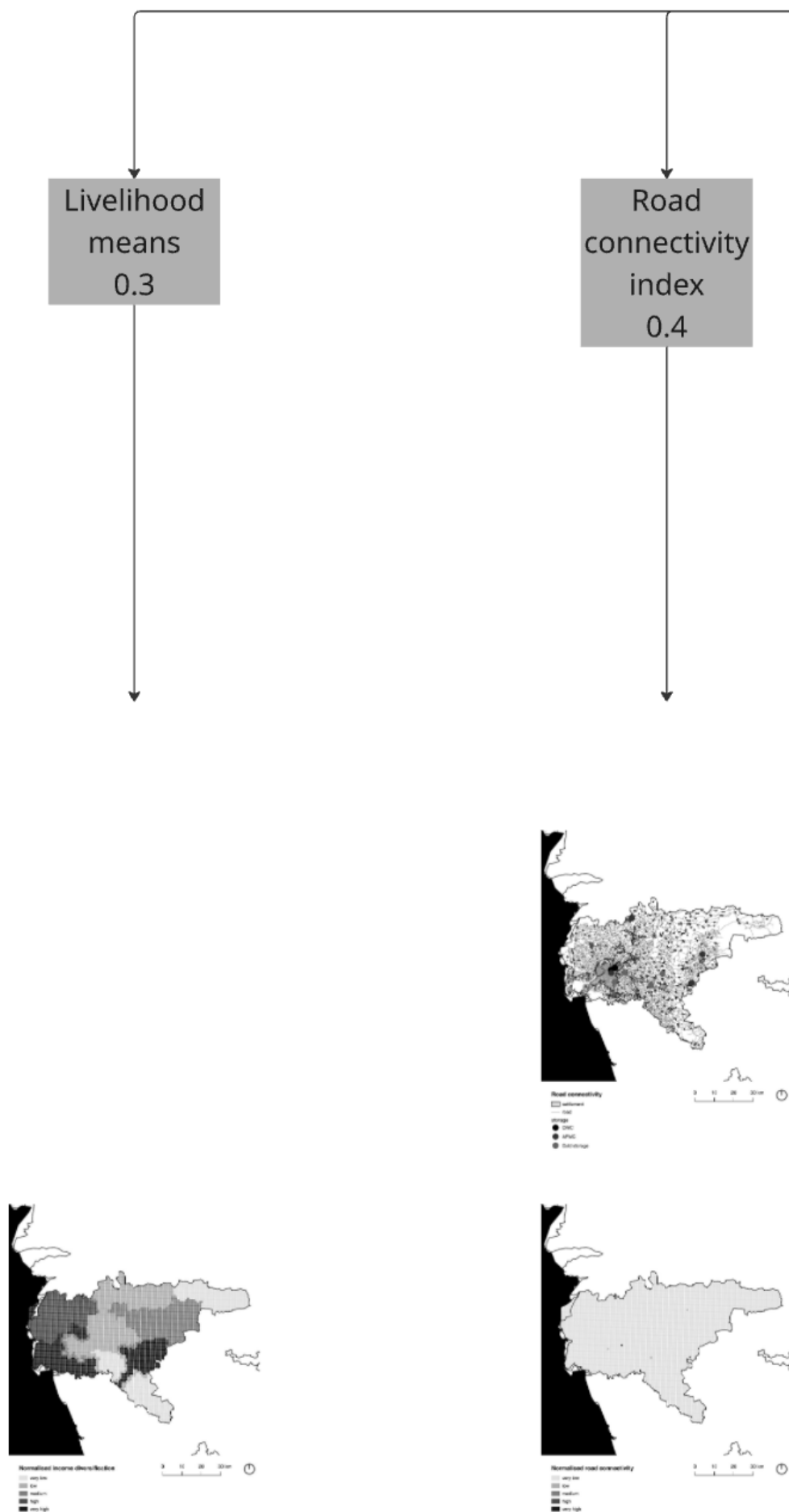
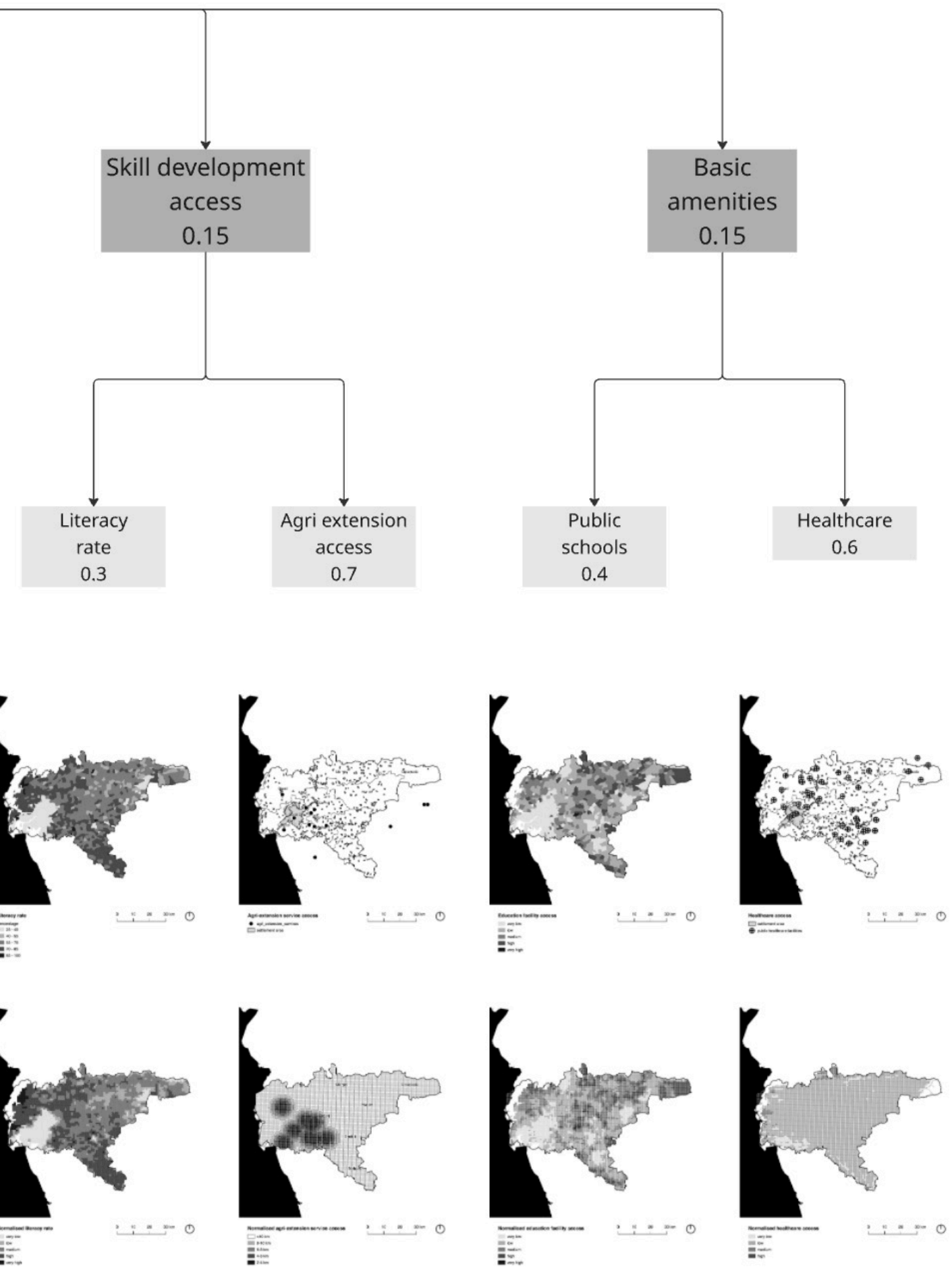


Figure A.2.2: Normalised rating spatialised for sub-subcriteria in the criteria 'Liveability'



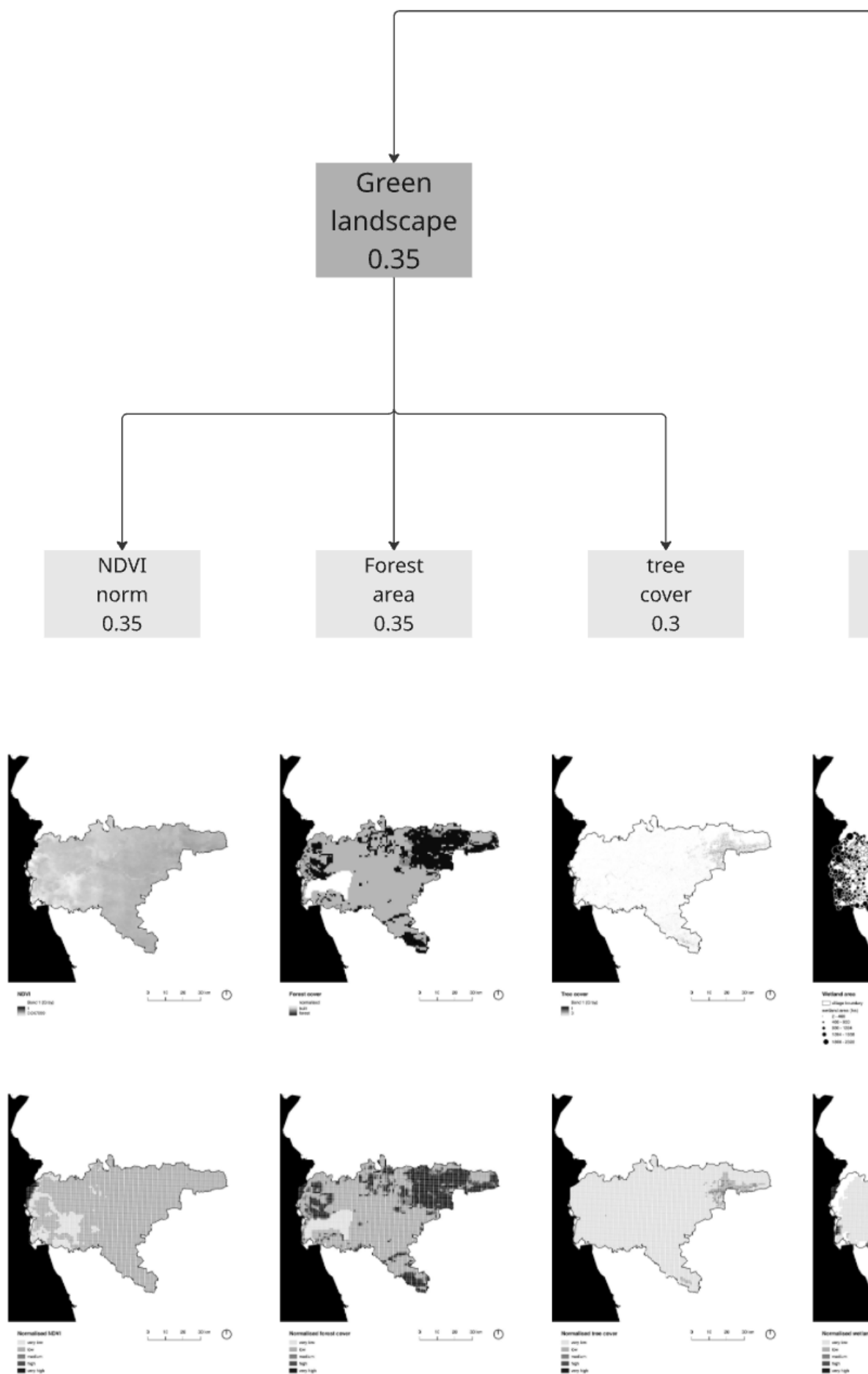
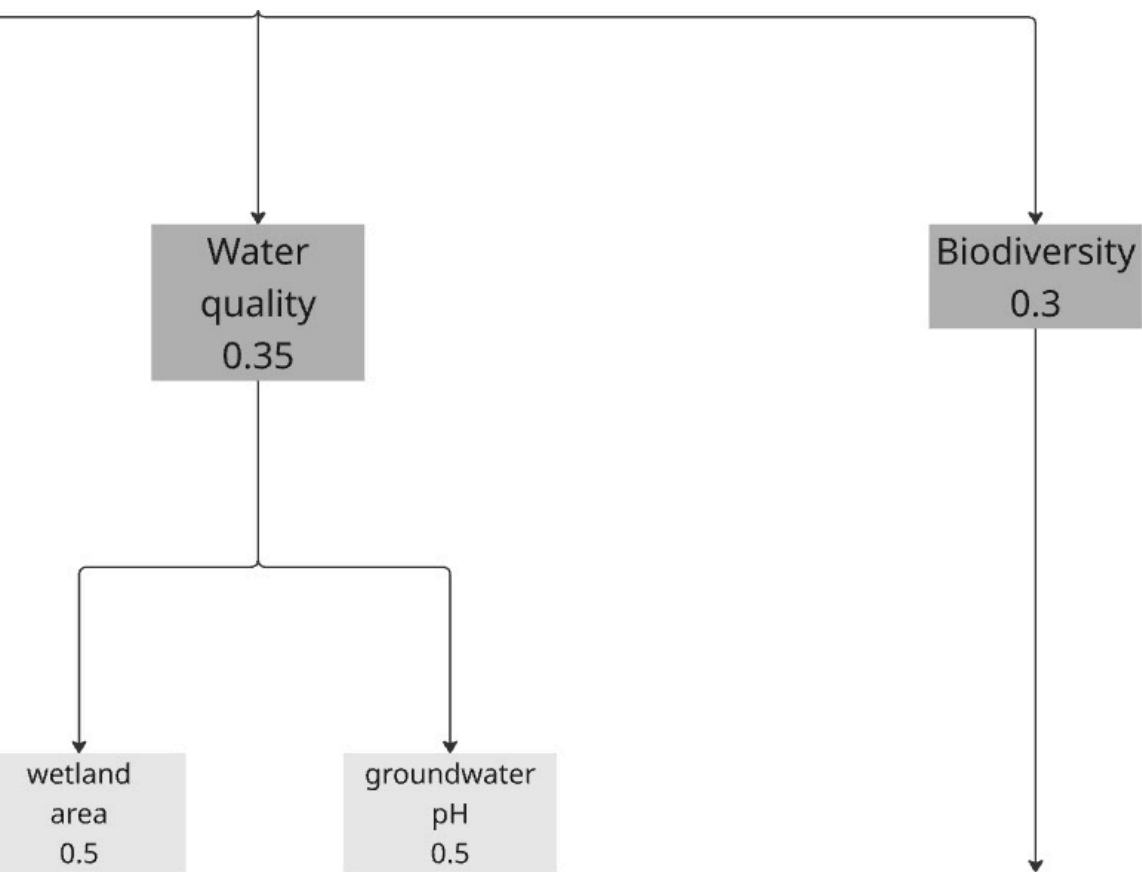


Figure A.2.3: Normalised rating spatialised for sub-subcriteria in the criteria 'Ecological Balance'



Criteria	Sub-criteria	Coastal	Eco-sensitive (Forest/Reservoir)	Mining Area	Urban
Agricultural Productivity	Irrigation Availability	Tidal/mangrove-compatible drip irrigation Desalination-fed micro-irrigation channels	Rainwater harvesting from forest catchments Check dams along reservoir periphery	Mine-pit water harvesting Constructed wetlands to reclaim and store drainage water	Treated wastewater reuse for peri-urban farms Stormwater harvesting in urban-edge food gardens
	Soil Type	Salt-tolerant cover cropping Mangrove buffer planting to reduce saline intrusion into agricultural soil	Forest floor protection Restrict soil disturbance Promote leaf-litter composting	Topsoil stockpiling and restoration Biochar and compost-based reclamation Phytoremediation plots	Raised-bed urban farming with imported soil Vermiculture on organic waste
	Temperature	Coastal windbreak plantations (casuarina, mangrove) to moderate thermal extremes	Forest canopy conservation as heat buffer No clearing near agricultural transition zones	Tree plantation on mine dumps Water bodies to moderate local microclimate	Cool roofs, street tree canopy, urban parks
Liveability	Livelihood Means (Agricultural Income)	Integrated aquaculture-agri models Coastal fisheries cooperative support Seaweed farming	NTFP-based livelihoods (honey, bamboo) Eco-tourism linked to farming communities	Skill retraining for displaced miners Reclaimed land leased for horticulture and poultry	Roof-top/community gardens Processed food enterprise incubators for urban-edge farmers
	Market Access & Infrastructure	Jetty-linked small produce markets Cold storage for fish and coastal produce	All-weather feeder roads to nearest mandi Mobile procurement vans	Repurpose haul roads for agri-logistics Establish rural mandi on reclaimed land	Urban farmer markets Direct-to-consumer digital platforms for peri-urban farmers
	Educational Access & Skills	Mobile school boats or coastal reach programmes Agri-fisheries skill centres	Forest ranger-linked adult education Eco-school models in buffer villages	Mining company-funded vocational centres ITES and green trade skills for displaced workers	Urban school densification Digital literacy centres in underserved wards
	Access to Healthcare & Housing	Floating or elevated health posts Cyclone-resistant housing with community shelters	Forest health camps AYUSH-integrated health posts near buffer settlements	Occupational health clinics Dust-proof worker housing with green landscaping	Affordable housing densification near transit Urban health and wellness centres
Ecological Condition	Green Landscape (Vegetation Cover)	Mangrove restoration and coastal afforestation with native species	Assisted natural regeneration Invasive species removal Eco-restoration corridors	Post-mining revegetation with native species Native grassland restoration on overburden dumps	Urban forest patches Mandatory tree coverage ratios in development plans; green roofs
	Water Body Quality	Coastal wetland buffer zones Regulation of aquaculture effluents Tidal flushing design	Riparian protection zones around reservoir Silt trap planting upstream	Acid mine drainage treatment wetlands Constructed wetland polishing cells	STP upgrades and zero liquid discharge Urban wetland restoration as tertiary treatment
	Biodiversity	Marine and intertidal habitat conservation Sea-turtle nesting beach protection	Wildlife corridor strengthening Eco-sensitive zone buffer compliance Camera trap monitoring	Post-mining habitat mosaic creation Reintroduction of native flora and fauna	Biodiversity parks and pollinator gardens Bird-friendly building guidelines

Figure A.3: Toolkit as per landscape systems and interventions as per subcriteria faring low

Peri-urban	Rural	Floodplain	Industrial	Infrastructure Corridor
Canal lining and drip retrofit Farm ponds and recharge wells along village commons	Check dam and nala bunding Community bore-well networks and traditional step-well revival	Seasonal flood-capture tanks Canal diversion weirs to extend irrigation into dry months	Industrial effluent recycling (post-treatment) for green buffer irrigation	Roadside swales and culvert ponds to capture runoff for adjacent farm use
Green manuring and crop rotation Vermicompost supply chains from urban organic waste	Contour bunding and mulching Soil health card-guided amendment programs	Silt deposition management Levee design that allows controlled sediment enrichment	Mandatory green buffer with phytoremediation species (vetiver, sunflower) around industrial plots	Roadside revegetation with deep-rooted native species to arrest erosion and improve structure
Agroforestry corridors Shade trees along field boundaries for microclimate regulation	Farm-scale agroforestry Shade net houses for heat-sensitive crops	Riparian tree belt restoration Seasonal crop calendar adjustment	Mandatory green belt to reduce heat radiation from industrial surfaces	Avenue plantations along highway/railway corridors Reflective surface treatments
Farmer producer organisations Contract farming linkages with urban supply chains	Diversification into horticulture, dairy, and cottage industries Crop insurance outreach	Flood-resilient crops (deepwater rice, fish culture in paddy) Post-flood income support	Industrial CSR-linked farmer markets Supply of organic produce to industrial canteens	Roadside vending zones and agri-logistics hubs along corridors
Warehousing and cold chain at taluka level Last-mile connectivity improvements	Village-level aggregation centres Kisan rail linkages to urban mandis	Elevated road design for year-round access Flood-resilient storage platforms	Industrial park roads dual-used for farm logistics Dedicated loading zones	Highway service nodes with agri-collection points Railway sidings for produce movement
Agri-extension kiosks in gram panchayat buildings KVK outreach camps	Satellite school clusters Krishi Vigyan Kendra (KVK) field schools	Elevated school buildings as flood-resilient community hubs Seasonal school calendars	Industry-linked ITI campuses On-site training for green and blue-collar trades	Transit-node education kiosks Mobile agri-extension along corridor settlements
Mobile health vans Site-and-services housing plots with tenure security	Sub-centre upgrades PM Awas Yojana-linked housing with kitchen gardens	Elevated plinth housing design Community health shelters on high ground	Worker housing with greenways Employer-funded health clinics	Corridor-linked dispensaries at highway nodes PMAY housing clusters near railway stations
Agroforestry and farm woodlots Village commons greening	Farm boundary tree planting Wasteland afforestation under MGNREGS	Riparian buffer strips Floodplain meadow restoration	Mandatory 33% green belt Native species plantations on industrial periphery	Right-of-way greening with native avenue trees Sound-barrier green walls
Agri-runoff interception swales Phytoremediation wetlands along drainage channels	Village pond desilting and bunding Organic farming transition to reduce agro-chemical runoff	Oxbow lake and seasonal wetland restoration Floodplain buffer no-build zones	Zero liquid discharge mandates Constructed treatment wetlands as industrial estate boundaries	Highway drainage filtration strips Bridge runoff treatment before discharge to water bodies
Hedgerow and field margin restoration Native plant nurseries in gram panchayat lands	Sacred grove protection Agro-biodiversity seed banks at village level	Floodplain grassland and seasonal wetland conservation No-till agriculture promotion	Industrial estate biodiversity plans Native-species landscaping within campuses	Wildlife crossing structures (underpasses, culverts) Corridor-side native planting

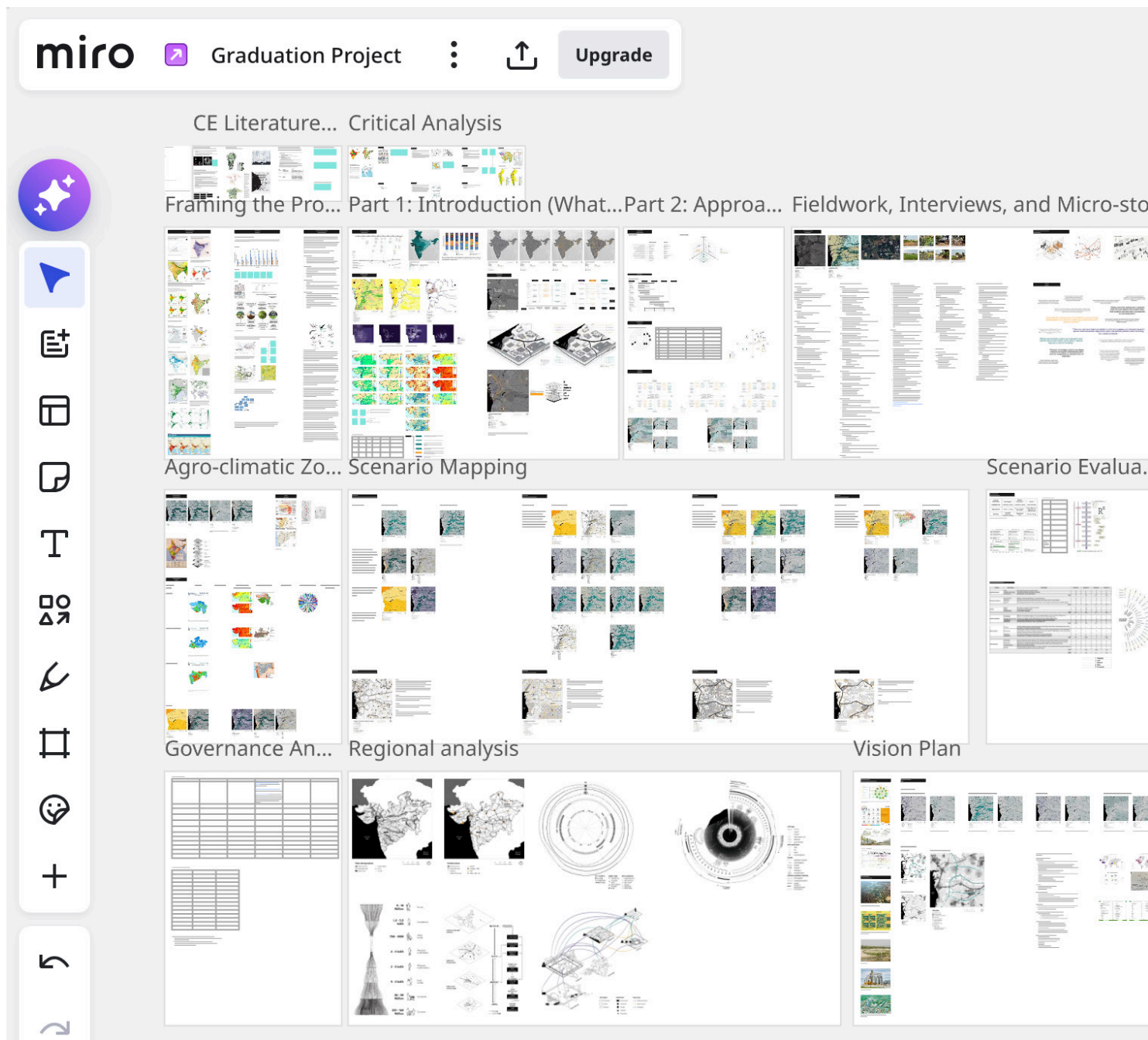
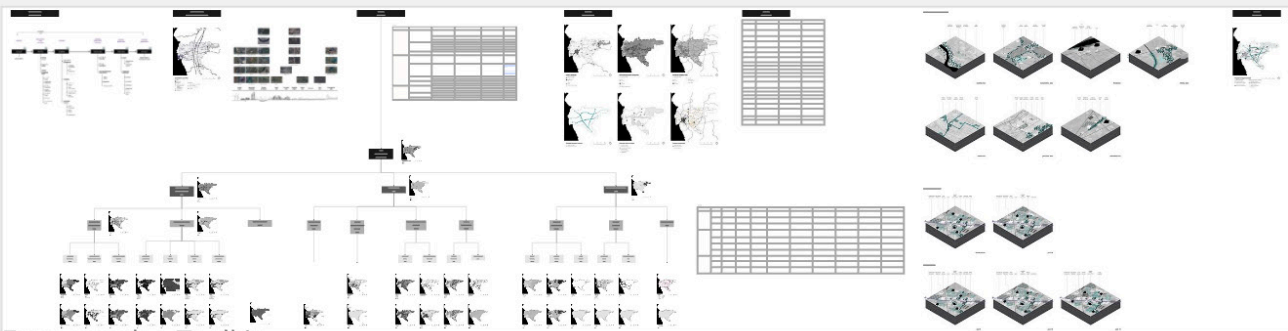


Figure A.4: Screenshot of the graduation project process and compilation on Miro board

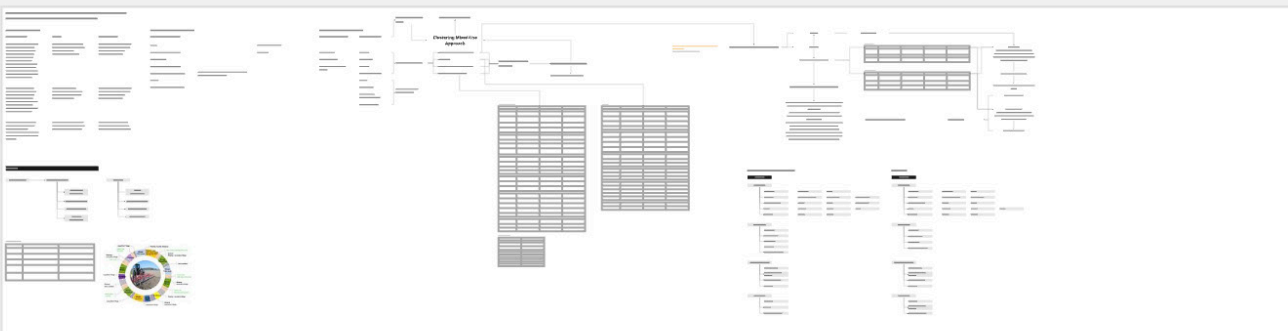


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APPENDIX B: DATA MANAGEMENT CHECKLIST

Instruction

This checklist is relevant for all graduation projects of the Master AUBS. The form is intended to highlight common aspects of graduation projects that require particular attention with regard to planning the research and data management. Relevant information and supplementary sources regarding each question are provided below each question.

With this checklist, the faculty wants to avoid that students unexpectedly find themselves in complex and stressful situations, in which ethical or privacy matters and/or other laws and regulations become an issue. In projects involving humans, certain types of data processing increase the risks to the human participants: planning such projects requires additional evaluations and advice from university staff before ethical approval can be received and the project can begin. In the case of a graduation project, obtaining additional advice or permits may delay the project with an extra education period or semester. To avoid this, it is recommended that students set up a graduation project with a low level of risk. Therefore, all students have to check their risk, by completing this checklist before their A1.

The first section of the checklist (A) should be completed by all students, together with their supervisor, during the planning of the graduation project, before the A1. It does not need to be submitted to anyone for review or approval. Please consider questions 1 to 3 carefully in relation to the intended graduation project, and answer with 'yes' or 'no'.

The second section of the checklist (B) should only be completed if the graduation project involves working with data from human participants. In that case, the student and their supervisor must apply for and receive ethical approval from the [Human Research Ethics Committee](#) (HREC) before the project can begin (see the paragraph 'Explanation and follow-up' after the questions). The student can submit the application to the HREC, but the supervisor is responsible for making sure that the project is compliant with relevant privacy regulations and ethical policies.

Section A. General considerations	yes	no
1. Is the graduation project conducted as part of an internship (at a company), or as part of a research project at TU Delft? If a student's graduation project is conducted at a company or as part of a research project at the university, questions of data ownership and intellectual property rights need to be addressed in a written graduation or internship agreement before the project begins. Student and supervisor should consult the Intellectual Property Rights of Students webpage. Additional information can also be found in the Extended Personal Research Data Workflow. If applicable, complete the Confidentiality Agreement.		✓
2. Does the project involve conducting (part of) the research outside the Netherlands? Students who intend to travel abroad (even to other EU countries) for study, exchange, research, internship, or graduation project purposes need to follow the Travel Safety Protocol. This includes attending a mandatory Travel Safety Training Session: see the Disclaimer.		✓
3. Will the research involve processing data from humans, such as running a survey, conducting interviews or workshops, collecting data through social media or internet forums, or re-using existing datasets about humans provided by a third party? (If 'yes', see follow-up questions 4 to 13 in Checklist B.) Students who work with data from human participants must complete the next section and apply for and receive ethical approval from the Human Research Ethics Committee (HREC) before conducting the research.	✓	

Section B. Extended risk factors (only if question 3 has been answered with 'yes'.)	yes	no
4. Will the project involve participants who may be considered vulnerable, such as the elderly, refugees or asylum seekers, ethnic minorities, patients, or people with disabilities? Participants who may suffer very adverse consequences (for instance, due to discrimination) if their personal data became publicly available can be considered vulnerable.		✓
5. Will the project involve participants who cannot themselves give informed consent for taking part in the project, but for whom consent must be obtained from a legal guardian? Participants who cannot give informed consent can include, for instance, children or participants with intellectual disabilities, mental disorders, or dementia. Such participants are also considered vulnerable in the context of the General Data Protection Regulation (GDPR).		✓
6. Will the project involve processing any of the special categories of personal data below? - Race - Ethnicity - Criminal offence data - Political opinion - Union membership - Religious or philosophical beliefs - Sex life and/or sexual orientation - Health data (including measurements such as heart rate) - Biometric or genetic data (including fingerprints, iris scanning, facial recognition) The General Data Protection Regulation (GDPR) defines a stricter rules for processing special categories of personal data. If it is necessary to process these data in a project, it is important to provide additional safeguards.		✓
7. Will the project involve processing personal data that could be considered sensitive, such as the ones listed below? - Information about a person's income, debts, or other payments - Information about a person's (un-)employment status - Information about a person's performance at school or work - Information about relationship problems or (gambling) addiction - Information about poverty, domestic violence, or youth welfare/social work involvement Some types of personal data are considered sensitive, because they can have a high impact on the privacy of the data subject if other persons gain access to these data. Sensitive personal data should only be processed if necessary: in such cases, additional safeguards need to be put in place.		✓
8. Will the project involve processing video-recordings, or photographs of participants? TU Delft considers photographic and video-materials of research participants to be sensitive personal data. If such data need to be processed, additional safeguards must be put in place.		✓

Section B. Extended risk factors (only if question 3 has been answered with 'yes'.)	yes	no
9. Will the project involve sharing or transferring personal data between multiple partners or collaborating organisations involved, such as between TU Delft and an internship company? According to privacy law, sharing personal data between organisations requires a privacy agreement to be in place: setting this up takes time, and requires support from additional university staff. Furthermore, personal data sharing can potentially expose research participants to different types of risks: these risks must be considered in the ethical application.		✓
10. Will the project involve deception, or covert observation of participants? In some types of research, obtaining informed consent for processing participants' personal data is not an option: for instance, if the research involves deception, or the research is covert (conducted without participants knowing about it). In such situations, the steps to mitigate risks to participants are important, and an alternative legal basis for processing the participant's data needs to be established with the help of additional support staff.		✓
11. Will the project involve working with social media data? Social media data are personal data, but since it is usually not possible to ask for informed consent for processing social media data, another legal basis for processing the participant's data needs to be established. Processing of social media data also involves legal considerations related to terms of use of data from third-party platforms: therefore, research with social media data requires expert support on privacy, ethics, and legal matters.		✓
12. Will the project involve using learning algorithms or other AI to analyse, combine, or otherwise process data from participants? The use of AI in research involves many considerations in terms of data protection, ethics, security, and intellectual property: for more information, see TU Delft's Instructions for use of Generative AI.		✓
13. Will the project involve participants who are based in a country or countries outside of the EU? Students affiliated with TU Delft must comply with Dutch and EU regulations of personal data processing (GDPR). Furthermore, the student and their supervisor must make sure that the research complies with local (privacy) legislations of any foreign destinations. Additional support from an external (local) expert may be required.		✓

Explanation and follow-up

If you have answered 'no' to all questions 4 to 13, your project is likely to be considered low or minimal-risk: see the paragraph 'Projects with minimal or low-risk' on the next page.

If you have answered 'yes' to one or more of the questions 4 to 13, your research likely involves extended or high risks to participants, according to the [General Data Protection Regulation](#) (GDPR) and TU Delft's privacy and ethical policies: for information regarding such projects, see the paragraph 'Projects with extended or high-risk' on the next pages.

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