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Sustainability-driven regime shifts in Complex Adaptive Systems: The case of animal production and food system

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ABSTRACT

The role of animal production in sustainability transitions has become the subject of a heated societal debate, and a variety of discourses delineating the role that animal production should take in the future prevail. Such discourses can act as attractors that configure the organisation of Complex Adaptive Systems, such as food systems. The evolution of food systems seems to follow a cyclical pattern with occasional regime shifts, which can be driven by the system swapping attractors. In this study, alternative regimes and regime shift dynamics were illustrated for the Finnish food system facing pressures for sustainability transition. Two questions were asked. First, what could be the attractors capable for facilitating a regime shift and from where could they emerge? Second, how the regime shift could happen and what would be the role of animal production in the alternative regimes? Discourse analysis and systems science methodology were used in a participatory foresight process. Five prominent new basins of attraction were identified: ethics, environment, health, national food security and global market. All these manifested a specific conceptualisation of sustainability and resulted in radically different roles for animal production in the food system. Each of the new regimes was accompanied by some new landscape level pressures for change, emphasising the importance of holistic system analysis to avoid unintended or unexpected outcomes of sustainability transitions. Insights for the difficulty of planned regime shifts, use of Multi-Level Perspective (MLP) as an empirical mapping tool, and the utilisation of societal discourses as a source for new attractors were novel elements in the approach of this study.

1. Introduction

The role of animal husbandry in the sustainable futures of food systems has been a subject of keen public and academic debate (Grimm, 2012; Herzon et al., 2024; Isomäki, 2016; Kohvakka et al., 2020; Koistinen, 2023; Winders and Ransom, 2019). Many have claimed that resource-efficiency, eco-efficiency and climate-friendliness would improve if crops were used directly for food rather than for animal feed (e.g. Chai et al., 2019; Elliot, 2022; Errickson et al., 2021). Especially ruminants contribute to climate change due to enteric fermentation, and the areas with input-intensive animal production are sources of eutrophication (FAO, 2023; Misselbrook et al., 2013). Besides greenhouse gas and nutrient emissions, livestock production systems are causing e.g. land degradation and deforestation at a global scale (Hietala et al., 2021). At the same time, animal production is an important source of rural livelihoods in many areas with scarcity of non-agricultural jobs, and decreasing the scope of animal production would lead to decreasing value added, income and jobs in the food chain (Knuuttila and Niemi, 2023; Lehtonen and Rämö, 2023). In climatically unfavourable areas where growing crops for food is not possible or economically feasible, grass-based animal production systems are oftentimes the only way of producing food and thus earning a livelihood (Houzer and Scoones, 2021). Further, livestock production systems based on grazing are important for farmland biodiversity, and animal manure plays a role in the recycling of nutrients (e.g. Kaemena and Bastiaansen-Aantjes, 2019; Pykälä, 2007; Török et al., 2014). Thus, to address the question of sustainability of animal production, there is a need to account for a variety of perspectives around the topic.

Many claims for change in the animal production that lean on specific environmental, economic or social arguments hide a large part of the complexity that resides within the food systems (Ericksen et al., 2009). As Eakin et al. (2017, 757) put it, 'Over the last decades, experts

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from diverse disciplines and intellectual traditions have worked to document the critical threats to food system sustainability and to define an appropriate agenda for action'. Nevertheless, these efforts have tended to focus selectively on only a few components of the food system or to be framed in particular discourses. Complexity has led to narrow specialisation rather than to genuine understanding of the wholes (Amara, 1974, 300). If and when overcoming the sustainability problems associated with animal production requires a systemic change of the food system, several alternatives for the whole food system should be designed and assessed. Finding a feasible analytical framework to integrate the diversity of elements and processes and iterating to an appropriate level of abstraction, are key challenges in such a research enterprise.

Design and assessment of several alternatives for a whole system is complicated by the fact that food systems are Complex Adaptive Systems (CAS) (Chapman et al., 2017, 2; Nesheim et al., 2015, 233). These kinds of systems lack central command and ownership (Holland, 1995) but may be affected by different kinds of force fields: policies, regulations, preferences, social norms, cultures, beliefs, worldviews etc. When such systems experience major changes, a large number of local and non-linear interactions take place at various levels and parts of the system, giving rise to emergence and self-organisation (Byrne and Callaghan, 2014). The fundamental reconfiguration of a CAS is 'pulled' by attractors (Gerrits, 2012, 157; Room, 2011, 130). Attractors can be e.g. shared visions (Vasileiadou and Safarzynska, 2010, 1178), new technologies (Geels, 2005) or biophysical entities such as climate (Brunetti et al., 2019). If a food system was to reorganise with a concomitant change in the role of animal production, what could be the attractors that reconfigured the system and from where could they emerge? This is our first research question. We look for answers to this question by studying briefly the public and scientific discourses regarding the sustainability of animal production, to expose candidates for the attractors.

What follows logically from the first question, is how specific attractors could reconfigure the food system? This is our second research question. Outside the short periods of crises or transformations, food systems tend to be highly institutionalised (McMichael, 2009). The concept of regime has been observed to be a useful tool to describe such a system state (Fuenfschilling and Truffer, 2014). Regimes are 'dominant structural configurations of social systems prevailing across certain time periods' (Kuhmonen and Kuhmonen, 2023, 2). We illustrate these regime shifts by means on Multi-Level Perspective (MLP), which has been extensively used to map transitions, transformations and regime shifts of various systems (Geels and Schot, 2007). MLP can map the elements of a regime shift, including both the characteristics of the old and the new regime as well as dynamics of the transition. As such, it is a useful framework to allow answering to our second research question.

By combining insights from complexity and systems research with socio-technical transition research, we provide a novel contribution to the literature that aims at understanding the role of discourses as attractors that can drive transitions in the food systems. Even though socio-technical transition literature, part of which the MLP framework is, positions itself in close connectivity with systems research (Rotmans and Loorbach, 2009), at the conceptual level the bridges between these strands of literature have been rarely built. However, building such connections can address many of the criticisms that have arisen in relation to the directionality of transitions: sustainability transitions are normative endeavours (Avelino et al., 2016; Lawhon and Murphy, 2011). Thus, addressing the core assumptions beneath the various framings of 'sustainability' with the conceptual tools offered by the concept of attractors can help in increasing transparency and effectiveness in navigating complex transition processes (Pearson and Bardsley, 2022).

The structure of our study is as follows. In Section 2 we discuss relevant characteristics of food systems as CAS, illustrate the role of discourses in indicating potential new attractors and introduce the MLP as a mapping tool for the regime shifts. We also present our stage for the empirical illustration: Finland, a developed northern country with a harsh climate and large animal production sector. In Section 3, the materials and methods will be reviewed, while Section 4 reports the results and Section 5 includes a discussion and reflection of the findings. The study closes with conclusions in Section 6.

2. Underpinnings of the empirical analysis

2.1. Characteristics of food systems as Complex Adaptive Systems (CAS)

The problems of the contemporary food system are visible for all: climate change, loss of biodiversity; eutrophication of waters; concentrated power; distorting agricultural subsidies; low profitability of farming etc. (e.g. Rosin et al., 2012; Wright and Middendorf, 2008). These are emergent properties of the dominant food regimes of many industrialised countries rather than random or anecdotal outcomes. While it is true that these collateral damages were neither decided nor intended at the early stages of the regime, but now that the regime has institutionalised, they are hard to remove without a regime shift (Pereira et al., 2020). This is a very typical setting for a Complex Adaptive System (CAS) that lacks central command: emergence and self-organisation leads to unexpected or undesired outcomes (Byrne and Callaghan, 2014; Holland, 1995; McDaniel and Driebe, 2005).

To alleviate the observed problems, the food system needs to transform fundamentally, possibly implying a regime shift. However, as there are many problems there is also a variety of transition pathways, each of which comes with their own expected consequences as well as unexpected collateral damages. Studying the alternative futures of the food system is central for identifying and assessing the pathways ahead. While nobody owns a food system and is thus incapable of deciding its future, a particular future is still determined by some forces. In complex systems thinking, the effective force fields are called attractors. A CAS operates in a basin of attraction (Kauffman, 1993, 174) which is like a cup that delimits the dynamics of a specific system to take place within certain limits (Gerrits, 2012; Room, 2011). These basins are constituted by specific attractors and surrounded by saddle points (Room, 2011, 135). Periods of dynamic stability (Geels and Schot, 2007) take place when a system stays 'in the cup'. This period can be observed as a regime: many changes take place but the 'magnetic core' of the regime does not allow major breakaways. The basin of attraction could be comprised of a particular set of beliefs or values, technologies, metabolism, power bases and governance models, for example. If the saddle point is crossed, the system moves into another basin of attraction with new attractors and a regime shift takes place (Kuhmonen, 2017).

Regime shifts take place, when new attractors emerge and consolidate to establish a power field strong enough to move the whole system into new basin of attraction. The transformative capacity of attractors creates a cyclical pattern of change, which food systems have also been observed to follow in their evolution (Friedmann, 2005; Kuhmonen and Kuhmonen, 2023; McMichael, 2009). The idea of cyclical pattern is also visible in Schumpeter's writings of creative destruction (1934, 225) wherein the old economic regime becomes obsolete and new entrepreneurs with their novel ideas, products and models take over as a 'swarm' contributing to a business cycle. Similarly, Kondratieff waves illustrate alternation of economic decline and technology-driven growth (e.g. Nefiodow and Nefiodow, 2017), wherein the technology can be seen as representing a new set of attractors delineating the development pattern of each cycle.

Understanding attractors can help to understand why food regimes exhibit certain characteristics (Kuhmonen, 2017). If a regime shift is anticipated or aimed at, a swap of attractors and basins of attraction of the food system is a prerequisite. Superficial structures and developments of the food systems are very complex and diverse, but the number of attractors organising them is much more limited (Gerrits, 2012; Kauffman, 1993; Smith and Jenks, 2006). As these attractors lay deep below the superficial structures, they are difficult to expose or

anticipate. Despite this challenge, both foresight of regime shifts and the planning for them could start with the analysis of the contemporary and alternative attractors of the complex adaptive food system, since all superficial structures and characteristics of the CAS are ultimately configured by them. Rotmans and Loorbach (2009, 184) suggest a recipe for managing planned regime shifts: 'stimulating niche development at the micro level, finding new attractors at the macro level by developing a sustainability vision, creating diversity by setting out experiments, and selecting successful experiments that can be scaled up.' Thus, finding new attractors is the next step in building the analytical framework for exposing alternative futures for the food system.

2.2. Attractors configuring food regimes

Depending on the system, the origin and quality of attractors can differ. In societal systems, the attractors could be related to culture, norms, beliefs and preferences (Jones and Hilde-Jones, 2023), technologies (Geels, 2002; Kemp, 1994), metabolism (Fischer-Kowalski, 2011) or governance mechanisms (Canfield, 2022; Renting et al., 2012), among other things. As food systems are societal systems, their attractors are born in social action. No matter how much for example a certain technology improves productivity, food safety or food availability per se, such improvement materialises only when these technologies are adopted by a large group of people. The powers of attractors become realised through 'massafication' (Iles, 2021, 8): 'movements may generate enough energy, embodied knowledge, and political power to put real pressure on entrenched regimes to start unwinding'. The new attractor must collect a critical mass of steam: some coalition must pass a needed law, some consumer preference must create a profitable market, some technology must become mainstream etc. Several general theories may provide plausible descriptions and explanations for how 'massafication' might happen, e.g. sociology of expectations (Borup et al., 2006; Chiles, 2013) or social contagion theory (Elliot, 2022). Further on, to set up a basin of attraction for a system change, several attractors should be effective.

Societal and scientific discourses serving futures-oriented choices in the present may have the capacity to attract enough steam to initiate societal changes, including regime shifts. Societal discourses capture cohesive sets of normative thoughts that constitute realities (Foucault, 1972, 49). Discourse denotes 'a practice not just representing the world, but of signifying the world, constituting and constructing the world in meaning' (Fairclough, 1992, 64). Societal discourses are social processes (Locke, 2004, 14). Food discourses convey meanings and manifest 'social tensions and struggles' (Leeuwis et al., 2021, 761). Concomitantly, social movements organised around specific discourses have played a role in food regime transitions as they act as 'engines of regime crisis and formation' especially in 'periods when several outcomes are possible' (Friedmann, 2005, 229). Attractors elaborated in various discourses may consolidate shared 'sustainability visions' (Rotmans and Loorbach, 2009, 184) as discourses are 'the origins of public opinion' (Simon and Xenos, 2000, 363).

Just like attractors are more feasible targets of foresight in regime shifts than separate elements of the system, so are societal discourses a better predictor of novel attractors than separate problems or arguments. Taking stock, a bewildering array of food system discourses exist in the service of emancipatory political initiatives and social movements: good food or industrial food (O'Neill, 2024), food from here or food from nowhere (Schermer, 2014), vegetarian food or animal food (Jallinoja et al., 2020), organic food or conventional food (Halberg et al., 2006), green capitalism or ecological public health (Friedmann, 2005), food sovereignty or transnational governance (Canfield, 2022), farmers markets and short supply chains or wholesale commodity markets (Brown, 2001; Kalfagianni and Kordili, 2019), natural food or laboratory food (de Oliveira Padilha et al., 2021), private food or food as a commons (Vivero-Pol et al., 2019), fair food or cheap food (Reynolds, 2002), distanced food or civic food (Lyson, 2004; Renting et al., 2012).

2.3. Discourses of animal production configuring a new food regime in Finland

Finland is a high-income post-industrial country in northern Europe. Forest land (77 % of the total area) as well as inland waters (10 % of the total area mainly comprised of 168,000 lakes) dominate land use in Finland, whereas agricultural land covers 8 % of the land area (National Land Survey). About 20 % of the area is located north of the Polar Circle. Still, Finland is the northernmost country in the world capable for producing bread grains and most of its own food (Latvala et al., 2023). In the climatically less favourable eastern and northern parts of Finland, grasslands provide better profitability and less crop failures than annual crops. Consequently, cattle farming is for the most part located in these areas, whereas production of cereals, special crops, pork and poultry takes place mainly in the southern and southwestern areas (Niemi and Väre, 2019, 49).

Especially water-intensive grass-based cattle production suits well the northern character of Finnish agricultural production with a short growth period, abundant freshwater resources and limited availability of soils and atmospheric conditions suited for production of bread grains and special crops (Leino et al., 2023). The dairy industry has played an important role in the Finnish food system for more than a century (Kuhmonen and Kuhmonen, 2023), and still today it is 'the only industry in the Finnish food sector that has maintained a positive trade balance throughout Finland's EU membership' (Latvala et al., 2023, 17).

While the contribution of animal production to the economic performance of food system is large, so are its environmental impacts. Animal sector has a significant carbon footprint (Lehtonen and Irz, 2013) and it is a major source of eutrophicating nutrient emissions, especially in areas with concentration of animal production. The eutrophication problem is aggravated by the fact that the food system is operating largely on external inputs, which leads to accumulation of nutrients in specific production areas (Kuhmonen, 2023, 24).

Taking the CAS perspective, the contemporary Finnish food regime operates in a basin of attraction that relies on economies of scale, productivity, specialisation, fossil economy and interdependence (Kuhmonen et al., 2023). It is characterised by five key attractors: 1) mixed consumption and production of animal and plant-based products, 2) intensive production methods, 3) domestic markets, 4) imported inputs and fossil energy as well as 5) comprehensive and extensive agricultural subsidies (Fig. 3). Relatedly, the share of animal products in farm output was 40 % in 2022 (Economydoctor, 2024). Even if the levels of mineral fertilizers and pesticides applied per hectare is low in Finland compared to the EU average, truly extensive farming methods are still very rare (Helenius et al., 2020). Further on, the share of food exports in Gross Domestic Product (GDP) in Finland is by far the lowest in the EU (Finnish Government, 2023), implying dominance of the domestic market which is partly explained by the most concentrated retail trade sector in the EU (Kuhmonen, 2023). Agriculture, as well as other parts of the economy, runs on the fossil fuels that are imported, as do all the pesticides, many feed components and farm machines. Finally, an extensive subsidy scheme worth of 2 billion euros per year covers all lines of farm production; 26 % of gross return of agriculture was comprised of subsidies and the subsidies were much higher than the farm net income in 2022 (Economydoctor, 2024).

In the following, we will review in more detail five prominent discourses pertaining the sustainability of animal production in Finland that relate to ethics, environment, health, food security and global markets. Many of the discourses share common drivers (e.g. climate change) but manifest different reactions, arguments, policies and outcomes of the potential change processes and are interlinked at that level. These discourses have 'enough steam' to upgrade into attractors, delineating a basin of attraction of a new food regime in Finland. These discourses are intimately related to the role of animal production in the food system, making it possible to assess the impacts of varying volumes of animal sector. In the following, the five discourses will be briefly

discussed in terms of their arguments, capacities for upgrading into basins of attraction through 'massafication' and potential impacts on animal production. Similar discourses can be found also in other developed economies with a large animal sector.

2.3.1. Ethics discourse

> [*There are*] '*…three concerns that might motivate those who adopt vegetarian diets: a concern with the human health costs associated with alternative diets, a concern with the infliction of unnecessary suffering on animals, and a concern with their being killed for food.*'
>
> (Deckers, 2009, 593)

National and global ethics-based food system discourses have a clear main argument: the animals should not serve human needs, as the human needs could be satisfied also without animals by means of vegetarian food (e.g. Deckers, 2009; Kohvakka et al., 2020; Leroy and Praet, 2017; Lonkila and Kaljonen, 2022; Mouat et al., 2018; Phillips, 2009; YLE, 2016). The discourses contain also other arguments related to for example achieving health, climate and environmental benefits (e.g. Kaipiainen, 2020; Kohvakka et al., 2020).

In the Finnish context, the discourse has the capacity for upgrading into a basin of attraction for a new regime through 'massafication'. Specific NGOs promote veganism (Vegaaniliitto ry, Animalia ry). Furthermore, about 10 % of the population does not eat animal based-food and 54 % would like to reduce consumption of animal-based food in their diet (STT, 2021). While there is a discrepancy between the values of many people and the practice of supporting animal production, there is an avenue for changing the food system through moving 'from ethical to political veganism' (Cochrane and Cojocaru, 2022, 60).

If effective, the ethics-related attractors could change preferences and ultimately consumption habits in a way that put an end to the commercial animal production upon a regime shift. Consequently, the regime that would arise from an overhaul of the ethics discourse would be a vegan regime.

2.3.2. Environment discourse

> '*Agriculturally derived GHG emissions, and in particular methane (CH_4), primarily result from enteric fermentation of ruminant livestock and, to a lesser extent, storage of manure. The livestock sector is the largest land-use system on earth.*'
>
> (FAO, 2023, 5)

> '*Numerous studies have reported positive effects of grazing and mowing on plant species richness in Europe.*'
>
> (Pykälä, 2007, 13)

Environmental food system discourses suggest diverse but conflicting change claims for the animal production, which causes confusion (Anttonen, 2019; Sandell, 2017). On the one hand, climate-related arguments suggest a sharp cut in products related to cattle and sheep due to their greenhouse gas emissions (FAO, 2023; IPCC, 2022), and this would evidently have positive climate effects in Finland (Saarinen et al., 2019). On the other hand, the low biodiversity of dominant monocultures with annual crops would ask for grasslands and grazing animals, i.e. cattle and sheep (Huuskonen, 2006; Laurila et al., 2015; Niemelä et al., 2008; Pykälä, 2001, 2007; Tälle et al., 2016). The most contradictory claims within the animal sector focus on the ruminants, which is the most important line of agricultural production in Finland.

The negative environmental externalities of animal production are well-known (climate change) and/or visible (eutrophication) whereas positive externalities (biodiversity) are more difficult to conceive and access. Consequently, the environmental discourses are dominated by claims to cut animal production and especially cattle farming (e.g. Koivisto, 2019; Ryynänen, 2017). The environmental discourse has potential for upgrading into a basin of attraction through 'massafication' as it has gained wide publicity in Finland in recent years. Specific elements of the discourse are also widely supported by various civic, professional, administrative and political organisations (Ilmastopaneeli, 2020; Kallio and Brax, 2019; MTK, 2020; Syke, 2023; The Greens in Finland, 2010; WWF, 2024). The citizens are also worried about the environment and e.g. ready to cut their own standard of living to save the climate (Pelli, 2023).

Compromising between the contradictory aspects and arguments to reconfigure the food system, the environmental attractors would cut the animal sector significantly but retain it in the service of both the humans and the environment. This could happen by following two parallel logics and subsystems: one subsystem cultivating positive externalities and another subsystem confining negative externalities.

2.3.3. Health discourse

> '*Consumers that had reduced or given up red meat intake and increased the use of plant protein products no longer represented a small minority.*'
>
> (Nevalainen et al., 2023, 10)

Arguments for change in the health-based food system discourses feature issues related to growing obesity and lifestyle-based health problems (Safaei et al., 2021; WHO, 2000). Convincing arguments are presented for the health benefits of reducing consumption of red and processed meat (Hiltunen, 2013; Libera et al., 2021; Qian et al., 2020; Salusjärvi et al., 2020; Wang et al., 2022; Wolk, 2016). Among the Finnish population there are 'meat sceptics' and 'meat believers' (Vainio et al., 2018), but still health motives have already cut consumption of meat in some consumer categories (Nevalainen et al., 2023).

Health discourse has the capacity to upgrade into a new basin of attraction for a new regime through 'massafication' for several reasons. First, the public nutrition recommendations that recommend cutting the consumption of red meat and processed meat (Blomhoff et al., 2023) have had an impact among enlightened citizens and those using public catering that observes the recommendations (Lehto et al., 2022, 1068). Second, the changes would not be very extensive and radical as only consumption and production of red meat would decrease (but not end). Third, lifestyle-based health problems and related costs are on the rise giving impetus for the health care system, public administration and health NGOs (e.g. Sydänliitto ry; UKK-instituutti; Terve Paino ry) to be active on the topic. Fourth, the argument is simple and appealing: eating less red meat improves your health (Schwab, 2023). Fifth, also consumer price of meat has risen faster than average food price in recent years (Latvala et al., 2023, 11).

Logically, health-based attractors would set up a regime that responds to the health claims. As a result, less beef and pork would be produced and consumed than at present.

2.3.4. National food security discourse

> '*The dominance of consolidated food chains threatens food security and leaves the food system vulnerable, with little resilience to external disturbance.*'
>
> (Helenius et al., 2020, 2)

Market disturbances and low self-sufficiency in several critical inputs (fuels, fertilizers, feeds) have fortified various risk concerns (Jansik et al., 2021; Knuuttila and Vatanen, 2021; Loi et al., 2024; Sokala, 2021) and given rise to arguments for national organisation of food security (Huoltovarmuuskeskus, 2022; Rikkonen et al., 2024). Specialisation has contributed to economies of scale and productivity but at the same time increased vulnerability along dependence on imported inputs (Kuhmonen et al., 2023). Along with increased global instability, the arguments and interests for national self-sufficiency as well as for local

and circular organisation of the food system have become more common (Coquil et al., 2013; Helenius et al., 2020; Kaihovaara, 2022; Karlsson and Röös, 2019; van Zanten et al., 2023). Cattle farming capable for utilising domestic feed and producing valuable manure would have an important role in such a food system. Apart from this, organic farming has gained ground in Finland (15 % of the farmland in 2023) and agroecology is in the upswing (Frilander, 2023).

Food-security and self-sufficiency discourse on food system futures has 'massification' potential. Expectations for increasing resource-scarcity, global food insecurity, detrimental climate change and new pandemics will keep up the concerns in the horizon for a long time (FAO, 2018; Kahiluoto, 2020; OECD, 2016). Further on, chronically and significantly negative trade balance of agricultural products and foodstuffs (Latvala et al., 2023, 14) creates pressure for the policy makers to introduce new attractors for the Finnish food system.

Concomitantly, attractors relating to national food security would configure a self-sufficient food system, cut down imported inputs, boost farming techniques based on a circular bioeconomy and rely on indigenous sources of nutrients and energy.

2.3.5. Global market discourse

> '*Regions that experience agricultural production declines due to climate change are expected to increase imports of agricultural products. Temperate regions, where production is projected to increase, will export more.*'
>
> (FAO, 2018, 20)

Climate change deteriorates production possibilities in many populous areas (e.g. FAO, 2018; Molotoks et al., 2021) and increases variability in food supply (Wheeler and von Braun, 2013). If climate change will proceed, around one third of global agricultural production would be pushed beyond safe and suitable climatic conditions, and this would likely take place in the zone between the Tropics of Cancer and Capricorn surrounding of the Equator (Kummu et al., 2021). Agricultural net imports in West and North Africa, India as well as South and Southeast Asia would increase, whereas net exports from northern temperate zone areas in North America, Europe and Asia would increase (FAO, 2018, 23). Novel food system discourses with global market orientation argue that Finland is in a good position to benefit from the reorganisation of the global food system due to abundant freshwater resources, cool climate (no irrigation needed), skilled labour, modern technology and excellent food safety (Karhinen, 2019). Exports have frequently been proposed as a solution to both domestic profitability problems and global food security convers (MTK, 2023; STT, 2023) and animal products have a long tradition as the most competitive Finnish food products (Hämäläinen, 2018; Latvala et al., 2023).

The global food market and food security discourse has potential for 'massafication' in Finland. If the climate change cannot be curbed and the population growth around the Equator continues (Molotoks et al., 2021), there will be gradually increasing export demand for sustainable and safe products. In addition, profitable exports could alleviate many domestic pressures for change, e.g. low profitability of farming, dependence on domestic markets with few alternative outlets and the need of extensive agricultural subsidies.

If the global food market discourse was translated into a basin of attraction for a new regime of the Finnish food system, animal production in the cool northern and water-rich country could expand significantly in response to increased export demand from the southern areas.

2.4. Multi-level perspective as a regime shift mapping tool

An integrative analytical framework is needed to map various elements of alternative regimes and dynamics of regime shifts. Multi-Level Perspective (MLP) is a prominent framework for this purpose (see Figs. 2–6 for graphical illustration). MLP is useful as a 'mapping and navigating' tool (Jørgensen, 2012) to describe various elements residing in various levels of the system as well as dynamics of regime shifts. Consequently, it has also been widely used for this purpose to highlight various aspects of sustainability transitions of agro-food systems (e.g. Averbuch et al., 2021; El Bilali, 2019; Elsner et al., 2023; Galli et al., 2020; Morrissey and Abbott, 2014; Özatagan and Karakaya Ayalp, 2021; von Oelsreich and Milestad, 2017).

MLP describes the interplay of three levels – landscape, regime and niche – that interactively reconfigure an existing regime or lead to a regime shift (Geels, 2002, 2019, 2020; Geels and Schot, 2007). The landscape level hosts highly institutionalised forces or megatrends that are exogenous to the regime actors: climate change, globalisation, digitalisation, urbanisation, population growth etc. (El Bilali, 2019; Kuhmonen, 2020; Saritas and Smith, 2011). At the other extreme, the niche level hosts novel ideas, weak signals and symptoms of change that exhibit a low level of structuration and institutionalisation (Geels, 2019; Kuhmonen, 2020; Saritas and Smith, 2011). In between, there is a regime with its lock-ins (Geels, 2019; Iles, 2021; Klitkou et al., 2015). A regime is organised along several dimensions, and it resists change due to many forces maintaining path dependency: shared norms, routines, mind-sets, practices, existing networks, infrastructure, standards, regulations, agreements, sunk costs, vested interests, lifestyles etc. (El Bilali, 2019; Geels, 2019; Geels and Schot, 2007; Unruh, 2000). Regime is a dynamically stable organisation of a specific system (Geels, 2020). The original dimension of a MLP regime (markets and user preferences, industry, policy, technology, culture and science; Geels and Schot, 2007) can be comprehended also as generic types of attractors that configure each specific regime.

There are occasions where the landscape level forces start to put pressure on the existing regime. For example, climate change has put a challenge on the livestock production due to its emissions (FAO, 2023; IPCC, 2022). As discussed above, societal discourses can translate these pressures into effective forces driving change. Simultaneously niches tender novelty that might provide feasible solutions to the emerging problems or responses to changed preferences, building up an 'internal momentum' (Geels, 2020, 1) for a regime shift. These tenders also need 'massafication' to turn into effective force fields. To illustrate the case with climate change and food systems, the novelties can include e.g. novel plant-based products, permaculture, rewilding, cultured meat and agro-forestry (Duenas-Ocampo et al., 2023; El Bilali, 2019; Geels, 2019; Saari et al., 2021). Niche level may host also novel governance models for the food system such as food democracy (López Cifuentes and Gugerell, 2021), agroecology (Iles, 2021; Lopez-Garcia et al., 2019) or alternative food networks (Geels, 2019). The result of the interplay of simultaneous processes at three stages may result in the reconfiguration of the existing regime or a regime shift when path dependence turns into path creation (Garud et al., 2010). It is quite often that 'discourse and framing struggles' take place between 'niche and regime storylines' (Geels, 2019, 193) – stages where exercising agency and coalition building (Geels, 2020, 4) are possible to reach for 'massafication'. Systems mapping is a useful and powerful tool to expose holistic aspects of regime shift including the elements and the processes. It may overcome the biases of planning just one future and ignoring the potentially negative ramifications of the planned changes.

3. Methodology

The study employed several methods to expose avenues for regime shifts involving a significant change in the role of animal production in the food system. As the first step, elements of the five discourses – ethics, environment, health, national food security and global market – were utilised in expert interviews to track the elements and dynamics of regime shifts. The systems changes were captured by means of Causal Diagrams that were crafted in 11 stakeholder interviews or focus group sessions with 17 participants. To this end, the informants were experts

representing various functions of the food system (primary production, processing, consumption) as well as different actors (businesses, research, interest groups, NGOs). Most of them had an experience of >20 years in their field. Description of the informants is provided in Table 1.

Interviews were conducted in 2018–2019. In each session, five diagrams were crafted representing the five alternative regimes of the food system configured by the five basins of attraction, resulting in 55 diagrams (Fig. 1). The time horizon was set to 2040. The informants were asked to identify drivers, elements and outcomes featuring alternative regimes configured by the five basins of attraction: ethics, environment, health, food security and global market. All of them had to describe all five futures and all of them equally contributed to the results. An example of a CLD is provided in Fig. 2 (for more, see Huuskonen, 2023).

Next, the elements of these diagrams (653 items) were abstracted into a smaller number of categories by means of conventional content analysis without predefined categories (Hsieh and Shannon, 2005). This phase resulted in 15 key elements that took different values or future states in each five regimes, which were then used to characterise the regimes (Fig. 2).

Finally, the causal dynamics of regime shifts were crafted by merging (1) the observations from literature on the alternative discourses concerning animal production as forming five different basins of attraction with (2) the elements identified in the expert interviews captured by the Causal Diagrams. The syntheses resulted in five alternative regimes that were mapped in the MLP framework. The maps feature elements of the contemporary regime and the new alternative regimes, drivers of the regime shift as well as pressures for change emerging upon the institutionalisation of the new regimes. It is worth of noting that even if the regimes serve the choice in the present by introducing divergent futures for the food system (ref. Slaughter, 1993) they are also interlinked, as for example climate change plays a role in many of them. The elements of the contemporary food regime were captured via synthesising the literature and the authors' knowledge of the field. The characteristics of the contemporary regime served as the starting point for each of the transition pathways, but the landscape forces and tenders from the niche were distinct in each case. In the analysis, each of the alternative regimes were characterised in relation to five topics: structure of consumption and production, method of production, main market, origin of inputs and focus of agricultural policy. The frequencies of the elements in each regime are given in Table 2. As shown, different regimes come along with different profiles outlined by the informants. For example, Vegan regime is profiled by values and environmental concerns, Environmental regime by production methods, Health regime by consumption patterns and policies, Self-sufficient regime by metabolism and Global market regime by production volumes as well as by foreign trade.

Altogether, the MLP maps expose five regime shifts with varying role and volume of the animal production. All the described futures are possible, but probability or desirability of the analysed regime shifts are not assessed in this study. Many of the alternative futures would face challenges to become reality (e.g. climate, soil, market and policy issues) some of which are manifested by the new landscape level forces emerging after the regime shift.

Table 1
Description of the informants.

No.	Education	Organisation and expertise	Experience
1	PhD	University; environment, food system	>20 years
2	PhD	Finnish Farmers Union; environment, agriculture, policy	>20 years
3	PhD	Research institute; sustainability, food system	>20 years
4	MSc	Meat industry; food processing, markets, agriculture	>20 years
5	PhD	University; food system	>20 years
6	PhD	Milk industry; food processing, agriculture, environment, policy	>20 years
7	PhD	Research organisation; aquaculture, environment, policy	>20 years
8	PhD	University; agriculture, policy	>20 years
9	PhD	Research organisation; laboratory food	>10 years
10	MSc	Meat industry; food processing, markets, agriculture	>20 years
11	PhD	Research organisation; food consumption, policy	>20 years
12	PhD	Crop and feed industry; food processing, agriculture, policy	>20 years
13	MSc	Non-governmental organisation; food consumption, policy	>20 years
14	MSc	Meat industry; food processing, markets, agriculture	>20 years
15	PhD	University; agriculture, food system, policy	>20 years
16	MSc	Consultancy firm; food markets, consumption	>10 years
17	MSc	Meat industry; food processing, markets, agriculture	>20 years

4. Results

In this section, we will present five MLP maps, each of which unveils a possible transition pathway towards an alternative future food regime. These regimes are configured by the discourses presented in the previous section that act as alternative basins of attraction. In contrast, the contemporary regime that serves as the starting point for the transitions is the same in each alternative. Before introducing the details of the regimes, their main characteristics are summarised in Table 3 conforming to a futures table (Kuhmonen and Kuhmonen, 2015).

4.1. Vegan regime

The vegan regime is built upon an overhaul of the ethics discourse. The key elements of the change towards a vegan regime, contrasted with the contemporary regime, are synthesised in a MLP map (Fig. 3). The regime shift would be driven by several simultaneous external pressures arising from the landscape level, including mainstreaming of ethical values and concerns caused by the climate change. Simultaneously, there would be several tenders of novelty arising from the niche level: new climate-friendly and tasty plant-based food products, new vegetarian lab-food products releasing land to non-agricultural uses, domestic sources of food protein (legumes, protein-rich cereals), all boosted by public trend-setters and taste-makers. Despite the rigidity of the dominant mixed diet regime, these forces would open it up, degrade it and ultimately pave the way for a new direction and emergence of a new regime: The Vegan regime. Fundamentally, this would be a value-driven regime shift with earthmoving impacts on the structure of consumption and production.

The experts considered that the Vegan regime would be based on the following dimensions: 1) completely plant based consumption and production, 2) agricultural production concentrated to the most favourable south-western areas (where special crops can be produced and not just animal feeds and grass like in the north-eastern areas), 3) domestic markets (no change in incentives), 4) imported inputs and fossil energy (no change in incentives) as well increased imports of some plant products (e.g. soy products to replace animal protein) and finally 5) subsidies for plant production (but not to animal production anymore). When commercial animal production would come to an end, so would too manure as organic fertiliser. This would increase the demand for mineral and imported fertilizers. Also trade balance would deteriorate further as dairy products have been the only product group with a positive trade balance. Further on, imports of some protein crops would increase since they are not competitive in the Finnish growing conditions. Bread grains with low quality would have no demand for feed and would become a waste stream. Overall environmental load caused by the shrinking agricultural sector would abate, but regional concentration of production and monocultures of annual crops would locally increase the load. Biodiversity benefits of grazing animals would be lost completely.

Later on, part of these collateral and possibly unforeseen impacts

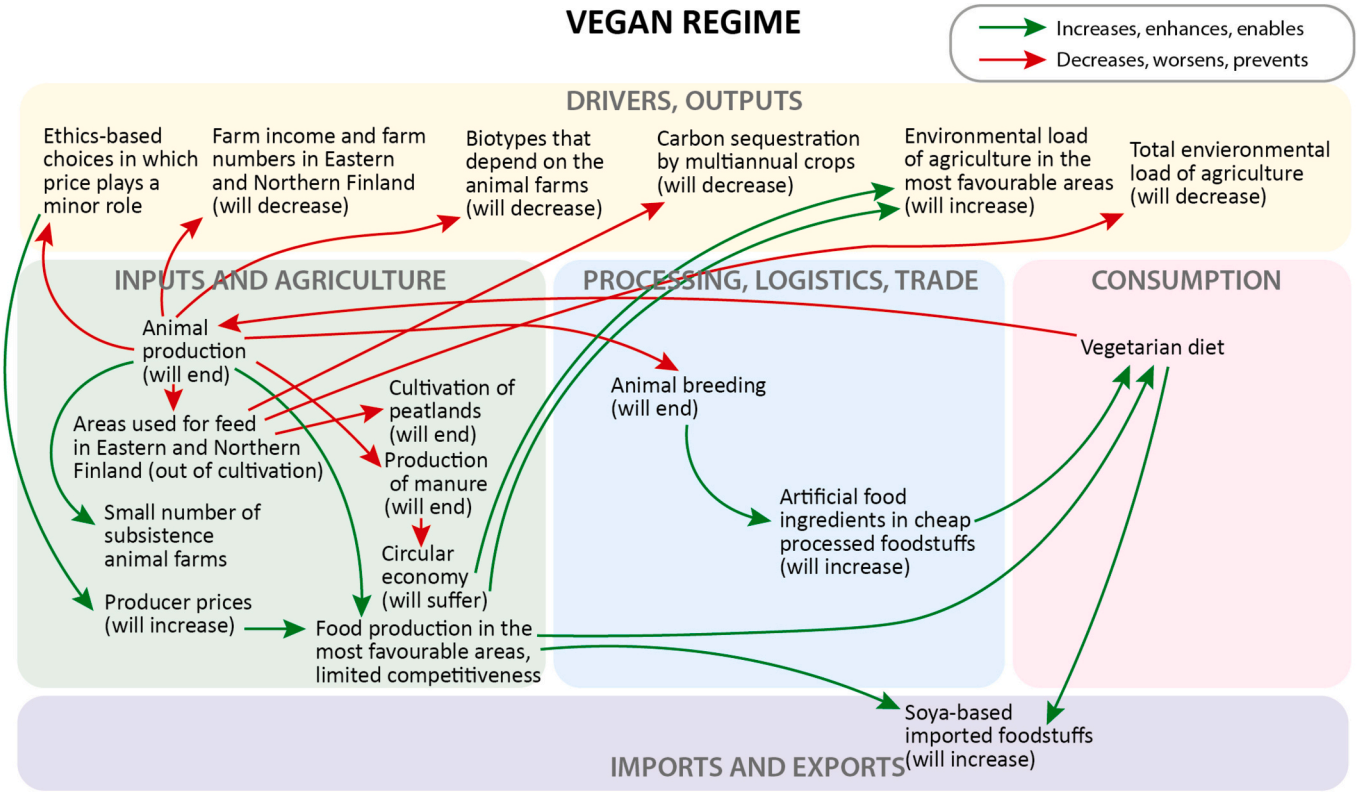

Fig. 1. An example of a Causal Diagram (Vegan regime).

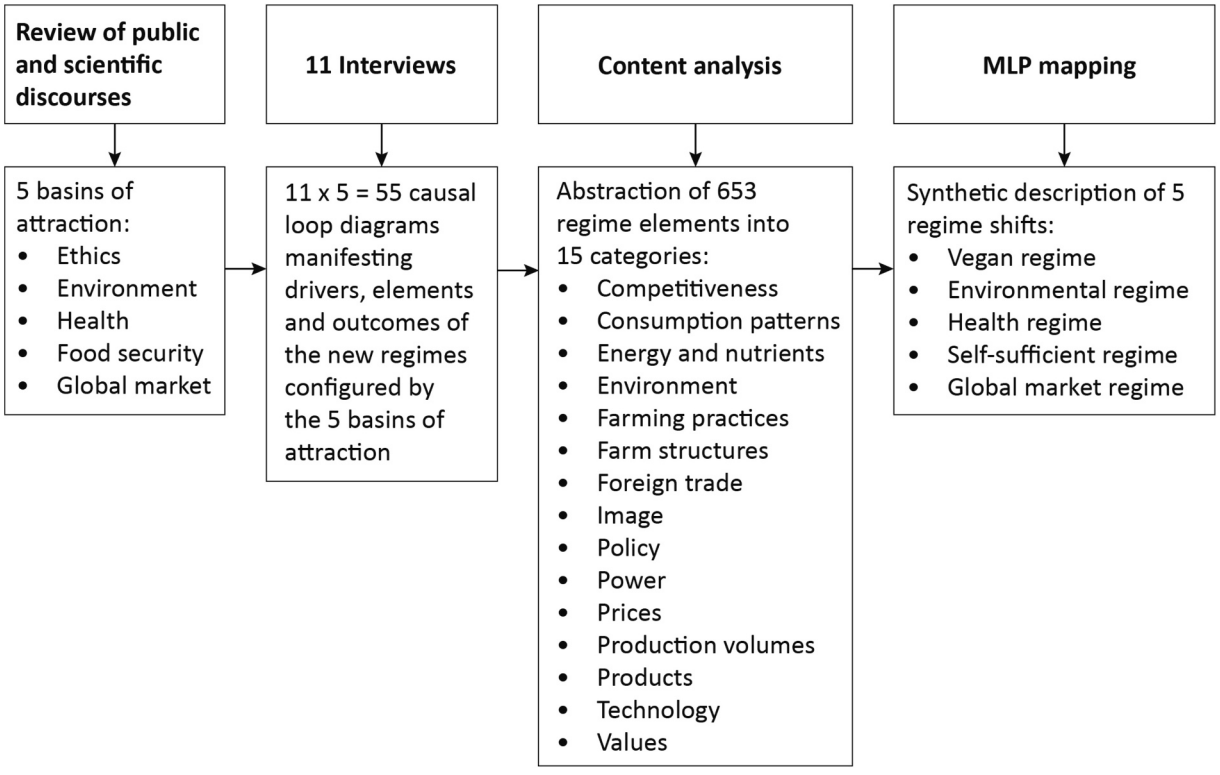

Fig. 2. Methodology of the study.

would become new sources of landscape level pressures. Animal-related biotopes and species would become endangered; the nutrient stock would become limited in the absence of manure that had to be replaced by green manure with increasing costs, or by increased application of climate-unfriendly mineral fertilizers; the elk stock and damage for young trees and traffic accidents could have exploded as they would be

Table 2
Profiles of the regimes by key elements based on the frequencies in causal maps, %.

Element	Vegan regime	Environmental regime	Health regime	Self-sufficient regime	Global market regime
Values	7	1	4	0	1
Energy and nutrients	2	4	0	17	0
Price changes	2	4	7	1	6
Image	0	1	4	0	2
Competitiveness	4	6	6	7	14
Consumer behaviour	14	7	34	9	5
Policy	5	10	12	8	1
Technology	7	4	1	4	4
Farm structures	1	6	0	2	6
Production volumes	17	19	17	18	27
Production methods	13	20	0	12	5
Products	5	2	3	0	3
Foreign trade	7	7	11	15	21
Power	1	0	0	2	0
Environment	14	9	0	6	5
Total	100	100	100	100	100

not hunted for food anymore. Further on, regional economies of the less favourable animal production areas in the eastern and northern parts of the country would lose open landscapes, incomes and jobs that could not be replaced. Finally, securing a balanced and safe diet would become a challenge for many people who have no interest or capacity to do detailed diet planning as vegan diets tend to be poor on many micro-nutrients. After some decades, these pressures with some currently unknown niche innovations could comprise a force field that replaced the Vegan regime with a different one.

4.2. Environmental regime

Transformation of the contemporary regime into Environmental regime would be again driven by an interplay of multiple levels (Fig. 4). Several environmental concerns that arise from climate change, nutrient runoffs, eutrophication and loss of biodiversity would put pressure on the current regime. Simultaneously, there would be many niche level novelties that provide responses to these common concerns. Circular economy would expand and become more fine-grained and, relatedly, promote innovations that modernise production systems towards more closed circulation. Plant breeding would provide solutions for the long-term problem of weak competitiveness of protein crops. Small-scale energy and nutrient technology would develop and undermine the scale economies underlying the dominant linear economy epoch. There would be several innovations in environmentally friendly products. Finally, targeted policies would promote two parallel paths: intensive, efficient production methods to reduce the environmental and carbon footprint of food and extensive production methods that promote farmland-related biodiversity. All these forces and process would consolidate around an environmental basin of attraction, lead to degradation of the contemporary regime and give birth to a new regime: The Environmental regime. This would be basically a policy-driven regime shift with significant impacts on the methods of production and production volumes.

Based on the views of the experts, the new regime would be characterised by the following dimensions: 1) radically reduced meat and milk consumption and production, 2) divergence of intensive and extensive production, 3) domestic markets (no change in incentives), 4) improved self-sufficiency in feed and energy as well as 5) adoption of extensive environmental subsidies and taxes. Production of pork and poultry that are based on cereals and imported foodstuffs without

Table 3
Main characteristics of the regimes.

Element	Current regime	Vegan regime	Environmental regime	Health regime	Self-sufficient regime	Global market regime
Food consumption	Versatile animal and plant-based products	Only plant-based products	67 % cut in the meat consumption	33 % cut in red meat consumption	Versatile animal and plant-based products	Versatile animal and plant-based products
Food production	Versatile animal and plant production	Only plant production on the most favourable areas	Intensive and extensive production will diverge at the farm level	Production of red meat 2/3 of the current level	Animal and plant production organised by self-sufficiency	Animal production will double
Farming methods	Intensive	Intensive without manure	Intensive and extensive separately	Intensive	Circular economy and organic methods	Intensive
Farming inputs	Lots of fossil and imported inputs	Lots of fossil and imported inputs	Improved self-sufficiency in energy and feed	Lots of fossil and imported inputs	Farm level self-sufficiency in energy, feed and nutrients	Lots of fossil and imported inputs
Agricultural land use	Both clearing of forests for cultivation and afforestation	Previous fodder fields will be used for energy or afforested	Previous fodder fields will be used for restoration, energy or afforestation	Previous fodder fields will be used for energy or afforested	All fields will be exploited for food	Clearing of forests to increase field area
Agricultural subsidies	Extensive and diversified general subsidies	Subsidies only for crop production	Subsidies for environmental improvements	Subsidies for healthy products	Subsidies for improving self-sufficiency	Subsidies for recruiting and educating farmers
Foreign trade	Large net imports of agricultural inputs and food products	Net imports of agricultural inputs and some plant-based products	Net imports of some plant-based food products; end of fish imports, decreased imports of feed and energy	Imports and exports as in the current regime	Net imports of some agricultural inputs (e.g. pesticides); end of meat, fish, feed and energy imports	Increased imports of agricultural input and plant-based food products; end of fish net imports; stark increase in the exports of animal products

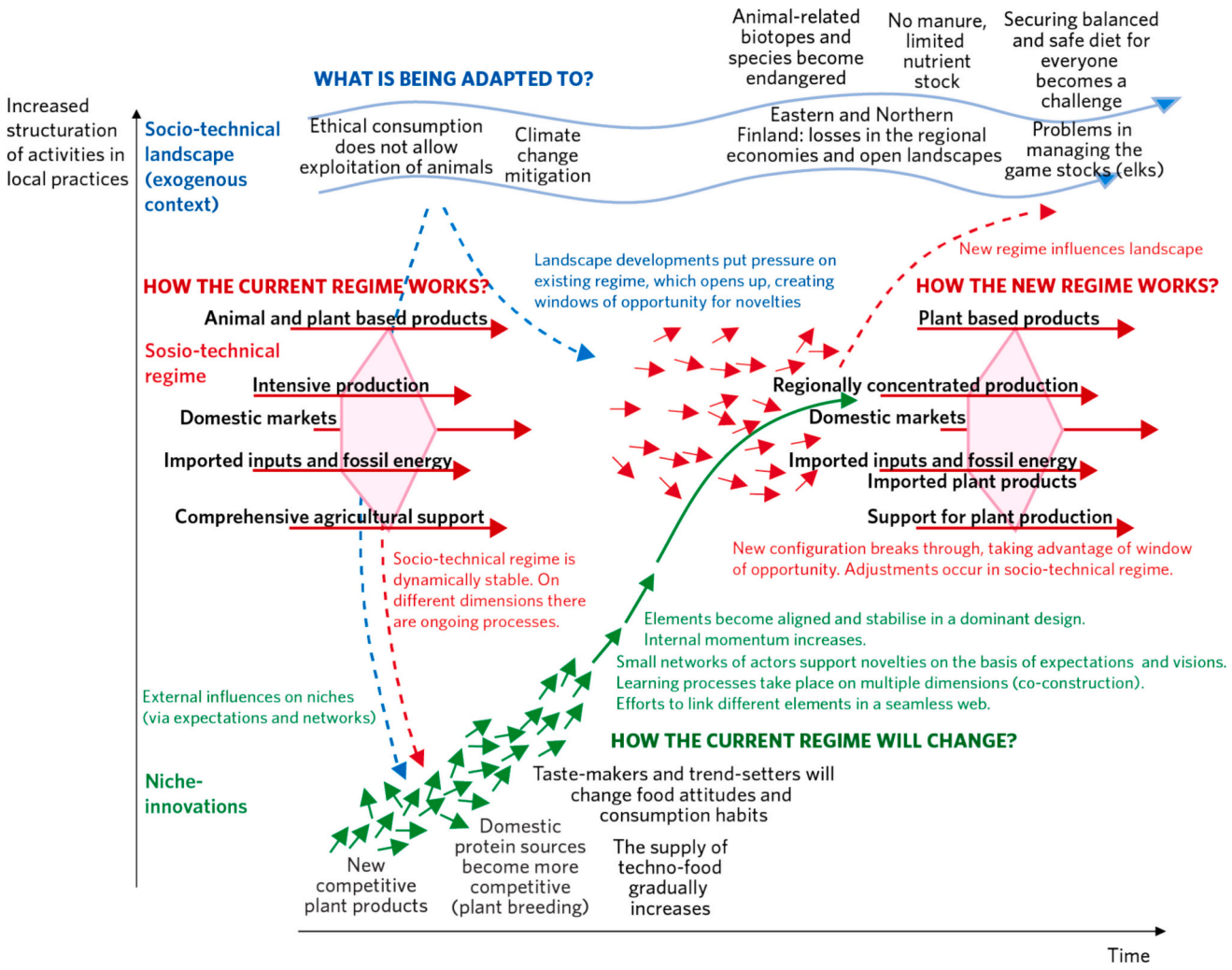

Fig. 3. MLP map of the regime shift from contemporary regime to Vegan regime.

biodiversity benefits or potential for carbon fixation would face the largest production cut (−75 %). In Finland, milk and beef production are integrated as on average >80 % of beef is of dairy based origin and <20 % is from beef herds (Hietala et al., 2021). Therefore, also milk production with grazing benefits would be cut (−40 %) but less than beef production (−50 %). Exploitation of natural fish would double to replace the loss of animal protein in the diets. Cultivated agricultural area would be cut significantly due to reduced feed demand and more protein crops would be produced to replace the animal protein. Farms would be sharply divided into 'production farms' and 'agri-environmental farms'. The production farms would aim at eco-efficiency with intensive production that minimises land use to cut carbon and nutrient emissions. Agri-environmental farms would employ extensive farming methods (e.g. organic farming, agroecology, regenerative agriculture, carbon farming) to maximise biodiversity and rely on diversified income sources (e.g. environmental subsidies, education, tourism, short supply chains). Biogas and circular economy would become mainstream and currently extensive imports of fossil inputs and Norwegian salmon would decrease radically.

Again, part of the impacts of the regime shift would become new effective forces at the landscape level putting pressure on the new Environmental regime (Fig. 4). First, large amount of support and regulation would be needed to maintain two parallel sub-regimes with opposite attractors: intensive and extensive. Further on, inequality would increase as some farmers live mainly on market-based income and some other farmers live mainly on subsidies. Eastern and northern parts of the country would lose part of the open landscapes, incomes and jobs along with a shrinking animal production. These pressures could lead to a decay of the Environmental regime and a consequent regime shift some time in the future.

4.3. Health regime

Abandonment of the contemporary regime and rise of the Health regime would not be as radical shift as the previous ones (Fig. 5). Limits of the state finances and growing costs caused by obesity and excessive consumption of red meat would add landscape level pressure for cutting consumption of red meat. Consumers would also give more attention to monitoring and taking care of personal health which leads to similar impacts. Health consciousness would increase, partly due to stark public nutrition recommendations and novel food information putting health to the first place. Concomitantly, taxes and public subsidies would be retargeted in favour of healthy products. Health-oriented product innovations would flourish. Extensive public catering would follow nutrition recommendations in detail, leading to a significant cut in red meat consumption. Monitoring of personal health and food consumption would mainstream. Altogether, these changes would lead to deterioration of the contemporary regime and ultimately to a regime shift when Health regime would take over. The shift would be driven by changed policies and consumer preferences.

According to the expert views, the resulting Health regime would be characterised by the following dimensions: 1) reduced red meat

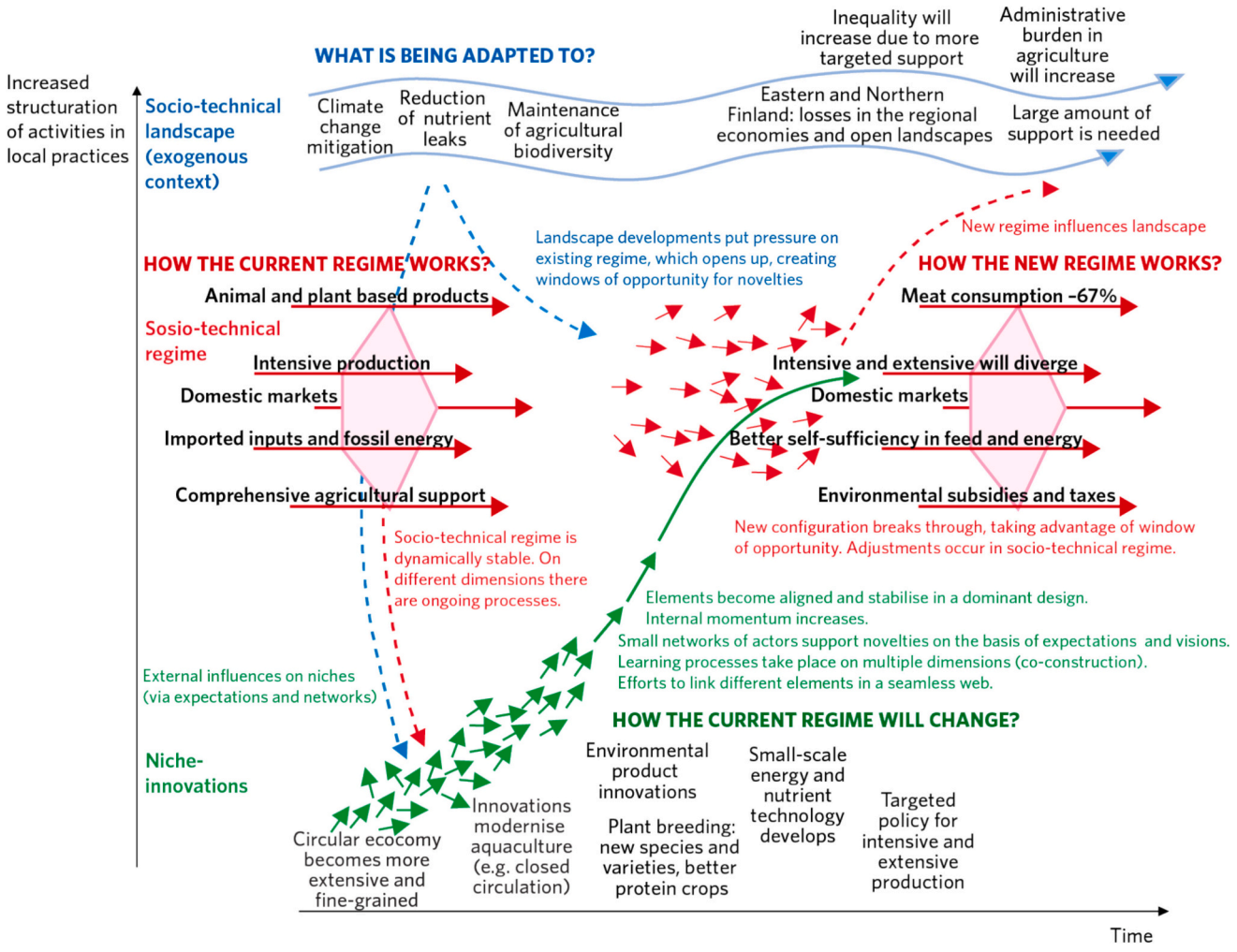

Fig. 4. MLP map of the regime shift from contemporary regime to Environmental regime.

consumption and production, 2) intensive production (no change in incentives), 3) domestic markets (no change in incentives), 4) imported inputs and fossil energy (no change in incentives) as well as 5) health-based subsidies and taxes. Beef and pork production and consumption would decrease by 33 %, but poultry production would remain at its current level. Reduced consumption of red meat would be replaced by increased consumption of vegetarian production and domestic fish. Consumption of cheap and processed food would increase. Part of the field area that was used for feed production would be used for protein crops but still imports of soy-based and other plant products would increase.

As the new regime would take over, new landscape level pressures would emerge. Cattle-related biotopes and species would become endangered along with the cut of grazing animals and grasslands. New types of taxes and subsidies would add administrative burden. Differences among consumer segments would increase due to many reasons (wealth, knowledge, lifestyle), not always adding health and wellbeing. Depending on their strengths, these developments could challenge the Health regime in the future.

4.4. *Self-sufficient regime*

A shift from the contemporary regime to Self-sufficient regime would reform most of all organisation and metabolism of food production. Increased global insecurity, market volatility and risks as well as uncertain availability of necessary imported farming inputs would raise concerns about the feasibility of the current regime (Fig. 6). Mitigation of climate change would ask for giving up fossil economy which is based on imported energy. The national economy also leaks money and jobs due to extensive imports of inputs. The current linear economic model would be replaced by a circular economy. New policies would introduce new attractors: food security, sustainability, self-sufficiency and locality. While the current regime is characterised by economies of scale, specialisation and concentration, development of small-scale energy technologies and novel uses of biomasses would provide new alternatives. Principles and methods of organic farming would be widely adopted, e.g. green manure and planned crop rotation. Farms or farm groups would become self-sufficient in terms of energy, nutrients and animal feed. Gradually, a new Self-sufficient regime would take over. The shift would be driven especially by proactive food security policies.

In the views of the experts the new regime would be based on the following dimensions: 1) animal and plant-based consumption and production (no change in incentives), 2) circular, organic and frugal production methods, 3) domestic markets (no change in incentives), 4) self-sufficiency in animal feed, nutrients and energy as well as 5) subsidies for better self-sufficiency at the farm and local level. Reformed metabolism of agriculture would be the key for change. Local biomasses (manure, field and forest biomasses, waste) would be fully utilised and nutrient management would improve along adoption of novel methods (nitrogen-fixing crops, carbon farming, agroecology, regenerative farming, permanent vegetation cover). Small-scale energy production would become mainstream: biogas, windmills and local energy communities. Reaching for maximum yields would be given up which makes the domestic stock of feed and nutrients sufficient for self-sufficient

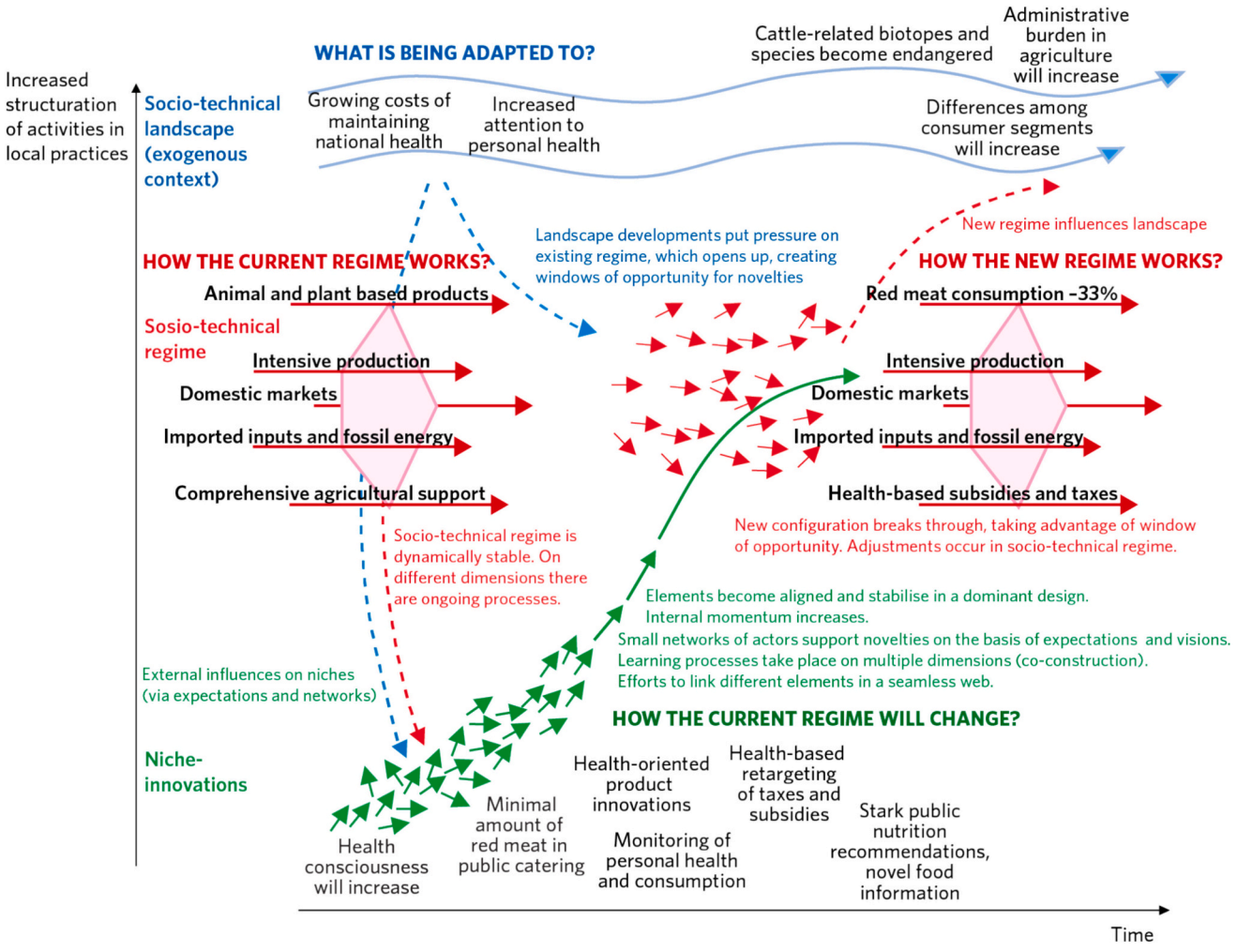

Fig. 5. MLP map of the regime shift from contemporary regime to Health regime.

agricultural production. Imports of fossil inputs would stop, but some feed ingredients (e.g. vitamins, amino acids) as well as some critical pesticides and machines would be still imported. The food and energy systems would become more decentralised compared to the current regime, redistributing power within the food chain in favour of primary and small-scale producers.

As soon as the new regime would institutionalise, new concerns would emerge that start putting pressure on the regime from the landscape level. Not all countries operating on the same markets could face a similar regime shift and global market prices would still manifest the (low) costs of fossil economy that omit negative externalities (e.g. contribution to climate change). For this reason, the need for support might increase at least in the short run. Further on, redistribution of power, markets and subsidies within the food chain could give rise to several conflicts and create dissatisfaction. Over time, these kinds of problems could turn the Self-sufficient regime fragile, obsolete and subject to replacement with a new regime.

4.5. Global market regime

A significant part of the global population lives in areas that are risk facing detrimental consequences of climate change (Fig. 7). If the areas close to Equator were to dry out, their capacity to provide nutrition to the local people would deteriorate. As a consequence, people would have to move out or more food would have to be imported to these areas. Areas with abundant freshwater resources can supply water-intensive foodstuffs to the drying areas. In this setting, Finland would be a superpower with its abundant freshwater resources and capability of responding to the sharply increased export demand of livestock products. This would challenge the contemporary food regime which is based on domestic demand. Besides these landscape level pressures for change, also niche level developments would play a role. Export-oriented policies would be gradually adopted, and new farmers with new competences would enter the profitable and growing business sector. Growing units would adopt new technologies and new management practices together with extensive use of foreign labour. Traditional family farms would become large and partly externally owned businesses. All agricultural resources would be in use: reserve lands would be taken back into cultivation and some new fields would be cleared from forests. Grasslands would be important for milk, beef and mutton production and their productivity would increase sharply due to new species, cultivars and cultivation techniques. The amount of manure would increase along with the doubling of animal production; new techniques to utilise this resource would also be deployed. A fully market-driven shift would replace the contemporary regime with the Global market regime.

The experts considered the new regime to be based on the following dimensions: 1) animal and plant-based diets (no change in incentives), 2) intensive production (no change in incentives), 3) export markets, 4) imported inputs and fossil energy (no change in inputs) and 5) support for recruiting new farmers as no other subsidies would be needed for profitable farming business. Farming methods would intensify further, and grass yields would double. Grass-based production (ruminants) would be the most competitive line of production as the costs of irrigation would skyrocket in the southern areas, whereas in Finland

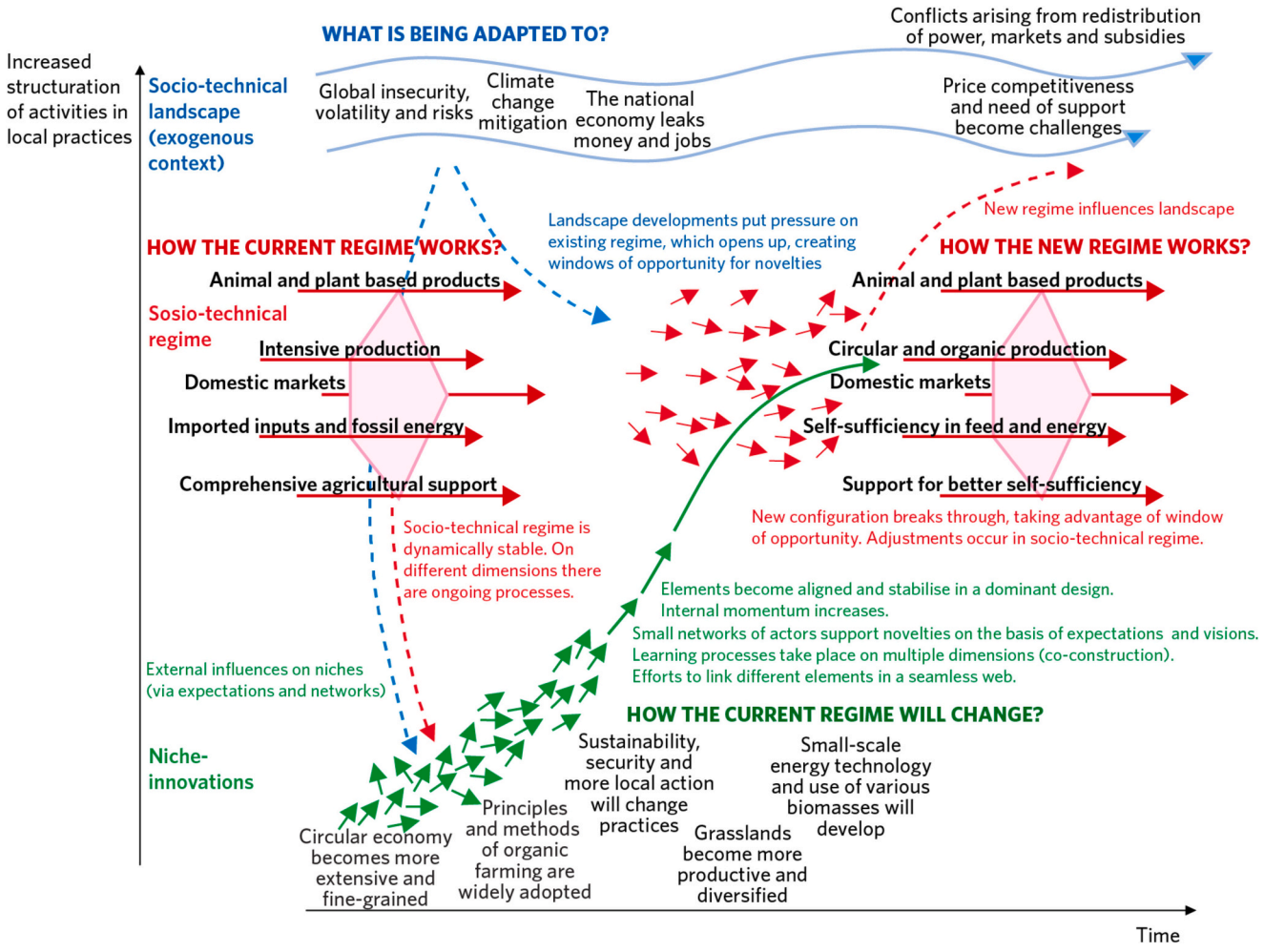

Fig. 6. MLP map of the regime shift from contemporary regime to Self-sufficient regime.

irrigation is unnecessary. Sustainable water management would be certified and together with antibiotics-free animal products this would sharpen the competitive edge of northern livestock production. The increase in environmental load caused by farming would be, however, an unavoidable collateral damage. Many part-time cereal farms would be converted back into livestock farms also in the southern and western parts of the country.

As soon as the new regime is established, new problems would emerge. As the increased demand is targeted at animal products, their market prices would rise considerably. This would take place also in the domestic market leaving low-income consumers without some animal products that have become a luxury. Environmental stress, nutrient runoffs and problems with nutrient management would accentuate in areas where new concentrations of animal farms appear. Over time, these pressures would challenge the established Global market regime.

5. Discussion

Comprehension, description and anticipation of the evolution of societal systems is a major challenge for science, especially in the case of Complex Adaptive Systems (CAS) that host emergence and self-organisation. Apart from this, many food systems seem to follow a cyclical pattern of evolution. During periods of dynamic stability, the system is trapped by a basin of attraction constituted by specific attractors that configure it. During these periods, the system takes the shape of an institutionalised regime. When the system swaps attractors, a regime shift takes place. This resembles the general evolutionary description of societal development with alternating stable phases and revolutionary paradigm shifts (Mannermaa, 1991, 364–366) or crucial epochs (Laszlo, 1985, 17). Mannermaa (1991, 358) defines the prominent role of futures research in this setting:

> "*The role of futures research in this model of social development is on the one hand to identify signs of breaks, social movements, technological innovations, signs of destabilization etc. On the other, it is to try to outline possible alternatives after the 'bifurcation', and in this way to create a kind of a map of possibilities for the future.*"

On this demand we aimed to contribute with this study. More specifically, we presented an empirical illustration of possible destabilization and bifurcation processes of food regimes. We studied discourses to map possibilities for the future after the bifurcation and employed systems science methodology (Causal Diagrams, Multi-Level Perspective) to describe the dynamics of the change. We used the food system as an example of a societal system that might swap attractors upon a regime shift, in this case due to contradictory role of the animal production. Our stage for the simulation was Finland, a post-industrial country in the cold north with a large animal sector.

5.1. Lessons for the study of Complex Adaptive Systems (CAS)

During our research enterprise, we learned three things that might be helpful for others sharing similar research aims and questions related to evolution of food systems or other societal systems. The first one is related to the *comprehension of the difficulty of the regime shifts* even when

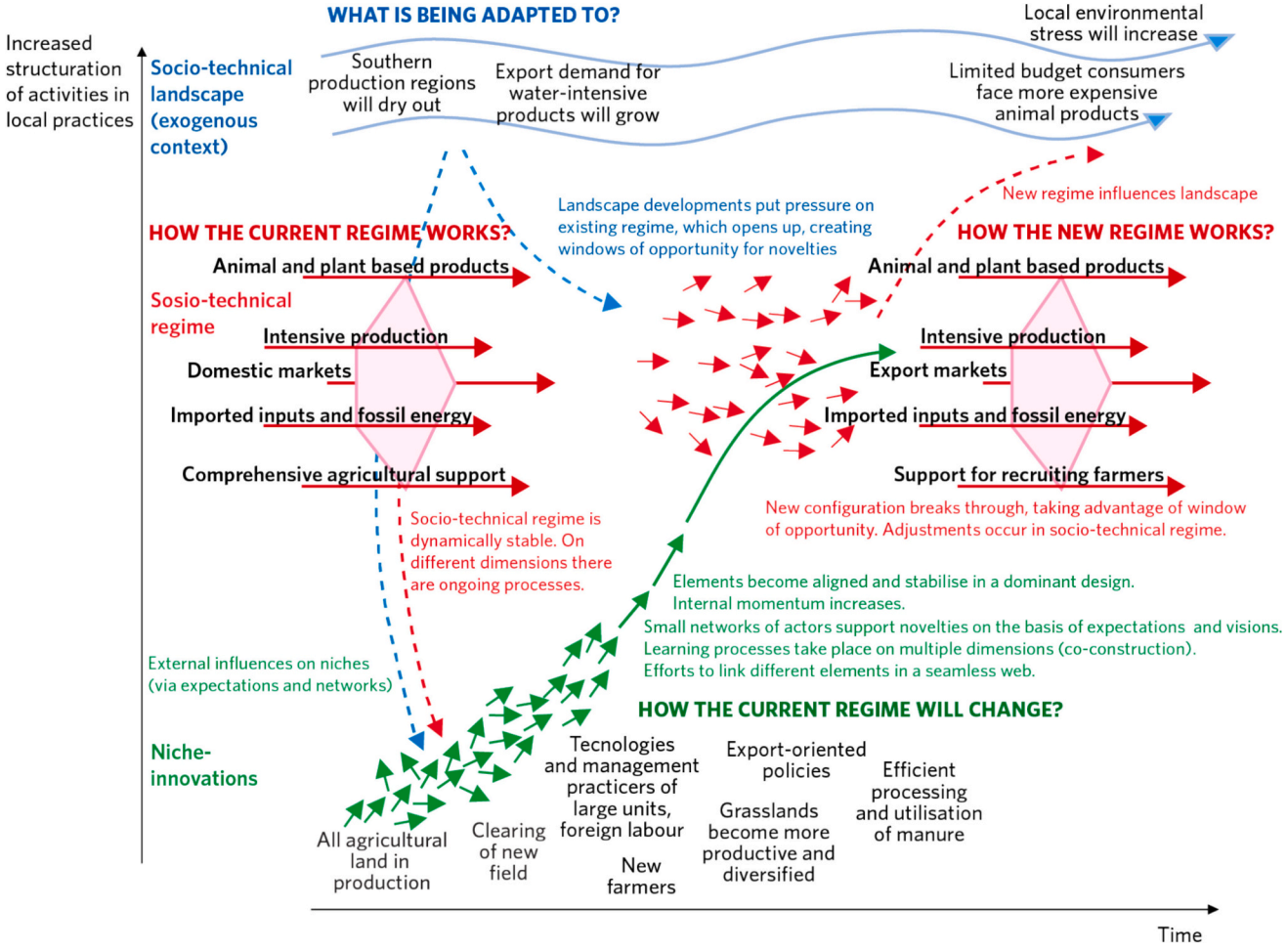

Fig. 7. MLP map of the regime shift from contemporary regime to Global market regime.

facing indisputable demands for such. Complex systems thinking provide a reason for this: the dominant regime is stuck in the basin of attraction configured by attractors that are effective in that particular basin (Gerrits, 2012; Room, 2011). The basin of attraction boxes the state space for 'allowed' practices and policies, a life space for the regime actors. In order to reconfigure or transform fundamentally, the regime actors should cross a saddle point and 'climb over a mountain' in the fitness landscape (Kauffman, 1993, 33, 40) to settle in another basin of attraction.

The reason for the endurance of the food regimes is caused by structure–agency asymmetry. A regime shift would ask for 'massification' (Iles, 2021) of the novel actions rather than reproduction of the allowed and institutionalised practices of the current regime. Such a change is hard to organise as the dominant regime makes rewards from obeying its rules with resources. Even if there was an understood, accepted and evident need for a change, there are not always resources or power to make it among the change agents that would be willing (Westley et al., 2013). As Kuhmonen (2023, 46) explains: "acting otherwise' becomes an influential power when exercised by social collectives, which gives rise to morphogenesis, but mobilising such powers requires the presence of strong tensions in the system, even a crisis.' Comprehending evolution of food systems as a sequence of regimes and regimes shifts provides insights and explanations for the challenges faced by policy makers and social movements in their difficult task in driving transformative changes.

The second contribution is related to the *description of the evolution of a CAS*. Apparently a synthetical approach and methodology is needed to abstract and capture the diversity of forces, existing and becoming elements of the system and change dynamics associated with the regime shift in a meaningful way. MLP provides a feasible platform for this need as it can be used as a mapping tool (Jørgensen, 2012). The MLP framework could serve in two roles more often than previously capitalised. For one thing, MLP framework has been widely used to conceptualise a single regime shift without illustrating the emergence of new landscape level forces that arise upon adoption of a new regime. The framework can also be used to describe this kind of longer-term cyclical pattern of system evolution. For another, MLP framework has been used to set a scene for sustainability transition or regime transformation, but it has been quite seldomly used as a synthetic empirical mapping tool to describe the elements and processes of a regime shift explicitly. We used the MLP in both these roles and observed that was delivering useful results.

In general, the main challenge in describing the evolution of any CAS arises from complexity. The systems host several hierarchical levels and innumerable local interactions. A meaningful description of such a system asks for iteration of a feasible level of abstraction: too many details may fog the big picture and too general descriptions may remain empty carriers of attributes. As there is no general rule for the correct choice, such is guided by the purpose of the research act. Fundamentally, the level of abstraction designates the 'range of questions that can be meaningfully asked and are answerable in principle' (Floridi, 2008, 315). In this study were asked two questions: what new attractors the food system could take and from where they could emerge as well as how the specific attractors could reconfigure the system. By means of conventional content analysis we iterated such a level of abstraction that these questions could be asked, answered and synthesised in the MLP

framework. Change in the level of abstraction would change the regimes and for example higher level of abstraction could merge many of the regimes under the title 'Climate change regime'.

The third contribution deals with *anticipation of the evolution of CAS*. Systems thinking connected with participatory foresight processes may well uncover also unexpected and unwanted outcomes of planned futures, as we have shown. These emergent outcomes are difficult to foresee without a proper analytical framework, however. The problem here is that the alternative futures taking a form of a new (food) regime are driven by specific basins of attraction with their attractors capable for reforming a whole system. In trying to figure out where these kinds of game changers might come from and why elements proposed by them could lead to 'massafication', contemporary societal discoursed proved to be easy, accessible and rich source of information. Indeed, as Geels (2020, 15) concludes: 'future research could also fruitfully focus on the role of cultural discourses and narratives in transitions.' In this study, beyond identification of alternative attractors we also discussed their 'massafication' potential. Adding this element into numerous trend analyses and transition studies listing possible elements of possible futures could make them more meaningful for anticipating societal changes.

Generally, quite many foresight studies focus on separate elements of possible, probable or preferable futures (Bell, 1998) instead of representations of whole regimes. This undermines the role of futures research as a design science to plan and create new future alternatives for the current dominant designs. As Mannermaa (1991) has underlined, the core of futures research mission is in the anticipation of bifurcations and sketching of future possibilities opening after that. The essence of bifurcation tells us that all past rules, regularities, power constellations, policies and practices are not valid anymore. This asks distancing from the past institutionalised imaginaries and 'allowed' practices. We used Causal Diagrams for the crafting of five alternative futures. This proved put to be a fruitful method and it also exposed how hard disciplined imagination (Weick, 1989) is outside the familiar domain or knowledge base for many stakeholders. As all of invited experts had to plan for all the five alternative futures, they were forced out from their paradigm prisons (Kuhmonen, 2010). What we learned from this is that if the research mission was to design future alternatives following a bifurcation, a strong method is needed to overcome the historical bias of path dependence of thought and the contemporary bias of familiarity of some alternatives. Teasing out truly divergent futures is a violent act.

5.2. Implications for food transition in Finland

Animal production that is subject to major changes upon sustainability transitions plays a major role in Finnish agriculture that comprises of 40 % of the farm output in 2022 (Economydoctor, 2024). As shown by the discourses, the objectives and means to realise the transition are mixed and contradictory. On the one hand, the need to observe climate change is agreed by most discourses. On the other hand, the ways to do it varies a lot from closing commercial animal production to expanding exports considerably. While the cutting of cattle farming due to climate reasons dominated the public debate some time ago, the contemporary publicity is now dominated by the new food vision, that heavily relies on expansion of food exports (Karikallio and Kaukovirta, 2023; MMM, 2010; MMM, 2023; VTT, 2021). This manifests itself in the impact of the transition to sustainable agriculture, but even more so in the lack of a holistic approach. Heavily expanding exports of animal products would lead to extensive environmental and social impacts, yet these aspects are missing in the current argumentation. Upon adoption of a global market regime, new landscape level forces would emerge that ask for new reforms and adaptations as shown in the MLP mapping. Closing eyes to unintended consequences leads to unexpected problems. Sustainability transitions are continuous processes, and it would be important to note that new pressures will emerge with each regime choice. This study illustrates some of the repercussions that are currently missing in the plans for food transition in Finland.

There is a tradition in Finnish policy planning to work with one option that is an extension or a slight modification of the dominant regime. History has shown that the food regime shifts in Finland have been crisis-driven radical changes (Kuhmonen and Kuhmonen, 2023). Attractors for the new regime have often been found at the 'reverse' side of the current regime. The current regime is characterised by economies of scale, specialisation and interdependency as well as concentration. In this vein, the new regime could rather be organised by economies of scope, diversification, self-sufficiency and locality. While some believe that these two regimes could coexist, history has shown that soon after the shift, one regime starts to dominate. This setting would also ask for running two distinct policies that is complicated and costly. It may understandably feel safer to choose something familiar and make just small adjustments, than to plan for jumping into a new mode of adoption, for example of agro-ecology as the main model to be promoted. This study has tried to encourage scientists and decision makers to take a look at how CAS evolves, how new attractors emerge and institutionalise, and how rather quickly they may set a new direction for the food system evolution. Planning to continue the old track may finally turn out to be the wrong choice. Futures images that are radically different may help to understand possible choices, how they might happen and what they might bring along to avoid unintended surprises.

6. Conclusions

This study illustrates how systems science and futures research approaches can be used in tandem to expose the evolution of complex adaptive systems. Such an attempt faces several challenges concerning the iteration of an appropriate level of abstraction, capturing the systems dynamics, anticipation of regime shifts and new attractors that configure them as well as describing meaningful forces, elements and change processes. We have used the Finnish food system and more specifically the contradictory animal production as an empirical case to iterate a feasible approach to overcome challenges. We found that societal discourses are easy, accessible and relevant sources of information to depict alternative basins of attraction for future food regimes. We also found that participatory foresight process with diverse stakeholders employing Causal Diagrams, fed by elements of societal discourses, can profit manifestations of alternative regimes and regime shifts with their elements, dynamics and impacts. Finally, we found that Multi-Level Perspective can be used as a mapping tool to bring together essential elements of the regimes and regime shifts in a single framework. Being able to present arguments for informed choices about alternatives for the dominant contemporary food regime with new attractors and resulting outcomes is a valuable contribution to the discussion about the futures of food systems.

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CRediT authorship contribution statement

Tuomas Kuhmonen: Writing – review & editing, Writing – original draft, Visualization, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization. **Irene Kuhmonen:** Writing – review & editing, Investigation, Conceptualization. **Arto Huuskonen:** Writing – review & editing, Project administration, Funding acquisition, Conceptualization.

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