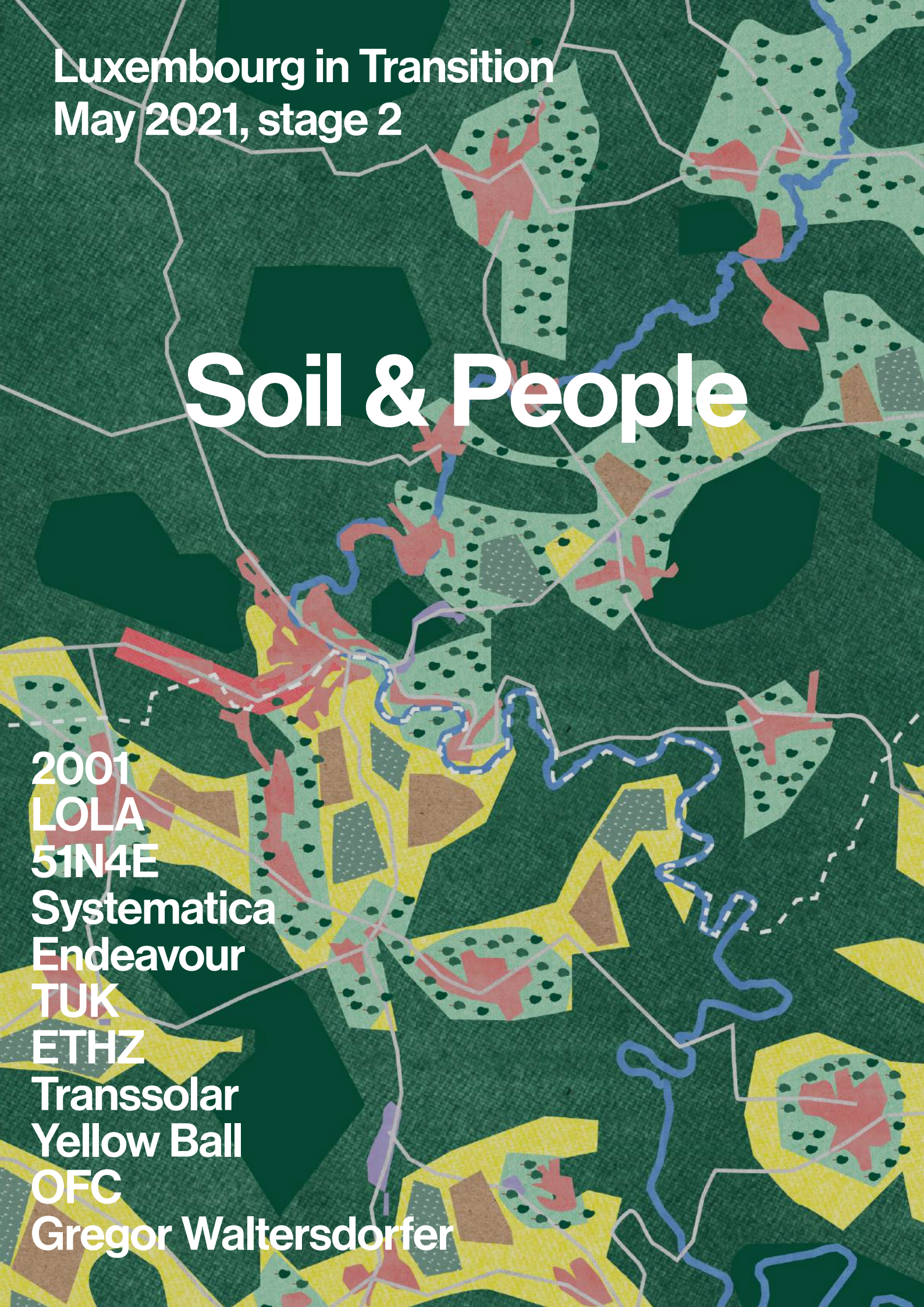
Luxembourg in Transition
May 2021, stage 2

Soil & People



2001
LOLA
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Systematica
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TUK
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Transsolar
Yellow Ball
OFC
Gregor Waltersdorfer

1.1 Executive Summary

With a concentration on lifestyle changes, land use change and regenerative agricultural practices, we have put forward a quantifiable decarbonisation trajectory for the functional territory of Luxembourg. We have adopted the European Commission's 1.5 LIFE scenario [1] as our baseline and have presented the tools and metrics by which we can exceed its ambitious goals.

We have translated these goals into territorial designs and have selected the sample areas in which we aim to continue our investigation.

We have also facilitated roundtable conversations with farmers and foresters, to get a better understanding of incentives and obstacles for such a transition.

By facilitating a transborder, multiscalar conversation among neighborhoods and nations we intend to embolden local actions that have global impacts. Adopting Soil & People as the principal focus would help steer a holistic, evidence-based transition.

We take inspiration from already adopted actions, as our pilot tools. These initiatives with quantifiable outcomes can then be accelerated by coalition building and alignment with supporting initiatives that educate and raise awareness to increase their reach and gradually evolve towards a contributive territory.

Our proposal anticipated a drastic shift in the dominant luxembourgish socio-economic model. How do we define growth? How can we live a more balanced life? Consume not too much, yet not too little? Do we need to change our diets? and can the Luxembourg territory produce the food that it consumes?

This shift will be felt strongly, but with progressive steps it will bear fruit in time, for the economy, and society as well as the environment.

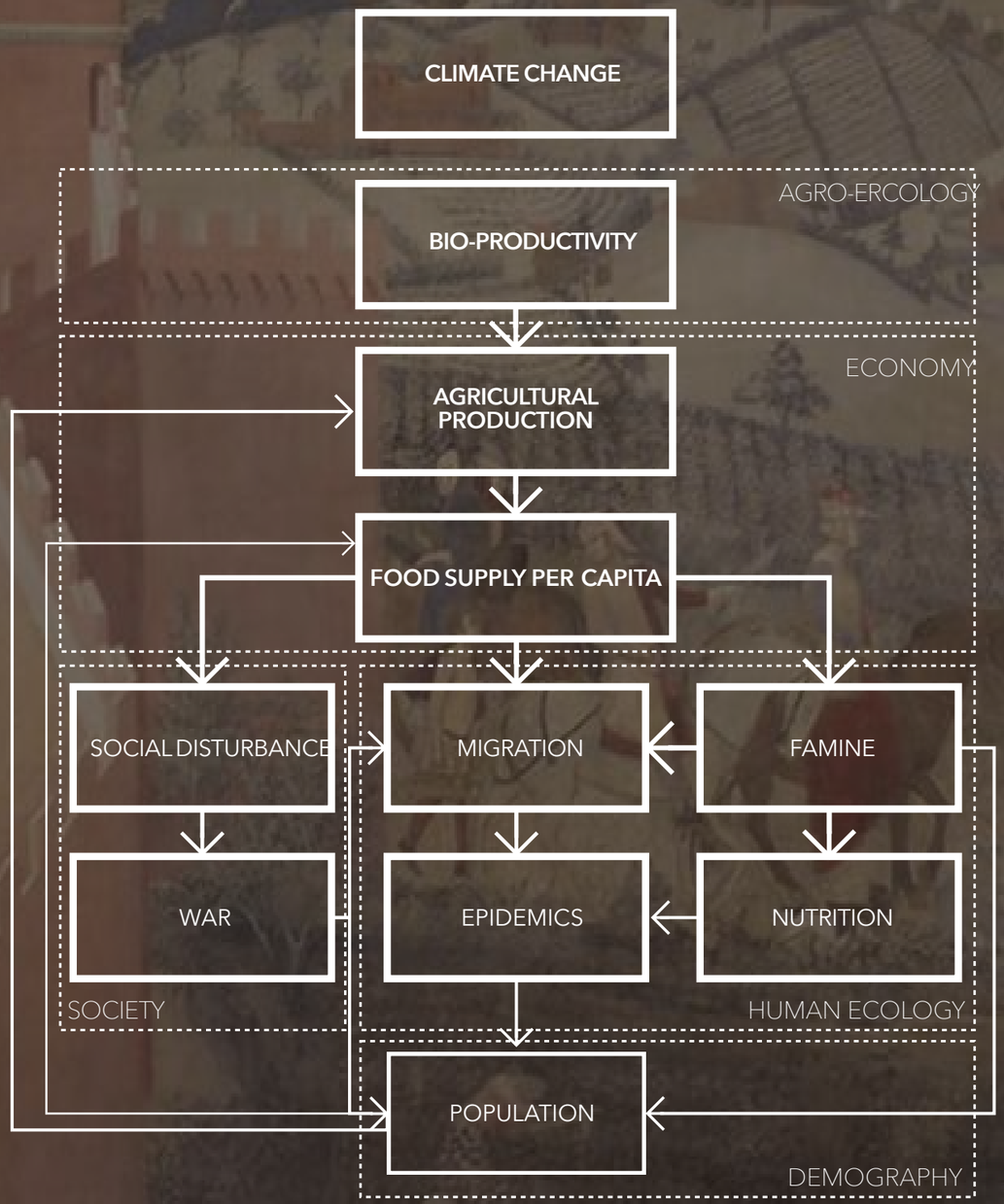
Climate change, countryside, crisis and causality.

In the 14th century Lorenzetti painted the "allegories and effects of good and bad government" in order to remind Siena's governing magistrates of their responsibilities. If half of the painting illustrates the city, the other half depicts the countryside, stressing its role and importance for society at large.
A 2011 study by David D Zhang et al. found that climate change was the ultimate cause, and climate-driven economic downturn the direct cause, of large-scale human crises in pre-industrial Europe and the Northern Hemisphere.

In the light of the challenges ahead, a dire warning to urgently reconsider and equip our landscapes.

A shift that requires us to rethink our relationship with the land in our vicinity and our behaviour as a society.

Set of causal linkages from climate change to large-scale human crisis in preindustrial Europe (Zhang et al., 2011). The background features Lorenzetti's painting in Siena.



Questions we have responded to

How vast is the impact of diet?
Its a game changer. [page 53]

Can the territory feed itself?
Yes, if the diet shift happens. [page 101]

What roles can farmers, citizens and politicians play?
Each has a role, and time to play. [page 102]

How can the functional region perform better ecologically and more sustainably?
By adopting the bioregion as a parallel resource management entity. [page 70]

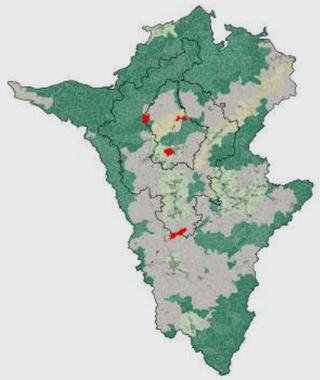
What concrete spatial steps can be taken?
The biofunctional land use vision. [page 92]

How can this progress be quantified?
By following the milestone identified for each shift . [page 96]

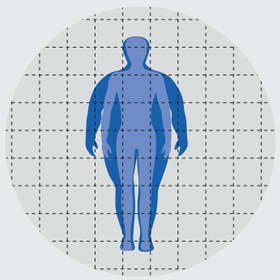
Key outputs

The 3 shifts

a diet shift;
led by citizens
to reduce land/CO2 footprint



a biofunctional shift;
led by politicians
to priorotise resources



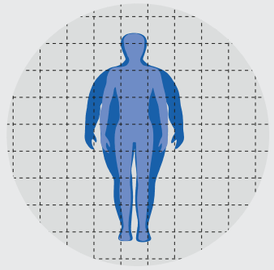
a cultivation shift;
led by farmers
to maximise sequestration

1.2 Methodology

Macro methodology

sequestration tools

conversation with farmers



Cultivation shift

supply

demand

Diet shift

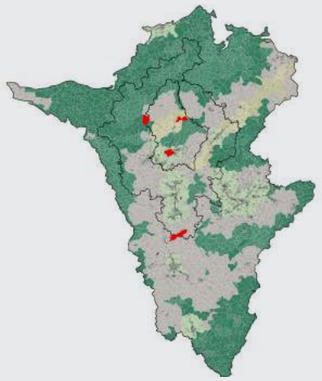
adaptive macro strategy

reduced land footprint

conversation with Citizens Committee

Meso methodology

dissection

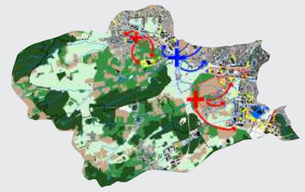


Landscape dissection

+

problematic patterns

+



project strategy

upscale

Nature-based & Lifestyle solutions

1.3 Nature-based & Lifestyle solutions

fig 1: Food emissions. (Ritchie, 2020).

To achieve carbon neutrality by 2050, increasing negative emissions are absolutely necessary.

From diet to forestry practices, the nature-based decarbonisation path is deeply interlinked. we have layed out a step by step path for achieving a bold yet feasable goal in emissions touching on agriculture, land use, forestry and food as a whole.

EU 1.5 LIFE scenario projections

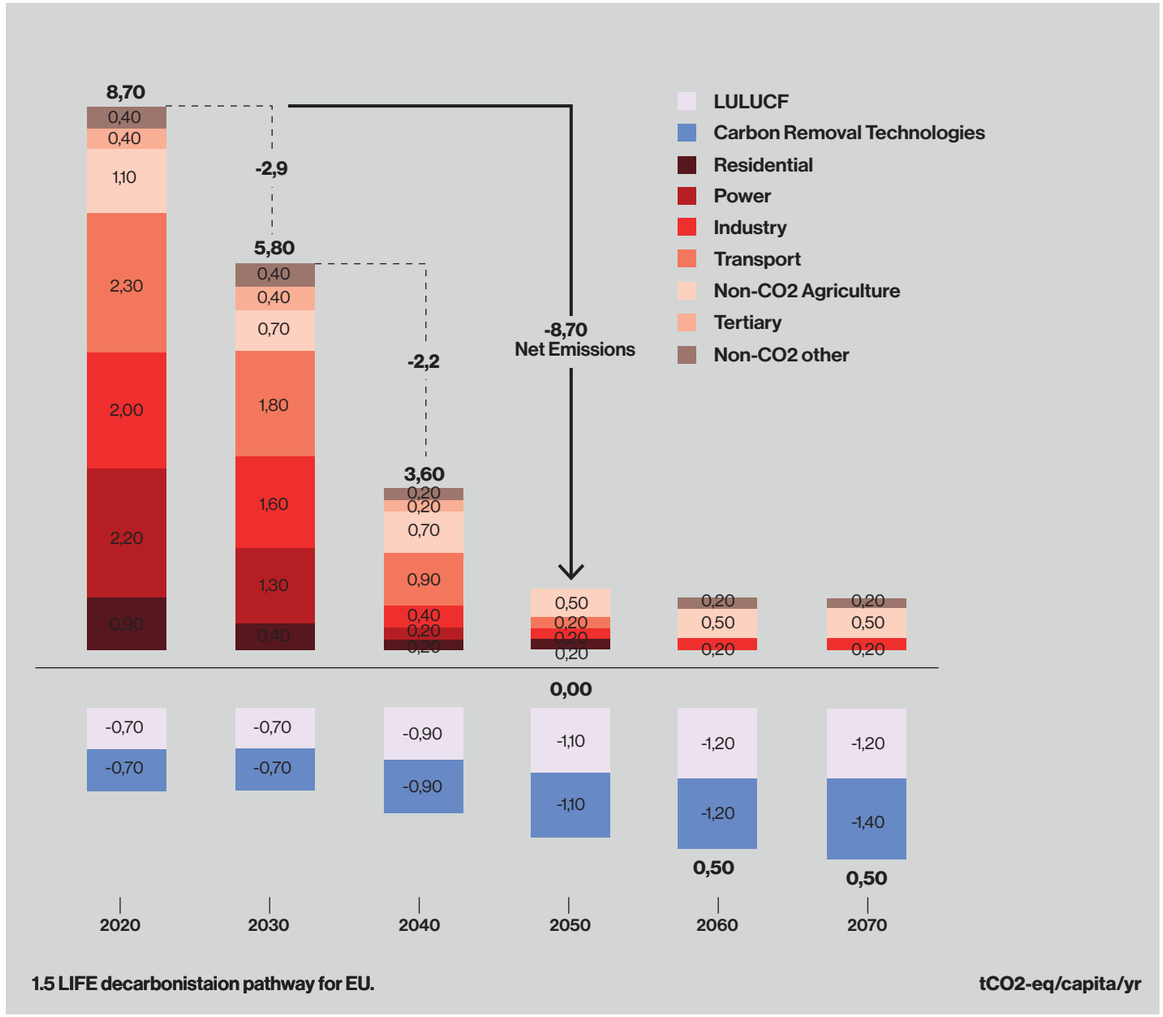


fig 2: EU 1.5 LIFE Scenario tCO2eq/capita/year. (European Commission,2018).

The 1.5 Life scenario provides an ambitious baseline for a net zero 2050 based on nature-based solutions and lifestyle changes. This fully aligns with our approach. That is why we use it as our benchmark for total emission.
From diet to forestry practices, the nature-based decarbonisation path is deeply interlinked. we have layed out a step by step path for achieving a bold yet feasable goal in emissions relating to food, agriculture, land use and forestry.

The power of individual actions

1.4 The power of individual actions

In phase 1, we focused on identifying key initiatives which are on the frontier of the transition.

In phase 2 we have shifted our attention to obstacles and incentives which would accelerate this transition

We have done so by a series of conversations with farmers, foresters & citizens.

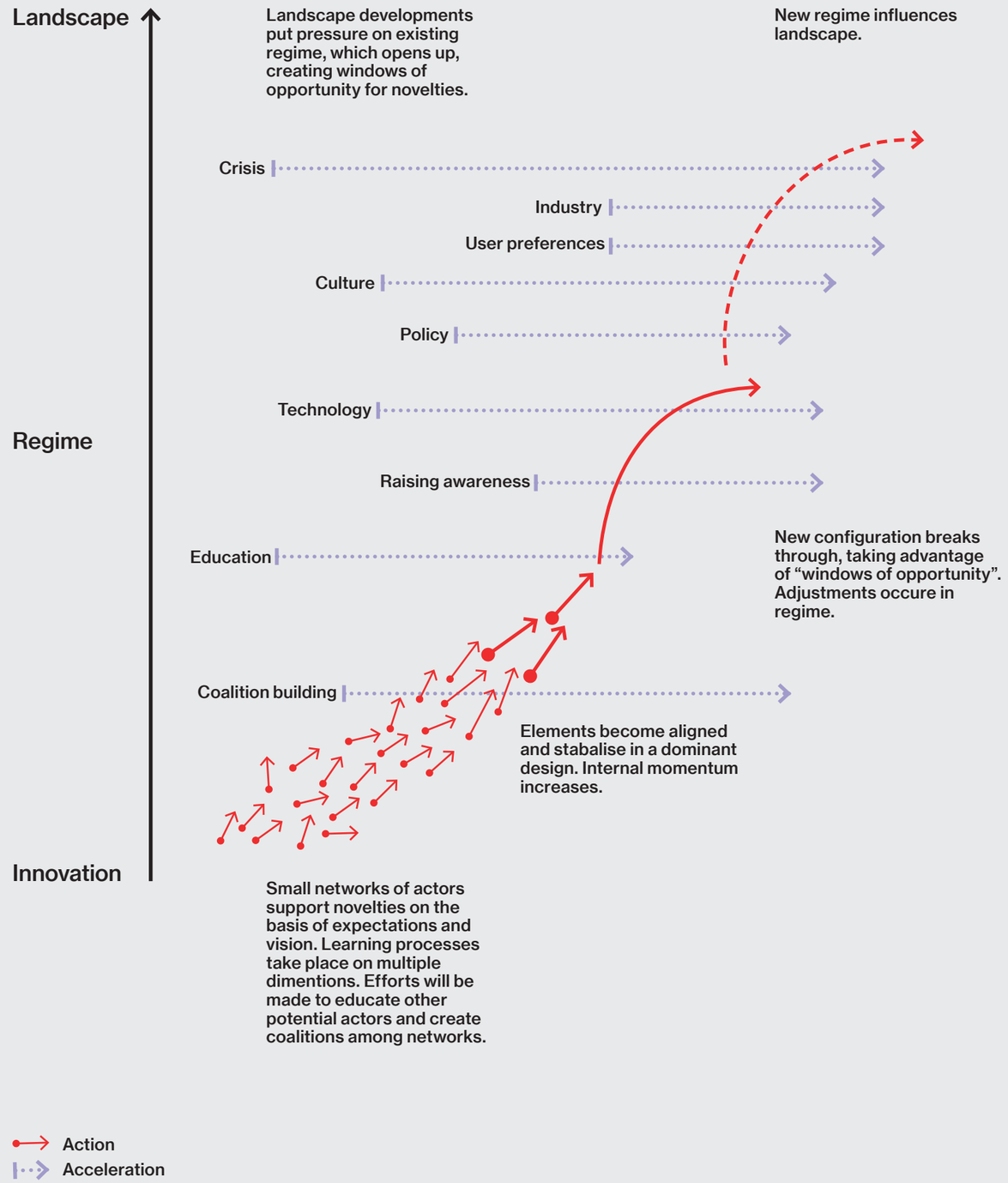


fig. 3: Multi-level perspective on transitions. (Geels 2002, 1263).

Land as a finite resource

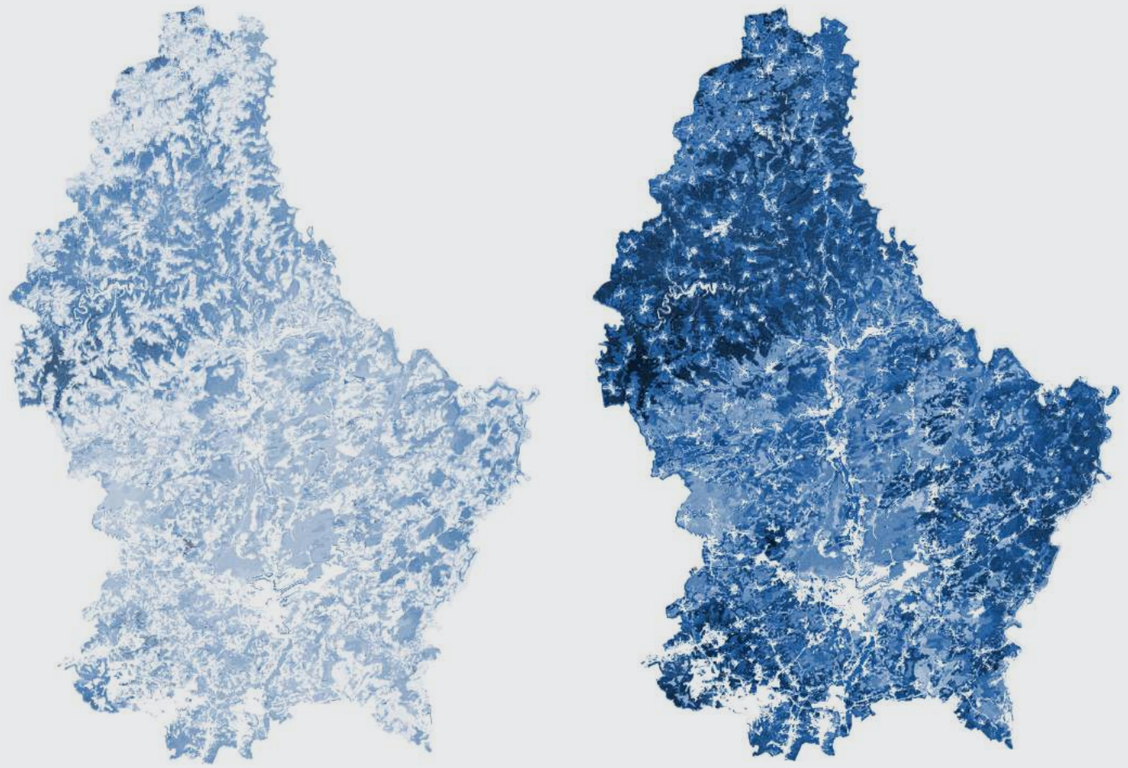
1.5 Land as a finite resource

To achieve carbon neutrality by nature-based solutions, we need to protect the existing footprint of the natural landscape.

By protecting the landscape we will be able to enhance biodiversity, sequester carbon optimally and guarantee the region's food security in a turbulent 2050 climate.

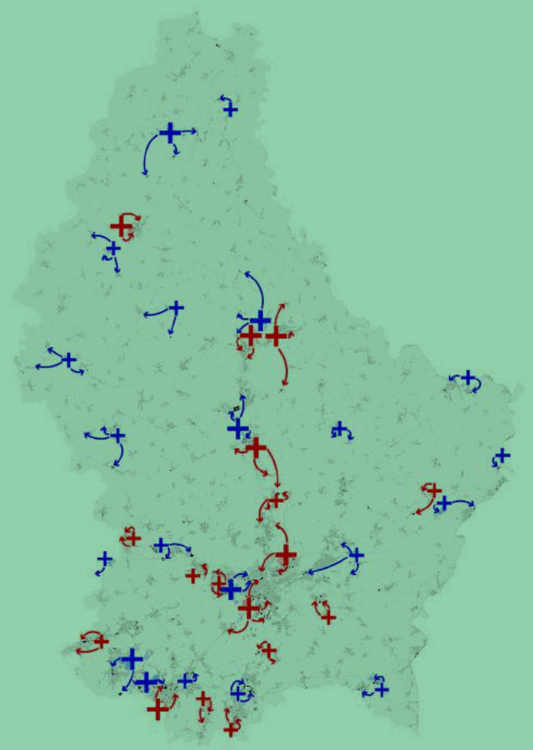
This does not mean blocking development and growth, but rather laying out synergistic alternative building cultures.

Luxembourg territory, 2020 to 2050



The LU territory alone can sequester more than 18.9 MtCO2-eq by 2050.

50-70 t C/ha 100-120 t C/ha 120-140 t C/ha 180-200 t C/ha 200-220 t C/ha 220-240 t C/ha



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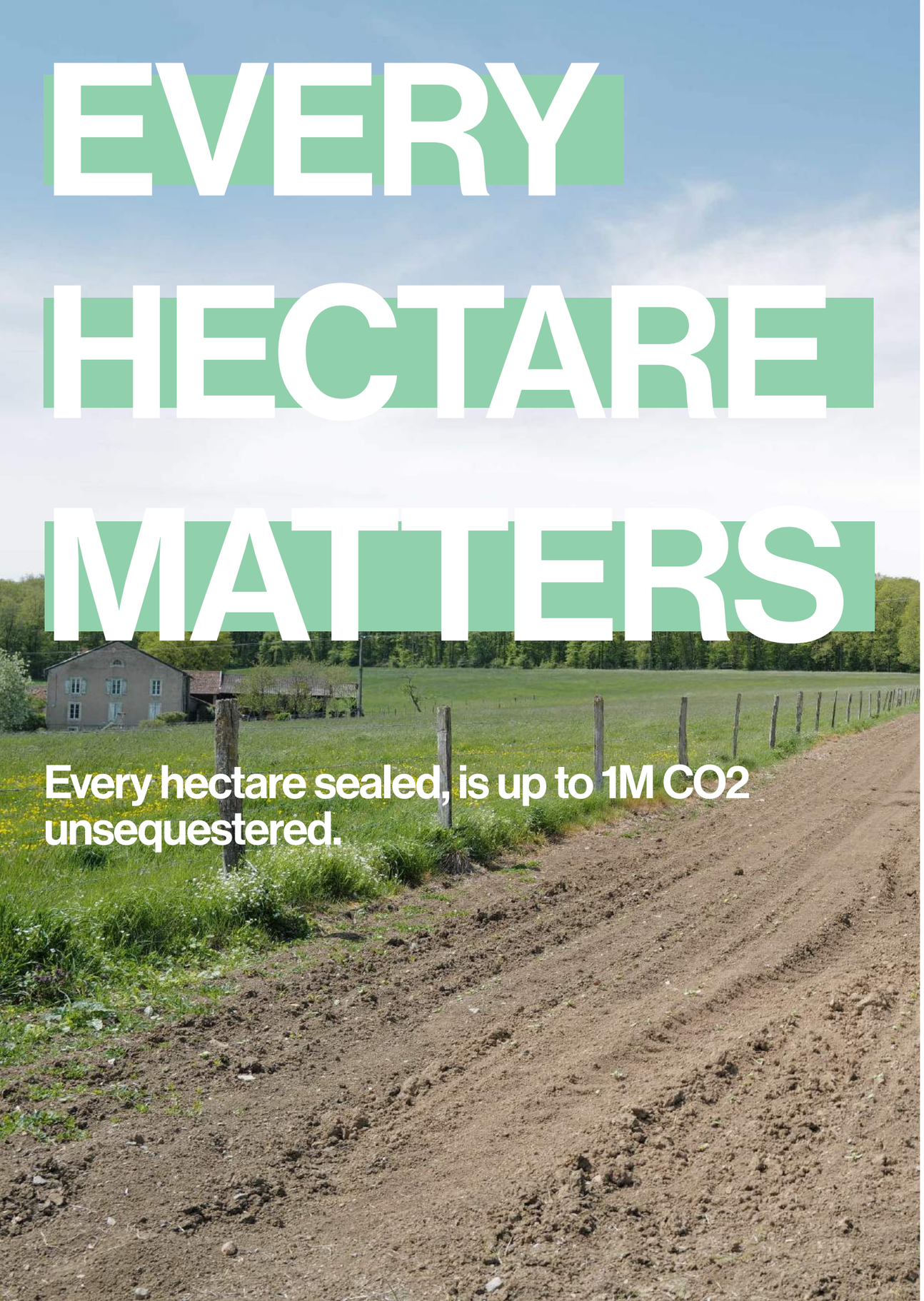
Landtake's carbon cost



2.1 Every hectare matters

Luxembourg's rising economic strength is married with an increase in number of jobs and in turn cross-border workers. It is partly due to this high share of cross-order workers that the country has the highest proportion of artificial land devoted to economic activities in Europe: 43% (MEDDTL, 2012). Due to high living costs, for both housing and consumer goods, and further incentivsed by subcidised fuel, the housing for this growing workforce is provided in the neighbouring regions of Germany, France and Belgium.

What is the role of land in this growth disparity? How do the various planning cultures in the greater region influence the expansion morphology of economic and housing zones?
Where and how does the city end? How can the landscape be protected?

The sequestration deficit of landtake*

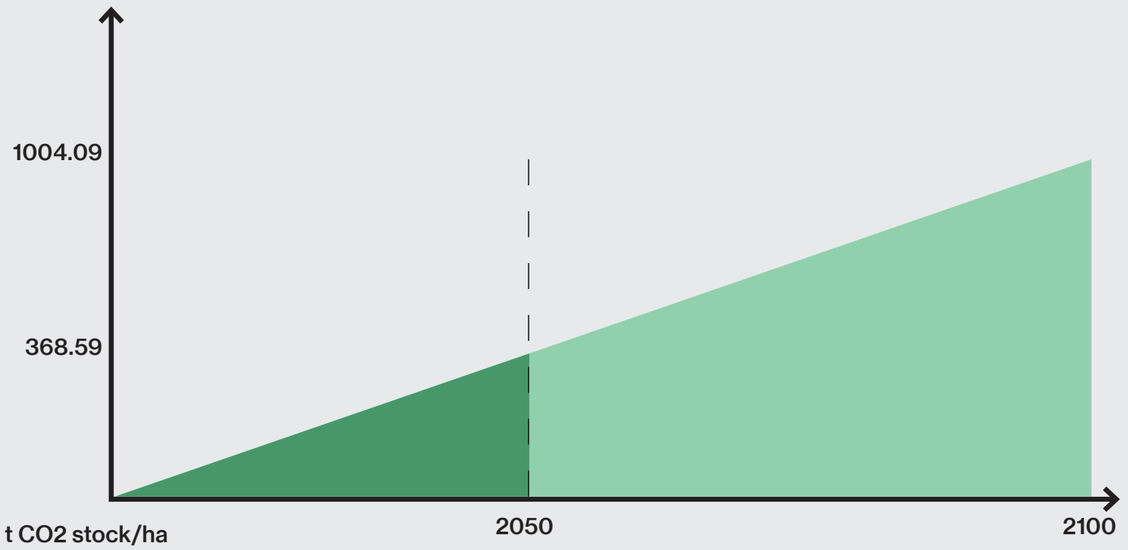


fig. 4: The sequestration deficit of landtake.
* for the purpose of this calculation, we have assumed the maximum sequestration capacity of 1 ha by considering it transformed into a forest.

2.2 The carbon cost of 1 hectare CO2-eq stock/ha over time for each tool

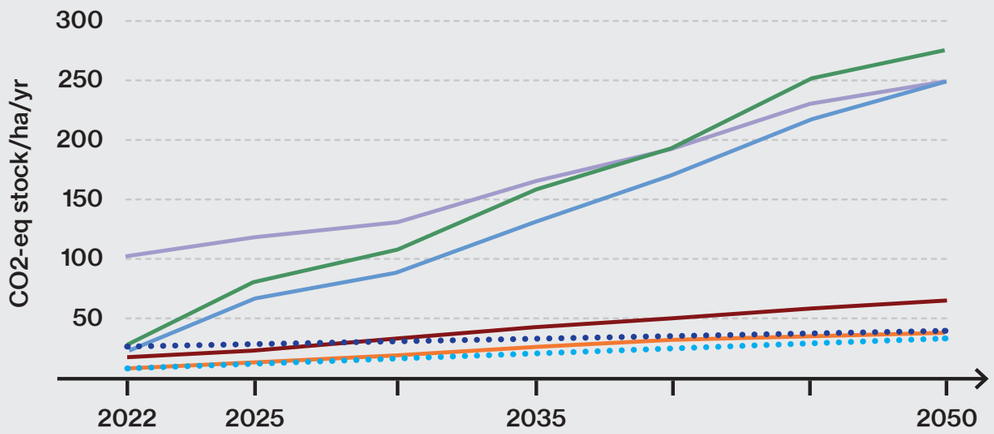


fig. 5: The capacity of the sequestration tools.

Short term gains

- Afforestation on agricultural land
- Silvo-pastures

Mid term gains

- Reforestation

Long term gains

- Zero tillage
- Cover crops
- Organic matter additions
- Hedges

Legend

Silvopastures
Medium starting point of SOC
Steep increase in biomass and SOC

Reforestation
High starting point of SOC
Gradual increase due to growth biomass

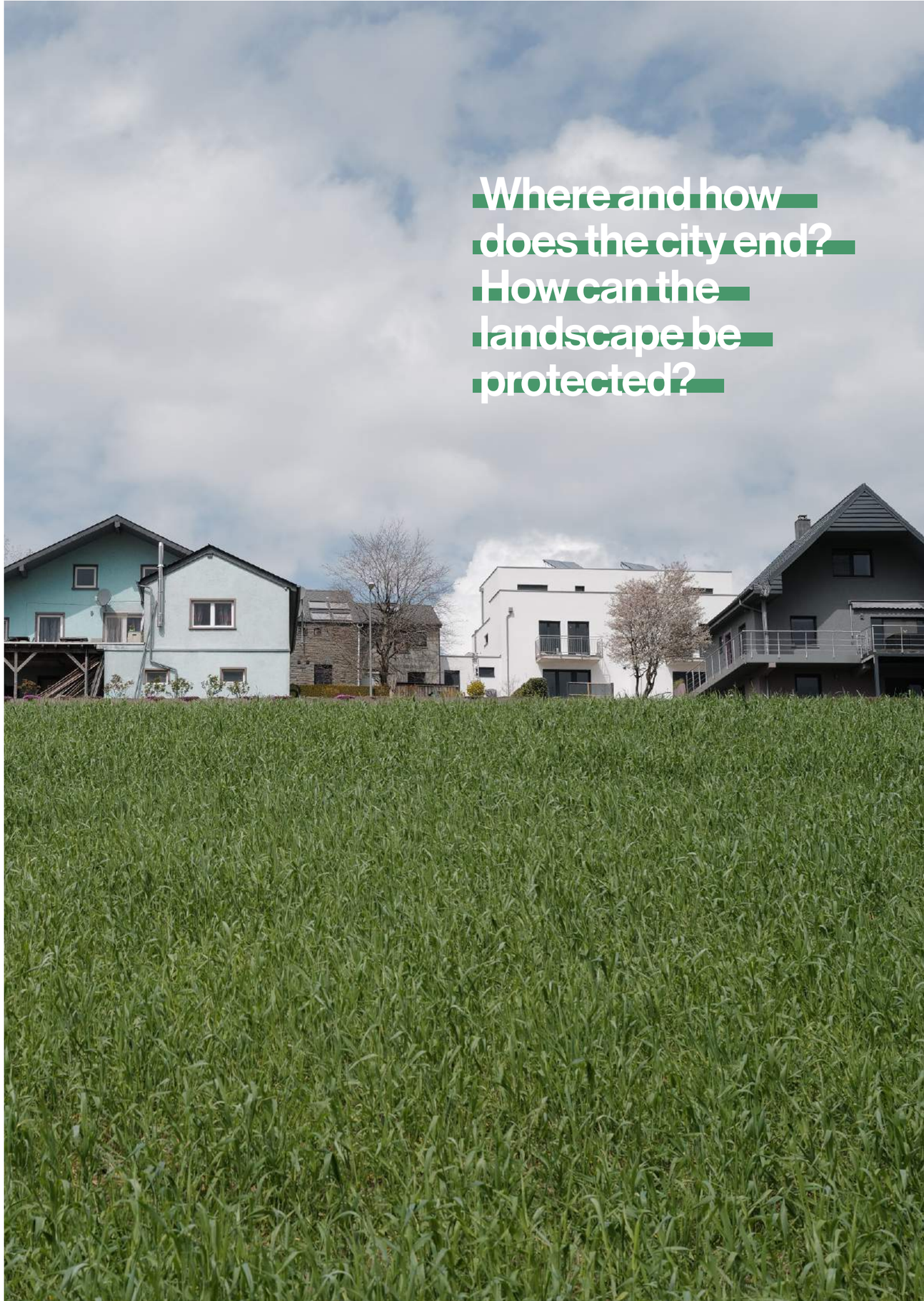
Agricultural land to forest
Low starting point of SOC
Steep increase in biomass and SOC

Hedges
Low starting point of SOC
Gradual Increase in biomass and SOC

Organic matter additions
Low starting point of SOC
Gradual Increase in SOC, leveling off over time

Cover crops
Low starting point of SOC
Gradual Increase in SOC, leveling off over time

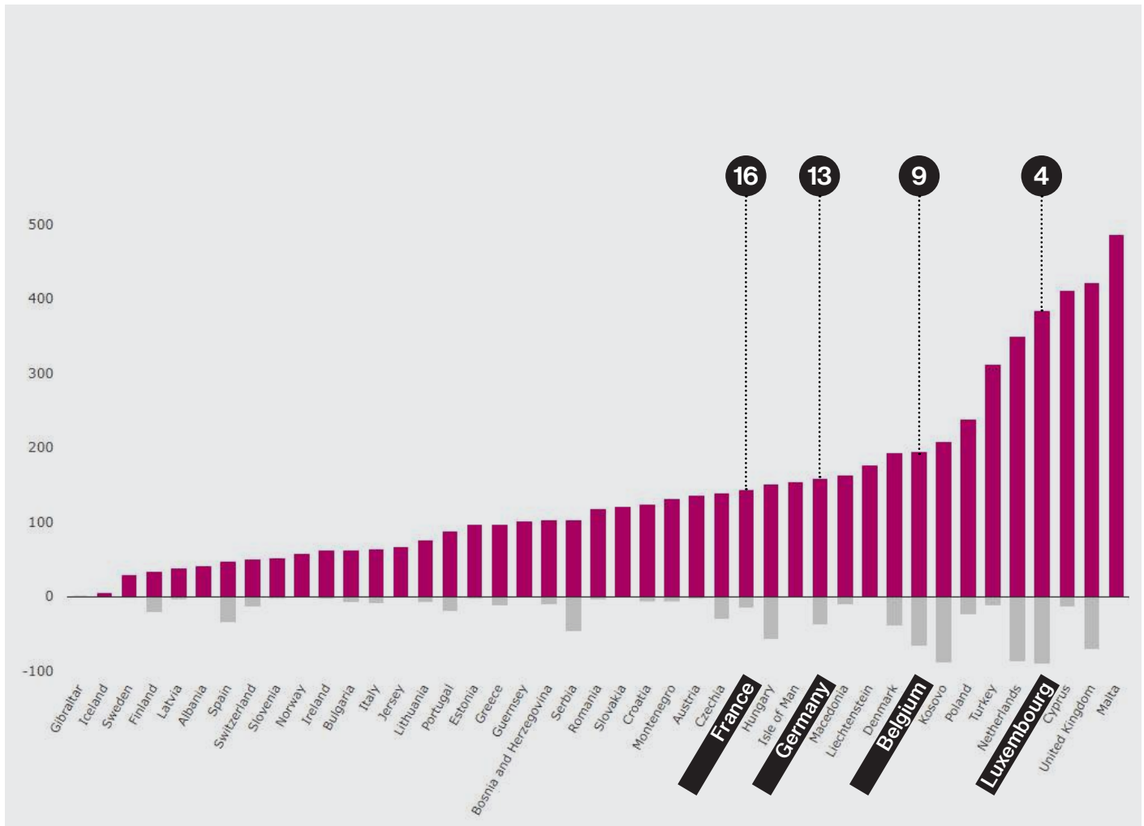
Zero tillage
Low starting point of SOC
Gradual Increase in SOC, leveling off over time



2.3 Necessity of preserving landscape; land, SOC and decarbonsation

For the biofunctional region to perform as imagined in the chapter before, we need to protect the existing footprint of the natural landscape. Natural landscapes are shrinking at a rapid rate in the region. Luxembourg for example has the 4th highest landtake rates among the EEA-39 countries (EEA, 2019). Protecting natural land, means protecting the capacity of our soils for carbon sequestration and in itself can be seen as a decarbonising tool.
By protecting the landscape we will be able to enhance biodiversity, sequester carbon optimally and guarantee the region's food security in a turbulent 2050 climate.

between 2007 and 2015, the rate of landtake in Luxembourg has been 0.5 ha per day.



Luxembourg has the 4th highest landtake rate in the EU
Landtake and recultivation in EEA-39 m2/Km2

fig 6: Landtake rates in Europe. (EEA, 2019)

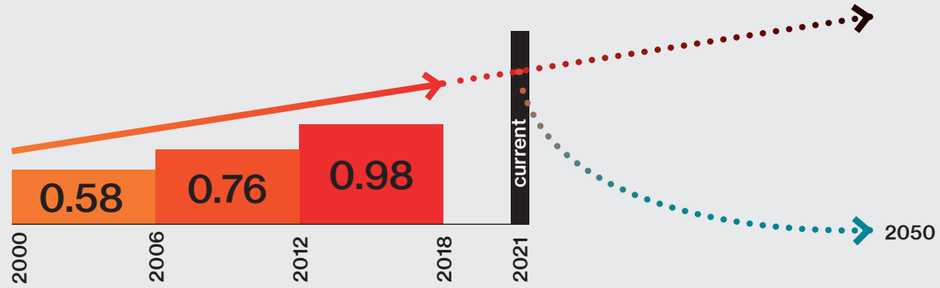
2.4 The landtake pandemic; definition

Considering the threat our natural landscapes are under, it is worth considering the possiblity of a nomos for the landscape, to hold back the expansion of urban footprints. While in ancient times the idea of the urban wall appeared as a boundary which secures all that sits within it, we might have to start thinking of the edge of the city as a boundary which protects all that is situated outside of it, as our wellbeing depends on that very land.

In our biofunctional vision for the region, we have emboldened the interdependecy of the city to its surrounding landscape while reducing transport emissions. Attempting to keep cities where cities are and landscapes where landscapes are, does not mean a freeze on growth. In the following pages we have explored how the most prominent land consuming functions can be housed within existing perimeters of our cityscapes.

"In his book The Nomos of the Earth, the German jurist Carl Schmitt postulated the concept of nomos as the relationship between the concreteness of the 'ground' and the construction of a political order. This relationship, he wrote, is made manifest in the primary event of land appropriation, an action that precedes the formation of any geo-political institution such as the community, the city or the state. The nomos is therefore the basis for all the categories that define the life of a community such as sovereignty, justice and distribution of resources."

(Aureli and Giudici, 2015)



Annual land cover flows Km2/year;

the rate of expansion of economic and infrastructure functions has increased by 70% since 2006

fig 7: Annual land-take rates in Europe and projections. (EEA, 2019)

The approach towards landtake reflects the relationship that societies have with their natural resources.

The biofunctional region needs to pioneer a consensual attitude towards protection of natural land which priorotises the wellbeing of the region as a whole and supports a collective response to growth of cities.

2.5 Disparity of land definitions in GRLU

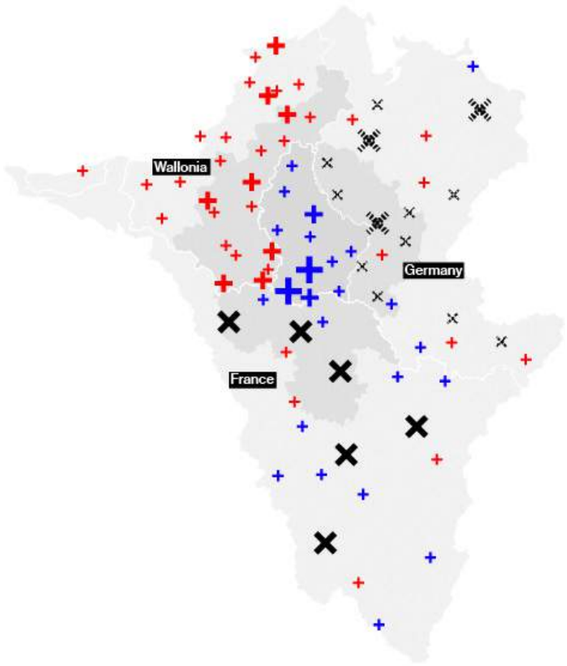
The member states of the Greater Region have defined landtake objectives that can be monitored, in order to promote a sustainable development of their territories, following the EU commission guidelines for 2050.

Germany and Luxembourg, for example, have set a cap for landtake which should not be exceeded. France intends to reduce its landtake rate to 1200 ha/year by 2020 and Wallonia has an aim of 900 ha/year by 2040 (European Commission, 2011). Those targets already show that the approach towards landtake reflects the relationship that societies have with their land resources. These relationships are nourished by historical, cultural, economic and political legacies rooted in local contexts.

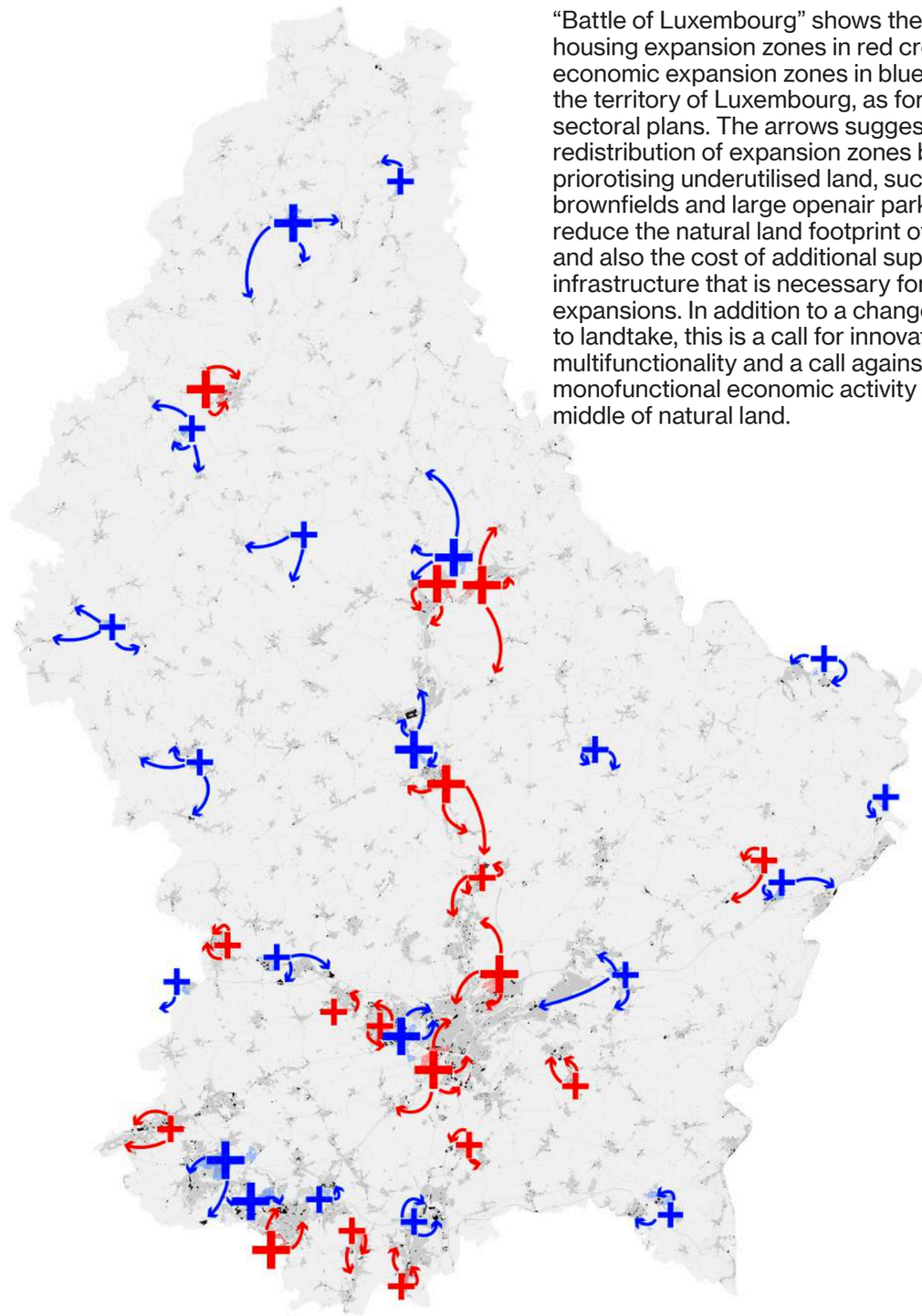
In Wallonia, the protection of land resources is a recent topic because of the historical political interests attached to housing policies. In Belgium, political parties believe that home ownership could mitigate the risk of poverty (De Decker and Dewilde, 2010) and spread out single family homes are still the preferable option to obtain it. Natural land protection is thus sacrificed.

On the other hand, in Germany, where nature is historically conceived as contemplative and romantic, the question of limiting landtake is part of a general strategy for sustainable development (Bundesregierung, 2002). The latter constitutes the most important document relative to the environmental stakes at a federal level. At local level some governments have come up with regulations that derive from the same document. Nevertheless, sometimes, the lack of vertical coordination of political decision-making causes less caution with unspoilt land in some local administration.

In France, the issue of landtake is addressed on the perspective of defending agricultural interests. Indeed, the National Federation of Farmer's Unions (FNSEA) are always pushing the protection of "mother earth". Nevertheless, as in the case of Germany, local administrations have certain decision-making freedom which allows different kinds of intervention on land as men are "masters and owners of nature" (Descartes, 1637).



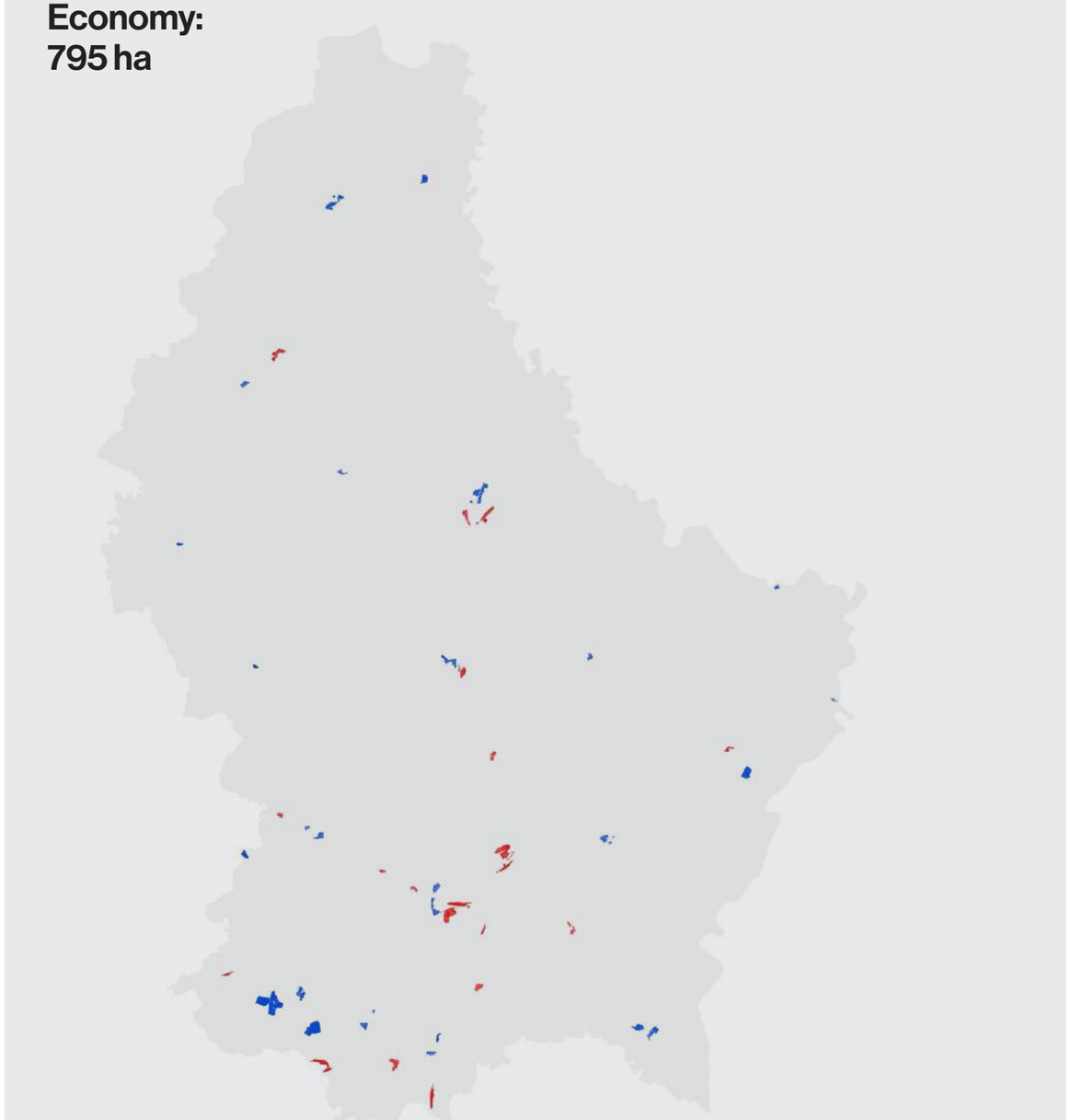
2.6 Battle of Luxembourg



“Battle of Luxembourg” shows the current housing expansion zones in red crosses, and economic expansion zones in blue crosses in the territory of Luxembourg, as foreseen in the sectoral plans. The arrows suggest a redistribution of expansion zones by priorotising underutilised land, such as brownfields and large openair parking lots, to reduce the natural land footprint of landtake and also the cost of additional supporting infrastructure that is necessary for such expansions. In addition to a change of attitude to landtake, this is a call for innovative densities, multifunctionality and a call against drive-in monofunctional economic activity zones in the middle of natural land.

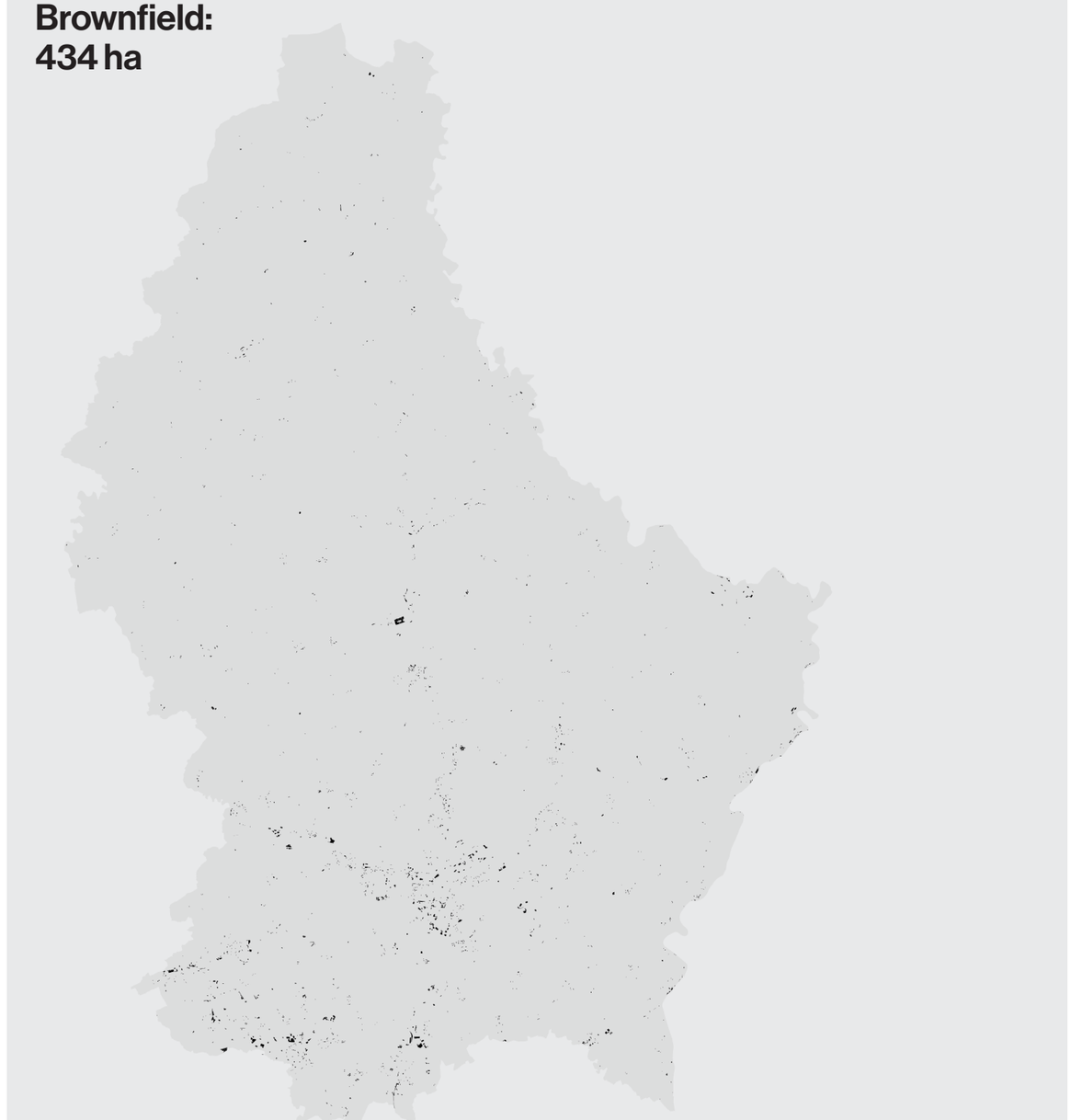
1335 ha of open landscapes, are categorised today as expansion zones.

Housing:
540 ha
Economy:
795 ha



778 ha of underutilised land, could meet the increasing demand.

Parking:
334 ha
Brownfield:
434 ha



2.7 The spatial planning law responsibilities and path forward

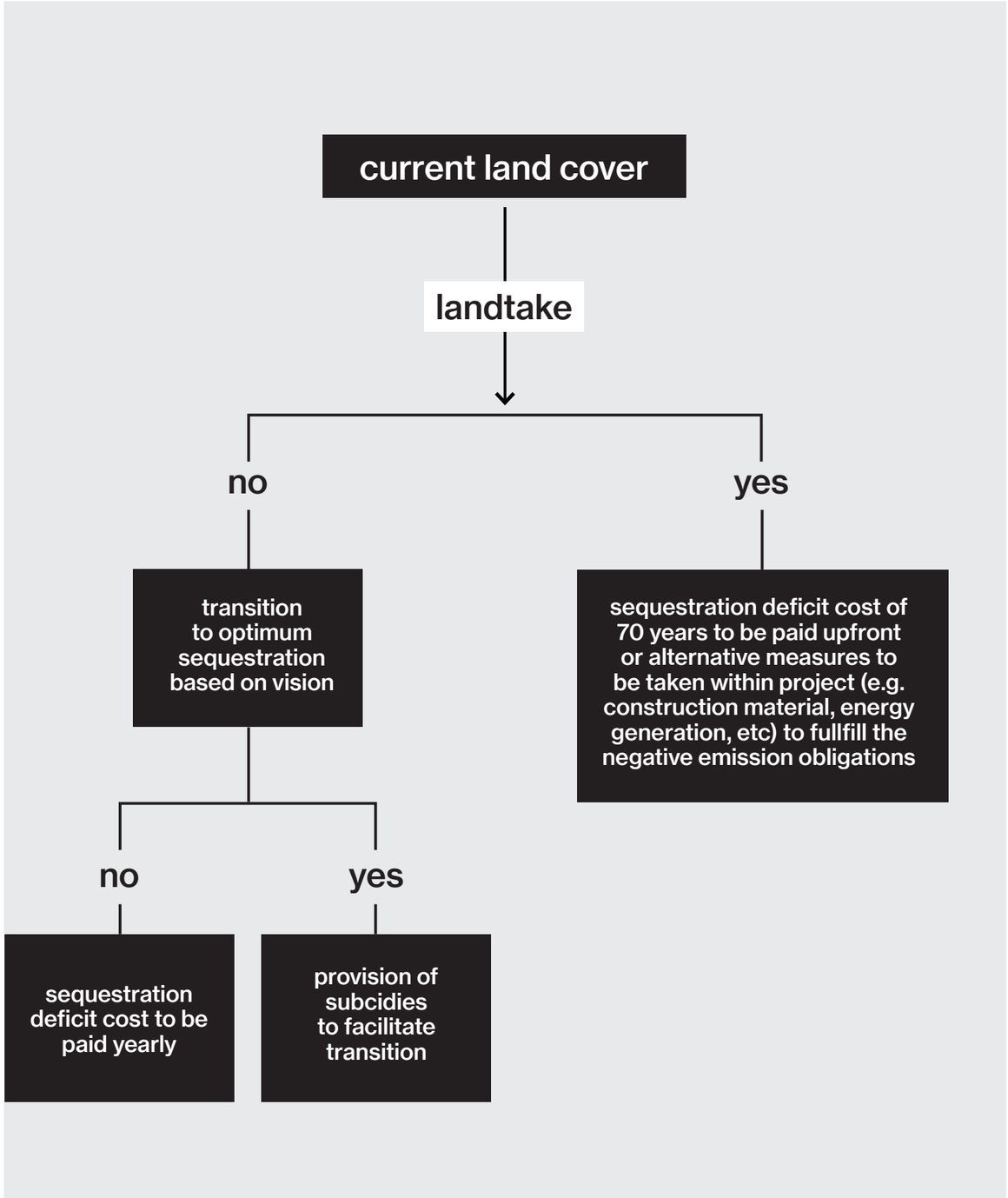
The spatial planning law allows for more careful and considerate regulations regarding landtake. If the value of each hectare to the wellbeing of society and our ecosystems is understood and measured, the regulations could expand to reflect the hidden value and loss in such transformations.

The objectives of Luxembourg's spatial planning law are as below (Fourmann and Tholl, 2019);

- ensure optimal living conditions to the population in all parts of the national territory.
- concentrate territorial development/land consumption to the most appropriate areas of the national territory
- observe the evolution of land use
- ensure the coordination of sectoral policies with an impact on land use
-ensure rational land use and concentric coherent urban development.

what if there was a carbon price attached to land use that took maximum sequestration potential as a baseline?

2.8 The carbon price of landtake how can the spatial planning law incorporate the sequestration deficit?



Territorial epitomes are problematic sociospatial patterns of the biofunctional region, that have a territorial footprint. Addressing these, could play a significant role in a widespread transformation.

2.9 Territorial epitomes; problematic patterns of the territory

Drive-ins & fuel hubs:

The largest fuel hub in Europe, Berchem, can serve up to 25,000 customers per day and sells 260 million litres of fuel per year. On average, 1,500 HGVs and 7,500 cars refuel there every day. Between 20 and 30 fuel trucks serve the station every day to replenish fuel supplies. The station has 51 gas pumps, including 24 for trucks. McDonald's and Starbucks have settled on the site of the Berchem area (Parachini, 2016).
Other large fuel hubs are the Q8 gas station Aire de Capellen on A6/E25, also nearby Luxembourg city and the Total station A1/E44 (close to Mertert)on on the border between Luxembourg and Germany.

What would be the future of this drive-in islands? How can they be reimagined?

Largest landtakers:
(EEA, 2019)

Suburban Housing
Parking surfaces
Economic sector;
- Warehouses
- Datacentres
- Office parks
- Factories
...

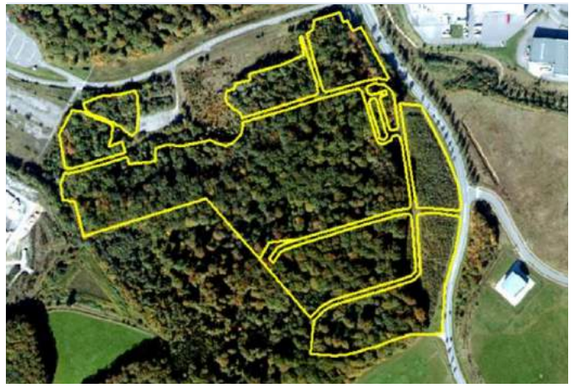
Optimisation by:
Collective amenities
Innovative densities
Decentralisation
Multifunctionality
Asset utilisation
Compaction
...

Datacentres:

A large data center is an industrial-scale operation using as much electricity as a small town. Luxembourg hosts many data centers normally in larger business parks, as in the images below.
LuxConnect is a very competitive data center facility and dark fiber provider, based in Luxembourg. Today, they count with 4 facilities, 3 of them in Bettembourg and one in Bissen. Also in Bissen, Google is planning to build a €1.2 billion data center covering almost 34-hectare of Luxembourg's countryside, which could burn through about 12 percent of the country's electricity while providing only about 100 jobs (Gurzu et al., 2020).

Warehouses:

The warehouse typology is normally one story extensive volume Developers and occupiers have favored these horizontal facilities because they are roughly 50 percent cheaper to build – and land in suburban areas comes at a steep discount to city pricing.
With the boom of the e-commerce, exacerbated by the pandemic, the need for warehouses has increased in the last decade. Not only: according to the UPS Pulse of the Online Shopper study, in 2017, 46 percent of consumers expected the possibility of next-day delivery when making purchases (UPS, 2018). Same-day service was expected by 20 percent of consumers and they were also willing to pay for it (Joerss et al, 2020). Proximity to dense housing settlement is becoming fundamental for future warehouses location.



2.9 Territorial epitomes; Housing

Long term projections by STATEC, mapped on various economic outlooks with GDP ranges between 0% and 4.5%, project an average yearly housing demand in Luxembourg of 6000 units to be produced between 2018 and 2060 (Peltier, 2019).

After 2001, a decrease in single-family houses could be observed: from 87% to 36.6% of built dwellings. However, the surface of the houses increased from an average of 150m2 to around 200m2 (OBSHAB, 2020).

Nevertheless, between 2000 and 2018, discontinuous urban fabric grew from 11,37% to 13,19%.

If collective housing is the increasingly dominant residential typology (49.9% of built dwellings), surfaces of units remained stable for the last century and relatively big at about 80m2.

A rise of units in collective dwellings is revealing itself: for the past century, 3 unit-buildings are in steady decrease. In the 1990's, buildings with 4 to 19 units increased, and from 2010, the part of 20+ dwelling unit buildings augmented.

Of the sealed surfaces in Luxembourg, 43,8 % are due to residential buildings (Fourmann and Tholl, 2019).

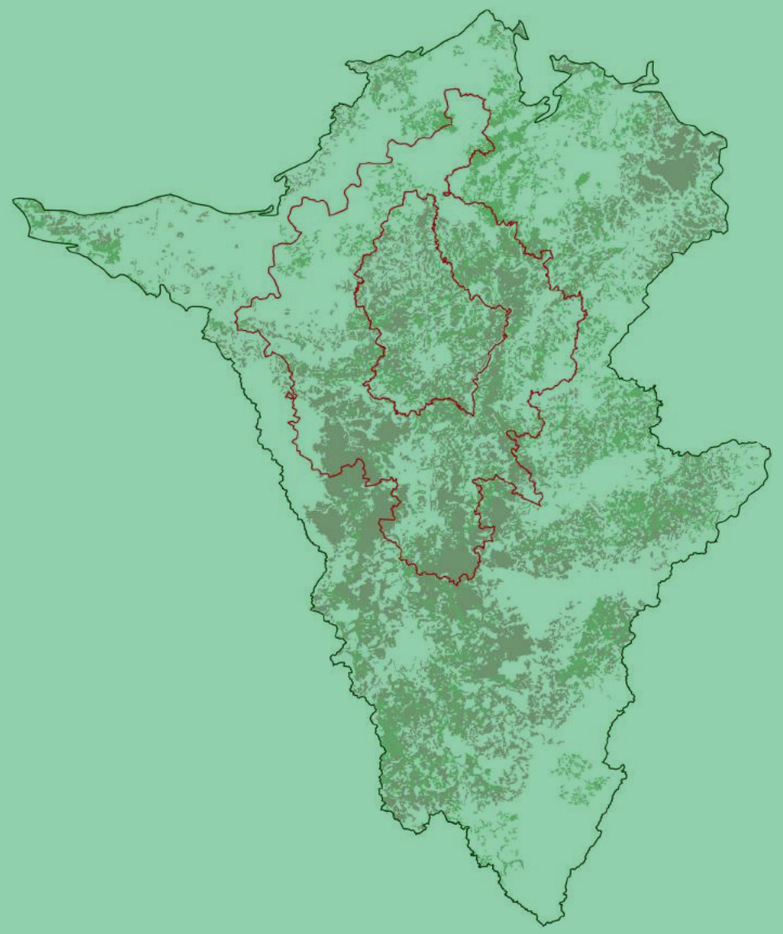
During a webinar held on April 29th 2021 the framework of the publishing in March 2021 of a note by the European Environmental Bureau, Pia Mamut, researcher at Münster University, made the case for the reduction of dwelling surfaces to 20m2/inhabitant in order to meet the Paris Agreement goals (Bauer-Babef, 2021).

Of the sealed surfaces in Luxembourg, 43,8 % are due to residential buildings.

(Fourmann and Tholl, 2019)


Mamer 2019


Mamer 2001



3 Footprint of our plates

3.1 Footprint of our diet

Food consumption is responsible for almost a third of total global emissions. This is not purely due to emissions from farming or packaging. It is an interconnected network of carbonising activities spanning from land use change, farms, animal feed, processing, transport, retail and packaging. That being said, land use change and agricultural practices are the activities which play the major role, and take up 71% of the emissions.

From a carbon footprint perspective; to put in comparison, the average diet in the US accounts for 2050 kgCO2-eq/capita/year, while a vegan diet is only 250 kgCO2-eq/capita/year.

From a land use perspectice; the current global diet requires more than 7 times the land a plant-based diet would consume.

These two factors in combination, make a shift in our diets, the most effective measure to take for reaching carbon neutrality targets of 2050 by means of nature-based solutions.

Role of food in global emissions

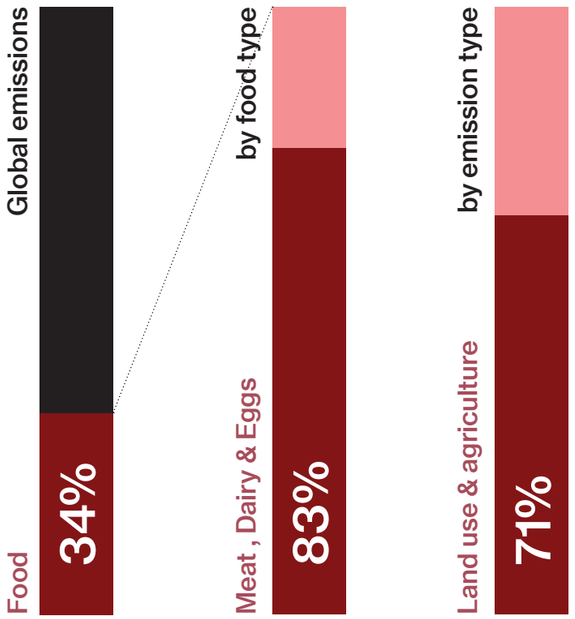


fig 8: Role of food in global emissions (Ritchie, 2020)

Current average diet; carbon price of our plate

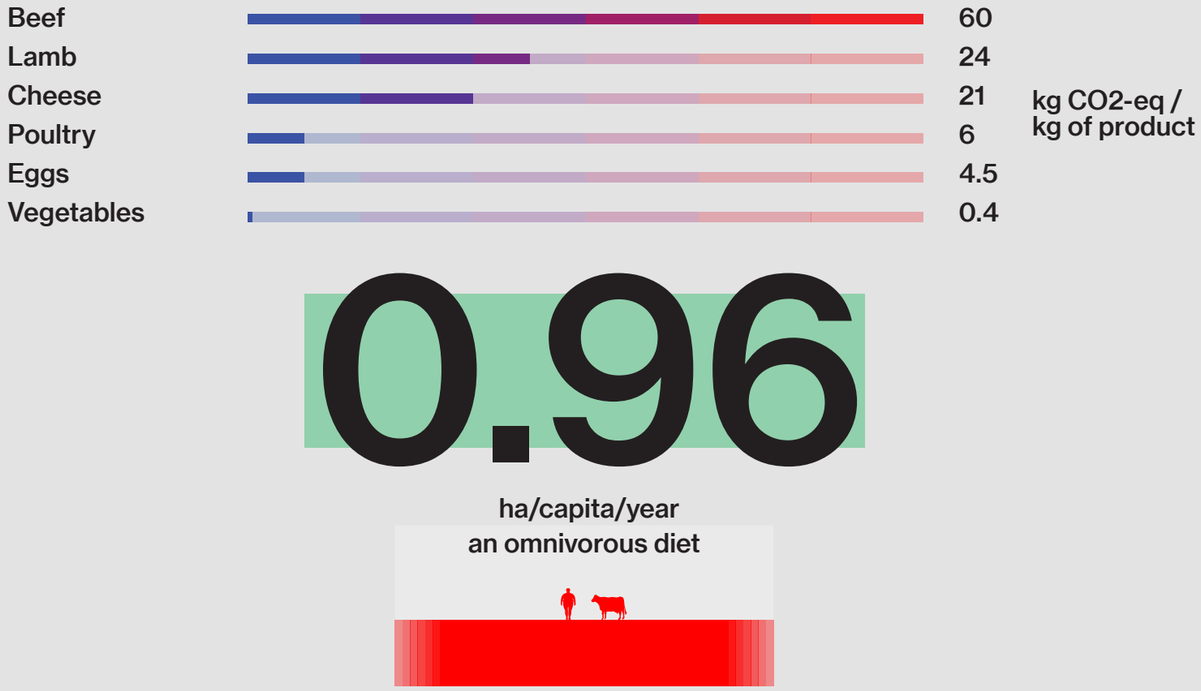


fig. 9: Food emissions for food type and equivalent land use. (Ourworldindata, 2018) (Peters et al., 2016)

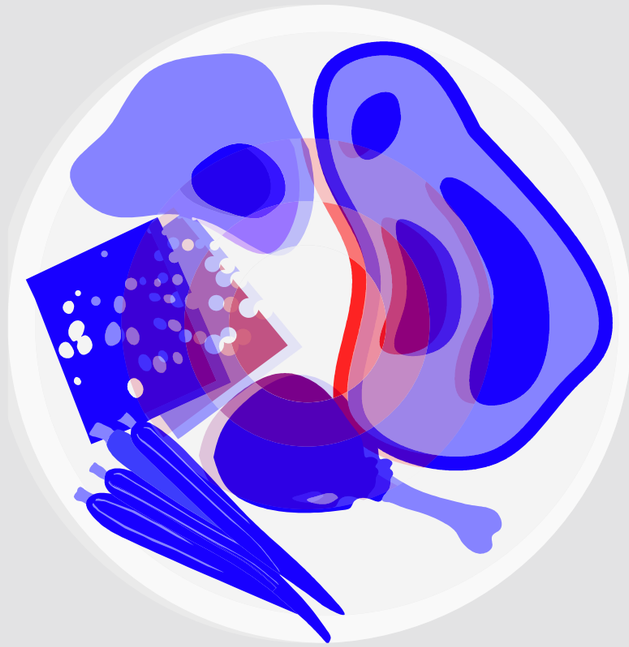
3.2 Comparison of possible diets

The shift in diet is a highly sensitive topic and it is due to this reason that it is either not discussed, or even when discussed only mild shifts are seen as plausible. This assumption is reflected in the EU's proposal for a diet shift which only recommends a modest replacement of consumption of beef and mutton with meat of goat (European Commission, 2018).

What we have decided to explore, is what we have called the bold shift. We do not believe in a total vegan diet for everyone. However, we anticipate a gradual shift to diets that have a much lower carbon footprints. This shift will not need to occur over night, and does not mean never eating meat or dairy. It is a step by step balancing act towards a healthy future for our ecosystem and a resilient future for our food security. By exploring the bold diet shift, we prove that it is possible for the region the feed itself, reduce its food-related carbon footprint, and enhance negative emissions beyond any of the current projections.

We prove that a bold diet shift driven by citizens, has the power to parachute the total emissions of the region towards neutrality.

Bold diet; carbon price of our plate



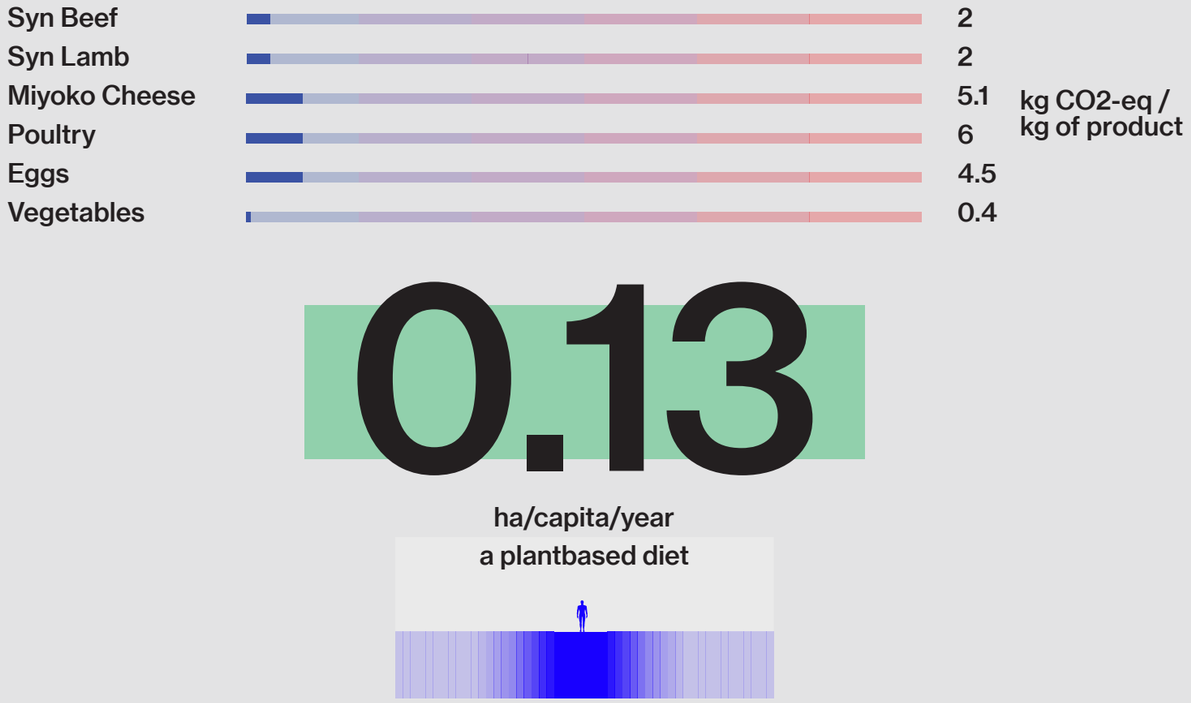


fig. 10: Food emissions for food type and equivalent land use. (Lynch et al., 2019) (Peters et al., 2016)

3.2 Comparison of possible diets; towards decarbonisation

For the purpose of making the calculation and presentations more tangible, we have translated the current dietary practices into two models, each representing one end of the spectrum of possiblities. The assumptions made to carry out this interpretation are layed out in the final spread of this chapter.

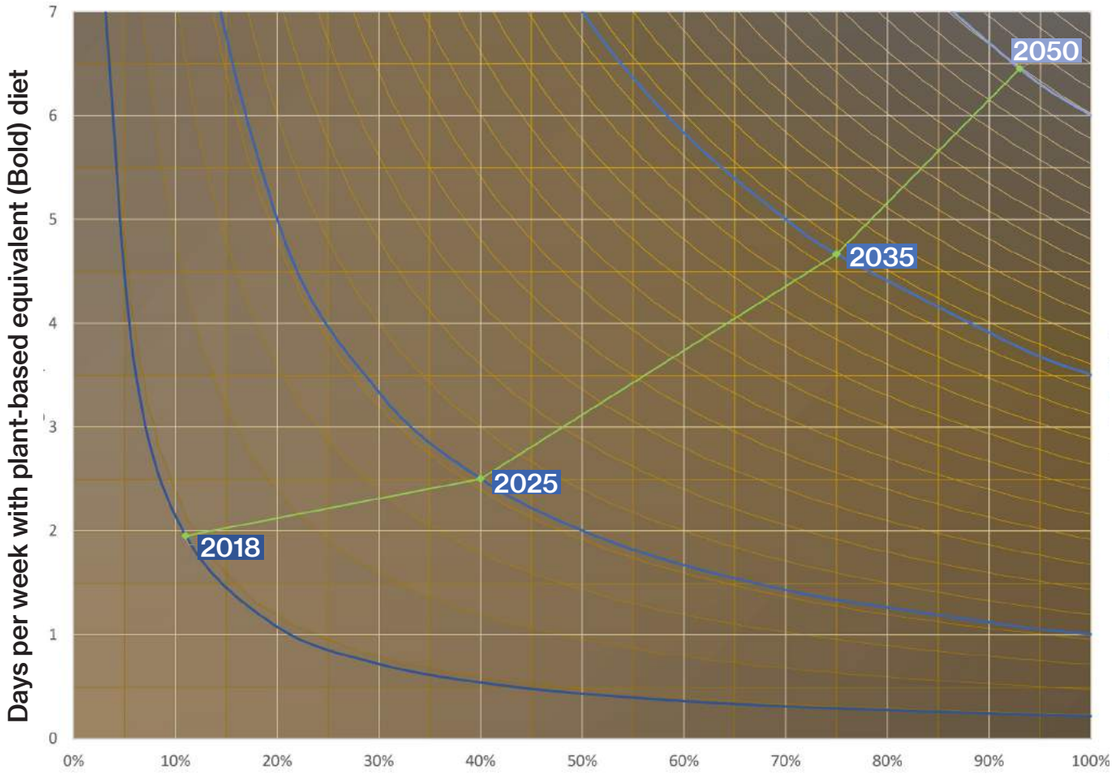
On one end of the spectrum we have the plant-based diet, which includes the current vegans, vegetarians but also other potential diets which are still within the bounds of a similar carbon footprint. For example, advances in foodtech have resulted in meat and dairy products produced in laboratories which mirror the taste and texture of natural meat, while greatly reducing the carbon footprint.

On the other end of the spectrum we have featured a diet called Omni100, which in simple terms is an omnivorous diet that includes a healthy balance of all ingridients.

All the other diets such as flexitarian and vegetarian, have been taken into account in this division as well. The process of translating diets to eachother have been explained at the end of the chapter.

The timeline on the next page shows the shift in 3 ways. On the right end vertical axis, we can follow the blue line to understand if everyone in luxembourg (100% of the population), had the same diet, they currently only consume 1 plant-based meal per week and the rest is omnivorous. This changes gradually to 6 days a week practice of a diet that has a footprint equivalent to a plant-based diet (Bold diet) by 2050. The top end horizontal axis, shows the percentage of the population which are fully practcing a bold diet. And finally the greenline represents a more nuanced and layered view of the shift.

3.3 Proposal for a bold diet shift;
dietrary habits of Luxembourg



We envision a fundamental but plausible dietary change by 2050, which is illustrated in the following graph. It shows how many percent of the population practice a diet with a similar footprint to a plant-based diet on how many days per week, while the remaining percentage eat meat daily. The blue lines stand for constant land use requirements, and the green line shows the evolution over time. We recognized other diets, such as vegetarian and flexitarian, by converting them into plant-baseds.

Starting from the latest survey from 2018 (TNS Ilres, 2020), we picture the following scenario, which builds on projected market shares of meat and alternative products (Kearney,2020) and political support:

Bold diet simplified explanation; if everyone had the same diet;
100% of the population will practice a bold diet on 1 day/week in 2025,

100% of the population will practice a bold diet on 3.5 days/week in 2035,

100% of the population will practice a bold diet on 6 days/week in 2050.

491,724 ha

of pastures & croplands of BFUR can be freed by 2050

The freed land can be cultivated towards decarbonisation rather than carbonising food production.

3.4 The 2000sqm farm;

According to the IBLA (Das Projekt – 2000m2.lu, 2019), on a global scale approximately 2000sqm of agricultural surfaces are available per person, and for Luxembourg, this is roughly the same (STATEC, 2019), even though in decrease.

However, the current agricultural surface use in Luxembourg unveils a behavioral pattern with considerable environmental impacts:

Of the 2000sqm per person, 1750sqm are used on average for livestock; either for its fodder, or for meat and dairy production.

Merely 250sqm, i.e. 1/8 of our 2000sqm are used for vegetables, fruit and/or cereals. Since 87,5% of Luxembourg's agricultural surfaces are used for animal products, the country relies heavily on imports of food.

The 2000sqm case study project launched worldwide and in Luxembourg by IBLA, NATUR&EMWELT and CO-LABOR at the Kockelscheuer, aims at demonstrating a sustainable use our available soil and the conditions under which we can feed of this land.

The project splits the surface in 2 parts:

1. 1000sqm are available for production, of which:
- 650sqm are for human use,
- 350sqm for animal fodder.

This is sufficient to cover the per capita demand in eggs, but not in chicken or pork meat.

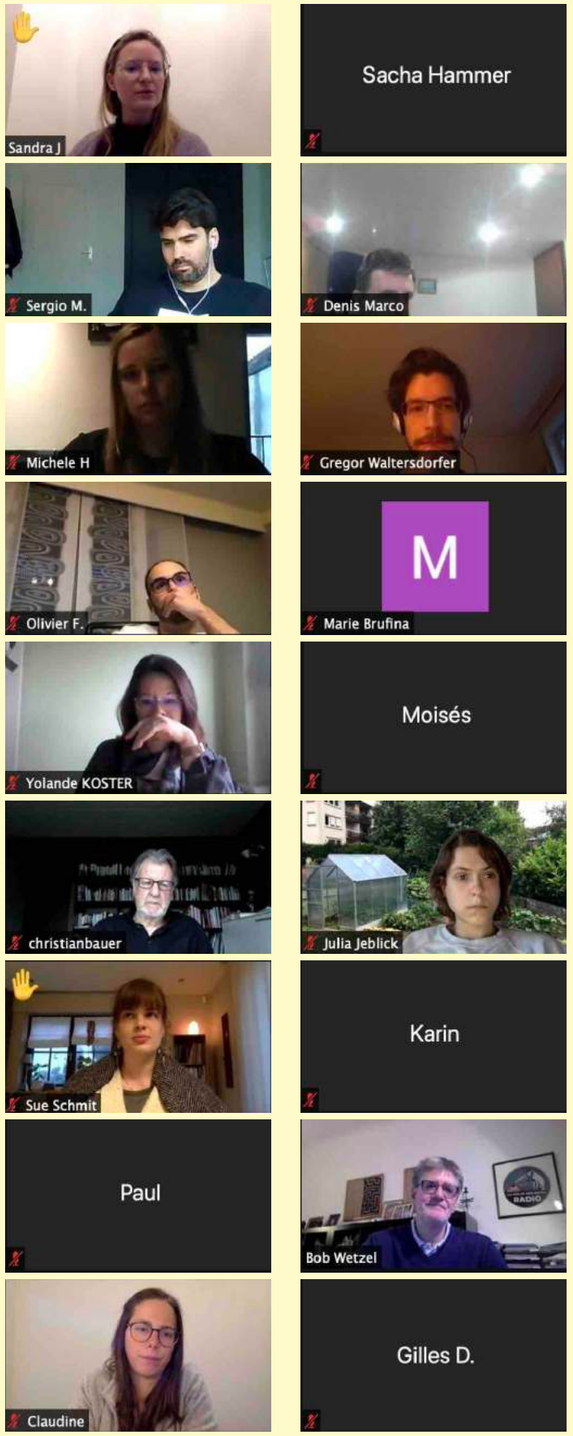
2. 1000sqm remain pastures, characteristic for Luxembourg's landscape, and are used for dairy and meat, but especially biological manure/fertilizer.

This split implies major diet shifts, especially a drastic reduction in meat and dairy, in order to be able to feed of this land.
Hence, the current meat consumption of ± 100kg/capita/year needs to be reduced to ≤55kg/capita/year in order not to over-use space.

Since 87,5% of Luxembourg's agricultural surfaces are used for animal products, the country relies heavily on imports of food.

3.5 Citizen Committee's feedback;

In a closed session with the Citizen Committee, we discussed the carbon footprint of food with the members and shared with them our outlook on diet change. In addition we asked them to fill a questionnaire so that we better understand their eating habits and their beliefs about the future of food in the region. The session was filled with insights and interesting questions for us. Some of the points discussed are featured in the opposite page in form of quotes. And the questionnaire response can be found in the appendix to this dossier. We would like to continue our conversation with the committee and work with them in developing the in depth proposals of the 3rd stage especially regarding community gardening, consumer habits and role of private gardens.



"Howcome we have practically no local vegetable production?"

Karin
citizens committee

"Most people will tend towards low-budget solutions"

Claudine
citizens committee

"Could there be a community supported agriculture?"

Sue
citizens committee

"Could quality food be made less expensive?"

Julia
citizens committee

"Gardens produce so much harvest, but so much is thrown away, because the sharing or distribution network is not in place"

Yolande
citizens committee

"If everybody goes for soy milk, where is the soy coming from? "

Sandra
citizens committee

3.6 Drivers of dietary change

The change has already started: sales of meat substitute food based on soy and peas grow by roughly 10% per year (Fleischatlas, 2021). Similar to the development during the energy transition, it is only a matter of time until cultured meat becomes cheaper than animal-based meat. Both, meat substitutes and cultured meat, require significantly less arable land.

We expect that raised awareness of consumers on meat-related health concerns, such as the use of hormones and antibiotics in meat production, processed meat being carcinogenic (WHO, 2015), and increased risk for cardiovascular diseases and diabetes, will accelerate the change in user preferences. Additionally, as young people are more affected by climate change, the generational shift will reinforce the transition (Fleischatlas, 2021).

Dietary change can get a boost, when the production of “Bold” food gets incentivized through carbon tax or credits for sequestrated carbon, and thus these products become cheaper than animal-based products.

As more options for meat substitutes and cultured meat will become available and demand will increase as well, restaurants, food trucks, grocery stores, canteens, magazine and book publishers and (TV) chefs will react to these trends, and by that make bold diets convenient, abundant, interesting, and culturally ingrained.

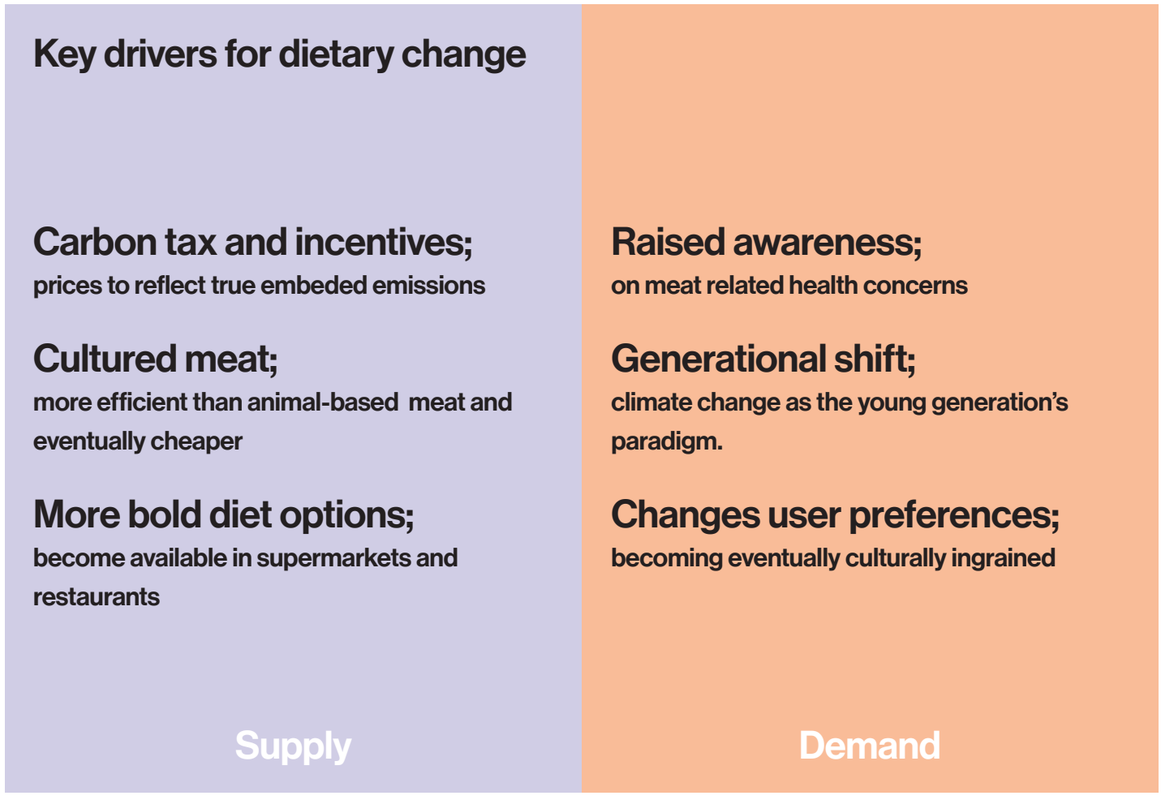


fig. 12: Key drivers in dietary change.

3.7 Role of politics

Politics need to support forward thinking farmers and other business actors in this transition so that Luxembourg’s society and economy can benefit from this global development as a whole.

Farmers need to be freed from an outdated subsidy system focussing on food security, leading to overproduction of carbon-intense food. The current system was absolutely necessary after WW2, however led to conserved agricultural structures and financially dependent farmers (1), which does not appreciate their contribution to society.

ad (1): Financially dependent farmers: without subsidies farmers would not be profitable, and in most cases profit is the farmers’ income; they don’t have a salary. (Landwirtschaft2.0, Ein Plädoyer für die neuausrichtung der luxemburgischen agrarpolitik, 2017)

New, smart and flexible subsidy systems based on carbon sequestration and other ecosystem services allow farmers to find economically viable opportunities and niches, which fit their individual conditions and available resources. A clear national agricultural long-term strategy provides planning reliability to farmers when investing in this transition.

Politics can establish whole value chains for meat substitutes and/or cultured meat in Luxembourg: providing and channeling green investment capital, campaigning for soy and pea cultivation as raw material respectively nutrient solution for culturing meat, and attracting know-how for food processing.

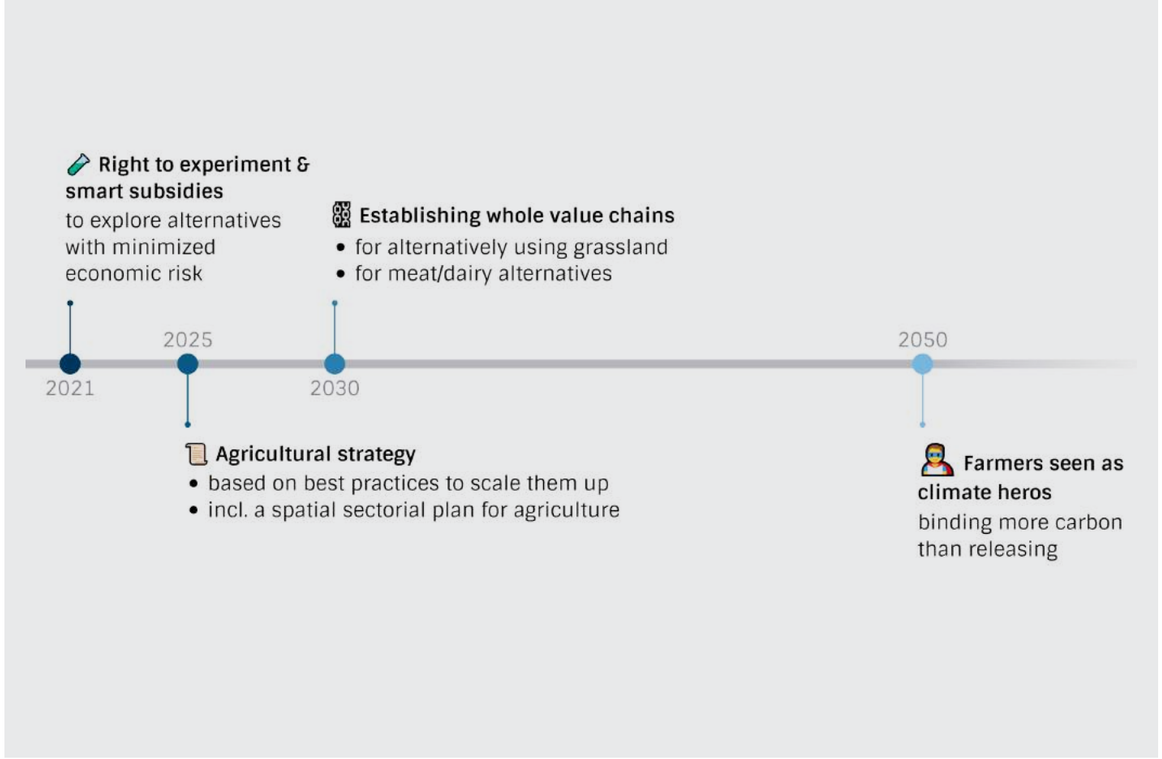


fig. 13: The role of politics.

3.8 Assumptions and uncertainties

In order to combine different diets into plant-based, we assumed that a vegetarian diet translates to eating vegan on 5.5 days/week in terms of land use. Uncertainties arise from flexitarians. TNS Ilres categorized participants of the survey as flexitarians, if they sometimes have days without eating meat. 18% of the participants fell into this category. In order to be precautious we valued their diet as being little plant-based (less than 1day/week vegan), due to the consumption of dairy products (TNS Ilres,2020).

Further, we envision to slightly surpass the projection by A.T. Kearney due to political interventions, which estimates that cultured meat will have a share of 22% in 2035 and 35% in 2040 in global turnover of meat and meat substitutes (Kearney,2020). Additionally, we assumed that cultured meat translates to 5.5 vegan days/week in terms of land use, such as the vegetarian diet, since it is not clear how substitutes for dairy products will be accepted. There are studies which estimate a 95% reduction in land use for cultured beef compared to animal-based beef (The Good Food Institute, 2018).

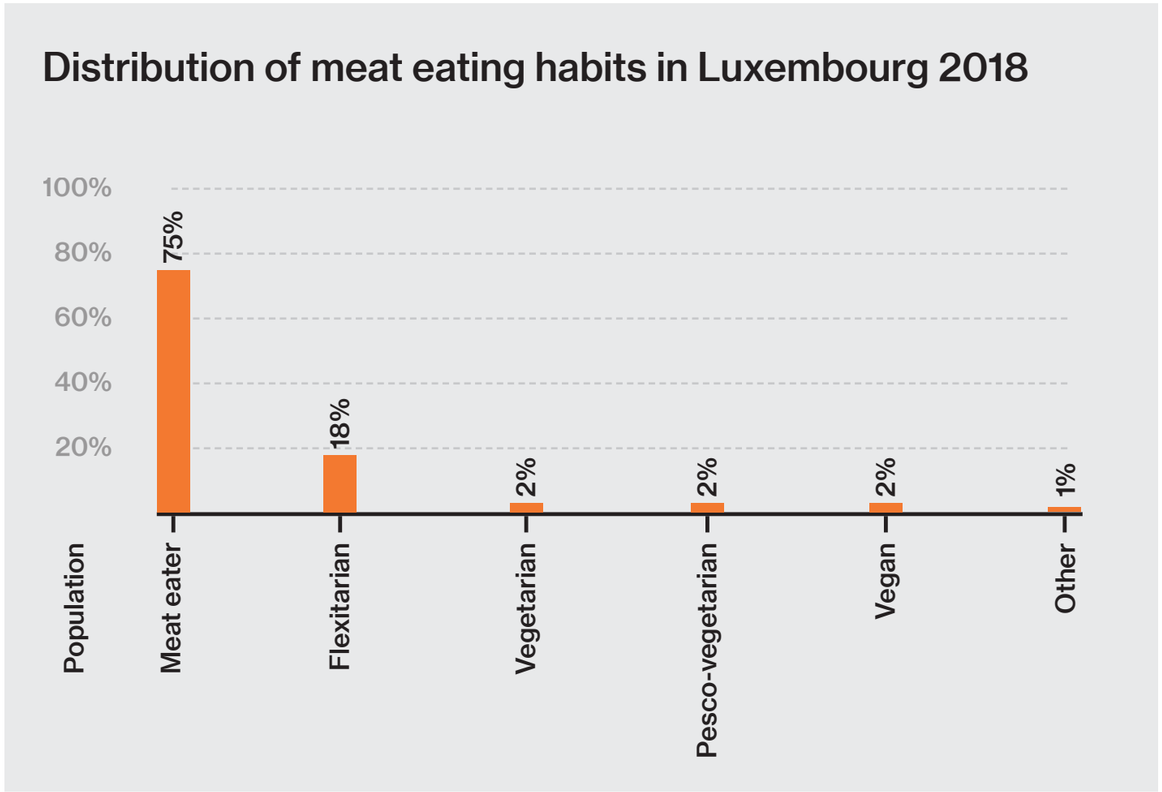


fig. 14: Distribution of meat habits in Luxembourg in 2018. (Kearney,2020)

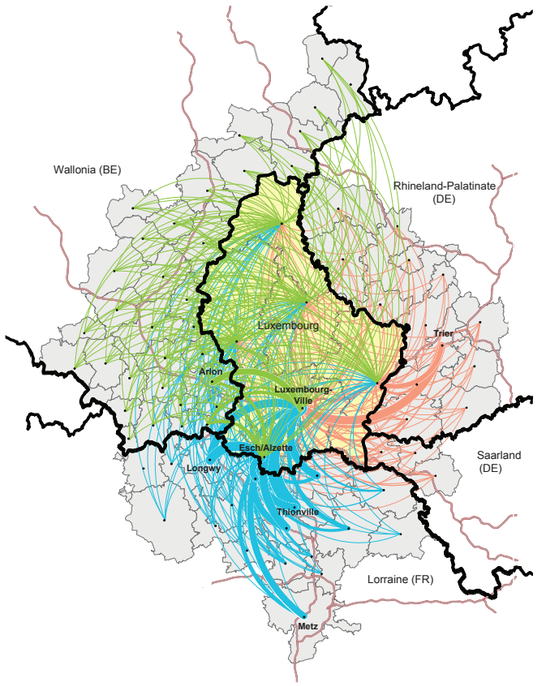
4 Bio-functional region (BFUR)

4.1 A biofunctional outlook;

For the territory to be resilient in face of climate change, it needs to foresee a management framework which integrates natural conditions, as well as economic factors.

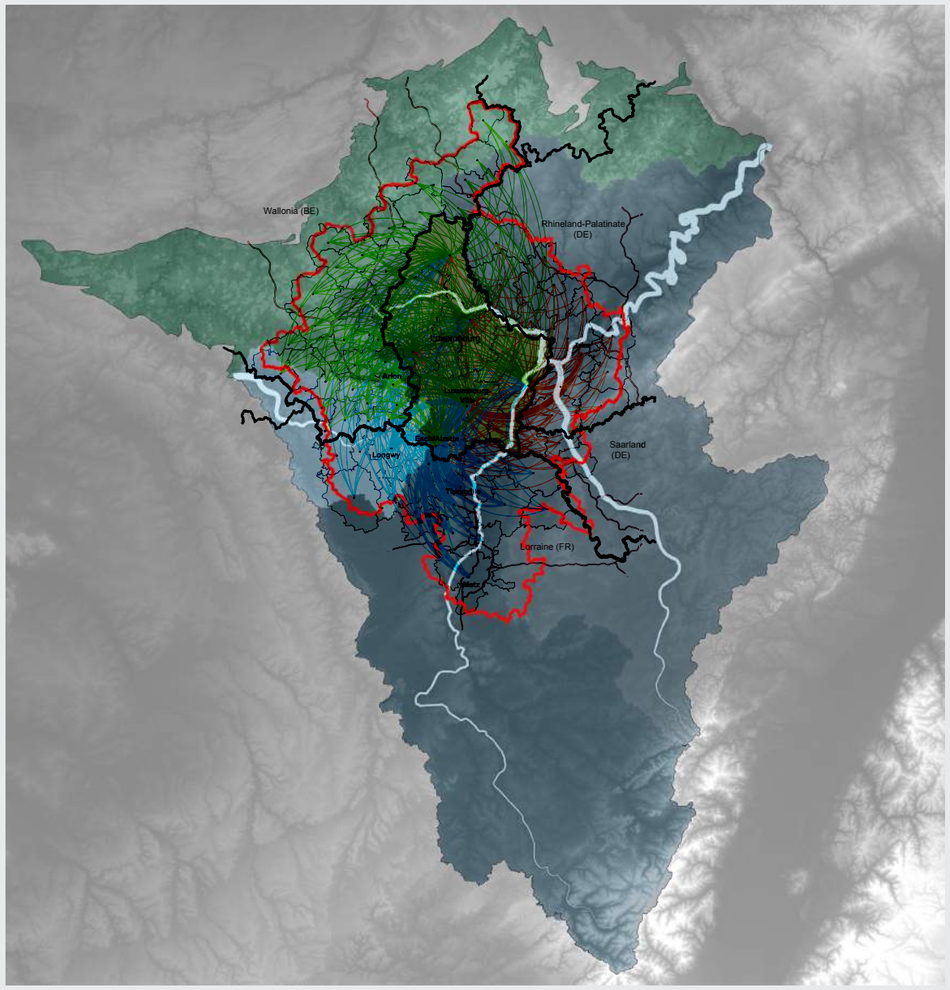
We believe the coexistence of a bioregional outlook and functional outlook will offer the possibility to bring together different land use and livelihood systems towards decarbonisation.

The Biofunctional region, is a geopolitical entity born out of the culmination of economic and natural interests. It allows for us to plan for prosperous and resillient communities around resources.



Functional region
surface: 1156419 ha
population: 2.00 M

fig. 15: Functional region and cross-border fluxes. (LISER,2017)



The biofunctional region;
surface: 4219347 ha
population: 4.87 M

4.1.1 Alignment with Greater Region's SDC

The Biofunctional Region (BFUR) concept developed by our team is fully in line with the Spatial Development Concept (SDC) of the Greater Region in both scale and strategy.

The SDC (Interreg, IPS-TUK, 2020-2021) is the latest regional planning concept of a regional development process which was launched in 2008 by the ESPON Metroborder project. (ESPON, 2010)

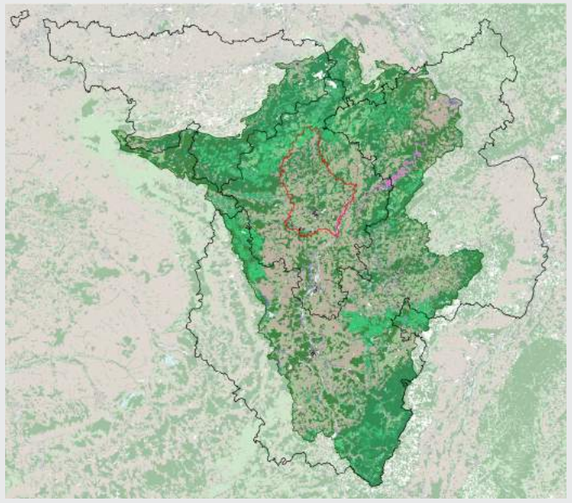
SDC aims at 3 cooperation scales & levels:

1. Greater Region as a whole

2. Metropolitan Region around Luxembourg, or: the Functional Region

3. Border areas

BFUR is set within the same 3 scales and levels, defined by a specific identification of the shared resources and landscape entities embedded in the Greater Region.



BFUR outlines an evidence-based context beyond a fluctuating economic definition of the Metropolitan/ Functional Region.

BFUR's 4 strategic axes of SDC

1. Resources

Steering of transformation processes to save resources and use them efficiently: a biofunctional vision.

• BFUR is by definition shaped by cross-border resource and landscape entities (soil, water, flora)

• This vision fosters new interdependencies, cooperation & alliances.

• BFUR highlights the capacity of soil in the transition towards a decarbonized territory and sketches out new potential value-chains and social developments: from environmental education to start-ups and shifts in agroforestry.

2. Services

Improvement and implementation: Towards a Region that can feed & build itself.

• Aiming at a territorial vision of shared resources, BFUR illustrates the potential of short supply & demand channels: A region that can feed & build itself.

• This capacity demands new cross-border cooperation & services, making its citizens benefit (and live) from the region's supplies.

3. Transition

Development of resilient and decarbonized rural and urban areas: Productive synergies between a strong & sustainable agriculture and a new building culture.

• By identifying the potential of soil, both for production and carbon sequestration, BFUR problematizes the need for positive change in agriculture.

• As a consequence of highlighting the necessity for resilient and local agriculture, a change in building culture becomes evident: towards limiting land take yet enabling development by new, alternative urban strategies and architectural typologies.

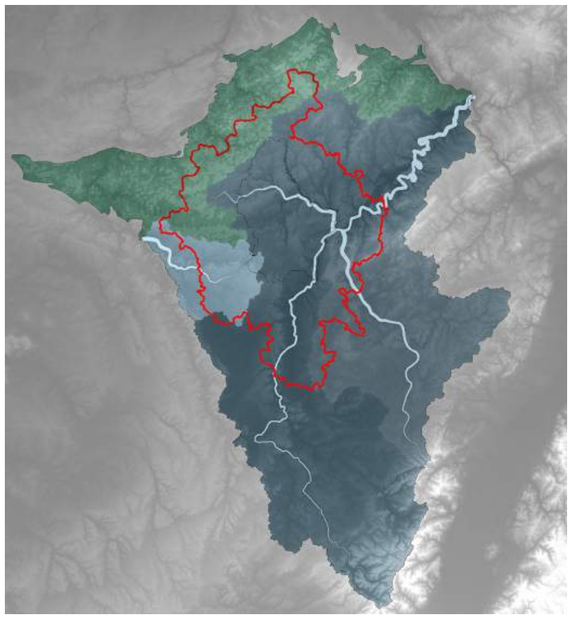
• Eventually, new hybrid and productive neighborhoods will develop from and within existing built patterns, mobilizing local resources as supply chains.

4. Cross-border participation

Elaboration of Greater-Region projects and structures involving the population: the power of upscaling local initiatives, soil&people.

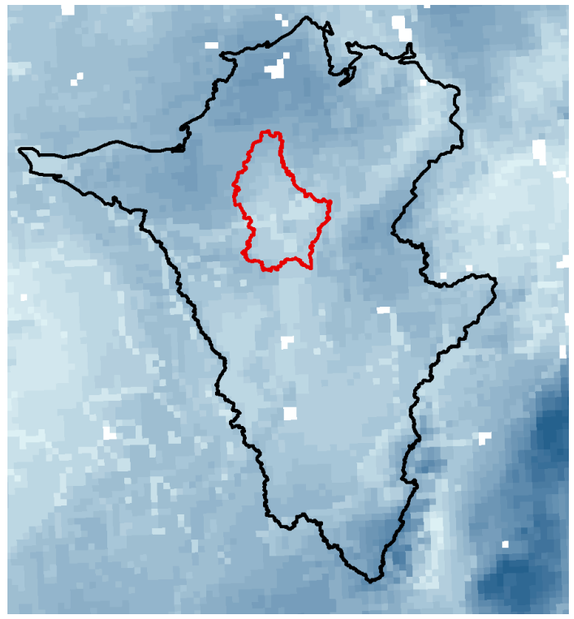
• Beyond the capacity of soil, BFUR problematizes the need for citizens evolvement as on-ground know-how and the power of small-scale initiatives.

4.2 Bioregional key factors;



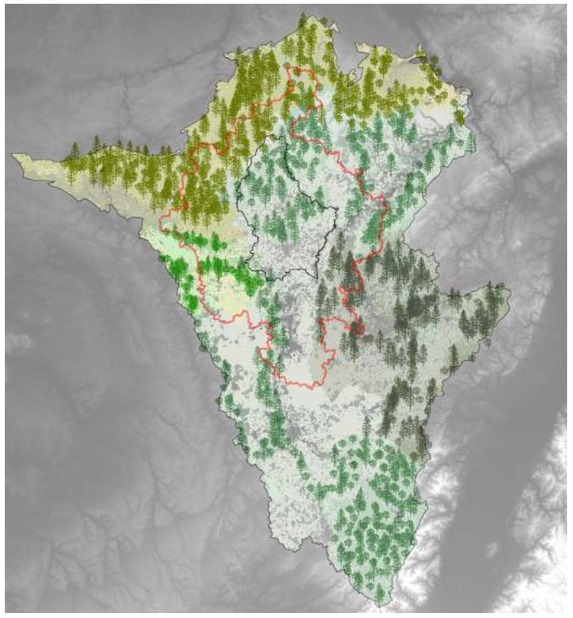
Geohydrographical position

The functional region is positioned within the Hydrographic basins of the Mosel, Saar and Chiers and the forested highlands of the Ardennes.



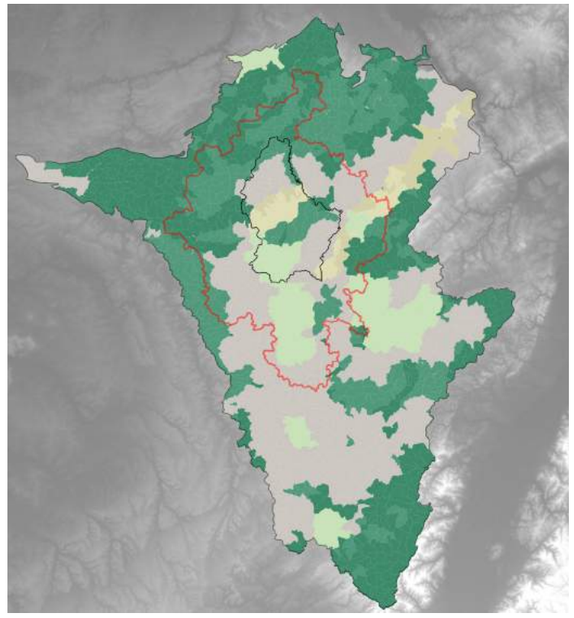
Diversified abiotic conditions

Within the bioregion there is a diversity of abiotic conditions resulting in differences in available water resources, temperature and soil conditions.
This abiotic diversity offers different conditions that are optimal for the sustainable production of different natural resources.



Inter-connected Eco-services

Land use in one location has a direct effect on the land use in another location. The systemic area of influence for natural resources well extends the boundaries of the functional region into a biofunctional region.
Forests on high elevation get the main share of the bioregions precipitation and act as a sponge slowly releasing outflow during the year to downstream agricultural areas.
By rather working with nature than against it natural habitats provide services such as pest control for cropland by bird populations.
Less use of pesticides and fertilizers and small scale local water retention practices by farmers in turn create more sustainable conditions for biodiversity to flourish.
To achieve resilience and productive landscapes in the face of climate change this interconnectedness of ecosystem services is a guiding factor to consider during spatial planning.



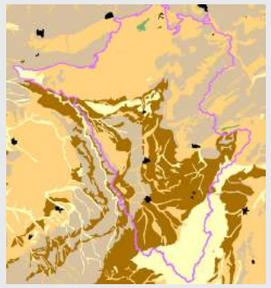
Diversified resource potential

Together the systemic functionality of inter-connected ecosystem services and the diversity of abiotic conditions result in areas with different resource potential.
The surface area of the bioregion can provide the population of the bioregion all food and wood it needs in a self-sufficient sustainable zero carbon manner. Resulting in a healthy and regenerative landscape. Removing the international ecological footprint the region currently has of importing natural resources and the accompanied devastating effect on global biodiversity.

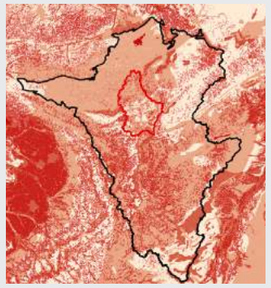
4.3 A biofunctional future;
Organising crop production in relation to the climate of the region in 2050, considering the suitablity of climatic & abiotic conditions.

Soil

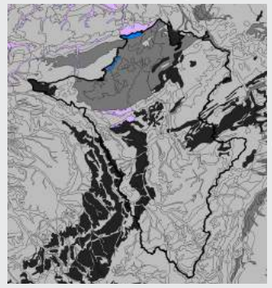
natural soil texture



current SOC

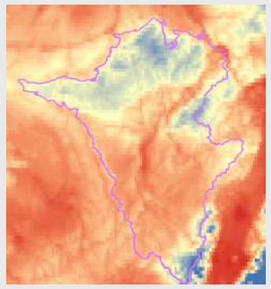


soil limitations for agriculture

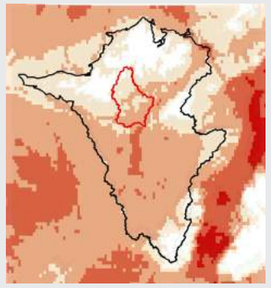


temperature 2050 RCP 8.5

Temperature (°C)



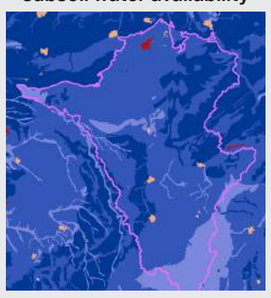
suitable growth zone



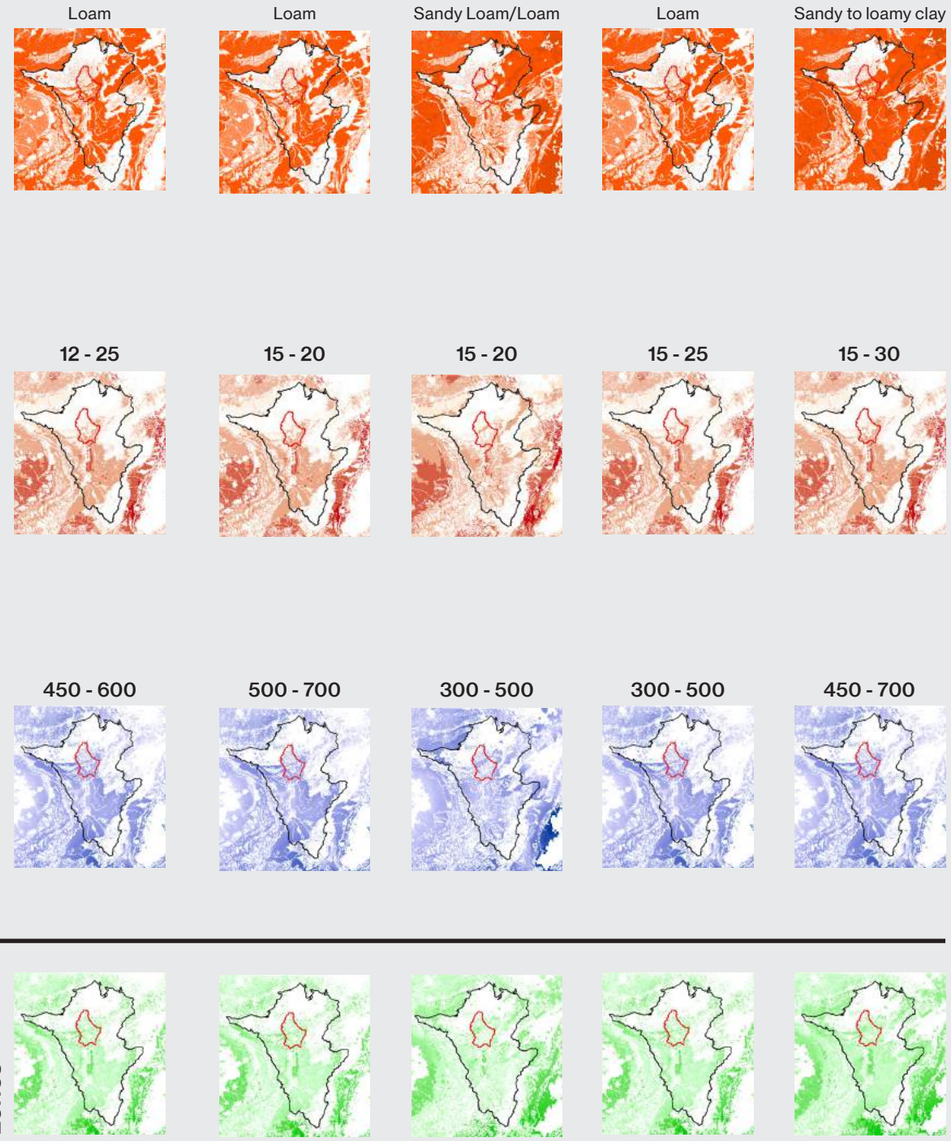
net precipitation growing season

Water availability (mm)

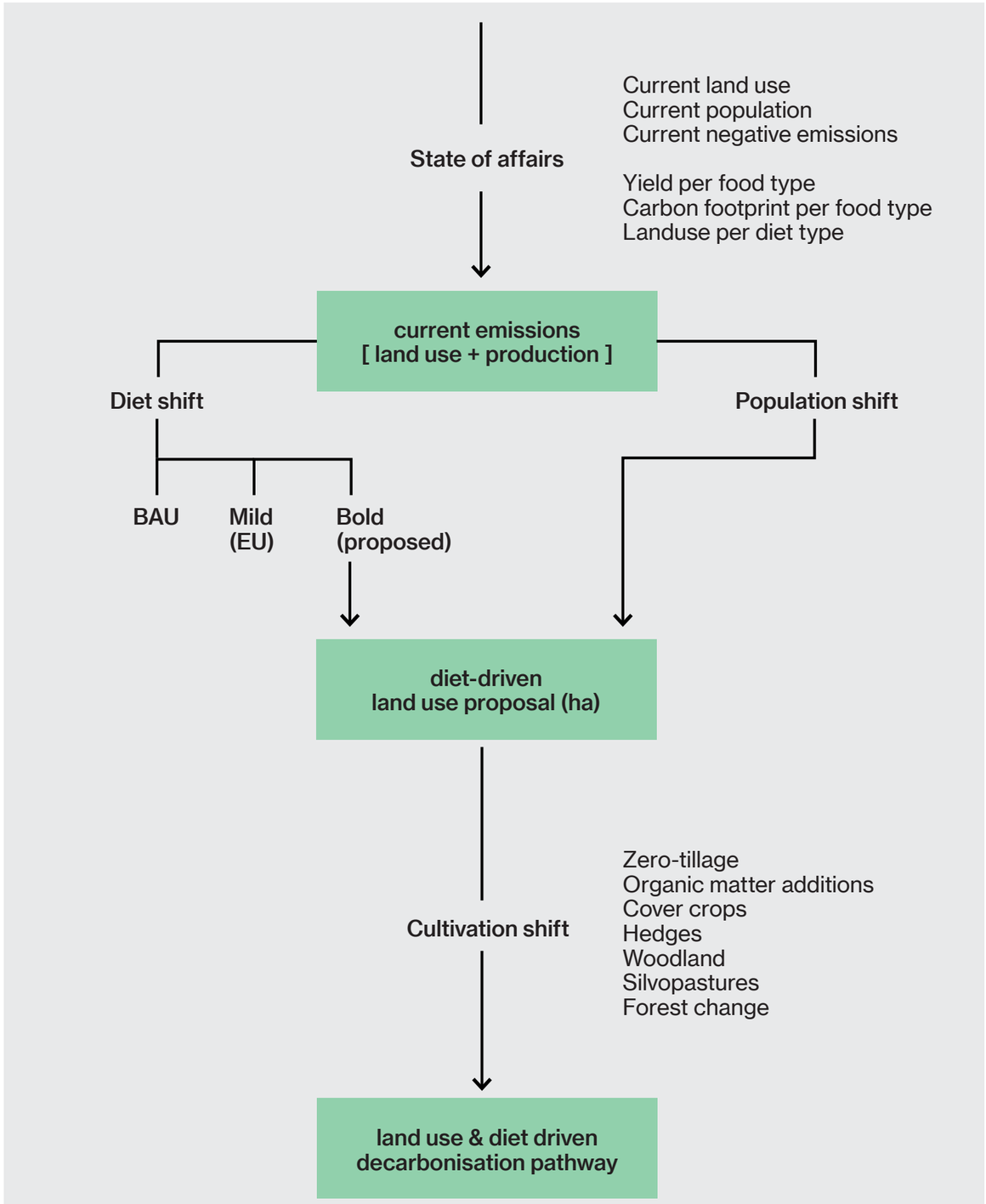
subsoil water availability



Main crop groups	Grains	Vegtables	Pulses	Sweeteners	Oilseeds
Crop proxy	Wheat	Potato	Bean	Sugarbeet	Soybeans
Soil	Loam	Loam	Sandy Loam/Loam	Loam	Sandy to loamy clay
Temperature (°C)	12 - 25	15 - 20	15 - 20	15 - 25	15 - 30
Water availability (mm)	450 - 600	500 - 700	300 - 500	300 - 500	450 - 700
Production suitability zones					



4.4 Flowchart of transition; building blocks of going carbon negative



4.5 491,724 ha of freed land;

One of the key impacts of the bold diet shift, is the land surface that will become gradually available for repurposing. As we had set food autarky and maximum sequestration as a goal, we chose to transform most of the excess pastures to forests. This shift enhanced our sequestration projections, and the wood output of the region. Another question we had to respond to was the choosing which pastures to be relieved from food production. Below we have represented some of the explored scenarios for making the choices above based on our adaptive land use tool for the Biofunctional region. We took lessons from each one of them to find the desired balance between favorable agricultural production zone, food logistics, ecological integrity both in mosaic habitat and large scale continuous natural habitat.

productive land use concentrated as closest to all urban fabric

This model favors small scale local food production and consumption but ignores soil conditions and more favorable climatic areas for food production.

productive land use concentrated as closest to urban cores

This model favors large scale food production and coincides to some extent to the areas with good soil conditions and favorable climatic areas.

new forests closest to existing forest

This model favors small scale growth of fragmented natural habitat and results in a mosaic landscape but being isotropic it misses out on the potential of large scale continuous natural habitat with minimal economical activity.

“Currently 75% of harvest from arable land is turned to feedstock for our dairy cows.”

Soil & People’s farmers roundtable

4.6 A biofunctional land use tool;

As the climatic conditions and the anticipated speed of diet shift and cultivation shift are variable throughout time, and due to the fact that the excess land from diet shift could be planned in a variety of possiblities, we have prepared an adaptive tool for managing the natural landscape of the biofunctional region.

As shown on the next page, this tool takes societal factors of change such as population and diet as well as spatial factors of change such as zoning plans and proximity as input, in addition to guidelines for what are the priorities for the excess land. It will then produce a new distribution of natural land use in the form of a strategic regional plan.

an adaptive tool for managing the natural & productive landscapes of the biofunctional region.

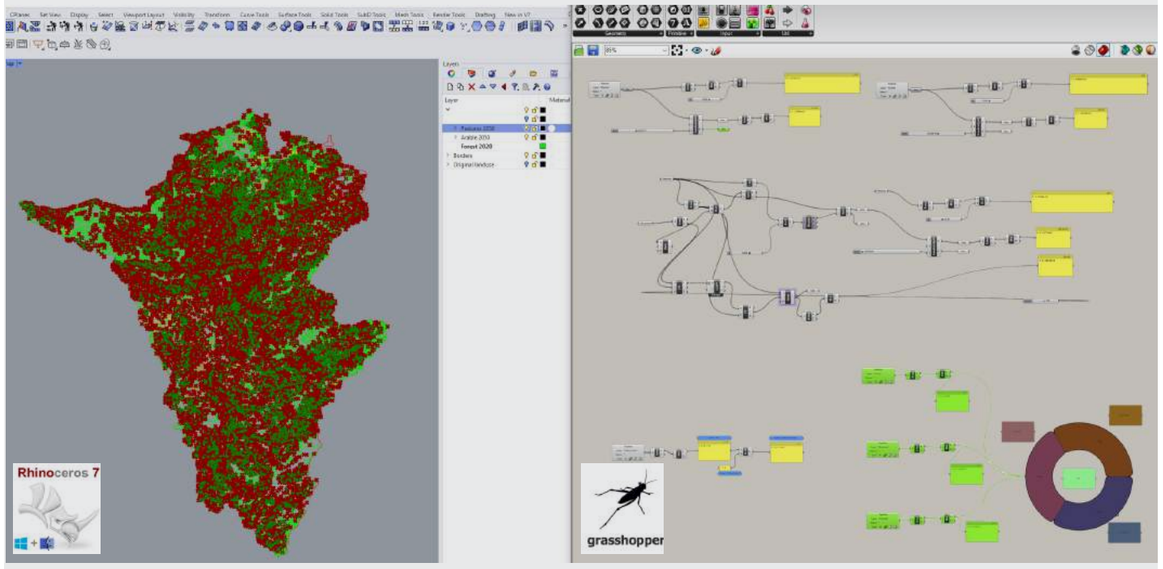
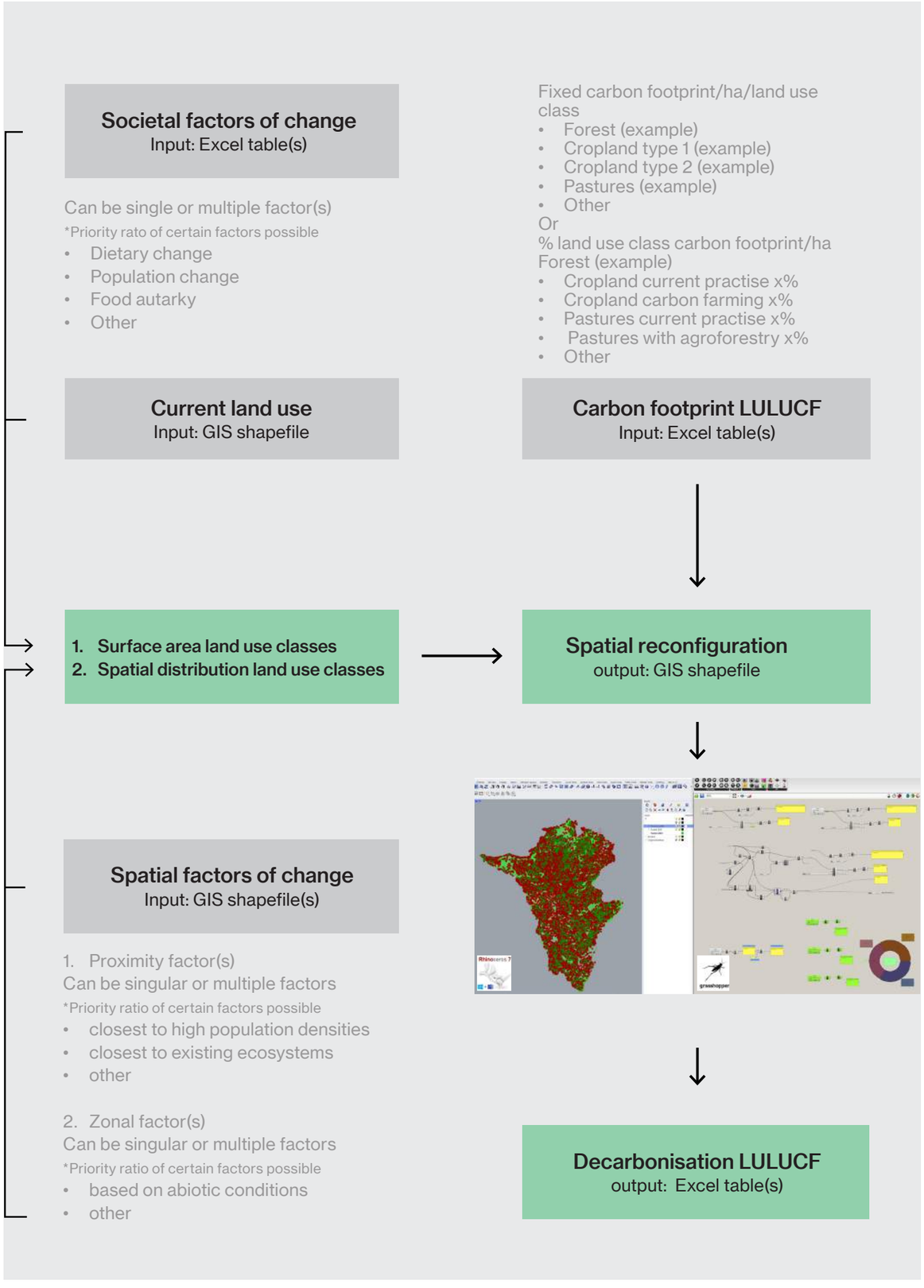
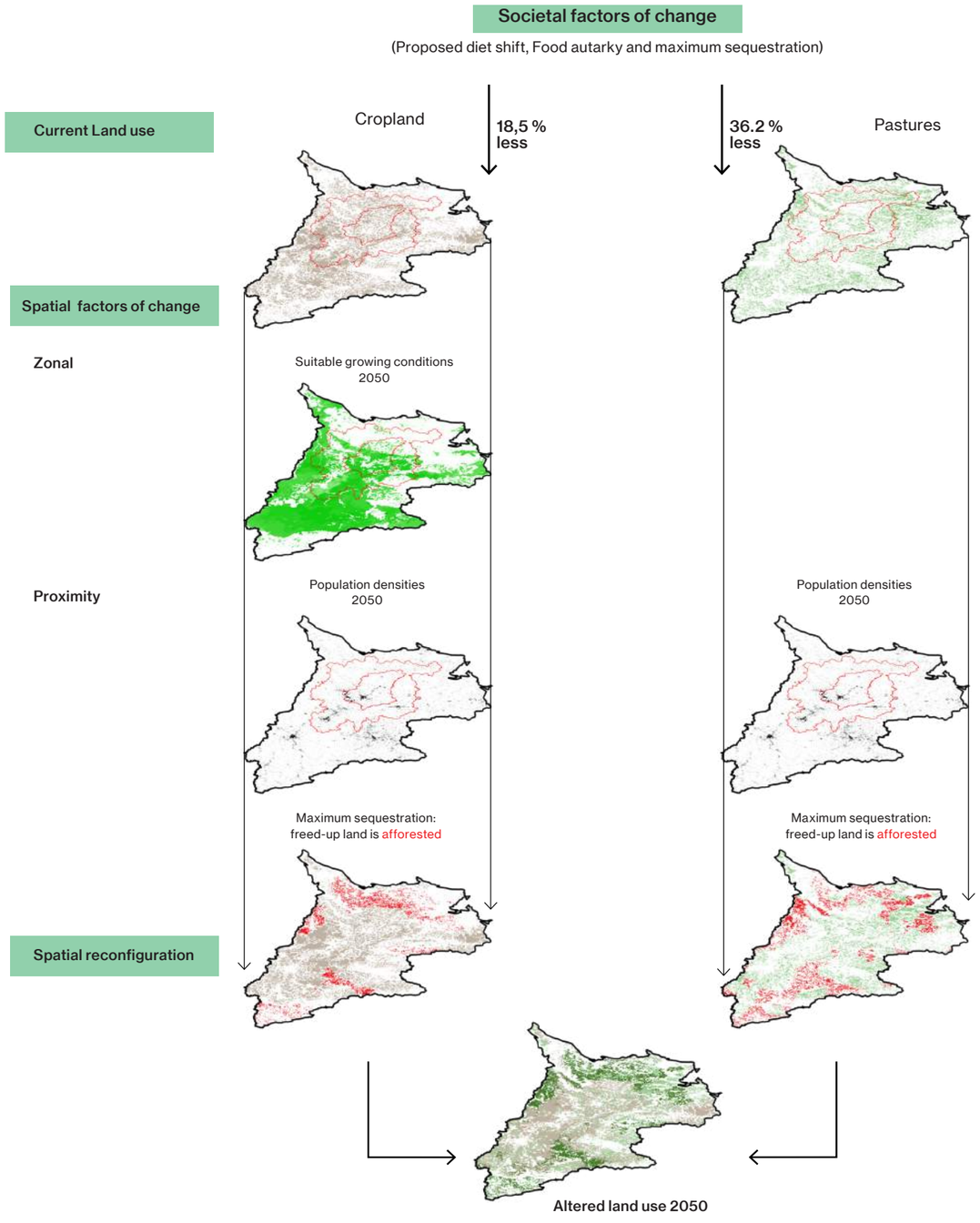


fig. 16: The adaptive tool for managing the landscape of the biofunctional region Rhinoceros + Grasshopper.



4.6 A biofunctional land use tool;
adaptive parametric tool: used factors



current land use

Population & Bold diet shift

land freed up due to diet change

maximise sequestration & wood export
[transform excess pastures to new forest]

maximise biomass and food export
[transform excess pastures to new cropland]

- distribution of new forests to connect to existing forests
- distribution of agricultural production based on abiotic conditions
- distribution of agricultural production near urban cores

diet-driven
land use proposal (ha)

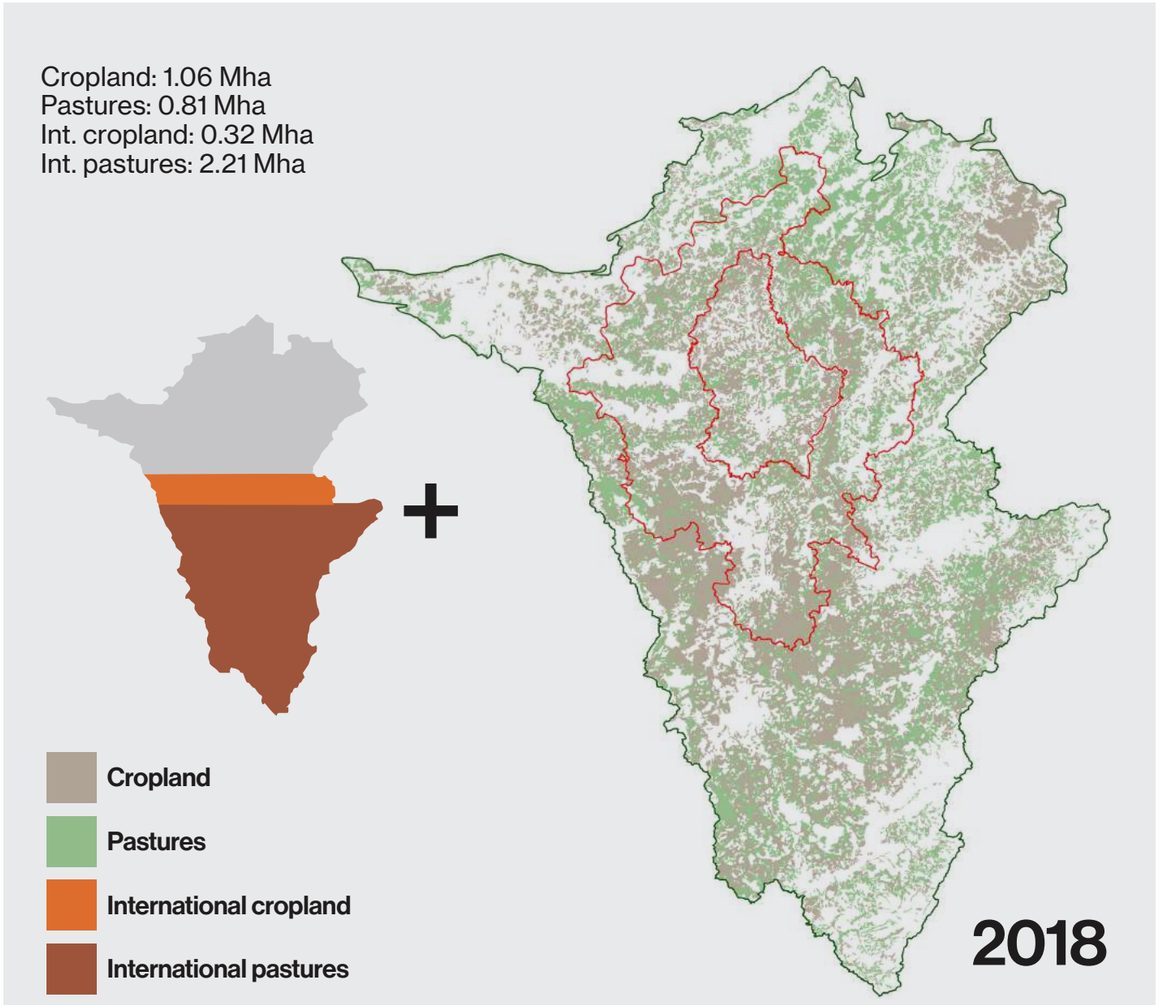
4.7 Agricultural footprint;

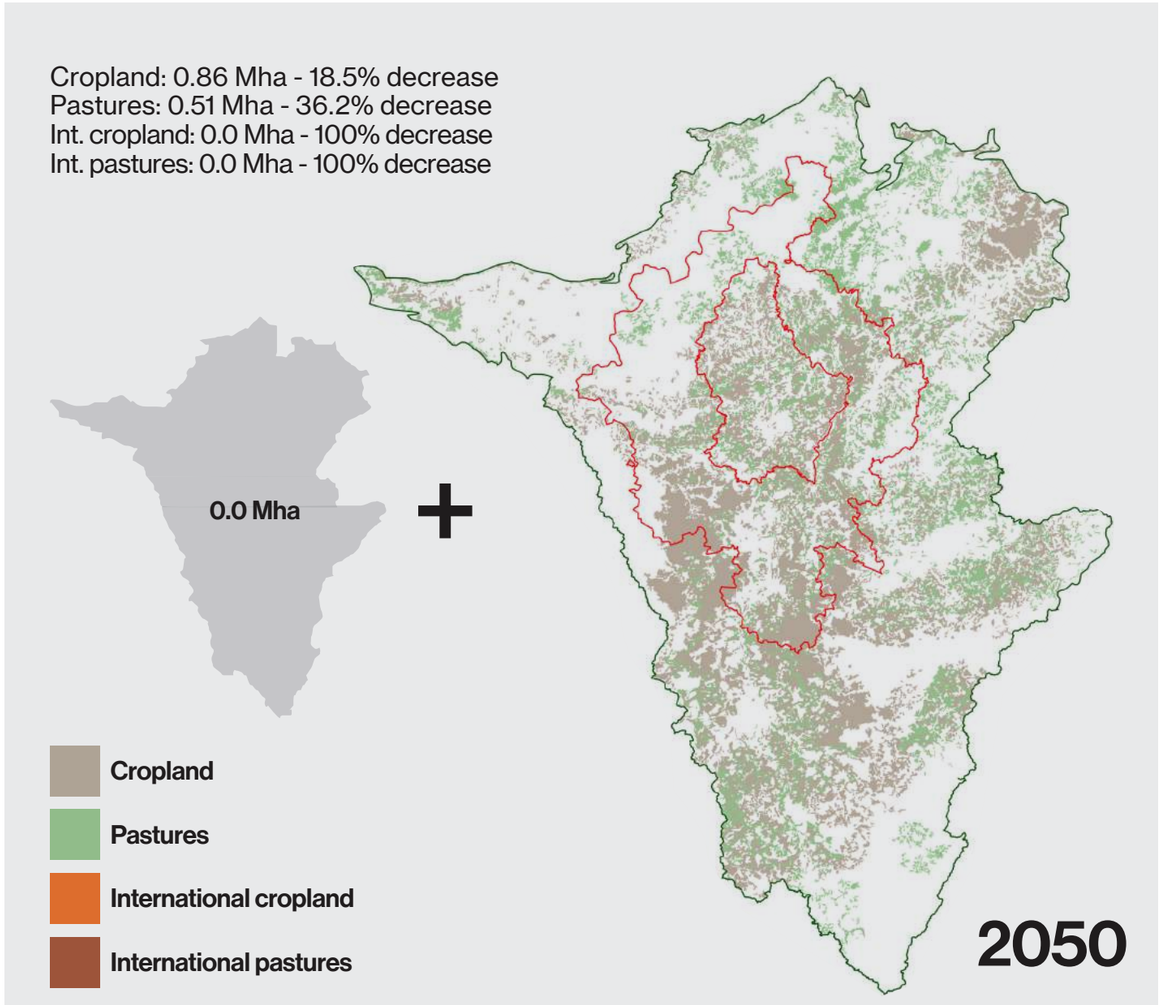
The land-use needed to feed the BFUR based on the current diet well extends the regions' carrying capacity. The region would still significantly rely on international production mainly relating to meat production. With ongoing problems such as international deforestation, biodiversity loss and desertification only to increase parallel to local population growth.

With the bold diet shift the region can feed itself and reduce its agricultural footprint in favor of local forest expansion. But more importantly the region would not rely on international food production anymore in favor of global biodiversity and natural habitat protection.

-3,3 Mha

decrease in land footprint of food consumption





4.8 Forestry footprint;

The BFUR is already heavily forested in relation to other Western European regions. But even so the forests are still fragmented and in bad health.

With the aim of maximum sequestration all the freed-up agricultural land is afforested creating large scale continuous natural habitat on the highlands (Ardennes and Vosges among others) with additional forest stepping stones and corridors in the agricultural lower areas. In addition agroforestry practices increase the total amount of trees and ecological habitat considerably,

+1 Mha

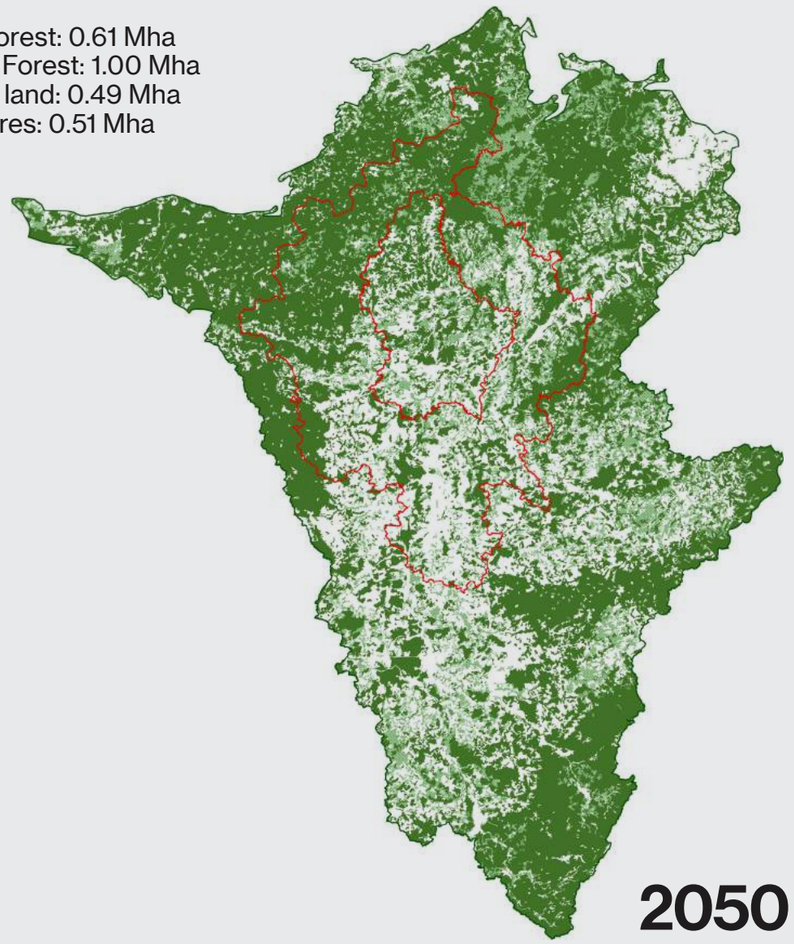
increase in surface area of forestry & agroforestry

Evergreen production forest: 0.61 Mha
Decideous Forest: 1.00 Mha

Forest

2018

Reforested decideous Forest: 0.61 Mha
Regenerated decideous Forest: 1.00 Mha
Afforestated agricultural land: 0.49 Mha
Agroforestry/silvo-pastures: 0.51 Mha



Agroforestry

Forest

2050

The forest-based sector will be an essential part of Europe's transition to a modern, climate-neutral, resource-efficient and most importantly, competitive economy.

Virginijus Sinkevicius,
European commissioner for environment, oceans and fisheries
(Growing the forest bioeconomy,2020)

Europe's forests could help to mitigate the EU's carbon emissions up to 20% by 2050.

(Nabuurs et al., 2017)

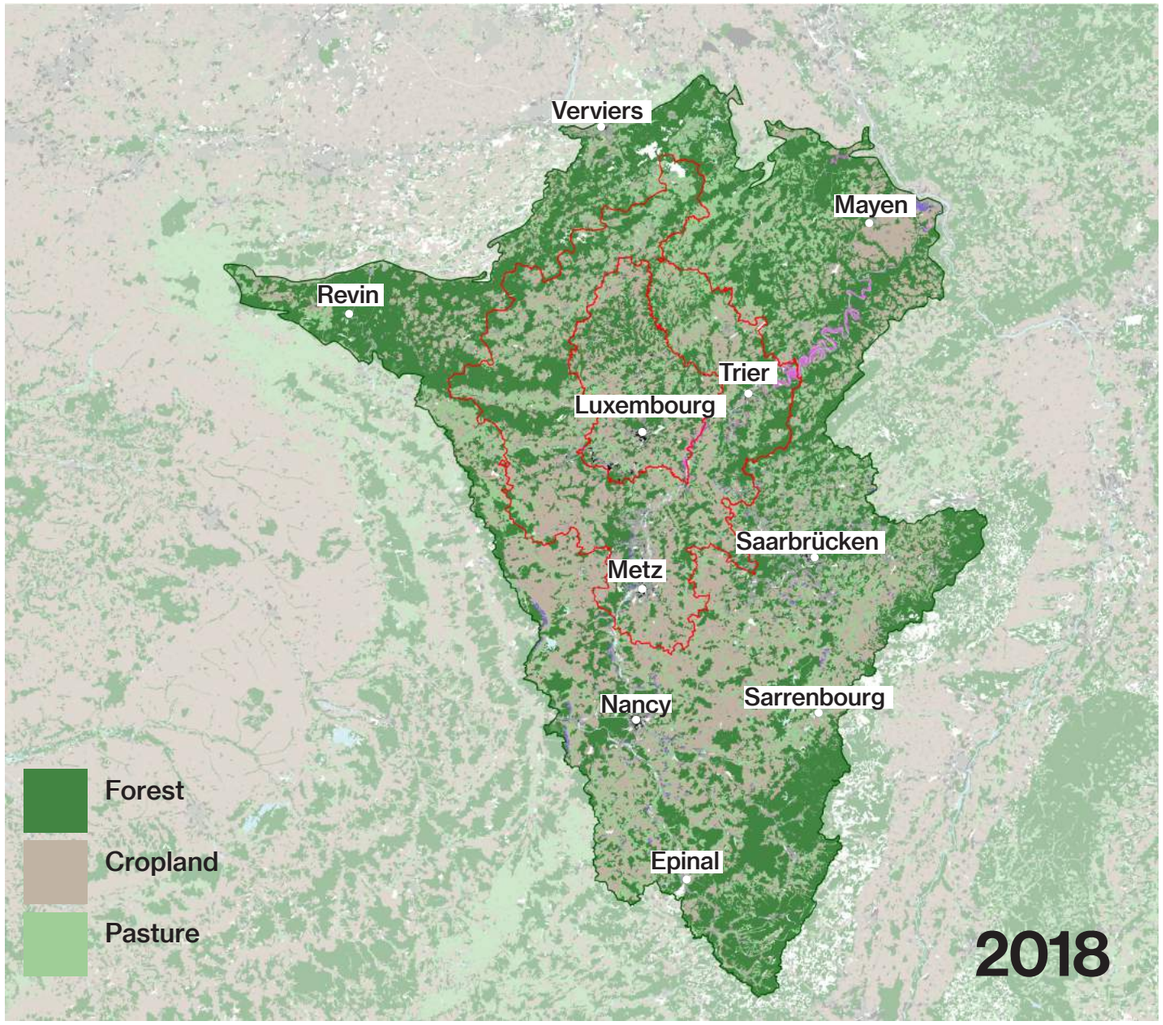
forest between Perlé and Martelange

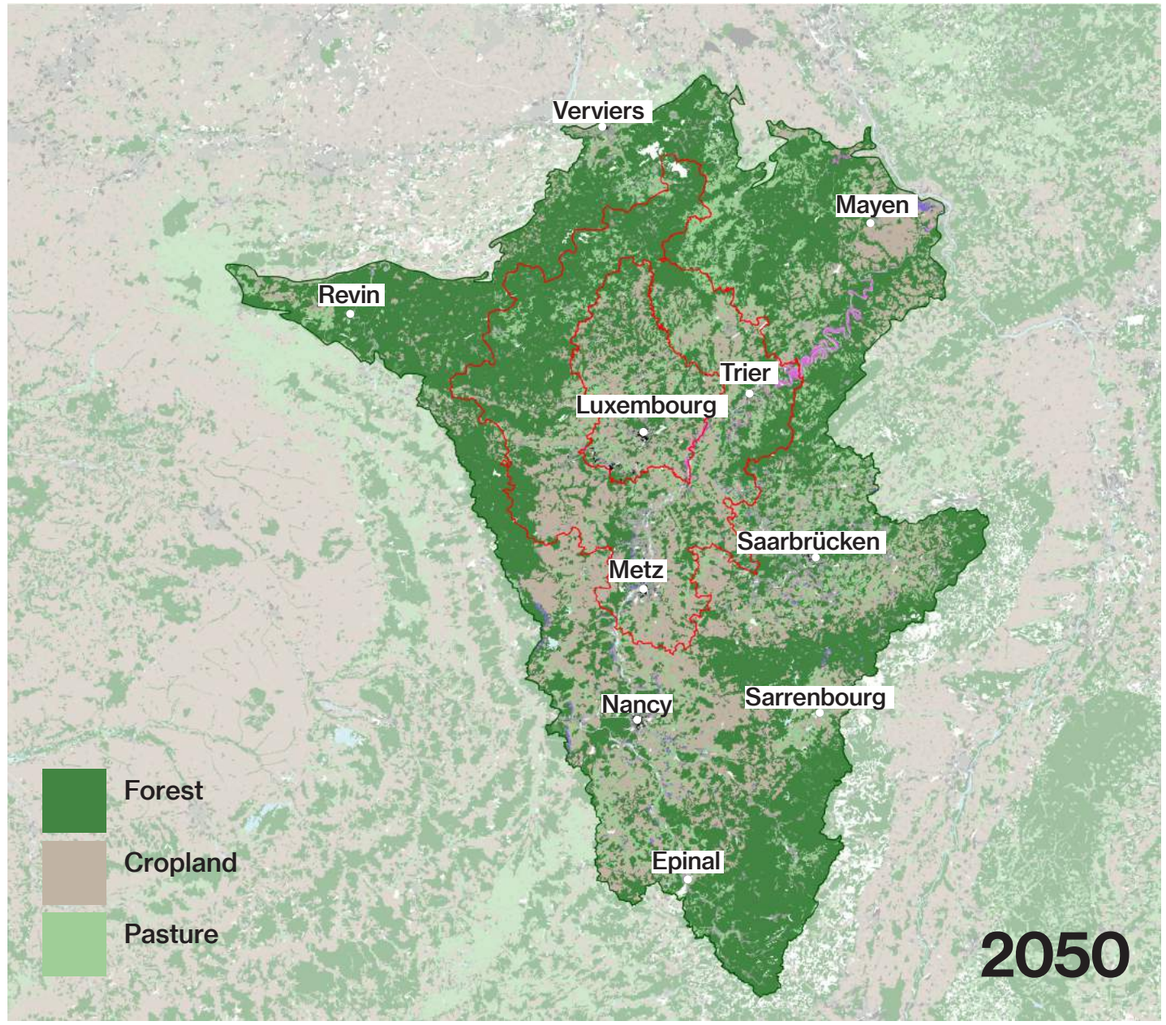
4.9 Land use 2018 vs 2050;

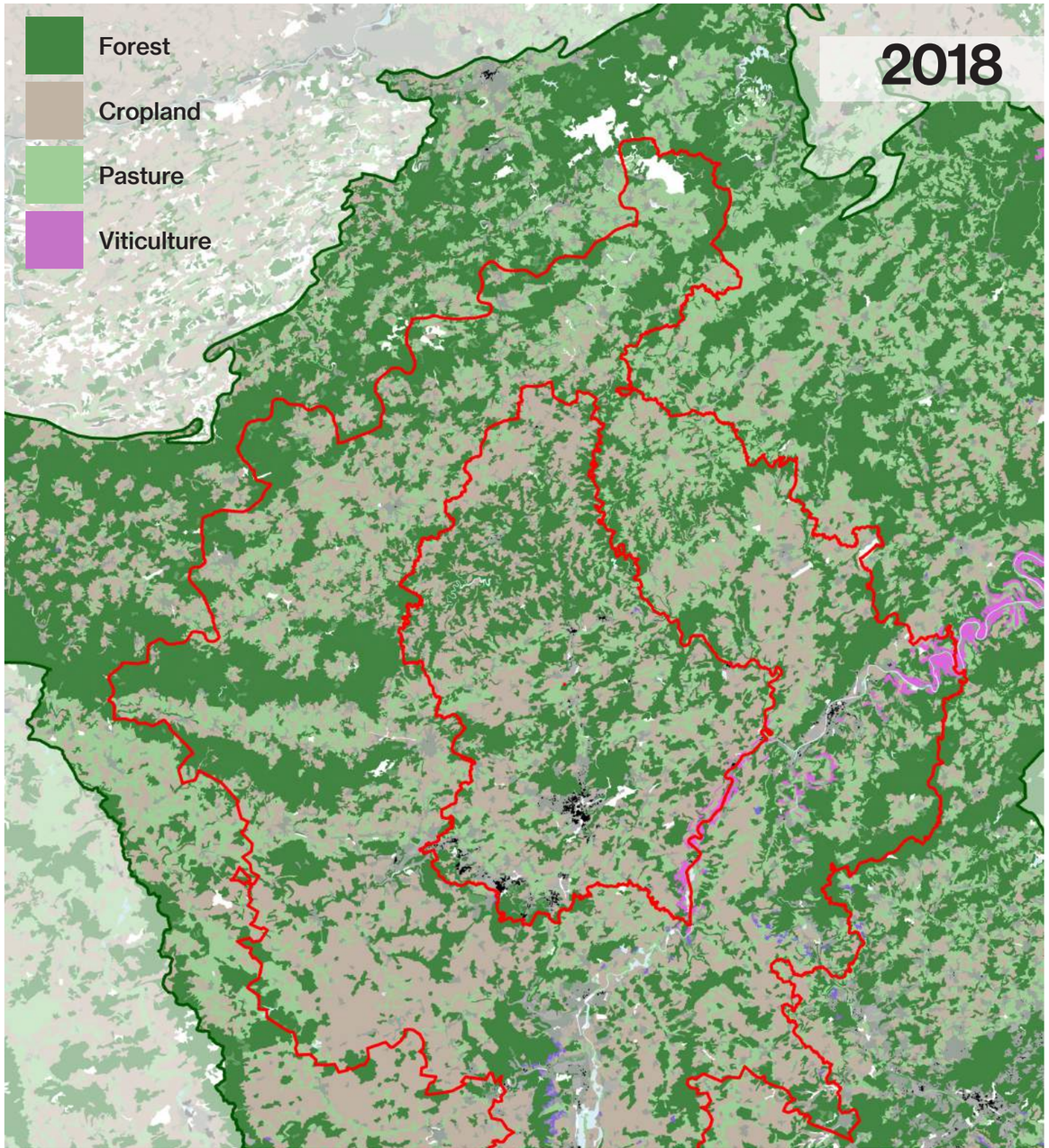
Due to agricultural sprawl the current land use is largely isotropic and fragmented.

Forests are not adapted towards current climate change and the effect of agricultural practices on water resources. Ecosystems and atmospheric carbon points away from the resilience these ecosystems can provide to sustain agricultural practices in face of climate change.

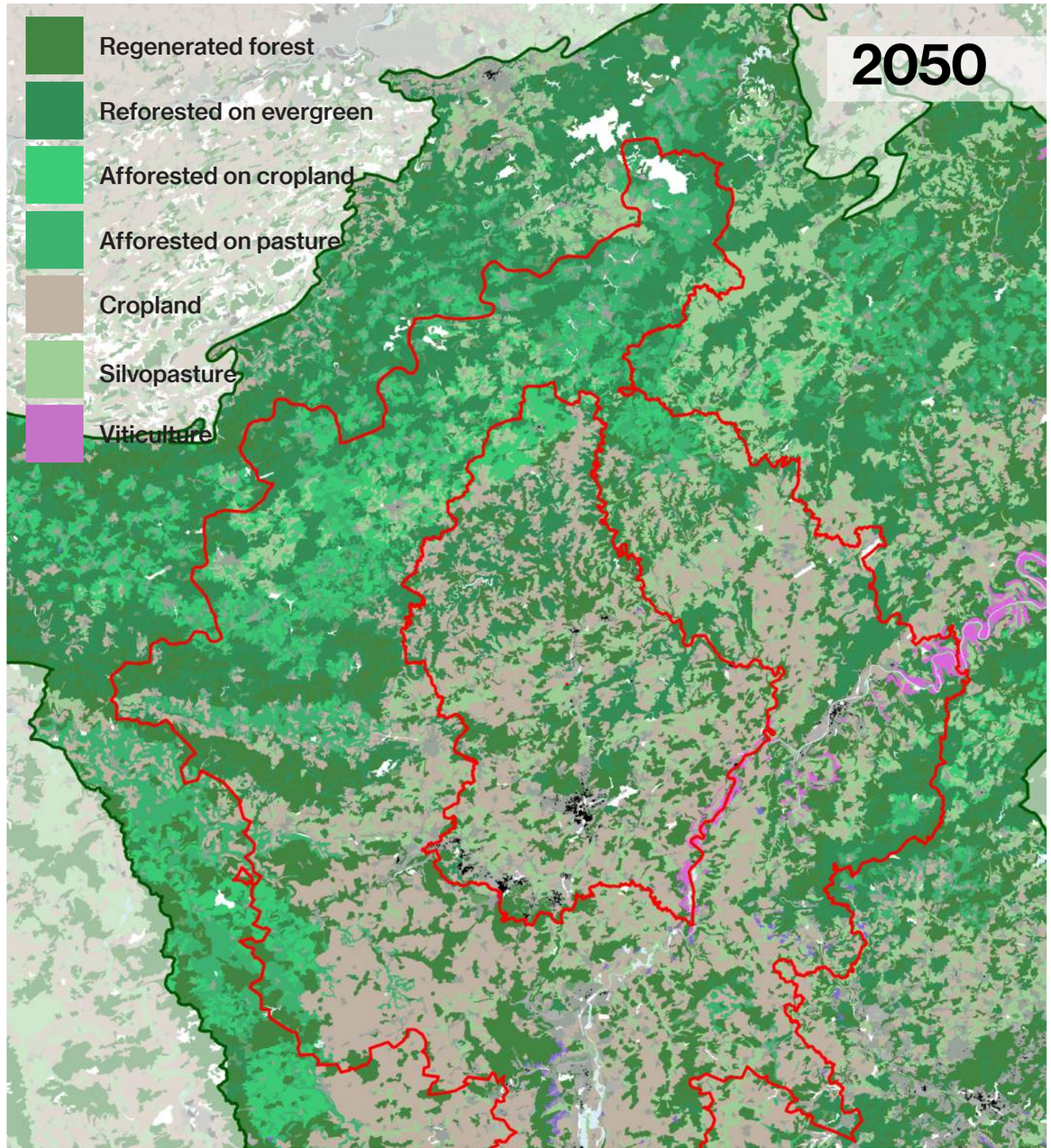
The envisioned land use is more in line with the systemic functionality of bioregions' inter-connected ecosystem services and the diversity of the abiotic conditions. Forests on the highlands are joined into continuous habitats, they get the main share of the bioregions precipitation and act as a sponge slowly releasing outflow during the year to downstream agricultural areas. Agriculture is reduced to meet local food demand and concentrated in the zone with the best climatic and abiotic conditions. Agricultural practices such as zero tillage, cover crops, hedges and organic matter additions eliminate the need for chemical fertilizers and their negative effect on biodiversity as well as increase local water retention and groundwater recharge. Most importantly the soil becomes a carbon sink, safeguarding soil biodiversity and health for future generations.





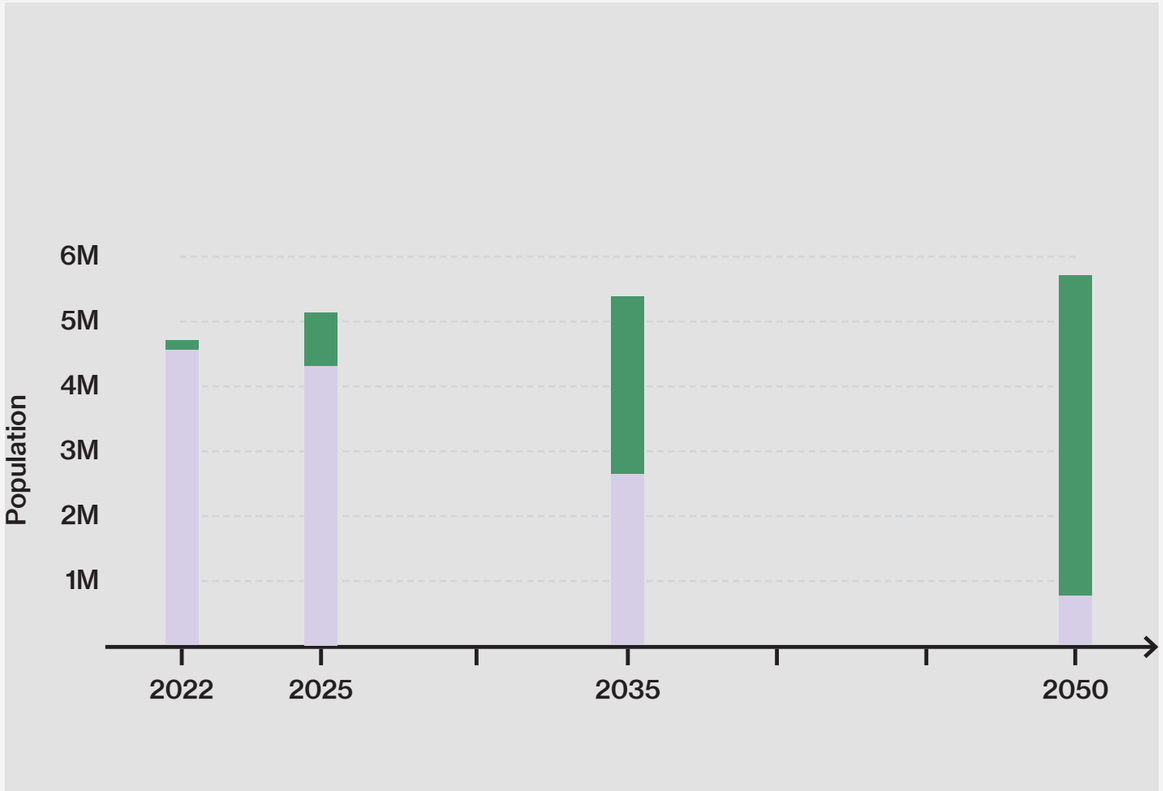


Only the land on truly infertile soils, impracticable topography or natural protected remnants remains uncultivated.



The transition towards climate resilient forest and the forest surface expansion result in a mixture of forest succession stages between regenerated deciduous, reforested evergreen and afforested agricultural that creates structural habitat diversity and enhances biodiversity.

4.10 Diet shift BFUR

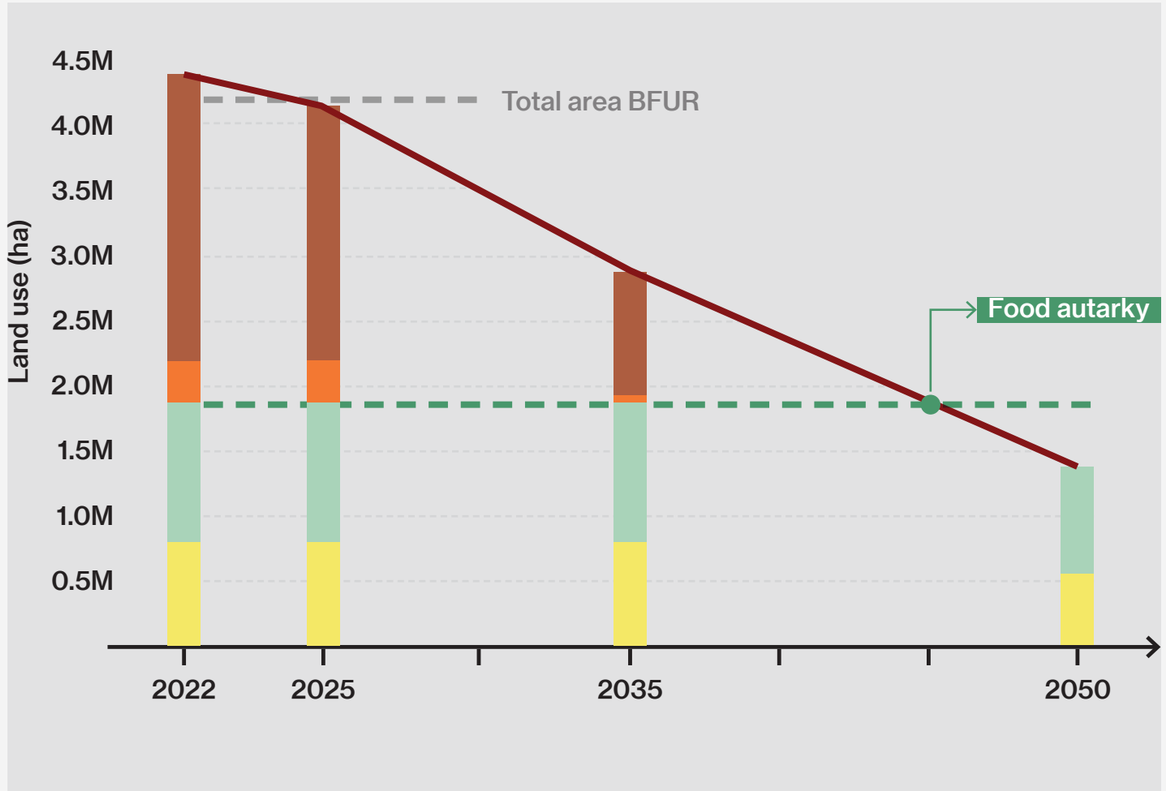


As explained in chapter 3, considering the trends and studies we anticipate if the society as whole decides to take an active role the transition, a bold diet shift could occur. The graph above, simply shows the bold diet shift in the bioregion, taking into account the population growth as well. All other transition proposal in the dossier are anchored on this shift. Diet change is the beginning of the path which provides the land necessary for enhancing natural sinks.

- Omnivorous diet population
- Bold diet population

fig. 17: Diet shift BFUR.

4.11 Land use footprint of food BFUR



In the short term due to the current diet the region would still depend heavily on international pastures to feed itself.

In the mid term the international land footprint can be reduced considerably.

By 2045 the BFUR could reach food autarky as the current agricultural land surface can sustain the population and by 2050 the agricultural land can be reduced opening up more space for ecosystems for biodiversity and climate resilience.

- Pastures
- Cropland
- International pastures
- International cropland
- Land use to feed BFUR
- Food autarky threshold

fig. 18: Land use footprint of food BFUR.

4.12 LULUCF & food emissions BFUR

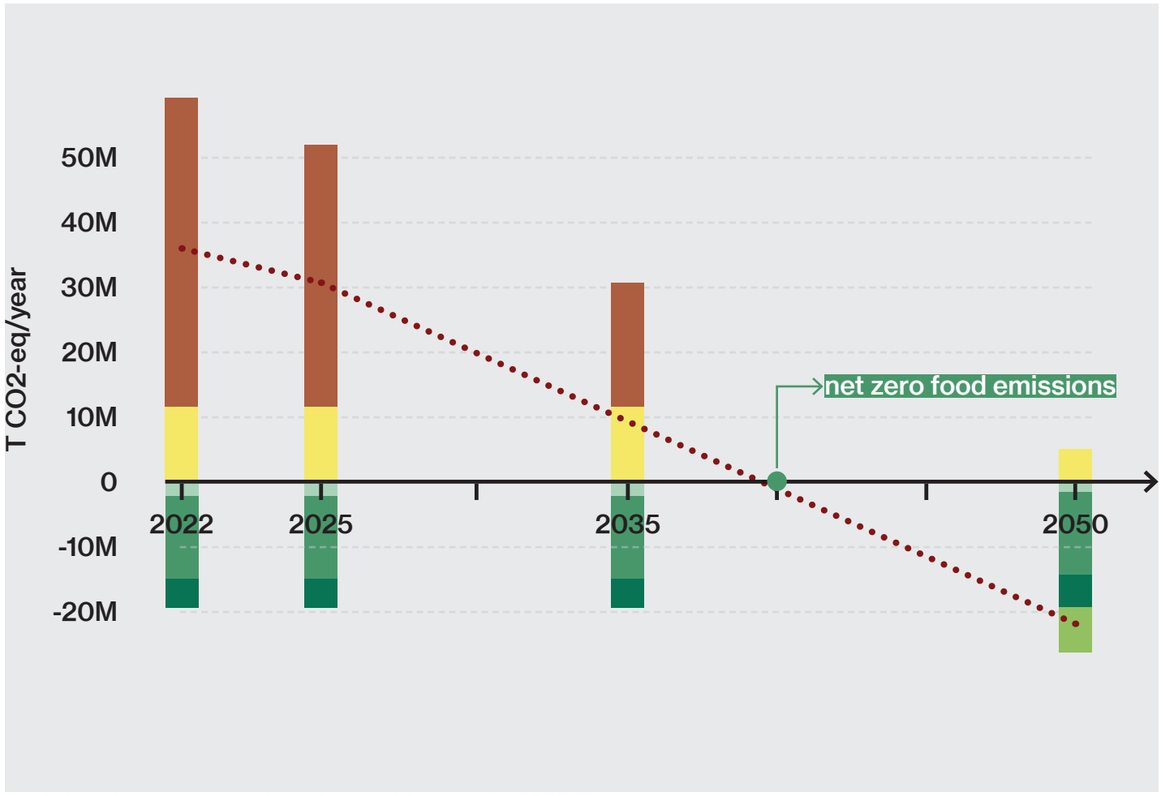


fig. 19: Annual sequestration/emission food provision and LULUCF BFUR.

By 2025 due to the current diet the region would still depend heavily on (international) pastures and cattle production to feed itself. This has a large impact on the carbon balance resulting in far greater (international) emissions than sequestration. Also the reliance on international cropland based on chemical fertilizers, pesticides and deforestation has a significant negative effect on the carbon balance.

By 2035 the (international) pasture and cattle production carbon footprint can be reduced considerably.

By 2045 the BFUR could reach food autarky eliminating international carbon footprint and local pastures and cattle production. It will integrate agroforestry to cut their emissions in half.

By 2050 the forests included afforested agricultural land and the carbon sequestering agricultural practices turn the carbon balance around and the annual sequestered CO2 is much higher than the annual emitted CO2.

- Pastures
- Arable land + tools
- International pastures
- Forest [existing broadleaf]
- Reforested [on healthy evergreen]
- Afforest [freed-up agricultural land]
- Net food emissions

4.13 Underlying dynamics; emissions per hectare per year

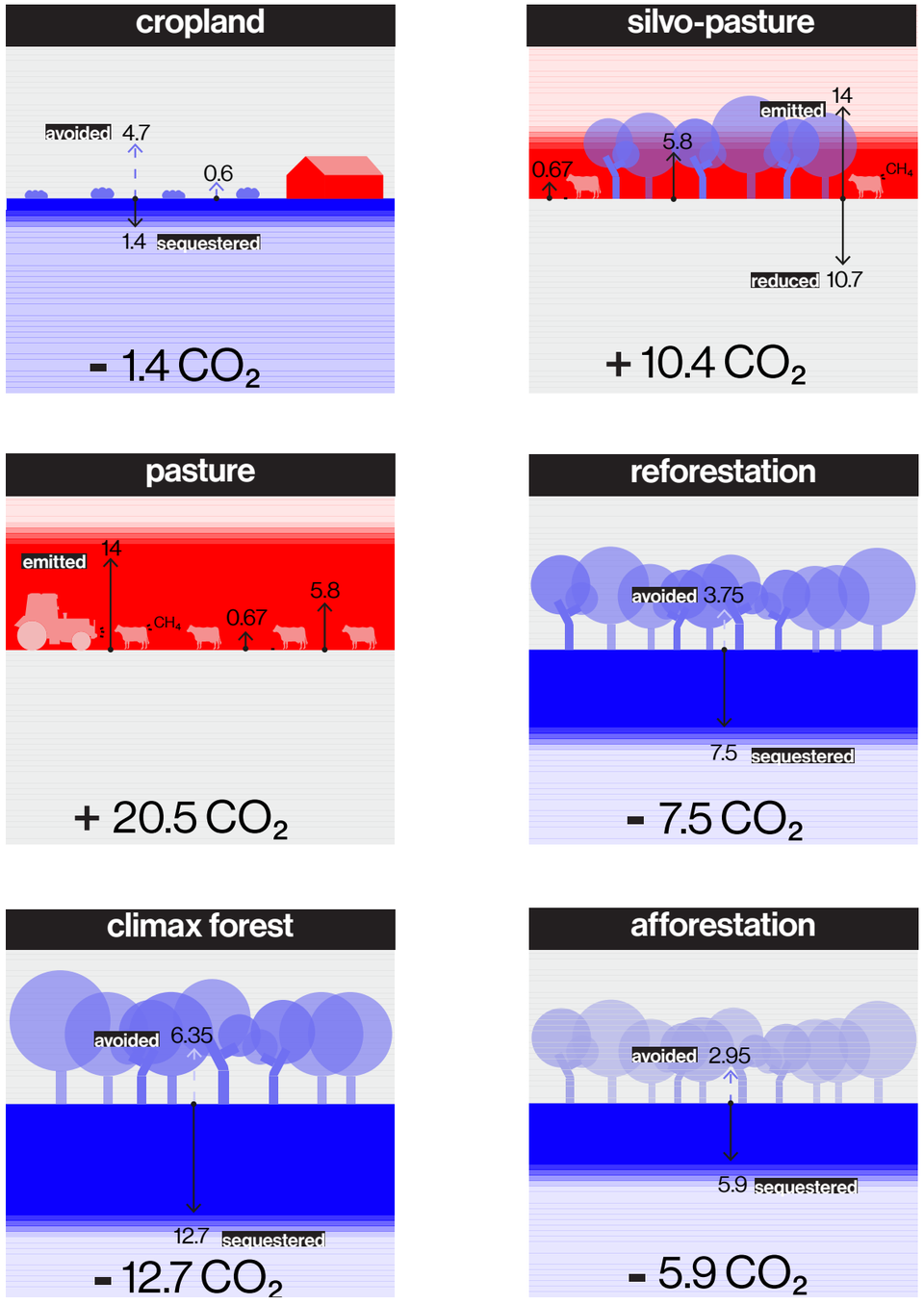
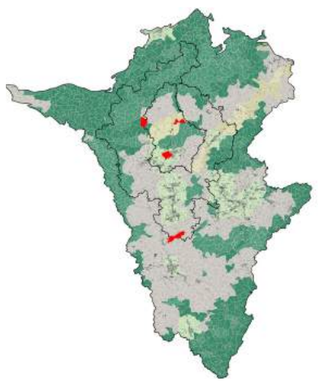
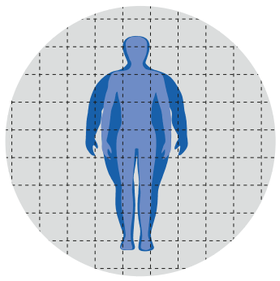
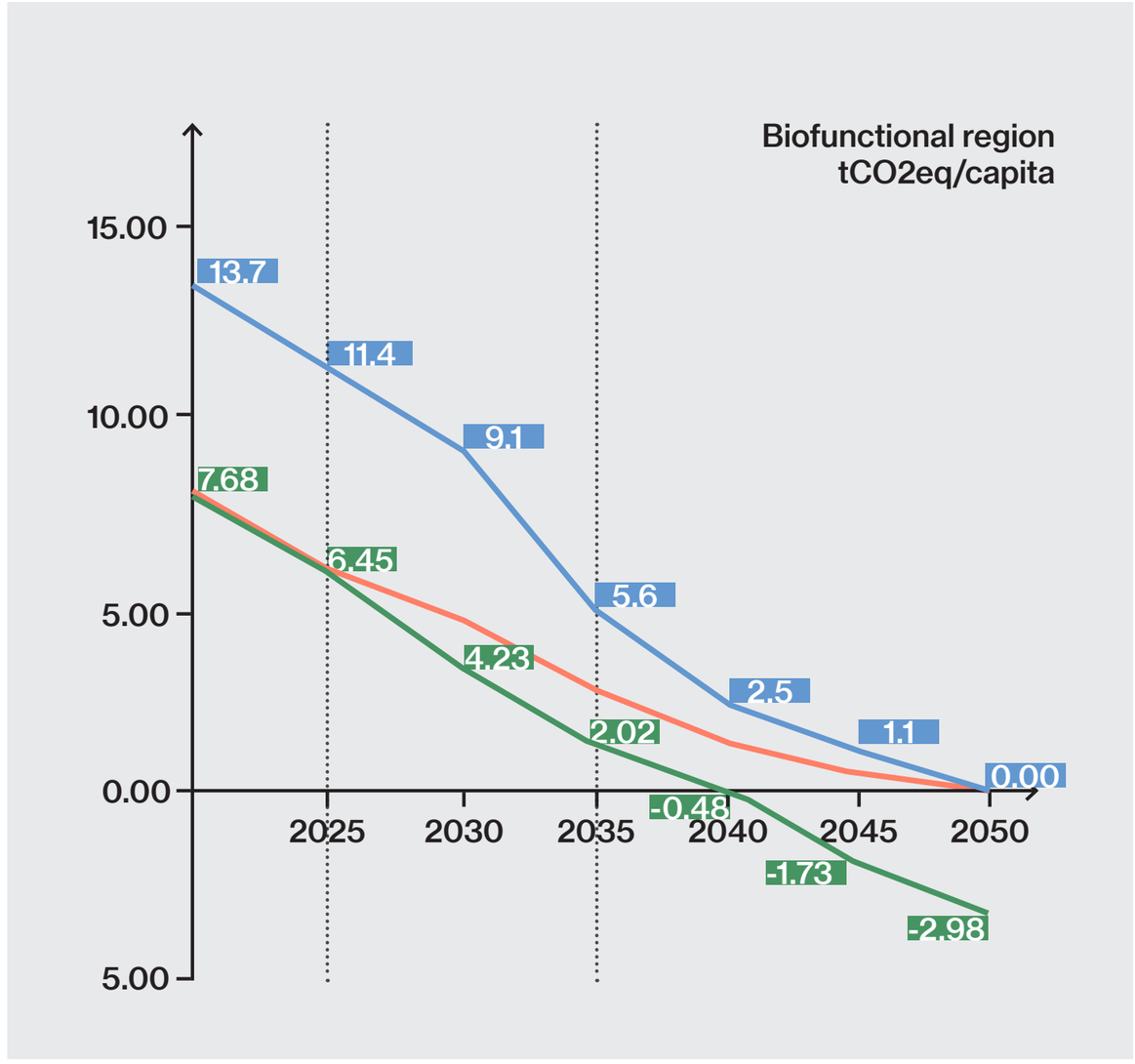


fig. 20: Total emissions/sequestration of 1 ha of land in cropland, silvo-pastures, pastures, reforestation, climax forest and afforestation.

	by 2025	by 2035	by 2050
 **diet shift**	the diet shift in the short term will be mild: 1 plant-based day per week. However, increasing investment is needed in meat and dairy alternatives and on raising awareness about the footprint of our plates.	as awareness grows with an increasing availablity of alternatives, our diets lower their footprint by adopting the bold diet half of the week.	the generational shift, on top of a very wide range of plant-based options, push the bold diet shift to its maximum impact. The bold diet is now practiced 6 days a week.
 **biofunctional shift**	preservation of the open landscape is paramount. The biofunctional region needs to prepare a collective framework for land use planning to protect its natural resources. Achieving this is the first step towards governing the decarbonisation transition.	regulations supporting the cultivation shift must come in place. Namely border adjustable carbon tarrifs, priorotising local wood, regional labels for food and wood, and provision of digital food and timber chain platforms. Governments must take an active role in developing demand in its own procurements.	the resource-driven, cross-border management will result in an economic boost in the longterm following the investments in agrifood R&D. Export of timber and agrifood knowledge will help the biofunctional economy, society and ecology to flourish in harmony.
 **cultivation shift**	farmers need to become central in the public debate and consensus needs to be made on common values. This societal debate will lead to an agricultural transition charter. Investment is needed in research & education of new crops, percision farming, and sequestration monitoring.	farmers can act on the transition charter and begin the pilot projects that are invested in by direct grants and research fund. Farmers build in-house knowledge of carbon balancing. Forestry sector is growing steadily and the post processing facilities are keeping up with the pace of the market shift.	forestry reaches is maximum impact following the land freed up by diet change. This will result in reaching net zero food emission by 2040 and reaching food autarky by 2045. The biofunctional ecosystem flourishes.

4.14 Decarbonisation timeline BFUR;



In the Bold diet path, we have looked at the true footprint of food emissions* including the international footprint and the total picture of land use emissions including agricultural practises, food production and wood harvesting and use. We have out this in comparison to the total emissions of the region, if other sectors follow the 1.5 Life path.

- Net emissions BFUR 1.5 Life
- Mild diet shift food emissions of BFUR (assumed in relation to 1.5 Life)
- Bold diet shift food emissions of BFUR

fig. 21: decarbonisation pathway for BFUR.
*excluding packaging, processing & distribution emissions with are insignificant compared to land use, agriculture and animal feed emissions.

4.15 Decarbonisation roadmap BFUR;

short-term milestone

- plant hedges
- optimize manure distribution
- learn about footprint evaluation tools
- experiment with new business models
- participate in R&D on pastures
- R&D in carbon accounting & monitring
- crop experiments such as soy production
- reforestation of unhealthy evergreen forests

- community supported agriculture
- direct distribution centres
- digital food & timber chain platforms
- diet shift to 1/7 week plant-based

- Tripartite territoriale;
- debates on regional planning between economy, ecology + society
- televised debate on future of agriculture
- a chair for agrifood at Uni.Lu
- subsidies per employee instead of per hectare
- build regional wood value chain & facilitate local wood consumption
- promote community gardens
- free business transition consultation available to farmers
- introduce multifunctional & experimental land use categories
- direct grants to R&D towards sequestering practices
- tax credits to sequestering practices
- protect natural land footprint
- regional labels

mid-term milestone

- electric vehicles for fieldwork
- maintain soil fertiliy [rotation & compost]
- business transition based on early experiments
- collective investment in precision farming
- increase presence in European networks
- local product “embassies”
- shift to carbon farming practices [see cultivation shift]

- digital food chain platforms
- invest in cooperatives for emerging sectors
- diet shift to 1/2 week plant-based

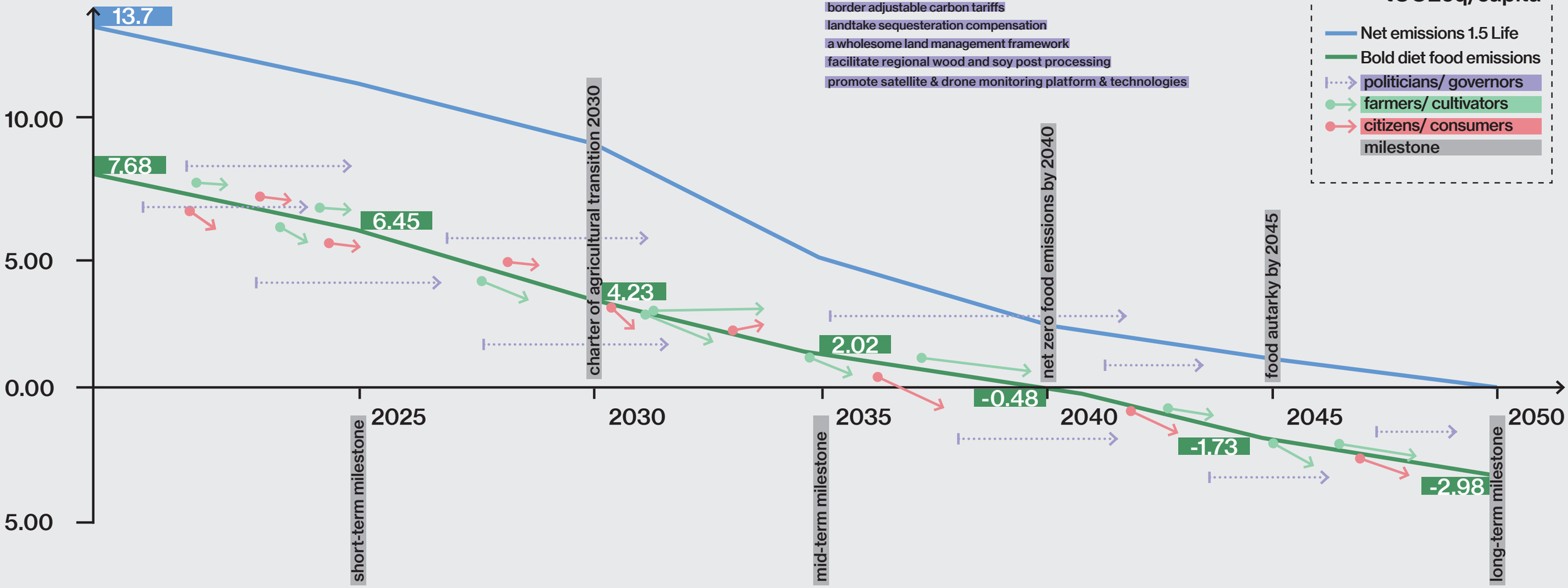
- promote natural capital accounting
- state sponsored strategic projects
- embed farming crash course in school system
- mandate local wood construction on governmental procurements
- mandate local vegtable produce on public institutions
- restructure landscape according to productive potential
- new crop R&D + testcases
- implement the biofunctional regional vision shift]
- priorotise local consumption to export
- border adjustable carbon tariffs
- landtake sequesteration compensation
- a wholesome land management framework
- facilitate regional wood and soy post processing
- promote satellite & drone monitoring platform & technologies

long-term milestone

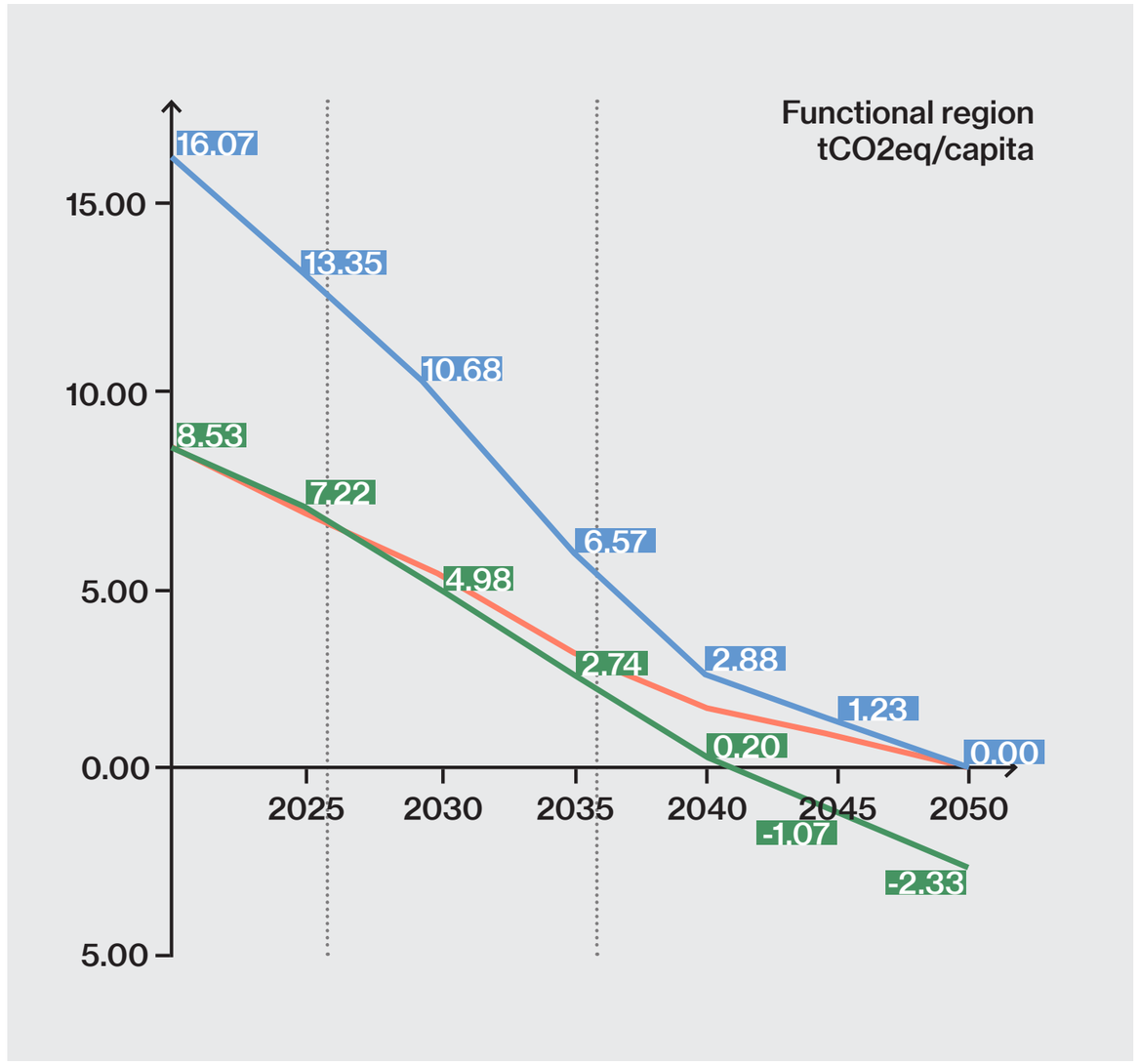
- supply biomass to grassland alternatives
- form cooperatives to cover whole value chains
- scale up new business models in whole region
- expand silvopastures & agroforestry

- recognizing farmers as climate heros
- diet shift to 6/7 week plant-based

- close gaps in regional value chains of timber
- close gaps in regional value chains of meat/dairy alternatives



4.16 Decarbonisation timeline FUR;



The difference between BFUR and FUR, with FUR reaching a lower sequestration amount/ capita is twofold;
In comparison, the FUR has a higher population density than BFUR. In addition, proportionately more agricultural land is concentrated here following the high population density as the Bioregion as whole includes more large scale forests. This results in higher population density and lower sequestration compared to the BFUR balance.

- Net emissions FUR 1.5 Life
- Mild diet shift food emissions of FUR (assumed in relation to 1.5 Life)
- Bold diet shift food emissions of FUR

fig. 22: decarbonisation pathway for FUR.

4.17 Round-tables with cultivators

Tom Kass in an educational room during visit at Kass Haff, Rollingen

4.17 Can farmers decarbonise?

Following the media, one can get the impression that nothing could be done, as 50% of the farmland is grassland and 75% of the agricultural value is created by livestock farming and animal feed (Tierzucht, 2018). Below are two examples of demotivating statements in the media:

‘Luxembourg is a grassland location. The alternatives are relatively limited. Grassland is best used with ruminants. The dairy cow brings the best financial return. Grassland is protected by European regulations.

Jeanne Bormann, Administration des Services Techniques de l’Agriculture. (Bormann as cited in Wirth, 2018)

We can't just turn it into farmland overnight. In addition, fruit and vegetables are labor-intensive crops that are not competitive with southern Europe due to our high labor costs.’

Christian Wester, Bauerenzentral (Wester, 2021)

Farmers are not recognized and appreciated enough for their work. Their hourly wage compares to the minimum wage and farmers’ services other than food production are little known in society.
Moreover, they face fast changing market and climate conditions, which increasing uncertainty. Society as a whole needs to understand the significance of agriculture and current subsidies overshadow such an understanding.

Most importantly, farmers need planning reliability in order to be able to experiment and dare to act upon a transition.
As proven during the COVID crisis, the state is a powerful actor and can initiate change.

We believe in farmers as heroes of the transition so we asked them during two workshops about obstacles and incentives from their perspective.

‘This speed of change in market & climate conditions is frightening.’
‘Some slaughterhouses are building up vegan branches of business.’

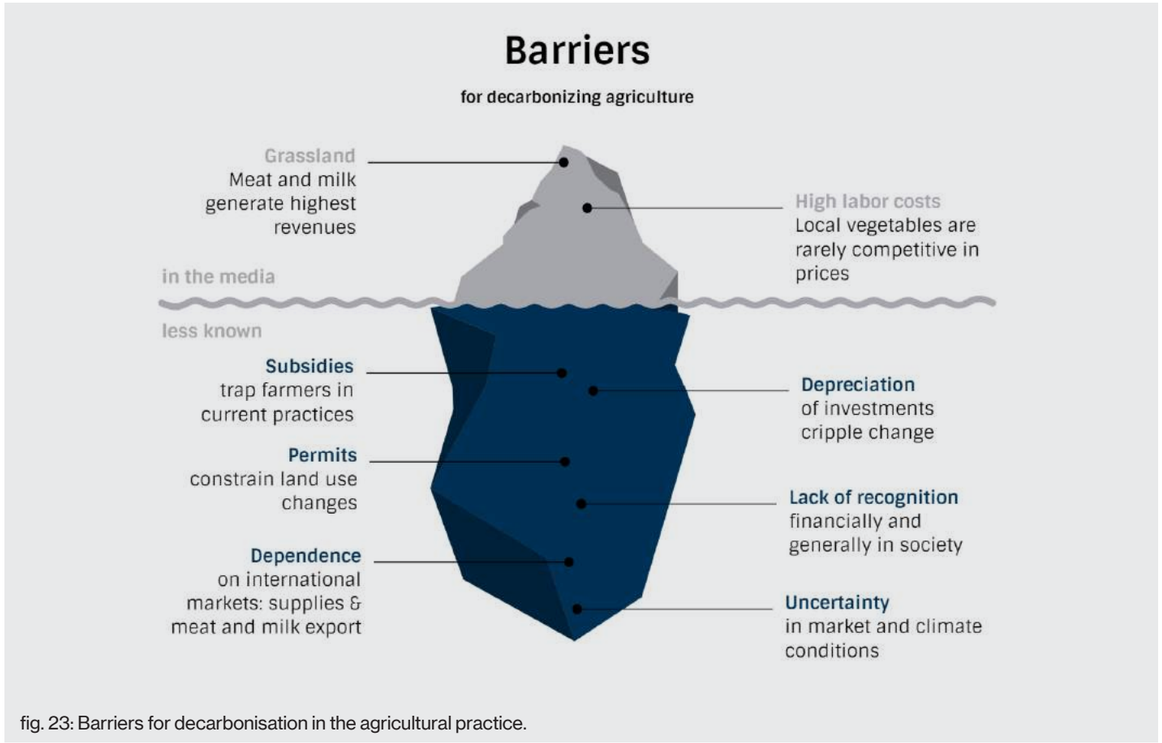


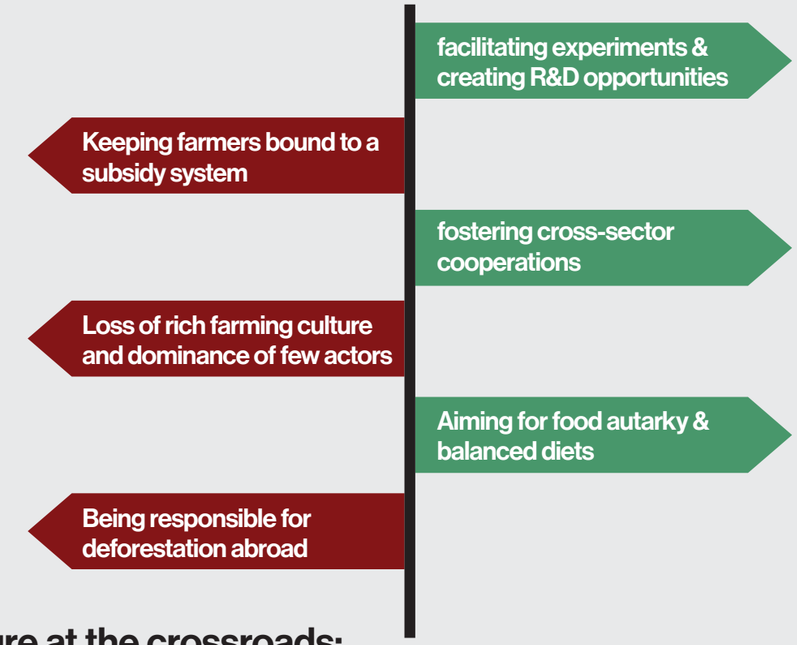
fig. 23: Barriers for decarbonisation in the agricultural practice.

4.18 Way forward;

It is often forgotten that agriculture is an economic sector with many hardships. That means people need to see a future in the work they do. Farmers consider themselves as economic actors, who do not want to be dependent on subsidies, which often do not land in their pockets, but want fair prices. Smart subsidy systems should act liberating for stimulating change instead of enslaving by creating dependence.
We want to develop new business models with farmers in a 3rd workshop to explore how framework conditions need to look like so that they make sense environmentally and economically.

“We are worried as the farms get bigger and less families are involved (from thousands to hundreds) the culture is being lost.”

Soil & People’s farmers roundtable



Agriculture at the crossroads; backward or forward

4.19 Participants final statements;

1
“We agree on the facts: climate change, biodiversity loss, ... We need to build from there. This is a problem that farmers are aware of. It’s a common ground.”

2
‘For viticulture, we need more research and development. The sector as a whole does not yet know enough to make the transition.’

3
‘We don’t need a one-fits-all solution. We need to create a variety of opportunities for farmers/ families to evolve in their own way.’

4
‘There is an urgent need for an in-depth, but wide-ranging, debate. As a group, as a country, as a society we seem to have no idea what direction we want to go with our agriculture. Without a societal strategy, politicians keep running us in circles.’

5
We need to bring more things into action. We have the feeling that everyone keeps running on the same spot, keeps making studies, ...’

4.20 Roundtable methodology;

We organized 2 workshops in April 2021 with 10 and 9 participants. Each workshop took 2.5 hours.

The first workshop focused mainly on the opportunities and obstacles that farmers encounter when they want to switch to more sustainable land use. Diet change and carbon incentives were put forward as impulses.

The second workshop went a step further and looked at what actions can be taken to capitalize on these opportunities and overcome obstacles.

The conversations took place online in different groups and were facilitated via the online platform MIRO. This chapter outlined the results of the two workshops in one whole.

We would like to thank each and every participant for the valuable contributions. The 13 participants came from a variety of background and mindset. The chart below shows this diversity.

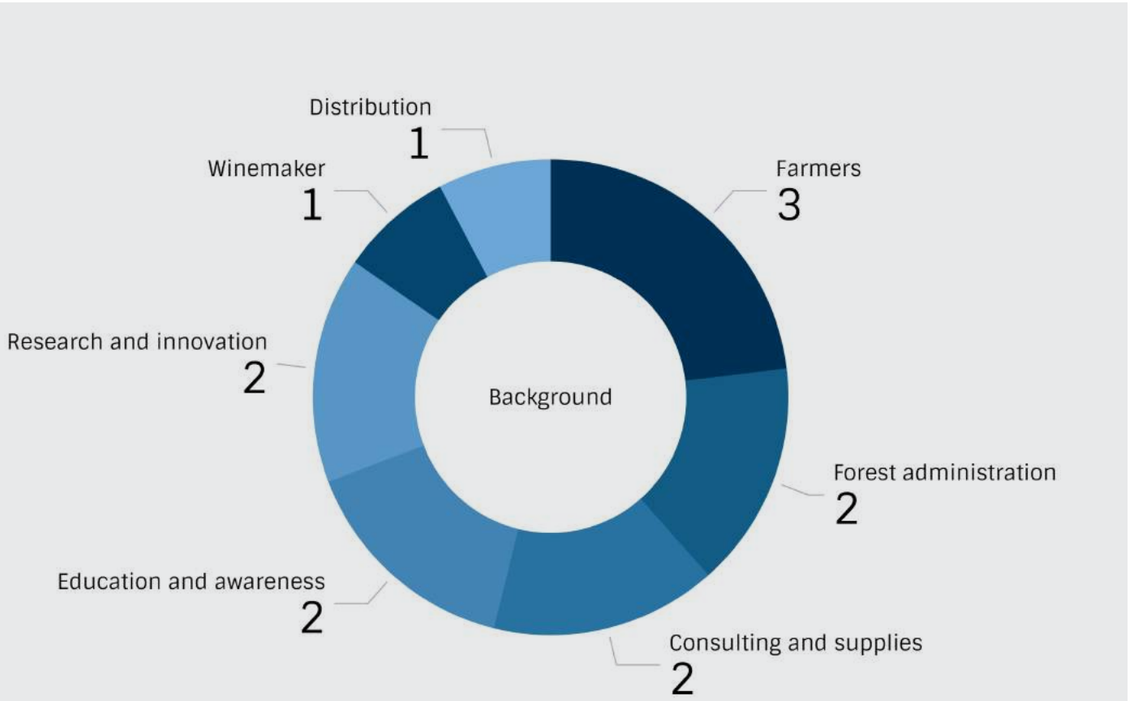


fig. 24: Background of the participants in the workshop “Agriculture in Transition”

4.21 Roundtable participants;

Raymond Andekerk
protection & valorisation
Meng Landwirtschaft

Charles Betz
research & innovation
Luxinnovation

Rene Diederich
agricultural equipment

Tom Dusseldorf
consulting
Livestock association

Tom Kass
farmer

Marco Koeune
dairy farmer

Corinne Kox
viticulture

Claude Loutsch
farmer
Schwain

Guy Reiland
education
LTA

Aender Schanck
distribution & retail
Cooperative for fair trade & bioproducts

Frank Wolff
forestry

Frank Wolter
forestry

Philippe Genot
Luxembourg wood cluster

4.22 Territorial food distribution strategy

Road transport is responsible for 73.9% of transport sector CO2 emissions globally and large and heavy vehicles are responsible for 46.5% of road sector CO2 emissions (ICCT, 2014), therefore rethinking logistic strategies and vehicles used for movements of goods plays a crucial role in decarbonization of transport sector.
Proposed changes in diet supported by new land use changes requires an ad-hoc green, sustainable and zero-carbon logistics strategy for movement of food products that aims at:

- Reducing the negative environmental impact of urban and extra-urban logistics;

- Encourages the shift towards electric and smaller vehicles for urban logistics and last mile delivery and

- Improving the performance of the logistics process by increasing accessibility and reliability.

The logistics strategy takes into account the changes in land use, population density for 2050 and current and planned transport infrastructure. It includes three scales of intervention from regional movement of cargo to urban logistics and local scale for last mile delivery. The following diagram shows the proposed process for each scale.

There is a need for a coordinated territory-wide logistics strategy.

The regional scale strategy includes:

- implementing distribution centers that would be used for storage of surplus of different corps categories for long to medium term;

- located at the proximity of main rail nodes in major urban poles of with highest population density in the region;

- products should be transferred from farms using railway or electric trucks in order to be stored and later redistributed to urban consolidation centers (UCCs) based on market demand.

Implementing the concept of “Physical Internet” for reginal scale logistics strategy is recommended in order to optimize type of storage area (distribution center or UCC), its location and preferred mode of transport for each type of corps is recommended. It requires a close coordination among farmers as suppliers, freight forwarders and customers to ensure an optimized, low impact, innovative and reliable delivery process that responds to needs of the region.

The logistics strategy at the urban scale includes:

- implementation of UCCs to aggregate cargo loads travelling on similar routes with the aim of reducing the number of vehicles accessing the city, thus reducing congestion and emissions;

- Preferably locate them in the outskirt of cities or as part of existing logistics infrastructure;

- products should be transferred with small electric delivery trucks, electric vans and trams, when available.

The last mile delivery strategy includes:

- implementation of neighborhood concierge, delivery pickup points and parcel lockers;

- located at both urban and rural areas with high to medium residential density;

- electric tricycle, cargo bikes, small autonomous electric delivery vehicles and delivery robots could be used for last mile delivery inside the city boundaries.
In addition to the above mentioned strategies, the agricultural lands located at the proximity of urban cores, provide the opportunity for the products to be send directly with cargo bikes and small electric vehicles, to those cities’ supermarkets, restaurants and neighborhood concierge centers or dedicated food lockers provided in densely residential areas, similar to the concept of “Zero kilometer Food”, in addition to minimizing the impact of food production it will embraces the local identity of Luxembourg functional region. It is noteworthy that by locating and keeping agricultural lands nearby cities emissions for people transport would be reduced too since the farmers and other workers will travel shorter distances from commuting to work. The mentioned strategies are valid for all type of cargo in the mentioned scales.

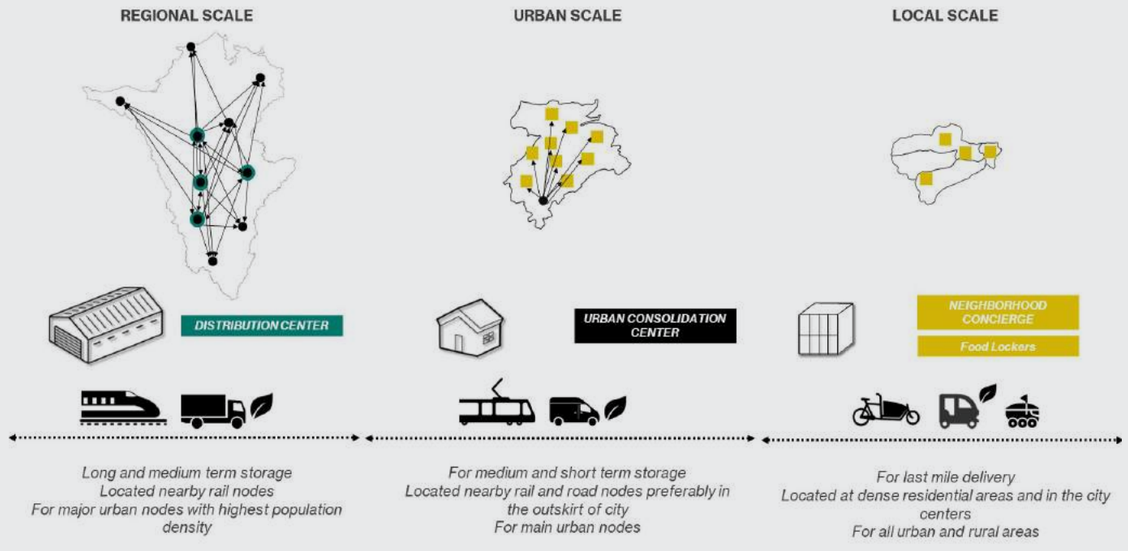
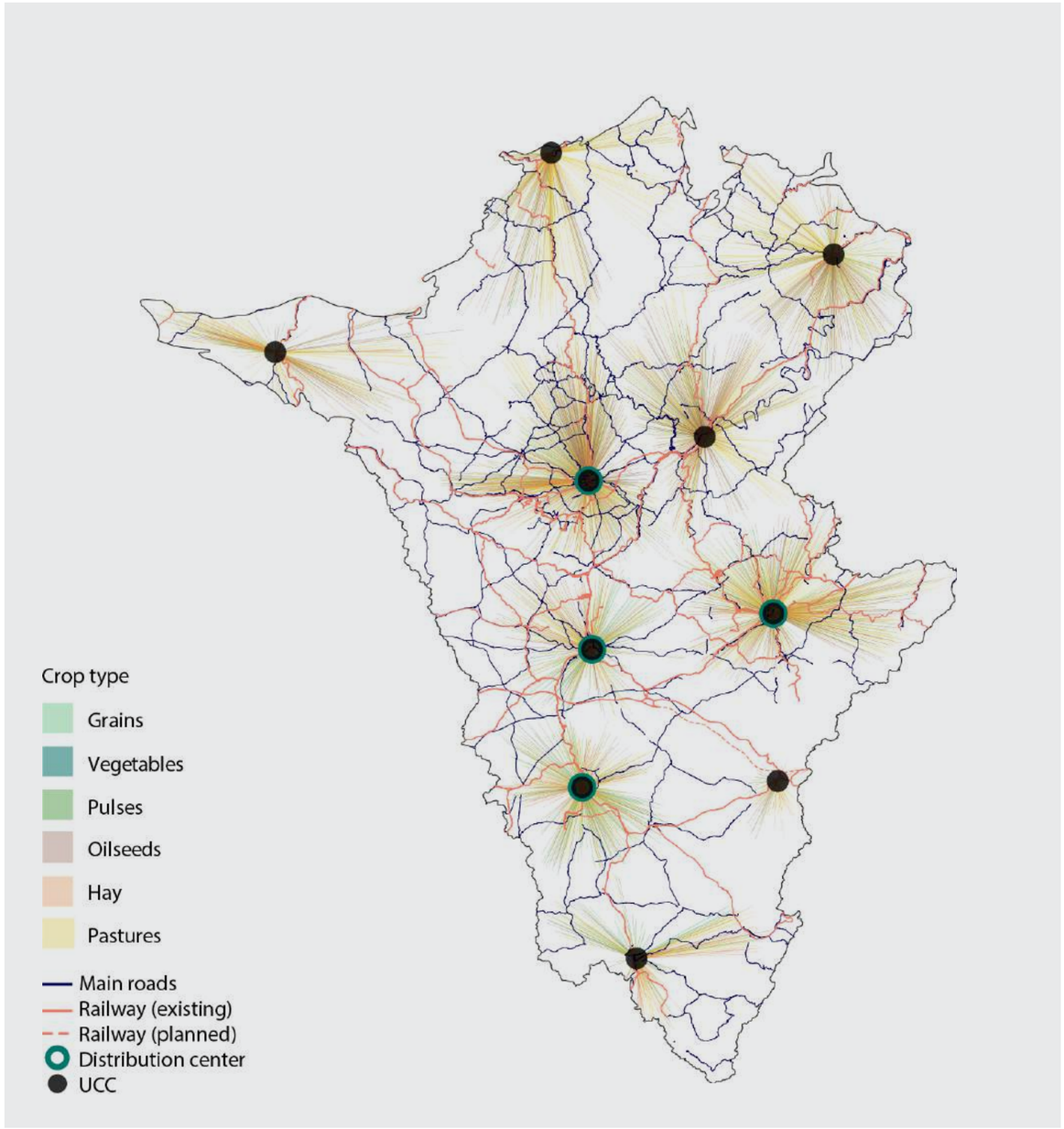


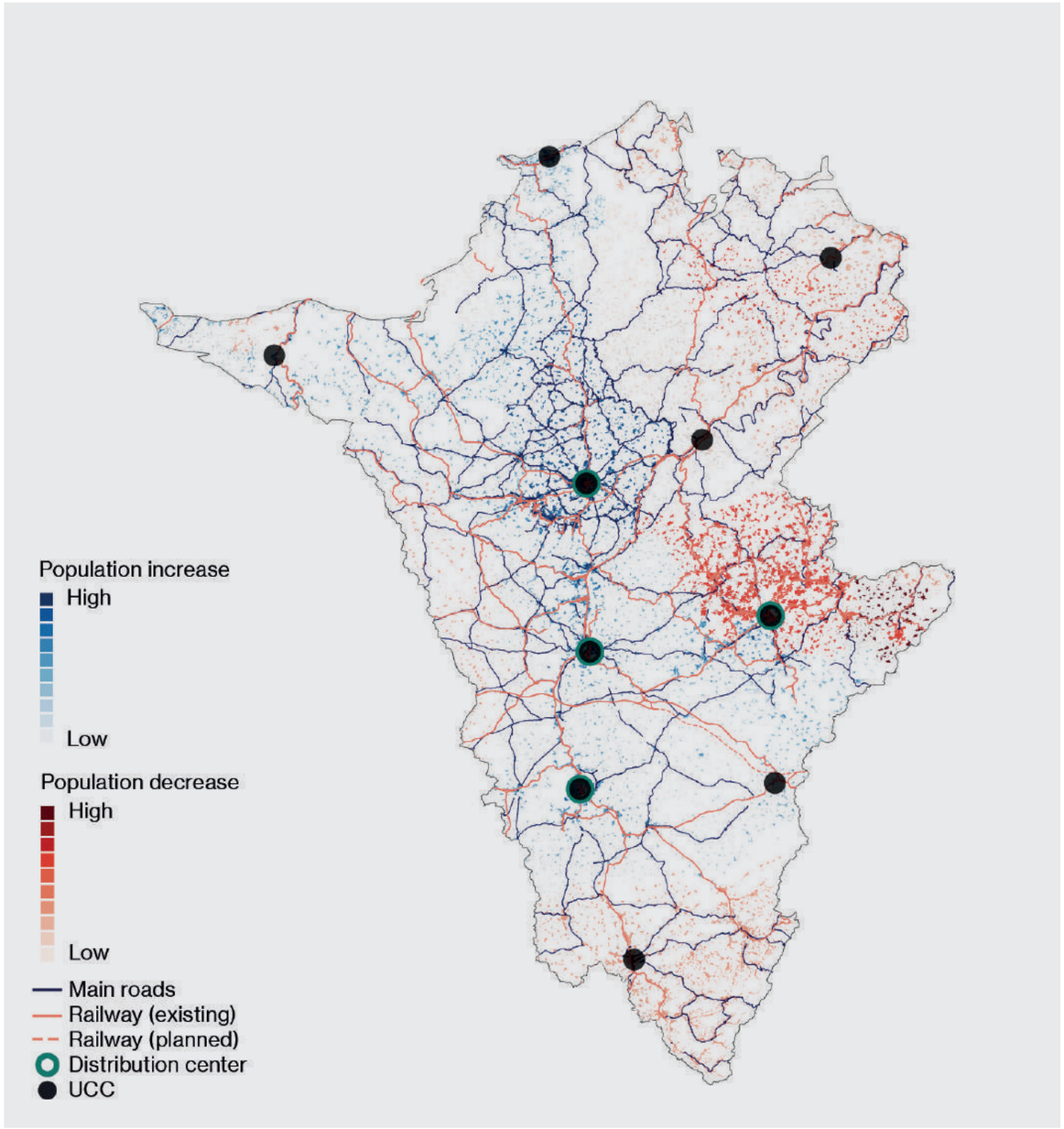
fig. 25: Production and distribution: regional scale, urban scale, local scale.

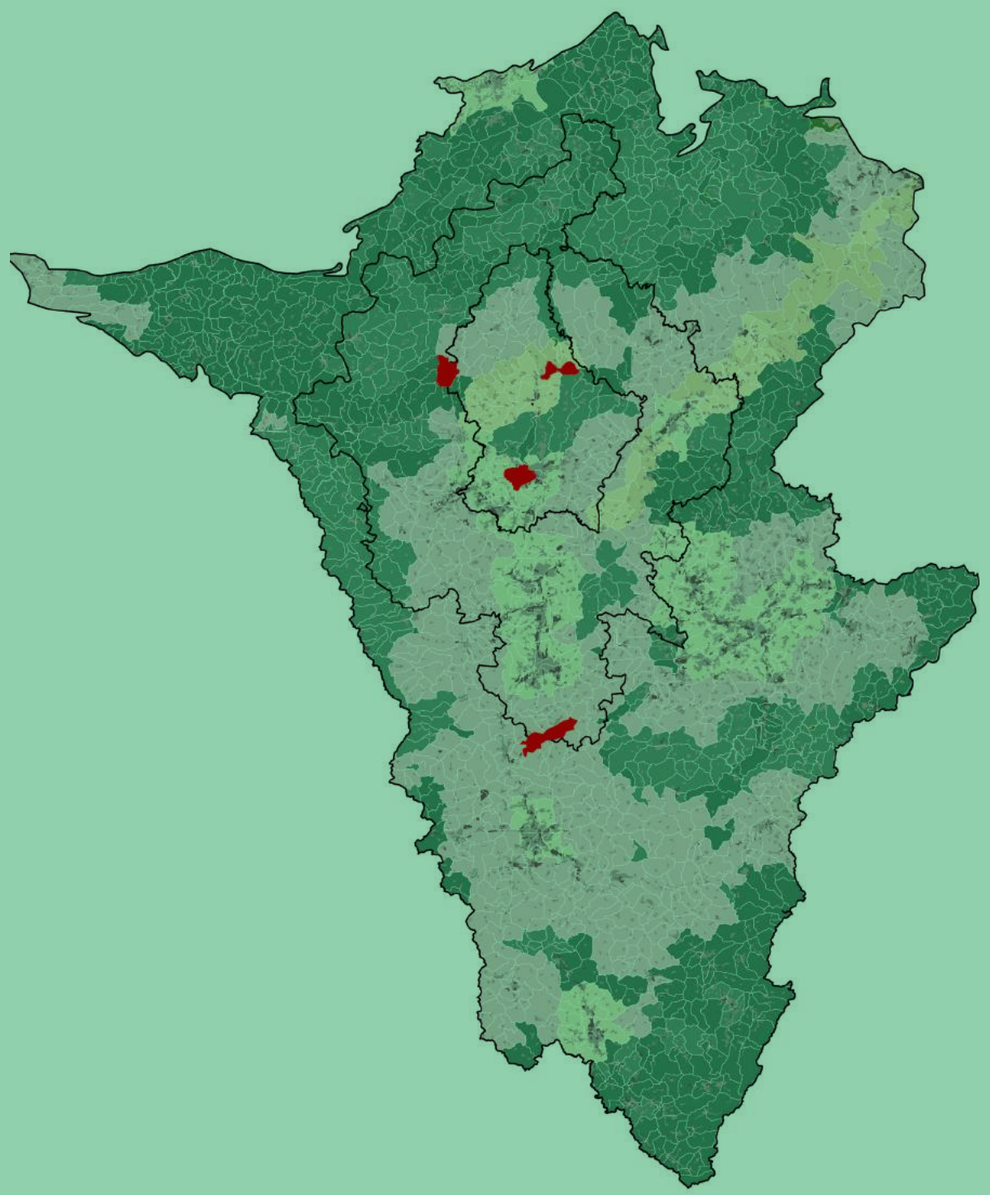
4.22 Territorial food distribution strategy

In view of the large scale shifts in diet and production of food, and with an eye on food autarky, we have proposed key distribution centers and UCCs in the territory. These are presented in the diagram below in relation to the main roads and railway infrastructure.



The proposed distribution centres are highlighted in the diagram below together with the anticipated population increase and decrease, which will have an impact on demand.

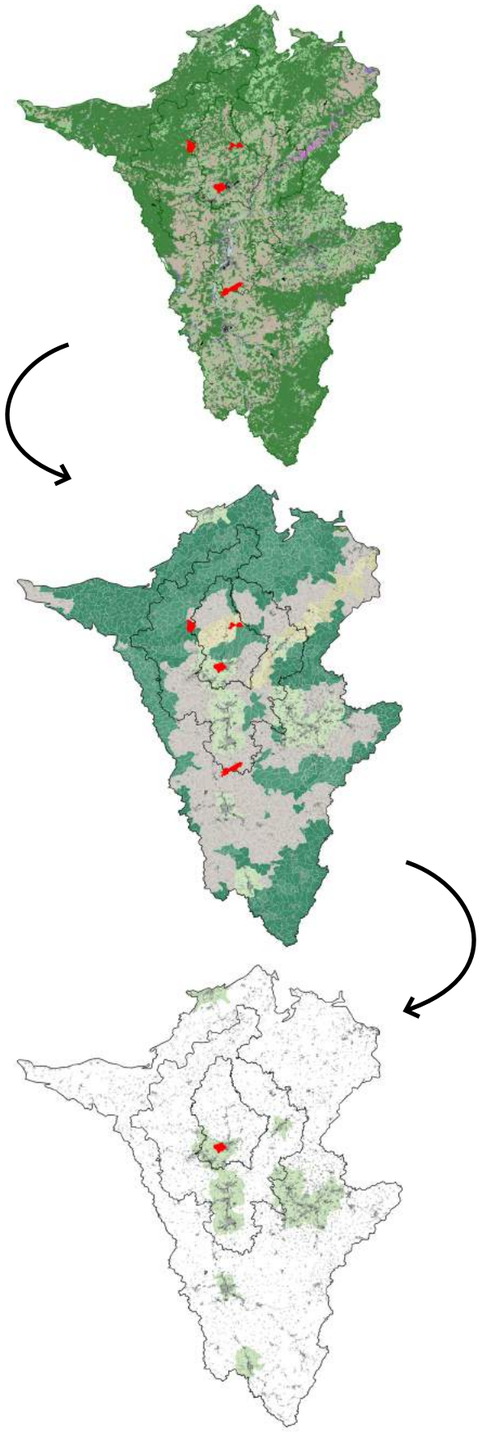


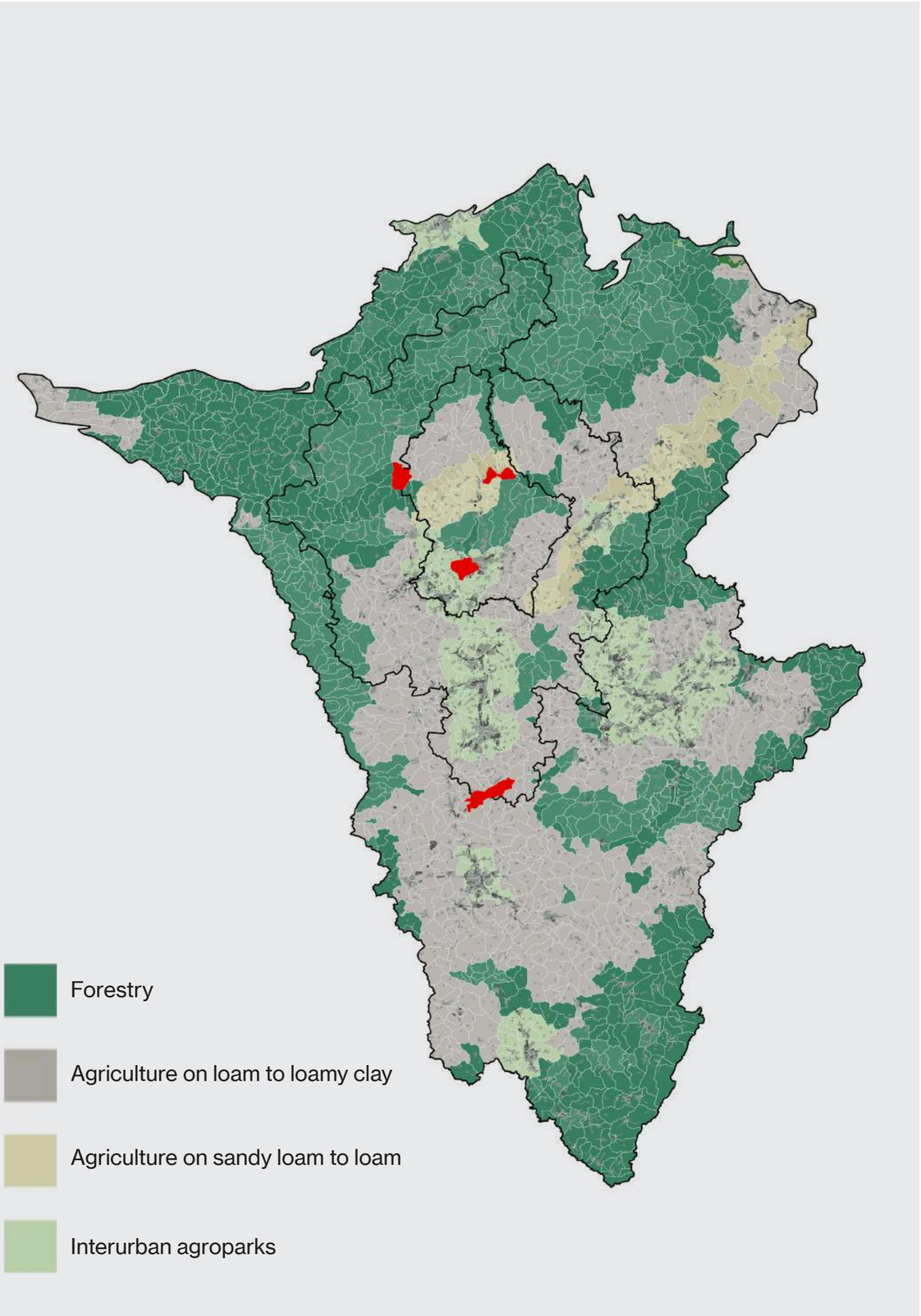


5 Bio-functional projects

5.1 Selective dissection;

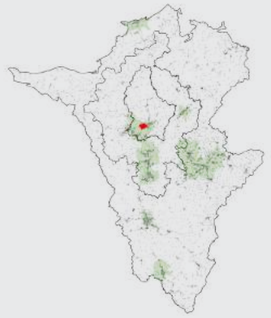
To be able to digest the biofunctional region into biofunctional pieces, we simplified the diversity of landscape types into 4 key samples.
Forestry in dark green, agriculture on loam and loamy clay in grey, agriculture on sandy loam presented in ochre, and interurban landscapes in light green.
This simplification is also structured by the network of local watersheds in the bioregion.
Considering the watershed as a unit, we have chosen a sample watershed from each landscape type to demonstrate our tools and their spatial implication in the local scale. Our choices are highlighted in red.



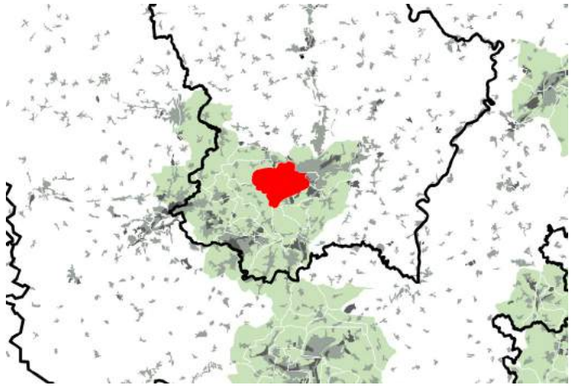


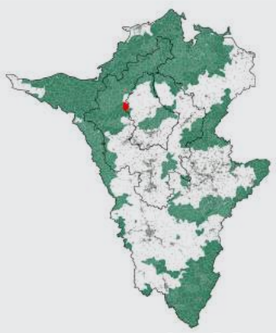
5.2 Watershed & municipal units

These watershed samples are not to be seen as a competing entity to municipal border. But rather a complementary, resource-based outlook which allows municipalities work together to achieve the most resilient and regenrative output from their landscapes. In the following pages we will layout our vision and observation for each of these samples, using the tools discussed in the previous chapters.

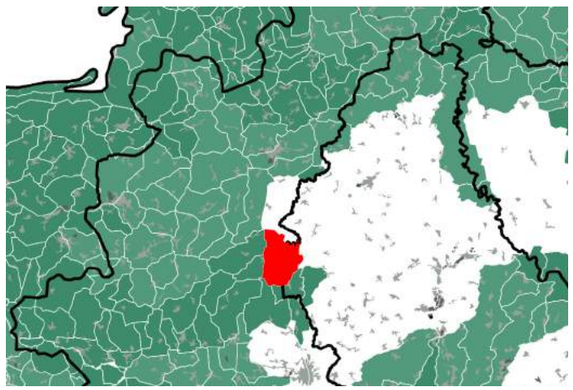


Interurban sample; Helfent

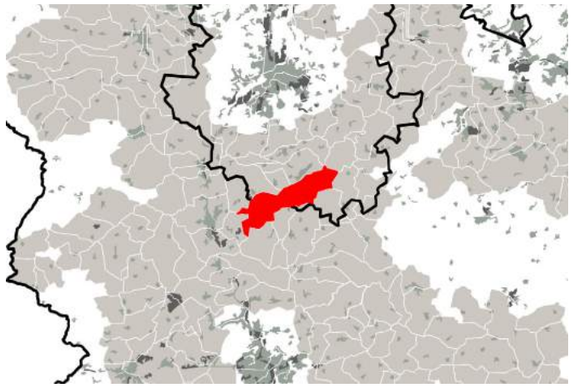


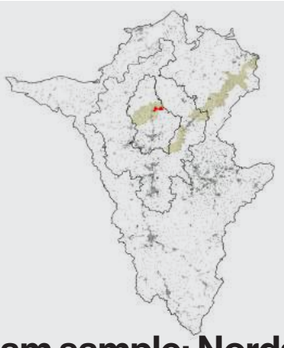


Agroforestry sample; Martelange

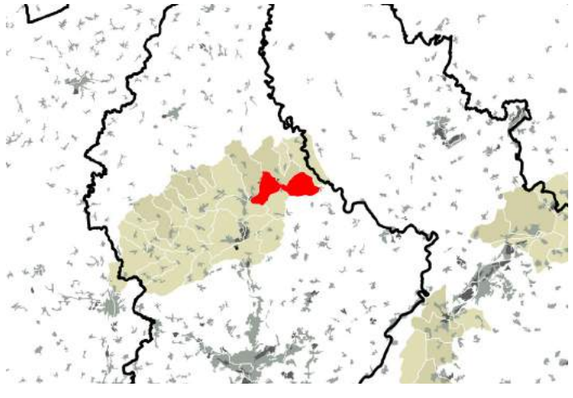


Loamy clay sample; Lorraine





Sandy loam sample; Nordstad



1

Interurban sample: Helfent.

Scattered peripheral activity zones into living neighborhoods belt

Between the major urban areas of south Luxembourg blend suburban developments infrastructure and big box drive-in areas which endanger residual agriculture fields and their carbon storage potential.

Bertrange, rue des près

KEY TRANSITIONS

1
limitless sprawl to productive green belt

2
diversification of activity zones into living neighbourhoods

3
increase in community gardens and citizen-farmer interrelations

4
Hybrid building typologies

Leudelange-gare / Schlewenhof

SECONDARY TRANSITIONS

1
pastures
to silvo-pastures

2
cropland industrial agriculture to cropland carbon farm

3
unhealthy forest
to healthy forest

4
vast openair parking areas to compact adaptable parking structures

Schlewenhof

Luxembourg

Helfent

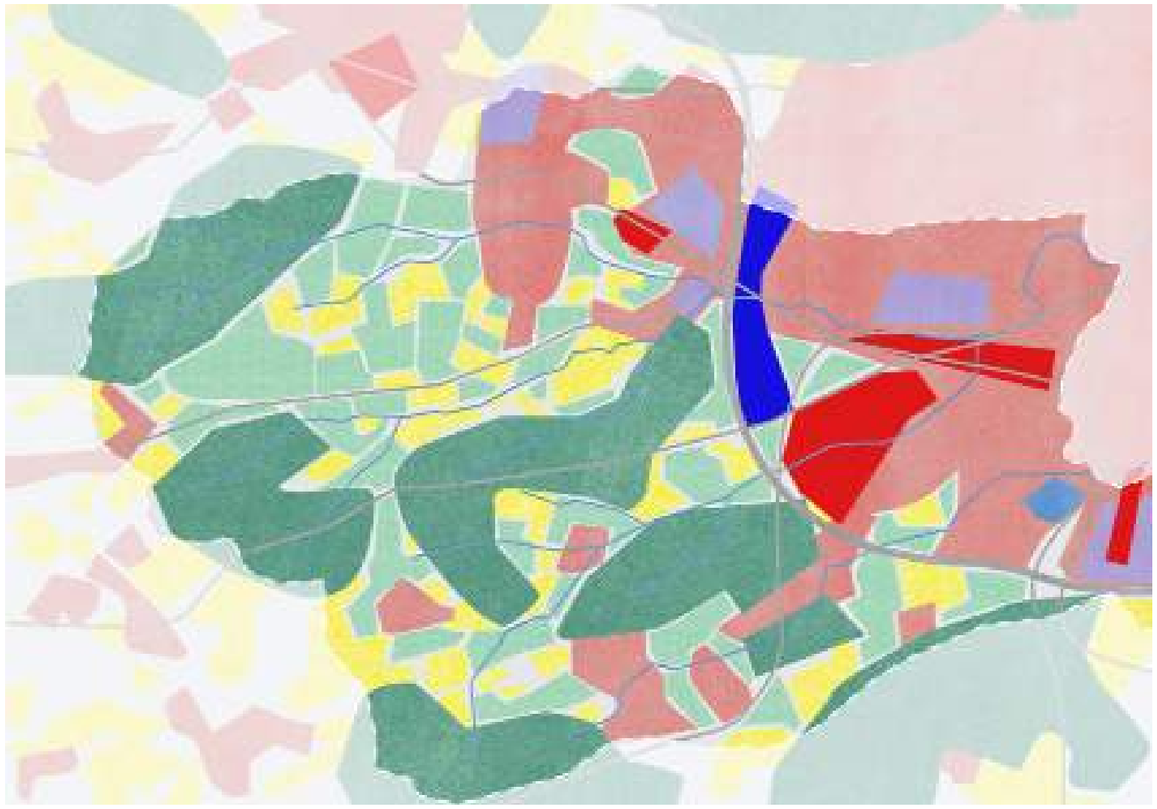
Bertrange

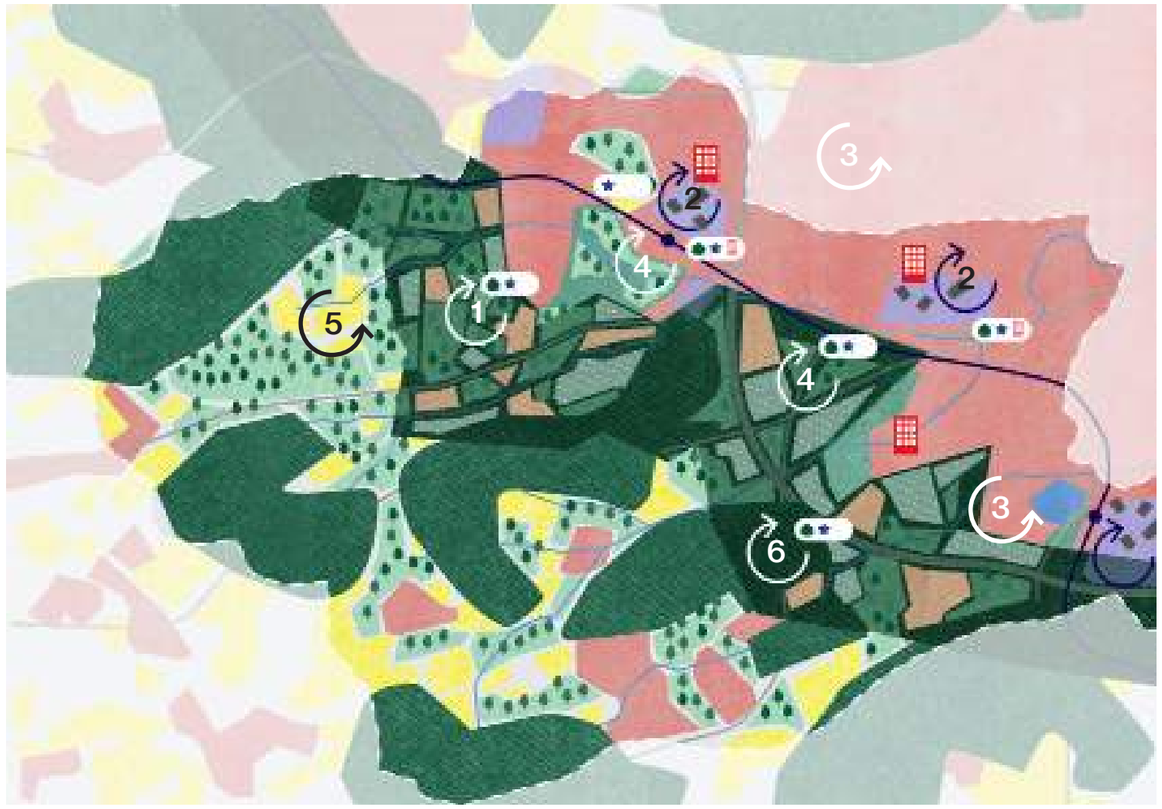
Housing as foreseen in sectoral plans

Economic areas as foreseen in sectoral plans

2018

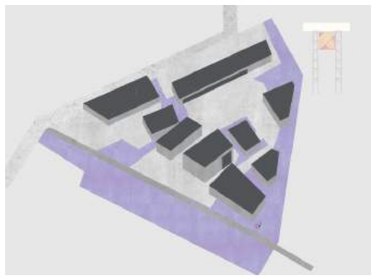
2050





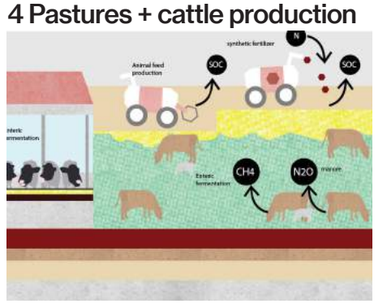
1 Loose edge, natural land under threat by landtake

2 Monofonctional economic islands accessible by car

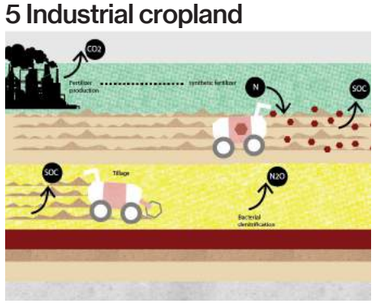


3 singlestorey datacentre replacing agriculturlal land

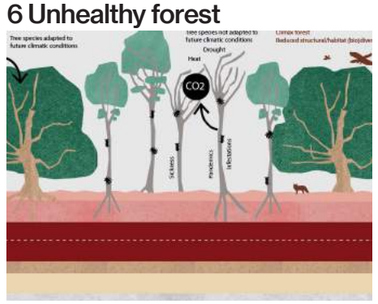
4 Pastures + cattle production



5 Industrial cropland

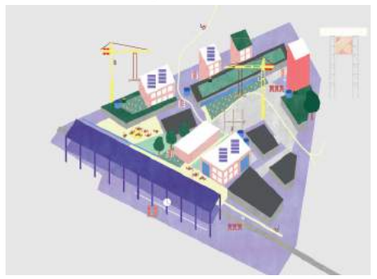


6 Unhealthy forest



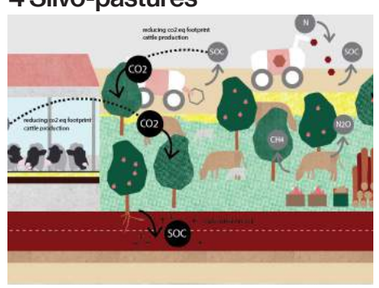
1 Productive green belt, protecting landscape

2 Mixed neighborhoods accessible by train

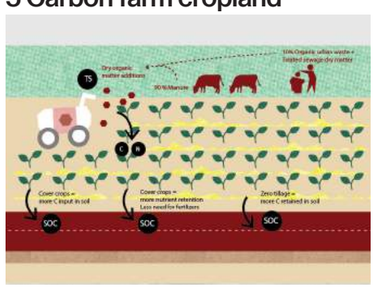


3 Datacenre mixes with housing highrise replacing parking surface

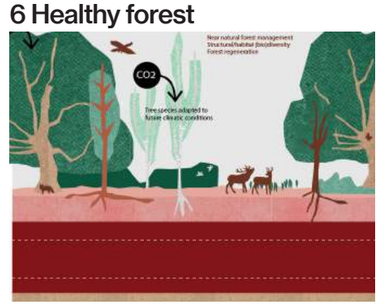
4 Silvo-pastures

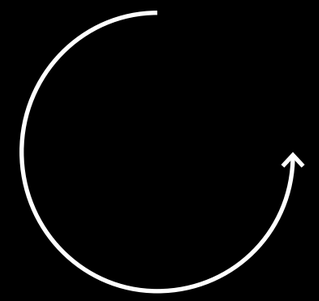


5 Carbon farm cropland



6 Healthy forest



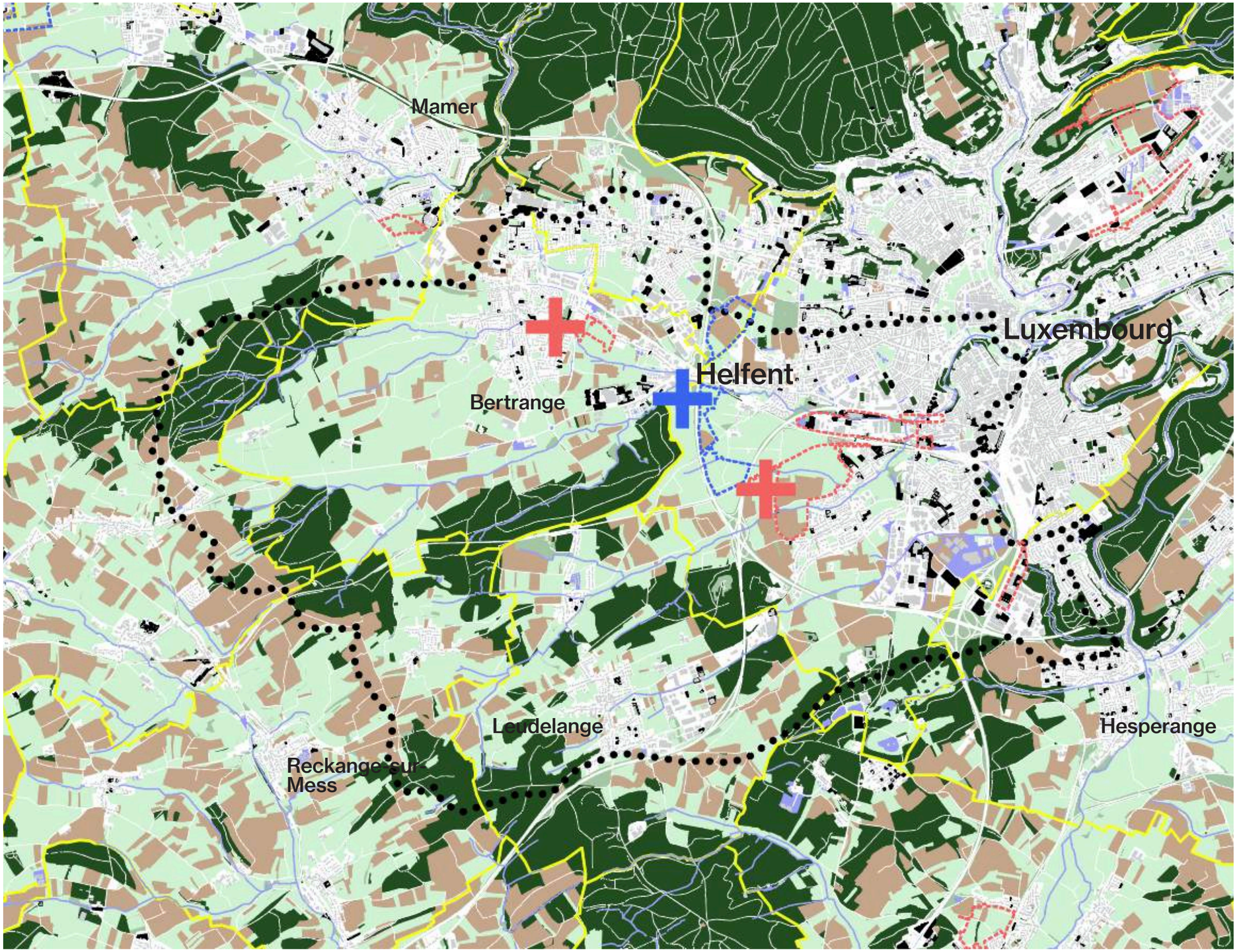


These spatial conditions can be turned into a productive green ecosystem belt structuring new mixed-use living neighborhoods around existing infrastructure.

5.2.1.1 Inter-urban sample; Helfent

existing land use

2018



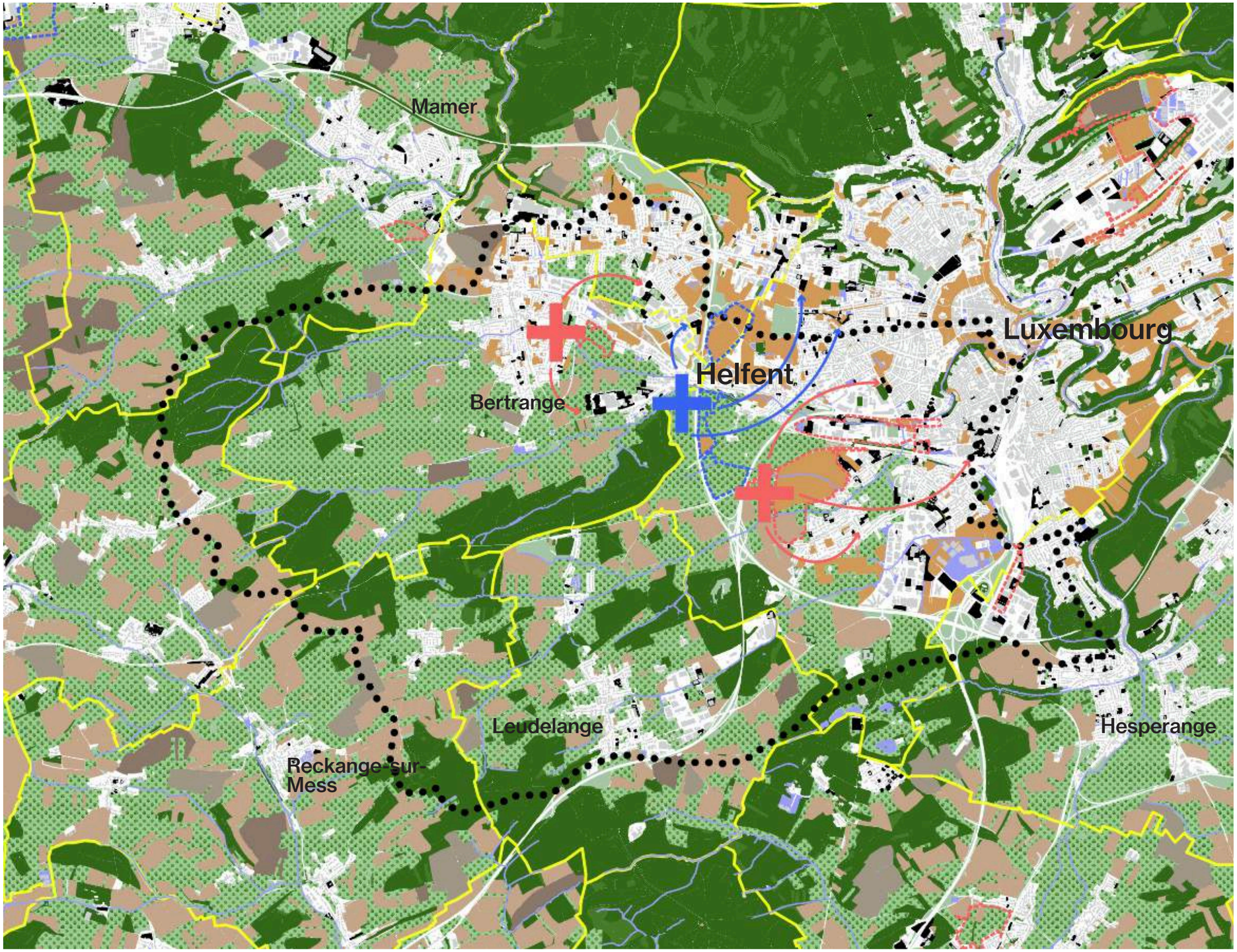
Legend

- Water bodies
- Pastures
- Forest
- Arable land
- Natural surfaces
- Sealed areas
- Existing building blocks
- Existing parkings and brownfields
- Municipal borders
- PSL (housing areas from sectoral plan)
- PSZAE (economic activities areas from sectoral plan)
- National borders

5.2.1.2 Inter-urban sample; Helfent

proposed land use

2050



Legend

- Water bodies
- Silvo-pastures
- Reforested (on current unhealthy coniferous)
- Regenerated broadleaved forest (mostly oak forest, only species that are not climate resilient such as beach could be removed)
- Natural surfaces
- Arable land with carbon farming practices zero tillage such as cover crops and organic matter additions
- Urban agriculture/leisure space
- Sealed areas
- Existing building blocks
- Existing parkings and brownfields
- Municipal borders
- PSL (housing areas from sectoral plan)
- PSZAE (economic activities areas from sectoral plan)
- PSL diplacement
- PSZAE displacement
- National borders

2

Agro-Forestry sample: Martelange.

Slates-fuel-wood

Set in the Ardennes, the former slate mining area is characterized today by fuel stations and liquor stores which are schizophrenically unmasking tax conditions.

Martelange seen from Rombach

KEY TRANSITIONS

1
Unhealthy evergreen fworest reforested

2
Unhealthy deciduous forest regenerated

3
Freed-up land afforested

Fields & forests in Wolwelange

SECONDARY TRANSITIONS

1
Pastures to silvo-pastures

2
Cropland industrial agriculture to cropland carbon farm

3
Gas-station retrofit into wood processing & services

Martelange , N4, the schizo strip & beyond: the forests

Radelange

Bigonville

Martelange

Rombach

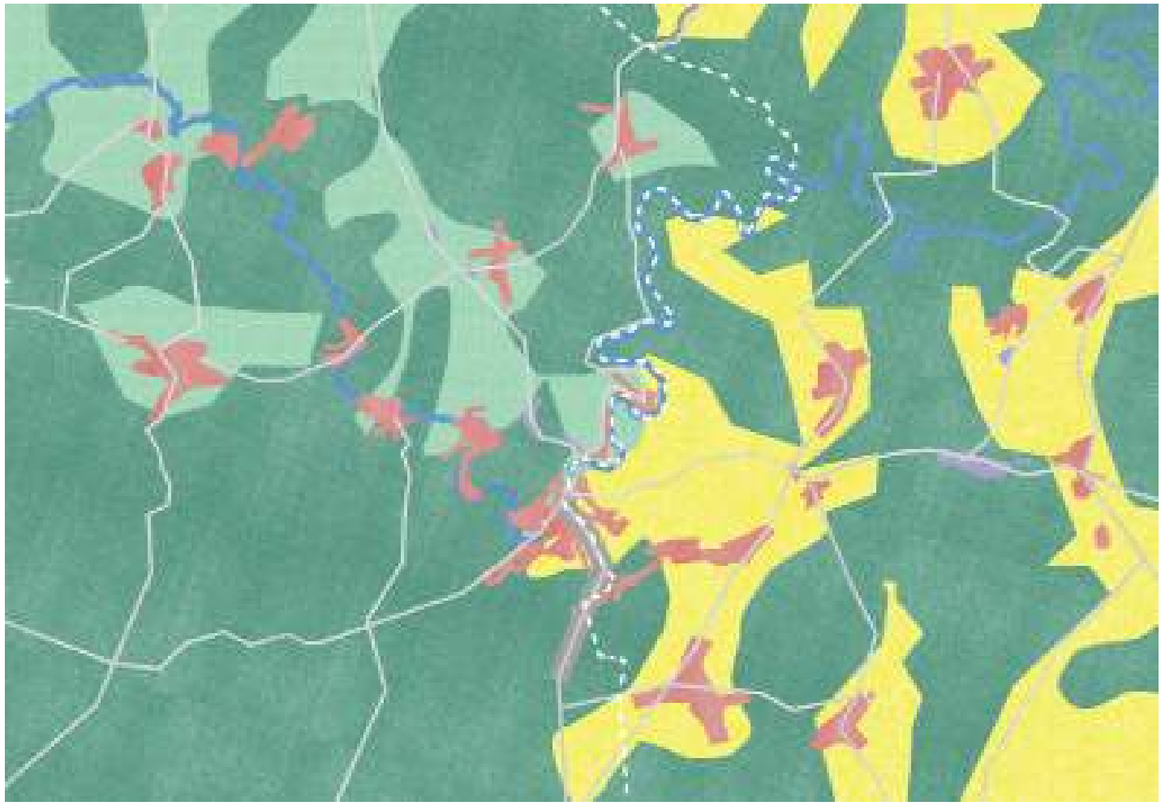
Belgium

Luxembourg

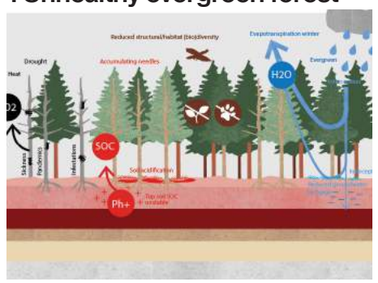
Housing as foreseen in sectoral plans

Economic areas as foreseen in sectoral plans

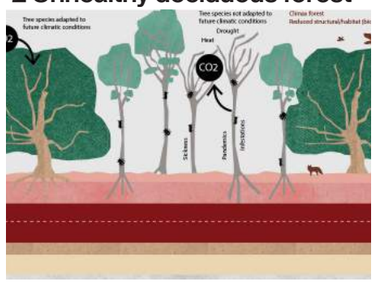
2018



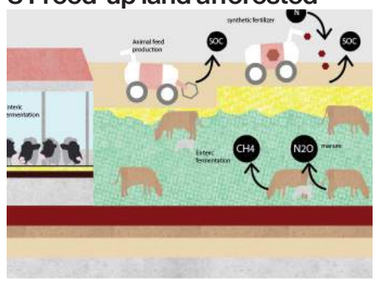
1 Unhealthy evergreen forest



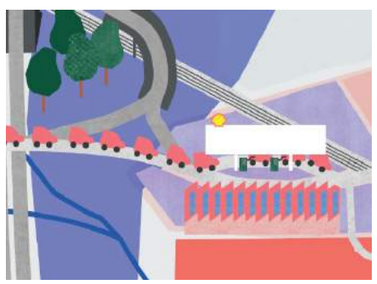
2 Unhealthy deciduous forest



3 Freed-up land afforested



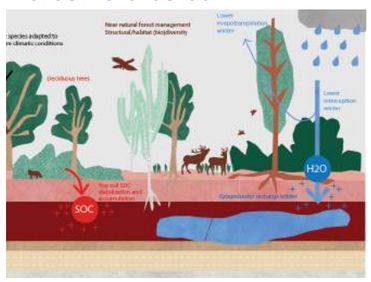
4 Array of fuel stations



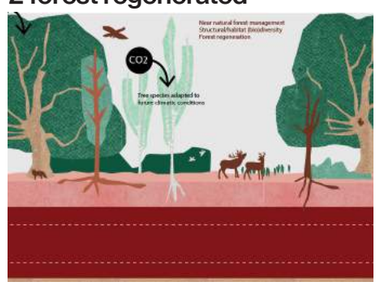
5 Centralised warehouse replacing forest

2050

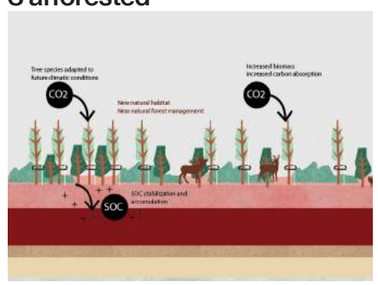
1 forest reforested



2 forest regenerated



3 afforested



4 Wood-processing workshops

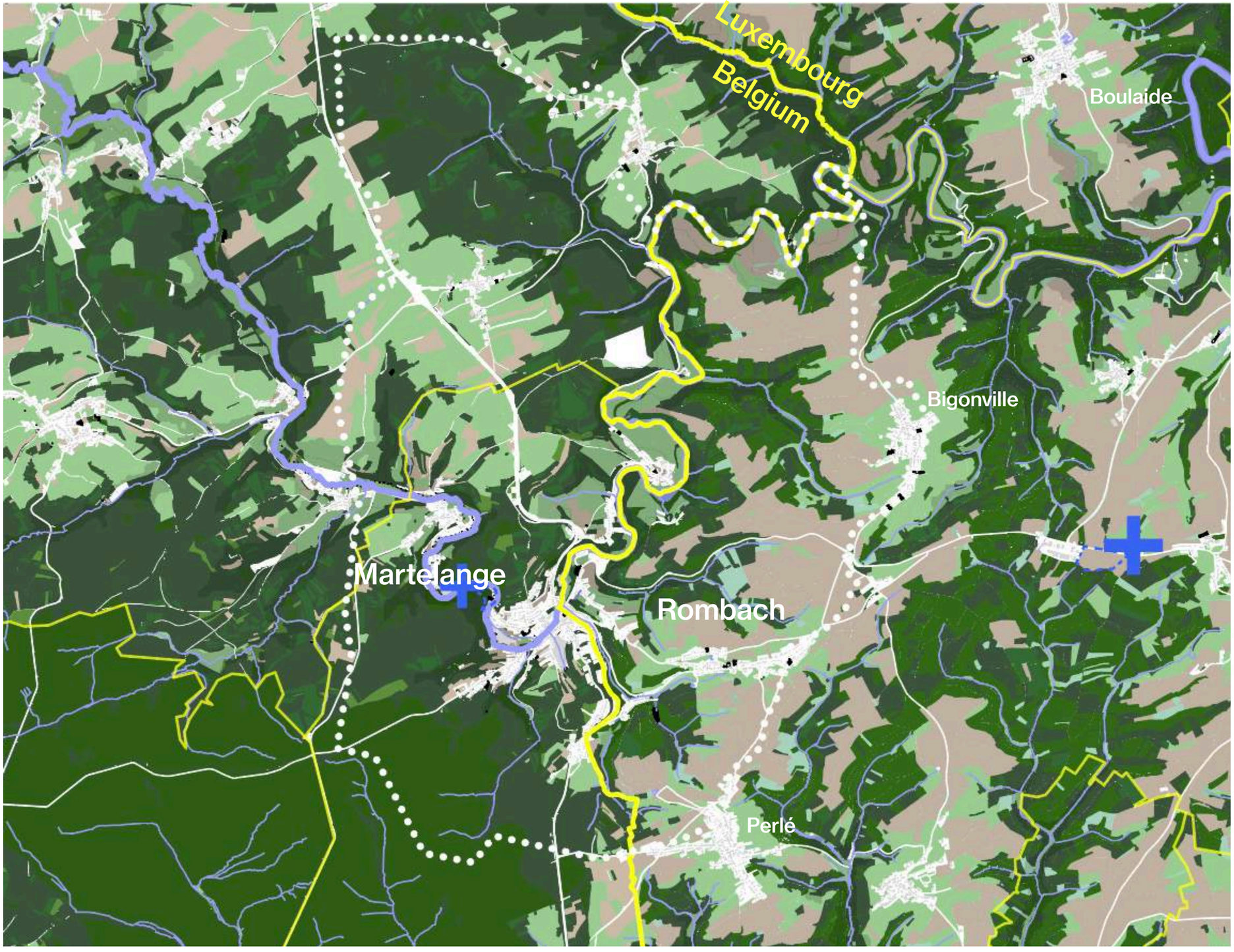
5 Multistorey, decentralised distribution centres

On the hills framing the Sûre river, unhealthy forests represent a vast economic, ecologic and social potential for renewal.

5.2.2.1 Agro-forestry sample; Martelange

existing land use

2018



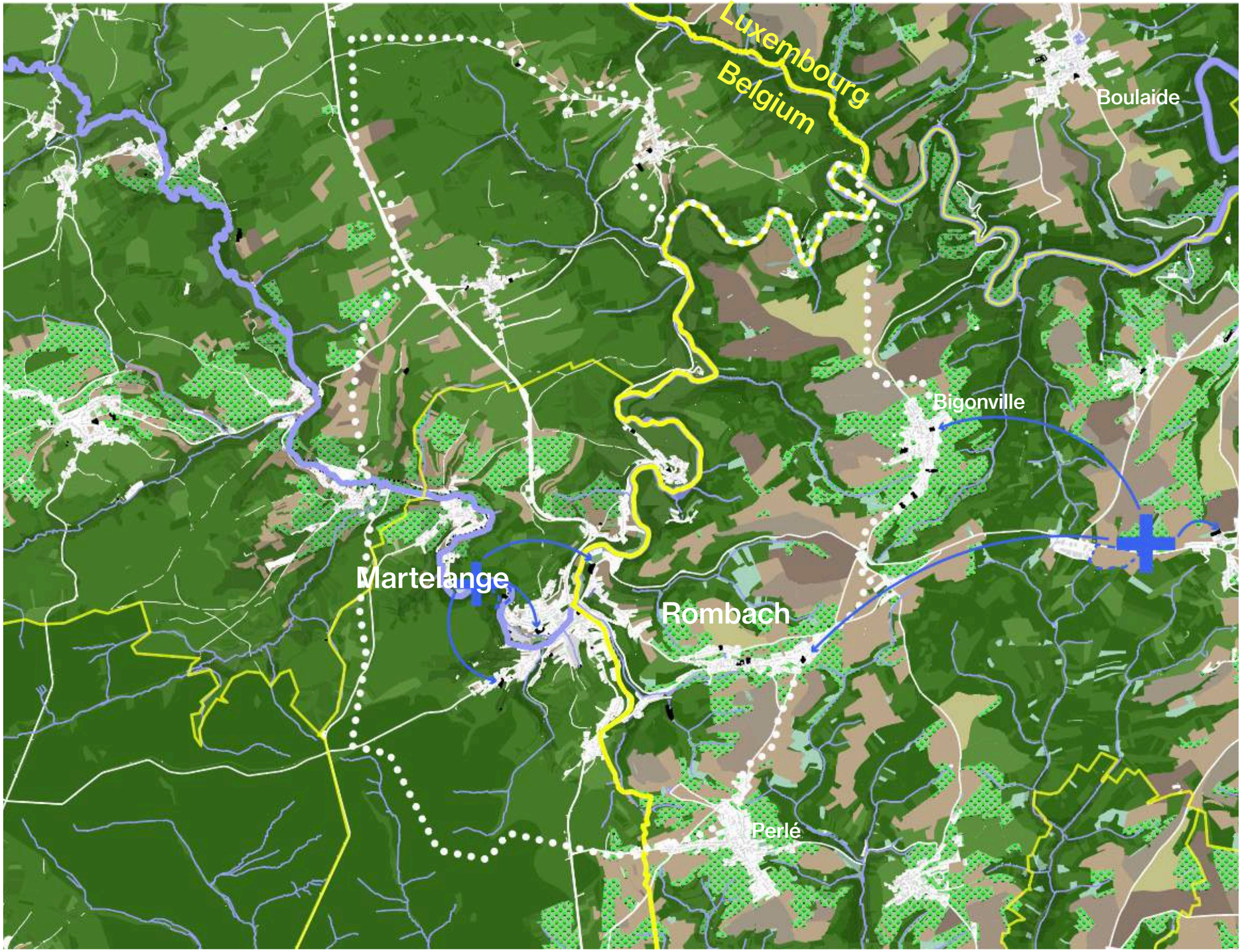
Legend

- Water bodies
- Pastures
- Forest
- Arable land
- Natural grasslands
- Sealed areas
- Existing building blocks
- Existing parkings and brownfields
- Municipal borders
- PSL (housing areas from sectoral plan)
- PSZAE (economic activities areas from sectoral plan)

5.2.2.2 Agro-forestry sample; Martelange

proposed land use

2050



Legend

- Water bodies
- Silvo-pastures
- Afforestation on arable land
- Afforestation on pastures
- Natural surfaces
- Arable land with carbon farming practices such as cover crops, zero tillage and organic matter additions
- Sealed areas
- Existing building blocks
- Existing parkings and brownfields
- Municipal borders
- PSZAE (economic activities areas from sectoral plan)
- PSZAE diplacement

3

Loamy clay sample: Lorraine.

Dispersed mono-cultures to carbon captive agriculture networks

Along the Grand Est high-speed railway and the A31 motorway, dispersed rural villages are shrinking and losing amenities to Metz and Nancy

Infrastructure and agriculture along the Seille river, Lorraine

KEY TRANSITIONS

1
Hill slope erosion to hedges

2
Pastures to silvo-pastures

3
Cropland industrial agriculture to cropland carbon farming practices

Eply: slow living & bucolic scenery off the fast pan-european networks

SECONDARY TRANSITIONS

1
unhealthy forest to healthy forest

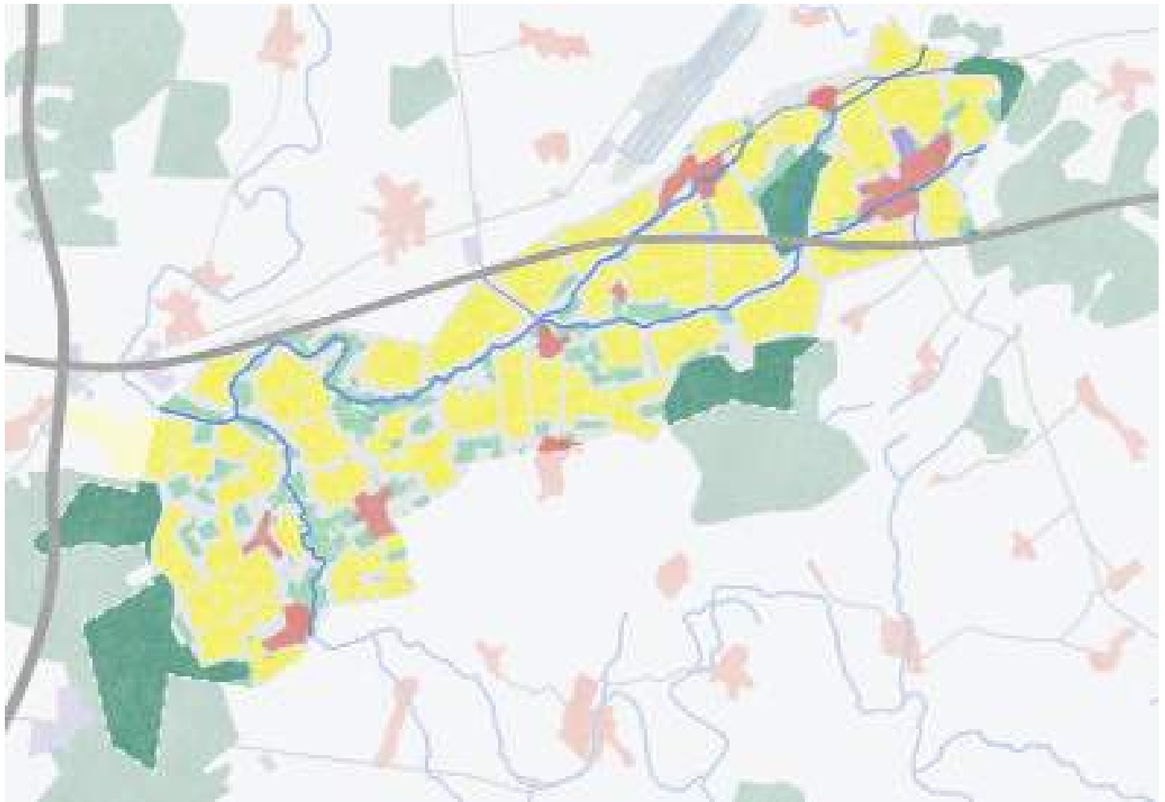
2
collective social infrastructure and amenities

3
soft network between dispersed villages to strengthen sociospatial fabric

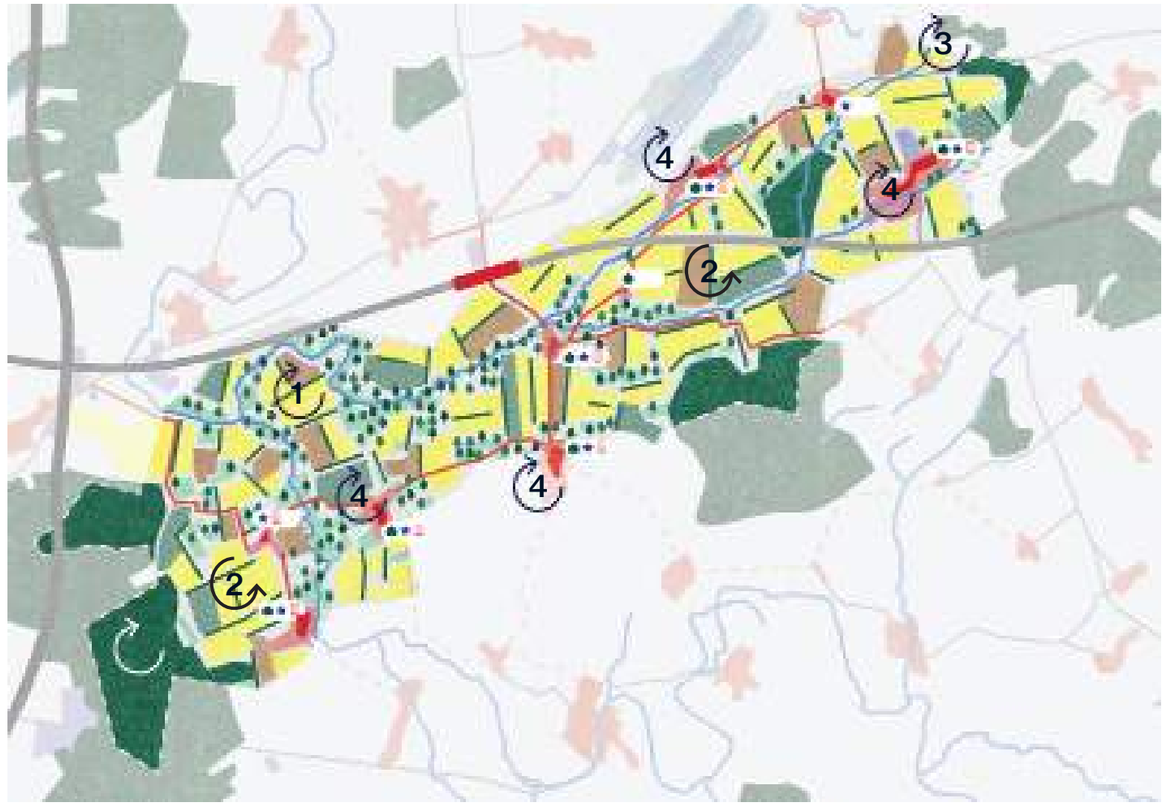
Sailly-Achâtel


Louvigny
Solgne
Cheminot
Saint-Juré
A31 Nancy-Luxembourg
Eply
Nomeny

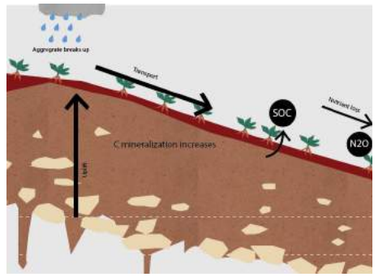
2018



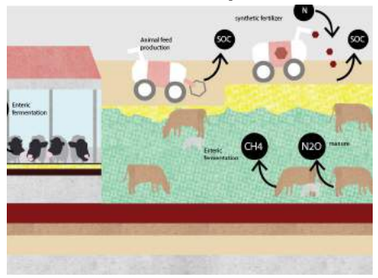
2050



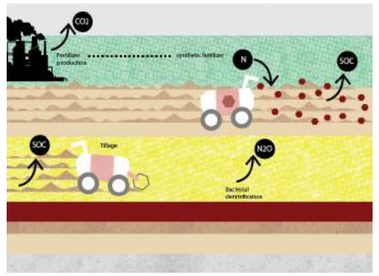
1 Hill slope erosion



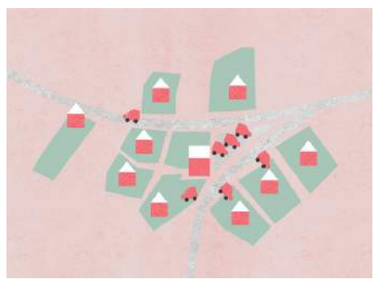
2 Pastures + cattle production



3 Cropland industrial agriculture

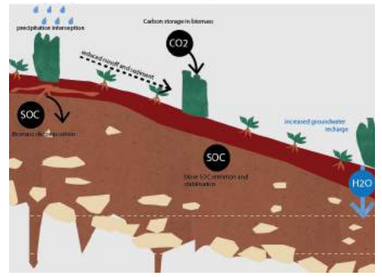


4 Isolated depleting villages

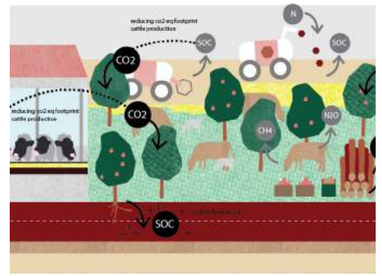


4 disappearance of amenities

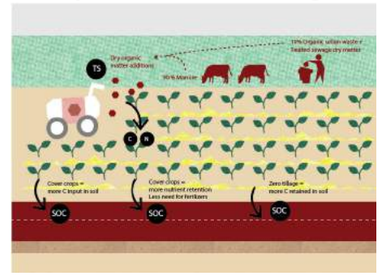
1 Network of hedges



2 Silvo-pastures

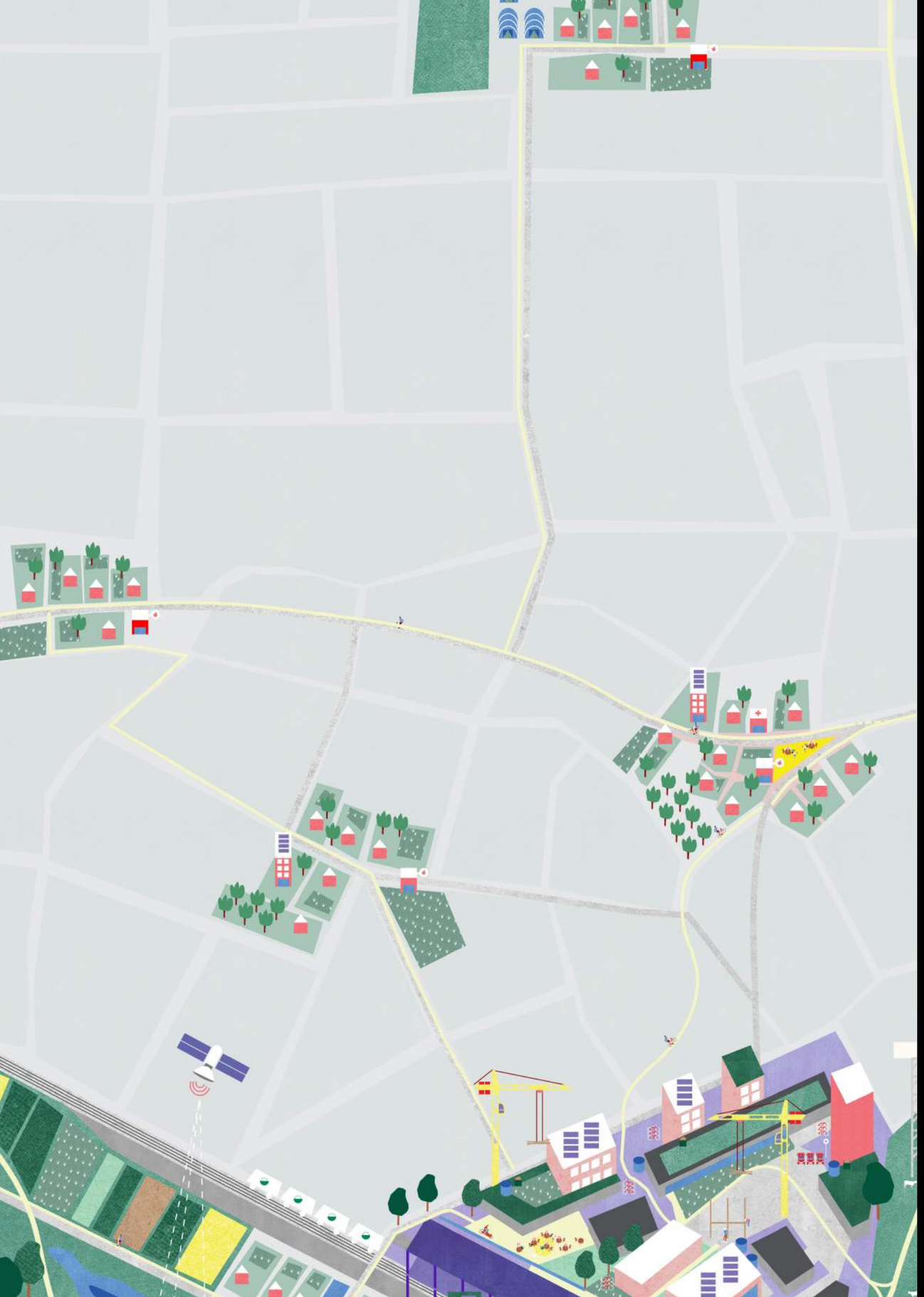


3 Cropland carbon farming



4 Interconnected village network

4 Appearance of shared amenities

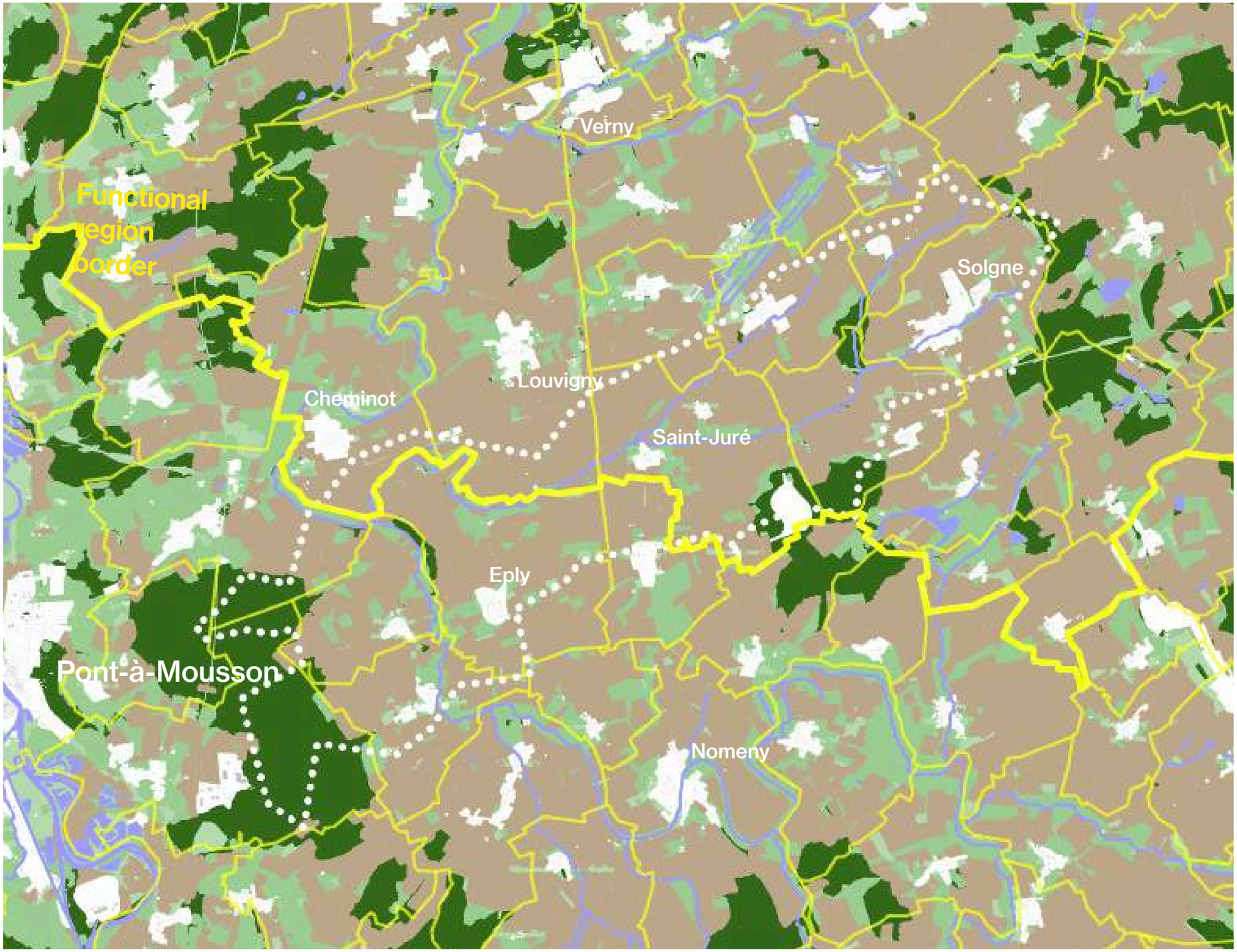


New agricultural practices, landscape features, and collective amenities will restructure both scenery and community in resilient networks.

5.2.3.1 Loamy clay sample; Lorraine

existing land use

2018

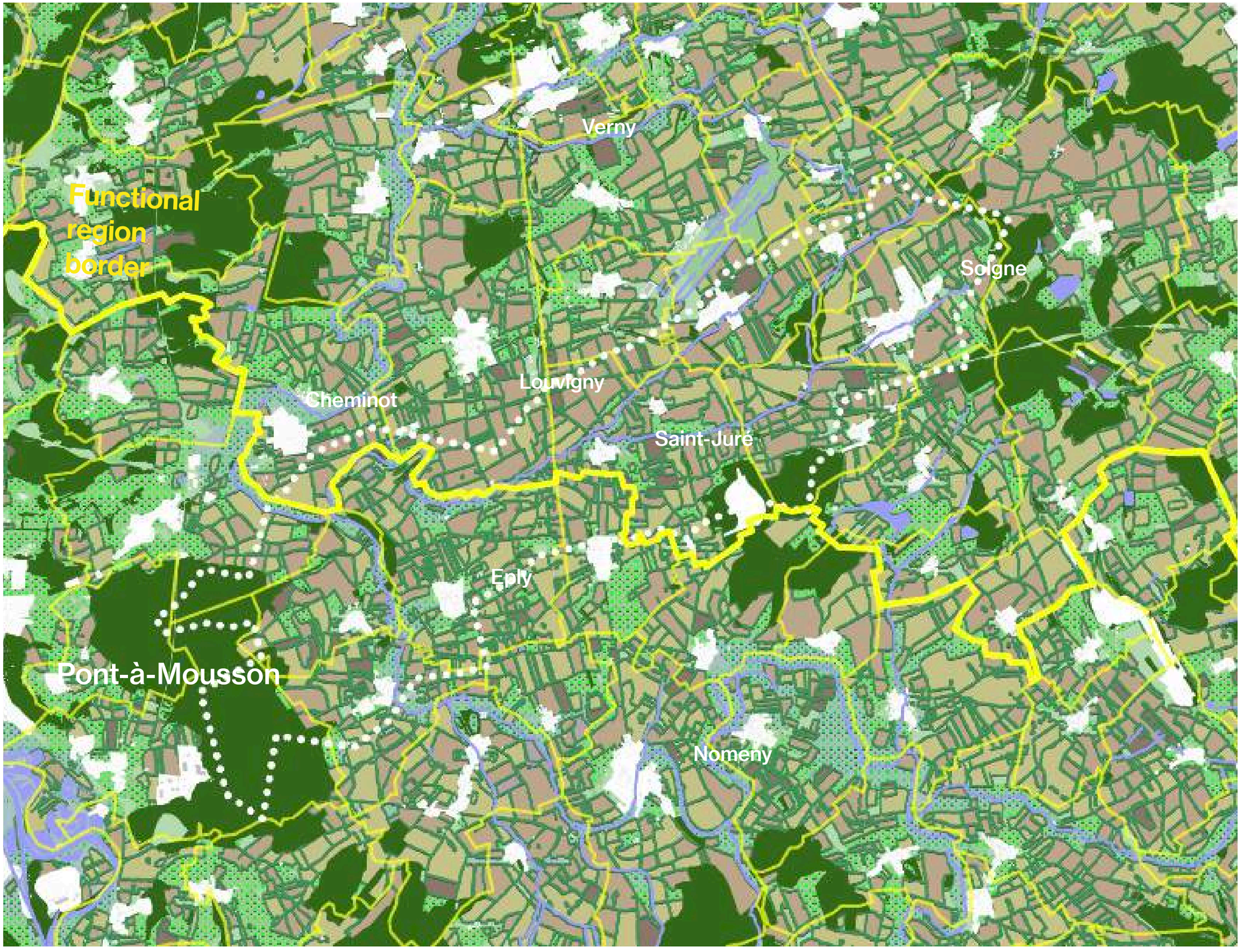


Legend

- Water bodies
- Pastures
- Forest
- Arable land
- Natural surfaces
- Sealed areas
- Existing building blocks
- Existing parkings and brownfields
- Municipal borders
- National borders

5.2.3.2 Loamy clay sample; Lorraine
proposed land use

2050



Legend

- Water bodies
- Silvo-pastures
- Regenerated broadleaved forest (mostly oak forest, only species that are not climate resilient such as beach could be removed)
- Natural surfaces
- Arable land with zero tillage carbon farming practices such as cover crops and organic matter additions
- Arable land with zero tillage carbon farming practices such as cover crops and organic matter additions
- Arable land with zero tillage carbon farming practices such as cover crops and organic matter additions
- Addition of hedges
- Sealed areas
- Existing building blocks
- Existing parkings and brownfields
- Municipal borders
- National borders

4

Sandy loam sample: Nordstad.

From meat & road villages to a soy & rail cities

The confluence valley of the Sûre and the Alzette is dominated today by monocultures, pastures, economic activities and suburban areas stretching along a strip between Ettelbruck and Diekirch.

Ingeldorf and Diekirch seen from Ettelbruck. 2012

KEY TRANSITIONS

1
International deforestation to local protein crops

2
Pastures to silvo-pastures

3
Cropland industrial agriculture to carbon farming practices

4
New protein source economy

Ingeldorf: rail, road, agrciulture and city

SECONDARY TRANSITIONS

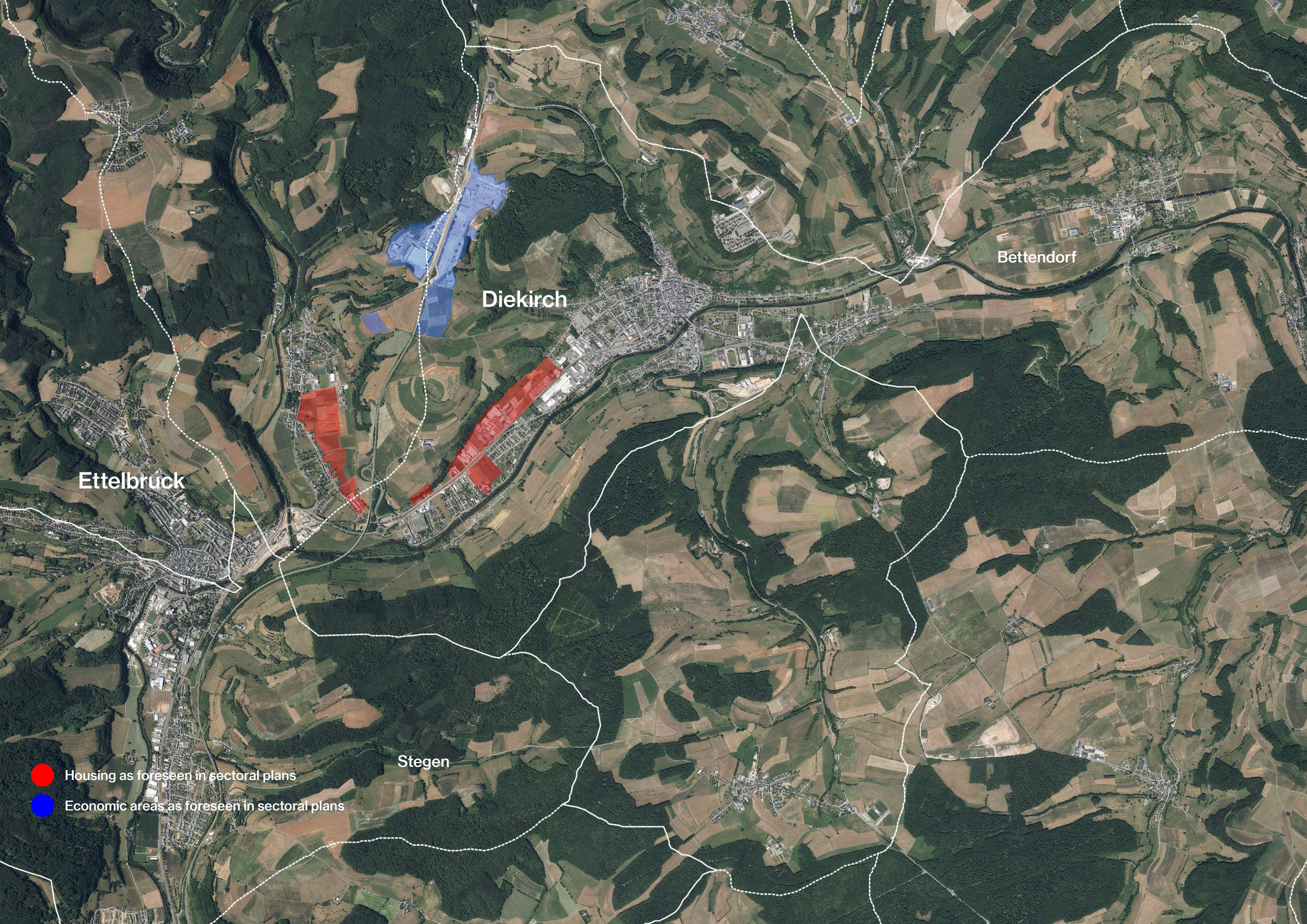
1
unhealthy forest to healthy forest

2
passive private gardens to bottom up R&D gardens of new crops

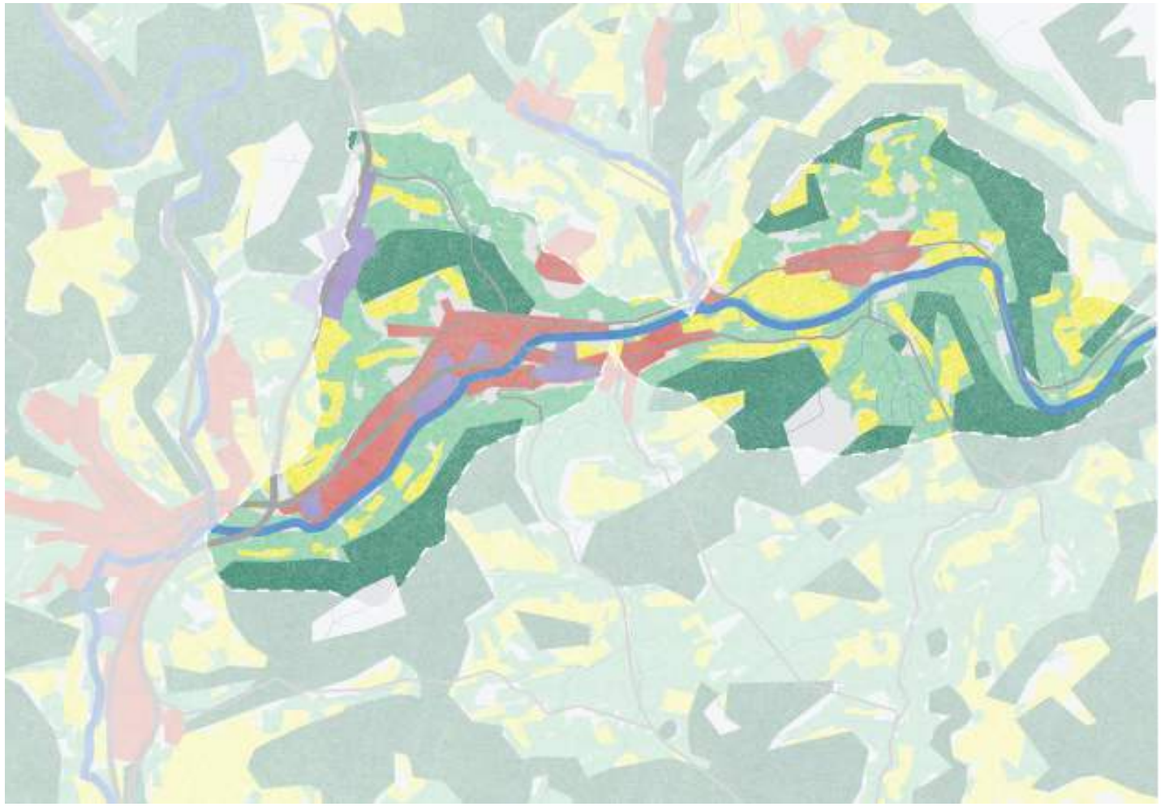
3
single family houses to dense housing mixed with agrifood businesses

4
roads to rails

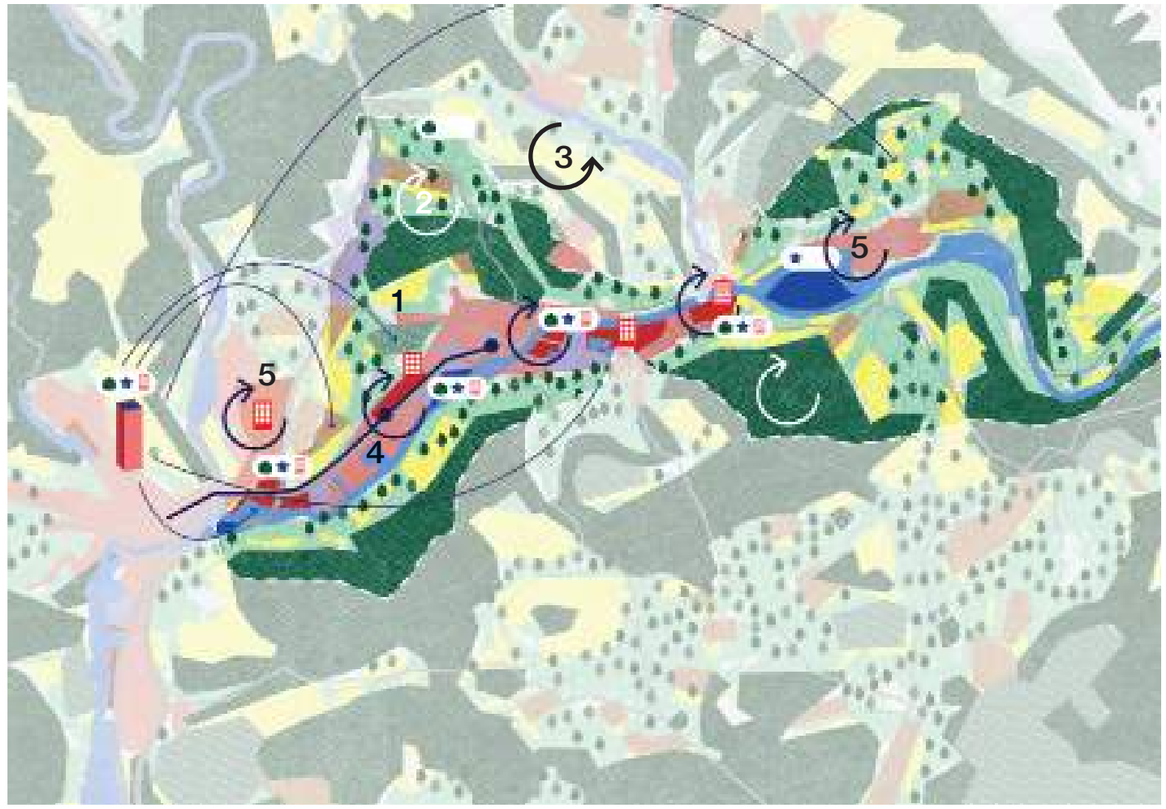
Ingeldorf: the mall as town center


Diekirch
Bettendorf
Ettelbruck
Stegen
Housing as foreseen in sectoral plans
Economic areas as foreseen in sectoral plans

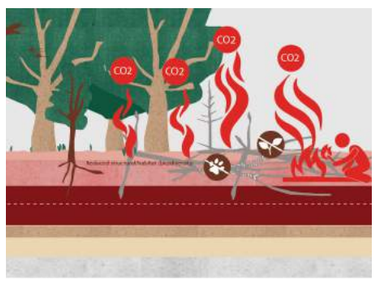
2018



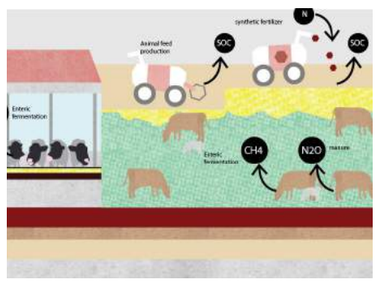
2050



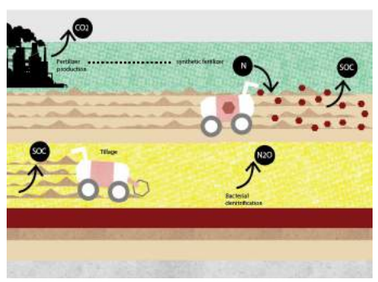
1 International deforestation



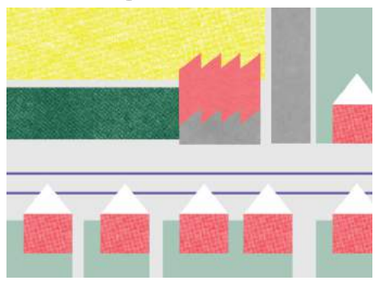
2 Pastures and cattles



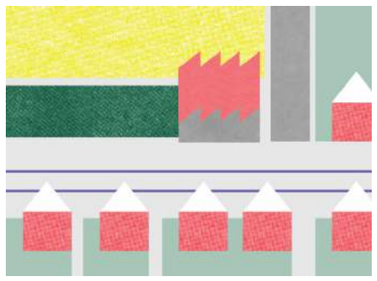
3 Cropland industrial agriculture



4 Slaughter house distributing meat using roads

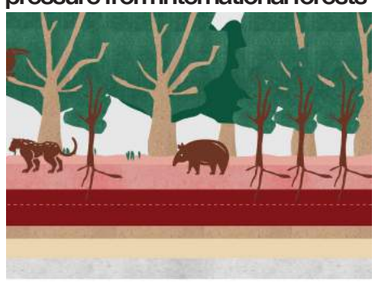


3 Increasing landtake by single family house developments

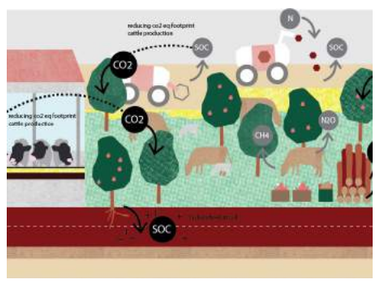


3 Hardscaped private gradens

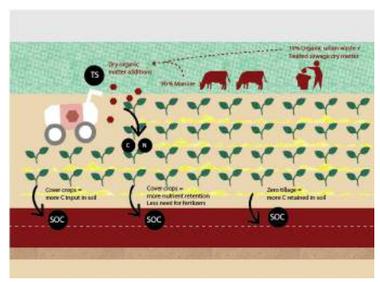
1 local soy production relieves pressure from international forests



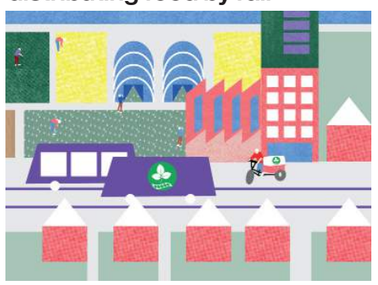
2 Silvo-pastures



3 Cropland carbon farming



4 New crop facilities distributing food by rail



5 Dense housing mixed with agrifood businesses

3 Private gardens piloting a 2 by 2 micro farm with new crops.

New
high-protein seed
cultures hold
the potential for
new economic
development and
urban structure.

5.2.4.1 Sandy loam sample; Nordstad

existing land use

2018

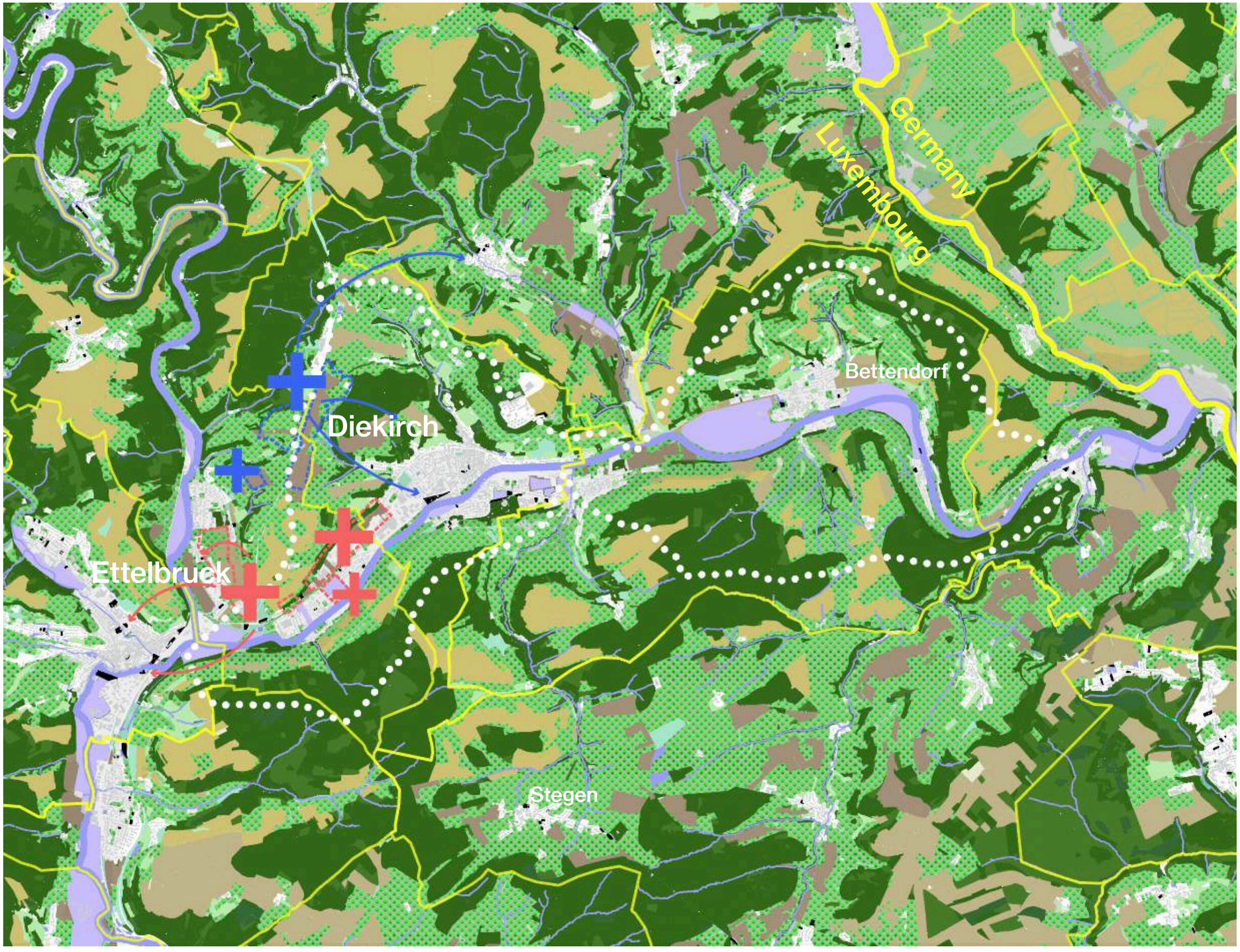
Legend

- Water bodies
- Pastures
- Forest
- Arable land
- Natural surfaces
- Sealed areas
- Existing building blocks
- Existing parkings and brownfields
- Municipal borders
- PSL (housing areas from sectoral plan)
- PSZAE (economic activities areas from sectoral plan)
- National borders

5.2.4.1 Sandy loam sample; Nordstad

proposed land use

2050



Legend

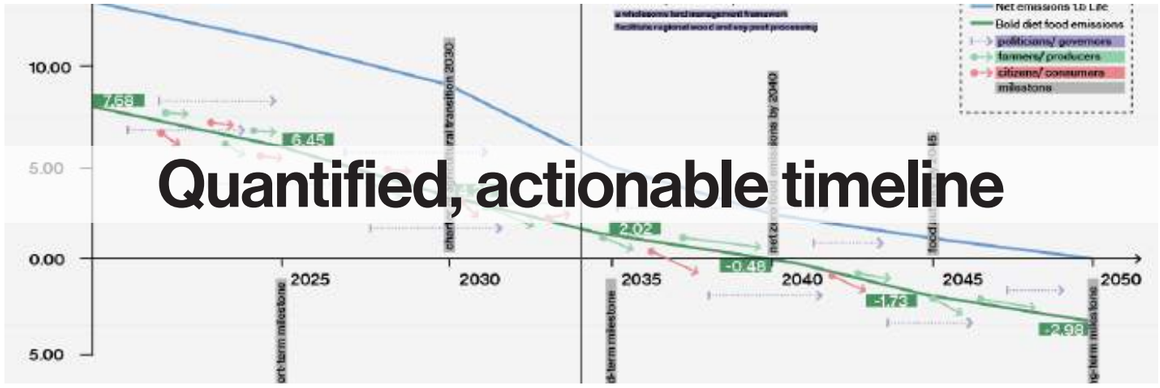
- Water bodies
- Silvo-pastures
- Reforested (on current unhealthy coniferous)
- Regenerated broadleaved forest (mostly oak forest, only species that are not climate resilient such as beach could be removed)
- Natural surfaces
- Arable land with zero tillage carbon farming practices such as cover crops and organic matter additions
- Arable land with zero tillage carbon farming practices such as cover crops and organic matter additions
- Sealed areas
- Existing building blocks
- Existing parkings and brownfields
- Municipal borders
- PSL (housing areas from sectoral plan)
- PSZAE (economic activities areas from sectoral plan)
- PSL diplacement
- PSZAE displacement
- National borders

6 Territorial project strategy

Macro Territorial strategy

We have investigated a decarbonising landscape, landtake, landuse & lifestyle vision anchored on provision of nutrition and wood (for construction) for the biofunctional region.

In addition, we tested our assumptions in conversation with farmers to better understand incentives and obstacles to the proposed transition.



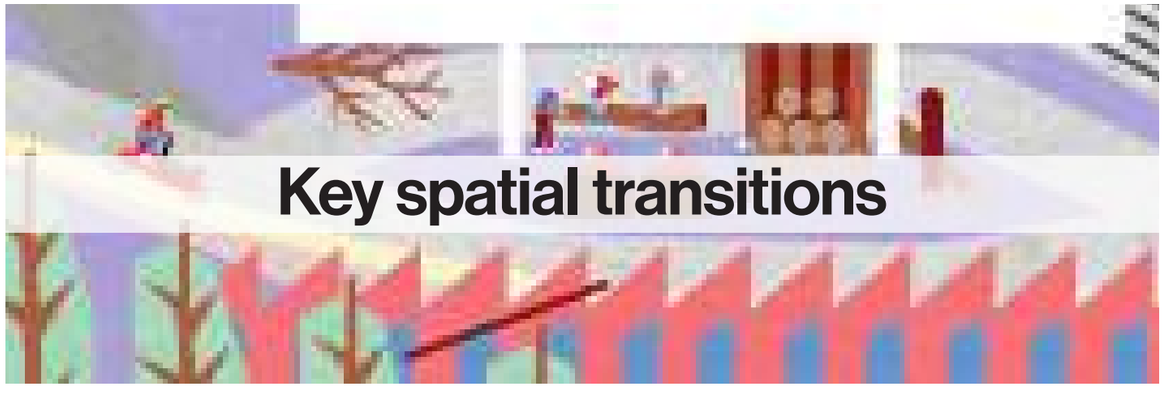
Quantified, actionable timeline


Farmers' views on incentives & obstacles

Bold diet shift pathway


Meso project strategy


Adaptive macro territorial strategy


Key spatial transitions

6.2 Next steps;

- detailed project actionplans & spatial recommendations selected sample areas.

- tailored decarbonisation pathway for selected sample areas.

- finalisation and handover of algorythm to produce macro territorial strategy.

- continue the talks with cultivators to develop possible future business models for them

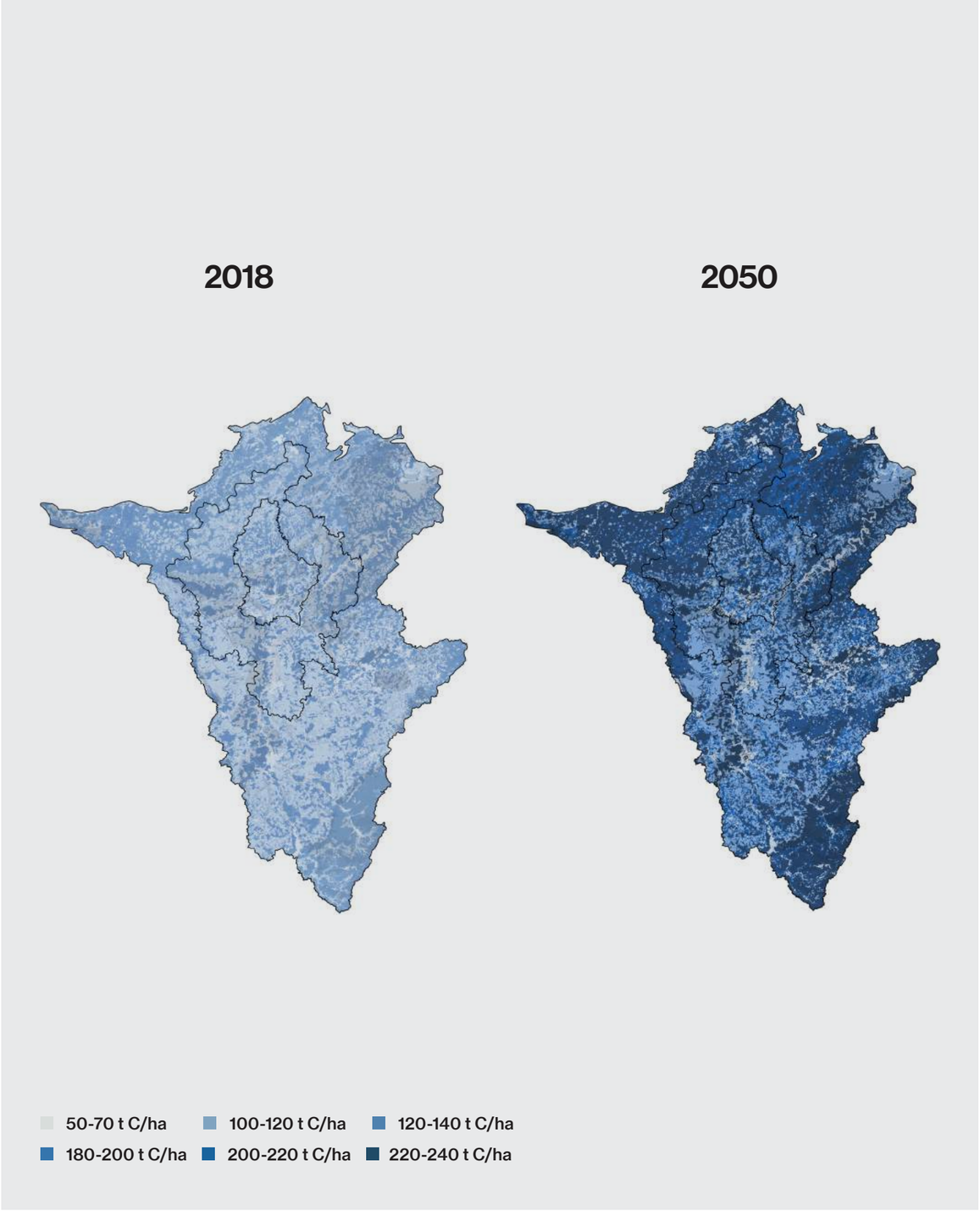
- research into future tree specie selection and forest management alternatives

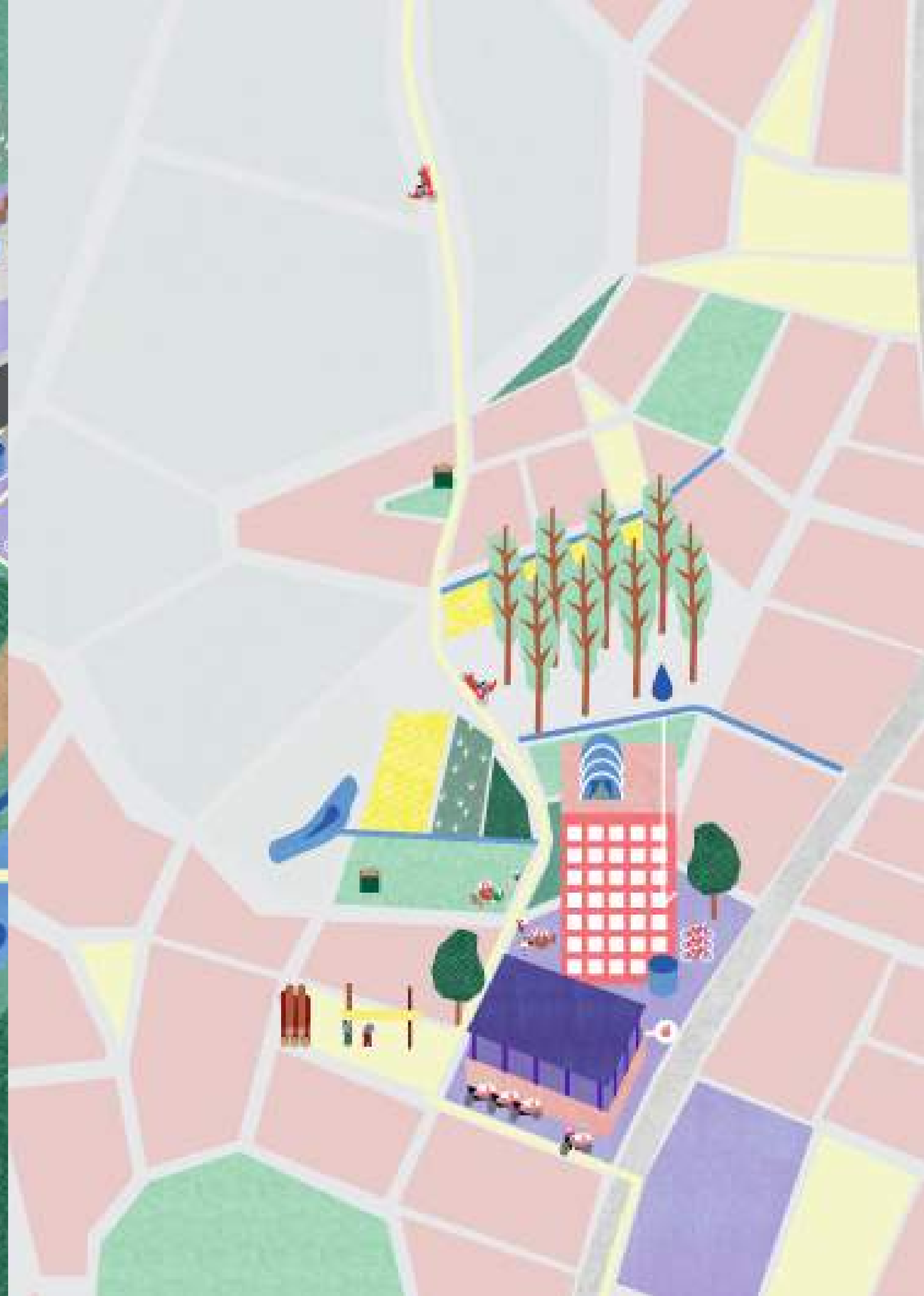
- research into crop types, crop rotations, future farm practices

- cross-sectoral territorial policy recommendations

- urban and architectural strategies for sustainable growth

6.3 Biofunctional carbon sinks;
enhanced carbon sink - Tn C/ha





7

Appendix

Contents

7.1 Workshops ‘Agriculture in transition’

Our vision has its core in land use change. The latter can be addressed once having raised awareness and having achieved a certain consensus mostly from the agricultural sphere and its protagonists: the farmers.

To this end, two workshops with the most preminent stakeholders in Luxembourg were organized. The first workshop mainly focused on the opportunities and obstacles that farmers encounter when they want to switch to more sustainable land use. Diet change and carbon incentives were put forward as main strategies.

The second workshop was a step further and looked at what actions can be taken into account to capitalize on these opportunities and overcome obstacles.

The conversations took place in different groups and were facilitated via the online platform MIRO. This collection outlines the results of the two workshops in one whole to promote readability.

fig. 26: Workshop through MIRO.

7.2 Identified transitions for a farmer
Workshops ‘Agriculture in transition’

All participants in our workshops agreed that the hypothesized change must happen as soon as possible. However, most of the people feels that the (political) discussion on agricultural change has not started yet.

Asking farmers to change, is asking them to change in a social, ecological and economic way. A new balance between those factors need to be found to counter the general doubts on the economic feasibility of such an ecological change. The transition, ideally towards a self-sustaining model, should for example be extended to other environmental services which are provided by cultivators, to other industry sectors (fairness) and to Europe. We need to ask ourselves as a society what our values around agriculture are.

This asks for three big changeovers.
One in business operations, do we want cultivators to remain free economic actors?

Two, in cultural operations, do we want to keep the farm-family in charge and prevent upscaling?

Three, in landscape and land-use operations, are we prepared to accept all the consequences if the whole landscape of farming changes?

Changeover in business operations

“As a society we often neglect the economic component of agriculture. The farmer is foremost a businessman that wants to make a living on what they do and provides for a family.”

We often forget that agriculture is a hard economic sector. That means people need to see a future in the work they do. There is probably a small margin of farmers willing to make a change (to organic farming or from pastures to crops), but the vast majority are motivated by a business model that is subject to subsidies and regulations. Also, farmers have long term investments that must be compensated of reimburse.

“Governmental decisions that are not supported by farmers or by the world wide capital market are cause harm to working man and women.”

If we want improvement, namely reducing CO2 emissions from agriculture, We put so much money into any number of projects (nature conservation (not that they are not important, but as a local councillor, which I am, I see how much money is spent for no added value, Leader, cycle paths, etc etc) but no one wants to take money and put it into a clear project.

“We need to back it up with money. Now we are asking farmers to finance this from their own resources.”

Changeover in culture

“We are worried as the farms get bigger and less families are involved (from thousands to hundreds) the culture could be lost.”

Besides an economic logic, there are also socio-cultural aspects of territory that need to be taken into account. Some participants showed high resistance to changing the current agricultural practices on grassland. Farming is also a tradition and a habit. They argued that animals need to be an integral part of agriculture (fertilizing cropland), and that the market determines agricultural production. They are however not rejecting the goal to become CO2-neutral by 2050, but hope to stay in the cattle business. Participants have few ideas how else to use grassland.

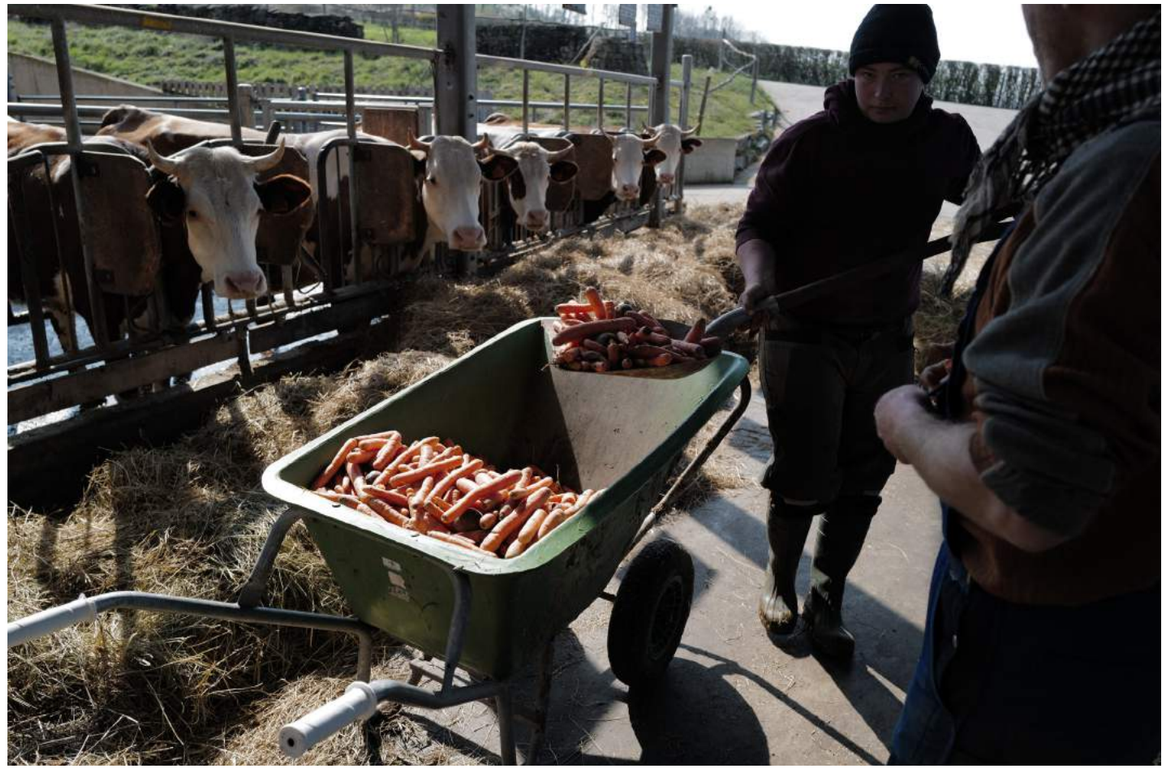
Changeover in landscape-landuse

The big shift of landscape and landuse comes with doubts on contextual coherence. A lot of farmers are sceptical about the conversion to 100% organic farming (problem of water, climate protection, food shortages, ...).

But most agree on another problem in agriculture in Luxemburg, namely the overproduction of milk and meet and the import of soya.

“Currently 75% of harvest from arable land (corn silage, cereals) is turned to feedstock to our dairy cows.”

Cattle should be fed by local production, mainly gras, few cereals. But in the current economic market this is seen as an unreachable dream.



7.3 Identified obstacles
Workshops ‘Agriculture in transition’

‘Who / what can throw a spanner in the works, slow down or thwart our transition?’

In addition to the three identified changeovers, there are a lot of practical obstacles in agricultural transition. Below is a non-exhaustive list of the mentioned obstacles in the workshop.

Uncertainty of demand
Changing to a more plant-based diet changes consumer patterns. This brings uncertainty and stops investments in efficiency. People wonder if this change is for the long term.

Interdependence with international market
“The self-sufficiency in Luxembourg is 2%.”

Farmers in Luxembourg are heavily dependent on their suppliers (upstream) for livestock, seeds, fertilizers, ... and the market (downstream) for demand. Luxembourg is dependent on international export (milk, meat). The market has global dimension (e.g. capital market, Russia) and the concern is that the Grand Duchy of Luxembourg has not enough clout power to influence the intertwined agricultural economy.

Imported products follow cheaper, carbon intensive practices
“We need a worldwide approach about reducing the carbon foot print in agriculture. Trying something alone will most likely end in a frustrating reducing of farmers community in Luxembourg.”

A few participants were demanding that the whole economic system needs to change. That in a growing global economy, just having criteria on CO^2 is not enough.

Power of middlemen
The revenues in relation to the costs for distribution are currently too low to be able to invest in alternatives. This is where the current power of intermediaries plays a role.

Expensive labour force
Croplands are highly intensive for processing. High wage costs put Luxembourg farmers at a disadvantage.

High investment costs and depreciation
“Coniferous forests are unresilient, but it takes a long time and high investments to change a forest (20-50 years).”

High investment costs and long payback periods reduce farmers’ desire to invest in sustainable systems.

Uncertainty on longiterm investments
“This speed of change in market AND climate conditions is frightening.”

Farmers wonder how to cope with a market that changes faster than businesses can change.

Uncertainty on long-term support
Uncertainty (about the indexation) of prices and premiums makes for risky investments.

Substantial loss of added-value
?

Protein balance
Some farmers, but also the broad population, have thoughts and concerns on the health issues of a plant based diet. They see man as omnivore and are concerned on protein balance.

Lack of clarity on emissions
“For me as a winemaker, glass bottles are influencing factor #1 but after that it becomes more unclear how to optimize CO^2 emissions.”

There is a lot of missing data if a farmer of any kind wants to make his/her CO^2 balance. Thus working with assumptions is the only option.

Permits
“Afforestation requires a national permit. Luckily not from the EU, whereas making silvopastures (and most likely also alley cropping) do not need permits.”

Poor soil
The topography and quality of the soil is in large parts unsuitable for horticulture or arable farming.

Water shortage
“In the last 5 years, farmers have already tried out new production methods such as vegetable growing. But many have already given up again because of the water price.”

We still do not have a solution to the water price for food production. Lower water prices and strong subsidies and simple permits for rainwater catchment basins are necessary, but politicians find it difficult to get away from the cost-covering water price or to give a subsidy for this water.

Lack of recognition
“There is need for a broad societal debate that includes farmer in political decision making processes.”

Farmers today are not appreciated enough for their work. Society needs to understand the significance of agriculture and subsidies do not help on that. There is a need and a demand for new consideration/societal understanding of agriculture.

7.4 Identified incentives
Workshops ‘Agriculture in transition’

“What or who can help us to achieve our goal, to successfully implement this decision?”

Economically viable regulations
Economically feasible regulation remains a working incentive.

Economically viable subventions
New systems of incentives and subventions think more creatively about the future role of a farmer.

Awareness raising for new economic models
New cooperative and short-chain-based models are increasingly finding their place in western European agriculture.

Political framing as model region
There is a growing ambition among politicians. G.D. of Luxembourg is a growing model region for the European Union. Communication and identity formation are accelerating factors in this.

Full cost pricing
Water protection by full cost pricing is brought up as a good example of how it could be in agriculture.

Planning reliability
Clear goals, time and competences are needs for all cultivators. Planning reliability for planning the next 100 years with exact criteria and measuring tools giver business models certainty.

Trial & error projects
“There is a clear need for experiments. But nobody dare to gamble with his own business.”

Market change
“Some slaughterhouses are building up vegan branches of business.”

Health insights on meat consumption and the COVID-19-crisis have changed the way people look at their meals. People in the last years take more time to cook, they eat more varied, and therefore often with more plant-based ingredients.

7.5 Summary
Workshops ‘Agriculture in transition’

At the end of our second workshop we asked the participants to prioritize what is absolutely indispensable to start the transition:

“We agree on the facts: climate change, biodiversity loss, … We need to build from there. This is a problem that farmer are aware off. It’s a common ground.”

“We need to bring more things into action. We have the feeling that everyone keeps running on the same spot, keeps making studies, use words, …”

“For viticulture, we need more research and development. The sector as a whole does not yet know enough to make the transition.”

“I agree with research and development. That, and more experimenting.”

“There is an urgent need for an in-depth, but wide-ranging, debate. As a group, as a country, as a society we seem to have no idea what direction we want to go with our agriculture. Without a societal strategy, politicians keep running us in circles.”

7.6 Workshops ‘Agriculture in transition’
continues...

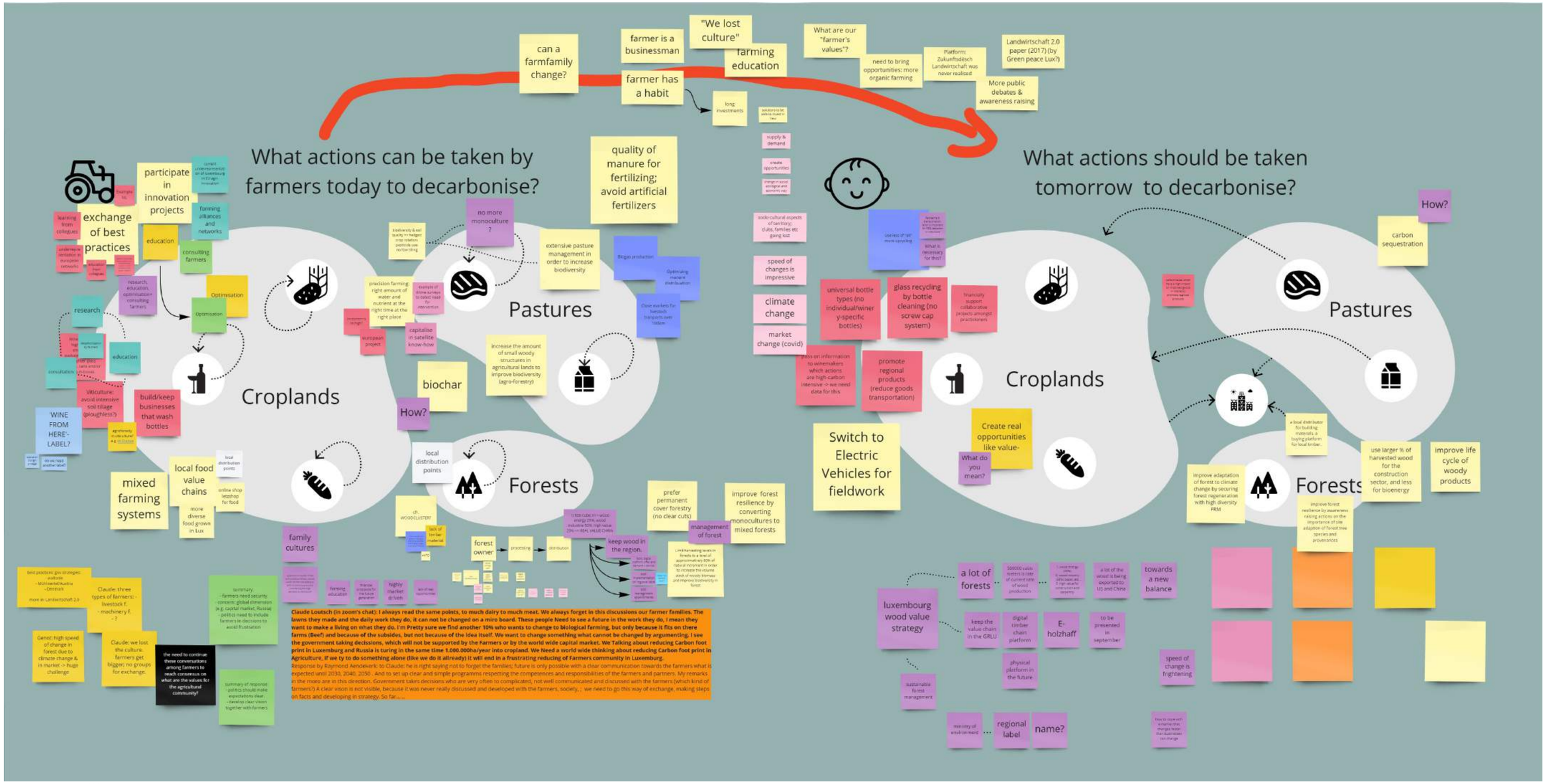


fig. 27: Workshop through MIRO.

7.7 Identified actions
Workshops ‘Agriculture in transition’

“We don’t need a one fit solution for everyone. We need to bring a variety of opportunities for families to evolve in their own way.

A public structured debate

In both workshop participants heavily strived for a round table debate regarding the future of agriculture. We need more public debate around what our ‘farming values’ are, to come to a societal strategy. The COVID-19-crisis has shown how political action can create a moving dynamic very quick.
To moderate this public debate, we need a platform where the farmers themselves are heard. The platform ‘Zukunftsdësch Landwirtschaft’ was never realised and needs new profesional input. Austria gives us a good example for that. There is a need to continue these conversations among farmers to reach consensus on what the values are for the agricultural community.

Townhall Conversations On Definition Of Agriculture
Townhall conversations are a low-threshold method the inspire public debate.

Televised National Debates
Debates can also be performed on TV.

Participatory trajectory
Set up a programme, for example in cooperation with the Chamber of Agriculture and ASTA, where farmers can participate voluntarily. A project group of 5-10 farms with different production orientations could shine their insights on technical and other innovations in order to improve the situation of farmers without damaging the business financially.

Politican strategy with action plan
Governments often take decisions that are very too complicated, not well communicated and discussed with the farmers. A clear vison was never visible, because it was not really developed with the farmers. After the debates on the future of our agriculture, the expectations should be clear and we can finally work on a clear action plan. Money, for the innovation, the technology, the monitoring, the evaluation, etc. should be linked to these outcomes.
There are some best practises of governmental strategies: Wallonie, Mühlviertel in Austria, Denmark (more in Landwirtschaft 2.0), ...

Organic Action Plan 2025
The Organic Action Plan of the EU needs to be pushed further from 2025.

Financial incentives for farmers

Historically, subsidies were brought into place to ensure food supply after WW2. These reformed themselves as a compensation for the production of cheap food costs and nowadays farmers are dependent on them. We need new innovative support systems in the next few years. That means shifting the subsidies towards more resilient production, processing, distribution. For example, incentives for carbon positive forest practises. This also means support people that already on track and valuing the work of the agricultural industry.

Value ecosystem services and promote natural capital accounting
If we fully recognise the farmers’ services, we need to take into account the ecosystem services they produce. This is a necessary step to be able to use nature as a leverage in the market. A first step is taken by the EU, from this year on there will be ecosystem services payment to forests in Luxembourg.

Carbon tax
Take a bonus malus approach to subsidies. A step-by-step implementation of a carbon market could be beneficial, but needs a global implementation to work.

Basic Income
Basic income for farmers independent from production pressure.

Subsidy per employee
Subsidizing per # of employees instead of ha (size) could be another way of thinking.

Direct grants
Communicate & support specific regions.

Tax credit
Tax credits provided to sequestering practices.

Raise awareness on existing ecological programs
Not all farmers are aware of the existing programs and subsidies for changing to organic.
Innovation incentives for food and agriculture
Zero interest loans on agricultural transition investments, for example for rainwater catchment basins.

Climate Bonus
First steps are made in forestry with the ‘Climate-bonus’.

Market Regulations

“Swich from a liberal capital democracy to a social communism, and it will work.”

It is said jokingly, but participants do express a dire need for a stricter legal & regulatory framework. In current competitive conditions and free market there is no responsibility on any level.

Government Procurement
In their own purchase policies, governments should impose higher requirements on local production, carbon emissions and more.

Border adjustable carbon tariffs
To be able to compete in price with imported products, border carbon tariffs to regulate prices could have a high impact and indirectly promote regional products.

Mandates
Further elaboration needed?

Close markets for livestock transport
For example over 100km

Close markets for timber
Fully closing a market will not be possible, there would be a shortage of timber material. But linking it might have better changes (for example Woodcluster). This does not need to follow national borders, but can be implemented with radiuses and distances.

Increase feed-in tariffs for biogas plants
Maintain and increase feed-in tariffs for biogas plants (at least 75% slurry and manure use of total input) and adjust organic fertiliser application rates. Artificial fertiliser production and use is energy-intensive and thus emits CO^2. But there is enough organic fertiliser in Luxembourg, which also can produce electrical and thermal energy.

7.7 Identified actions
Workshops ‘Agriculture in transition’

Education and communication

Agricultural education needs to be adapted to support new sustainable systems and other resilient values. This requires extra technical knowledge, but also a change of way of thinking.

Filling knowledge gaps
Specific knowledge is lacking in some cases.

Awareness of carbon sequestration methods
Raise awareness about possible practices that sequester carbon

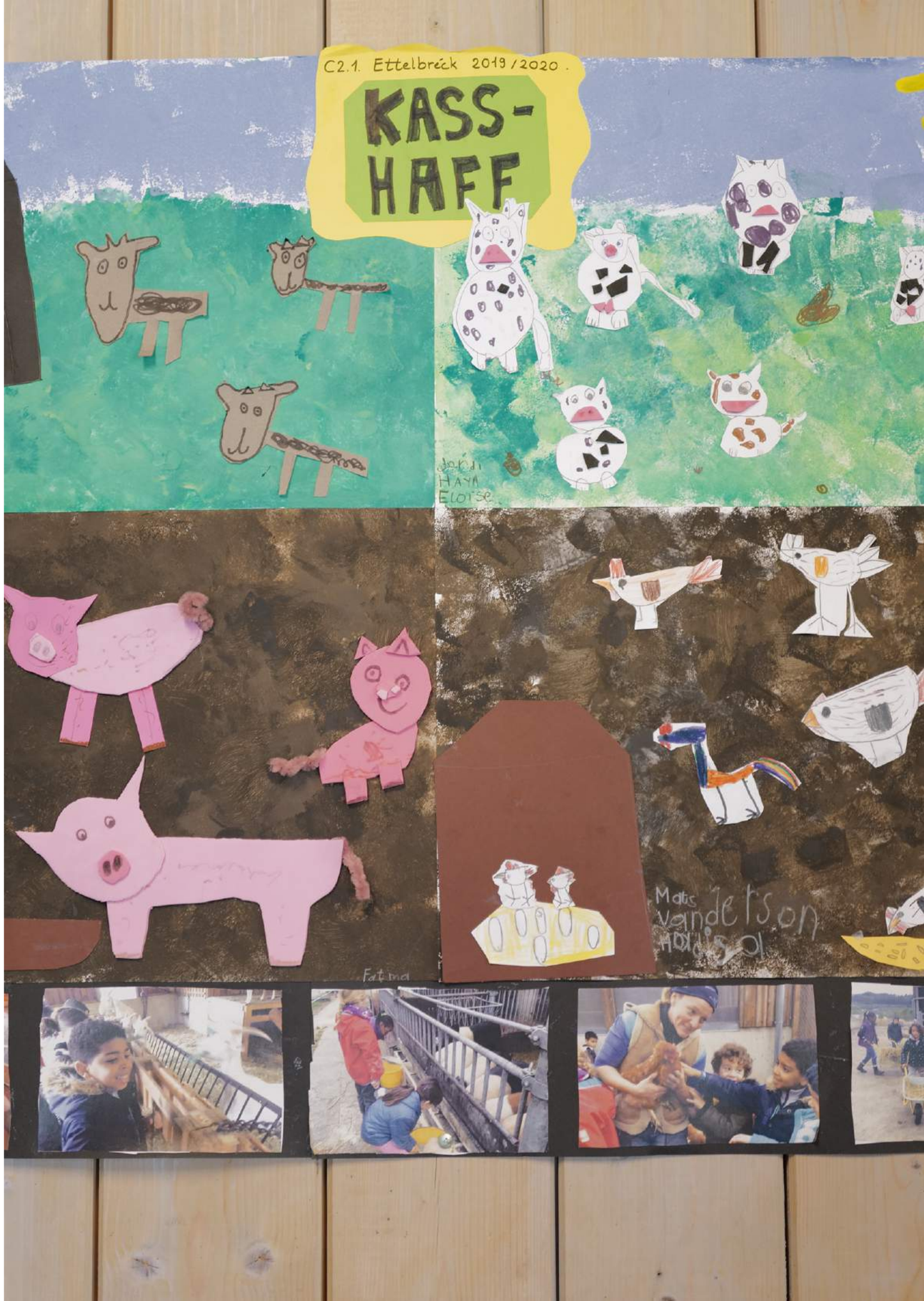
Awareness of forest regeneration
Improve forest resilience by awareness raising actions on the importance of site adaption of forest tree species and provenances.

Priority plan for farmers
Future is only possible with a clear communication towards the farmers of what is expected until 2030, 2040 and 2050. We need to set up clear and simple programs that respect the competences and responsibilities of the farmers and partners.

Business transition consultation
To cope with a rapidly changing market, free business transition consultation must be made available to farmers .

Representation in European networks
Forming alliances and networks is a crucial part of transition management. Currently there is an underrepresentation of Luxembourg in EU agri-innovation. Stimulate participation in experimental projects.

Perspectives for young farmers
Giving perspectives and financial prospect to young people (example: fruit production ‘Aus der Regioun’) is indispensable. There is a lack of real opportunities.



7.7 Identified actions
Workshops ‘Agriculture in transition’

Research and development

Agriculture, viticulture and forestry have not been a priority of R&D in Luxembourg so far. FNR/Lux-innovation’s priorities need to be redefined. This optimisation needs consulting by universities, businesses, farming tech companies and the farmers themselves (ibla.lu also as partner). This will have a two-fold consequence: first creating knowledge bases the sectors and second redefining these sectors as a priority at other levels too (especially at the political level). This asks for a multi-actor approach

Supporting the research in organic and resilient farming

Improve life cycle of woody products

Organise a chair for agri-food
Organise a chair for agri-food at the University of Luxembourg.

Build knowledge and databases for making DYI CO^2 balances
R & D in Luxembourg does not only need to evolve but also increase the independence of farmers to make their own evidence-based decisions.

All-on financing in new start-ups
New start-ups in agriculture are difficult to get off the ground due to a limited range of financing options.

More data analyses on carbon footprints
Studies and data analysis on carbon footprints of farms (especially the more special productions like viticulture, organic fruit cultivation, ...) are lacking. R&D in monitoring positive and negative emissions is necessary.

Wood value strategy
A lot of the timber in Luxembourg is being exported to US and China or being used for heating or bioenergy. We need a strategy to keep the value chain in GRLU. This is not only an adaptation of the market-chain but also ask for a switch to more sustainable forest management.

Cooperation between farmers

“We also need to work together, this is THE collective assigement.”

Provision of shared high tech equipment
Hi-tech and precision farming demand a solid investment. A cooperation, collaboration or group purchase of for new techniques and materials should be institutionalised. These types of innovations, for example the purchase of drone surveys nor capitalising on satellite know-how, reduce the amount of water and nutrients needed.

Charter of transition
Even today, there is not really an agreed upon set of priorities for the farmer community. A charter of transition, agreed by farmer unions, could set a bottom-up framework as a start for public debate.

Financially support collaborative projects amongst practitioners

Exchange platform
An exchange platform, for and by farmer, to chare best practices and learn from colleagues. Even a platform for people that are open to it, would need a jumpstart with some financial support, more structure and more time commitment.

7.7 Identified actions
Workshops ‘Agriculture in transition’

Social behavioural change

Personal choices and habits are a crucial for the transition. How do we influence or shape desired social behaviour like consuming less, upscaling, buying local and organic. In both workshops participants brought up in addition a clear lack of recognition for farmers and the agricultural practice. We need to bring people closer to farmers and viceversa. How do we foster exchange between farmers and citizens?

Support investments in organic farming
In order to grow more diverse food in Luxembourg we need to create local food value chains for people.

Supporting local initiatives
Farmers actively need to start looking for cooperation with consumers, while communes should get more involved in land use.

Regional labels
Today, there are already some labels for local production, like Appellation d’Origine Protégée - Moselle Luxembourgeoise. Participants disagree if we need another label ‘produced in the Greater Region’ for artisanal & agricultural products. This said, there can be more promotion on regional products on different political levels. Also it could be interesting for an intertwined region as Luxembourg to implement a system based on radius, not on national borders.

Direct distribution centres
Local distribution points, like food markets, create opportunities for local value chains, a decentralised direct marketplace for farmers and citizens.

Local product “embassies”
Product embassies, like ‘Maison du vin’ in Luxembourg City, promote local products and give them more visibility.

Digital food-chain-platforms
Today there already is a digital platform (letzshop.lu) for local food distribution. Participants agree that there is no need for a second platform, but we need to further promote these platforms also for fresh products.

Digital timber-chain-platform
Similarly, a local distributor for building materials is coming (E-Holzhaff, a buying platform for local timber).

Physical timer-chain-platform
In the future, a physical platform can be organised.

Evaluation and impact measurement

“To take evidence-based decisions, we need to make more.”

Evaluation tools
The government needs to set up a scientific evaluation of the farms, like the SMART evaluation by IBLA.

Priority Communication
After that we can to pass on the information on high-carbon intensive actions. We need to make clear communication formats for what actions are essential.

Governamental reorganization

“Creating opportunities for farmers also asks for reorganizations on a governmental level. For example, to create a round table on agriculture, that idea is in the ministerial pipeline since ‘08.”

Working Between The Ministries
More participatory work between the ministries.

Public tenders
In their public tenders, governments should impose higher requirements on local (wood)production, carbon emissions and more.

Re-evaluate existing reports
Participants feel like a lot of existing studies, statistics and reports are ignored or don’t find the right ears.

Follow-up of research
In the same way a lot of research and scientific results are not accepted or not used to the full extend.

Experiments
Participants ask more presence of the ministry for the more innovative ideas and trial & error projects. In France there is for example a ‘Permis de fair’, a law that allows municipalities to experiment with a limited federal budget.

State-sponsored “strategic” projects
Strategic projects are area-oriented and regional collaborations in which knowledge is built up, experimented with various process approaches and implemented.

Supporting new creative business models for companies
New cooperative structures can provide more security in turbulent times

Regional/European glass washing system
Glass recycling (and other reusable packaging systems) by bottle cleaning, would drastically lower the emissions of for example wineries. Building a system and businesses that wash bottles do not originate without strong governmental support.

Regulatory measures

Different legal frames, government procurement for example, are indicated by participants as obstacles in the region. Certain change to proactive legal and regulatory frameworks must be made.

‘Light glass’ policies
In wine industry, the highest CO^2 emissions come from packaging. Universal bottle types and switching to lighter glass bottles, cans and/or bag-in-boxes need to be made mandatory before a working recycling system can be implemented.

Regulations bioenergy
Use a larger % of harvested wood for the construction sector, and less for bioenergy.

Limit harvesting levels
Limit harvesting levels in forests to a level of approximatively 60% of natural increment in order to increase the volume stock of woody biomass and improve biodiversity in forest

Protect farming land
The new forest law acts and sets up vision for forests to be seen beyond natural land. Can a simirat tool for agriculture be installed?

Simple permits for rainwater catchment basins
With high water prices, placing a rainwater catchment basis will become evident. But the construction process is complicated.

7.6 Identified actions
Workshops ‘Agriculture in transition’

Technical and spatial changes

This last category of actions are changes that need to be made to the agricultural practise itself.

Switch to electric vehicles for fieldwork

Packaging & transportation reductions

Avoid artificial fertilizers
Quality of manure for fertilizing needs to go up.

Optimizing manure distribution

Biogas production

Precision farming
With precision farming you give the right amount of water and nutrients at the right time at the right place, which saves a lot in resources and emissions. On the downside, high investments must be made to implement this system.

Mechanisation
It is always said that farmers have too large tractors and machines. Unfortunately, the time window for the work to be done is getting shorter and shorter, the farms are getting bigger and the workforce is getting smaller.The digitalisation of mechanisation could help farmers to get away from pesticides (robots for hoeing) and at the same time reduce CO2 emissions from tractors (electric robots can drive day and night controlled by GPS). This already exists, but not here in Luxembourg. So why not, for example, start a project with a large contracting company for diesel-reduced farming and buy a test robot.

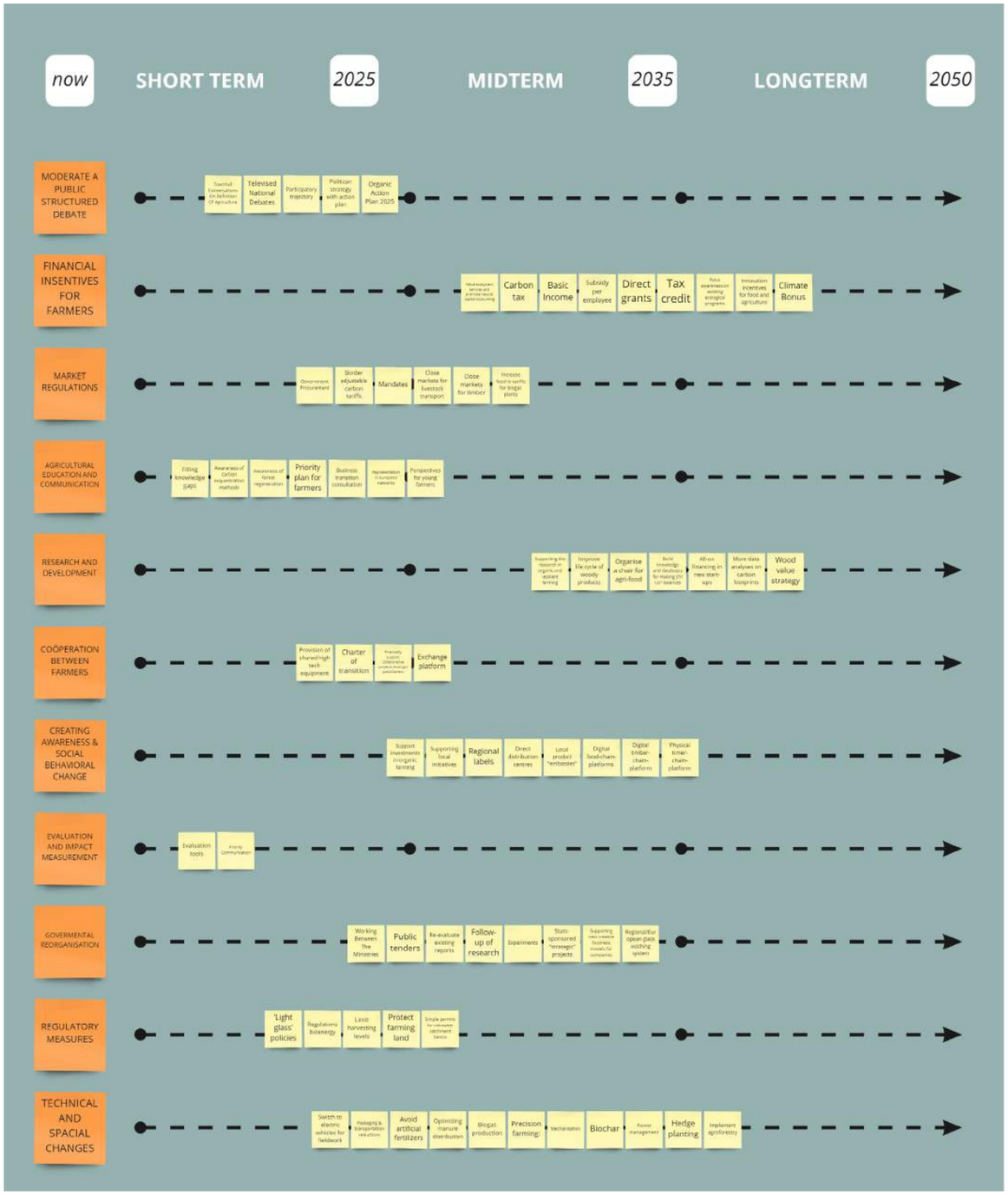
Biochar
Administration of biochar in the soil has been shown to increase soil fertility and reduce greenhouse gas emissions from the soil and also promote carbon sequestration.

Forest management
Improve forest resilience by converting monocultures to mixed forests.

Hedge planting
Increase the amount of small woody structures in agricultural lands to improve biodiversity.

Implement agroforestry
Implementing agroforestry, like they do for example in France in viticulture, is an interesting step, but needs to be government-driven, because no winemaker will give up his/her vineyard plots for trees. In addition (especially in more rainy regions), vineyards shall not cultivated in the shadow of trees: moisture, slow drying after rain, high fungus pressure and more fungicide spraying.

Timeline



7.7 Citizen Committee feedback

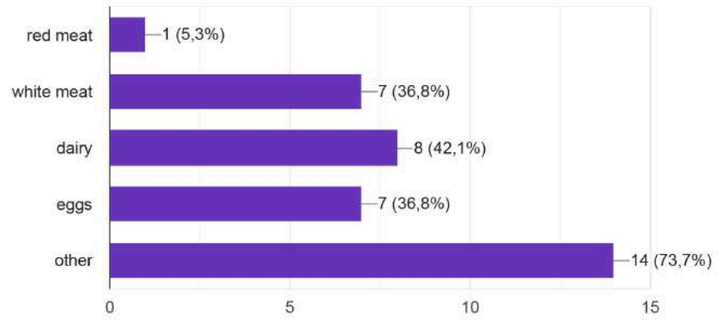
In a closed session with the Citizen Committee, we discussed the carbon footprint of food with the members and shared with them our outlook on diet change. In addition we asked them to fill a questionnaire so that we better understand their eating habits and their beliefs about the future of food in the region. The session was filled with insights and interesting questions for us. Some of the points discussed are featured in the opposite page in form of questionnaire.

Biergerkommitee Lëtzebuerg 2050 / 2001, 51N4E, Lola Land

19 risposte

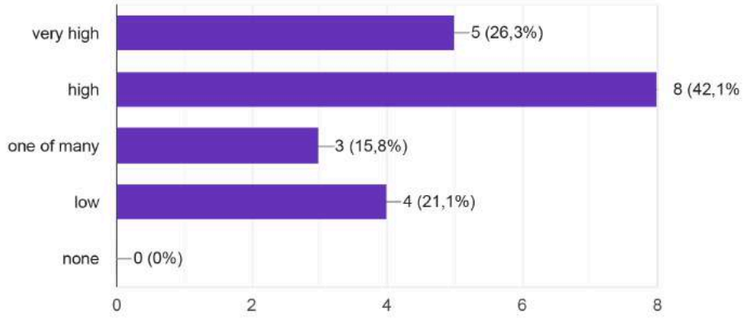
1. Which of the products below does your average daily diet include?

19 risposte



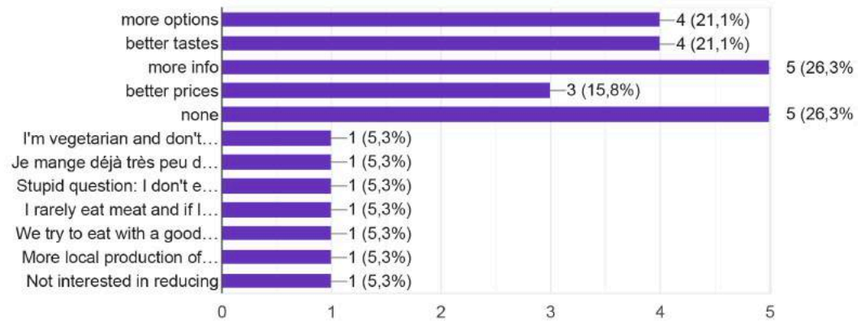
2. How much of a concern do you believe food security is for the region facing climate change?

19 risposte



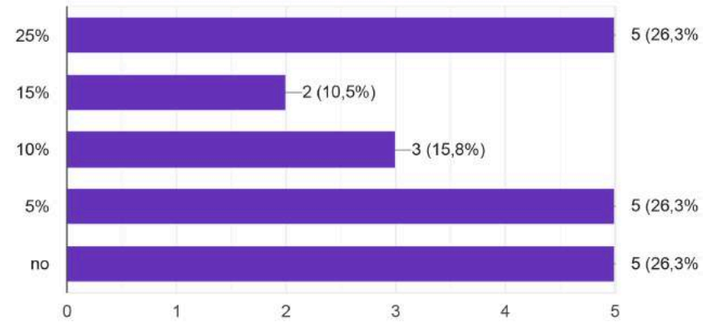
3. What would you say you would need most to reduce your meat and dairy consumption?

19 risposte



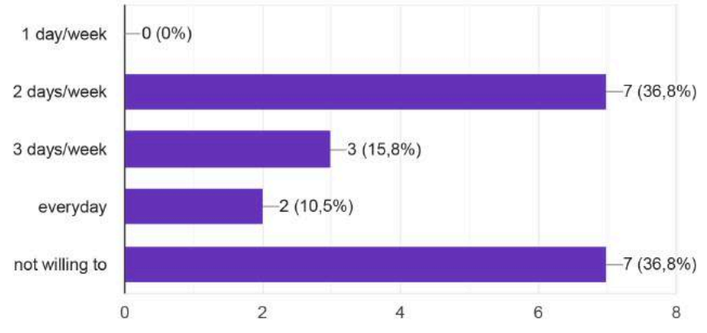
4. If a higher price needs to be paid to consume carbon zero food, how much more are you willing to spend compared to your current food costs?

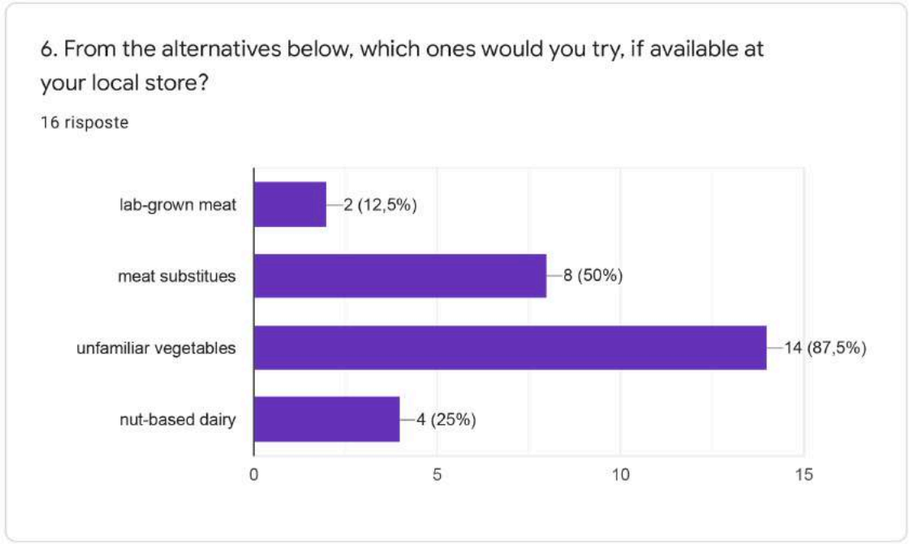
19 risposte

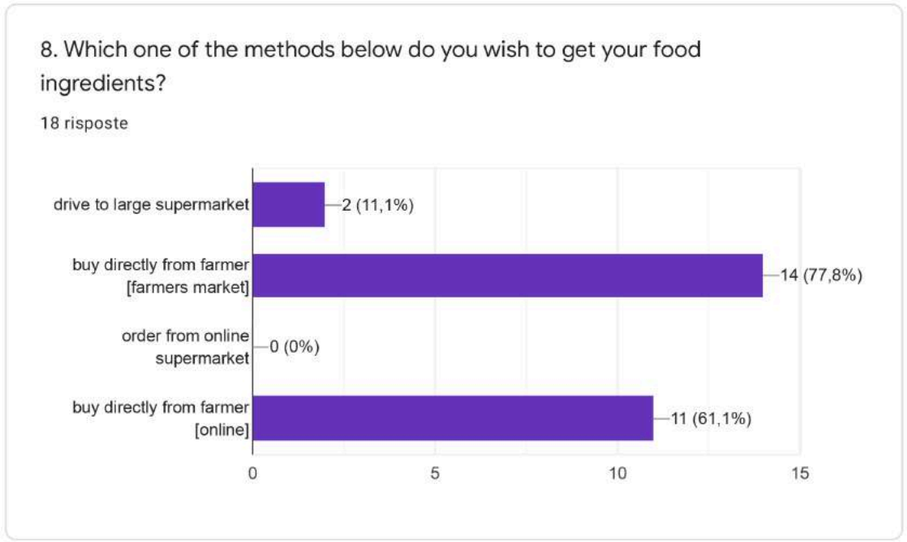


5. If you are willing to shift your diet, how would you start doing so?

19 risposte







LIT CITIZENS COMITEE 20210506

- CLAUDINE :
  - I wonder if people are happy in Luxembourg, maybe they're not, this whole lifestyle… and that's the reason they eat so much. #Frustessen
  - I fear that if everybody goes vegan we're still confronted with mass production, and that is one of the problems no?
  - Could you make community gardens mandatory?
  - I doubt that we have the capacity to change our lifestyle..
  - Do we need to eat 3 times a day? Apparently we wouldn't need to, it's just what our society has come to set as standard
  - I fear that taxing food will again be at the charge of poorer people, and rich people can still afford anything.. and then anyways people will tend towards low-budget solutions

- JULIA:
  - Indeed the taxing could be problematic, but the way I understood it is that
  - Quality food could be made less expensive?
  - I'm vegetarian, so the questionnaire was problematic; I won't change my diet
  - We live in co-housing and have a garden. This is a blessing that not everybody can afford. There is a demand for community gardens but no supply.
  - We have actually too much harvest from this garden, that we share or trade against other vegetables.
  - I studied and lived in Edinburgh, there is a culture of younger people working in and on older people's gardens. (Edinburgh Garden Partners https://www.edinburghgardenpartners.org.uk)

- YOLANDE:
  - There is, even in bio shops, so much waste in Europe, due to unconformity to calibration standards. This has to stop
  - Food sharing and trading should also become a subject in communities
    - I often bake 3 breads instead of one and I share in in my network
  - Gardens produce so much harvest, but so much is thrown away, because the sharing or distribution network is not in place

- KARIN:
  - Vegetarian for 40 years
  - Currently reading this book "new climate war" suggested by Christian Bauer (note: in committee, one of the leading architects in Luxembourg)
    - The book illustrates how the responsibility is always put on the citizens' back, like you do now
  - How come we have practically no local vegetable production?
  - And actually no seasonal production
  - Everything you find is calibrated, so the waste must be enormous
  - Back in school we've been taught/educated/indoctrinated, I remember this slogan:
    - "Mellech as gesond a belleg, keen Daag ouni Mellech!"
    - "Milk is healthy and cheap, no day without milk!"

- SANDRA:
  - In case of a tax it should be clear to what end this money would be used.
  - I come from a farm and live in Trier, my mother lately told me she gets 30€ for a calf. That is just disgusting.
  - In the vegan died the question can be asked of health: there are lots of products full of sugar or salt
  - And if everybody goes for soy milk, where is the soy coming from? Then the impact can be extremely devastating too
  - In general we always go for the extremes, there is for sure a balance to be found

- SUE SCHMIT
  - Also living in co-housing, we'll start a garden now
  - The monoculture-culture is a huge issue
  - Could there be a community supported agriculture?
    - There are actually a few examples in Luxembourg that show the potential beyond industrial production
    - It could push towards large-scale community based permaculture

7.8 Figures and tables

2.x.x Support chart, diagrams and tables for figures in chapter 1, 2 and 3.

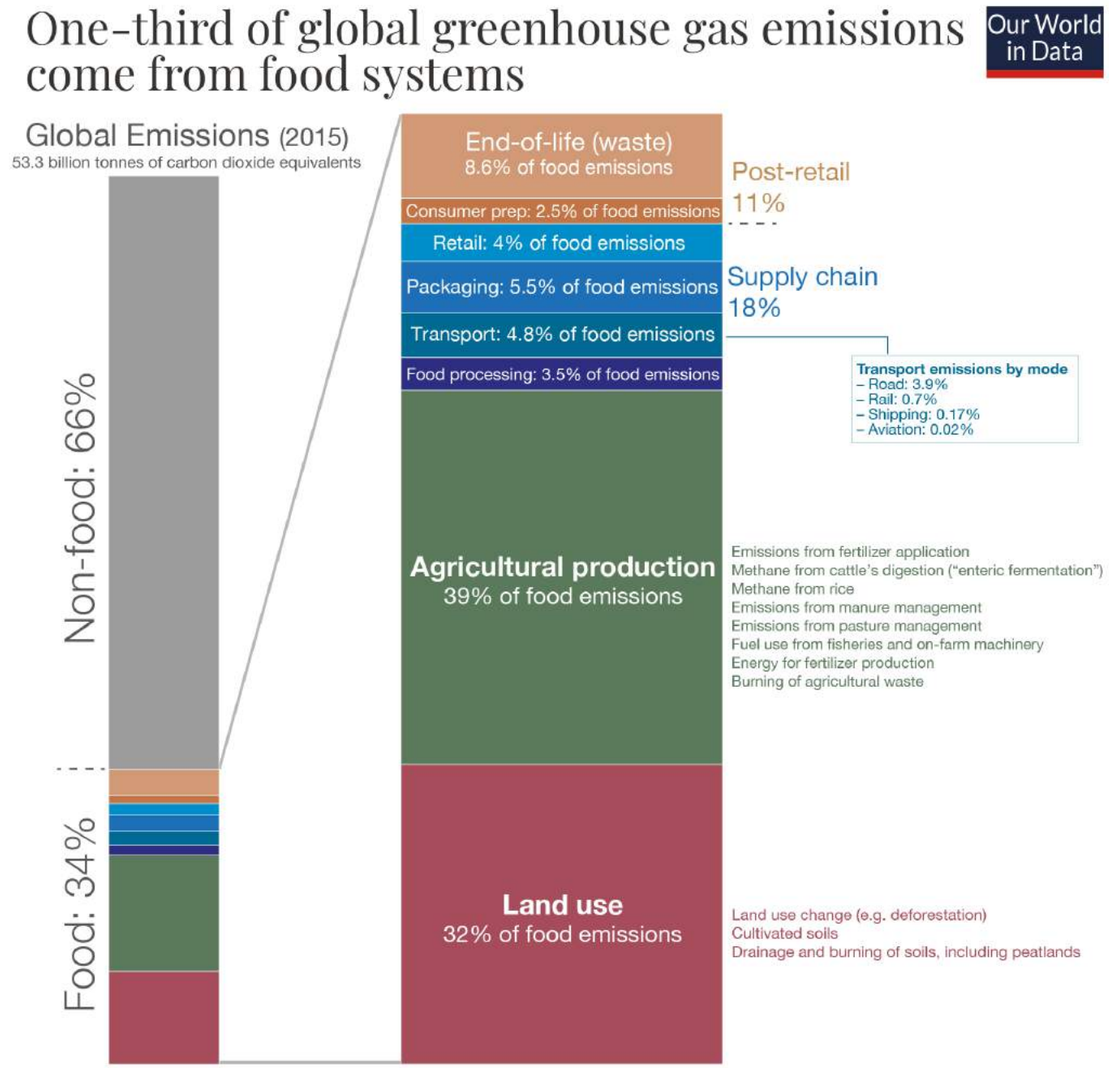


Fig. 1: Food global emissions. Source: Ritchie, H. (2020). Environmental impacts of food production. Our World in Data. https://ourworldindata.org/environmental-impacts-of-food?country=#breakdown-of-where-food-system-emissions-come-from

Fig. 6: Land-take rates in Europe. Source: EEA - European Environment Agency. (2019). Land take in Europe. https://www.eea.europa.eu/data-and-maps/indicators/land-take-3/assessment

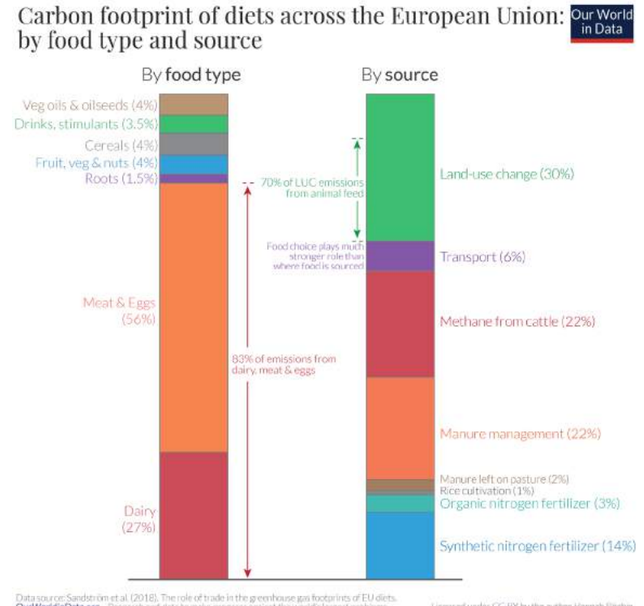


Fig. 8: Food global emissions by foodtype. Source: Ritchie, H. (2020) You want to reduce the carbon footprint of your food? Focus on what you eat, not whether your food is local. Our World in Data. https://ourworldindata.org/food-choice-vs-eating-local

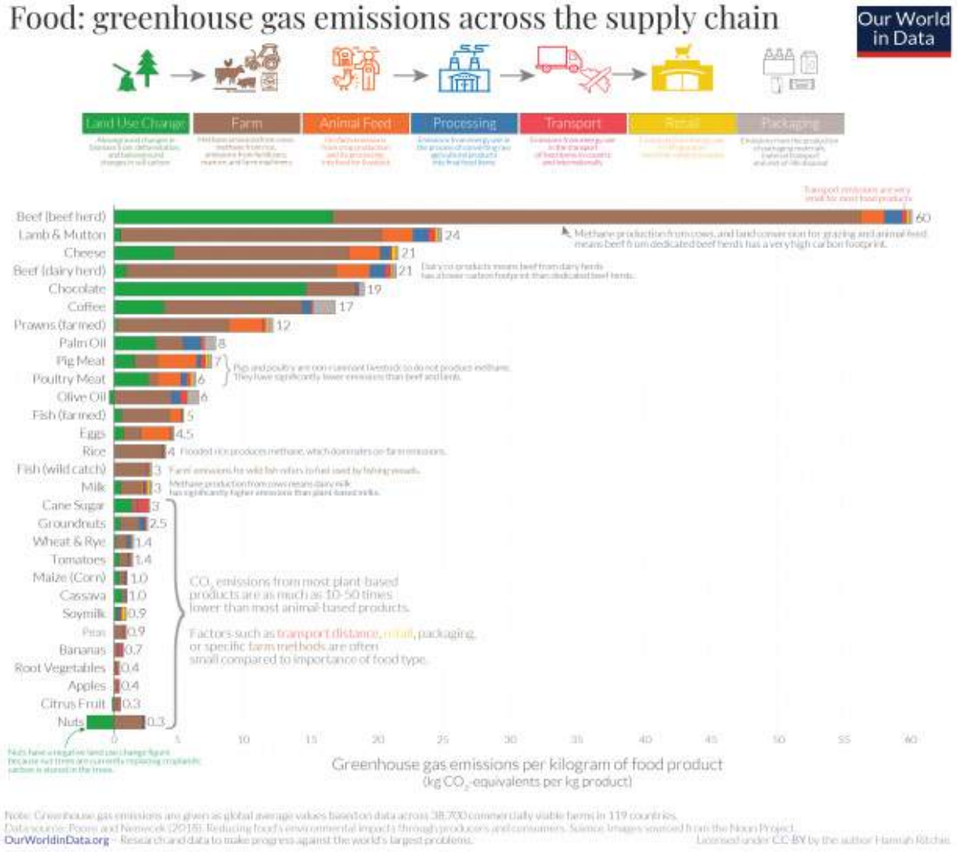


Fig. 9: Carbon footprint per kg of food type. Source: Food: Greenhouse gas emissions across the supply chain. (2018). [Graph]. https://ourworldindata.org/uploads/2020/02/Environmental-impact-of-food-by-life-cycle-stage-612x550.png

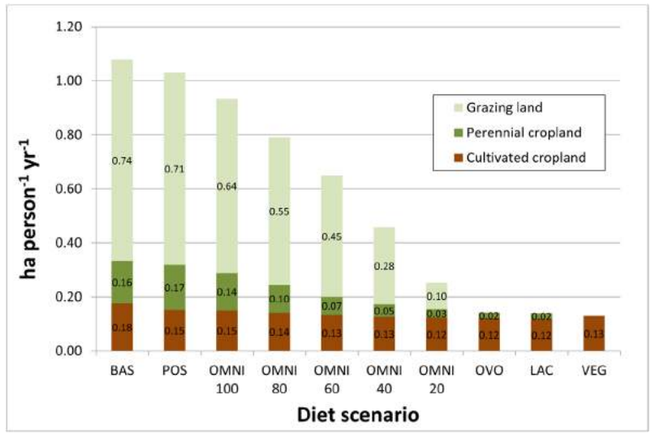


Fig. 9/10: Landuse footprint based on diet. Source: Peters, C. J., Picardy, J., Darrouzet-Nardi, A. F., Wilkins, J. L., Griffin, T. S., & Fick, G. W. (2016). Carrying capacity of U.S. agricultural land: Ten diet scenarios. Elementa: Science of the Anthropocene, 4, 000116. https://doi.org/10.12952/journal.elementa.000116

2.x.y Support chart, diagrams and tables for calculations and figures in chapter 4.

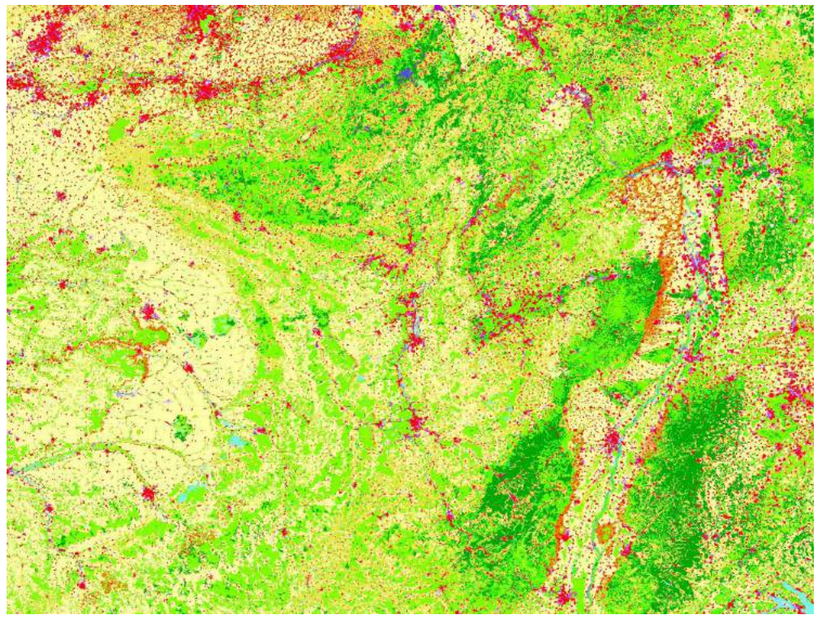


fig. a: Current land-use. source: Corine Landcover. (2018). Https://Land.Copernicus.Eu/. https://land.copernicus.eu/pan-european/corine-land-cover/clc2018

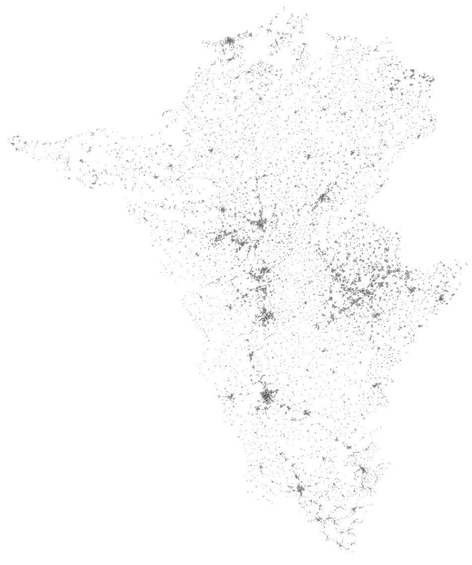


fig. b: Current population density. source: Population density Europe. (2016). Http://Cidportal.Jrc.Ec.Europa.Eu/. http://cidportal.jrc.ec.europa.eu/ftp/jrc-opendata/GHSL/GHS_POP_EUROSTAT_EUROPE_R2016A/GHS_POP_SOURCE_EUROPE_R2016A_3035_100/V1-0/

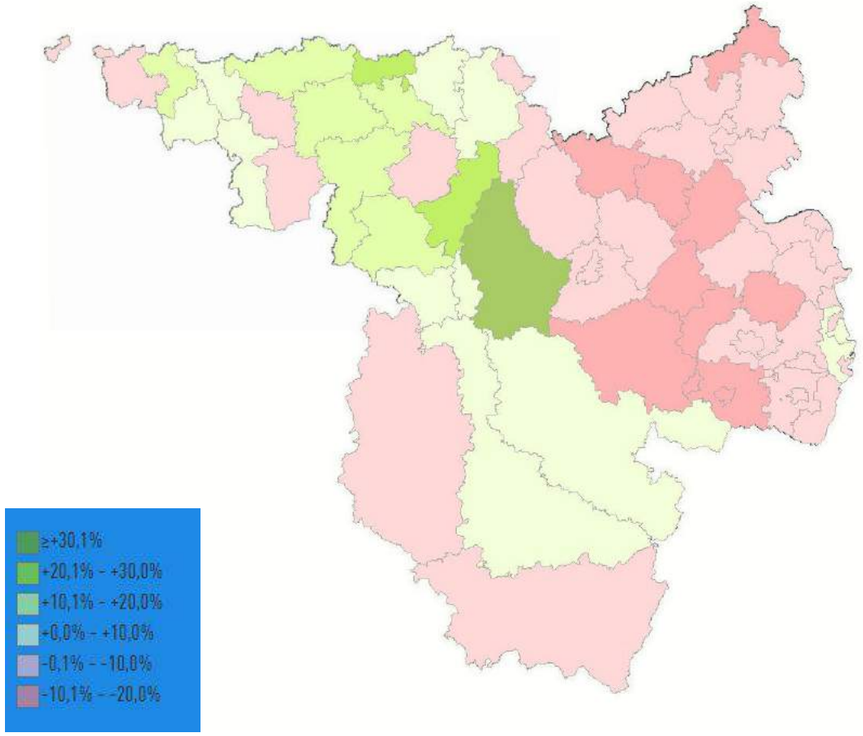


fig. c: Change in population density. source: Population totale 2020–2050. (2020). Https://Data.Public.Lu/. https://data.public.lu/fr/datasets/projection-of-total-population-2020-2050/

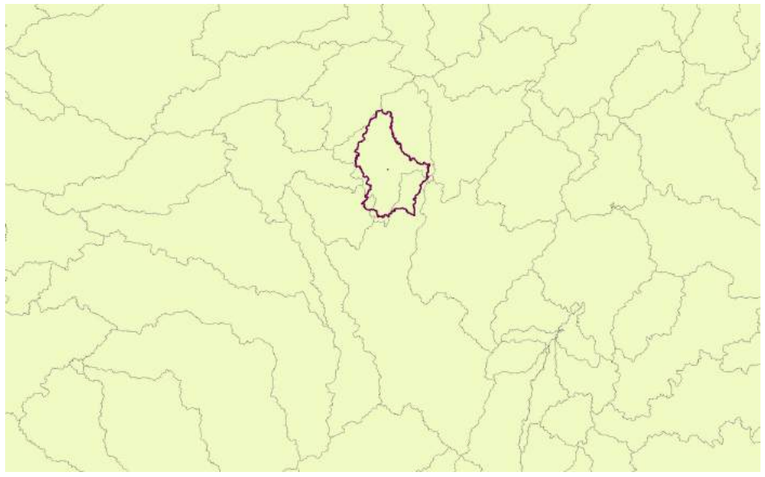


fig. d: Regional watersheds. source: European river catchments. (2016). European Environment Agency. https://www.eea.europa.eu/data-and-maps/data/european-river-catchments-1

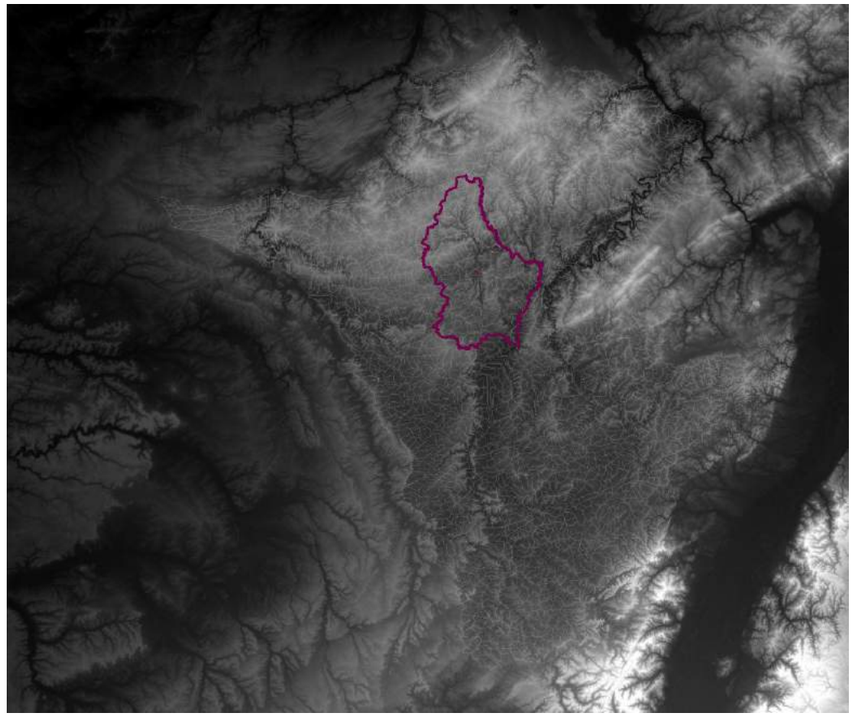


fig. e: Local watersheds generated on height map. source: Copernicus Land Monitoring Service - EU-DEM. (2017). European Environment Agency. https://www.eea.europa.eu/data-and-maps/data/copernicus-land-monitoring-service-eu-dem

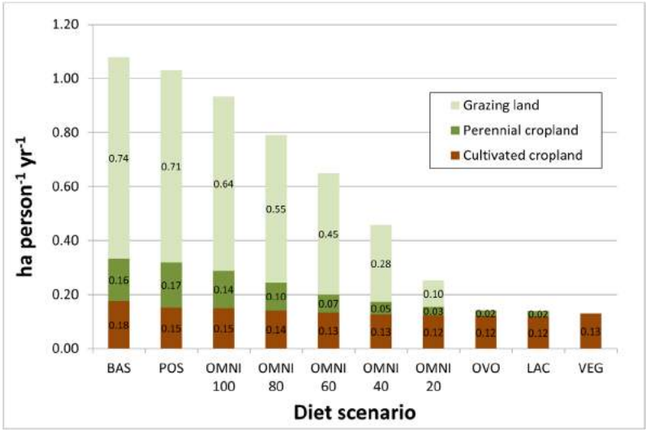


fig. f: Landuse footprint based on diet. Source: Peters, C. J., Picardy, J., Darrouzet-Nardi, A. F., Wilkins, J. L., Griffin, T. S., & Fick, G. W. (2016). Carrying capacity of U.S. agricultural land: Ten diet scenarios. Elementa: Science of the Anthropocene, 4, 000116. https://doi.org/10.12952/journal.elementa.000116

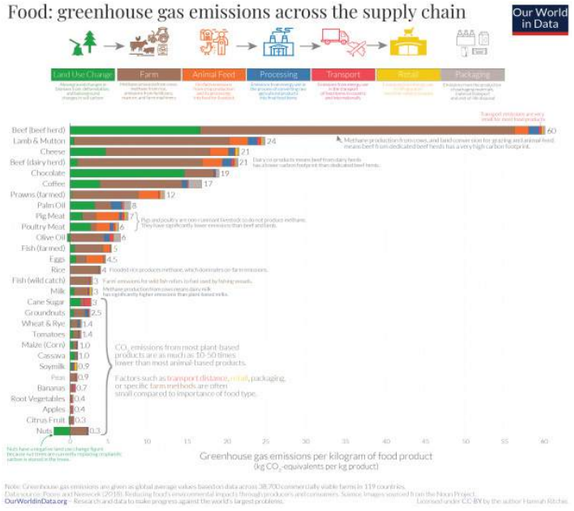


Fig. g: Carbon footprint per kg of food type. Source: Food: Greenhouse gas emissions across the supply chain. (2018). [Graph]. https://ourworldindata.org/uploads/2020/02/Environmental-impact-of-food-by-life-cycle-stage-612x550.png

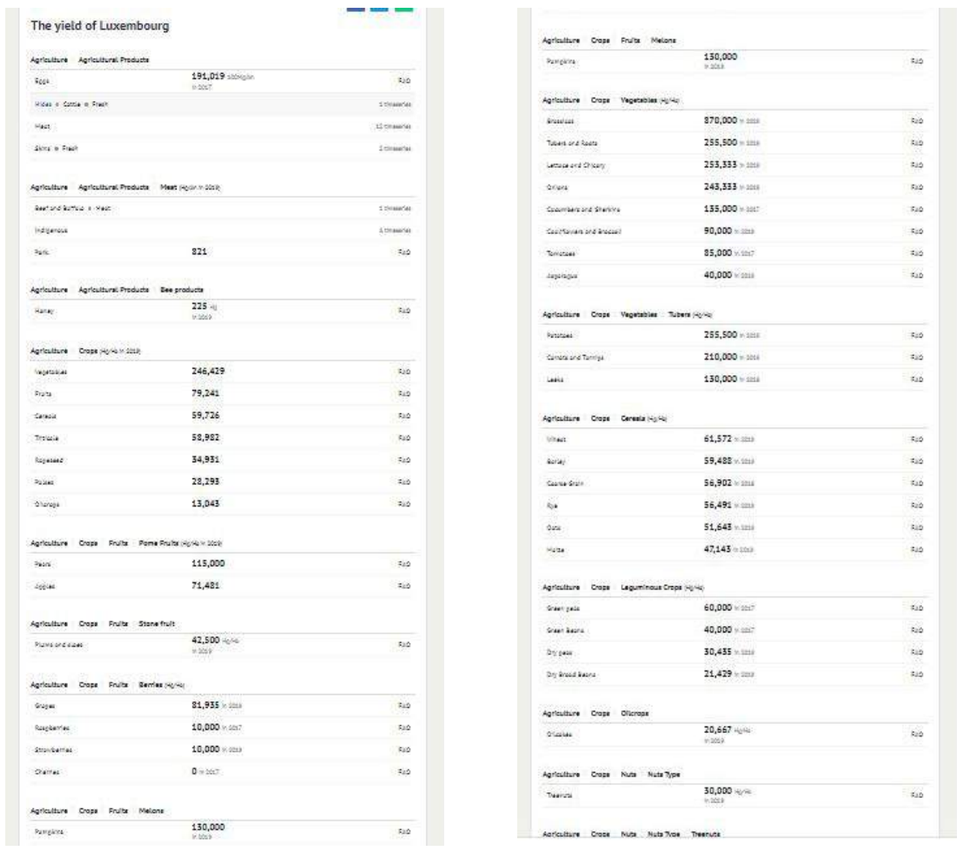


Fig. h: Yield food type/ha. Source: The yield of Luxembourg. (2019). Https://Knoema.Com. https://knoema.com/data/luxembourg+yield

4.1.1.2 *Emissions and removals from forests as shown in greenhouse gas inventories and relevant historical data*

Figure 4-3 *emissions and removals from forests as calculated in GHGI*

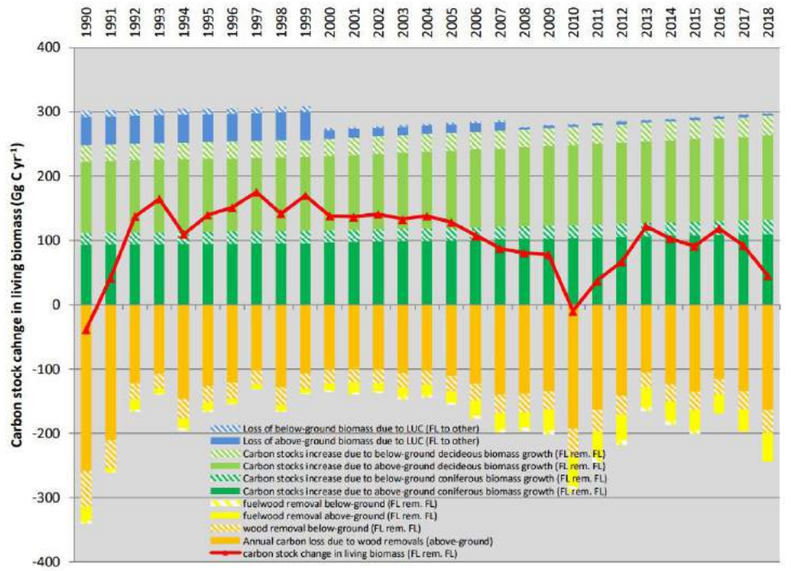


Fig. i: Forest sequestration rate and loss. Source: National Forestry Accounting Plan Luxembourg. (2019). https://environnement.public.lu/content/dam/environnement/documents/natur/forets/NFAP-Luxembourg-2019-review.pdf

Table 2 Measures for increasing soil carbon stocks in agricultural soils and potential yearly soil carbon sequestration rates (t CO_2 ha^{-1} y^{-1}).

Measure	Potential soil carbon sequestration rate (t CO_2 ha^{-1} y^{-1})	Estimated uncertainty (%)	Reference / notes
Crop-land			
Zero-tillage	1.42 but see reference	> 50%	1, 2
Reduced-tillage	< 1.42	>> 50%	3
Set-aside	< 1.42	>>50%	4
Perennial grasses and permanent crops	2.27	>50%	5
Deep-rooting crops	2.27	>50%	5
Animal manure	1.38	> 50%	1
Crop residues	2.54	> 50%	1
Sewage sludge	0.95	>50%	1, 15
Composting	1.38 or higher	>>50%	6, 15
Improved rotations	>0	Very high	7
Fertilisation	0	Very high	8
Irrigation	0	Very high	8
Bioenergy crops	2.27	>>50%	1
Extensification	1.98	>>50%	1
Organic farming	0-1.98	>>50%	9
Convert arable to woodland	2.27	>>50%	1
Convert arable to grassland	7.03 ± 2.08	110% (2.3 to 11.2)	10
Convert grassland to arable	-3.66	>>50%	11
Convert permanent crops to arable	-3.66	>>50%	11
Convert woodland to arable	-?	?	?

Fig. j: Zero tillage and organic matter additions. Source: European Climate Change Programme (ECCP) Working Group Sinks Related to Agricultural Soils Final Report. (2012). Https://Ec.Europa.Eu/. https://ec.europa.eu/clima/sites/default/files/eccp/second/docs/finalreport_agricsoils_en.pdf

Results

Annual and cumulative above-ground C assimilation

At both sites, annual and cumulative plant above-ground C contents were calculated and represented the sum of C assimilation from CCs and main crops planted each year and C accrual over the duration of the study, respectively. Differences in C assimilation among years largely reflect the main crop grown and the length of time the cover crop grew as well as weather conditions (Table 1). At both sites, among the tested CCs, OSR (avg. 1.11 Mg C ha^{-1} $year^{-1}$), had the greatest annual above-ground C content (Table 1). Cumulativ CC C inputs were 7.87–8.42 Mg C ha^{-1} at the two sites (Fig. 1). But no differences in the main crop C content among the CC treatments were detected at both sites (Fig. 1). Hence over the 9 years, oilseed radish (OSR, avg. 22.8 Mg C ha^{-1}) had the greatest cumulative plant (main crop and CC) C while no-CC was the least (avg. 13.8 Mg C ha^{-1}, main crop only) at both sites (Fig. 1). Thus, soil C inputs were attributed to CC, rather than main crops.

Fig. k: Cover crops. Source: Chahal, I., Vyn, R. J., Mayers, D., & Van Eerd, L. L. (2020). Cumulative impact of cover crops on soil carbon sequestration and profitability in a temperate humid climate. Scientific Reports, 10(1), 1–11. https://doi.org/10.1038/s41598-020-70224-6

Table 1
EU-27's technical potential for agriculturalmeasures increasing C-stocks.

Measure	Potential area EU-27 (million ha)	Potentialper ha peryear (tonnesC)
Agroforestry on arable land	90	2.750
Agroforestry on pastures	50	2.750
Hedge rows	178	0.100
Cover crops	119	0.160
Low/no tillage	60	0.100
All		

Assuming a potentialof 100 m hedgeper ha.

Fig. l: Hedges and silvopastures. Source: Aertsens, J., De Nocker, L., & Gobin, A. (2013). Valuing the carbon sequestration potential for European agriculture. Land Use Policy, 31, 584–594. https://doi.org/10.1016/j.landusepol.2012.09.003

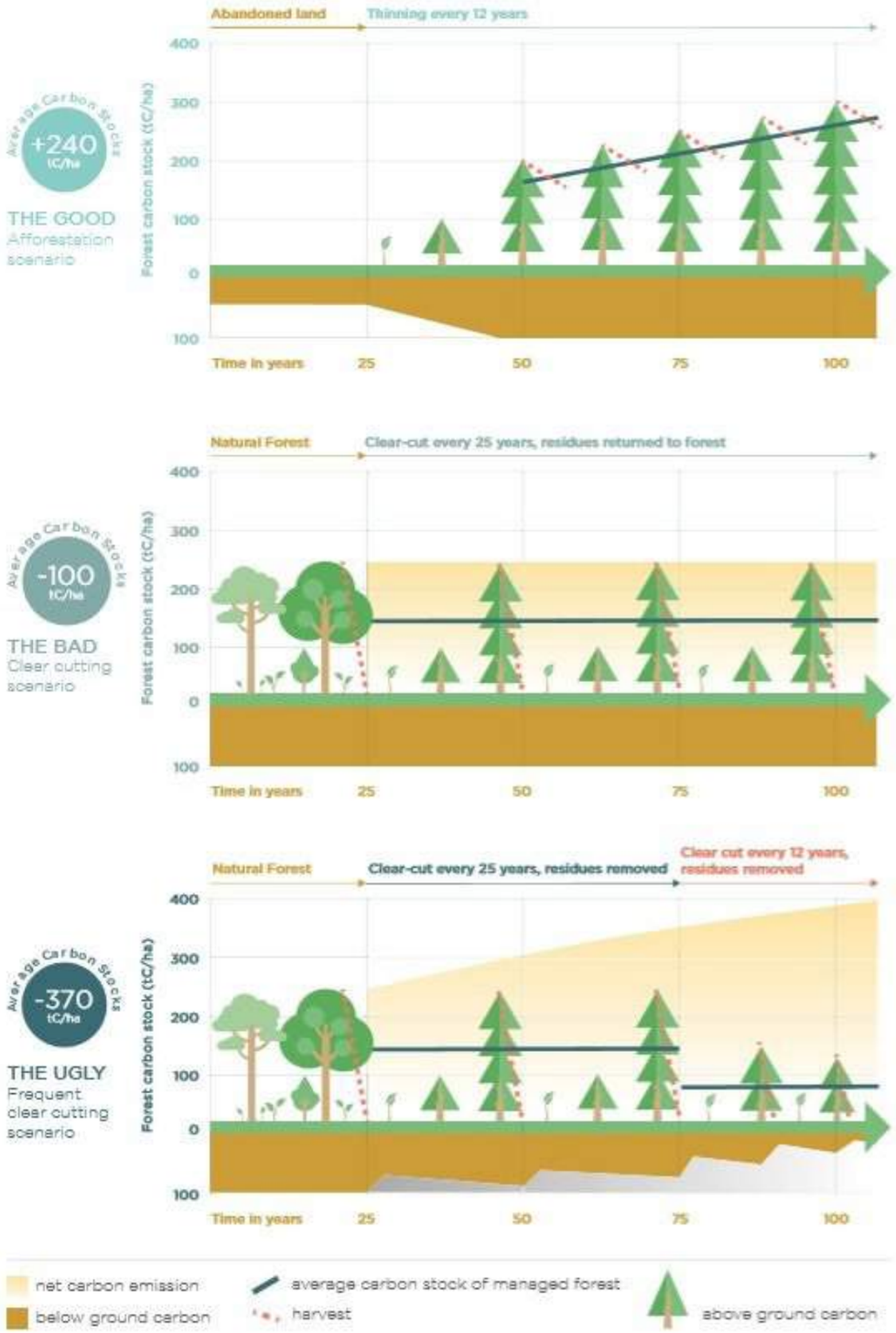


Fig. m: Forest sequestration rate. Source: Sequestration rate management scenarios. (n.d.). [Graph]. http://www.stanrams.com/wp-content/uploads/KNAW.jpg

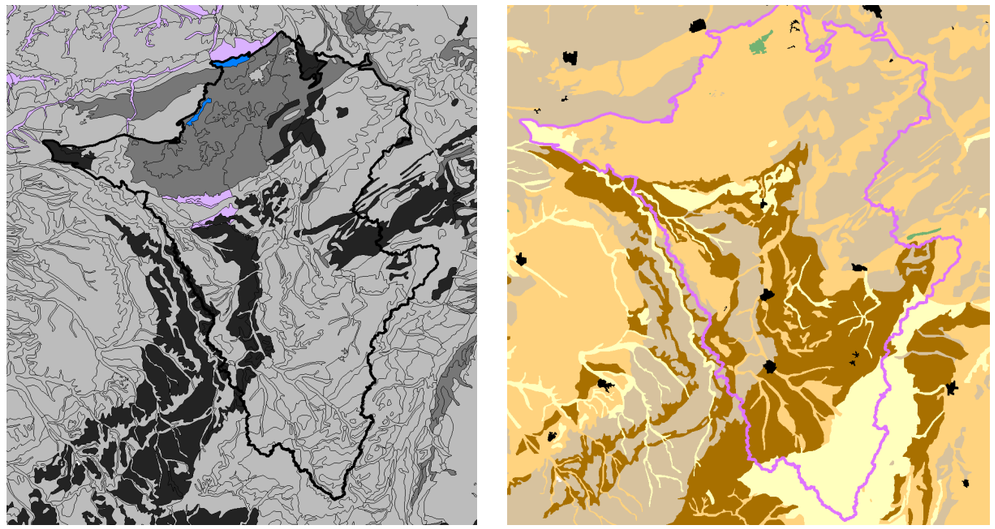


Fig. n: European soil database: soil texture and soil limitations for agriculture. Source: European Soil Database & soil properties - ESDAC - European Commission. (2010). Https://Esdac.Jrc.Ec.Europa.Eu/. https://esdac.jrc.ec.europa.eu/resource-type/european-soil-database-soil-properties

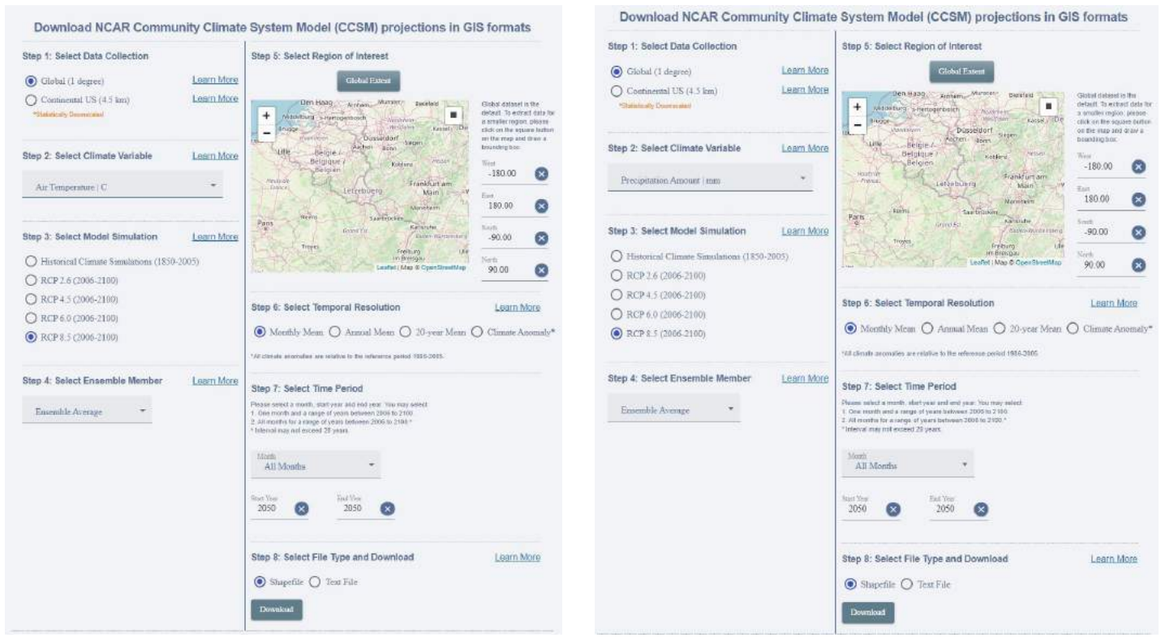


Fig. o: Climate change scenarios. Source: Download NCAR Community Climate System Model (CCSM) projections in GIS formats | GIS Climate Change Scenarios. (2021). Https://Gisclimatechange.Ucar.Edu/. https://gisclimatechange.ucar.edu/gis-climatedata

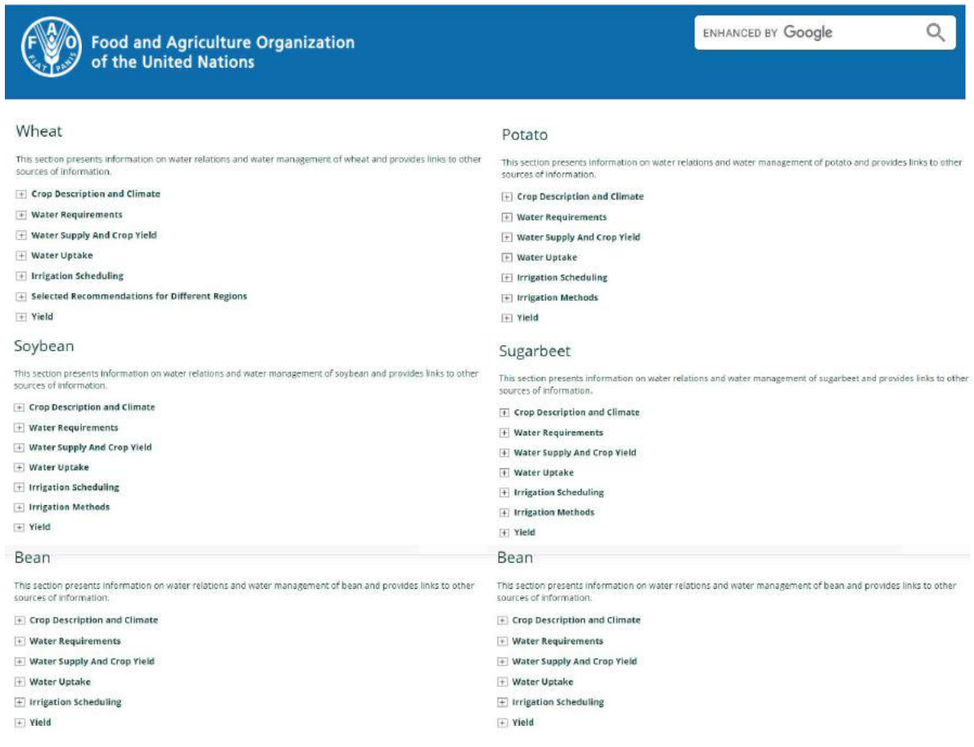


Fig. p: Crop growing conditions. Source: Crop Information | Land & Water | Food and Agriculture Organization of the United Nations | Land & Water | Food and Agriculture Organization of the United Nations. (2021). Http://Www.Fao.Org/. http://www.fao.org/land-water/databases-and-software/crop-information/en/

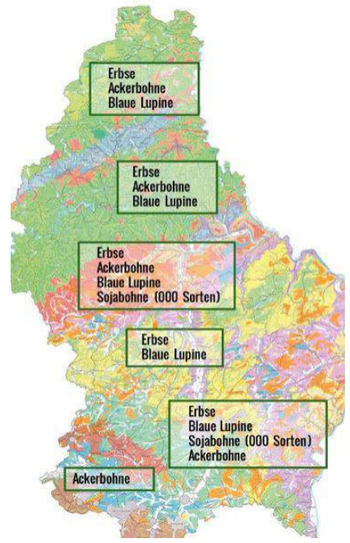


Fig. q: Soybean growing conditions. Source: Körnerleguminosen für Luxemburger Äcker Anbau von Erbse, Ackerbohne, Lupine und Sojabohne. (2015). https://ibla.lu/_res/uploads/2016/07/Koernerleguminosen.pdf

7.9 List of figures

7.10 References

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