FINLAND FUTURES RESEARCH CENTRE

UNIVERSITY OF TURKU

DESIGN PRINCIPLES FOR ALTERNATIVE FUTURES OF COMPLEX ADAPTIVE SYSTEMS

Tuomas Kuhmonen

Academic dissertation

FFRC Publications 1/2025
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University of Turku
Turku School of Economics
Finland Futures Research Centre
Futures Studies
Doctoral Programme of Turku School of Economics

Supervised by

Professor Petri Tapio
Finland Futures Research Centre
University of Turku
Finland

Director, Dr. Soc. Sc. Juha Kaskinen
Finland Futures Research Centre
University of Turku
Finland

Reviewed by

Professor Ahti Salo
Department of Mathematics
and Systems Analysis
Aalto University
Finland

Professor emeritus Juha Helenius
Ruralia Institute
University of Helsinki
Finland

Opponent

Professor Ahti Salo
Department of Mathematics
and Systems Analysis
Aalto University
Finland

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This project is dedicated to my son Otto Johannes Kuhmonen (1992–2023).
I will send one copy to you in heaven.

Fly little bird

Fly little bird just fly.
Though you are weary to try.
Danger is watching your wonder
Darkness is more than nigh.
Home has many heartbeats
Beat your wings I pray
Fly little bird just fly now
Fly for heaven sake.

Try little bird just try
Though you are weary to fight
While we are watching your wonder
Danger is more than nigh
Home has many heartbeats
Beat your wings I pray
Try little bird just try now
Try for heaven sake

Tiny wings beat to the sky
Free yourself from dangers eyes
Nature‘s hand’s as cold as ice.
Fly to where your future lies

Fly little bird just fly.
Out on the dusk of the sky.
Fate is watching your wonder
Danger is more than night.

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Finland Futures Research Centre, Turku School of Economics, University of Turku
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ABSTRACT

Societies are made of Complex Adaptive Systems (CAS) which have no central command or ownership and which self-organise through local interactions. Becoming aware of their possible futures is critical since they provide us food, energy, mobility, housing, democracy and much more. One of the main challenges in this mission is the innumerable set of future possibilities. A feasible number of manifestations of alternative futures (visions, futures images, scenarios) that can serve choices in the present is about a handful. How to reduce the diversity of future alternatives in a transparent, disciplined and systematic way, is the key challenge discussed in this research.

Design principles for alternative futures of CAS are provided as one solution for resolving the challenge. Design principles feature generic principles of creating manifestations of alternative futures on the frontier of diversity and confinement. They are related to choosing an appropriate level of abstraction, delimitation of the choice space and identification of new attractors for the systems. Six empirical studies illustrate application of the principles in the domains of spatial, personal, system, policy and sector futures.

CAS tend to organise regimes that are highly institutionalised, path dependent dominant designs that resist significant changes. From time to time, the societal systems would need a reform toward better resilience and sustainability. In the domains of agrifood and rural systems, such have taken place only through deep crises. Even in these cases it is helpful to have concrete designs and visions for the developments that might take place after the bifurcation, since ‘becoming aware of different future alternatives’ (Slaughter 1993, 290) is the key to survival and success in any potential future. In fact, it is the reason for the existence of futures science.

KEYWORDS: agriculture, Complex Adaptive System, complexity, design, evolution, food, foresight, futures, regime, rural

Tulevaisuuden tutkimuskeskus, Turun kauppakorkeakoulu, Turun yliopisto
Turun kauppakorkeakoulun tohtoriohjelma, Tulevaisuudentutkimus
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TIIVISTELMÄ

Yhteiskunnat rakentuvat mutkikkaista sopeutuvista järjestelmistä (Complex Adaptive Systems, CAS), joilla ei ole keskusjohtoa, joita ei omista kukaan ja jotka itseorganisoituvat paikallisten vuorovaikutussuhteiden kautta. Tietoiseksi tuleminen näiden järjestelmien mahdollisista tulevaisuuksista on kriittistä, koska ne tuottavat meille muun muassa ruokaa, energiaa sekä mahdollisuuksia liikkumiseen, asumiseen ja demokratiaan. Mahdollisten tulevaisuuksien lukematon määrä asettaa vakavan haasteen tietoiseksi tulemiselle, koska vaihtoehtoisten tulevaisuuksien ilmentymiä (visioita, tulevaisuuskuvia, skenaarioita) tulisi olla vain 'kourallinen', jotta niiden pohjalta voitaisiin tehdä valintoja nykyhetkessä. Tässä tutkimuksessa keskustellaan juuri tästä haasteesta: kuinka mahdollisten tulevaisuuksien kirjoa vähennetään läpinäkyvällä, kurinalaisella ja systemaattisella tavalla.

Mutkikkaiden sopeutuvien järjestelmien vaihtoehtoisten tulevaisuuksien suunnitteluperiaatteet voivat tarjoa yhden ratkaisun haasteeseen. Yleiset suunnitteluperiaatteet kuvaavat, kuinka vaihtoehtoisten tulevaisuuksien ilmentymiä voidaan luoda ottaen huomioon sekä moninaisuus että rajallisuus. Periaatteet koskevat sopivan abstraktiotason valintaa, valintamahdollisuuksien avaruuden rajaamista ja järjestelmiä ohjaavien uusien attraktoreiden tunnistamista. Periaatteiden soveltamista on havainnollistettu kuudessa empiirisessä paikkojen, yksilöiden, järjestelmien, politiikkojen ja toimialojen tulevaisuuksiin kiinnittyvässä tutkimuksessa.

Mutkikkailla sopeutuvilla järjestelmillä on taipumus organisoitua regiimeiksi, jotka ovat vahvasti institutionalisoituneita, polkuriippuvaisia ja merkittäviä muutoksia vastustavia hallitsevia kokonaisuuksia. Ajoittain yhteiskunnan järjestelmien tulisi kuitenkin uudistua merkittävästi säilyttääkseen toimintakykynsä eli resilienssinsä. Maatalouteen, ruokaan ja maaseutuun kytkeytyvissä järjestelmissä tämä on aiemmin edellyttänyt syvää kriisiä. Myös kriisien kautta tapahtuvassa uudistumisessa on hyödyllistä, jos uudelleensuuntautumisen jälkeisestä ajasta on olemassa konkreettisia visioita, koska 'tietoiseksi tuleminen erilaisista tulevaisuuden vaihtoehdoista' (Slaughter 1993, 290) on selviytymisen ja menestymisen avain kaikissa mahdollisissa tulevaisuuksissa. Tosiasiassa se on syy tulevaisuudentutkimuksen olemassaoloon.

ASIASANAT: ennakointi, evoluutio, kompleksisuus, maaseutu, maatalous, muotoilu, mutkikas sopeutuva järjestelmä, regiimi, ruoka, tulevaisuudet

Acknowledgements

This is my second visit to the House of Sciences. The first visit in 2010 was a messy one. It resulted in a 300 pages monograph entitled ‘Metatheory of small firm performance and entrepreneurship’. But it was a step forward. And it was accepted.

The idea of making a second dissertation was kind of typical for me. A lazy person needs deadlines – and I do have lots of deadlines in my life, believe me. The first ambitious deadline was set eleven (11) years ago. Due to my high age, I can’t remember what it was. But it was ambitious.

‘Then came the churches, then came the schools, then came the lawyers, then came the rules’ tells Mark Knopfler in Telegraph Road. A story of a pioneer travelling deep into wilderness somewhere in the American frontier.

‘Then came the projects, then came the boose, then came the horses, then came the booze’ I could tell. A story of an ordinary Finnish man getting lost with a horse woman somewhere in the Finnish backwoods.

I had many plans for the thesis during the ten years of ‘incubation’. There is an evident reason why I eventually finished the ‘unended quest’ (ref. Sir Karl) only after all those years. My wife. She defended her (first) thesis at 15th of December 2023. It was only after this I could really start to work with my own dissertation. ‘You can’t have your second one before I will have my first one’. Roger that. I started next day.

One sunny winter day while working in the forest I started to think what had puzzled me during my years at FFRC. I found out that ‘level of abstraction’ was mentioned in almost every article I had written. The higher you fly, the more things you see beyond the horizon. And the less accurate they are. Suddenly the research questions were there: level of abstraction, delimitation of choice space, identification of new destinations. I had been thinking about these topics throughout the years without noticing it.

But here we are. And me, sleeping with another book under my pillow.

What comes with the miles in research business is the improved capacity for disciplined imagination (ref. K. E. Weick). At least in studying the non-existing – the future – such capacity is welcome. It is a capacity of keeping various theories, frameworks, models and concepts as subordinates instead of superordinates. It is capacity to escape from the paradigm prison (ref. D. Miller). The looking glasses of young Tuomas were focused on positive economics (ref. M. Friedman) and farming as a god-given duty for someone born on a farm. After seeing the awakening, touching, inspiring and encouraging 'Don Quixote' movie made by Stanford professor James March quite exactly 20 years ago as part of my management studies, I started to make plans for the escape. Ever since I have tried to avoid belonging to any schools, sciences or traditions. It has had implications you can observe in this piece of work.

But that's for the excuses. There would be more, as you can guess.

I have been lucky to get Professor Petri Tapio and Director Juha Kaskinen as my supervisors. They are both born in Savo, just like me. They know what it means to be born in Savo. It has implications. They have let me Breath (ref. Pink Floyd): 'Run, rabbit, run/ Dig that hole, forget the sun/ When, at last, the work is done/ Don't sit down/ It's time to dig another one'. Sincere thanks for support and flexibility, Pete and Juha!

I had two experienced reviewers: Professor of Systems Analysis Ahti Salo at Aalto University and Professor emeritus of Agroecology Juha Helenius at University of Helsinki. Ahti Salo kindly agreed to act as my opponent in the public defence of my thesis. The role of reviewers in academic world can't be overemphasised. They are the doormen at the House of Sciences. They either let you in or propose you further training. It is like a vehicle inspection service: Is it safe or not for you to ride on with this gizmo on the rocky roads (around the House of Sciences). I was in good hands, I know, and I am truly grateful for getting a green light from both distinguished reviewers. 'On the road again' (ref. W. Nelson) – with a permission to drive on.

Who is the next in line to say Thank You should not be a surprise for anyone who knows me. Or us. The public defence will be mild version – like a glass of milk – compared to the 'discussions' I have had with her while sitting at the kitchen table, loading shit in the horse stables or sitting in the sauna. Topics of the discussions have been mixed: ontology, epistemology, methodology, phenomenology, sociology, biology, agroecology, life and death – you name it. At the same time, she has been probably the most expensive investment in my life. Belyta once comforted me: 'If it does not cause costs, it is not a hobby, it is a job'. Women and horses…

To be honest, Irene Kuhmonen, my wife, has been my mirror, my mentor and my teacher. One of the most wonderful stories I have witnessed in my life has been her growth story as a scientist. When she moved to Vesanto 13 years ago, she was a young

geographer who had made empirical environmental research for quite many years. During the last few years, she has published more books and articles than me, read more scientific literature than me, become more competent in finding productive research questions than me and asked for expert posts more often than me. My life has become easy. When I have a problem, I will consult Irene.

We both have background in research institutes: she in Jyväskylä University Institute for Environmental Research and I in Pellervo Economic Research Institute PTT. We have agreed that such a base training period would be very beneficial for all young researchers. Compilation of some dozens of empirical reports is good for a young human being before making a dissertation. For me, the years at PTT were worth of gold. Research Director Seppo Aaltonen reviewed my first ever research report on taxation of farms in European countries. The report was full – I mean really full – of remarks on the language. Seppo said: 'I know what you mean, but the reader does not'. During those years I learned to write.

Already before that I run into trouble in the Netherlands. In 1987 I drove with my Opel to Landbouw-Economisch Instituut LEI in the Hague to make a study on the impacts of the Common Agricultural Policy of the EC on the agriculture and agricultural policies of the Scandinavian countries. Three months, 100 pages, they said. I had no idea of the topic to be studied. After six weeks Associate Director of the Department of General Economics Dirk Strijker had a look at my draft report. He said: 'You have written what you happen to know and not what was to be studied'. Target: trash can. New report in six weeks. Roger that. It became my first Master's thesis. And Dirk became the opponent in my first dissertation 23 years after that visit. During that visit I learned to answer to the research questions. I have many Dutch friends. Luckily, they all belong to a head-on nation, but they won't bite.

After the intensive base training period, I could lurk in the shadows of the House of Sciences for quite a long time. Projects after projects, more than a hundred. Topics come and go. Time passes. I probably got quite bored with making research proposals, promising a lot to get little money and then trying to complete what was promised. Then a second internationalisation era in my life started with new EU Horizon projects. The first era took place in the 1990s along the Finnish EU accession and expert duties around that.

Along with the new projects I was able to hire new people. I hired a young lady from Oulu, Belyta Tembo. In a few years, she has grown into a skilful researcher that can handle anything. I have been so lucky.

I have had the opportunity to live in several parallel worlds. I certainly would have stopped making research a long time ago without that opportunity. I have three important tribes, communities or families.

The first of these clans is the Finland Futures Research Centre (FFRC) staff. FFRC-family is an extraordinary population. It would survive in Mars with zero oxygen since it survives and flourishes in research business with zero basic funding for research. And still, it is one of the largest academic futures research organisations on Planet Earth. Top performance with zero support by the university. These strange people give a lot of energy and inspiration for anyone who happens to join the family. So proud of these aliens! Amos Taylor, part of the family, kindly made the language written by a Savo-man understandable to an Englishman (also outside New York, ref. Sting).

The second clan is comprised of international mates and colleagues. They have been onboard throughout my research career. When the small circles in Finland have turned smaller and smaller, when only finetuning of the existing has been accepted and when 'diversity' and 'alternatives' have been dirty words, this open-minded and positive community has provided me fresh air. Thank you, Louise, Maura, Aisling, Michelle, Victor, Beatrice, Jaap, Dirk, Ida, Willem, Gerdy, Silvia, Annamaria, Domenico, Milada, Jan, Imre, Boldizsár, Barbara, Sara, Irma, Annie, Anna, Kati, Florian, Natalia, Guillaume, Hilde, Jostein, Jenni, Claudia, Frederike and others.

Then were have this Vesanto tribe. I have lived my whole life with this small, vital, happy and mutually supportive tribe. All my role models belong to this tribe. So many shared sorrows and successes. I am never alone. I have made remote work for 35 years to be close to this energising community has keeps on kicking against the will of Helsingin Sanomat and YLE. To name just a few: Ari, Sirpa, Jori, Marianne, Minna, Pia, Petri, Sanna, Janne, Mari, Keijo, Marianna, Arto, Hanna, Suvi, Juha, Pia, Pentti, Anne, Katri, Janne, Tiina, Erkki, Anne, Anna-Maija, Anneli, Timo, Sanna, Emma, Jaana, Marko, Kari, Niko, Juho, Eino, Sisko, Jari, Katja, Ari, Topi, Jarmo, Markku, Päivi, Tukki, VJ, Markku, Antti, Sari, Jarmo, Laura, Jässi, Arto, Anne-Leena, Aarni, Aino Maija and Jukka – my oldest and best friend.

Being 35 years on the road means that you have had a chance to work together and exchange ideas with thousands of people. Without names: Thank You all!

There are still some names I want to mention. Thursday 5th of February 2019 was a cloudy day. We had postgraduate seminar at FFRC in Turku. I presented one of the many versions of my becoming thesis (that eventually had nothing to do with this one). People were struggling to stay awake. After my chatter one of the participants got an idea. I saw a light come on in her years. Marjukka (Parkkinen) said: 'You were presenting something like … hm … they were … something like … design principles'. I remember

nothing but these two words from those seminars. But when I finally sat down to do the job, I remembered her words and made a thesis based on that idea. Thank you, Marjukka!

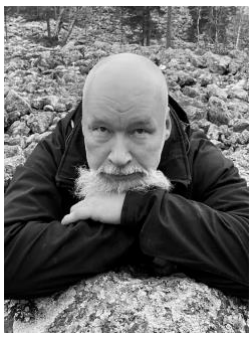
Every creative work – like a dissertation – benefits from inspiring environment and proper facilities. For me they have been the forest and the excavator. Most of the thinking work behind this book was carried out in Caterpillar 312 excavator cabin. I was cutting the trees with Arbro 400S harvester and every now and then stopped to write down some immortal ideas (?) on my phone. So grateful. I would be lost without you two (and your frequent electricity problems that make me feel small, stupid and helpless).

Last but not least. My children Eeva, Iida, Niilo – and Otto that we all miss so much. Many feelings: gratitude, proudness, joy, fun, fear, comfort, laughter and cry. Answering to your endless questions of the planetary system, speed of light, traversable wormholes (ref. Einstein & Rosen 1935), rules of Paskahousu plus other topics have preserved my trust on the future of the Mankind. We are a curious species. We don't have a predetermined destiny. We have agency. We have hope. Let the force be with you and allow you to walk on the sunny side of the ~~street~~ village road!

Contribution of the zoo (currently Santtu, Helmi, Helka, Kaapo, Sisu and the sheep) has not been anecdotal, either.

Vesanto, 6th of September 2025

Tuomas Kuhmonen



TUOMAS KUHMONEN

Tuomas Kuhmonen is Research Director at Finland Futures Research Centre, University of Turku. He is permanently placed in Vesanto, Savo. He has been Professor of Entrepreneurship at the University of Jyväskylä and Professor of Agricultural Policy at the University of Helsinki. He has recently struggled with evolutionary epistemology, heuristics in complex systems, socio-economic transformations and alternative futures of food systems and rural areas.

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List of original publications

This dissertation includes six original research articles, which are referred to in the text by their Roman numerals:

I Kuhmonen, T. & Kuhmonen, I. 2015. Rural futures in developed economies: The case of Finland. *Technological Forecasting and Social Change* 101, 366–374.

II Kuhmonen, T., Kuhmonen, I. & Luoto, L. 2016. How do rural areas profile in the futures dreams by the Finnish youth? *Journal of Rural Studies* 44, 89–100.

III Kuhmonen, T. 2017. Exposing the attractors of evolving complex adaptive systems by utilising futures images: Milestones of the food sustainability journey. *Technological Forecasting and Social Change* 114, 214–225.

IV Kuhmonen, T. 2018. Systems view of future of wicked problems to be addressed by the Common Agricultural Policy. *Land Use Policy* 77, 683–695.

V Kuhmonen, I. & Kuhmonen, T. 2023. Transitions through the dynamics of adaptive cycles: evolution of the Finnish agrifood system. *Agricultural Systems* 206, 103604.

VI Kuhmonen, T., Kuhmonen, I. & Huuskonen, A. 2024. Sustainability-driven regime shifts in Complex Adaptive Systems: The case of animal production and food system. *Sustainable Production and Consumption* 52, 469–486.

Contributions of the authors to the research articles

Article	Research idea	Research design	Empirical research	Writing the manuscript	Editing the manuscript
I	TK, IK	TK	TK, IK	TK	TK, IK
II	TK	TK	TK, LL, IK	TK	TK, IK, LL
III	TK	TK	TK	TK	TK
IV	TK	TK	TK	TK	TK
V	IK, TK	IK, TK	TK, IK	IK, TK	IK, TK
VI	AH, TK	TK, AH, IK	TK, IK	TK	TK, IK, AH

TK = Tuomas Kuhmonen
IK = Irene Kuhmonen
LL = Liisa Luoto
AH = Arto Huuskonen

1 Introduction

1.1 Multiverse of alternative futures as a study object

Futures involving human action are open (Bell 1997, 151):

> 'The future is a domain of liberty not simply because we cannot know the future in any certain sense. It is also because the future itself is contingent, not only our knowing of it. What will happen depends on many things, including what we ourselves choose to do.'

This means that in any field of societal activity there exists a multiverse of alternative futures. The more complex the system, the more alternative future states it can potentially take. Societies are by far the most complex human systems (Ball 2012). In order to exist, these human systems have to be deeply intertwined with various biophysical systems, which adds complexity. Furthermore, societies are comprised of several subsystems, for example food, energy, mobility, manufacturing, settlement and decision-making systems. All these systems have many levels, often referred as macro, meso and micro levels (e.g. Dopfer et al. 2004, 277; Geels 2002, 1261). These features put a challenge for describing, analysing and anticipating their evolution in time. These challenges are discussed in this study.

Various stakeholders have different political, business or personal interests to anticipate the futures of societal systems. All choices and decisions made in the present will materialise in the future (Rescher 1995, 5–6). Proposed by Richard Slaughter (1993, 290), futures research serves the interest of becoming aware of future alternatives. He details his position as follows:

> 'To the extent that we become aware of different future alternatives, we gain access to new choices in the present. If we become aware of something we want to avoid we can take appropriate action. Similarly, if we can imagine something we want to create, we can set in motion the means to create it.'

Studying alternative futures may indeed be comprehended as a process of becoming aware of future alternatives. Usefulness of this 'unended quest' (Popper 1992) is evident in serving informed choices, but the quest is complicated by at least two serious

epistemological grievances. The first epistemological grievance is related to the position where all knowledge about the future is conjectural (de Jouvenel 1967, 17). As there is no data from the future, the truth-value of the conjectures remains 'epistemically inaccessible' (Barnes & Cameron 2009, 298) even if truth claims were made (Bergman et al. 2010). The conjectures or cues lacking accessible and verifiable truth-values (Niiniluoto 2001, 372) resemble Kant's 'synthetical propositions á priori' that are employed to 'widen the range of our á priori knowledge' (Kant 2003, 11).

Apparently, the progress of futures science does not come with the adoption of methodological falsificationism of conjectures and refutations (Lakatos 1970; Popper 1963). While the truth-value of empirical manifestations of societal futures is anecdotal, the progress of futures science may relate to the usefulness of the conjectures in widening our á priori knowledge as such and to increased meta-level understanding about how societies and societal systems might evolve over time. On this mission we need to exceed the limits of historical evidence, experience and elucidation (Ulrich 1983). Looking the other way around, if the conjectural nature of futures knowledge was not observed, overconfidence on evident or established 'truths' becomes a risk as even extrapolation of the most familiar megatrend is a conjecture: tomorrow the world may be different. In the futures field, external validity (Calder et al. 1982) of the conjectures is of less importance than their feasibility in the service of becoming aware of future possibilities and options for choices.

The second grievance is related to the bewildering array of possible future states and evolutionary pathways of various societal systems. It is not about becoming aware of five alternatives; it is about becoming aware of basically infinite number of alternatives – or at least, say, "5,000". This is due to the essence of many societal systems being Complex Adaptive Systems (CAS). In general, these kinds of systems lack central command, and they host emergence and self-organisation through non-linear and heterogenous local interactions (Byrne and Gallaghan 2014; Gerrits 2012; Kauffman 1993; Room 2011).

These systems are not chaotic but organised by various kinds of attractors – preferences, values, habits, routines, norms, power bases, technologies – that limit their possibility space as well as define their trajectories and configurations (Gerrits 2012, 157; Kauffman 1993, 174; Room 2011, 130). Nobody owns the Finnish food system and thus no one can dictate or define its future, but still some forces configure its evolution as 'alternative futures do not just "happen"' (Kuhmonen and Kuhmonen 2015, 366). Becoming truly aware of the future possibilities of these kinds of complex systems asks for covering the extensive state space with both holistic and reductionistic mindsets: how to observe "5,000" and come up with, say, "five"?

Envisioning the alternative futures of CAS essentially implies analysis of evolutionary processes of complex systems. The fitness landscape testing the prospects of their survival and success may be rugged and contain several "good" configurations (McCarthy 2004). As a result, a similar business or activity may possess diverse chances for survival and success in different parts of the system turning search for "optimum" or "maximum" an odyssey. Diversity is an inherent element of CAS and that makes derivation of one possible, preferable or probable future for the system surreal. Diversity may also be vital for the system to maintain functionality (Jen 2005, 11; Page 2011, 13).

In addition, complex systems also contain several loosely coupled sub-systems and hierarchical layers (Allen 2005, 452; Safarzynska et al. 2012). These characteristics explain for example why such a rich variety of agrifood subsystems and practices flourish within the European single market: what are the preferences and the practices that prevail in France are not the ones that prevail in Finland despite of the common market. Preferences and practices are examples of attractors that configure CAS (Kauffman 1993, 177–178; Room 2011, 132–133). The setting also explains why studying the future alternatives of any CAS is so complicated. Predictability of such complex system is low (Allen 1994) as everything is multi-level and interconnected, attractors may change and local contexts matter. Numerous alternative elements, configurations and possible pathways of the system makes "becoming aware" of alternative future states a burdensome task.

In the enterprise of trying to grasp the multiverse of options, incompleteness errors ('too few'; Smithson 1985), irrelevance errors ('wrong ones'; Smithson 1985), anchoring errors to the past (Harvey 2007; Robinson 1982; Tversky and Kahneman 1974) as well as attribution errors (obvious, popular or motivated rather than balanced causes; Goodwin and Wright 2010) all lurk in the shadows. Moreover, desirability biases (dominance of positive aspects; Ecken et al. 2011), availability biases (dominance of common and easily available reasons and outcomes; Dubé-Rioux and Russo 1988) as well as narrative biases (dominance of established ploys and narratives; Vervoort 2014) hide in corners. Observing the state space of future alternatives without too many biases is important as otherwise we observe just the few relevant, past-based, popular, positive, easily accessible and established alternatives. And still, we can't work with "5,000" future alternatives.

Disregarding the two grievances, generation of the future alternatives is not a problem as such. There are plentiful methods for extracting the five or so alternatives. Manifestations of alternative futures take most often the form of explorative scenarios or futures images or normative visions (Bell 1997; Bishop et al. 2007; De Smedt et al. 2013; Dreborg 1996; van der Helm 2009; van Notten et al. 2003; Vásquez 1999). They detail various future states of the systems (visions, images) and possibly alternative

paths between the present and the future (forecasting scenarios) or the future and the present (backcasting scenarios). In the futures research toolbox, there is a wide variety of methods for creating or co-creating these manifestations: Delphi (Linstone and Turoff 1975, 2011; Tapio 2002), Cross-impact analysis (Gordon 2021), Trend analysis (Ansoff 1975; Kuosa 2011), Scenario techniques (Bradfield et al. 2005), Futures workshops (Jungk and Müllert 1987; Lauttamäki 2016), Futures wheel (Glenn 1972), Morphological analysis (Ritchey 2011), Soft systems methodology (Checkland 2000), Gaming (Aguilar-Milan 2019), Personal futures (Wheelwright 2005, 2009) and Causal layered analysis (Inayatullah 1998) to name but a few. Application of the rich toolbox into empirical cases has contributed to a thickening stock of manifestations of future possibilities in various contexts. But how to bridge the present reality and the alternative futures in a meaningful way, observing the epistemological grievances?

To serve choices in the present, the possibility space must be delimited radically in a way that still serves "adequate" awareness of the diversity of possibilities but at the same time avoids radical reductionism sometimes prevailing in natural sciences and economics (Checkland 2000, 12). Solving this dilemma asks for a wider perspective than just a method. This wider perspective could be opened up through specification and application of design principles for the alternative futures. Design principles feature generic principles of creating manifestations of alternative futures on the frontier of diversity and confinement. The futures of complex adaptive societal systems contain often economic, social, environmental, cultural, technological, institutional, behavioural and/or biophysical elements asking for a multidisciplinary approach as a starting point. Design principles may encourage the marriage of design science, systems science, futures science and other disciplines. Such a marriage is needed to make meaningful and useful contributions to become aware of the alternative futures of CAS.

First of all, the design principles may provide answers to the most basic questions: how to capture "5,000" alternatives with few designs in a meaningful way; how to deal with an appropriate level of abstraction; how to identify potential new attractors for the CAS? All these questions highlight the importance of metalevel reflection and discussion while exercising the unended quest of becoming aware of the future alternatives. This is where the design principles may play a role. Considering futures research as a design science rather than as a forecasting science or a confirmatory science provides some antidotes for the two epistemological grievances as well (Bell 1997, 90; Niiniluoto 2001, 376). Forecasting science and confirmatory science would both ask for validity of mirroring the past that is not plausible with open futures, or epistemological accessibility to the future that does not exist.

To reach the noble end of becoming aware of the multiverse of future alternatives, the mission of academic futures research could be 1) transparent, 2) disciplined and 3) systematic design and assessment of alternative futures. Equipped with the task of

hammering manifestations of the alternative futures, futures research is genuinely a design and evaluation science that should observe the three demands of being transparent, disciplined and systematic. The three qualities are necessary qualities of a research enterprise working at the edge of holism and reductionism, existing and non-existing, known and unknown.

Taking stock of the first one of the qualities, transparency is needed as there is no specific theory about futures, but rather a mix of theories, models, analytical frameworks and conceptual repertoires (Minkkinen 2020). For this reason, all futures studies are driven by disparate research questions, analytical frameworks, local theories and methods dictated by the research mission. As futures research cannot present verifiable conjectures or cues about the future, it has to expose the research process rather than the results for external assessment and criticism. In order to maintain credibility in the absence of a firm universal theoretical background, transparency in terms of paradigms, approaches, perspectives, methods and origins of the cues and conjectures is necessary (Kuusi et al. 2015; Piirainen et al. 2012; Schüll and Gerhold 2022; Van der Steen and Van der Duin 2012). Transparency exposes steps of the dance on the verge between holism and reductionism.

Disciplined imagination (Weick 1989) is needed as societal futures are not mirrors of the past. Mannermaa (1991, 358) argues:

> '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.'

Forecasts based on the past or existing behaviours and structures may be unproductive in the face of bifurcation. Such deterministic approaches possess limited potentials to cover most societal futures in terms of bifurcations and their descendants. If the future was like past there would be no need for a futures science. As it is not like the past, the reasons, processes and outcomes of deviant developments are in the core of futures research. Such deviant worlds exist only in the minds of people. Teasing them out asks for exercising disciplined imagination. Amara (1991, 646) calls this premise 'the art of the possible' whereas de Jouvenel (1967, 17) calls it just 'work of art'. Disciplined imagination may keep both holism and confinement alive in the research act.

A systematic approach is needed to cope with the multitude of options that may deceive the interested mind (Slaughter 1993; Vasileiadou and Safarzynska 2010). Without a systematic approach, whatsoever futures could be imagined. While designing alternative futures, causal ambiguity prevails: a certain state of the future

may be attributed to several alternative drivers, or a certain driver may effectuate several alternative future states. In the futures field, causal ambiguity is intimately related to contextual ambiguity. Contextual ambiguity prevails when the relationship between drivers and futures states varies according to the context. Specific contexts may host specific selection environments, each of which organises the drivers and the outcomes in a specific way. Ambiguity, however, may also serve as a futures research method as laws of the past do not necessarily apply in the future. Whatsoever futures are being studied to become aware of the alternatives, the alternatives need to be selected, analysed and assessed in a systematic way to observe the challenge of ambiguity. A systematic approach allows confinement to be included in an appropriate role within the scientific quest.

Putting together, comprehending the mission of futures research as transparent, disciplined and systematic design and assessment of alternative futures – may also help to overcome some of the key challenges in describing, analysing and anticipating alternative futures of CAS. The key challenges are related to the delimitation of the choice space in a meaningful way ("five" instead of "5,000" to serve choices for the future in the present); to the iteration of an appropriate level of abstraction (to cover an appropriate territory of possible futures at the frontier of diversity and confinement); and to the identification of new attractors of the CAS (to expose avenues for novelty and change). These challenges may be alleviated by adoption of relevant design principles of alternative futures.

Observing the key challenges, the design principles of alternative futures may play a role on two stages. The first stage is set by the research mission intervening futures of societal systems. Whether the mission is related to bifurcation points (Mannermaa 1991, 364–366) or crucial epochs (Laszlo 1985, 17) or to the more stable periods following those, has crucial impacts on the choice of analytical frameworks, models, concepts and methods. The second stage is set by the research topic. Characteristics of the research topics have impacts on the scope, content, quality and importance of various drivers, elements, ploys, levels and patterns of alternative futures. Studying global, national or local systems as well as studying food, energy or mobility systems ask for different emphasis of the previous aspects. Putting explicit design principles in between the research mission and the research topic may add credibility to the research act, as well as serve the appropriate choices of theories, analytical frameworks and empirical methods.

1.2 The research task, questions and strategy as well as structure of the study

This study discusses alternative futures of Complex Adaptive Systems (CAS) featuring many important societal systems. Characteristics of these systems pose several and severe challenges for studying their futures. Observing these challenges, the selection of approaches, analytical frameworks, concepts and methods for empirical inquiries may be facilitated by design principles. Design principles of alternative futures of CAS are elaborated and illustrated in this study.

The straightforward research questions are 1) how to choose an appropriate level of abstraction to study alternative futures of societal complex adaptive systems, 2) how to delimit the choice space and 3) how to identify future attractors for the systems. Six empirical studies illustrate application of the design principles in the domains of rural areas, agriculture and food (Table 1). Each of the six studies hosts also specific topics, methods and data. In all cases, possible futures are studied, in some cases also probable or preferable futures.

The research strategy to answer the research questions is provided in Figure 1. The research process starts with an elaboration of the conceptual framework featuring an introduction of CAS, derivation of contributions from evolutionary and complexity sciences and an introduction of the regime concept. After this, the analytical framework is developed including refinement of the design principles. The third step involves six empirical inquiries into rural and agrifood contexts manifesting spatial, personal, system, policy and sector perspectives on CAS futures. This diversity is necessary to properly answer the research questions. Next, the results will be presented both in terms of application of the design principles and empirical findings of the studies while studying CAS futures: systemicity, framing effects and multiplicity of attractors. Finally, contributions for science, practice and further research will be discussed.

Table 1. Characteristics of the empirical studies.

Article	Topic	Domain	Futures	Methods	Data
I Technological Forecasting and Social Change 2015	Rural areas	Spatial futures	Possible and probable futures	Content analysis, futures workshops, futures tables	Literature, workshops
II Journal of Rural Studies 2016	Futures dreams of young people	Personal futures	Possible and desirable futures	Content analysis	Literature, survey
III Technological Forecasting and Social Change 2017	Food system	System futures	Possible and desirable futures	Content analysis	Literature, workshops
IV Land Use Policy 2018	Common Agricultural Policy	Policy futures	Possible futures	Content analysis, Causal Loop Diagrams	Literature, survey
V Agricultural Systems 2023	Food system	System evolution	Possible futures	Thematic analysis	Literature
VI Sustainable Production and Consumption 2024	Animal production, food system	Sector futures	Possible futures	Causal Loop Diagrams, Content analysis, Multi-Level Perspective	Literature, interviews

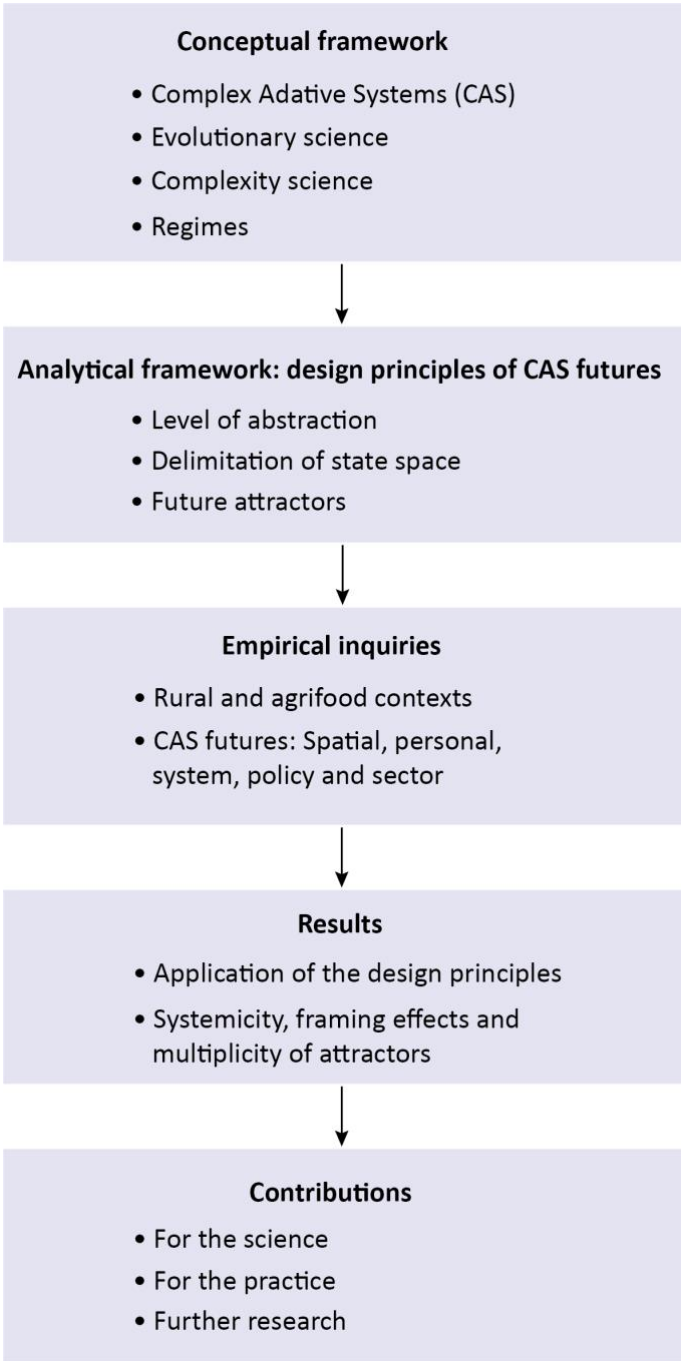


Figure 1. Research strategy.

The structure of the study is as follows. Contexts of the empirical inquiries will be introduced first in Chapter 1.3. Chapter 2 presents some theoretical and conceptual underpinnings to assist and to frame the foresight and design mission of Complex Adaptive Systems: cyclical pattern of their evolution, qualities of the state space that they occupy as well as regimes and regime shifts that shape their evolution. Chapter 3 illustrates the methodological approaches that were used to iterate an appropriate level of abstraction, to delimit the state space and to identify future basins and attractors. Empirical findings of the research articles are presented in Chapter 4. Finally, discussion and reflection of the study is presented in Chapter 5.

1.3 Introducing the contexts of empirical analyses

Our societies are made of Complex Adaptive Systems (CAS) that are nested cohesive wholes serving specific goals and containing heterogenous elements within their boundaries (Ackoff 1999; Meadows 2008). Such systems reside in all parts of the society in varying scales, scopes and contents. In empirical inquiries, definition of the system boundary is often pragmatic and depend on the research question. This study investigates societal systems that deal with rural areas, agriculture and food. A specific rural area is a CAS as also any regional, national or global food system.

Rural areas

Rural areas can be defined and described from several perspectives emphasising spatial characteristics, resource endowments, settlement structures, demographics, economic structures, cultures or targeted policies (e.g. Terluin 2001). These have laid foundations to various spatial typologies to master the huge diversity of places (e.g. Eurostat 2018; Newsham and Rowe 2022; OECD 2011; Stjernberg 2024). Each approach will bring about a specific definition and profile for "rural". Therefore, beyond synthetical typologies, a pragmatic and contextual rather than universal and stable definition of 'rural' predominates scientific and political inquiries and interventions. This setting derives from the spatial and functional diversity (Verburg et al. 2010, 217–218): 'The same driving factors may lead to a different result at different locations as a consequence of a different context and different location characteristics'. Causal and contextual ambiguity prevails in rural development.

Still, there are some common features in many conceptions of rural areas. First, they tend to be contrasted to urban areas, and in this setting, they are characterised by low(er) population density and 'strong natural resource reliance' (Dax and Fischer 2017, 298). Rural areas of many developed economies share a common historical storyline for the last century: mechanisation and increase of labour productivity in farming, release of rural labour to growing cities (outmigration), diversification of the national

economy, increased welfare, servisification of the economy and concentration of the settlements (Kuhmonen and Niittykangas 2008; Symes and Jansen 1994; van der Ploeg and Long 1994; Figure 2). As a result, rural people and rural businesses have turned into minorities in developed societies. The role of rural areas in these societies has evolved from the source of labour-force and raw materials to a source of raw materials and well-being (Kuhmonen 2015).

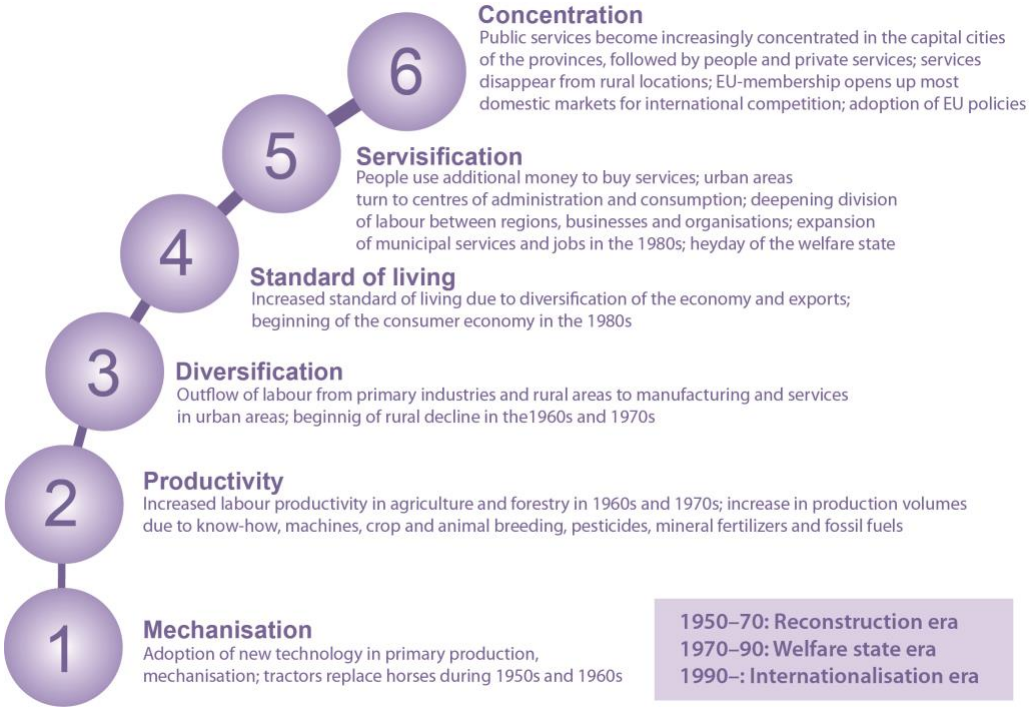


Figure 2. Recent evolution of rural areas in Finland. Source: Adapted from Kuhmonen 2015.

Turning to rural Finland, it is quite an extreme case among developed economies. Most part of the country is covered by sparsely populated rural areas (Figure 3). About 20% of the area is north of the Polar Circle and 168,000 lakes comprise about 10% of the total area. There are half a million summer cottages, often at the lakeside. Forest land covers 77% of the land area (10–50% in the most continental EU countries) but agricultural land only 8% (40–60% in the most continental EU countries). Despite harsh climate, long distances and low population density, the country has reached a rather high level of income and development (GDP about 40,000 EUR/capita for the last 20 years; Statistics Finland).

Urbanisation took place in Finland quite late compared to many European countries. Still, urbanisation rate of Finland was 86% in 2022 (World Bank) and rapid release of labour from rural to urban areas has implied extensive restructuring of the economy and society (Vartiainen 2006). Many rural inhabitants have seen closure of the local services and deterioration of the infrastructure in face of population loss. Asymmetry of development between rural and urban areas has had many causes and consequences. Concentrations of population have been born on places where land could be easily taken into cultivation and that were accessible through water routes (in south-western parts of the country and main inland waters). Concentration has been also a public policy choice and despite of rural and agricultural subsidies, a vast majority of the state budget and public procurement money flows to the cities (Makkonen et al. 2023; Moisio and Sirviö 2021). Most of the rural spending is preservative money to upkeep existing structures and practices and the regenerative or creative money goes for the urban destinations and actors (Lehtonen 2023; Makkonen et al. 2025). 'Rural areas and smaller urban centres have been difficult to incorporate in policymaking, which takes its inspiration from the idea of innovation-led growth' (Moisio 2018, 157). As a result, rural actors have found it difficult to catch up and establish new roles in the Finnish society.

Rural policy in Finland has two tracks (Kattilakoski et al. 2022). The "narrow" rural policy includes targeted finance to different types of rural areas and activities (e.g. EU funds, Leader, municipal programmes, village action) whereas the "broad" rural policy includes coordination of all other general level policies with rural impacts but without targeted funding (e.g. social and health policy, environmental policy, climate policy). Despite the long-standing place-based approach in rural policy, the policy has not managed to reverse rural decline.

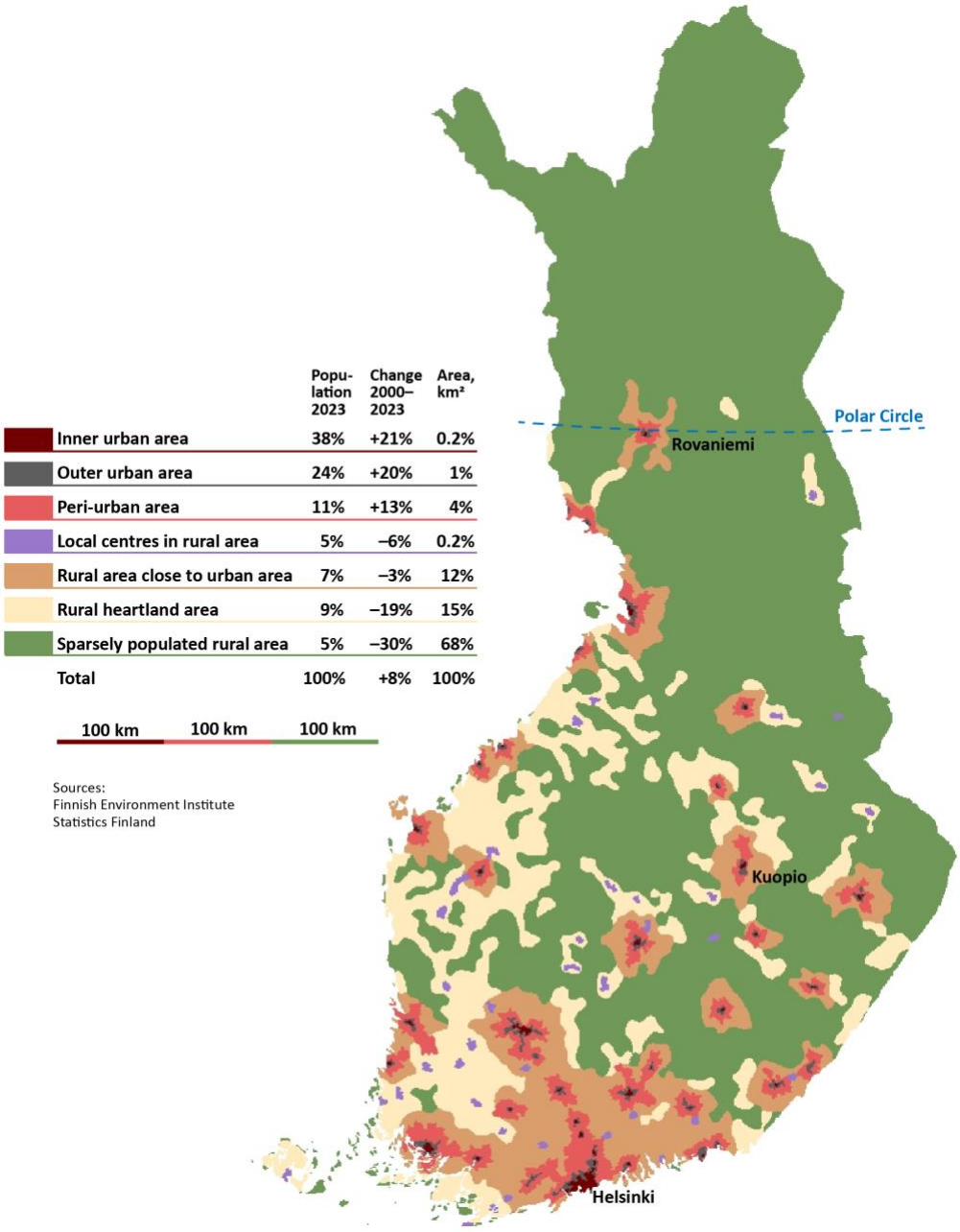


Figure 3. Rural Finland.

Agriculture and food

Agrifood systems exist to provide nutrition to the people who depend on them (Kuhmonen 2023). Technology, know-how, international trade and the steadily growing demand for the food have been important drivers for the long-term evolution of both agriculture and the food systems (Béné et al. 2019; FAO 1968, 1974). Novel and more efficient ways to exploit the natural resources have secured food supply to growing populations. Consequently, dominant narratives for farming and food relate to standardisation, technology, profit and growth (Giampietro 2023; Loring 2023; Thompson et al. 2007).

This has not come without externalities: pollution, eutrophication of waters, erosion and acceleration of climate change etc. that can be considered as hidden costs (FAO 2023). Agriculture has also positive externalities or hidden benefits: food security, landscape aesthetics, agrobiodiversity etc. (FAO 2002, 2023; Skolrud et al. 2020). Notwithstanding this, agriculture and the food system are subject to many claims for change across the globe, for varying reasons (Béne 2022; Campbell et al. 2017; IPCC 2022; Rikkonen et al. 2024; Tilman et al. 2002). Depending on the scope and scale of interest and investigation, the food system can be described and defined in many ways. Food system is a wider concept than supply chain, as synthesised in Figure 4. This setting adds to the complexity in food and agriculture studies.

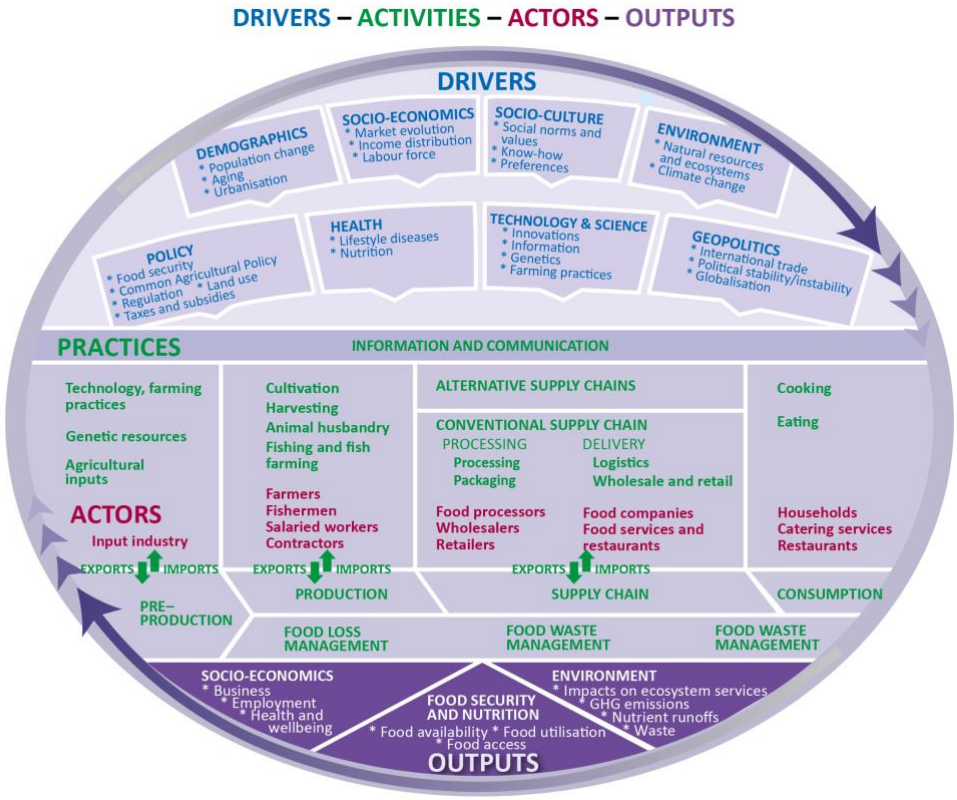


Figure 4. Stylised description of the food system. Source: Adapted from CIAT 2017 and Karttunen et al. 2019.

As long as communities and societies have existed, the food system has been a hot spot of concerted action, intervention, conflict and public policy (Anderson 2010; Halcrow et al. 1994). For more than 100 years, the evolution of food systems in developed economies has been embedded in the fossil economy, besides which specialisation has increased dependence on the system-external resources and actors (Kuhmonen et al. 2023; Pfeiffer 2006). This development has increased vulnerabilities of the local and national food systems even if international trade has also alleviated temporal shortages. Management of complexity is costly, and this has led to specialisation, concentration and homogenisation (Khoury et al. 2014, 4005) of the food regimes.

These developments have facilitated losses of biodiversity and eutrophication of waters along with excess nutrients asked by maintenance of monocultures and regional concentrations of specific types of production (EEA 2022; Huuskonen 2023; Rosenqvist 1997; Schulte-Uebbing and de Vries 2021). Apparently, ‘support for many divergent

trajectories' (Knickel et al. 2017, 575) has been missing in most contemporary food regimes and policies.

While the previous developments can be found in most developed economies, they have been accentuated in Finland for several reasons. Finnish agriculture is operated close to the Polar Circle and for this reason the yields tend to be low and volatile as compared to more favourable areas. In addition, farm structures in Finland have been strongly affected by the resettlement of almost half a million people that came from the lost regions in wars of the 1940s (Granberg 1989; Laitinen 1995; Simonen 1947). They were given land to set up a farm and consequently 100,000 new farms and households were established (Roiko-Jokela 2004, 56; Figure 5). Even if this generation was saved for a life with their small farms, many of the established farms were closed in the great structural turmoil starting soon after (e.g. Karjalainen 2011). Based on the hardships of wartime food shortages, Finland opted for a very strong self-sufficiency policy with extensive subsidies and strict protectionism for decades (Granberg 2004; Ihamuotila 1979; Komiteanmietintö 1987). It was a costly policy for the treasury (subsidies for production and cutting production, export refunds for the surpluses) and for the consumers facing high food prices (Kettunen 1992; Komiteanmietintö 1985; OECD 1989).

It was only EU membership in 1995 that finally resolved the puzzle of conflicting goals. Upon the EU accession, the traditionally strong social dimension in agricultural policy was dismantled and replaced by the environmental dimension (Kuhmonen 1998; Kuhmonen and Aaltonen 1997). Still, the food is cheap (partly due to the subsidies) as consumers need to spend only 14% of their disposable income on food (in 2022; Statistics Finland). For the farmers, however, the cost-price squeeze has not been overcome by the benefits of specialisation and growth: in (2000-2004 average) – (2019-2023 average) the farm businesses grew by 70% but farm income in real terms declined by 14% (own calculations based on Economydoctor 2024). The Finnish retail trade is by far most concentrated in Europe (Kuhmonen 2023) and takes more than its fair share leaving farmers with structural profitability problems.

Figure 5. Recent evolution of agriculture and food system in Finland. Source: Kuhmonen 2014, supplemented by Granberg 1989 and Kettunen 1992.

Ever since 1995, the Finnish agriculture and food system has been part of the EU policies and markets. The accession took place at a stage when the European agrifood policy had evolved from a sectorial policy to a societal policy that better observed socio-economic and environmental aspects and differences among the Member States (Terluin et al. 2017). Interestingly, during the post-war era, the EU policies started with a market and trade focus and evolved toward a social and societal focus, whereas the Finnish policies started the with a social and societal focus and evolved toward a market and trade focus (Figure 6).

Figure 6. Evolution of the Common Agricultural Policy of the European union. Source: Kuhmonen 2018.

Obviously, agriculture and rural areas in Finland – as also in many other developed economies – have faced turbulent times and significant transformations during the last century. This setting will probably continue in the future, and that is why it is important to study alternative agricultural, food and rural futures. It concerns not only climate change but also food security, ethical concerns, loss of agrobiodiversity, concentration of farmland ownership, polarisation of regional development, biased demographics and external threats (e.g. climate refugees, trade wars, natural disasters, geopolitical earthquakes) that require being prepared for the futures that are different from the past.

2 The multiverse of Complex Adaptive Systems as a target of foresight

Societies are comprised of systems: food systems, energy systems, settlement systems, mobility systems, religious systems, political systems, health care systems, education systems, manufacturing systems etc. Societal systems and biophysical systems are interlinked in many ways: systems run by the humans cannot exist without biophysical systems and biophysical systems benefit and suffer from human action (Folke et al. 2007). These kinds of systems are Complex Adaptive Systems, CAS (Bale et al. 2015; Beinhocker 2006; Buckley 2008; Fleming and Sorenson 2001; Khraisha 2020; Levin 1998; Nesheim et al. 2015; Oughton et al. 2018; Saxton & Johns 2009; Thomas and Zaytseva 2016).

Alternative futures of these systems play an important role not only for the design and delivery of societal policies that address societal problems and challenges (Kuhmonen 2018; Laswell 1971) but also for the survival of the mankind (Falkenmark 1977; Meadows et al. 1972). Consequently, they are important targets of foresight and design: how could they evolve, what could be their alternative pathways, which alternative states could they take? Due to self-organisation and emergence hosted by the CAS (Byrne and Callaghan 2014; Holland 1995), the foresight task may appear as mission impossible. No one can foresee what might come up in the innumerable local interactions and which kinds of novelties will emerge, aggregate and institutionalise over time (Holland 1995; Levin 1998). Observed regularities in the evolution of many Complex Adaptive Systems and some of their inherent properties may turn the mission to become possible, however.

Mika Mannermaa captured the cyclical pattern of societal evolution in his evolutionary paradigm for futures research. In his words (1991, 364):

> ‘The development of a society can be described as a process of creative discovery where both stable and chaotic phases play vital roles. Instead of understanding societies in “equilibrium terms” or as “mechanisms” we see a world of incomplete information and changing values, a world where we can meet several different futures, development, turbulence and even catastrophes.’

Mannermaa (1991) made a distinction between the periods of stability and bifurcations. In bifurcations 'small social groups and movements' in the periphery collect steam and take over the stage (ibid., 364). Laszlo (1985) calls this occasion a 'crucial epoch'. During the periods of stability there is predictability in the development of the society and its systems, whereas upon the 'change into a new dominant systemic state' (ibid., 364) unpredictability prevails: the system and its governance takes a new form (Figure 7). Cycles of stability and change follow each other over time.

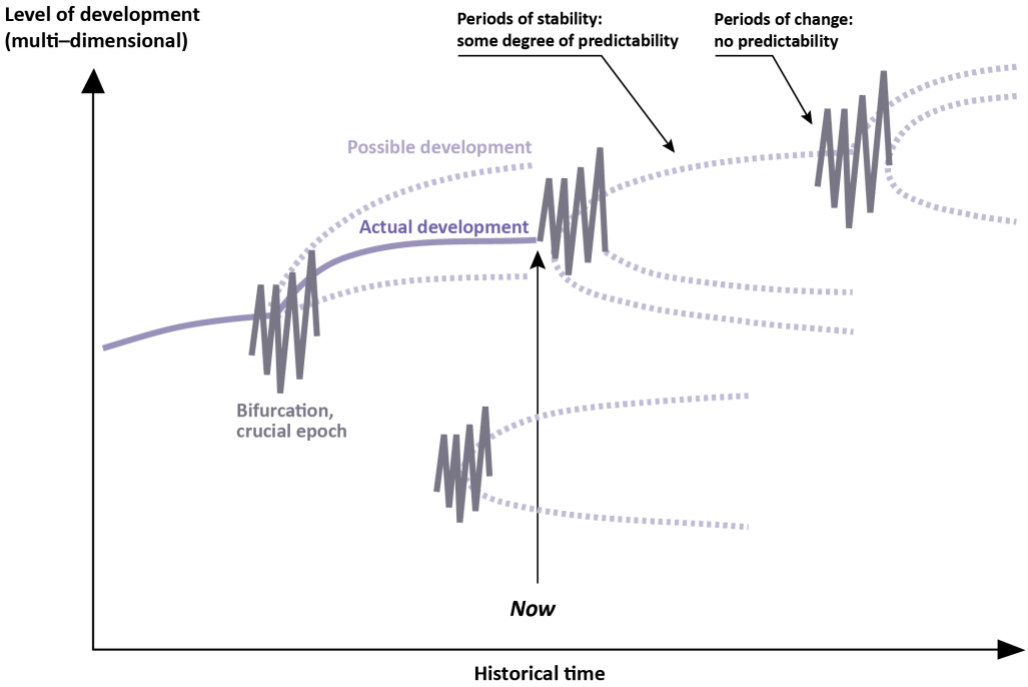


Figure 7. Evolutionary development of societal systems (based on Mannermaa 1991, 365 and Laszlo 1985, 17).

Following this kind of reasoning where evolution of societal systems – that are CAS – exhibit cyclical behaviour, a logical question is where this cyclical pattern derives from? This asks for an investigation of the inherent properties of CAS.

2.1 Cyclical pattern of evolution

CAS tend to follow a cyclical evolutionary pattern of evolution in varying scales (Dangerman and Schellnhuber 2013; Gunderson and Holling 2002; Kuhmonen 2023; Kuhmonen and Kuhmonen 2023; Marcus and Colding 2014; Meuwissen et al. 2019; Parsons 1949; Pearson and Bardsley 2022; Rotmans and Loorbach 2009; Wainstein et

al. 2019). The systems seem to alternate between periods of steady states, equilibria or gradual change, which are interrupted by rapid changes or even quantum changes (Demers 2007; Folke 2006; Gunderson and Holling 2002; Holling 1973; Miller 1982; Miller and Friesen 1984; Mitchell 2009; Prigogine and Stengers 2017; Romanelli and Tushman 1994).

The cyclical pattern of evolution has been furnished with numerous theories and models. In the case of economic systems, Kondratieff cycles feature long-term cyclical evolution of the world economy in which crises and technology driven growth periods alternate (Nefiodow and Nefiodow 2017; Wilenius 2014). In CAS terms, the novel technologies that bring about the new growth after crises form new attractors (Room 2011, 135). Taking a shorter time horizon, Schumpeter's business cycles feature creative destruction in which the old regime becomes obsolete, and new entrepreneurs with their novel ideas and innovations take over the markets 'like a swarm' (Schumpeter 1934, 225). Obviously, the new innovations that come along with the new entrepreneurs are the attractors that reconfigure the economic system (ibid., 66). Various applications of the Adaptive (Renewal) Cycle (AC) model feature an evolutionary pattern of social-ecological systems with four phases: release, reorganisation, exploitation (growth) and conservation to be followed by a next cycle. Panarchy features their hierarchical evolution over the scales (Gunderson and Holling 2022). Cyclical evolution has been observed even in the rise and fall of dynasties, empires, cultures and civilisations (Sztompka 1993; Tainter 1988). At this level of observation, there are many explanations for the cyclical oscillations, including the fact that investments in increasing complexity come with declining marginal returns as just the maintenance of the increasing complexity takes more and more resources (Tainter 1998, 55):

> 'More complex societies are more closely interlinked, with greater mutual influences among parts. Self-sufficiency and autonomy of local systems are reduced as specialization increases. As special-purpose subsystems become increasingly differentiated, stability declines. Disruptions occurring anywhere will be spread everywhere, whereas in less complex settings a society would be cushioned against disruptions by less specialization, less interlinkage among parts, and greater time delays between cause and ultimate outcome. Civilization itself … may be maladaptive.'

All these descriptions, models and explanations of cyclical evolution are relatives to each other. For example, Schumpeter's model of creative destruction can be rewritten in AC language: forces of creative destruction trigger the release phase that breaks apart old institutions and release resources; new actors with their innovations catch up these resources and reconfigure the system in the reorganisation phase; market forces and competition take an increasingly tighter control of the system in the

exploitation/growth phase; finally institutionalised hierarchies, established monopolies and saturated social rigidity govern the conservation phase leading to conflicts, destabilisation and decay that result in a breakdown of the system in the release phase (Folke et al. 2007; Holling and Sanderson 1996; Schumpeter 1950). Many of these accounts put mounting complexity into the spotlight as complicated governance adds costs, rigidities and conflicts and – ultimately – may lead to a crisis and reconfiguration of the system.

Despite their differences, what is remarkable in all these models and their numerous empirical applications is their common message: cyclical evolutionary pattern is an immanent and inherent property of many complex societal systems. 'Cycles are not, like tonsils, separable things that might be treated by themselves, but are, like the beat of a heart, of the essence of the organism that displays them', states Schumpeter (1939, v). 'The long waves arise out of causes which are inherent in the essence of the capitalistic economy', declare Kondratieff and Stolper (1935, 115). The temporal scale in these models is not per se chronological but 'social time' (Sztompka 1993, 41) or 'biological time' (Holling and Gundersen 2002, 35) that record aging, maturation, accumulation and consolidation rather than days or years. Anyway, the pattern is helpful for the foresight mission: being able to identify a current phase of the system makes it possible to anticipate the next one. As crises and reorganisations of the systems create losers and winners, however, such 'revolutions are taken to be unnecessary evils' (Miller 1982, 132) to be avoided rather than studied as inherent properties of many societal systems. For this reason, policies targeted to revolutions are rare even if they would be necessary for systems living in the conservation phase.

Various conceptual models expose some common characteristics of the cyclical evolution of CAS. To start with, the cyclical patterns seem to host several specific phases (Figure 3). These may manifest the interplay of structure and agency (Archer 1995, 2000; Barnes 2000; Bhaskar 1998; Caldwell 2006; Emirbayer and Mische 1998; Giddens 1984; Sayer 2000) – more specifically the sequential interplay of structure and agency (Parker 2000, 115). Along the maturation of the system, various path dependencies and lock-ins may turn the system unresponsive to external demands and internal pressures for change. The latitude for exercising agency for the system agents turns limited as 'the external structure is the principal and the human agency is the subordinate' (Kuhmonen 2010, 31).

A crisis or a release and reorganisation phase will unleash resources, break institutional shackles and open a window of opportunity for new actors to step on the stage and exercise agency with novel ideas, innovations, policies and institutions. In these interplays, structure and agency are married even if analytically separable 'the former being prior to the latter' (Archer 1996, 694). Furthermore, along with this alternation of power bases between structure and agency, also diversity residing within the system

and degree of centralisation of the system may exhibit cyclical behaviour. Diversity and decentralisation flourish in young systems but become reverted along with the maturation of the systems. Various interpretations of the phases of the cyclical behaviour are presented in Figure 8.

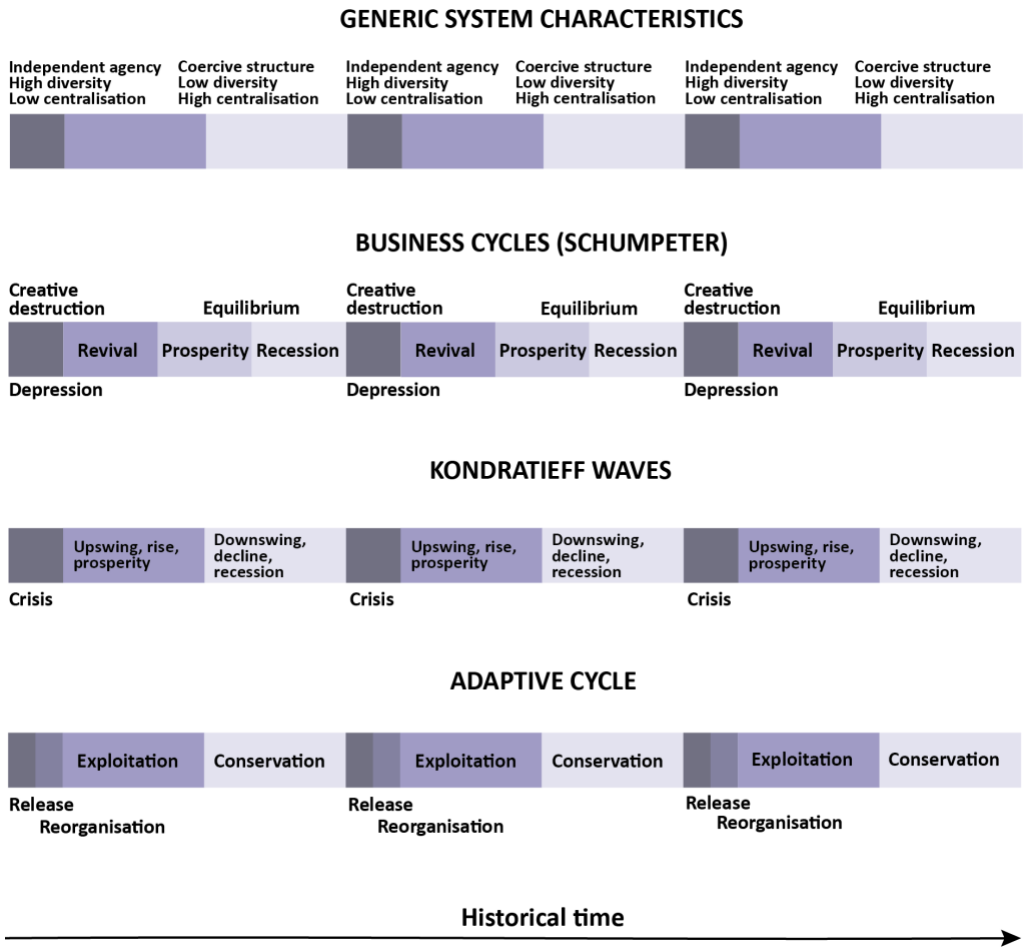


Figure 8. Cyclical pattern of evolution in societal systems: generic characteristics (own elaboration) and three conceptual models synthesised and adapted from Gunderson and Holling (2002), Kondratieff and Stolper (1935) and Schumpeter (1935).

While pattern explanation for the cyclical evolutionary pattern of many societal systems may be adequate as such for anticipating a bifurcation and subsequent reorganisation of the system, it is still useful to take stock on the logics and concepts that go beyond observed patterns.

2.2 Stability of CAS as framed by the complexity science

Complexity science provides reasons for the cyclical evolution of Complex Adaptive Systems. During periods of stability, the system lives in a basin of attraction, in a 'bowl' (Holling 1973, 20). In these times the system maintains its identity and essentials characteristics. While a state phase or phase state of the system represents all possible states of the system in terms of parameters manifesting the fundamental properties of the system as a whole (Byrne and Callaghan 2000, 26–27), the basin of attraction sets boundaries for these parameters and constitute 'a watershed which drains toward a given attractor' (Room 2011, 130). Kauffmann (1993, 176) explains further:

> 'The idea of basins of attraction and steady-state point attractors is essentially the same as the idea of mountainous region with hills, ridges, valleys, lakes, and a water-drainage system. Lakes correspond to point attractors; drain age basins, to the basin of attraction. Just as a mountainous region may have many lakes and drainage basins, so may a dynamical system have many attractors, each draining its own basin. Therefore, it is natural to conceive of the state space as being partitioned into disjoint basins of attraction. When released from the initial state, the dynamical system is on the trajectory lying in only one basin, and the system flows to that basin's attractor. This restriction means that each disjoint basin leads to only one attractor and thus that the different attractors constitute the total number of alternative long-term behaviors of the system.'

If a societal system has only one or very few alternative attractors in the horizon, it consequently has a small number of 'alternative long-term behaviours' (ibid.). In societal systems, the basin of attraction may be comprised of several intertwined attractors forming a power field or a "source of gravity". Systems are dynamically stable and can evolve within the limits set by the 'bowl' while being driven by its attractors. An effective basin of attraction has an established history since institutionalisation of such a power base takes time. In essence, the state space with various basins of attraction can serve as a map featuring not only potential for future alternatives but also the degree of institutionalisation and structuration (Boulton et al. 2015, 76):

> 'The qualities of an attractor basin capture, in a sense, the history, the path dependence of the market, ecology, or society in question. They show what relationships have 'locked-in', those which have become instituted. The map of state space with its attractor basins, separations between basins, and areas of turbulence and chaos represents the starting point, the map that informs considerations of what might be well established, and what might be less stable and more prone to change.'

The existence of an effective basin of attraction means that the system is destined to one particular basin at a time but may occasionally swap attractors and take a new trajectory. Notwithstanding this situational and contextual setting, societal systems often have many alternative basins of attraction, many alternative trajectories and positions in the state space and – consequently – many alternative futures as observed in the "epistemological guidebook" of futures research (ref. open futures) that could be captured by some kinds of futures maps (Kuusi et al. 2015). Small basins may be embedded in larger basins and form sub-populations. The basin concept has also its limitations, however (Anderies et al. 2023, 10):

> 'A basin of attraction notion of resilience is not particularly useful in analyzing world-earth systems for two reasons: (1) because there may exist very resilient basins that humanity cannot thrive in, and (2) transient pathways to desirable basins may be very difficult to navigate.'

Indeed, currently observable effective basin that does not necessarily equate with an optimal or desirable basin. Nevertheless, basins of attraction host effective attractors that configure the systems and their dynamics with their "gravity fields". These fields may be visualised as "mountains" and "valleys" representing their gravitational force. Following this idea, Figure 9 represents 'attractor landscape' (Hooker 2011, 24). Basins of attraction are manifestations of the sphere of influence of the attractors they host (DeLanda 2005, 14). Attractors themselves 'are a diverse group of topographies, mappings, routes, regularities, successful outcomes, capabilities, knowledge forces and powers that pattern complexity' (Smith and Jenks 2006, 12–13). During periods of dynamical stability, societal systems are kept in the "bowls" or "valleys" by the gravitational force of institutionalised attractors.

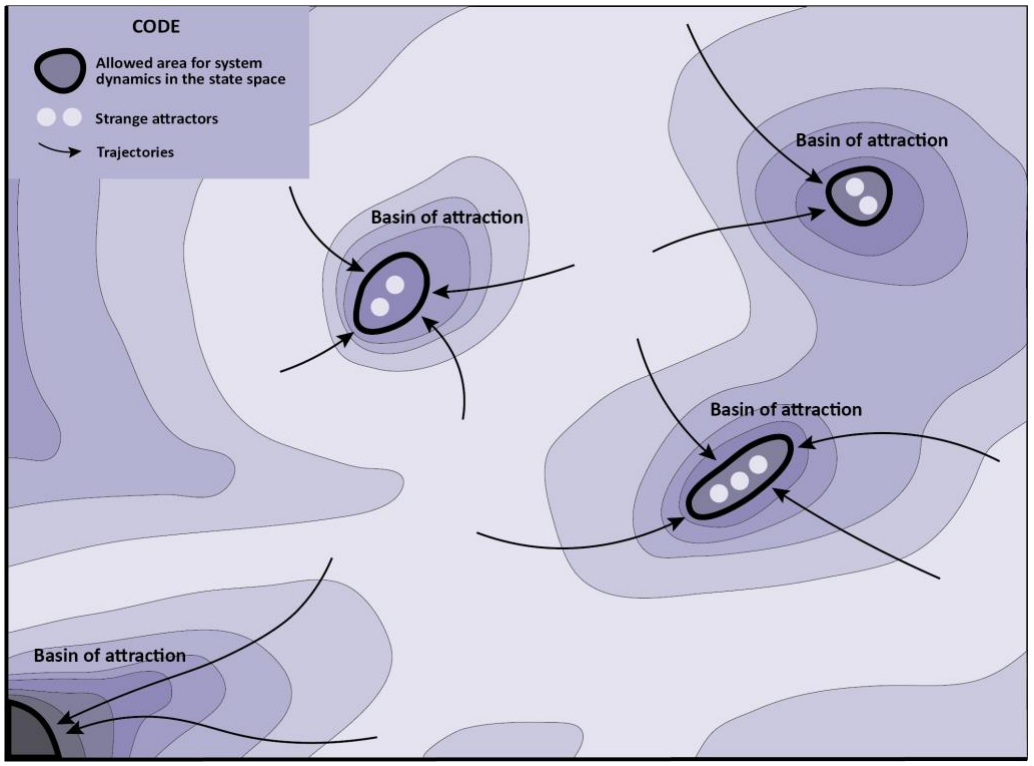


Figure 9. Basins of attraction and attractors.

Qualities of the attractors play a role in organising the systems. Attractors can be simple or strange (Kauffman 1993, 177–178; Room 1991, 132–133). Most simple point attractors may lead to one predictable steady state or equilibrium state of the system 'in which nothing exciting can happen any longer' (Popper 1956, 173), whereas more complex attractors and especially strange attractors have more unimaginable features.

First, strange attractors may organise divergent trajectories as 'tiny differences in initial conditions make vast differences in the subsequent behavior of the system' (Kauffman 1993, 178). To illustrate the phenomenon, the highly institutionalised Common Agricultural Policy of the EU creates a magnetic field for the European agriculture around specific attractors deriving from common markets, subsidies and regulations. Still, the agricultural sectors among the member states exhibit huge differences even after 60 years of common policy. This is due to the differences in the initial conditions among the member states including e.g. biophysical conditions, farm structures, tenancy traditions and food cultures. To be successful in the foresight endeavour for CAS, observation of the initial conditions or the structure may be useful: entities having different initial conditions may not reach the same destination after 30 from now.

Second, strange attractors may have very few dimensions even in a very multidimensional state space. Subsequently, behaviour of the system is boxed in a very small, limited state space even if the state space itself was '100-dimensional' (Kauffman 1993, 178). The attractors can also be comprised of fuzzy sets (Byrne and Callaghan 2015, 73) which may add to the internal dimensionality of them. To illustrate the setting, trajectory of the European agriculture during the last decades has been boxed by fossil economy, specialisation, intensification and economies of scale (Billen et al. 2021; Jepsen et al. 2015; Levers et al. 2016; Zakrzewska and Nowak 2022). This setting has left a large part of the possible state space unoccupied – more extensive occupation of the state space has been promoted mainly by NGOs and agroecologists (NGOs 2018; van der Ploeg et al. 2019). To be successful in the foresight endeavour for CAS, a scientist should come up with few limited "boxes" in the state space rather than extensive fields since CAS reside in small worlds. This is a major challenge.

Coming back to the world of the empirical to illustrate the concepts, scientists have identified and proposed many kinds of existing and possible attractors for societal and agrifood systems in varying scales: global capitalism (Lawrence et al. 2024, 8), just and safe operating space in the Antropocene (Anderies et al. 2023, 1), green regenerative society (Tabara 2024, 8), just and sustainable food system (Pereira et al. 2020, 7), food as industry, food tech, culture or forgotten (Carlsson 2021, 36), ecological plant protein food system (de Vries et al. 2022), high-status, broadly liked food (Boutyline et al. 2021) and balanced predator-pest food web (Chapman et al. 2017, 12), just to name a few.

Discussion about the distinction between a basin of attraction and an attractor is not well developed, especially not in the context of societal systems, as also applies to the concepts in general. Let us illustrate this frontier with an example. Basins of attraction and attractors of societal systems are not stable but evolve over time. The "magnetic field" of the basin of attraction at the early history of the system, subsystem or regime may be a rather weak "shallow bowl". Over time, institutionalisation and path dependence take over and the attractor may become deeper and steeper.

This is evident in our illustrative case of the Common Agricultural Policy, CAP. In the 1960's the common policy dealt only with the common markets leaving large part of the agrifood system untouched, whereas nowadays it has specific and precise measures and regulations on farm investments, regional payments, environmental management, food safety, animal welfare and many other things (Daubjerg and Swinbank 2016; Feindt 2010; Kay 2003; Kay and Ackrill 2010; Kuhmonen 2018; Oskam et al. 2011; Tangermann and Cramon-Taubadel 2013). The nascent thin basin of attraction for the European agriculture has grown both wider and deeper and has several attractors. Whether the current CAP should be considered as a single basin with several attractors or as several basins with basin specific attractors, can be studied by the existence of "mountains" and "valleys". Is it possible or not for the agent subjected by the CAP to

switch between the attractors of, say, competitiveness on the markets, provision of good animal welfare, maintenance of biodiversity and contributing to the vitality of rural areas – all for which CAP has objectives and measures? If yes, then it might be one basin with several attractors. If not, then it might be several basins with basin specific attractors.

Notwithstanding sorting out basins and attractors, the case when societal systems swap basins of attraction and attractors) is an important topic for the foresight mission with CAS. It may become possible that the systems will swap attractors and move into a new basin of attraction by crossing the saddle points or 'separatrixes' that separate the basins (Kauffman 1993, 173; Room 2011, 135). Such an occasion 'represents evolutionary change, a change in kind, a metamorphosis' (Byrne and Callaghan 2014, 27). This resembles a bifurcation or a crucial epoch in the language of evolutionary futures research (Laszlo 1985; Mannermaa 1991). Leaving the conceptual crossfires behind, for the system to "climb over the mountain" and cross the verge there must be effective forces that lower the mountain or energise system agents to ignore previous limits. Unfortunately, complexity science has x-rayed both these alternatives rather arbitrarily.

Sticking to pure logics of causation, for the basin of attractor to crumble there must be some fundamental changes in the processes that reproduce the force fields of the existing basin (that has to be constantly reproduced to exist) or there must be a crisis that breaks the rules, power bases and institutions: a loss of power or structure of the "magnetic field". Populations of the system may change the landscape, too (Allen 1990, 568): then the attractor landscape will change (Hooker 2011, 26) e.g. along adoption and mainstreaming of niche practices. Another option is that the 'bowl' remains as it is, but the agency residing within the basin collects enough steam to leave the existing power basins, institutions, routines, sunk costs, norms, regulations and other elements of the "magnetic field". Either the structure will break up or the agency will defeat the structure (Figure 10). As a consequence (Kauffman 1993, 190): 'a basin would contract to nothing or a new basin might appear'. By then, for example the following case might become possible (Tabara et al. 2024, 328):

> 'For instance, in some regions the former dependence on carbon-intense activities in the energy sector at one point in time was abandoned or 'released' in a way that the system moved towards a new basin of attraction and reorganized itself around new governance, economic, energy, and socio-cultural foundations.'

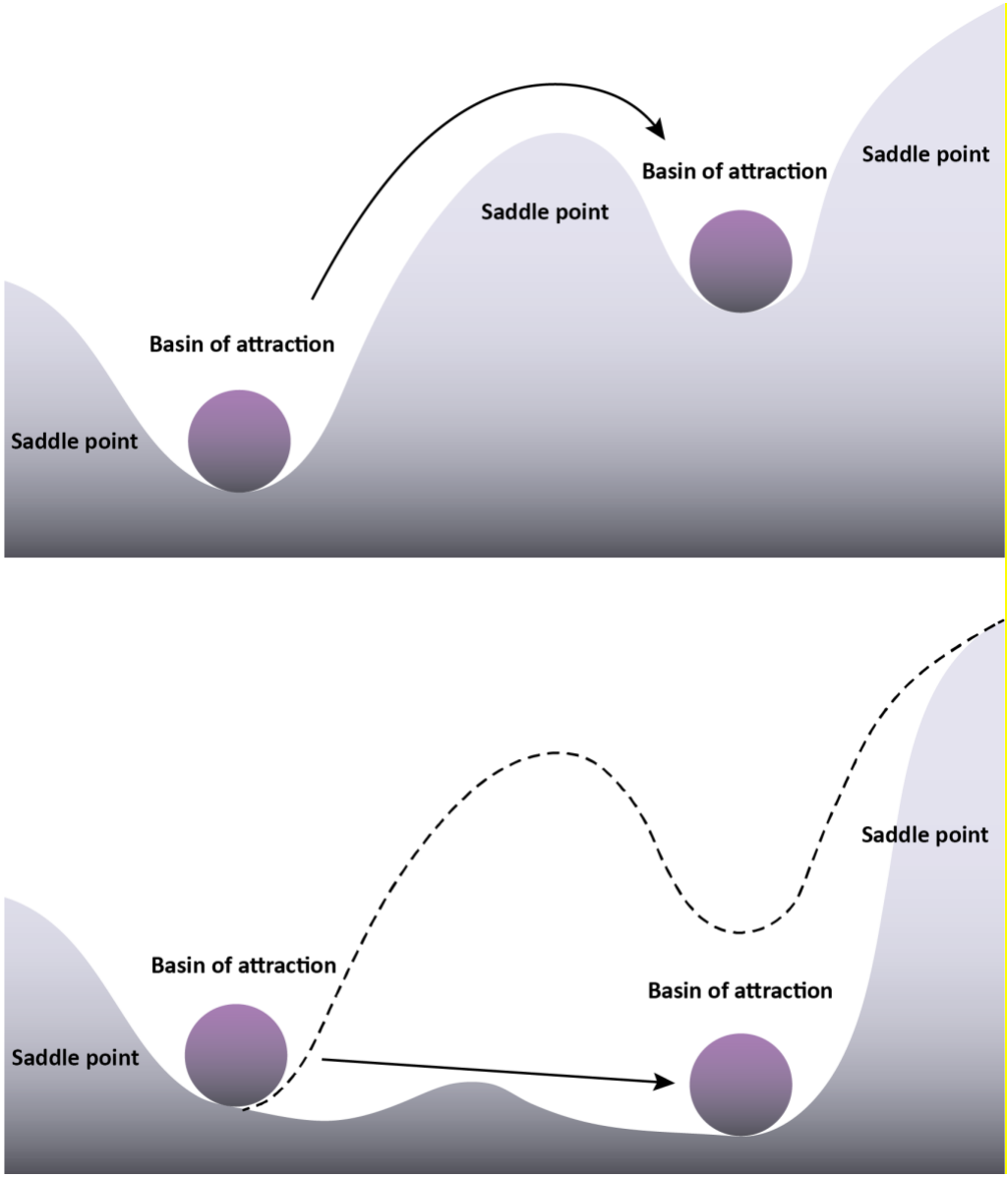


Figure 10. Stylised illustration of a move of the system to a new basin of attraction: the case of crossing the saddle point and the case of changed structure of the basins.

2.3 Dynamics of the CAS as framed by the evolutionary science

Evolutionary science has discussed stability and change of complex systems with different concepts that might provide a better idea of the dynamics between the system and its environment than complexity science. Location in a basin of attraction implies a good fitness with the effective selection environment when the topological map is regarded as a fitness landscape (Dawkins 1996; Gerrits and Marks 2017; Kauffman 1993; Martin and Wainwright 2013; Reeves 2005; Wright 1932). The concept of fitness landscape derives from the evolutionary thought, and it maps the match between an agent or actor and its environment generally in the opposite way to Figure 9: the highest fitness is on the mountain tops and the lowest fitness is on the valleys, where the mountain itself could be considered a basin of attraction (Gerrits 2012, 146; Levinthal and Warglien 1999, 345). A good fitness is rewarding to the agents or actors – whether they are societies, societal systems, various organisation, business firms or individuals. Being different from the fit ones in a highly institutionalised selection environment provides low payoffs and high risks in the short term. Contours of the map manifest varying fitness values.

From the point of view of the foresight mission, there are several interesting points in this conceptualisation of the evolution of systems and populations in their environments. First, there is an 'expectation that natural selection will drive populations toward' the mountain tops (Gavrilets 2004, 35). However, agents or actors tend to make local search in the state space to find a better fitness through their adaptive walks (Levinthal and Warglien 1999, 345; Miller and Page 2007, 216; Room 2011, 34) which – if successful – leads them to the nearest mountain top (van den Bergh and Kallis 2013, 284) around which they will cluster (Gerrits 2012, 155). Moreover, 'once the agents are placed in such a world' (Miller and Page 2007, 216), their pathway or trajectory toward the nearest mountain top manifests path dependence (Page 2006). That is the way many systems follow path dependence in their dynamics: the agents that contribute to self-organisation of the system look at their vicinity which does not bring about bifurcations but calibration of the system. Gerrits (2012, 155) underlines:

> 'Actors can only deploy a limited, myopic search processes. Consequently, they will only scan the nearest opportunities and what may appear to be an opportunity nearby may in fact be a dead-end road in the long run because other actors have moved in a different direction and the environment may have evolved in a different way.'

Indeed, a good fit in the short term may vanish in the long run. The nearest mountain top may not possibly be the highest one in the landscape and thus it may not provide the best possible fitness. A setting where the majority of agents occupy a local fitness

peak may not be sustainable as this majority may have been blind for more distant options. Calibration of the existing system around the single, close "mountain top" may ignore more promising options in the evolutionary struggle for survival and success. In the foresight mission of CAS, it may be useful to observe also more distant "mountain tops".

Second, in environments where there is only one mountain top, fit agents cluster around it. Consequently, there is only one model or practise to succeed, and diversity of the system becomes very limited. This can happen also along maturation and institutionalisation of the system as large population may affect the environment through co-evolutionary processes (e.g. Baum and Singh 1994; Carcía-Cabrera and Durán-Herrera 2016; Porter 2006; Lewontin 1983). The system then becomes homogenous and rigid, which can be observed in many existing societal systems: exercising agency is limited to complying with the rules of the rigid system and to doing things in one way like the others (Kuhmonen 2023, 45). This kind of a system may have difficulties in adapting to changing environment: current fitness is not a guarantee for survival and success in the societal context. Thus, basing a foresight mission on the characteristics of the current system may leave an important part of the dynamics of fitness unobserved.

Third, if the fitness landscape is rugged, it contains many 'fitness peaks' and many 'fitness valleys' (Gavrilets 2004, 34) – or basins of attraction and saddle points in complexity language. In such a setting, there is a chance for numerous viable subpopulations and local innovations (Martin and Wainwright 2013, 208). The more rugged the landscape, the more variants – systems or sub-systems – can survive and succeed. Small populations may have an evolutionary advantage in such rugged landscapes (Jain et al. 2011) as their can inhabit several "peaks" that ask for different qualities of the agents. So, it is not only the characteristics, competences and objectives of the agents or the system actors that matters but also the quality of the operating environment in which they are embedded. Maintaining diversity within and between the systems may be an evolutionary advantage in the long run. Observing also smaller 'mountain tops' may be valuable for the evolution of the CAS.

For the CAS foresight mission all these points are important news: in multidimensional systems it is important to identify not only 'local' mountain tops but also some alternative, distant and possibly higher mountains. Not only the evident and nearby mountains should be studied to become aware of future possibilities. There might be a niche to live also for several distinct populations and sub-populations. Moreover, for the critical systems of societies to survive they could benefit from being consisted of several variants that are able to occupy several locations in the evolving fitness landscape – which is evidently rugged and subject to change for all societal systems. Strategic Niche Management (SNM) policies, for example, observe this evolutionary

advantage (Kemp et al. 1998; Raven et al. 2010; Schot and Geels 2008). Covering rugged landscapes asks for diversity thinking and a holistic approach, whereas observing only a local search (e.g. improvement of productivity in the current operating environment) risks long-term survival of systems and their agents.

Fourth, dimensionality of the fitness landscape is context dependent. In societal systems the effective selection environment may include economic (profitability, livelihood), environmental (ecosystems), socio-cultural (shared values, norms, health, competences), technological (available machinery, infrastructure), political (regulations) and many other dimensions (Coenen et al. 2012; Meyer and Gauthier 2013). Achieving a good fitness in such a multidimensional landscape is challenging. The fitness landscape of food systems has different dimensionality than the fitness landscape of healthcare systems. Furthermore, despite of the multidimensionality of the system, the effective forces or dimensions may be very few, as was suggested by complexity science. For example, in the era of globalisation and free trade, low productions costs may be the by far most important fitness force (or gravitational force in complexity language), ignoring most parts of the environmental and social dimensions (Borghesi and Vercelli 2003; Hatzichronoglou 1996; McCorquodale and Fairbrother 1999). For this reason, the CAS foresight mission should observe explicitly the dimensions and variations of the effective selection environment in each case.

Fifth, the landscape evolves over time for many reasons. Societal systems are embedded on the biophysical systems that may change the dimensions and parameters of the selection environment, as for example in the cases of advancing climate change and loss of biodiversity. Evolving cultures, policies and technologies will also change the landscape. Notwithstanding these external demands, the behaviour of some groups of actors may become more homogenous through various feedback systems and constitute forces to make the landscape more favourable for their preferences, resources and outputs through niche construction (Allen 1990, 2011). All these aspects have an important implication for the foresight mission of CAS: both structure and agency should be observed when studying alternative futures as ‘agency without structure is blind, structure without agency is empty’ (Caldwell 2005, 109). Over time, coercive forces deriving from the fitness landscape (or structure) may change and latitude for exercising agency change accordingly, which may open up avenues for bifurcations.

Fourth, a population with a good fitness is typically clustered around the mountain top or occupies a basin of attraction thus representing temporal stability, internal coherence and capacity to attract resources from the environment (Gerrits 2012, 155). The honey pot attracts new exploiters. Such an entity could be called a dominant design (Geels 2002; McCarthy 2003; Murman and Frenken 2006; Nemet 2009; Suárez and Utterback 1995; Suarez et al. 2015) or a regime (de Haan and Rotmans 2011;

Fuenfschilling and Benz 2018; Fuenfschilling and Truffer 2014; Geels and Schot 2007, 2010; Kuhmonen 2023; McMichael 2009), depending on the context and the conceptual vocabulary. These manifestations of stability in the evolution of CAS are important as for most of the time they define the provision of services and benefits of the societal systems in their episodic evolution of 'fits and starts' (Boulton et al. 2015, 42). Sometimes, a major change is required for the societal system to maintain its resilience and the capacity to fulfil its purpose of existence (Kuhmonen and Kuhmonen 2023; van der Merwe et al. 2018; Westley et al. 2002), however. This is the case for bifurcation (Mannermaa 1991), crucial epoch (Laszlo 1985) or regime shift.

2.4 Regimes and regime shifts

Various societal – socio-technical or social-ecological – Complex Adaptive Systems have tendency to organise regimes (Fuenfschilling and Truffer 2014; Geels 2002, 2019, 2020; Geels and Schot 2007; Klitkou et al. 2015; Rotmans and Loorbach 2009). This is caused by the existence of basins of attraction in the state space or mountain tops in the fitness landscape that bring actors together and create clusters. Location in the basin of attraction provides a good fitness with the current effective selection environment and thus access to resources, survival and success. Location in the state space may be a matter of existence for the actors. Regimes are discussed especially in sustainability science and transition research.

The resulting regimes are dynamically stable configurations of systems comprised of more of less homogenous actors. 'In order to understand stability, it is the regime concept that is of most importance' (Svensson and Nicoleris 2018, 463). Stability of the regime may be maintained by several force fields: shared beliefs and values, dominant technologies, cultures, institutions, routines, policies, institutionalised practices, established power constellations, regulations, sunk investments, capabilities etc. (Fuenfschilling and Truffer 2014; Geels 2005; Loorbach et al. 2017). Regime sets the rules for the system, material or ideational.

Dynamic stability may be quite persistent as societal regimes can have a life cycle that lasts decades or even centuries (Arapostathis and Pearson 2019; Cherp et al. 2017; Friedmann 2005; Friedmann and McMichael 1989; Guldi and Armitage 2014; Kuhmonen and Kuhmonen 2023; McMichael 2009), observing that empirical delineation of subsequent regimes is arbitrary. While there may be changes in the elements and interactions of the regime, their basin of attraction and identity remains the same over their lifetime. For example, the fossil economy regime has existed for 150 years and retained its identity despite of the emergence of internet, electrification and nuclear power and despite of its growth and diversification: carbon is still taken up

below the ground and pumped into the atmosphere (Höök and Tang 2013). Societal regimes evidently live at different levels and domains and with different lifetimes.

A regime shift (or bifurcation) happens when the regime loses fitness with the landscape and runs out of steam. Often the regime becomes rigid and homogenous along with its maturation and institutionalisation and thus turns unable to respond to changing environment. Rigidity and growing internal tensions may coincide with external shocks and lead to a loss of resilience, the ability of the regime to fulfil its purpose of existence, and ultimately to a regime shift (Friedman 2005; Kuhmonen 2023). Many societal, socio-technical and social-ecological systems 'do not always respond in an incremental and predictable way to increasing or decreasing external pressures', but exhibit 'regime shifts, critical transitions, or alternate stable states' due to shifts in the feedback processes (Reyes et al. 2018, 273-274). These can be called also phase shifts or qualitative changes (Byrne and Callaghan 2014, 215). Often both the drivers and the feedback systems will change upon the regime shift setting up a new development trajectory (Abel et al. 2006; Biggs et al. 2018; Folke et al. 2004; Geels 2019; Kemp et al. 1998; Rocha et al. 2015; Schlüter et al. 2019; Steffen et al. 2005). For example, if the fossil economy was punished and the circular bioeconomy was rewarded in a serious way, the feedback systems would change radically from the present. As Reyers et al. (2018, 273–274) explains in the case of social-ecological systems (SES):

> 'Shift in feedback processes leads to a fundamental reorganization in the structure and functioning of the SES, propelling it onto new states and development paths. The resultant large and persistent changes in system structure and function are referred to as regime shifts, critical transitions, or alternate stable states.'

While theoretical–conceptual foundations for the regime shifts are abundant in sustainability science and transition literature, they are vague in the evolutionary and complexity thinking. Notwithstanding this, analytical frameworks to study them are more developed especially in sustainability science and futures studies. For the regime shifts or transitions in socio-technical systems, the Multi-level Perspective (MLP) has been most widely used analytical framework (e.g. Geels 2002, 2005, 2010, 2019, 2020; Geels and Schot 2007; Lauttamäki 2018; Markard and Truffer 2008; Smith et al. 2010). For the regime shifts in social-ecological systems, Adaptive Cycles (AC) model (Holling and Gunderson 2002; Sundstrom and Allen 2019; Walker and Salt 2006) or X-curve (Hebinck et al. 2022; Petrović 2024; Silvestri et al. 2022) have been frequently used. Figure 11 illustrates their straightforward logics.

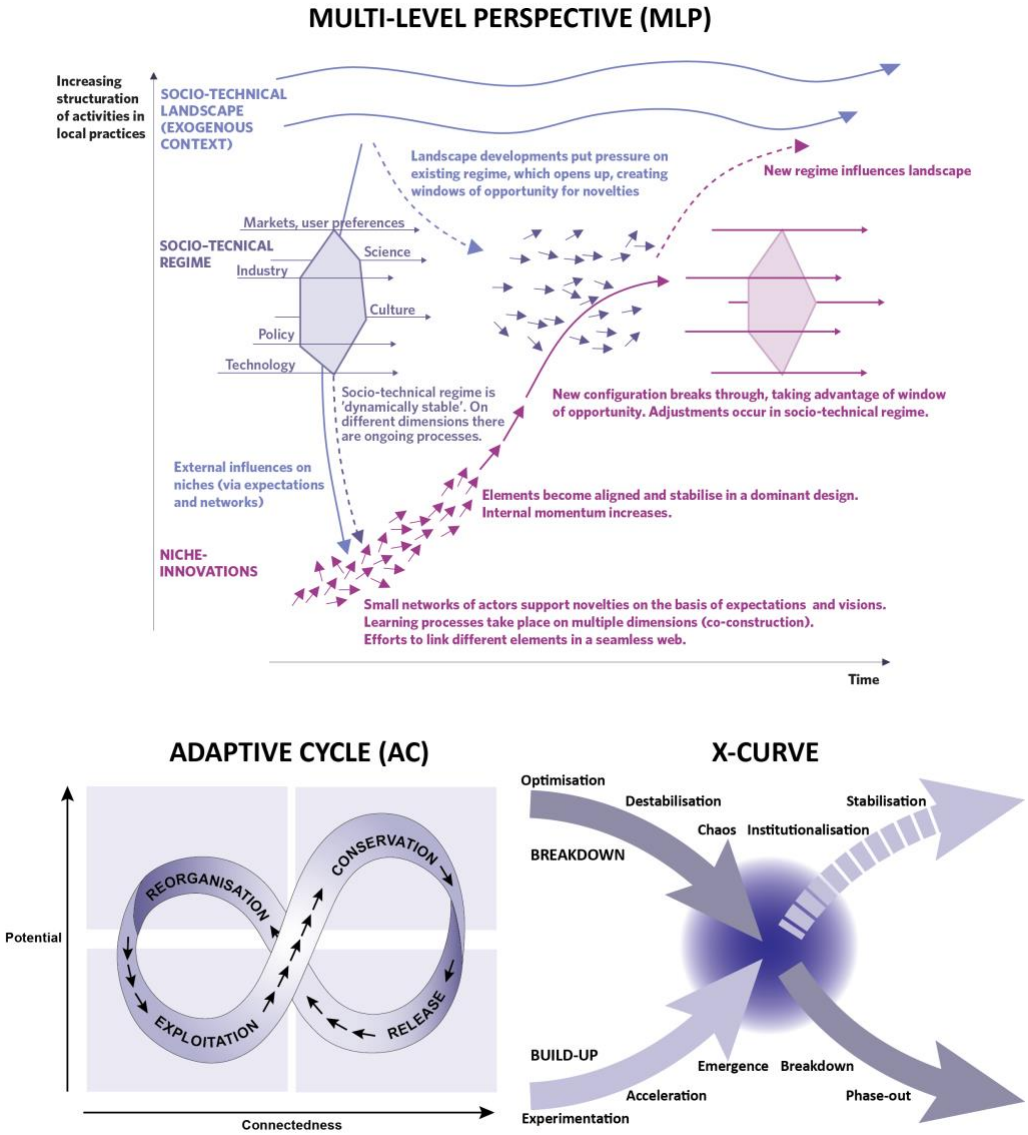


Figure 11. Analytical frameworks for a regime shift: Multi-Level Perspective (Geels and Schot 2007, 401), Adaptive Cycle (Holling and Gunderson 2002, 34) and X-curve (Hebinck et 2022, 1012).

The various analytical frameworks can be used for description and mapping of regimes as well heuristics related to regime shifts. All the frameworks essentially feature cyclical evolution of systems. MLP framework provides a feasible model to bring together elements that reside at various levels (macro, meso, micro) of the system and contribute to the reconfiguration of the regime even if more detailed dynamics remains

unobserved in the basic model. While MLP describes a single regime reconfiguration or shift, several patterns can be attached to the transition pathways (Geels and Schot 2007). X-curve similarly puts a single regime shift in the spotlight, but it captures also some phase-based dynamics in the breakdown of the dominant regime and build-up of the new regime (Figure 6). Unlike these two models, the Adaptive Cycle (AC) framework pictures cyclical patterns of recurring process comprised of four immanent phases over the lifespan of consecutive regimes. All the models are basically life-cycle models capturing birth, growth, maturity and death (van de Ven and Poole 1995).

As we are interested in the alternative futures, each of these analytical frameworks provides some assistance to this heuristic mission. Identification of the current stage or phase of the dominant regime is the first stage of any foresight mission. By then, the next evolutionary phases or a regime shift can be planned or foreshadowed. The current stage or phase of the regime can be traced in all three models by studying the degree of structuration and institutionalisation (MLP), the degree of potential and connectedness (AC) or the phase of breakdown vs. build-up (X). If the regime under study is at the age of maturity and stands in conservation phase where deviant behaviour is troublesome, homogeneity prevails and rigidity takes over, destabilisation and release can be expected to occur next upon a regime shift.

2.5 Conceptual underpinnings for the foresight mission of CAS: synthesis of complexity and evolutionary views

While there are many distinctive characteristics, applicable concepts and detailed models that feature evolution of the Complex Adaptive Systems that have not been discussed here extensively (e.g. feedbacks, coevolution, lock-ins, punctuated equilibrium, morphogenesis, game theory), the previous ingredients may shed some light on the arena where the research mission is accomplished. It is observed that bringing together concepts from various disciplines – in our case complexity science, evolutionary biology, evolutionary economics, sustainability science and futures studies – is always a risk, as pointed out by Gerrits and Marks (2017, 47), but at the same time any framework that serves disciplined imagination and transparency may be valuable (de Jouvenel 1967, 17–18):

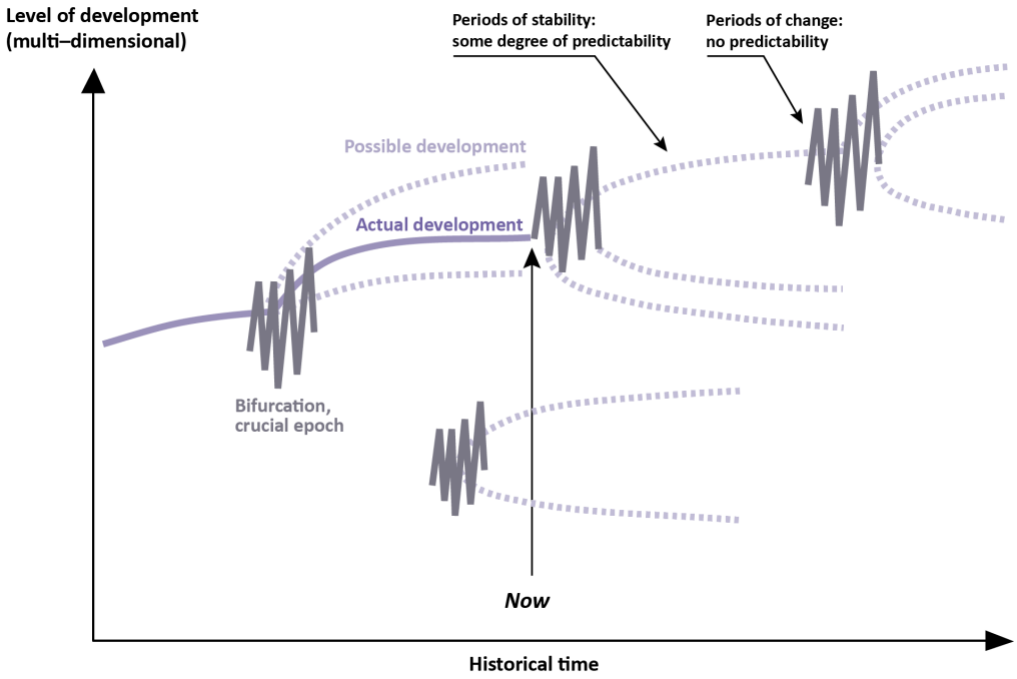
> ‘The supposition that the possible futures are ‘given’ to us … is very far from the truth. On the contrary, they have to be constructed by ‘pro-ference’: the action by which the imagination derives possible futures out of present states, which are known more or less well … In this ‘composition’ of the mind, we should make use of all the relevant causal relations that we can find … What is of vital importance for the progress of this art of conjecture is that an assertion about the futures should be accompanied by the intellectual scaffolding which supports

it: this 'construct' must be transparent and articulated, and subjected to criticism.'

Results of futures research are not meant as a test of their truth-value, but for becoming aware of multiple future possibilities (e.g. Tuominen et al. 2014). For this reason, utilisation of various analogues, metaphors and concepts that may possibly serve the research mission will not be harmful if their origin and applicability is explained. As there are many diverse research missions targeted at futures, so are there many philosophical, theoretical, conceptual and methodological underpinnings that may be leaned on during these missions.

Observing these risks and entitlements, a synthesis of the conceptual elaboration is presented in Figure 12. The foresight mission of CAS futures is targeted to the anticipation of bifurcations (evolutionary futures research), swapping of attractors by escaping the basin or through crumble of the basin (complexity science), changes in the fitness landscape and search for new fitness (evolutionary science) or regimes shifts (sustainability and transition research). The specific interest of futures research is not on the stable periods of evolution, as 'nothing exciting' happens then (Popper 1956, 173), but in the bifurcations. Various analytical frameworks provide some heuristics for their anticipation e.g. based on the life-cycle stage of the regime. When considering the mission of academic futures research as transparent, disciplined and systematic design and assessment of alternative futures, the main focus would be in what might happen upon and after bifurcation. What are the future basins and attractors in the attractor landscape, future 'mountain tops' in the fitness landscape and future regimes following regime shift?

Our capability to imagine becoming worlds is limited on two frontiers – existing vs. becoming, real vs. observable – and this limitation is especially severe when we have extensive, complex, evolving systems as our study objects. Their kaleidoscopic movement in our scientific detectors gives us (correct) impression of a huge number of details that we can never capture in a meaningful way by achieving the three qualities of generality, accuracy and simplicity at the same time (Thorngate 1976). The level of abstraction and the research design should be calibrated in such a way that we can reasonably fill the research mission without getting lost in the colour play of our kaleidoscope. As Simon (1996, 148) points out: 'Design for distant futures would be wholly impossible if remote events had to be envisioned in detail'. This is also confessed by Room (2011, 133): 'It is impossible to predict with entire precision how trajectories will develop'. Future basins, attractors, saddle points, fitness peaks and regimes are more feasible targets of foresight as they are more robust than the specific trajectories of the system that they configure at a certain point of time. Three design principles, discussed next, may help in this crusade.



Perspective	When stability?	When bifurcation?
Complexity science	Systems occupy limited 'boxes' of the state space when agents cluster in the basins of attraction	Systems swap attractors by escaping the basin or through crumble of the basin
Evolutionary science	Systems occupy limited parts of the fitness landscape when agents cluster in 'mountain tops'	Change in the fitness landscape and search for new fitness
Regimes	Maturation and institutionalisation of the regime	Regime becomes homogenous, rigid, contradictory and non-responsive for external shocks, leading to regime shift
Futures research	Not in the interest of evolutionary futures research	Anticipation of bifurcation, change in the fitness landscape or regime shift as well as design of new basins, attractors, 'mountain tops' and regimes following bifurcation

Figure 12. Synthesis of complexity, evolutionary and futures perspectives on stability and change of Complex Adaptive Systems. Figure on the evolutionary development of societal systems is based on Mannermaa 1991, 365 and Laszlo 1985, 17.

3 Design principles for the alternative futures of Complex Adaptive Systems: methodological approaches

Let us start our trial to connect the world of ideational and the world of empirical in the CAS context with a methodological assessment of the research questions: how to choose the level of abstraction, and how to delimit the state space and how to identify future attractors. There is no single specific theory or analytical framework that would have been created to tackle these three challenges in the foresight context. Furthermore, if the research mission is to anticipate specific regime shifts and to envision alternative regimes that might follow after, one is inclined to defer to topic-driven instead of theory-driven or method-driven research.

Absence of a specific theory of the non-existing futures and abundance of the methods in the futures research toolbox is a relief in this respect and paves the way to avoid a paradigm prison that bothers many sciences of the existing (Kuhmonen 2010, 148; Miller 2007, 179–180). Nevertheless, the three challenges need to be elaborated before going to the empirical studies of the CAS futures. Table 2 provides a general idea of the approaches used to tackle the three challenges in this study: how to find an appropriate level of abstraction, how to find a way to delimit the state space and how to find future basins and attractors for the system under study. The first challenge asks for finding an appropriate "flight altitude" whereas the second challenge asks for finding a feasible way to box the state space. The third challenge asks for "traditional" futures research tools to uncover alternative futures. These approaches will be discussed next.

Table 2. Approaches used to tackle the three challenges: abstraction, delimitation and attractors.

Article and domain	Iteration of the level of abstraction	Delimitation of the state space	Identification of future basins/attractors
I Spatial futures	Context-sensitive and objective-driven abstraction.	Boxing the state space into 11 dimensions.	Four futures images as future basins of attraction with their elements as attractors.
II Personal futures	Context-sensitive and objective-driven abstraction.	Boxing the state space into three logical domains (livelihood, accommodation, lifestyle).	Three dream recipes for four regional contexts as future basins of attraction with their elements as attractors.
III System futures	Context-sensitive and objective-driven abstraction.	Boxing the state space into four domains by sustainability dimension.	Four futures images as future basins of attraction with their elements as attractors; saddle points for each basin.
IV Policy futures	Context-sensitive and objective-driven abstraction.	Boxing the state space into 22 issues to be addressed by the policy.	Twelve issues will gain importance and become attractors.
V System evolution	Context-sensitive and objective-driven abstraction.	Boxing the state space into 6 regimes delimited by Adaptive Cycles.	Six basins of attraction with their attractors for each regime.
VI Sector futures	Context-sensitive and objective-driven abstraction.	Boxing the state space into five domains by sustainability perspective.	Five basins of attraction with their elements as attractors.

3.1 Level of abstraction

Abstraction is an intuitively clear but epistemologically tricky concept. The concept was introduced by Locke (1690, 142) as follows:

> ‘The use of words then being to stand as outward marks of our internal ideas, and those ideas being taken from particular things, if every particular idea that we take in should have a distinct name, names must be endless. To prevent this, the mind makes the particular ideas received from particular objects to become general; which is done by considering them as they are in the mind such appearances, — separate from all other existences, and the circumstances of real

> existence, as time, place, or any other concomitant ideas. This is called abstraction, whereby ideas taken from particular beings become general representatives of all of the same kind; and their names general names, applicable to whatever exists conformable to such abstract ideas.'

Ever since its inception, the topic has been discussed in various fields for example, computer science and artificial intelligence (Ganascia 2015), psychology (Gilead et al. 2019), sociology (Chazel 2006), education (Olsson and Lehtinen 1997), political science (Brutger et al. 2022), mathematics (Mancosu 2016), linguistics (Torreano et al. 2005) and philosophy (Floridi 2008; Rainey 2016).

Keeping with the domain of social sciences, Parsons (1949) contributed to the discussion by distinguishing between three levels of abstraction: descriptive frame of reference, formulation of concepts and search for mechanisms. Descriptive frame of reference ultimately specifies meanings, ordering of things and relevant topics of the study (Chazel 2006; Parsons 1949). Chazel (2006, XIV) explains:

> 'Any description, and a fortiori any explanation, of social phenomena depends on the prior choice of a frame of reference. This frame of reference defines the perspective on reality, governing and organizing the way it is perceived.'

The decisive role of the frame of reference resembles the interpretative hard core of the Lakatosian scientific research programmes that includes research questions, general assumptions and other elements that are protected from refutation (Lakatos 1970, 133–134) but which give a direction for the travel of the scientific enterprise, advises to interpret the facts and empirical findings as well as 'saves the scientist from becoming confused by the ocean of anomalies' (Lakatos 1970, 135). It is important for the research mission for the futures of complex systems for understanding that in the societal world several alternative frames of reference exist. Changing a frame of reference may result in a radically different set of future alternatives for the system (e.g. Kuhmonen et al. 2024). Without several alternative frames of reference, a large part of the existing complexity would be cleared away from the stage even if the complexity itself was 'essential for the healthy existence and evolution of natural, biological, and social systems' (Manovich 2007, 346).

However, the difficulty here comes with complexity itself. One may take a typologist worldview where archetypes are "real", archetypes variation is "unreal", or a populationist worldview where variation is "real" and archetypes are "unreal" (Kuhmonen 2010, 7; Mayr 1976, 27–28). Choice of a feasible frame of reference may help in positioning to this continuum. In general, confessing that there is no theory about the future and that there are several future alternatives, gives us entitlement to

use feasible and possibly several frames of reference or interpretative stances to accomplish our research mission.

The second level of abstraction is related to the formulation of concepts. The concepts are used to identify ideal types or archetypes, regularities and general properties of the systems (Chazel 2006; Parsons 1949). This level brings us to the theory of concepts and its various facets like empiricism, rationalism, historicism and pragmatism (Hjørland 2009, 1519). Pragmatism has its merits as there are no observations from the future to feed empiricism; as the principles, logics, essentials, rules and categories of the present may not be valid in the future to serve rationalism; as the existing preunderstandings as well as culturally embedded frames and assumptions may not be valid in the future to allow leaning on historicism. Following pragmatism, for example, encourages us to choose our concepts on the basis of our research mission as 'if we cannot clarify our goals, then we cannot clarify our concepts either' (Rey 1994, 192). Rainey clarifies (2016, 194):

> 'A level of abstraction (LoA) is a set of observables deemed relevant by an individual or group with respect to some system under appraisal, assessment, discussion or what-have-you. These 'observables' are labelled according to some epistemic criteria in order to pick out salient features of the system at hand. Importantly for the context here, this is relative to purposes, interests, conceptual schemes and so forth, constitutive of an epistemic perspective held by an individual or group.'

In this line of thinking, the choice of concepts and their derivatives (constructs, analytical frameworks etc.) is guided by the frames of reference and knowledge needs. 'Different purposes require different concepts' (Hjørland 2009, 1526) and thus topic-driven research – as foresight of specific complex adaptive systems is – entitles us to choose the appropriate concepts rather than obliges to follow some orthodoxy.

The third level of abstraction is related to the search of (social) mechanisms in terms of processes, motivations and consequences (Chazel 2006, Parsons 1949). This level of abstraction relates to the analysis of various kinds of relational dimensions and processes. In this way, abstraction may open doors to more extensive knowledge structures (Olsson and Lehtinen 1997, 46). A generic methodological strategy to achieve a manageable and plausible number of futures designs is to apply logical abstraction. Logical abstraction reduces diversity while maintaining an explicit logic of coherence or 'logic of wholes' (Harris 1987, 82). The logic of coherence may be a topic-driven association, causal relationship, contextual hierarchy, chronological order, immanent life cycle or other logic to which the future is expected or planned to conform with. Logical abstraction of ambiguous topics implies disentangling the problem of sameness vs. otherness (Durand and Calori 2006). It should also observe the possibility

of emergence when past logics and rationales may be partly or completely invalid and 'new dynamical form does come into being' (Hooker 2011, 28).

Discussion on the level of abstraction is called levelism in philosophical analysis and the previous points deal mostly with epistemological levelism. They could help in tackling the epistemological grievances of this research mission (see Chapter 1.1). In this view, specification of the level of abstraction also specifies the 'range of questions that can be meaningfully asked and are answerable in principle' (Floridi 2008, 315). Furthermore, 'reasonably complex systems can be understood only by distinguishing between levels of analysis' and 'one must be prepared to contemplate different kinds of explanation at different levels of description that are linked, at least in principle, into a cohesive whole, even if linking the levels in complete detail is impractical' (Floridi 2008, 319–320).

As a conclusion, all these points mean that the choice of the level of abstraction ultimately depends on the research questions as well as on the nature of knowledge and level of representation that are searched for. The choice of a certain level of abstraction defines the range of results that can be obtained in empirical inquiries – different levels of abstraction bring about different understandings. The more conscious and explicit the choice of the level of abstraction in studying multi-level, hierarchical and messy CAS, the better chances there are to find answers that match with the research questions. As Sayer (2000, 19) underlines:

> 'So much depends on the modes of abstraction we use, the way of carving up and defining our objects of study … Unfortunately, the bulk of the methodological literature on social science completely ignores this fundamental issue, as if it were simply a matter of intuition.'

Table 2 summarised how the level of abstraction was chosen in each of the research articles of this study. While each of the articles explicitly discusses the level of abstraction, no particular principle was employed but rather "context-sensitive and objective-driven abstraction" as mentioned in Table 2. A more detailed description of the iteration process is given in Table 3.

The degree of compression of the elements or topics in various data sets varied according to the research question, as suggested by the epistemological–methodological literature. Compression rate refers to the final number of categories as compared to the original items in the data. In the case of the attractors and saddle points of the food system (article III), a rather low compression rate (14–18%) was used to have enough elements to differentiate between the four futures images. At the other extreme, a rather high compression rate (2–4%) was applied to the dream recipes of the youth (article II) and attractors of the animal production (article VI). The difference

is due to knowledge demands which was more open and explorative in article III than in articles II and VI. The compression rate in the other articles varied in between these extremes. Reflected against the previous methodological–epistemological discussion, the choice of the level of abstraction was serving the task of getting feasible answers to the research questions. The method of compression and categorisation was conventional content analysis without predefined categories in all cases (Hsieh and Shannon 2005; Krippendorff and Bock 2009).

Regarding the three levels of abstraction, the articles had different profiles. Articles I, III and VI related mainly to the descriptive frames of reference. How do alternative frames of reference in terms of valuation of natural resources (more/less value), promotion of their exploitation (promoted/not) and realisation of multidimensional sustainability (yes/no) effect on the set of future possibilities (article I)? How do alternative frames of reference in terms of sustainability to be maximised (economic, environmental, social, cultural) effect on the contents of the possible and desirable futures (article III)? How do alternative frames of reference in terms of sustainability to be served (ethical, environmental, health, national food security, global market) effect on the contents of the possible futures (article VI)?

Article II on futures dreams of the youth was related mainly to the formulation of concepts rather than to the frame of reference. What kinds of concepts may be iterated to identify and describe archetypes or general properties of the heterogenous dreams (Article II)? Finally, articles IV and V were primed for search of mechanisms. What is the mechanism behind the observed path dependence of the Common Agricultural Policy of the EU while looking at the problems to be addressed by the policy (article IV)? What are the mechanisms behind the evolution of the historical food regimes and their shifts (article V)? As such, all the conceptualisations of the levels of abstraction were useful to describe and explain the process and the outcome of the iteration of the level of abstraction in this study.

Table 3. Iteration of the appropriate level of abstraction in the six empirical studies.

Article, domain and topic	Research questions or tasks	Iteration process of the level of abstraction	Quotation
I Spatial futures, rural areas	What alternative roles could rural areas have in developed economies (observing that in the past they have been	1) Conventional content analysis without predefined categories of relevant literature (200 documents) to identify 130 drivers of rural change, 2) conventional content analysis to	'We have used content analysis of the relevant literature for identifying drivers and elements of alternative rural futures, futures workshops for structuring ploys for the futures and a futures table

	sources of raw materials, labour force and welfare)?	organise the drivers into 11 dimensions, 3) application of exclusive logic (yes/no) to create four futures images that can be positioned on the 11 dimensions. CR 8%.	for providing coherence of structures, contents and agency in the futures. This research strategy allows oscillation between single drivers, alternative ploys, coherent prototypes and underlying universals and, in this way, calibration to an appropriate level of abstraction in the final images. Finding a feasible "flight-altitude" or level of abstraction is one of the most critical challenges in covering the field of possible futures of complex phenomena.' (p. 367)
II Personal futures, futures dreams of young people	What kinds of macro-level patterns could arise from micro-level behavioural intentions (dreams of young people) targeted to various types of rural areas?	1) Organisation of the personal future into three important domains (livelihood, accommodation, lifestyle), 2) conventional content analysis of the survey responses to abstract 698 livelihood dream elements into 16 categories, 700 accommodation dream elements into 26 categories and 682 lifestyle dream elements into 19 categories of the 'dream recipes'. CR 2%–4%.	'As a methodological solution for finding an appropriate level of abstraction, the three recipes for livelihood, accommodation and lifestyle was a feasible way to structure heterogeneous personal futures and to connect them with specific regions. This structuring provided a reasonable level of abstracting universals for the important aspects of personal futures. The recipes appeared relevant for the respondents, they formed compact tools for research and they appeared to be relevant for policy design.' (p. 98)
III System futures, food system	What is the potential of futures images in anticipating and informing transitions of complex adaptive	1) Decision to limit the future alternatives into four manifestations of sustainability dimensions (economic, environmental, social, cultural), 2) provision of	'Our findings also suggest that the analytical darkness in studying evolutionary complex systems could be reduced by carefully choosing a rather high level of abstraction: by targeting

	systems toward sustainability?	exemplary images and their elements for the workshop participants to reach an appropriate level of abstraction, 3) conventional content analysis of the futures images created in the workshops to abstract 370 elements into 68 categories and 213 obstacles for their realisation into 30 categories. CR 14%–18%.	the foresight of attractors and saddle points of the possible representations of the future.' (p. 222)
IV Policy futures, Common Agricultural Policy	What are the societal problems addressed by the policy and how could they evolve as a system?	Conventional content analysis to abstract 303 problems with their arguments (survey) into 22 key problems. CR 7%.	'Generally, using a causal loop diagram as a mapping tool is a powerful analytical device for discussing problem-driven narratives and policy design puzzles. The main challenge in crafting the diagrams is finding an appropriate level of abstraction, because 'modelling is the art of simplification' (Sterman, 2000, p. 166).' (p. 686)
V System evolution, food system	What can past transformations inform the current attempts to steer the system's development into a more sustainable direction?	1) Identification of nine dimensions and five system properties that manifest historical configurations of the system, 2) using Adaptive Cycle framework, the dimensions and the properties as sensitisers in the thematic, interpretative and iterative analysis to describe the regimes and to identify regime shifts.	'First, we identified the regimes and regime shifts on a coarse level. Second, we finetuned this initial understanding about the regimes by analysing the nature of the agrifood system in nine dimensions. Third, we analysed the temporal development of the regimes in terms of the adaptive cycle. In practice, the research process was iterative and moved back and forth between these stages: understanding about the dimensions of the systems as well as the phases of the adaptive cycle

			fed back to dating the regimes and regime shifts.' (p. 6)
VI Sector futures, animal production, food system	What could be future attractors for the system and how could they reconfigure it?	1) Identification of five discourses that have capacity to upgrade into attractors, 2) conventional content analysis of 653 elements of the 55 versions of the five discourse-based futures images to abstract them into 15 categories, 3) synthetic presentation of the five reconfiguration processes with Multi-Level Perspective mappings. CR 2%.	'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.' (p. 481–482)

CR = Compression rate.

3.2 Delimitation of the state space

Societal futures and 'social systems are open by definition' (Gerrits 2012, 125). This means that the possibility space in a detailed level is infinite. Say, for example, '5,000' or more visions, futures images or scenarios are out of service for the human mind, however. Coming down to a reasonable number of future alternatives that may possibly serve the 'choices in the present' (Slaughter 1993, 290) asks for delimitation of the possibility space from the outset. Plausible number of manifestations of alternative futures seems to be only about a handful (Bradfield et al. 2005).

In the case of CAS, the chance for delimitation logically derives from the tendency of these systems to inhabit the rather narrow basins of attraction (DeLanda 2005) or mountain peaks of the fitness landscape (Levinthal and Warglien 1999). The actors and actions tend to 'cluster' around these allowed or fruitful areas (Gerrits 2012). In societal systems, a good fitness rewards the actors and actions with resources and various forms of capital. These successful and low risk locations in the state space are defined, delimited and effectuated by the basins of attraction. This aspect is closely connected to the level of abstraction. The higher the level of abstraction, the fewer basins of attraction can be observed in the landscape: small "bowls" are not visible at a high-flying altitude. This is an important aspect for a desperate scientist trying to bring down the number of future alternatives.

In a rugged landscape, each societal system may have several basins of attraction with their attractors. Some of the basins are deeper than others and thus 'much more likely to trap the adaptive agents' (Miller and Page 2007, 83). This existing structure of the state space is a product of historical interactions that have created institutionalised artefacts. It can be conceived as a map of allowed and no-go areas. A specific choice space is a room that is available for actors' manoeuvres (Potschin and Haines-Young 2008). Structure of the state space regulates path dependence of the system (Boulton et al. 2015, 76; Byrne and Callaghan 2014, 34) as a source of 'persistence and causal force' (Westergaard 2003, 2). The state space and dynamics of a system can be visualised through mapping (Dentoni et al. 2022) and defined through basin portrait (Kauffman 1993). The state space is then considered as a parameter space where each location represents a fixed combination of parameter values to make up a basin portrait (Kauffman 1993, 180). Each system is organised around a specific number of dimensions or axis (ibid.). In the case of food systems these could manifest, for example, metabolism, power balance, trade orientation, support policy, regulation, consumption habits and land use patterns. These characteristics of the state space may advice the efforts to delimit it for analytical purposes.

Implicit or explicit understanding of the current structure of the state space of the system is an important starting point for the foresight mission. Which part of the possible state space is currently inhabited? Which of the basins are large and which are small? What is their life-cycle status? Regarding these question, Kauffman (1993, 191) made an interesting notion: 'Dynamical systems can have basins of attraction draining to small attractors, then such systems spontaneously box themselves into small volumes of their state space'. This means that the effective basins of attraction cover only a small part of the state space. The actors with their similar type of actions have clustered on these areas, whereas outside them there might be some smaller number of actors carrying out search for new fruitful basins.

Taking food system again as an example, many national food systems host several basins of attractors: agro-industrial food basin, agroecology basin, local food basin, fair trade food basin, high tech food basin etc. Obviously, some of these are larger than others, but actually each of them boxes only a rather limited area in the possible state space. The basins "allow" location for a short range of variation on the axis around which the systems are organised regarding for example, metabolism, power balance, trade orientation, support policy, regulation, consumption habits and land use patterns. In other words, the landscape is rugged and actors – that have a common tendency to do local rather than global search (Levinthal and Warglien 1999) – have accumulated around limited basins comprising institutionalised regimes (Figure 13). Various dynamical accumulation processes lead to sizes of the basins and dominance of the regimes to differentiate over time.

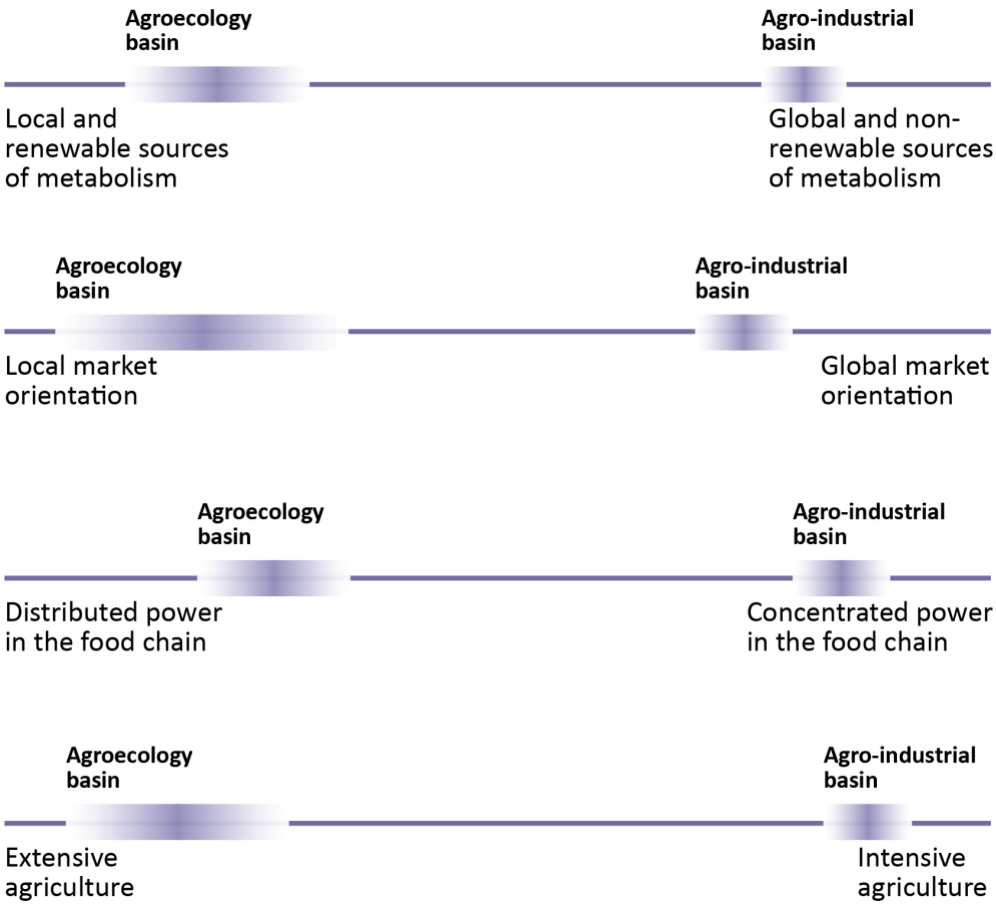


Figure 13. Boxing of the state space in food systems, a stylised illustration with two basins.

Emergence poses additional challenges for the delimitation of the choice space. Emergence implies potential appearance of new basins and attractors (Boulton et al. 2015, 45). It would be rather straightforward to delimit the choice space with the existing – even if small – basins of attraction. But over time, also something totally novel may appear. The futures research toolbox may assist disciplined imagination to tease out these options, as also the enterprise of imagining also (currently) improbable, impossible and undesirable locations in the state space (ref. Bell 1998).

Limiting the empirical foresight mission, mainly to possible futures, implies that we try to figure out possible areas of the future state space to become occupied by various CAS regimes, actors and actions – which already delimits the state space. The previous discussion further suggests boxing of the state space into rather small but distinct volumes, which regimes distinct identities. In each of the articles, the state space was

boxed into specific dimensions (article I), domains (articles II, III and VI), problems and issues to be addressed (article IV) or regimes (article V). These are illustrated in Figure 14 (see also Table 3 discussing the level of abstraction).

The 11 basins of article 1 are continua between dualities where both ends – e.g. decentralised and centralised or trust and distrust– cannot become occupied by a single system with a specific identity. This setting allows 22 potential basins (and their intermediary forms) to be employed in morphological design endeavours to come up with visions, scenarios or futures images. Each of the options boxes a discernible location in the state space and allows observation of larger and smaller basins.

Three basins in article II are derived from personal futures literature and these 'bowls' capture livelihood, accommodation and lifestyle "recipes" in the futures dreams of the youth. This structure and level of abstraction allows identification of attractors at the level of analysis that is relevant for policy design to make the dreams come true. Various clusters of dreams comprise attractors that have different profiles according to the type of region and thus each region (that is CAS) may host specific basins with their attractors.

The four basins in article III are based on convention on the dimensions of sustainable development: economic, environmental, social and cultural. There are numerous trade-offs between these dimensions: being economically sustainable may not allow reaching high rank in environmental or social sustainability and, in that respect, there are saddle points between the basins. This specification allows the analysis of the attractor landscape with basins, attractors and saddle points or separatrixes.

Article IV has 22 basins that observed the problems to be addressed by the specific societal policy (CAP). The problems and the measures addressing them comprise a CAS that evolves over time. The analysis revealed how the priority of the problems might change in the future and thus illustrated evolution of the attractors landscape.

The six basins of attraction in article V were based on historical analysis of regimes and regime shifts. They seemed to follow a specific life-cycle pattern captured by Adaptive Cycles. Each regime had a specific basin of attraction comprised by a specific location in nine dimensions and five propertied of the system, e.g. main source of energy and nutrients, internation trade, agricultural policy and feedback loops. The evolution of the basins of attraction illustrated how co-evolution of the regimes and their environments follows a clear cyclical pattern.

Article VI took six societal discourses capable for massification and formation of basins of attraction as a starting point: ethics, environment, health, food security and global markets. These are all manifestations of specific framing of sustainability. The analysis

revealed that gaining a position of a dominant basin of attraction by each of the candidates would bring about dramatically different outcomes in terms of animal production and organisation of the food system. Totally different parts of the state space would be occupied by the food system. Framing impacts of possible futures may be immense.

As it is obvious that there was not a specific method for boxing the state space, but here again pragmatism took over. Still, the task was informed and guided by the research questions and performed as a transparent, disciplined and systematic process as promised in Chapter 1.1.

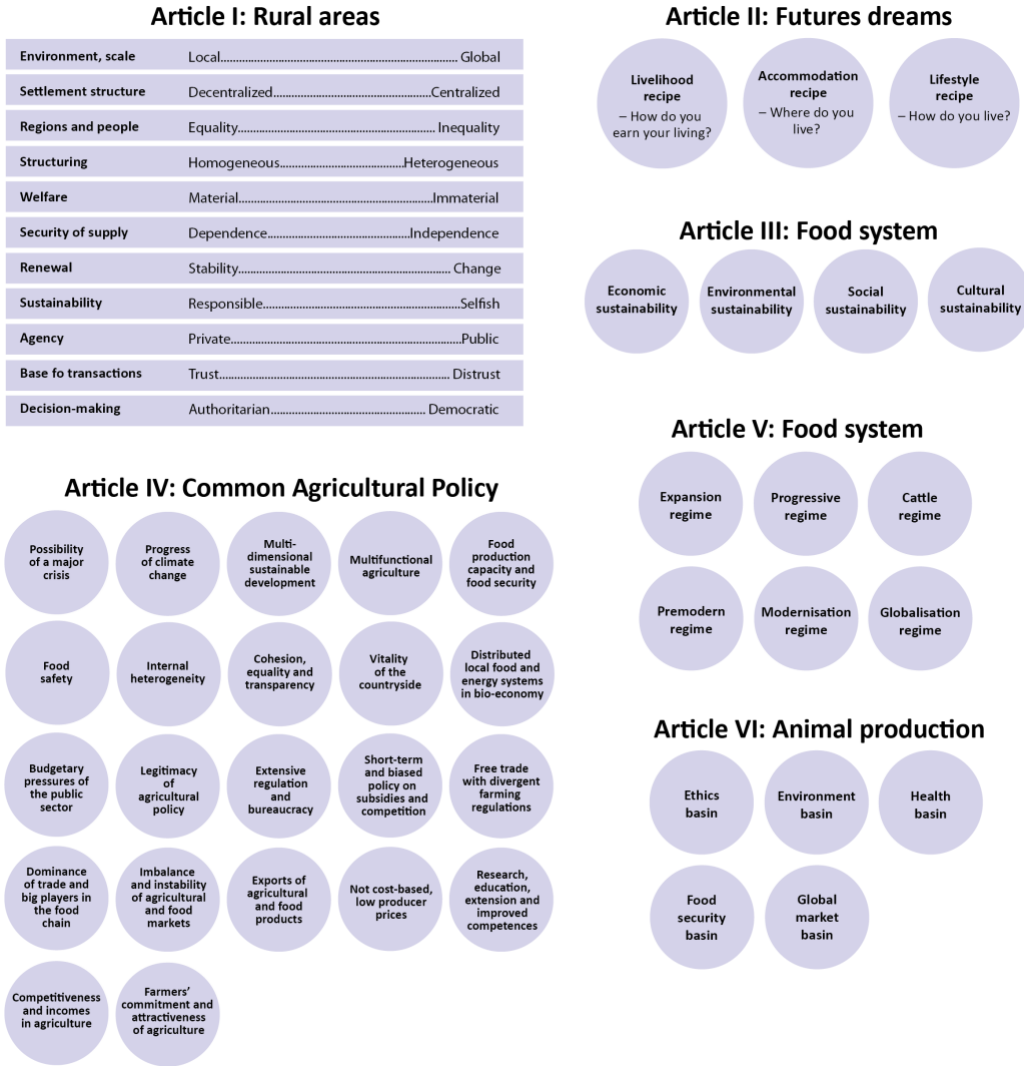


Figure 14. Empirical boxing of the state space in the research articles.

3.3 Identification of future attractors

After iteration of the feasible level of abstraction and boxing of the state space, identification of possible future attractors for the societal system was an empirical matter. The attractors took different instances depending on the context and, especially, the research question. Figure 15 illustrates this connection.

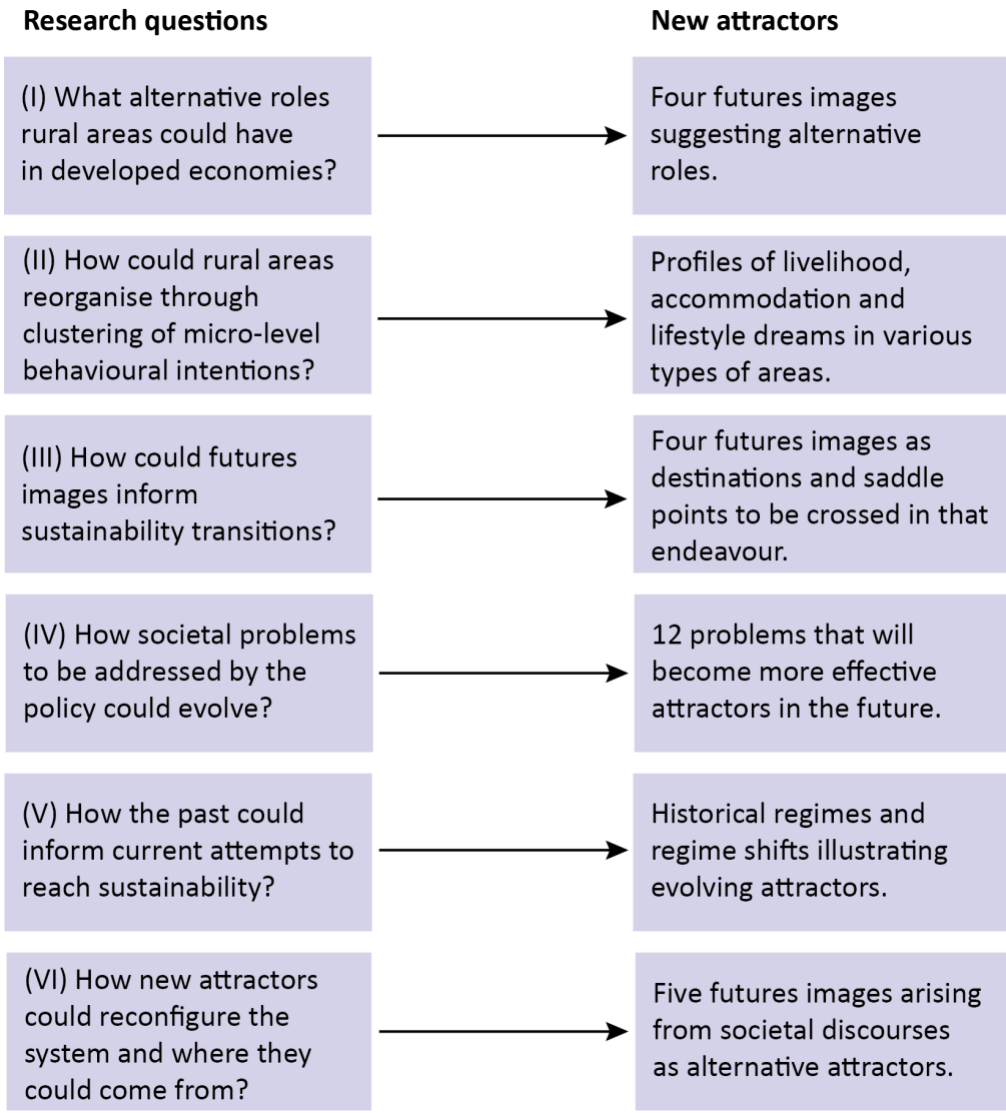


Figure 15. The research questions and responses to them in terms of attractors.

Regarding research article I, the question about alternative future roles of rural areas in the society was responded by introducing four futures images (Beers et al. 2010, 725; Bell 1997, 82; Polak 1973, 114–122; Vasileiadou and Safarzynska 2010, 1178) that represent four coherent but different locations in the accessible state space. Futures image is 'an expectation about the state of things to come at some future time' (Bell and Mau 1971, 23). These coherent wholes differ considerably and make informed choices in the present possible (Slaughter 1993). The four futures imaged represent rather large basins of attraction (e.g. decentralised bioeconomy) whereas their elements are more limited attractors (e.g. local involvement). These basins and attractors indicate around which kinds of activities various rural areas – which are evidently CAS – could cluster in the future along with organisation of new regimes.

In research article II, the demand for 'rural' in the future was sought for by investigating futures dreams of young people. Personal futures are not widely studied (Wheelwright 2005, 2009), but they may expose what kinds of profiles different types of areas have in the dreams that are primitive behavioural inclinations or intentions. They also profile the young people in terms of what kind of people are interested in specific types of areas and activities. Informed by these profiles, new rural policies can be designed, for example. The basins of attraction in each type of area (cities, urban-adjacent rural areas, rural villages, remote rural areas) consisted of three recipes (livelihood, accommodation, lifestyle) whereas elements of the recipes made up the attractors (e.g. multi-local living, own peace, large courtyard and gardening in urban-adjacent rural areas). These basins and the attractors manifest potential future clusters of activities in various types of rural areas that could become realised through self-organisation facilitated by the individuals following their dreams. These abstracted clusters or regional profiles consisted of specific attractors were responses to the research question.

Research article III discussed the potential of futures images to inform sustainability transition of the food system. Each actor in the system has unique goals, resources and objectives regarding sustainability (Flynn and Bailey 2014; Sage 2014). For this reason, provision of several alternative destinations for the sustainability journey may assist them in making possible and feasible choices in the present to take steps toward sustainability. Manifestations of four basins (economic, environmental, social, cultural) with their specific attractors (e.g. new trading methods, self-sufficiency, transparency, new food culture) were elaborated to serve as guiding stars for the societally preferable destinations featuring four dimensions of sustainability. As reconfiguration of CAS is based on self-organisation instead of central command or ownership of the system, engaging and inspiring images of the possible and desirable futures can inform the current actors in appealing and credible ways. Along with this, new clusters of actors, social movements and regimes could be born.

Public policies try to address societal problems (May and Jochim 2013) which are often wicked in the sense that attempts to resolve them create new problems (Rittel and Webber 1973). The evolution of the system of problems to be addressed by the Common Agricultural Policy (CAP) therefore sheds light to the future of the policy. The evolution of these problems was studied in research article IV with the expectation that their significance will change over time. As the most striking result, progression of the climate change would put food production capacity and food security in a clear pole position among the problems to be addressed by the CAP. All in all, 12 out of the 22 problems would gain more importance during 2020–2040 and reorganise the regime around a more concise cluster of problems.

Research article V documents an ambitious attempt to box a large volume of history of the food system into specific dynamic patterns and logics following Adaptive Cycles (AC; Gunderson and Holling 2002; Walker and Salt 2006). We asked if the regularities of the historical evolution of a specific system could serve as a heuristic tool for the becoming patterns. Six regimes and five sharp regime shifts were identified by using the AC model as an interpretative lens. Life cycles of the regimes seemed to obey the four phases of the AC (release, reorganisation, exploitation, conservation) with their specific characteristics. The system swapped basins of attraction and attractors several times upon regime shifts whereas the trajectory within each regime was defined by the AC life cycle model. The response to the research question was two-folded: food regimes have life cycles, regime shift happens after maturation of the regime, and the new direction for the system can often be found from the "reverse side" of the previous regime: from protectionism to free trade, from diversification to specialisation etc. This information has some heuristic capacity in the policy design for the future. It also shows how agglomeration of actors around new topics happened in the past to set up a new regime.

Finally, research article VI was looking for the sources of future attractors for the societal systems and the ways they could reconfigure the system – in this case animal production and the food system. Five prominent societal discourses were consulted as candidates for future basins of attraction: ethics, environment, health, food security and global market. How these five basins with their dimensions (food consumption and production, farming methods, markets and trade, metabolic basis, subsidies) could reconfigure the current regime was illustrated by means of Multi-Level Perspective mapping (Geels 2002; Geels and Schot 2007). Effective attractors for each basin had unique profiles: food security, vegan food, extensive farming methods etc. Attractors of the societal systems are fundamentally social constructs that emerge, reach 'massafication' potential (Iles 2021, 8) and institutionalise through social interaction (Locke 2004). The problem of finding new accessible locations for the societal systems in the state space could be overcome also through this kind of a process. This study also

explicitly discussed the clustering or massification potential and processes of alternative attractors.

The data in all articles was derived from literature as well as expert informants via interviews, workshops and surveys. The method to transform this data into final products (futures images, profiles, problems, regimes) was based on conventional content analysis, futures tables, Causal Loop Diagrams and Multi-Level Perspective mapping (Table 1). Details of the research processes of each article are highlighted in Figure 16. Details of the data sources, informants and application of research methods are given in the research articles.

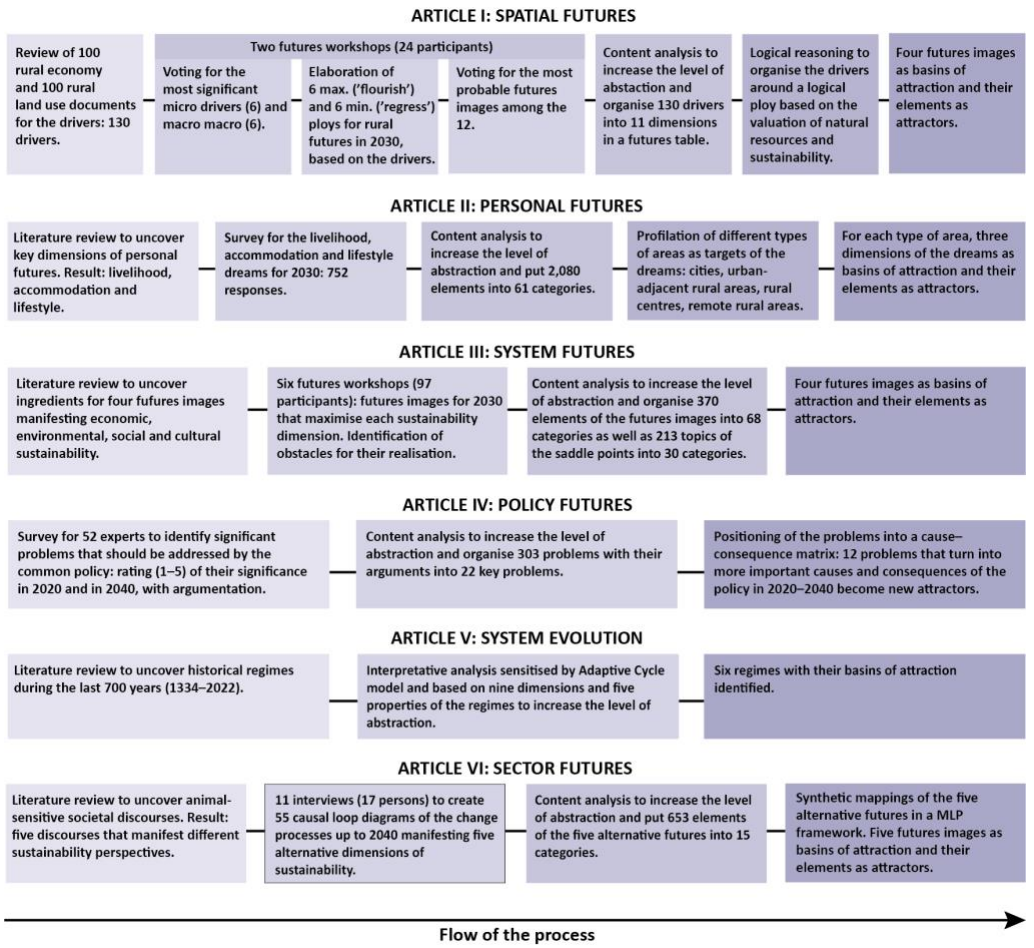


Figure 16. Methods used to tackle the three challenges: level of abstraction, delimitation of the choice space and indentification of future attractors.

4 Results of the application of the design principles: overview of the research articles

Each of the six original research articles presents a process where basins and attractors for the future regimes to settle are identified and assessed in the domains of agrifood and rural. Each of them also covers a specific spatial-temporal context. The following overview of the articles includes a summary of the main findings, whereas the process of reaching these results has been described in the earlier sections in general terms and in the articles in detail. The set of articles that was to be included in this dissertation was decided in such a way that a diversity of futures could be covered: spatial, personal, system, policy and sector futures.

Each of the articles present not only specific empirical findings but also highlights specific aspects of CAS foresight enterprise. Each foresight enterprise has a specific mission regarding the purpose of becoming aware of futures alternatives: personal, organisational or societal choice in the present. Three aspects are shared by several research articles: systemicity, framing and multiplicity. The results will be discussed next under these themes.

4.1 Systemicity as an empirical finding in CAS foresight mission

Societal policies exist to exploit opportunities and to address problems, the latter being in the key core of the Common Agricultural Policy (CAP) of the European union discussed in article IV (Systems view of the future of wicked problems to be addressed by the Common Agricultural Policy). The CAP has evolved from a rather simple market policy in the 1960s to a very complex and expensive societal policy chasing a long list of problems (Daubjerg and Swinbank 2016, Kuhmonen 2018). The system of problems to be addressed by the CAP in the future was found to be really extensive web of networked problems in the empirical inquiry: 22 key problems and 114 causal links between them (Figure 17). None of the problems can be expectedly resolved and any attempt to solve them would change the status of other problems in the 'jam' (article IV, p. 690), which is typical for wicked problems (Rittel and Webber 1973).

Based on the expert views, the list of most significant challenges to be addressed by the CAP would remain quite stable during 2020–2040. Only the negative impact of

climate change on food production capacity and food security would significantly grow in importance. Other causal links within the system of problems that would grow in significance were the negative impact of extensive regulation and bureaucracy on farmers' commitment and attractiveness of agriculture and the positive impact of research, education, extension and improved competences on competitiveness and incomes in agriculture. In addition, the negative impact of free trade with divergent farming regulations on competitiveness and incomes in agriculture as well as the negative impact of internal heterogeneity on legitimacy of agricultural policy would grow in significance. These basins with their contextual attractors would expand in the future. Expectedly, these topics would ask for more attention in the future, but putting more emphasis on them would not remove other problems.

The problem network status could provide some leverage points to intervene the system of problems. Driver problems (e.g. free trade with divergent farming regulations) are powerful targets of intervention as they can alleviate also dependent problems (e.g. food production capacity and food security). Networked problems (e.g. multidimensional sustainable development) ask for careful policy design and delivery as they affect the configuration of the whole system. Finally, punctuated problems (e.g. food safety) allow direct intervention without extensive repercussions.

Understanding the CAP problems as a Complex Adaptive System characterised by non-linear feedbacks, autonomy and self-organisation may assist governance of the policy field and getting rid of 'incremental, reactive, and path-dependent policy changes' (article IV, p. 684). Problems have been born at the system level, and they should be resolved at the system level, as everything is interconnected. This is very typical for CAS: they have no central command, they are not owned by someone, and they evolve through self-organisation. Once for a while one may observe that the system has turned very different from the beginning and hosts many characteristics that were not pursued or that were to be avoided. A highly institutionalised CAS – like the CAP – asks a huge amount of energy to become transformed as a system, as new incentives and powers should be provided for the system actors to change the structures from within through novel interactions. Addressing disparate problems may not remove the problematic system level characteristics that have turned wicked problems. Probably only a revolution following a radical transformation of the fitness landscape, or internal collapse of the CAP could change the system through a deep crisis.

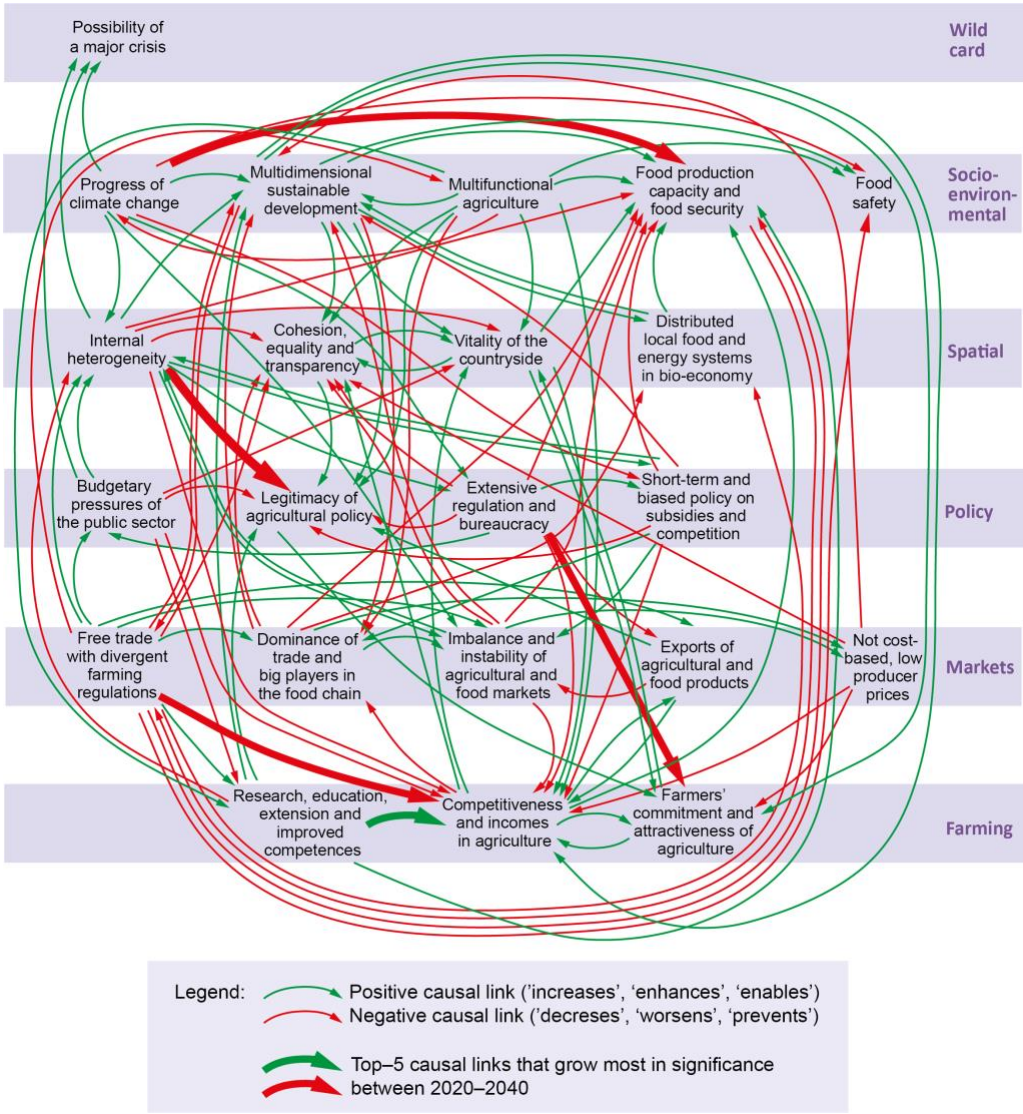


Figure 17. Causal loop system of problems underlying the CAP and its evolution in 2020–2040 (graphical abstract of article IV).

Article V (Transitions through the dynamics of adaptive cycles: Evolution of the Finnish agrifood system) discusses such transformation-through-crisis cases in the context of historical agrifood regimes in Finland. Adaptive Cycle model was used as looking glass to the history for the last 700 years. After discovering dimensionality of the state space in historical agrifood systems, it was possible to trace empirically their cyclical evolution and specify six regimes: Expansion, Progressive, Cattle, Premodern, Modernisation and

Globalisation regimes (Figure 18). The last regimes have lived for 25–50 years, the ongoing 30 years so far.

Life cycles of the regimes shared similar patterns: growth along with the occupation of a feasible location in the state space, decreasing diversity and increasing rigidity and fragility, loss of resilience after an external shock (weather, war, recession) and finally reorganisation with new attractors. The most significant regime shifts were related to the changes in the metabolic basis of the system and in trade orientation. A sharp crisis and loss of resilience was needed to facilitate regime shift, as deliberation and conflicting views of regime actors prevented planned, smooth transitions: 'while the release of the contemporary mode of organisation can have detrimental consequences for the system's capacity to deliver on its central function – feeding the people reliant on it – it opens up the window of opportunity for systemic renewal' (article V, p.13).

Interestingly, regime shift reorganised existing resources but also asked for system-external activation energy: 'They have taken the form of knowledge and innovations originating elsewhere in Europe (Progressive regime), the commercial value of forests allowing investments in iron tools and farm machinery (Cattle regime), imported synthetic fertilisers and fossil fuels (Premodern and Modernisation regimes) and EU subsidies (Globalisation regime)' (article V, p. 11). Another interesting feature in the past regimes shifts is related to the "reverse side" pattern. It was quite often that the attractors of the previous regime turned to their opposites upon the regime shift: from extensive and decentralised to intensive and centralised resource use, from system-internal to system-external inputs, from renewable to non-renewable sources of energy, from free trade to protectionism and back to free trade etc.

The history of agrifood regime shift provides valuable advice for the policy design aiming to maintain food security in all times. If the current global fossil-based agrifood system was to be replaced with a more sustainable one, some system-external activation energy could be needed again to facilitate growth after reorganisation. What could this be in this case: labour, sales revenues, subsidies? Furthermore, the past regime shifts advice to look at the reverse side of the current regime for the attractors of the next regime. The current regime is based on fossil fuels, free trade and interdependence, extensive subsidies, specialisation and concentration (article V, p. 10). Following the past logic, could renewable energy, protectionism, self-sufficiency, market revenues rather than subsidies, diversification and decentralisation play a key role in the next agrifood regime? These patterns and logics could assist heuristics and various foresight missions of the agrifood CAS.

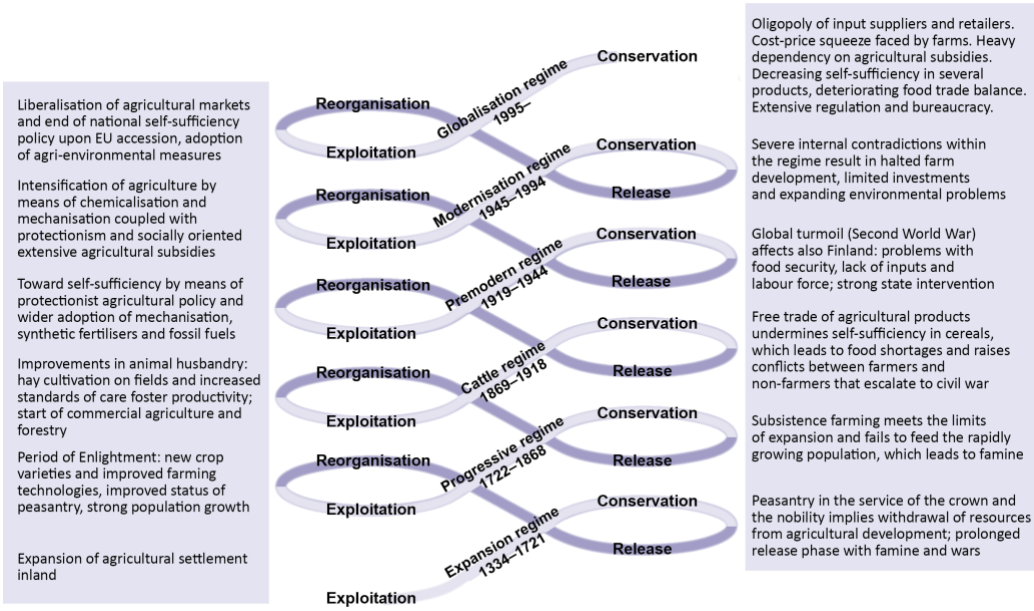


Figure 18. Adaptive cycles in the Finnish agrifood system in 1334–2022 (graphical abstract of article V).

4.2 Impact of framing effects as an empirical finding in CAS foresight mission

Framing effects are present in any research act along with application of specific theory, model, analytical framework, concept or domain of reality. It is quite often that manifestations of alternative futures crafted by futures research mission deviate a lot from each other. This is meant to observe the difference in outcomes of the choices to be made in present and in that way assist the choice. Even if the visions, futures images or scenarios were distinct, real-life evolution will often fuse their elements and blur their storylines. If these kinds of blurred, mixed and omnibus futures were designed, also their impacts would be blurred, and some important implication could be potentially missed that are present in the coherent, tidy futures. Coming up with these kinds of futures asks for intentional framing as part of the research process; this was the case in articles III and VI, especially.

Article III (Exposing the attractors of evolving complex adaptive systems by utilising futures images: Milestones of the food sustainability journey) studies sustainability journeys of the food system. The 20th century food regime has been increasingly characterised by the dominance of 'big players' in the retail trade and supply of farm inputs, extensive processing, packaging and cross-transportation fuelled by non-

renewable energy as well as long, non-transparent supply chains permitting unethical conduct and health risks (article III, p. 214). Many dimensions of sustainability are evidently at stake and a paradigm shift is called for (e.g. Loring 2023). Various "alternative" food systems provide some hints for more sustainable alternatives.

Attractors and saddle points to be crossed in the sustainability journeys were identified in the empirical inquiry. Four futures images – corresponding basins of attraction – were designed that maximised economic sustainability (Short Food Chain), environmental sustainability (Green Food Chain), social sustainability (Fair Food Chain) and cultural sustainability (Genuine Food Chain). Self-organisation of each of these was pushed by specific drivers and pulled by specific attractors that occupied the four basins (Figure 19).

Surprisingly, both the attractors and the saddle points in each four basins had common features. For the Short and Fair Food Chains many of them were related to governance of the food system: trading methods, ownership, public procurement, concentration, legislation, transparency, co-operation as well as organisers and players on the field. For the Green and Genuine Food Chains many of the attractors and saddle points were related to consumption (consumption habits, price-driven choices, self-sufficiency, self-made food, appreciation, food culture, know-how) and products (food processing, product development, production technology, certification, food brands, food tourism). In addition, low profitability of farming was an important saddle point in all but the last case. This means that the basins box a rather limited state space: what attracts you also binds you into specific basin. The four alternative regimes would occupy – more or less – reverse side of the current dominant food regime and realisation of any of them would imply a regime shift:

> 'These attractors are different from those of the 20th century corporate food system, which organised around manufacturing and processing to make food unperishable, transportable and suitable for easy shopping. Furthermore the results suggest that the main source of innovation and organisation comes from the food producers and the main resistance comes from within the inert, institutionalised and locked corporate food regime; especially from the powerful retail trade and from the consumers who are habitualised to easy and cheap food.' (article III, p. 221).

Sustainability that was used for delimitation of the state space is a vague and fuzzy concept (Phillis and Andriantiatsaholiniaina 2001), that as a stand-alone concept means nothing. Sustainability is a relational concept: sustainability of something in a specific context and in relation to something ('unsustainable', normative convention, indicator value etc.). The four dimensions of sustainability are based on convention. Sustainability as a concept can thus be used as a tool to delimit state space or define

future attractors for the system, but it needs to be contextualised. Contextualisation implies framing. In this case contextualisation was done by the participants of the futures workshops in which contents became co-created for the four futures images. Another set of participants would have framed the four dimensions of sustainability in the context of Finnish food system at least slightly differently. Sustainability is sensitive to framing effects and should be attached with a label: “use with care”.

	Short Food Chain for economic sustainability	Green Food Chain for environmental sustainability	Fair Food Chain for social sustainability	Genuine Food Chain for cultural sustainability
Drivers	Consumers and producers get bored with the dictatorship by the retail trade and unite their forces to bypass it.	Global instability and climate change drive the worried citizens and policymakers for regional self-sufficiency.	Acknowledgement of social inequality put responsibility and social justice to the core of food economy.	Food education and food enlightenment breed a new food culture.
Top-5 attractors	New trading methods Reorganised retail New ownership Food processing Public procurement	Self-sufficiency Product development Production technolgy Circular economy Self-made food	Transparency New trading methods Certification Co-operation Traceability	New food culture Food brands Food tourism Product development Food education
Top-5 saddle points	Consumption habits Low profitability Concentrated food trade Legislation, bureaucracy Price-driven choices	Lack of innovations Consumption habits Lack of appreciation Low profitability Environmental problems	Concentrated food trade Lack of organiser Lack of appreciation Low profitability International forces	Lack of know-how Lack of appreciation Consumption habits Lack of co-operation International forces
Hot spot of structural change	Trading and delivery	Production	Trading and delivery	Trading and delivery
Outcome	The short chain maximises the common value added by producers and consumers within the food chain. Consumers buy 40% of their food from the local food cell, 40% from the web shop and 20% from ordinary supermarkets.	The green chain maximises the local environmental capital stock and its productivity in food production in the long run. 20% of the consumer food is self-produced, 60% comes from the local region (<100 km) and 20 % comes from further away.	The fair chain maximises the food-related social capital among the stakeholders. 80% of the domestic food that consumers buy is certified and 20% is not.	The genuine chain maximises the food-related cultural capital. 95% of the domestic food purchased by consumers includes information concerning the producers and production sites, dates and methods, while 5 % remains without a history.

Figure 19. Drivers, attractors, saddle points, hot spots of structural change and outcomes of food system sustainability journeys guided by various dimensions of sustainability (graphical abstract of article III).

Article VI (Sustainability-driven regime shifts in Complex Adaptive Systems: The case of animal production and food system) analyses the role of animal production in the food systems for the future. The role of animal production in the sustainable futures of food systems has been under keen, contradictory and emotional public and academic debates in recent years. Indeed, animal production has both positive and negative impacts. Without doubt, the animal production will face changes in the future and its role in the food system might change. Where do future attractors come from and how could they reorganise the system in this case?

In MLP framework, landscape level pressures for change and niche tenders for novelty may open the dominant regime for change, for adoption of new attractors and ultimately for a regime shift. The study took five societal discourses as candidates for future basins of attraction: ethics, environment, health, food security and global market discourses. Each of them has potential for 'massafication' (Iles 2021, 8), for clustering of actors into these basins to realise a regime shift. Each regime shift would imply a significant change as compared to the current regime. For example, the volume of commercial animal production could range from 0 % (Vegan regime) to 200 % (Global market regime) of the current volume.

Current intensive farming method with lots of fossil and imported inputs would prevail also in Vegan, Health and Global market regimes. Environmental regime would divide farms into "production farms" and "agri-environmental farms", whereas Self-sufficient regime would be based on circular economy and organic farming methods. Indeed, the new attractors would reconfigure the food system with major impacts on production, consumption, farming methods, land use, agricultural subsidies and foreign trade (Figure 20). As article V points out, regimes and regime shifts follow each other in historical time, and this was observed also in this case along with emergence of new landscape level pressures arising from institutionalisation of the regime.

Alternative "sustainable futures" are often designed starting from the present: how could a certain current sustainability problem become alleviated. This approach includes the risk of staying with technical fixes rather than bringing about system level solutions. It also includes the risk of missing unexpected or unwanted outcomes. Taking a truly system level stance on the design of future alternatives and following disciplined imagination (Weick 1989) may provide access to holistic images with 'positive' and 'negative' aspects that might be missing in the probable or preferable futures that dominate sustainability studies. Taking radically different parts of the state space systematically as a starting point of the analysis and using methods that force informants to focus on their manifestations, is a feasible way to have all kinds of outcomes onboard. Being systematic was one of the premises of this study. All the five futures of this study maximise some dimension of sustainability with radically divergent outcomes, which indicates the fragility of the sustainability concept but merits of this method.

One of the challenges in crafting alternative futures derives from the presence of open futures: in principle, anything is possible. Taking a specific view on the possible futures is a must. There are many options for framing the future possibilities for CAS. All six alternative regimes manifest a specific framing of 'sustainability' and all can be said to be 'sustainable' from some specific perspective.

There is another perspective on the foresight of CAS futures than complying with some specific definition of sustainability, however. Many foresight missions are targeted on future basins of attraction with their attractors, “mountain tops” in the changed fitness landscape and new regimes. For this kind of a change to happen, the candidates should have a potential to redirect and reform the system. Coming up with a long list of trends, possible future states or potential niches can raise a justifiable question “so what”. Candidates for the cores of regimes should have a potential for clustering agents around these bases of gravitation, for massafication. This is rarely explicitly assessed in the designs of alternative futures. Observing this stipulation, societal discourses may be used as a framing tool as they have a massafication potential to upgrade into mainstreams. What was remarkable in employing societal discourses as framing tools was that they resulted in strikingly different outcomes when placed as guiding stars for future regimes.

	Current regime	Vegan regime	Environmental regime	Health regime	Self-sufficient regime	Global market regime
Landscape level pressures for change		• Ethical consumption does not allow exploitation of animals • Climate change mitigation	• Climate change mitigation • Reduction of nutrient leaks • Maintenance of agricultural biodiversity	• Growing costs of maintaining national health • Increased attention to personal health	• Global insecurity, volatility and risks • Climate change mitigation • The national economy leaks money and jobs	• Southern production regions will dry out • Export demand for water-intensive products will grow
Niche level tenders for novelty (examples)		• New competitive plant products • Taste-makers and trend-setters will change food attitudes and consumption habits	• Targeted policy for intensive and for extensive production • Circular economy becomes more extensive and fine-grained	• Health-based retargeting of taxes and subsidies • Health consciousness will increase • Minimal amount of red meat in public catering	• Principles and methods of organic farming and circular economy in use • Small-scale energy technology and use of various biomasses will develop	• Export-oriented policies • New farmers • Technologies and management practices of large units, foreign labour
Regime:						
Food consumption	• Versatile animal and plant-based products	• Only plant-based products	• 67% cut in meat consumption	• 33% cut in the consumption of red meat	• Versatile animal and plant-based products	• Versatile animal and plant-based products
Food production	• Versatile animal and plant-based products	• Only plant production on the best areas	• Intensive and extensive production will diverge	• 33% cut in the production of red meat	• Self-sufficient versatile production	• Animal production will double
Farming methods	• Intensive	• Intensive without manure	• Intensive and extensive separately	• Intensive	• Circular 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	• Self-suffiency in energy, feed and nutrients	• Lots of fossil and imported inputs
Agricultural land use	• Afforestation and clearing of forests for fields	• Previous fodder fields will be used for energy or afforested	• Previous fodder fields will be used for energy, afforestation or restoration	• Previous fodder fields will be used for energy or afforested	• All fields will be exploited for food production	• 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 new farmers
Foreign trade	• Large net imports of inputs and food products	• Net imports of inputs and some plant-based products	• Net imports of some plant-based products	• Large net imports of inputs and food products	• Net imports of some inputs (e.g. pesticides)	• Increased food exports imports of inputs
Emerging new landscape level pressures for change (examples)		• Animal-related biotopes and species become endangered • Limited nutrient stock • Losses in open landscapes and regional economies in unfavourable areas	• Administrative burden will increase • Large amount of support needed • Losses in open landscapes and regional economies in unfavourable areas	• Cattle-related biotopes and species become endangered • Administrative burden will increase • Differences among consumer segments will increase	• Conflicts arising from redistribution of power, markets and subsidies • Price competitiveness and need of support become challenges	• Local environmental stress will increase • Limited budget consumers face more expensive animal products

Figure 20. Landscape, regime and niche level characteristics in the current and alternative regimes (graphical abstract of article VI).

4.3 Multiplicity of attractors as an empirical finding in CAS foresight mission

The Finnish mass media tends to showcase only one option for the futures of rural areas: decay and the role of resource periphery. Research article I (Rural futures in developed economies: The case of Finland) offers 'antidote for intellectual

monocultures tending to dismiss the diversity of the rural areas' (p. 366). As rural people with their businesses, crafts and lifestyles now form a minority in developed economies, 'focus-gain' (Schackle 1955, 65) of the mainstream actors may be based on historical relics or narrow views seen between the bars of a paradigm prison (Kuhmonen 2010; Miller 2007). As rural areas with their unique natural resources may play many kinds of roles in the fossil free futures, this multiplicity of the potential roles deserves to be studied in transparent, disciplined and systematic ways.

Four alternative societal roles were defined for the rural areas: decentralised bioeconomy, colonial countryside, museum countryside and rural business islets. Main differences between these roles arise from the different valuation (more vs. less) and exploitation (promoted vs. not, sustainable vs. not) of natural resources why each of them would occupy radically different part of the state space. Decentralised bioeconomy could be called also "an involvement economy" as it would be based on equality of regions and people, responsible use of natural resources, trust as the basis of transactions and democratic decision-making. Colonial countryside could be labelled as "a rural mine" since it's foundations would be global scale, material welfare, selfish behaviour toward sustainability, private agency and distrust in transactions in which 'private profits made by the fortune hunters, intruders and global corporations override other objectives' (article I, p. 370). Museum countryside would be large "a traditional biotope" featured by centralised settlement structure leaving place for nature, inequality of regions and people (part of the country will be closed), immaterial welfare, distrust originating from majority autocracy and authoritarian decision-making not observing the wishes of the rural minority. Finally, rural business islets would be manifestations of "survival society" in which market liberalisms dominates nation states and leaves rural areas to struggle for survival of the strongest. In this future, the settlements would concentrate around survivor locations in market competition, inequality of regions and people would accentuate, and private sector would dominate the shrinking public sector (Figure 21).

The attractor landscape for spatial futures is evidently rugged, allowing numerous larger and smaller basins of attraction to coexist. Every region is a CAS organised by specific attractors. Presenting alternative positions is the state space as continua allows visualisation of the diversity of "more than five" options in a feasible manner. 11-dimensional state space then captures 22 alternative locations in the ends of the continua as well as several locations in between them. This specific version of morphological analysis allows many alternative combinations in configuring e.g. visions, futures images or scenarios while keeping the choices transparent. Each location in the continua represents a specific attractor. This methodological choice shows the multiplicity of attractors even if ending up with a limited number of them.

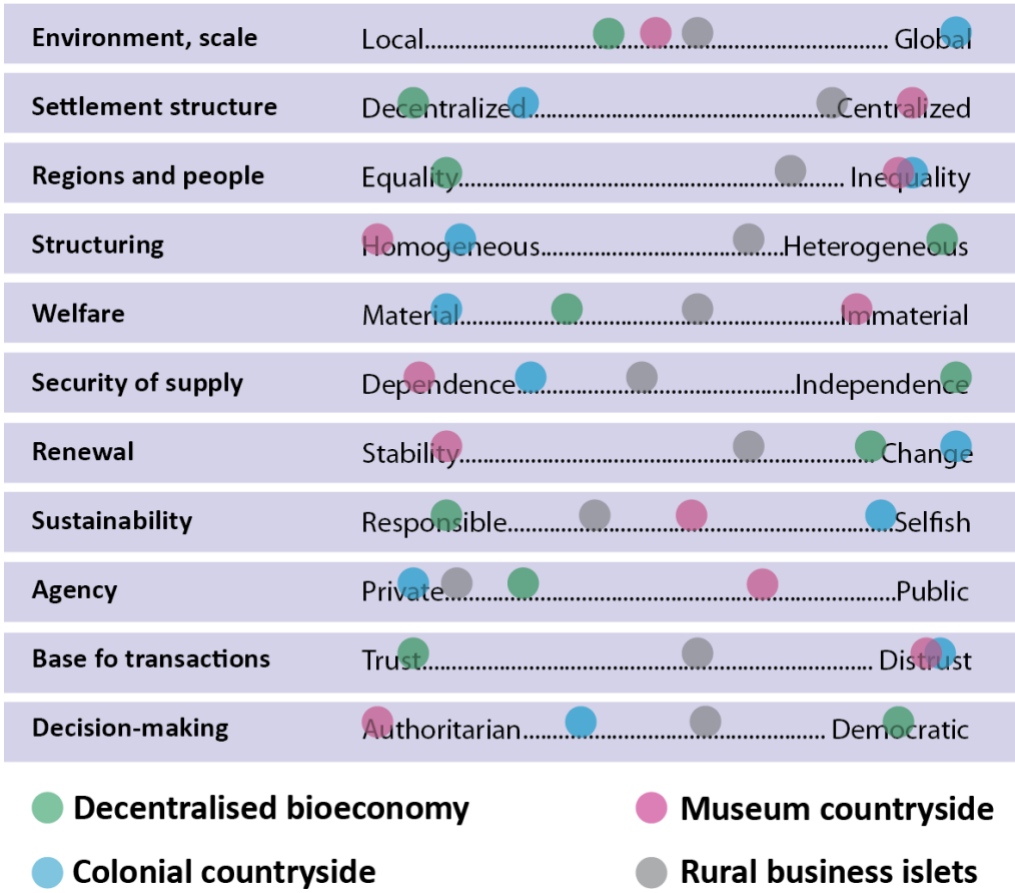


Figure 21. Four alternative rural futures inhabiting various parts of the 11-dimensional state space (graphical abstract of article I).

Macro-level societal patterns arise from clustering of micro-level behaviours (Schelling 2006). Societal evolution during the past decades has witnessed urbanisation and downturn of rural population. Whether there could be some new behavioural tendencies germinating among the youth that could affect this trend, is a critical question for rural futures. This was studied through a survey of livelihood, accommodation and lifestyle dreams of the youth in research article II (How do rural areas profile in the futures dreams by the Finnish youth?).

Diversity of personal futures is high. The study, however, observes strong clustering in the elements of the futures dreams that are targeted to different types of rural areas as each of them had a distinctive 'profile of attraction' (article II, p. 98). If the dreams were realised, activities in each type of rural area (which are CAS) would self-organise around the most common elements of the dreams, the profilers (Figure 22). City

dreams were urban: services jobs, small apartments, services nearby, urban attractions etc. Rural areas close to city would be organised around homes as peaceful and cosy places detached from the urban life and other people. Rural centres (villages) would be organised around small-scale life and local social interaction that provides safety and communality. Remote rural areas would be organised around self-made life, traditions, freedom as well as living in the nature and with the nature. In the Finnish context nature was an important part of the dream in all kinds of areas. It was observed that there is also a life cycle in the dreams as 'becoming older, having a family and having a profession seemed to increase the probability of rural futures' (article II, p. 98).

All types of rural areas were destinations for futures dreams of the young people. Through various policies it is possible to respond to the dreams and improve fitness between the dreams and opportunities of the region (Thissen et al. 2010) – observing that dreams may change along the life cycle and not all dreams will be realised. Attractors that are common in each type of area also suggest the policy makers to take action to realise the dreams and increase the vitality of the area.

Diversity dominates personal futures as compared to macro-level futures in which less attractors are present. Each person is pulled toward the future with unique personal attractors. Through increasing the level of abstraction is became evident that – despite of different wording – the contents of the futures clustered around specific topics that were typical for the destination of the dream. The attractors of urban futures were strikingly different from the rural futures. Analysis of personal futures also makes visible the diversity of attractors in rural areas that are not present in the mass media or macro level studies.

The same methodology has been used in two other studies (Kuhmonen and Kinnunen 2017, Kuhmonen et al. 2021b) and the results were surprisingly similar. 'With this approach it is possible to produce future-oriented, systematic and rich knowledge as compared to extrapolation of demographic trends or place-specific case studies' (article II, p. 99).

Target of the dream and its predictors	Livelihood dream	Accommodation dream	Lifestyle dream
Cities • *Urban region* • *18–24 years* • *Single* • *No children* • *Student or unemployed* • *Elementary school, high school or university*	**Other (miscellaneous)** *Services jobs*	**Sea nearby** **Block of flats** **Semi-detached houses** **Row house** **Small apartment** **Other (miscellaneous)** *Good connections* *Services nearby* *Small countyard* *Large apartment*	**Visiting cities** *Undefined hobbies* *Communality, friends* *Connected to nature* *Other (miscellaneous)* *Societal involvement*
Urban-adjacent rural areas • *Urban region* • *18–24 years* • *Couple* • *Children* • *Employed* • *High school or vocational school*	**Two or more places** *Salaried work* *Services jobs* *Manufacturing jobs*	*Neighbours far away* *Lake nearby* *Own peace* *Nature nearby* *Good connections* *Detached house* *Large courtyard* *Large apartment* *Old house*	*Housework* *Machinery* *Gardening* *Freedom* *Self-sufficiency* *Being alone* *Animals*
Rural centres • **Intermediate** *or rural region* • *25–30 years* • *Couple* • **Children** • *Employed, unemployed or* **outside labour force** • **University of applied sciences** *or university*	**Two jobs** **Small place or work unit** **Nature** *Salaried work* *Services jobs* *Culture and tradition work*	**Neighbours nearby** **Services nearby** **Semi-detached houses** **Row house** **Small courtyard** *Island* *Sea nearby* *Wooden house* *Old house* *Large courtyard* *Large apartment*	**Societal involvement** **Safety** **Communality, friends** **Connected to nature** *Handifrats* *Self-sufficiency* *Peace and silence* *Nature sports*
Remote rural areas • *Intermediate or* **rural region** • *25–30 years* • *Couple* • *Children* • *Outside labour force* • *Elementary school or vocational school*	**Primary sector jobs** **Two jobs** *Entrepreneur* *Manufacturing jobs* *Sustainability*	**Island** **Villa, summer cottage** **Farmhouse** **Wooden house** *Lake nearby* *Nature nearby* *Neighbours far away* *Own peace* *Detached house* *Old house* *Other (miscellaneous)*	**Hunting and fishing** *Societal involvement* *Freedom* *Family life* *Connected to nature* *Animals* *Handicrafts* *Safety* *Being alone* *Peace and silence* *Machines* *Other (miscellaneous)*

Strong profilers (location quotient >2): **bold purple font**, weak profilers (location quotient >1): *regular italic font*. Background predictors of each destination include current place of residence (type of the municipality), age group, family status, children (yes/no), working life status and highest completed education.

Figure 22. Profilers of various types of areas in the futures dreams of young people aged 18–30 years (graphical abstract of article II).

5 Discussion and conclusion

This study discusses the challenges in trying to penetrate to the non-existing future of Complex Adaptive Systems (CAS). There are several barriers along the way. One of the barriers is related to epistemological grievances. We don't have data from the future and the future is open. All our cues are conjectural and subject to fail. We have no means to convince ourselves about their truth-value in the present. Still, we should make choices and commit ourselves to a specific pathway toward the future. All our choices in the present will materialise in the future. Furthermore, as the futures are open, there are many variants of possible CAS futures. To make sensible choices, the number of future alternatives should be reduced in a meaningful way to end up with a relevant set of distinct alternatives. Tackling these challenges could be assisted by design principles of alternative futures. The principles concern the choice of an appropriate level of abstraction, delimitation of the choice space and identification of future attractors that guide the evolution of the systems. Next, findings of the study are summarised, for the science and for the practice.

5.1 For the science: design principles

How to choose an appropriate level of abstraction to study alternative futures of societal complex adaptive systems?

Complex adaptive systems are kaleidoscopic in the sense that they host multiple hierarchical levels as well as emergence and self-organisation arising from ongoing dynamics of local interactions. Any attempt to anticipate or control the futures of these kinds of systems is subject to several biases and ambiguities. Just a small turn and the world looks different in your kaleidoscope.

Observing that CAS lives at multiple levels, the iteration of the level of abstraction is crucial in any research mission on their futures. There is no common principle, rule or method for choosing a correct 'flight altitude' for the analysis. Figure 23 illustrates the multitude of aspects that were observed to play a role in the research articles serving the research mission that was documented in this study and how they were used as design principles.

Futures of complex adaptive societal systems are always studied from a certain perspective. The first task is to set research questions and to plan a research process that can possibly provide answers to these questions. The level of abstraction has an intimate relationship to the range of questions that can be asked and answered (Floridi 2008, 315). The level of abstraction could be "low" if the objective is to achieve denser understanding of a certain topic or to extend current understanding to the neighbourhood areas (diffusion strategy), whereas it should be "high" if the objective is to achieve metalevel understanding or to spot grey areas in the current understandings (abstraction strategy; Kuhmonen 2010, 19). Some parts of the possible state spaces of the societal systems may be already widely studied, whereas some other parts may reside outside the light of the research enterprise. As the basins and attractors of these systems tend to box only a small part of the possible state space, there are often large areas that have not been studied or covered by the current system. Most part of the societal research is focused on studying the existing systems and regimes that are organised around very limited force fields (diffusion strategy). For example, the dominant food regime (globalisation regime, corporate food regime or agro-industrial regime) covers a very specific part of the state space that is possible for the food systems: fossil metabolism, lowest possible monetary production cost -based prices without observing externalities, specialisation, concentration, interdependence etc. (articles III and V). As every trend and regime has an end, it would be valuable to learn about alternative configurations and locations in the state space that could be inhabited by the food systems. The abstraction strategy could uncover these territories. This study has used a quite high level of abstraction for this purpose in the contexts of agriculture, food and rural to serve societal choices.

As soon as the answerable and meaningful research questions have been formulated, the challenges of abstraction deal with the operationalisation of the research strategy. Descriptive frame of reference is the ocular of the kaleidoscope that defines the view that can be seen. In the empirical inquiries of this study, the frames of reference were particularly visible in articles I, III and VI, and they were related to valuation and exploitation of natural resources as well as to sustainability. As the mission of futures research is the design of future alternatives and the futures are open (i.e. there are many of them), multiple frames of reference are often useful. This multiparadigm perspective (Denzin 1989; Gioia and Pire 1990; Lewis and Grimes 1999) is also a way to avoid the paradigm prison (Kuhmonen 2010, 148; Miller 2007, 179–180). For example, choosing alternative dimensions of sustainability as frames of reference produces totally different manifestations of possible and/or preferable futures (e.g. article VI). These outputs serve especially abstraction strategy where uncolonized state spaces are explored. An explicit but transparent choice of the frame of reference serves also focusing of the empirical inquiry as some thousands of possible futures, details and 'anomalies' (Lakatos 1970, 135) may be left out of the scope. The frame of reference is

always normative (Lincoln 1985, 29) as it defines what can be seen in the kaleidoscope, and for this reason transparency is needed in the research act.

Concepts are hammers, drills and saws of a scientist who explores and explains the reality. The hammers we use in penetrating to the non-existing future derive from the past. How far to the future can you penetrate with the torch light of the past? At some point darkness of the non-existing wins the lightness of the existing (Simon 1996, 156). No matter how rigorously disciplined imagination will be exercised, there are limits in grasping the becoming. Becoming may be very different from being (Chia 1996). How far can answers to the research questions rely on the existing understandings, conceptions, regularities, patterns, causal relationships, logics and rules? Visions and futures images may serve this critical task of distancing (Inayatullah 2013) better than (forecasting) scenarios that face the risk of 'extending the present' (Slaughter 1993, 294). If there are for example cyclical patterns in the evolution of specific systems, they have heuristic potential for anticipating the future. While path dependency is a solid attribute of the evolution of the CAS, it can be overcome by the choice of an appropriate manifestation of the future (visions and futures images rather than forecasting scenarios) and application of empirical methods that encourage distancing from the present. Sometimes a rather high level of abstraction may assist in escaping the complexity and noise of the present.

Many explorations of alternative futures of the complex societal systems envision alternative future states at some point of time, rather than the mechanisms of their emergence. This is also the case in many volumes of this research mission: articles II, III and IV illustrated alternative states of the future, whereas articles I, V and VI addressed also the processes of becoming. Focusing on the processes of becoming may also help in getting rid of path dependency of thought. The emphasis, logically, derives from the research questions.

Summing up, the choice of an appropriate level of abstraction in the studies of societal CAS futures is primarily a pragmatic question. Ultimately, it should be a transparent choice rather than 'a matter of intuition' (Sayer 2000, 19) and provide 'meaningful' answers to the research questions (Floridi 2008, 115).

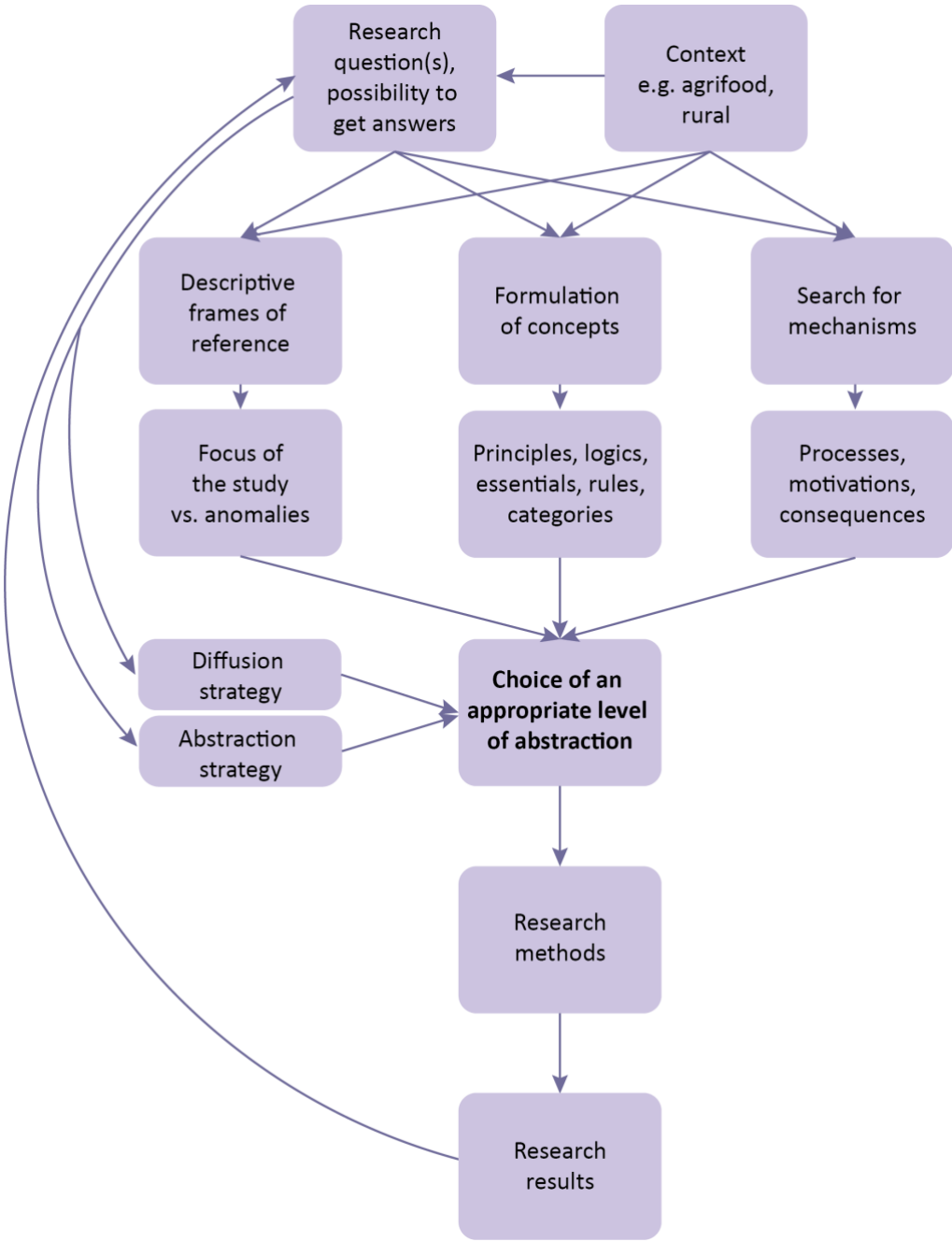


Figure 23. Choice of an appropriate level of abstraction.

How to delimit the choice space for the futures of societal complex adaptive systems?

Current regimes of societal CAS tend to box only rather limited volumes of the possible state space (Kauffman 1993, 191). This is due to common tendency of the actors to do local rather than global search in the rugged landscape (Levinthal and Warglien 1999). Over time, they cluster in the basins of attraction or mountain peaks of the fitness landscape, self-organise and set up regimes leaving large part of the state space unoccupied. The regimes gradually become more institutionalised, more resistant to change, more homogenous, more focused and also more vulnerable (Conti et al. 2021; Kuokkanen et al. 2017). Deviant behaviour becomes difficult and rare, as the incentives of the system reward compliance with the dominant regime: being similar is a merit and being different becomes a risk for the actors. Growth, efficiency, productivity and profit show how efficient the regime is in attracting and extracting resources from the state space. The loss of diversity implies loss of flexibility and so the regimes generally turn fragile and less resilient along with their maturation (Kuhmonen 2023). Finally, some external shock or turbulence can lead to release, phasing out or failure of the regime and open door for a regime shift (Holling and Gunderson 2002; Walker and Salt 2006). This life cycle pattern can be used as a heuristic tool for the delimitation of choice space in CAS foresight missions (Figure 24).

If the dominant regime is at the early stages of the life cycle it can possibly grow through expanding to correlated landscapes. In this case adaptation implies stable development with some degree of predictability: the future may be a modified extension of the present and diffusion strategy may be a possible research strategy (Chapter 5.1). If the dominant regime is at the mature stage of its life cycle, it has less possibilities for growth in its existing form. If there is a pressure for growth (e.g. continuous growth of food production due to population growth), the system must reach new areas in the state space to reach additional resources. In these parts of the landscape, novel basins and attractors prevail. They cannot become occupied by the system without bifurcation and without swapping attractors upon a regime shift. In such case the fog of the future is thick, predictability is low (Laszlo 1985; Mannermaa 1991) and Knightian uncertainty prevails (Knight 1921).

If societal CAS regimes occupied only limited parts of the state space, the alternative basins would be rather specific and limited locations in the state space, defined by a small number of effective attractors. The basins and allowed areas for the regimes are small boxes within the wide state space (see Figure 12 as an example of the food system). This sets a challenge for the foresight: how to box limited volumes – rather than broad areas – of the state space as places where the becoming regimes could settle in? The becoming regimes should be as sharply designed and configured as the current ones. Historical evolution of the state space and regimes and well as dimensions of the system in question may shed some light for this task. Qualities of the existed

regimes and landscapes provide valuable information for the analysis of becoming landscapes: the systems may for example share same dimensions (e.g. metabolism in the case of food systems). The width and quality of the boxes depend on the research question and topic of the study. In this study, the boxed state spaces included dimensions (article I), domains (articles II, III and VI), issues to be addressed (article IV) and regimes (article VI).

Summing up, delimitation of the choice space for the futures of societal CAS asks for systematic approach as the becoming regimes possibly occupy only specific, limited volumes of the state space. At a general level Archer's morphogenetic approach may be helpful: historical structures condition actors who, over time, elaborate them in interaction (Archer 1995). History matters in framing why the discussion of correlated and uncorrelated landscapes (Kauffman 1993, 181) as hosts for future basins, attractors and regimes are useful. For some needs, more familiar basins, attractors and regimes can be designed. For some other needs, more distant future wildernesses have to be explored to mark potential locations for future basins. Pragmatism prevails also in this task, as the futures are open and there is no theory or specific method to besiege the "right" terrains.

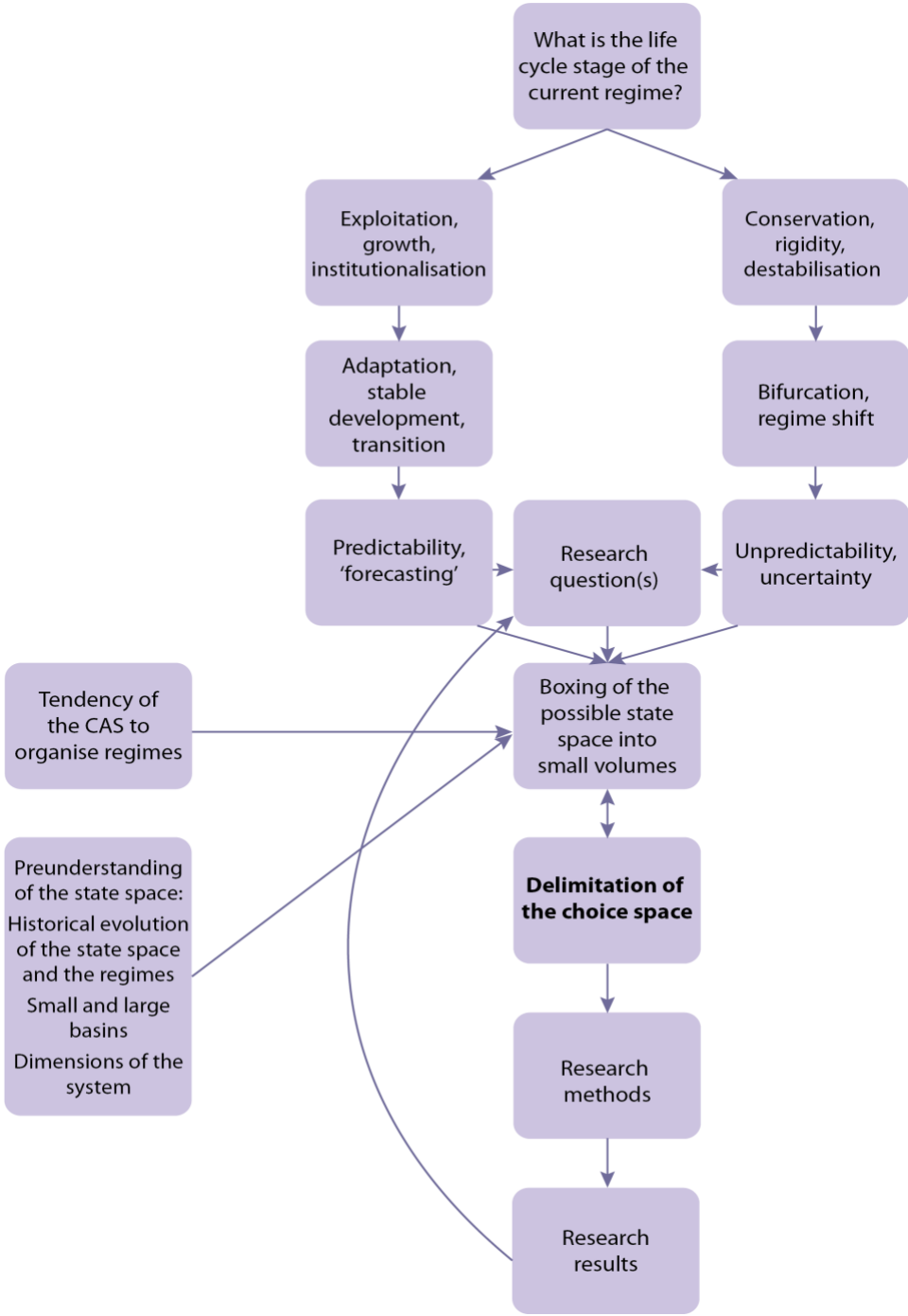


Figure 24. Delimitation of the choice space.

How to identify future attractors for the societal complex adaptive systems?

After the iteration of feasible level of abstraction and delimitation of the state space, the identification of future attractors for the societal CAS is an empirical task in which the rich toolbox of futures research methods can be exploited. The potential basins, attractors and regimes are often described through visions, futures images, scenarios or horizon scanning. Even if the organising principle or logic of future alternatives is decided along with the choice of the level of abstraction and delimitation of the state space, the actual elements and contents of the futures still need to be found.

To find these primitives of the becoming regimes that occupy varying locations of the state space, many kinds of methods and logics can be used. The results should provide explicit and final answers to the research questions. In this vein, qualities of the becoming attractors could be problems, policies, practices, patterns, preferences and much more (Gerrits 2012, 157; Kauffman 1993, 174; Room 2011, 130). As the functions of various systems are quite stable (e.g. provide nutrition, energy, logistics or housing), the previous regimes carry important information about dimensions of the system and qualities of the potential attractors. As article V indicates, the new attractors could materialise from the "reverse side" of the previous regime. Delimitation of the choice space (Chapter 5.2) also paves some avenues for identifying the possible attractors (Figure 25).

In order to qualify for attractors of new regimes, the candidates should have potential for clustering actors and actions (Gerrits 2012, 155; Iles 2021, 8). Such potential is hard to foresee. It could be sought after by organising votes among experts and stakeholders on the probability, preferability and/or possibility (article I). Societal discourses and social movements could also be studied as to whether they host and incubate seeds of change (article VI). Furthermore, exposed preferences for the future as primitives for intentions and actions may include new embryos of attractors (article II). Another normative approach includes ranking of topics that could become attractors (articles III, IV and VI). Finally, past regime shifts and reorganisations show how new attractors emerged and took over (article V). As the new attractors should have the capacity for clustering and 'massafication', there should be a magnetic pull toward them and/or a push to leave the present ones. The system with its actors should cross saddle points on their migration or adaptive walks toward the new destination and, for this reason, the journey needs incentives to be seen on the horizon: better profits, better environment, higher ethical standards, more fair distribution of costs and benefits, better food security, a place for the dream come true etc. Alternatively, some saddle points may vanish along with the evolution of values, technologies, social norms or policies. It is quite often in futures studies that alternative futures are designed or assessed to be possible, preferable and/or probable (Bell 1998), without explicit

discussion of the capacity of their potential to develop into guiding establishments of societal developments and regimes.

The rich methodological toolbox of futures research can assist in the attempts to identify future attractors and assess their massification potential (Chapter 1.1). In this study, rather simple methodology was used that was based on futures workshops, futures tables, Causal Loop Diagrams, Multi-Level Perspective mappings as well as thematic and content analysis. This kept the research processes transparent.

The manifestations of alternative futures are often visions, futures images or scenarios in the practise of futures research. Each of these may serve different purposes. Visions are normative descriptions of the states of future at a certain point of time (Van der Helm 2009, 100). They are widely used powerful tools to engage and inspire actors to move toward a common target (de Jouvenel 1967). Futures images similarly capture (most often) several alternative future states at a certain point of time. Their derivation processes intentionally try to weaken or break the link to the present through distancing (Inayatullah 2013) in order not just to extend the present. Scenarios focus on the pathways from the present toward alternative futures (forecasting scenarios) or from the future to the present (backcasting scenarios). A scenario also necessarily includes some sort of description of the future state in the end of the pathway (Kosow and Gaßner 2008). While futures images may better serve the sociology of order and anticipation, the visions and the scenarios may be more useful servants of the sociology of control (Byrne and Callaghan 2014, 107). Notwithstanding the format, many kinds of representations of alternative futures may serve the foresight mission to uncover future attractors for the societal CAS.

Summing up, disciplined imagination (Weick 1989) is needed to distance from the present and identify potential topics and force fields that could capture the ideas and actions of the agents of change. This is needed to ignite and scale up societal discourses and social movements to entrench settlements on new terrains of the state space and gradually configure new regimes through ‘massafication’ and institutionalisation.

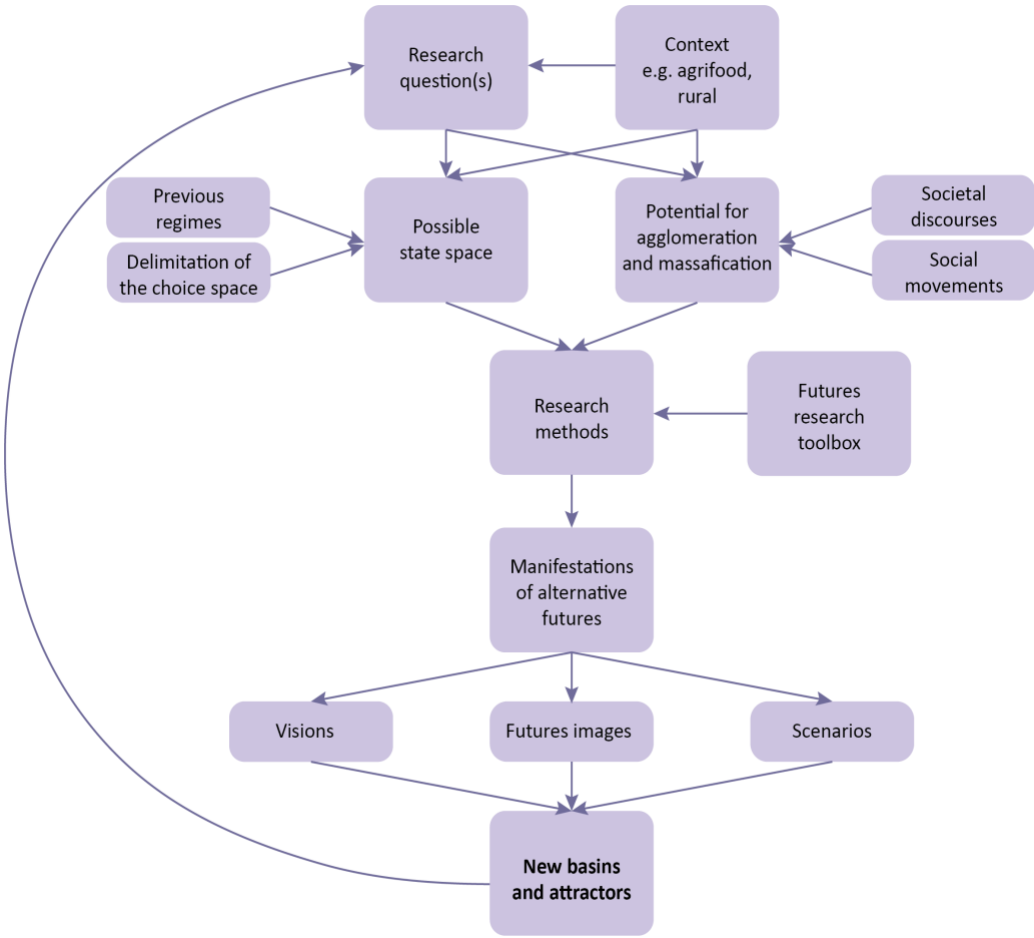


Figure 25. Identification of future attractors.

5.2 For the practise: food system and rural futures

The six empirical studies illustrated alternative futures for the Finnish food system and rural areas. The results are relevant for many other developed countries as well. Focus of the empirical studies has been in the anticipation of bifurcations or regime shifts and elaboration of possible future alternatives following them. Following the idea by Mannermaa (1991) and Laszlo (1985), this is the topic in which evolutionary futures research could make a contribution. There are many signs that bifurcations can be expected: sustainability transition research is booming (e.g. Fischer-Kowalski 2011; Loorbach et al. 2017; Markard et al. 2012; Rauschmayer et al. 2015), several global developments seem destructive (e.g. FAO 2018; Kummu et al. 2021; Rockström et al. 2023; Steffen et al. 2015) and contradictory discourses on the feasible pathways to the

future are blooming (e.g. Bulten et al. 2021; Geels 2011; Wittmayer & Schäpke 2014). Something big is expected to happen. Sitting ahead of this situation, it would be an intellectual waste if the futures research enterprise created just reflections of the past or extensions of the present. The argumentation of Mannermaa (1991, 358) is worth of repeating also here:

> '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.'

As Figure 26 indicates, rural and agrifood futures have many possible developments paths if x-rayed with a transparent, disciplined and systematics approach. Many of the possible futures are antidotes for the detrimental developments of the past. As such, many of these expose the "reverse side" of the current regimes. They are not predictions but observe cyclical patterns, behavioural intentions, normative sustainability frames and deepening policy concerns to be addressed. Their details can be accessed in the six articles.

The most critical point in intended realising regime shifts is not the lack of ideas for future attractors and pathways but getting enough steam for the novel enterprises. That may happen through introducing inspiring manifestations of the future alternatives and engaging change agents with them. 'If you can see it, you can be it' (Kelly 2025). Unfortunately, historical evidence shows that regime shifts rarely happen this way. The dominant regimes are path dependent, highly institutionalised entities that resist significant changes and for this reason, a crisis is needed to change the track of developments. Even in these cases it is helpful to have concrete designs for the developments that might take place after the bifurcation, since 'becoming aware of different future alternatives' (Slaughter 1993, 290) is the key to survival and success in any potential future.

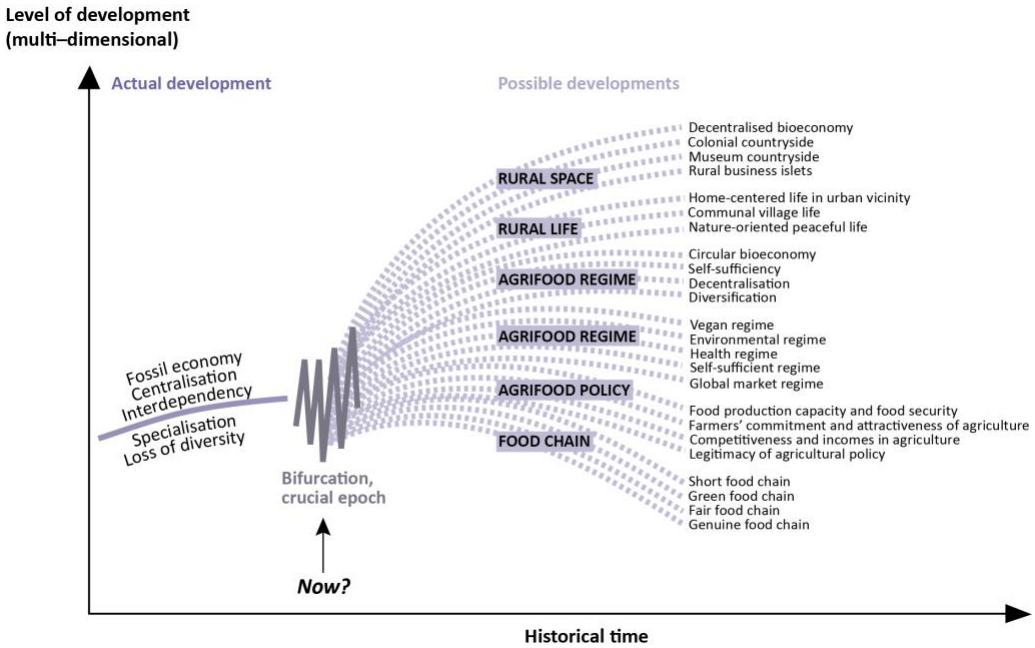


Figure 26. Possible agrifood and rural developments after bifurcation.

5.3 Avenues for further research and limitations of the study

All our efforts to penetrate to the non-existing future are propositional, conjectural and subject to failure. We have no means to convince ourselves about their truth-value ex ante. The future lurks in the world of the metaphysical. Kant (1724–1804) promoted the role of synthetical á priori propositions and intuition in expanding our sphere of knowledge (Kant 2003). As the future does not exist, Kants's idea that knowledge is not fully dependent on the experiences is a valuable key for moving beyond the known to the metaphysics of divergent worldviews. de Jouvenel (1967) acknowledged the conjectural nature of knowledge on the futures and emphasised the role of foreknowns for the designs of alternative futures (ibid., 113–114). History matters, but does not predetermine societal futures. Cooksey (1996) featured the role of cues in reaching correspondence with the alternative explanations of the reality. Immanuel Kant (2003) struggled his whole life with the challenge of expanding our sphere of knowledge beyond the experience through á priori intuition (at the age when natural sciences dominated). And this is the real challenge: even if the futures are open, even if we know that they can be very different from the present and even if we know that we have only cues, we still need to find even a vague ground for our choices in the present – and all these choices will materialise in the future. We need to expand our contemporary

sphere of knowledge about future possibilities. To be successful in this mission, more metaphysical discussion is needed within the futures research and not just application of some methods; this is one of the key messages of this study.

The futures research enterprise serves the need and the possibility to make choices for future pathways in the present (Slaughter 1993). The first step toward this goal is the ability to make productive (research) questions. With our specific needs to know something about future alternatives, can we formulate "correct" research questions? Observing that societal CAS are huge systems with many levels and subsystems and diverse evolutionary processes, formulation of productive research questions is a key challenge.

If we manage to define our knowledge needs properly and set research questions accordingly, the epistemological grievances pop up on the stage. There are thousands of possible answers to any research question on the futures of societal CAS. They could ask for limited or radical distancing from the present. They could ask for distancing from the past patterns, universals, conceptions and concepts that are used to understand and describe the past and current reality. They could ask for skills to create inspiring and engaging manifestations of future alternatives that are capable to attract and cluster actors in organising completely new regimes through 'social movements' as Mannermaa (1991, 358) illustrated. The three design principles related to the iteration of appropriate level of abstraction, delimitation of the choice space and identification of future attractors for the CAS may help in the ideational and practical struggles.

The design approach has an established nest in the design school of strategy. The impetus of this approach is 'to design a strategy that establishes, allows and/or promotes a continued fit between the organization and its external environment' (Chermack and Coons 2015, 72). Designs should be simple results arising from 'designing multiple possible solutions to a given problem, based on a variety of perspectives' (ibid., 73). Design science features systems approach and comprehensiveness (Gano 2015, 60). These notions resemble many elements that have been discussed in this study, for example evolving fitness landscapes, systems, multiple future alternatives and choices in the present. As futures research is not a descriptive science working with facts and truth values but rather a social technology (Kuhmonen and Kuhmonen 2015; Niiniluoto 2001), design is a more appropriate name for the process and its output serving 'creation and design of tomorrow' (Inayatullah 1990, 136) than some traditional idea of justified true belief, verification or prediction.

There is not a single research act that could escape the fallibility of the attempts that besiege possible, preferable or probable territories in the future state space. This study is not an exception. Regimes of the societal CAS with their attractors seem to converge toward very limited and very specific parts of the possible state space. This means that

a productive foresight research mission should be able to point out very sharp and specific configurations of these systems instead of very broad and generic tableaus. There is an evident chance to miss the target for many reasons. One may obey the principles of triangulation strategy and employ several data sources, investigators, theories and methods (Denzin 1989, 237) as well as utilise various 'certainification' practices (van Asselt et al. 2007) to escape the epistemological grievances. None of these practices – some of which were employed also in this study – can remove Knightian uncertainty. All cues of the futures of societal CAS are potentially fallible and possibly affected by desirability, availability, narrative, incompleteness, irrelevance, anchoring, framing and analytical biases. This study is not an exception that could have escaped these evils. In all cases, trying to cover a correct part of the state space resembles throwing darts from a long distance. Transparency is needed to allow readers observe potential shortcomings of the research process in this respect.

In this gamble, all means may be legal (ref. de Jouvenel 1967, 17) as long as they are transparent, disciplined and systematic. This research has borrowed quite carelessly from other disciplines including evolutionary biology, ecology, organisation studies, computer science, policy studies, management, sustainability science, evolutionary economics, complexity science, systems research, sociology and philosophy. Access to different futures may ask for diverse tools and rationalities. This approach may be rebuked on the grounds of the autonomy of various sciences in developing their own theories, concepts and methods to describe, explain and predict the world (Newton-Smith 1981). It is a risky business to take concepts and analogues out from the domain and context in which they have been incubated and legitimated. This study is positioned in the futures field, but its conceptual basis is a patchwork. The risk of abuse of the borrowed materials has been alleviated by transparent and explicated placement of the concepts into the analytical frameworks of this study.

Observing the risk of becoming an outlaw, such risk may be justified. The adoption of some specific role as a member of the society or a specific science may lead to lock-in of thought and action and to a narrow vision toward the future. Even if the societal regimes occupy a narrow position in the state space, there are most often several possible positions in the landscape. One of the foundational principles of academic futures research is the fight against colonialisation of the future. Is the museum countryside promoted by the mass media our only choice (article I)? Do all young people cluster in cities as many argue, not mentioning that it is obligatory rather than a dream after all educational opportunities have been concentrated in the cities (article II)? Is the green food chain the only option and all other dimensions of sustainability can be given up (article III)? Will the CAP try to resolve the same old problems forever without any true reform (article IV)? Does the current dominant globalisation regime have an end without a major crisis (article V)? Should all people eat only vegan food or do the benefits of domestic animals matter in terms of agrobiodiversity, food security

and vitality of remote rural areas (article VI)? The only way to avoid colonisation of the future by some societal actors and social movements is the production of many alternative manifestations of possible futures. Importantly, futures science is an integral part of the society. Consequently, the societal values, discourses and contradictions are reflected in the research topics. This is also the case in this study: many of the research ideas and questions reflect societal challenges and discourses. On the one hand, this could be considered as a problem for the "purity" of the science. On the other hand, if the futures research does not follow the pulse of the society and provide alternatives for one-sided 'truths', it would possibly serve irrelevant or past-based choices.

5.4 Conclusion

As a conclusion, futures research does not produce "correct" results. It may identify valuable questions and meaningful answers. As the future involving human action is open, the truth value of our inquiries remains inaccessible ex ante. The value of the questions and answers lies in their ability to expand our sphere of knowledge of future possibilities. In this service, a writing on the toilet wall may be as valuable as a dissertation for someone who is about to make a choice for the future. Futures work has always a low efficiency coefficient because of the huge number of future alternatives. For this reason, it should be made in large volumes and with diversified ideas, approaches and methods.

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Rural futures in developed economies: The case of Finland

Tuomas Kuhmonen [a,*], Irene Kuhmonen [b]

[a] Finland Futures Research Centre, Turku School of Economics, FI-20014, University of Turku, Finland
[b] Jyvaskyla University School of Business and Economics, P.O. Box 35, FI-40014, University of Jyvaskyla, Finland

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ABSTRACT

This study presents four possible images of rural futures in Finland: decentralized bio-economy, colonial countryside, museum countryside and rural business islets. They are distilled through literature reviews, futures workshops and futures tables. Alternative specifications of structures, contents and agencies result in highly divergent states of key dimensions and, consequently, divergent rural futures. This diversity challenges the conventional public wisdom or intellectual monoculture that considers decay as the only future for rural areas. Key challenges in crafting plausible but divergent futures images are finding an appropriate level of abstraction or "flight altitude", establishing a credible logic or model for the system of futures, defining roles for the agency and applying a proper balance between imagination and discipline. This study provides one example for tackling these challenges. It can be utilized to stimulate ideas of using futures images as a social technology or tool for social learning about alternative rural futures. This intellectual perch is an antidote for intellectual monocultures tending to dismiss the diversity of the rural areas.

1. Introduction

For what are the rural areas needed in developed economies? Common key words that are used to describe rural futures in the public debate and several studies are recreation, retirement and regression (Amcoff and Westholm, 2007; Lennert and Robert, 2010; Lowe and Ward, 2009). Using different looking glasses or world hypothesis (Pepper, 1942, 142–143) could result in different conclusions. After looking at the grand challenges of mankind – for example, the transition from oil economy to bio-economy, the increase in food demand, the scarcity of freshwater, the climate change, the loss of biodiversity, pollution and concerns about the security of critical supplies – it becomes evident that rural areas could have many fates. Many grand challenges have essentially rural solutions. The rural minority will have a major challenge in feeding, heating and fuelling the urban majority in their cities. To overcome this flux between passive and active roles of the rural areas in developed economies, some new avenues of though are needed.

A key challenge in outlining alternative roles for the rural areas arises from our limited capability to comprehend complexity and uncertainty. All sceneries of social life are complex. As individuals or as collectives within organizations, cultures or nations we all live in our partially insulated micro-cosmoses belonging to the nested branches of complex, hierarchical and adaptive social systems (Simon, 1996, 9). Uncertainty and our need to manage the complexity make us hungry for predictability (Heiner, 1983, 567). They keep up our desire for habits, routines and institutions (Swindler, 1986, 281). The same hunger has created the demand for ancient and modern ways of studying futures as instances of "social technologies" (Burns, 1986, 28; Niiniluoto, 2001, 375). Even though our *á priori* judgment of true uncertainty is always subjective, contextual and limited by experience (Knight, 1921, 224–230), we may employ futures studies methodologies to not only project the covering laws to the future but also to uncover metaphysical "synthetic *á priori* judgments" (Kant, 2003, 11) that expand our *á priori* knowledge and understanding.

However, extending causal explanations to the future to simulate them is a risky business due to discontinuities and evolving contexts. Using loose pattern explanations (linear, wave, jump, exponential, nested, noise, break; Kamppinen and Malaska, 2004, 68) that may host a diversity of alternative causal substances is another way to probe the futures. Attempts to apply this peculiar technology may serve "creation and design of tomorrow" (Inayatullah, 1990, 136) by constructing systems of "predictive argumentation" (Aligica, 2003, 1035) and "inspiring actions and structures that address the grand challenges" (De Smedt et al., 2013, 432) of each micro-cosmos. We may explore, simulate and justify the specific outcomes of the dialogue between various structures and agencies in the incubation of futures. Essentially, futures research methods and processes are examples of *social technologies or platforms for social learning* (Robinson, 2003). This approach also assists in distinguishing the roles of structures and agencies explicitly in emerging futures: despite of complexity, uncertainty and our limited foresight, the alternative futures do not just "happen".

This study discusses rural futures in the context of a developed economy and provides an example of futures studies as a design tool in social

* Corresponding author.
E-mail addresses: tuomas.kuhmonen@utu.fi (T. Kuhmonen), irene.a.kuhmonen@jyu.fi (I. Kuhmonen).

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learning about rural futures. We want to demonstrate how the dialogue of structures and agencies may bring about several alternative rural futures. Our examination of the possible outcomes takes the form of *futures images*, which are configurations of alternative end states of developments. The scenery of these images is Finland: a small (population 5.5 million) developed country in northern Europe with a rare combination of extensive rural areas, extremely low population density, rapid socio-economic transformation and high economic wellbeing. In 2013, rural areas covered 95% of the land, population density reached 18 inhabitants/km^2, the share of agriculture and forestry in employment was 4.4% and GDP per capita was 37,000 euros (Statistics Finland data). The article starts with contextualizing the study and proceeds to discuss method, data, interim results and final futures images. The article is concluded with general reflections about the use of the approach as a social technology and a tool for social learning about rural futures.

2. Storyline of past and "structural inheritance"

The heading of the storyline of the rural change in Finland is shared by many developed economies. Since the wars in the 1940s, agriculture and forestry, along mechanization and modernization, have released most of their labor force to other industries. Regional main cities have received numerous new inhabitants, implying large-scale depopulation of the most remote rural regions. Rural areas have been incubators of city dwellers. Many services, which were extended to rural regions still in the 1990s in the era of the Nordic welfare state, are now pulled back to main cities like reverted rivers. In remote areas, the layers of economic activities have become thinner, but the urban-adjacent areas have been able to replace job losses with new inhabitants: commuters. The deeper division of labor resulted in a diversified economy and a better standard of living for all. When people were better off, they tended to use their extra earnings on services. When most services are produced and consumed simultaneously – in the same time and place – the growth of services was engaged to regional concentration of population and economic activities.

Along these developments, the role of the countryside in society has changed. For decades, rural areas "produced" and released new labor-force, who lacked rural jobs and moved to cities. Population of the 20 largest cities tripled in 1950–2013 and their share in total population grew from a quarter to a half (derived from Statistics Finland, includes municipal mergers). On the rural verge, about 1.5% of the population inhabit 68% of the country. However, this rural *well of labor-force* will dry out in the future. Until the 1980s, the majority of Finnish exports were agri-food and forestry products. Now dawn of a bio-economy could valorize natural resources in novel ways, and all natural resources are located in the countryside. Consequently, the role of the countryside as a *source of raw materials* could even expand. Rural areas have provided nature-based welfare since the hunting-gathering society. In the future, many lifestyles diversify the role of the countryside as a *source of welfare* (e.g., rural housing with commuting or remote work, self-sufficiency, green care, nature sports, fishing & hunting). Along these transformations, the rural population has become a minority, which gives impetus for new opportunities and conflicts along the way toward new societal roles. In developed economies, the rural minority is affected by the dreams, fears, needs and power of the urban majority.

Alternative futures take place in specific places and in the ether of time. The past is manifested in "structural inheritance" (Archer, 2000, 307–308), which affords and constrains choosing specific futures. In the Finnish rural areas, at least four aspects of structural inheritance condition future choices and development paths. First, the space of rural activity is *geographically dispersed*. The logic of agglomeration lies within city boundaries, but coordination and governance of the rural activities follow the logic of a dispersed economy. Second, rural activity is *bound to specific places*, which has many implications. Fields, forests and minerals cannot be moved and transplanted to new places where business booms. Due to the law of diminishing returns in the biological processes, the "industrialization" of primary industries faces problems. The rural businesses are bound to be rather small and local, and so is the scale of success. Third, the *adaptability* of the rural economy is limited in some respects. The evolution of biological production is slow (e.g., change of animal stock or crop varieties), the yield of natural resources cannot become regulated in the same way as a machine (e.g., natural conditions have an effect) and several sunk costs glue the activity to the existing line of action (e.g., expensive buildings with few alternative uses). Renewal of the rural economy is relatively slow. Fourth, rural activity is often severely *policy-dependent*. The use of natural resources, the supply of food and the supply of energy are sensitive issues, which many societies wish to control, regulate, tax or subsidize. Rural bureaucracy is an institution. Among others, these four features provide structures for the various agencies that effectuate ploys for rural futures.

3. Methods, materials and interim results

There is no general theory about the future, and this is why the choice of the best research strategy and methodology is guided by the research topic and by the research problem. This study aims at distilling rural futures, which include observations about the specific structural inheritance and the role of agency in emergent futures. Possible futures are iterated by relying on traditional futures studies methods as a four-step process: content analysis, futures workshops, futures tables and futures images. We have used *content analysis* of the relevant literature for identifying drivers and elements of alternative rural futures, *futures workshops* for structuring ploys for the futures and a *futures table* for providing coherence of structures, contents and agency in the futures. This research strategy allows oscillation between single drivers, alternative ploys, coherent prototypes and underlying universals and, in this way, calibration to an appropriate level of abstraction in the final images. Finding a feasible "flight-altitude" or level of abstraction is one of the most critical challenges in covering the field of possible futures of complex phenomena (Levins, 2006). The research process with interim results before the final images is presented next. Since the interim results (drivers, elements, futures tables) are part of the research process, they are discussed in this section along with methodological notes and remarks.

3.1. Content analysis: drivers and elements of the futures

As the first step, conventional content analysis (Hsieh and Shannon, 2005, 1286) was carried out to identify drivers of change. Documents (research and foresight reports, planning documents) that represent diverse domains and perspectives on rural economy and on rural land use were chosen, 100 documents for each strand. Appropriate search strings were applied for finding documents in the web and in the scientific databases, for example rural economy + future and rural land use + future. The candidate documents were studied for their contribution (e.g., a major planning document), relevance (e.g., foresight study on land use patterns), comprehensiveness (e.g., inclusion of major rural businesses) and insightfulness (e.g., novel alternative futures). After this screening, 100 most prominent documents per theme were selected for the analysis based on the judgment of the authors. The documents were from recent years (97% published in 2005 or later) and the timespan in the foresight and futures studies was mostly 15–35 years. The rural areas were defined as regions outside the regional main towns; drivers of change were considered as broad forces and developments, which affect the purpose (what), the location (where) and the way (how) of utilizing rural space. Factors providing answers to these questions were identified, arranged into generalized nodes and registered for their frequency (hits). These data sources capture the ideas and observations of scientists, policy-makers and experts of rural, regional, economic and social development.

The most often mentioned drivers of change in both strands of data were environment and sustainability, processes of concentration and dispersion, technological development, the expansion of regulation and rural areas as a source of welfare and as an origin of natural resources. The drivers were arranged into domains of economic, governance and personal and their strength and breath (megatrend, trend, weak signal) was obtained from the source when possible. Table 1 summarizes 15 drivers with highest frequency of hits for both strands of data; taken together, 130 different drivers were identified.

Regarding the literature on *rural economy*, drivers related to personal domain (31%), economic domain (30%) and governance domain (29%) played rather balanced roles. Drivers related to personal domain included a broad array of megatrends (e.g., competence & capacity for renewal, welfare & health), trends (experience-based choices, roots & traditions) and weak signals (ethical choices, life control). Megatrends (globalization & interdependence, productivity & resource efficiency) dominated economic drivers, but also some trends (bio-economy, subsidy culture) and weak signals (ecosystem services, immaterial consumption) were identified. In turn, weak signals (holism, decentralization) and trends (regulation, new communality) were common within the governance domain. Among the few megatrends there was the driver with the highest frequency of hits within this strand of literature: environment & sustainability. This first strand of data exposed 76 drivers.

Regarding the literature on *rural land use*, economic drivers (46%) were more common than governance drivers (33%) or personal drivers (21%). Megatrends (e.g., urban sprawl, pronounced role of accessibility) and trends (attraction of cheap rural housing, regional specialization) were equally present among the economic drivers, whereas weak signals in this domain were rare (local phenomena: food, energy, nature, democracy). Within the governance domain, trends (promoting compact settlement structure, strategic land use planning) and weak signals (local planning, crisis of everyman's rights) were equally present; megatrends were rare but again included the most common driver within this strand of literature: environment-based planning. This second strand of data exposed 54 drivers of rural land use.

The interim conclusion of the previous flux is evident. The bewildering array of drivers with varying strength, breath and domain frames a multiversum of positive, negative and stagnant futures. In a hierarchical and complex setting, some rural areas and activities are exposed and sensitive to some particular selective forces or drivers only (Allen, 2005, 452). The impact of these forces may be very case specific. Evidently, the diversity of habitats for rural life forms face the possibility of zillion futures.

Table 1
Most frequently mentioned drivers of change in the two strands of literature.

Rural economy	Rural land use
1 Environment & sustainability (M)	1 Environment-based planning (M)
2 Bio-economy & natural resources (T)	2 Promoting compact settlement structure (T)
3 Technological development, ICT (M)	3 Centralization (M)
4 Expansion of regulation (T)	4 Urban sprawl (M)
5 Local phenomena: food, energy etc. (T)	5 Rural areas as source of welfare (T)
6 Unequalization of humans and regions (T)	6 Expansion of regulation (M)
7 Centralization & urbanization (M)	7 Technological development (M)
8 Safety & vulnerability (M)	8 Decentralized energy system (T)
9 Competence & capacity for renewal (M)	9 Unequal access to services (T)
10 Globalization & interdependence (M)	10 Local planning (W)
11 Dispersion & decentralization (W)	11 Pronounced role of natural resources (T)
12 Pronounced role of energy (M)	12 Diversification of lifestyles and housing (W)
13 Welfare & health (M)	13 Strategic land use planning (T)
14 Aging population (M)	14 Unequalization & polarization (M)
15 Crisis & major change (W)	15 Increased leisure & tourism (M)

M = megatrend, T = trend, W = weak signal; the classification is mostly adopted from sources.

3.2. Futures workshops: ploys for the futures

The second step of the research strategy was comprised by futures workshops. Workshops are a useful tool for creative structuring of extensive and complex phenomena (Bell, 1997, 300). Each of the drivers and elements discussed above could contribute to dozens of alternative rural futures. A lot of structuring, sense-making, contextual and temporal interpretation and even imagination (Jungk and Müllert, 1987) is required in arriving at ploys of alternative rural futures. However, the output of a workshop is heavily dependent on the design and participation. For example, too few participants are unable to bring in a rich array of perspectives and ideas whereas too many participants fail in working interactively and collaboratively in a shared mission (Mannermaa, 1999, 48). In the organization of the workshops in this study the possibility of a directional bias (top-down or bottom-up), a perspective bias (narrow view) and a normative bias (preference-based selection) were taken into consideration.

Directional bias was alleviated by organizing two workshops focusing on the impacts of markets and policies ("macro-workshop") and on the impacts of personal choices and behaviors ("micro-workshop"). New regimes for rural futures may arise top-down from the interplay and transformation of landscape level macro forces top-down or emerge and consolidate bottom-up from the micro level niches and domains (de Haan and Rotmans, 2011). *Perspective bias* was alleviated by selecting the 12 participants to represent an expert matrix (Rikkonen and Tapio, 2009, 981) with two dimensions: spatial level (local, regional, national) and sector (state, municipality, research, trade unions & NGOs). This matrix was applied to both workshops and it proved out to be a sound solution to gain both regional and professional insights. The persons were invited for the workshops on the basis of their experience in regional and land use issues. They represented important organizations in this field: central ministries, regional councils, local municipalities, farmers' unions, research institutions, nature conservation associations and local action groups, for example. *Normative bias* was alleviated by forcing the participants to present both positive and negative futures in a balanced way. This procedure challenged the preferred futures of each participant, reduced the risk of reproducing purely past-based projections and enhanced creative reorganization of the drivers and elements into coherent ploys (Dator, 1993).

The procedure was the same in both futures workshops and facilitated a compromise between professional competence and intuition. Within the three hours intensive session each of the participants first listed independently three most significant drivers (macro or micro) based on their own ideas; these were collected and generalized into thematic topics. Finally, the participants put a vote for each theme by simultaneously raising a card rating its significance (scale 1–5). After voting, six most significant drivers were taken as the basis of ploys (Table 2). Two ploys or narratives for rural futures were elaborated for

Table 2
Drivers of change voted as most significant ones and their scores (max. 60) in the two futures workshops.

Macrofactors	Microfactors
1 Natural resource economy (58)	1 Entrepreneurship & renewal (56)
2 Centralization & urbanization (51)	2 Infrastructures & technological development (56)
3 Rural business (49)	3 Bio-economy (49)
4 Sustainability & climate change (48)	4 Politics and policies (48)
5 Municipal affairs (46)	5 Exploitation and quality of natural resources (47)
6 Regional divergence (44)	6 Provision of services (46)

each driver by answering the questions "how would the rural areas flourish due to this driver: a maximum outcome for rural areas" and "how would the rural areas regress due to this driver: a minimum outcome for rural areas". The elaboration was organized as a World Café (Slocum, 2005). After presenting and discussing the outputs, the participants voted for their probability to become realized at around 2030 (scale 1–5). This second step resulted in 12 drivers and related boundary sketches or min–max ploys for alternative rural futures.

The most significant drivers in the two strands of literature and in the workshops did not deviate much from each other: aspects relating to natural resources, technology, policy, regional development and the environment were present in both lines of data. The fates of rural economies and rural municipalities – providers of public services – had much more pronounced role in the workshops than in the literature, however. Surprisingly, entrepreneurship as a manifestation of taking the initiative and capacity for renewal was considered as the most important driver of rural change at the micro-level, but counted very few hits in the literature on rural economy and none in the rural land use literature. Evidently, the small but balanced group of experts in the workshops observed the importance of agency more explicitly than the large community of scientists and land use experts in their studies, programs, plans and guidelines.

The boundary min–max ploys for rural futures offered a rich pool of coherent prototypes for futures images by 2030. These sketches were important contributions in achieving integrity. Four ploys which were voted as the most probable ones among the 12 ploys in each workshop are synthesized in Table 3. A blooming countryside along sustainable and decentralized use of *natural resources* was the only theme in top-4 futures in both workshops. It came up in two manifestations in both workshops. On the basis of this evaluation, the fate of rural areas is strongly bound to the ploys that define the use of natural resources. Another top-4 meta-level ploy deals with *policies and politics*. This force has manifestations in several ploys related to the municipalities, regional divergence, rural infrastructures (regional policy) and conditions for utilizing natural resources (environmental policy). Surprisingly, the most significant micro-level driver entrepreneurship did not result in a top-4 future for the rural areas, which indicated that the experts were not able to craft a proper ploy for it or were not confident about its role. The contributions of the futures workshops altogether indicate that there is a portfolio of ploys for possible and probable (Amara, 1981) rural futures, some of which are preferred (maxs) and others unpreferred (mins) from the rural point of view.

Table 3
Futures voted as most probable ones by 2030 and their scores (max. 60) in the two futures workshops.

Futures driven by macrofactors	Futures driven by microfactors
1 Rural areas will regress driven by problems in *municipal affairs*, when resources are not nursed, rural areas will decay and people look for scapegoats. (36)	1 Rural areas will flourish driven by *bio-economy*, when competent people and firms benefit from the value-chain and thereby rural areas attain a new culture and a role in society as the best place to live. (49)
2 Rural areas will flourish driven by environmental *sustainability and climate change*, when ecosystem services become valued products and locality-bound lifestyle becomes mainstream. (34)	2 Rural areas will regress driven by *politics and policies*, when these overrun individuals and contradictory sectorial policies restrict and erode private initiative and support stags only. (42)
3 Rural areas will flourish driven by *natural resource economy*, when superior competence and technology facilitate dispersed refinement of biomasses around the countryside. (33)	3 Rural areas will flourish driven by *infrastructures and technology*, when the local energy, electric cars and decentralized "Silicon Valley" vanish the economies of agglomeration and the reasons for concentration; the countryside is a sustainable place to live. (42)
4 Rural areas will regress driven by *regional divergence*, when rural areas become vassals and face colonialism, unfair competition and increased distrust. (33)	4 Rural areas will flourish driven by *sustainable exploitation and high quality of natural resources*, when agile and flexible production extracts sustainable welfare from them and cares about their quality. (42)

3.3. Futures table: coherence of structures, contents and agency in the futures

The integrity of the futures images or scenarios is a cornerstone of their value as a tool for planning, policy or further research. A futures table, crystallizing the key variables (themes, topics, fields; drivers, outcomes) with their alternative states or values, is a common launch pad for constructing scenarios or futures images (Varho and Tapio, 2013, 621). In this study, a futures table was constructed from the 130 drivers of the literatures review by raising the level of abstraction considerably. This exercise resulted in 11 thematic dimensions (Table 4). Four of these were related to structures, four to contents and three to activity. The dimensions are presented as continua rather than as categories, since many of the covered issues exhibit no meaningful and exclusive states as discussed below.

After consulting the long lists of drivers, four *structural dimensions* can be abstracted. First, the scales of effective forces range from very local (e.g., local food, energy, nature, democracy) to very global (globalization), having numerous positions in between the extremes (regional development, national policy). Second, some of the drivers and trends point to decentralized settlement structure (decentralized energy system), whereas others enhance centralization and agglomeration (promotion of compact settlement structure). Third, a number of drivers are linked to more equal futures among regions and citizens (social sustainability in land use planning, freedom to choose a place to live in), while other drivers are linked to increased inequality (countryside for elite, unequal access to services). Fourth, structures guide attention and action and structuring may treat the objects as a homogeneous entity (extending promotion of compact settlement structure to backwoods) or take the heterogeneity of the entities into consideration (local planning). These four dimensions capture coordinates for navigating on the ocean of rural futures regarding their structural features.

The huge diversity of *the substance matter* for rural futures is compressed in four dimensions. First, the basis of the welfare provided by rural areas may become directed toward the material (natural resource economy) or toward the immaterial end of the continuum (immaterial consumption). Second, security of supply at the individual or national level may become directed toward dependence (globalization & interdependence) or independence (security of supplies, self-sufficiency). Third, renewal concerns many phenomena and may take steps toward stability and preservation (roots & traditions) or toward change (adaptability & resilience). Fourth, sustainability may be realized through responsibility (ecological or ethical choices) or be disregarded by selfish behavior (individualism). At this higher level of abstraction,

Table 4
Futures table.

Variable (theme, topic)	Alternative values (states in the continuum)
1 Environment, scale	Local……..Global
2 Settlement structure	Decentralized……Centralized
3 Regions and people	Equality……Inequality
4 Structuring	Homogeneous……..Heterogeneous
5 Welfare	Material……Immaterial
6 Security of supply	Dependence……Independence
7 Renewal	Stability……Change
8 Sustainability	Responsible……..Selfish
9 Agency	Private……Public
10 Base of transaction	Trust……..Distrust
11 Decision-making	Authoritarian……..Democratic

these four dimensions provide barrels for the diverse substance matters of the rural futures.

The structure and the contents of the futures would not be realized without *action and agency*, which are captured by three dimensions. First, agency could be based on private action (self-made & independent, entrepreneurship), on public action (reorganized public sector, subsidy culture) or their combinations. Second, the base of transaction could range between trust (society of trust, empowering institutions) and distrust (increased regulation). Third, decision making for the futures could be placed on the continuum between authoritarian (weak local municipalities) and democratic (involvement) regimes.

Achieving integrity of the futures images by working with single drivers is a challenge, which can be alleviated by working with the more fundamental dimensions. Coherence and integrity is easier to achieve at a higher level of abstraction. Appropriate configurations of effective forces and plausible outcomes may become iterated and placed on the continua, anomalous configurations may be filtered out (Rhyne, 1995, 659) and the selected configurations may be specified via contextualization. In this task, the futures table is a charter to be communicated with.

4. Results: futures images for rural Finland

At a certain point the enterprise of crafting alternative futures reaches a zone where art and science meet each other (Niiniluoto, 2001, 371). Formal logic fuels the journey by providing universal laws, patterns of change and causal relationships that have prevailed in the past. For the rest of the trip, one has to rely on disciplined imagination (Weick, 1989, 520), predictive argumentation (Aligica, 2003, 1038), intuition (Schirrmeister and Warnke, 2013, 465) or some other creative skill to tease out the rigorous realms of the non-existing. The operating system we use to understand the reality works backwards, but we are forces to live forwards (Kierkegaard, 1938, 161). Choices have to be made, also in research.

In this study, the final futures images were designed by first positioning ploys from the workshops into the futures table and then adding drivers from the literature review to bring about integral, coherent and assorted narratives. The formal logic of the system of futures is based on the utilization of natural resources, which were considered as the most significant meta-level driver and theme of ploys for the rural futures in the literature and in the futures workshops. The central role of natural resources in rural futures is, as such, widely acknowledged in rural studies (e.g., Angus et al., 2009; van Berkel and Verburg, 2011; Léon, 2005) and futures studies (e.g., Nowicki et al., 2007; Rienks, 2008; Öborn et al., 2011). Temporal horizon of the images is settled around 2030.

Depending on how natural resources are valued and exploited, rural regions will face varying fates and could manifest four distinct developments (Fig. 1). First, when the markets grant natural resources an increasing value, their exploitation is promoted by policies and the exploitation is economically, environmentally, socially and culturally sustainable, the outcome could be decentralized bio-economy. Second, a non-sustainable version of the same story is called colonial countryside. Third, if the valuable natural resources would be protected rather than exploited, we would end up with museum countryside. Finally, if the markets gave less value for natural resources, the national economy and public sector declined and rural areas businesses would be left on their own: only the strongest rural business islets would survive.

The logical skeletons of the futures bind together a number of drivers and they originate from somewhat different domains. *Decentralized bio-economy* brings together a balanced and rich array of drivers from the economic domain (e.g., bio-economy, security of supplies), from the governance domain (sustainability, local planning) and from the personal domain (quality of life, local phenomena). This future takes place when the problem of increasing scarcity of natural resources and the problem of sustainability are solved together. The metaphysical core of this future is an "involvement economy", where society affords rather than constrains rural actors and concomitantly they are entrepreneurial and empowered, willing and able to take over the emerging opportunities. *Colonial countryside* is deeply rooted in the economic domain (natural resource economy, globalization). This future comes along if globalization becomes clearly stronger than nations and governments and results in "rural mines", where private profits made by the fortune hunters, intruders and global corporations override other objectives. *Museum countryside* leans on the governance domain (environment-based planning, compaction of settlement structure). This future comes along when environmental sustainability is sought for on the basis of the dreams, fears, needs and powers of the urban majority. This future of extreme resource protection is powered by strong governmental regulation and urban thought and the role of the countryside is to be a gigantic "traditional biotope". *Rural business islets* have their foundations in the economic domain (centralization, capacity for renewal) and in the personal domain (quality of life, teleworking). This future comes along when a structural financial deficit of the government is resolved through cuts and natural resources are not seeding economic growth. At the metaphysical level, this future is a manifestation of a "survival society", where government has empty pockets and only the most resourced and competent prospectors will succeed in the business agglomerations. Detailed storylines of the four futures images are provided in Table 5 and the related positioning of the images in the futures table is presented in Fig. 2.

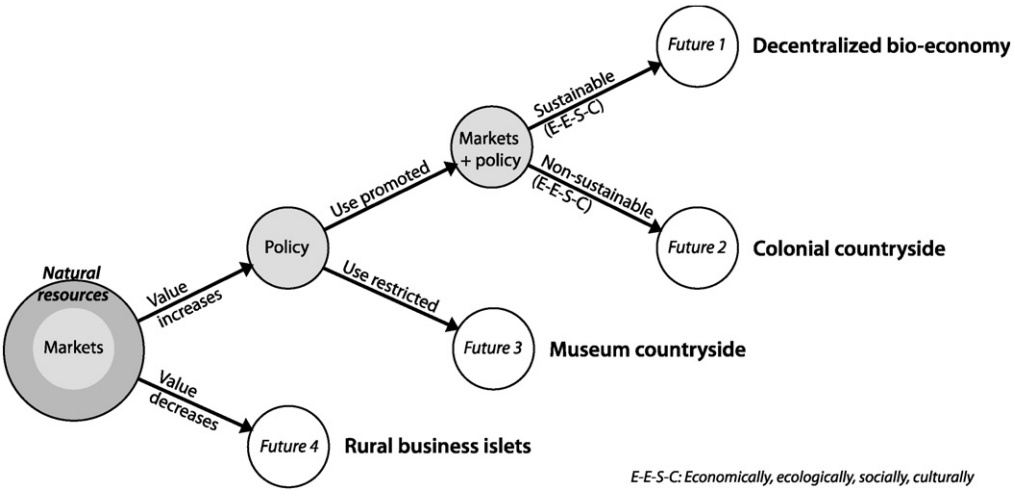

Fig. 1. Four futures images for rural areas.

Table 5
Storylines of the four futures images.

Decentralized bio-economy	The playground of the economy is framed by local and global factors, as globally demanded and valued natural resources are exploited locally. Geographical dispersion of valuable resources maintains dispersed settlement structures. Local ownership of natural resources contributes to equality among people and regions in terms of power and wealth. Rural people are equally involved in the value-chains of bio-economy — a kind of an "involvement economy". Policy is based on a heterogeneous world model, which acknowledges regional diversity and makes sustainable use of natural resources possible. This sustainability contributes to both the material (e.g., food, energy) and immaterial (e.g., tourism, public goods) elements of welfare. Decentralized, sustainable bio-economy maintains security of supply and contributes to national independence in life-maintaining supplies (food, shelter, energy). A change-oriented agency enhances capacity for renewal and facilitates a future that holds economic, environmental, social and cultural sustainability as an indisputable guiding star. Locomotion toward the future is maintained by the private actors, but the movement requires empowering institutions and policy measures which promote sustainable use of natural resources (e.g., criteria for sustainability in four dimensions, institutions for ownership, competence, technology, infrastructure). The base of transactions is in trust and decision-making at various levels is based on democratic regime.
Colonial countryside	In the colonial economy, natural resources are globally valuable and they are utilized by international business organizations. Settlement structure is organized around dispersed extraction sites of the natural resources. The best profits of these businesses are collected by foreign firms and investors. If conjunctures happen to favor extraction of natural resources, also local people benefit from jobs. Based on conjunctures, the extraction sites are sometimes open, sometimes closed, sometimes here and sometimes there; a part of the labor force follows this epidemic movement and lives in barracks and caravans. The grip of the policy is delicate and treats rural areas as a homogeneous area for exploiting natural resources — a kind of a "rural mine". The base of welfare is for the most part material; nor does the unsustainable exploitation of the natural resources leave room for immaterial values and services. Security of supplies is weak despite of the extensive exploitation of the natural resources, since the resources are owned by foreign businesses and they are out of any national control. Entrepreneurship and adaptability are prerequisites for volatile rural livelihood. The business is sustainable in economic terms, because profit-oriented owners uptake only profitable ventures. Environmental sustainability reaches only minimum norms as excessive demands are eliminated by the threat of business withdrawal and lost jobs. The rural business life is dominated by private actors, international organizations and their local subcontractors. Public finance is able to maintain very limited social security only. Distrust is the starting point of transactions, when controllers of the public sector and lawyers of the private actors are having a continuous dispute; local subcontractors have a fragile position. Decision-making is characterized by a dictation policy of big companies, which overruns democratic bodies and casual civic activity.
Museum countryside	The concerns underlying the museum countryside are global (e.g., sustainability), but policies are national or local (e.g., development of urban regions). Settlement structure is very concentrated, because rural areas lack prerequisites and incentives for business. The few rural residents carry out their eccentric lifestyles or live on public subsidies by providing public goods; together these groups form a powerless small minority as compared to city dwellers. Policy is based on a very homogeneous world model, where cities are the areas of progress, innovation and welfare and where rural areas are devoted for resource protection. Rural areas comprise a kind of a huge "traditional biotope". When society leaves valuable natural resources unexploited, welfare must be based on services and their exports. The security of supplies is weak and very dependent on imports. Competence in cultivation and exploitation of natural resources has degenerated along the resource protection regime, but competence in design and supply of services has improved. Economic and environmental sustainability is achieved, but social and cultural sustainability is at a low level in the rural areas. Public agency dominates. Rural economy has become more or less a part of the public sector, when rural livelihood and activity is fully defined by the public decisions, regulations and subsidies. Extensive regulation, monitoring and sanctioning of rural activity maintains distrust in the rural–urban transactions. Decision-making is either authoritarian use of power by the urban majority or norm-based coercion by the official authorities. Any use of natural resources requires a permission.
Rural business islets	Rural business islets are facilitated by global free trade, market liberalism and local prospectors of the "survival society". The economies of scale and agglomeration have paved the way to a settlement structure which is dominated by cities and rural business islets in manufacturing and services; outside these, there are some nature freaks and members of elite who are able to finance their rural living. Regional inequality accentuates, when cities and rural business islets do not radiate wealth extensively. Agglomerations dominate in policy perspectives. Welfare is equally based on material (e.g., manufacturing centers) and immaterial (e.g., adventure centers) origins. The state of security of supplies depends on the performance of the business islets in market competition. Capacity for change, competence, technology, infrastructures, resource productivity and innovations in agglomerations enhance their renewal, but other regions are stuck to outdated modes of operation. The business islets exhibit economic, environmental, social and cultural sustainability, which do not exist outside their sphere of influence. Activity in rural areas is purely private, since gauzy and reorganized public sector directs its limited resources to most prominent cities and business islets. Networking, co-operation and mutual trust between the actors prevail within the business islets; outside the islets there is a deep distrust between the public sector and local residents, who defend their territories, which are self-made and self-financed. Decision-making in the cities and in the islets is democratic, but in the views of the other regions it appears to be external and authoritarian.

5. Discussion

All these four rural futures are already among us in some place, in some scale and in some context — not only in Finland but also around the globe. They exist not only in discourses about the rural (Nilsson and Lundgren, 2015, 93) but in many rural localities. None of them could possibly apply to all regions, nor are they overarching. As usual, the value of futures images as alternative states of the future lies not in their accuracy of description or prediction (Bell, 1997, 107), but in their contribution to the *futures management support system*. In this role, they may assist in identifying, interpreting and choosing some possible and preferable futures at the personal, organizational and societal levels.

Futures images may be used as *design tools* to construct alternatives for possible, impossible, desirable or undesirable futures in order to be able to define ends and objectives for social action and policy. In this service, the main challenge is related to finding an *appropriate level of abstraction* to describe plausible images of the future. Simon (1996, x) stated: "the goal of science is to make the wonderful and the complex understandable and simple — but not less wonderful". On the other hand, for the purposes of choice, simplification of the reality is necessary (Simon, 1955, 114). Finding a balance between these demands is one of the greatest challenges in social research. For any theory, explanation, model or description it is rather impossible to be general and simple and accurate at the same time, as Thorngate's (1976, 406) "clock" with two but not tree hands illustrates. This postulate on commensurate complexity is a watershed. If one tries to present general and accurate futures, they might turn complex (e.g., Gomi et al., 2011, 864). If one tries to present general and simple futures, they might turn inaccurate.

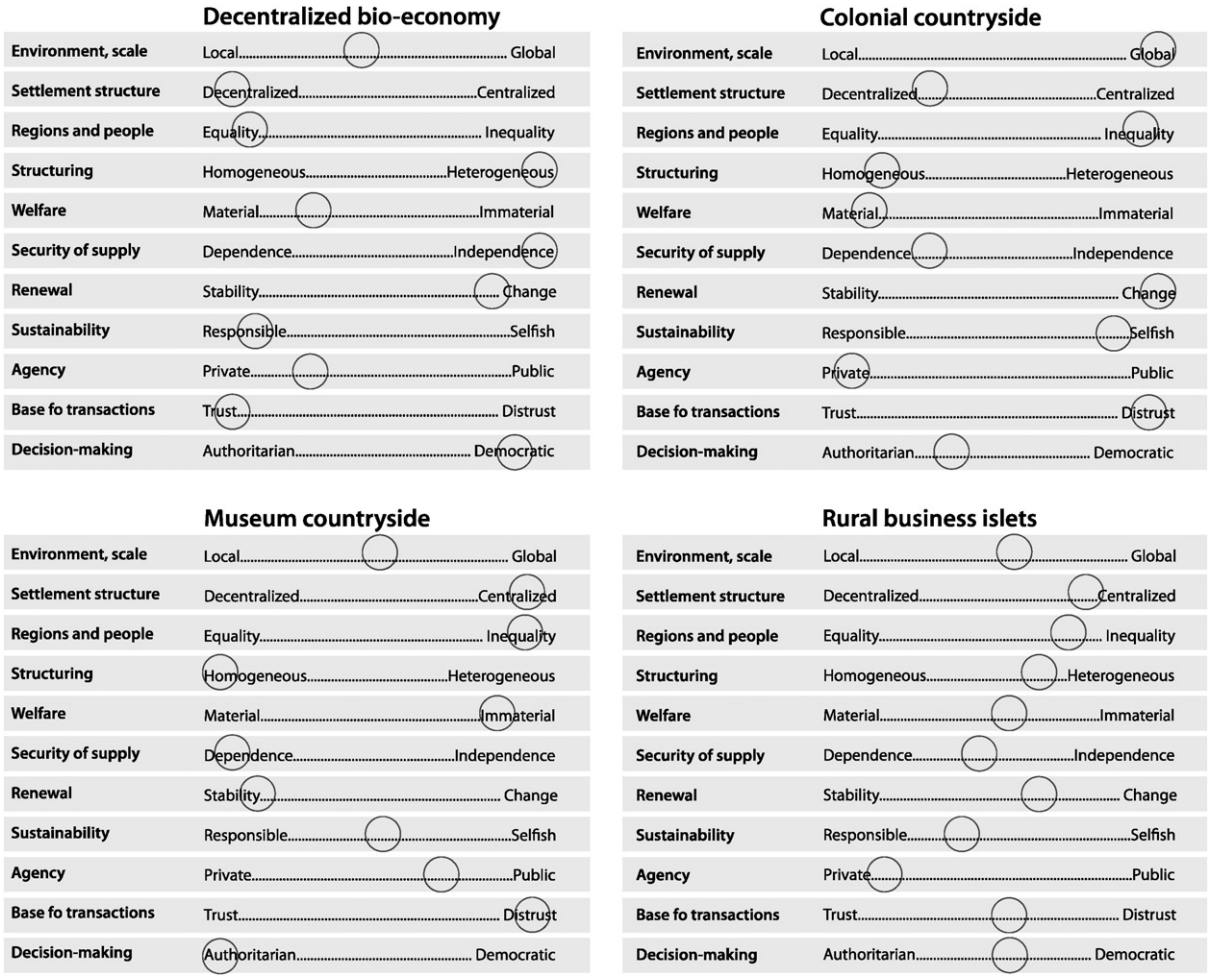

Fig. 2. Positions of the four futures images in the futures table.

If one tries to present simple and accurate futures, they might turn very local. So, which of the three qualities is to be sacrificed — and to what extent? It depends. The key word in plausible futures images is integrity. What is the level of abstraction or flight altitude that presents the landscape of current research topic as logical and coherent entities? So, the question is, how to consult alternatives, how to frame entities, how to make them mobile and, finally, how to come up with all this? From this starting point, the use of futures images as a social learning technology relates to mentality of futures thinking (the alternatives), models of rural change (the entities), roles and specifications of agency (the mobilization) and methods of crafting rural futures (the art).

Regarding the association of futures images and the *mentality of futures thinking*, the main problems in designing rural futures in Finland have been a path dependence of thought and a monoculture of view. The monoculture of thought and the narrow view may lead to common bias of perception in what is possible or necessary, to non-ambitious agenda setting and to institutionalization of low-key behaviors. In rural research, the camps of "productivist" (mainly economists) and "post-productivists" (mainly other social scientists) have difficulties in sharing a common horizon about the role of the countryside as a place of production vs. consumption (Angus et al., 2009; Halfacree, 2007; Léon, 2005; Marsden, 1999). The Finnish frontline media tends to serve the dreams and fears of the urban majority by considering rural activity as a cost burden, as a threat to nature and as a symptom for inevitable decay. On the other extreme, the frame of reference by farmers and their organizations is deeply rooted in highly professional issues and pathology of the heavy regulation. Agenda setting and policy design for rural development, in turn, has suffered from path dependence when the same strengths, weaknesses, possibilities and threats have been repeated for decades. In many instances, rural futures are discussed within-the-boxes. Each science, school of thought, ideology, stakeholder group or other instance makes claims for a "focus-gain" (Shackle, 1955, 65) in prescribing the rural future. The mentality of futures thinking is to have a focus, but not to become blinded by the determinism of an exclusive ideology.

The purpose of this study is to outline one possible approach for jailbreaking monochromatic mindsets by comprehending alternative roles of the rural areas in Finnish society and by providing a shared horizon for alternative specifications. This kind of futures thinking reflects realist ontology (Patomäki, 2006). The futures are loosely wired to the present, which leaves room for alternative specifications and different logics in the futures trees. The level of abstraction was medium and kept touch to recognizable artifacts of the contemporary physical and social world. In other instances, there may be a need for a more limited scope and more refined structuring of alternative futures to serve choice and policy design more explicitly. More focused futures may be achieved for example by backcasting (Dreborg, 1996), policy gaming (Geurts et al., 2007) or strategic planning (Roney, 2010). The demand for specific contents may also differ among regional levels (Rijkens-Klomp and Van Der Duin, 2014, 25). The dance on the edge of integrity and diversity provides challenges but enriches thinking. Futures images provide a ready platform for argumentation for and against alternative rural futures, their ploys and contents (Aligica, 2003, 1040) instead of only being able to agree or resist the dominant monoculture. At the other edge of the monoculture there is the ocean of anomalies and the madness of absolute relativity (Huston, 1998, 439), however, which

are met if the agency ignores contextual "structural inheritance". This study took medium level of abstraction to serve divergent thinking about rural futures. Other studies might need other flight altitudes.

Regarding the *models of rural change*, rural futures come along general societal and economic development. The changing role of the countryside in society does not come out of the blue. In the Finnish publicity, the few tenders for futures thinking (e.g., Heinonen, 2001; Kuhmonen and Niittykangas, 2008; YTR, 2006) have become outweighed by the extensions of the historical trajectories. The domestic intellectual monoculture on rural development in the Finnish case could be broken by active provision of models and examples. The logic of modeling alternative futures in this study is based on the salient role of natural resources, but even working with this stance makes it possible to consider a wide array of alternative specifications. For international use, the demand of models is more diversified. As the first aid, a pattern recognition approach may help, when the medium-run storylines of socio-economic development in modern world share some universals (Laszlo, 1996, 109; von Stackelberg, 2009, 29; Wilenius and Casti, in press, 5). The contemporary discussion about the futures of rural Finland resembles the discussion about rural America 20 years ago (Coates, 1993). In the future, the discussion about rural futures in many developing economies will share concerns that are now topical in Finland and discussed in this paper. The pattern works like a coloring book: the figurative images may be turned sensible with contextual colors or substance matters.

Models still have their limits. Discontinuities and surprises may label them outdated; this is a known risk within futures research society but not that well known outside it. Further on, alternative futures images are plausible stories or narratives (Jarva, 2014) and in order to be such they need to fit into a context that keeps them meaningful. In this context, the role of natural resources bound the narratives together. In another context, this role could be taken by gender issues or by tenure, for example. Transplantation of futures images and their specific storylines across countries and cultures is thus limited even though their logics and elements would make some sense elsewhere too. The integrity of the images may become artificial, biased or meaningless. However, temporal and spatial distance may serve substantive or logical proximity.

Regarding the *roles of agency* in rural futures, agency (who) as such is often weakly specified in futures studies (Wangel, 2011, 881) as compared to contents, structures and processes (what & how). Agency refers to a capability of doing things (Giddens, 1984, 10) and to a capacity to effect change (Barnes, 2000, 25). Agency may hide in relational networks (Latour, 2005, 247), become exercised by various legitimate manifestations of institutionalization (Suchman, 1995, 574) like markets, policies and organizations, or emerge from many other sources. Nevertheless, structure and agency have a permanent love story for an understandable reason (Caldwell, 2005, 109): "There has always been only one practical guiding principle for the exploration of agency and structure: agency without structure is blind, structure without agency is empty". Social and personal futures are always partly open for deliberation except for some relatively isolated, local deterministic subsystems (Niiniluoto, 2001, 373) and this deliberation facilitates agency. The role of agency should not be overlooked. Discussion of agency makes the study more intimate and contradictory, but may serve the ends of becoming "responsible" (Bell, 1998, 323). Futures studies that deal only with structures and contents are hygienic and innocent but leave many important questions unanswered.

Markets host an important source of agency by granting value for various elements of rural futures. Policies play a key role in how the value becomes assessed and accessed, as evident from this study. In the case of rural futures, we would like to emphasize the role of rural agency. Rural populations and businesses are scattered and lack powerful agglomerations when compared to cities. A lack of agency may put rural people in a resigned role as executors of rural decay; these features are found in the futures of colonial countryside and museum countryside. In the case of decentralized bio-economy, the rural agency has organized itself into an extensive and effective network; in the case of rural business islets it gets steam from agglomeration.

Regarding the *methods of crafting rural futures*, there are many strategies to arrive at plausible designs and configurations. In search for the appropriate level of abstraction and integrity, images of the future cannot become derived directly from facts and past-based causal relationships *á la* logical positivism; rather, they combine "quasi-laws", contextual background information and personal judgment (Aligica and Herritt, 2009, 256). The whole complexity of social change may not be managed with deterministic configurations. In the quest to besiege unfolding social futures with credible conceptual intelligence, the method of "disciplined imagination" or "artificial selection" is helpful (Weick 2001, 516). This study presents one version of exercising disciplined imagination.

In this study, disciplined imagination was realized by constantly keeping in mind the integrity of the ploys (discipline) and by keeping up the diversity of alternative ploys and substance matters (imagination). Many specifications of futures studies methods actually manifest this approach. Essentially, futures images are social innovations. They are generated through "mental testing" (Weick, 2001, 529) of alternatives from the scientific community, from the public or stakeholder groups and from the mental exercises of the involved scientists. In developed economies, the contexts and the "quasi-laws" of rural life are not necessarily shared collectively any more and ideas of what is possible may differ strongly among stakeholder groups. Still, rural areas like any other areas with their people and businesses deserve a bit of futures thinking to inspire for example innovations that offer solutions for grand challenges (De Smedt et al., 2013). For these reasons, explication of the framework and the logic of the images becomes important. In diversified economies, rigor is a merit in designing systems of rural futures.

6. Conclusion

Rural areas have many futures. Rural futures in many developed economies could include, among others, decentralized bio-economy, colonial countryside, museum countryside and rural business islets. Diverse "structural inheritances", policies, markets, others domains of agency and emergent events unavoidably divide rural areas into diverse pathways toward the future. The approach used in this study may assist in using futures images as a social learning technology. In this role, the futures images may help in the struggle with the key challenges in crafting futures images: finding an appropriate level of abstraction, establishing a credible model for the logic or system of futures, defining roles for agency and applying a proper balance between imagination and discipline. Like any other portfolio of alternative futures, this is just an exhibit. The futures images could and should be elaborated more. The diversity of the rural areas should not be forgotten.

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Tuomas Kuhmonen is currently research director at Finland Futures Research Centre, University of Turku, Finland. Before this, he has been professor in entrepreneurship at University of Jyvaskyla and professor in agricultural policy at University of Helsinki. He has worked together with many governments, experts and stakeholders to learn about agricultural, rural and regional futures and socio-economic evolution.

Irene Kuhmonen is a PhD student in corporate environmental management at Jyvaskyla University School of Business and Economics, Finland. Her doctoral studies focus on the relationship between economic and environmental behavior. Her background is in human geography and she has worked on environmental studies.

II

HOW DO RURAL AREAS PROFILE IN THE FUTURES DREAMS BY THE FINNISH YOUTH?

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How do rural areas profile in the futures dreams by the Finnish youth?

Tuomas Kuhmonen [a, *], Irene Kuhmonen [b], Liisa Luoto [a]

[a] Finland Futures Research Centre, Turku School of Economics, FI-20014, University of Turku, Finland
[b] Jyvaskyla University School of Business and Economics, B.O. Box 35, FI-40014, University of Jyvaskyla, Finland

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ABSTRACT

Demographic trends do not give much hope for rural regions in developed economies. Many studies prescribe rural futures as manifestations of consumption of the countryside by an urban majority. However, many of these macro-images and typologies lack explicit micro-agency. This article illustrates what are the expectations from personal futures in rural areas, where specifically and by whom. The respondents of a national survey represented the Finnish youth, who described their dream future in 2030 in terms of livelihood, accommodation and lifestyle recipe. Analysis of the dreams resulted in distinct regional profiles. Urban-adjacent rural areas are profiled as places for a cosy life with spacious housing, home-based activities, nature, privacy and commuting. Rural centres (villages and parishes) had a comparative advantage in small-scale life. The advantage is related to benefits of smallness and economies of proximity: communality, safety and societal involvement. Self-made life attracted the youth to remote rural areas along with opportunities for entrepreneurship, pluriactivity and nature-related activities. Those of rural origin and a higher age increased the probability of rural destinations in the dreams. The effectiveness of rural, regional and municipal development policy could potentially benefit significantly by providing direct responses to the dreams of the youth, based on the research contributions which profile regions for the future at this level of abstraction.

1. Introduction

Rural areas in developed economies are at a crossroads. Expanding cities absorb the youth that has grown up in the countryside (Amcoff and Westholm, 2007, 368) and traditional rural occupations engage a diminishing share of the future generations (Nowicki et al., 2007, 24; Terluin, 2003, 327). Positive rural developments are often based on societal megatrends: increased mobility, increased leisure and the ageing population. Rural areas have a competitive advantage in terms of local nature and spacious housing, which increase commuting and urban sprawl (Léon, 2005, 303; Lowe and Ward, 2009, 1324; Vepsäläinen and Pitkänen, 2010, 198). Increase in leisure and welfare, have afforded city dwellers to reconnect with nature by making touristic visits to attractive coastal, lake and mountain regions (Lennert and Robert, 2010, 837). Some attractive rural areas with low cost housing, adequate care services and tempting activities for seniors are occupied by the elderly (Coates, 1993, 205). However, in numerous studies (e.g. Future Foundation 2004, 42; Jansson and Terluin, 2009, 47; Pinto-Correia and Breman, 2008, 11; Rienks, 2008, 20) the remote rural areas are prescribed with a passive role involving decay and conservation. The old-fashioned, stagnant image of the countryside represented in the media repulses the youth but attracts tourists (Alasuutari, 2011). Evidently, the true heterogeneity of rural regions (Marsden, 1999, 505) and the dispositional heterogeneity of our thinking (Bell, 2007, 410) have mixed up "the rural"; as the very same rural region may be considered a problem, a resource, a region of growth and a victim (Nilsson and Lundgren, 2015, 88–91) and much more, as is discussed later in this article.

Many rural areas have regressed as a result of "unavoidable" social and economic development. Transformation from agrarian societies to services societies along with increased productivity in primary activities has released rural labour that has not become assimilated by new rural businesses but by services in the cities. As Brereton et al. (2011, 218) illustrate, this rural transformation has left many physical contributions to welfare unaffected (peace, space, nature, freedom, privacy) but has lead to the deterioration of many social aspects of welfare such as access to services and availability of social activities. The rural part of developed economies has traditionally served the material welfare of society as a

* Corresponding author.
E-mail addresses: tuomas.kuhmonen@utu.fi (T. Kuhmonen), irene.a.kuhmonen@jyu.fi (I. Kuhmonen), liisa.luoto@utu.fi (L. Luoto).

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place of production. Increased welfare has increased the demand for immaterial welfare; rural housing and various forms of experience economy (adventures, caring, self-definition, peace and tradition; Jensen, 1999; Swinnen et al., 2012) that support many rural economies. In many developed economies this rural transformation has resulted in "greater rural economic diversity, selected rural population decline, increased rural–urban interdependence, emergent exurban areas, and amenity-led rural growth" (Irwin et al., 2010, 522). In some instances, the material productive roles and immaterial consumptive roles of rural areas compete and conflict (Angus et al., 2009, 230; Rienks, 2008, 29). Livelihood issues have become more complicated in rural development politics, policies and practices (Scoones, 2009, 181). However, new opportunities for place-based development and policies emerge as rural economies and urban demands of rural welfare become more diverse (OECD, 2006; Olfert and Partridge, 2010; van Eupen et al., 2012).

These types of development patterns of the past seem evident and obvious. Instead however, the roles in which the heterogeneous rural areas may serve society in the future are a much more complicated issue. Also rural macro-patterns arise from micro-behaviours (Schelling, 2006), when heterogeneous desires and beliefs turn into action. These desires, beliefs and conditions for their realisation evolve over time. Prescribing and predicting rural futures with past patterns may leave some emergent patterns unobserved and ignore the potential of disruptive micro-behaviours (Dopfer et al., 2004, 272; Hedström, 2009, 339). Besides the well-known patterns, new future demands for rural areas may germinate at the contemporary micro-level of desires and motives. We try to observe both of these potentials by exploring personal futures of the Finnish youth. The dream futures of the youth may feature futures images of how rural areas may contribute to society.

In this article, the scene is first set by discussing the previous literature on rural macro-futures in general as well as the rural dispositions of the youth in developed countries. After this, the challenges in exploring personal micro-futures are discussed. The details and methodology of the survey and its results are then presented. The article concludes by engaging with the findings and insights in relation to the previous research literature.

As a brief overview, we can consider that Finland is a small (population 5.5 million) developed country in northern Europe with a rare combination of extensive rural areas (95% of the land area), extremely low population density (18 inhabitants per $km^{2)}$, rapid socio-economic transformation (2.9% of GDP from agriculture and forestry) and high economic wellbeing (37,000 euros GDP per capita; Statistics Finland data 2013).

2. Profiling rural regions for the future

2.1. The rural transformation

Rural transformation has resulted in different developments for different kinds of rural areas. Since the 1960's, agriculture and forestry have released about 600,000 jobs for other industries in Finland (Kuhmonen and Niittykangas, 2008, 50). The capital province around Helsinki has benefited from a net migration of half a million new inhabitants from rural provinces during the past five decades (ibid., 37). From a broader perspective, the population of the 20 largest cities has tripled in the years from 1950 to 2013, and on the rural borders 68% of the country is inhabited by only 1.5% of the population (this includes impact of merged municipalities; derived from Statistics Finland data). Alongside industrialisation, urbanisation and increased mobility, the large cities have had adverse backwash effects (Myrdal, 1957) on their hinterlands since the 1970's (Tervo, 2009) and a regional imbalance has become more persistent (Tervo, 2010). Since the 1980's, only services have tended to provide new jobs and most of these jobs are located in the main cities (Kuhmonen and Niittykangas, 2008). A striking feature of this evolution has been the gender selectivity of the change. In the Nordic countries especially, young people and young females have moved out from remote rural areas to cities, which is connected to the supply of services jobs in the cities (Hedlund and Lundholm, 2015; Johansson, 2015; Muilu and Rusanen, 2003).

The rural well of the labour-force will dry out in the future, first from regions with a low population density and population base, meanwhile the exodus is still expected to continue. Simple demographic projections in Finland indicate that remote rural regions could still lose one sixth of their population before 2040 (Ponnikas et al., 2014). Several developed economies share similar developments. The projection of the demographic data in Sweden up to the year 2025 suggests an expansion of large university cities and a decline of peripheral rural regions (Amcoff and Westholm, 2007). Espon-scenarios for Europe in 2030 forecast an expansion of the metropolitan areas and marginalisation of the rural areas except for the coastal, lake, mountainous and other pleasant regions attracting tourists and retirees (Robert and Lennert, 2007). In Finland, the in-between urban-adjacent areas with good connectivity to city jobs and services, moderate housing costs and convenient living environment have gained more population for decades (Ponnikas et al., 2014).

The rural transformation has resulted in a differentiated regional functional and socio-economic structure, which is captured by several typologies (e.g. OECD, 2011; van Eupen et al., 2012). As these typologies and related studies indicate, different types of regions offer different opportunity structures and prospects for individuals and economic activities. Over time, the rural fabric has evolved from the simple Thünen rings to more heterogeneous structures including regions, mosaics, clusters and networks (Holmes, 2008; Lehtonen and Tykkyläinen, 2010; Verburg et al., 2010). Within the types of rural regions and between various levels of analysis, some heterogeneity of opportunities exists (van Eupen et al., 2012). "Rural is not synonymous with decline, just as urbanisation and agglomeration do not guarantee prosperous development" (von Meyer and Muheim, 1996, 26).

The emergence of the urban majority and the marginalised role of the primary employment have resulted in the ideas of the production countryside and consumption countryside (Marsden, 1999). This division may take place between the competitive agro–forestry activities and the "residual" consumption countryside supplying amenities, leisure, nature conservation and some special products (Potter and Tilzey, 2005, 595). Various manifestations of the productive opportunities in the rural areas are strongly bound to natural resources (Kuhmonen and Kuhmonen, 2015; Rienks, 2008). Rural regions have an everlasting role in the society as the source of raw materials (agricultural commodities, timber, peat, other biomasses, minerals, water, game and fish) and this keeps up some opportunities even for remote areas also.

The ways of consuming the countryside are expected to create new rural opportunities, when the rural areas profile as a source of immaterial welfare. Halfacree's (2007, 131) vision of rural "consuming idylls" is characterised by leisure, residential and contemplation practices, whereas "effaced rurality" is occupied by essentially non-rural practices and the rural issues live only in historical and nostalgic domains. In Mitchell's (2013) study of non-metropolitan villages in Canada, "heritage-scape" featured consumption of authentic and local commodities and "leisure-scape" featured leisure consumption. In Future Foundations' (2005, 14) manifestations of the rural idyll in the UK by 2055 "vibrant variety" is provided by leisure activities and sports, retirement-related services "with little emphasis on production". In Holmes' (2008)

conceptualisation of rural transition in Australia, "rural amenity mode" reflected dominance of consumption values. These amenities are evidently an important reason for some people to visit or live in rural areas (Chi and Marcouiller, 2013), and in novel combinations with entrepreneurship, creativity and external linkages they could contribute to growth and renewal (McGranahan et al., 2011; Naldi et al., 2015, 99). Another role placing increasing immaterial demands for the rural space is protection and conservation. This may be realised in "nature regions" (Rienks, 2008, 46), "conservation and indigenous mode" (Holmes, 2008, 212), "preserved heritage" (Future Foundation, 2005, 15) or "museum countryside" (Kuhmonen and Kuhmonen, 2015, 5). The conservation values are reflected also in some rural lifestyles featuring sustainable and low impact life (Halfacree, 2007, 132; Heinonen, 2001, 195; Neal, 2013, 62).

Apparently, there is an evolving supply of opportunities for organising livelihood, housing and the way of living in the different kinds of rural areas. For the future, the realisation of this potential is especially affected by the demands of the current youth. Their aspirations and resources together with external possibilities define what, where and how the rural space will be actually used.

2.2. Rural futures and the youth

The contemporary literature on youth's dispositions, preferences and intentions for a rural life presents contradictory results. For example, Waara (2000, 138) argues that Swedish young people perceive rural communities as generally traditional, underdeveloped, backward, old-fashioned places not suitable for a youthful lifestyle. Bjaarstad (2003, 48) reports that, the Norwegian urban youth consider rural as primitive. According to Thissen et al. (2010, 433), the "rural dull" of some Dutch and Belgian rural regions is comprised, among others, by a limited, boring and old-fashioned life. The Finnish youth barometer (Myllyniemi, 2007) observes that large cities attract young people more than rural locations especially due to opportunities for employment and education. Part of the youth considers the urban fabric also more tolerant and liberal than the rural habitat (Ollila, 2008; Tuhkunen, 2002).

On the other hand, spacious housing close to nature, safety, peace, communality and roots are common reasons for choosing rural destinations amidst the Finnish youth (Kupari, 2011; Pöyliö and Suopajärvi, 2005). Indeed, the notion of "rural idyll" is a very widespread social representation among developed economies, which is shared by many young people (Auclair and Vanoni, 2004; Halfacree, 1995; Lowe and Ward, 2009; Rofe, 2013; Valentine, 1997; van Dam et al., 2002; Vepsäläinen and Pitkänen, 2010). The Norwegian youth describe the rural regions with positive words; nature, everyone knows everyone, neighbourliness, peaceful, solidarity and spirit of cooperation (Rye, 2006, 415). Some Dutch and Belgian rural regions are regarded as beautiful, cosy, quiet and pleasant by part of the local youth (Thissen et al., 2010, 433). Cultural heritage, clean and ethical food, space and peace and experiences were the four most important contributions of rural areas for the personal life of the Finnish youth in the recent Rural Barometer (Aho and Rahkonen, 2014). Generally, these kinds of elements of a good life appear as the reasons among the youth for staying at, moving into or visiting rural areas. However, the youth is not a monolith. In this regard, Rye (2006, 420) observed in a large survey of the Norwegian youth that the dominant images of "an idyll" and "dullness" (also Woodward, 1996, 60) co-existed among the youth, but a substantial minority of the youth did not subscribe to them and held more diversified, heterogeneous images of the rural.

Several studies report the central role of images or perception instead of just "facts" in the formation of location-related intentions and choices among the youth (Bjarnason and Thorlindsson, 2006; Dax et al., 2002; Ollila, 2008; Thissen et al., 2010; Tuhkunen, 2007). Those who are committed to stay, seem to have a realist-optimistic vision of their chances (Muilu and Rusanen, 2003, 304) whereas those who are sensitive to move see some "greener grass" outside their own region (Bjarnason and Thorlindsson, 2006, 297; Tuhkunen, 2007, 11). Rural areas are different from urban areas in terms of physical, economic and social fabrics, but they may host rather similar platforms of a good life (Haukanes, 2013, 205; van Dam et al., 2002, 473) and fuse in transition cultures and practices (Neal, 2013, 60). Evidently, push and pull factors differ among these areas and so does their framing, importance and impact among the youth. It is important to know about the images, dispositions and preferences of the youth, since they affect actual migration behaviour (van Dam et al., 2002, 469).

However, preferences and possibilities to act upon them may change even during the youth years. A life-cycle model features the behavioural outcome of these dynamics, as many young persons aged 18–25 years tend to move to cities to find an education, a job, a career, a spouse or to obtain an urban lifestyle (Haukanes, 2013; Johansson, 2015; van Dam et al., 2002). According to the extensive (n = 1903) Finnish Youth Barometer (Myllyniemi, 2007, 83), the youngest cohort aged 15–19 years, the students, the singles and those without a professional or education comprised the most migration-oriented group, among the youth aged 15–29 years. In her study on northern Scandinavia, Tuhkunen (2007) found that the migration alacrity among the youth (14–30 years) was a consequence of a mismatch between the local supplies and personal demand regarding opportunities for education, employment and career. Cities offer female-friendly labour markets, which contributes to the long-term trend of outmigration of young females in many rural areas (Bjarnason and Thorlindsson, 2006; Hedlund and Lundholm, 2015; Johansson, 2015). Notwithstanding this, after having a family and children, the migration rate declines (Geist and McManus, 2008) and some young people tend to move back to rural areas at the age of 25–35 years (Johansson, 2015) or later upon retirement (Jauhiainen, 2009). Especially urban-adjacent rural areas with an access to urban jobs and services, but with a safe and natural environment for the children, form a popular destination for this group (Feijten et al., 2008; Ponnikas et al., 2014). The life cycle ties people to certain age-specific activities and moves the separation line between rural and urban destinations in terms of what is preferable and what is possible, a wish or a must (Geist and McManus, 2008; Lundholm et al., 2004).

To sum up, in order for someone to stay in or move into a specific rural area, there has to be an adequate fit between the personal motivations and resources, and the place-specific opportunities (Dax et al., 2002, 169; Thissen et al., 2010, 434; Tuhkunen, 2007, 168; van Dam et al., 2002, 473). Over the course of their becoming lives, young people have to find a fit between livelihood, accommodation and other elements of the "good life" (Muilu and Rusanen, 2003, 305). Since the place-specific supply and person-specific demand of these elements are heterogeneous, we have to take this nexus into our focus. What elements of a personal good life do the youth hope to find at various types of rural areas in the future? This is our research question.

3. Personal futures – a desperate search for universals?

The macro-level futures of technologies, societies and regions have been studied extensively, but studies on personal micro-futures are rare. The reasons for this may be two-fold. Firstly, socio-technological macro-futures are associated directly with wealth, business and policies, which explains part of the demand for and financing of this type of research. Secondly, studying

personal futures is tentative. At this micro-level, heterogeneity prevails and finding an appropriate level of abstraction to identify universals is a significant challenge. The investigation of personal futures portrays an unbalanced mixture of values, attitudes, interests, fears and hopes – more elaborate futures may capture intentions of specific choices or paths. Furthermore, the probability of meeting some unforeseen and unexpected events that disrupt personal intentions or plans is much higher than in the case of accumulated social futures. And finally, personal futures like any other futures may be crafted or explored in terms of their possibility, desirability and probability (Amara, 1981).

The literature on personal futures, especially concerning the youth, seems to converge around three topics: whether the futures are planned or not (how), what the temporal orientation is (when) and what the contents are (what). Studies have yielded contradictory results. The results differ depending on whether futures are captured by "extending" or extrapolating the present (Brannen and Nilsen, 2002; Ono, 2003.) The futures may be considered as a partly controllable portfolio of opportunities (Anderson et al., 2005) or as a structured mixture of several temporal orientations in a social process with significant others (Woodman, 2011). If one has control over one's own future, for example through competence, detailed planning becomes unnecessary (Brooks and Everett, 2008). The past and the present as a context have a significant effect on how young people think about the future (Brannen and Nilsen, 2007). A period of major social change may shift the views of a whole cohort to a certain direction (Molnár and Vass, 2013). It seems that, generally, the youth observe their personal futures to be more positive than the contemporary social futures (Eckersley, 1999) – which is also the case in Finland (Rubin, 2013, 38). These remarks suggest that the perspective and the method of investigating personal futures should be well explained and clarified.

Psychological research explains that the foundations of the characteristics described in the paragraph above are related to a temporal orientation and a temporal representation. As such, our minds are very skilful and effective in simulating futures (Anderson et al., 2015). According to Schacter et al. (2015), episodic futures thinking (what could happen) is connected to episodic counterfactual thinking (what could have happened in the past). There are numerous experiments which show how history matters for futures thinking at the individual level – or even at the brain level (Abraham et al., 2008; de Vito et al., 2012; Schacter et al., 2012). Generally, compared to thinking about the past, thinking about futures contains less detail and has a positive flavour, even some idyllic aspects (Rasmussen and Berntsen, 2014). For exploring the contents of personal futures, this is not a problem as such but it reminds us that different backgrounds and histories carry explicit effects on how the future is being conceived and what substance matters (episodes, experiences, semantic issues), that the future might contain.

Indeed, personal futures are personal. Despite the individual structuring and processing of personal futures, they still may share universal content. Thus, personal futures escape absolute relativity and extreme heterogeneity and become relevant topics of research. One of the very few attempts to frame the particulars of personal futures has been made by Wheelwright (2005). He defined six personal domains representing forces in every individual's life, which are: activities, finances, health, housing, social and transportation (ibid., 81). These domains are a good point of departure for finding an appropriate level of abstraction for personal futures.

4. Materials and methods

For this research, a survey was conducted by us in December 2013, concerning all Finnish citizens aged 18–30 years based on the population census retrieved in November 2013. A random sample was then obtained from the national population register. Observing the generally declining trend in the response rates to surveys (Tourangeau and Plewes, 2013, 12) and because of the general low response rates among the youth (Novo et al., 1999, 155), 25,000 invitation letters were sent to respondents, where they were directed to go to a protected website to deliver their responses online. The survey was provided both in Finnish and Swedish, as approximately 5% of the population speaks Swedish as their first language. The survey was open for a period of two weeks and no re-invitations were sent, which resulted in a total of 752 participants and a response rate of 3%. The response rate was low even considering the age group of respondents. Based on the literature of survey techniques, this was partly caused by the lack of pre-notification and follow-up contact (Sheehan, 2001) along with short notice, a complicated procedure and the timing of the survey being close to the Christmas period. Also rural futures are not among the most popular topics among the Finnish youth, and the low salience tends to result in nonresponse and contribute to a low response rate (Bean and Roszkowski, 1995, 25; Groves et al., 2004, 25). However, according to our analysis the low response rate did not represent a problem, because the sample size was adequate for the statistical inference and the representativeness of the sample was very good (Table 1). We suspected there was no sample selection bias, since there were significant urban-rural and rural-urban cross-flows between origins and destinations and also dedication to current urban or rural locations. This suggests that not only those interested in rural affairs were responding. This type of a self-selection bias, which reduces the external validity of the findings, was of course still possible. However, if the low response rate resulted in some bias unobserved by us, it was not sensitive to the demographic or socio-economic representativeness of the sample.

In addition to the background information, the survey included six rural futures images with narratives and illustrations. These images were crafted on the basis of the current rural, youth and futures studies literature and a futures workshop. The respondents evaluated them in terms of preference and probability as their personal futures. As these provided images were only examples of

Table 1
Compositions (%) of the sample and the population.

Indicator	Sample, %	Population, %
Municipality type of residence:		
Urban	76.8	77.7
Intermediate	12.9	12.2
Rural	10.3	10.2
Age category:		
18–24 years	48.9	53.4
25–30 years	51.1	46.6
Gender:		
Female	52.3	48.8
Male	47.7	51.2
Children:		
No	87.2	85.4
Yes	12.8	14.6
Employment status:		
Student	42.6	..
Employed	40.3	..
Student or employed	82.9	81.9
Unemployed	9.6	8.0
Out of labour-force	7.5	10.1
Education, highest:		
Primary	13.8	17.8
Secondary	59.6	63.8
Tertiary	26.7	18.4
Total	100.0	100.0

many alternative futures, the respondents were asked also to describe their own “dream futures” in 2030, in their own words. This timeframe shift means that the respondents move from the age cohort of 18–30 years to 35–47 years during the 17 years time travel. The crafted manifestations of a good life represent positive visions of life after attaining an education, a job and possibly a family. These expressions of preferable futures are at the core of this analysis.

The 'dream futures' were divided into three domains on the basis of three questions that everyone has to deal with: how do you earn your living? *(livelihood recipe)*, where do you live? *(accommodation recipe)* and how do you live? *(lifestyle recipe)*. This livelihood recipe corresponds roughly with Wheelwright's (2005) domains of activities and finances, and the accommodation recipe to the domains of housing and transportation, and the lifestyle recipe corresponds to the domains of health and social. These three domains or recipes are more extensive, however, and provide direct linkages to the three important domains of rural development policy: employment, housing and welfare & leisure (Fig. 1).

The descriptions of the dream futures varied in size between just a few words to long stories. They were analysed with *the conventional content analysis method* (Hsieh and Shannon, 2005, 1286) in order to identify the key elements of the subject matter. The analysis was carried out for each of the three recipes taking account of their most important element in each of the domains. The livelihood recipe was analysed by looking at the three domains: labour-market status, industry and specific contents of the job. The accommodation recipe was analysed by the two domains (location and housing) and their subdomains (specific characteristics). The lifestyle recipe was analysed for its specific content only. The specific contents or characteristics were defined by identifying the most important element or quality on the basis of the semantic statements, the level of specification and the order of presentation. The categorisation was iterative and was established along with the analysis process, as is usual in conventional content analysis.

The frequencies of the elements and characteristics within the three domains, featured the main lines of valuing alternative futures by the Finnish youth. However, specifically we were interested in how various areas profile in these futures: *what the youth dream about in various types of regions*. After the location of the dream was fixed, it became possible to present profiles for different areas. The location was classified on the basis of an adapted typology of rural areas (OECD, 2008, 39): cities, urban-adjacent rural areas, rural centres (villages and parishes) and remote rural areas. The various domains and subdomains were considered as categorical variables and tested statistically for their independence (chi-square goodness-of-fit test for categorical variables). If there was a statistically significant association ($p < 0.05$) between the location of the dream and another domain (e.g. labour-market status in the livelihood recipe), further analysis was then conducted to expose the differences. This judgement was made by means of the location quotient technique. When a certain element or characteristic was over-represented in the dream futures, that was located to a certain region (share within a region higher than the average), the measure gets values above one. We defined the values above two as *strong (positive) profilers* of the region and values above one but less than two *as weak (positive) profilers* of the region. These could also be considered as strengths of the regions in the minds of the youth. Even though we were interested in rural futures, many respondents described their urban futures; these results were included in the analysis to inspire counterfactual thinking. There were 682–700 cases including descriptions of the dream futures (see Table 2) and 655–673 of them included all the necessary data for the test of independence for the location quotient analysis.

The background information of the respondents was profiled in a similar fashion, exposing the respondents *who dream of specific regions*. After testing for the independence between the location of the dream future and the background variables, the significant relationships ($p < 0.05$) were analysed further by means of the location quotient analysis. When the background characteristics were over-represented in the futures located to a certain region (share within a region higher than the average), the quotient gets values above one. Again, the values above two were considered as strong (positive) profilers of the region and values above one but less than two as weak (positive) profilers of the region. The number of cases in this analysis were 673–710 in total.

5. Results

The analysis of the dream futures in 2030 by the Finnish youth, resulted in 16 elements defining the livelihood recipe, 26 elements defining the accommodation recipe and 19 elements defining the lifestyle recipe (Table 2). According to the results, a typical young person dreams about having salaried work in the services sector and living close by to a city in a large detached house, with the possibility to interact with nature and other people. However, the average in of itself has little potential for providing insights when profiling preferences. The individual elements comprise of a huge array of possible combinations that form the configurations of preferred futures. However, some patterns and configurations emerge from the diversity of the substance matter. Some configurations are nevertheless more common than others and some are factually non-existent. These configurations are the key to profiling rural areas to reflect the youth's dreams and serve policy design. Alternative configurations of the contents of the three domains are the next to be identified. Having identified the configurations, we arrive at regional profiles (what). Also the origin of the people

Fig. 1. The three domains in personal futures.

Table 2
The elements of personal dream futures by the youth and their shares (%) in the three domains and subdomains.

Livelihood recipe (n = 698)		Accommodation recipe (n = 700)		Lifestyle recipe (n = 682)	
Labour-market status:		*Type of location*:		*Specific contents*:	
Salaried work	67.1	Urban-adjacent rural	54.1	Nature sports	18.3
Entrepreneur	26.9	City	21.5	Undefined hobbies	11.9
Not defined	6.0	Remote rural area	15.0	Communality, friends	11.3
Total	100.0	Rural centre	5.8	Animals	7.6
Industry:		Not defined	3.6	Family life	6.9
Primary sector	11.7	Total	100.0	Peace & silence	5.9
Manufacturing	8.0	*Location characteristics*:		Other (miscellaneous)	5.3
Services	48.3	Own peace	16.4	Hunting & fishing	5.1
Not defined	32.0	Services nearby	13.4	Connected to nature	4.5
Total	100.0	Nature nearby	9.6	Homework	3.5
Specific contents:		Good connections	7.1	Gardening	3.4
Two or more places	16.5	Neighbours far away	6.6	Being alone	3.2
Two jobs	14.9	Neighbours nearby	6.0	Self-sufficiency	2.9
Other (miscellaneous)	13.8	Lake nearby	4.4	Handicrafts	2.9
Tele-working	9.5	Sea nearby	2.3	Visiting cities	2.3
Animals	3.7	Island	2.3	Machines	1.7
Nature	2.9	Not defined	31.9	Societal involvement	1.6
Small place or unit	2.2	Total	100.0	Freedom	1.0
Benefit the others	1.7	*Type of housing*:		Safety	0.7
Children	1.4	Detached house	80.1	Total	100.0
Sustainability	1.4	Block of flats	3.0		
Culture & tradition	1.1	Row house	2.9		
Not defined	30.9	Semi-detaches houses	0.4		
Total	100.0	Not defined	13.6		
		Total	100.0		
		Housing characteristics:			
		Large courtyard	19.7		
		Large apartment	8.7		
		Farmhouse	6.0		
		Other (miscellaneous)	4.9		
		Old house	3.7		
		Small apartment	3.3		
		Wooden house	2.7		
		Villa, summer cottage	1.1		
		Small courtyard	1.0		
		Not defined	48.9		
		Total	100.0		

interested in each region (who and wherefrom) is distilled from the data.

5.1. Profiles of the regions in the dream futures by the youth

There was a statistically significant association between the type of the region and all seven domains and subdomains (Table 1) characterising the three recipes of the dream futures (chi-square test, $p < 0.05$). It appears that regions profile differently in the dream futures by the youth, regarding the specifics of livelihood, accommodation and lifestyle. These differences are discussed next in more detail.

5.1.1. Futures in the cities

The urban futures were profiled by employment in services and by appreciation of urban infrastructures, housing styles and lifestyles (Fig. 2). The urban livelihood recipe was characterised by services employment and a wide diversity of preferences regarding its specific contents (e.g. creative, meaningful or a pleasant job). The location aspect of the accommodation recipe was characterised by its proximity to the sea (many Finnish cities are by the coast) and by the availability of connections and services. Important aspects for the residence featured compact and easy living: modern and functional urban housing styles, small residences, small courtyards and easy living without a maintenance burden. The lifestyle recipe captured the diversity of urban opportunities: visiting urban resorts for shopping, opportunities to engage in different hobbies and social interaction. Being connected to nature and having a special orientation (e.g. music, dance, active life) were important also in the urban futures. What was special about urban futures was that the number of profilers was more limited than in other regions (18 vs. 21–28) and more than half of these urban profilers were related to accommodation (10 vs. 8). Urban futures are rather concise and accommodation-dominated. On the other hand, the "other" alternative was included in all three recipes, which manifests as individualism out of the common categories.

Overall, strong profilers were very urban in nature. The young people who prefer a future in cities are attracted by personal opportunities for versatile business life and private life and by easy housing.

5.1.2. Futures in the urban-adjacent areas

The urban-adjacent futures were profiled by salaried jobs with commuting, a dispersed settlement structure with spacious housing and home-related lifestyles with privacy (Fig. 3). Employment in manufacturing or services and living and working between two or more places (commuting or travel jobs, especially in services) characterised the livelihood recipes of these regions. Regarding the accommodation recipe, the location was important in three respects: the respondents desired that there should be a private property (neighbours far away, own peace), there should be nature nearby and there should be good connections to the city. Spacious housing was also important: detached houses, large courtyards and large apartments were often featured in the answers. The livelihood recipes included a rich array of elements attached to these areas. Being active with housework, machinery or animals provide

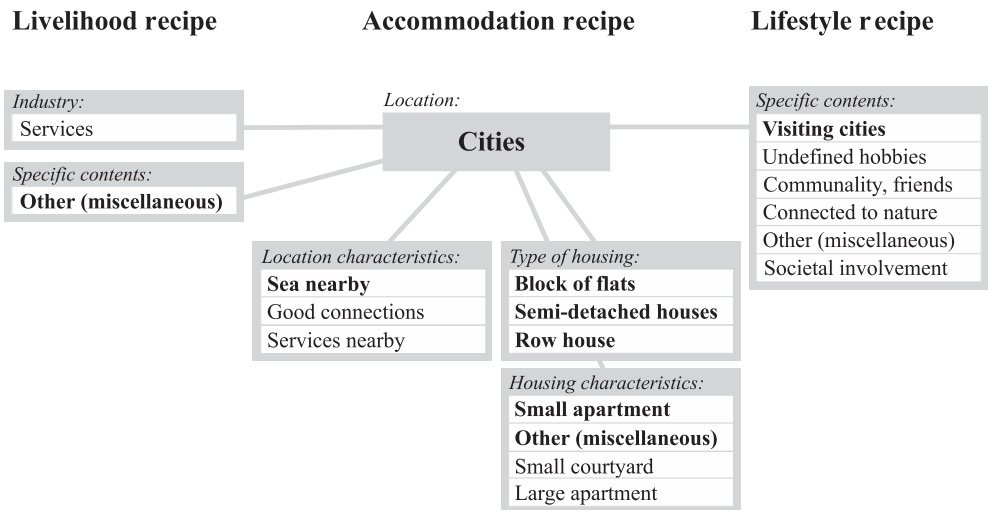

Fig. 2. The profile of cities in the dream futures by the youth (strong profilers in bold, weak profilers in regular font).

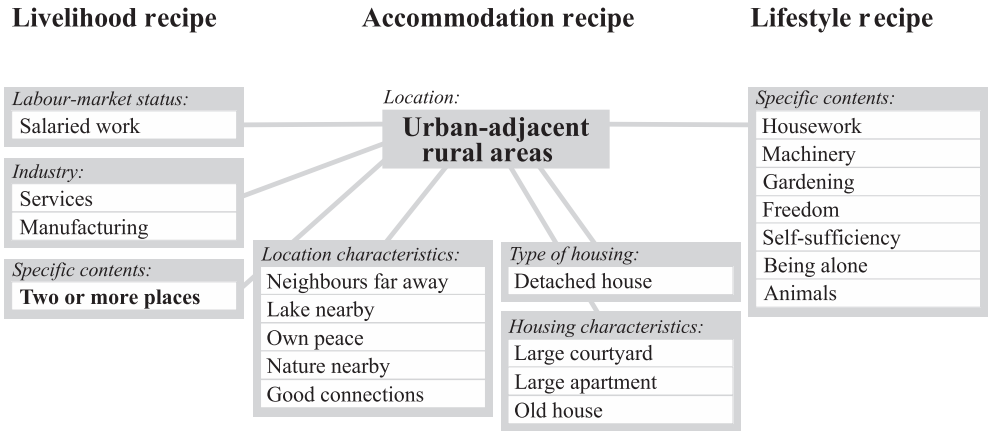

Fig. 3. The profile of urban-adjacent rural areas in the dream futures by the youth (strong profilers in bold, weak profilers in regular font).

home-related experiences and gardening also contributes to self-sufficiency. Local nature was an important place for walking, jogging, hiking and cross-country skiing. Possibilities for different activities were important in these lifestyles. Nevertheless, privacy also mattered, as both freedom and the possibility to be alone were considered important.

Generally, a configuration that was specific to urban-adjacent rural areas included mobility, spacious housing close to nature and varied activities in one's own peace and property. Those members of the youth who would like to live in the rural areas, but still close to cities are attracted by the combination of nature, privacy, home-related activities and urban employment opportunities. They are also willing to cover the costs of commuting to achieve this kind of life; living and working in multiple places was the only strong profiler of these urban-adjacent rural areas.

5.1.3. Futures in rural centres

The futures in urban centres (villages and parishes) were profiled by working in small units and having many jobs and by communality, involvement, safety and a nature-connection (Fig. 4). The youth especially expects the centres to provide salaried jobs in services, but decent living or variation is sought for through pluriactivity. What was special in the livelihood recipe in these areas, was the will to work in a small unit: in a small municipality, in a small firm, in a small school etc. Also nature-related jobs were appreciated by the young people. Contrary to the urban-adjacent areas, the proximity of neighbours was a positive aspect in housing. For example, the respondents preferred communal, compact and easy housing styles (semi-detached or row houses, small courtyards). Part of the young people also considered these locations to provide nature-connected, (island, sea), traditional (wooden, old) and spacious (large apartments and courtyards) housing. In the lifestyle recipe, human relationships mattered a great deal. Possibilities for participating in the NGOs, municipal affairs and other forms of social life and communality with friends, relatives, neighbours and co-residents were important profilers of these locations. Safety comes along with these networks and the small community. Being connected to nature was important as such, but also through nature sports, peace and silence. Also handicrafts and self-sufficiency were characteristics for lifestyles in these places.

Altogether, strong profilers of the futures in rural centres included manifestations of communality, small-scale life, nature and safety. The section of the youth that is attracted by villages and parishes prefer the benefits of smallness and the economies of proximity. The number of strong profilers was the highest among all regions, which suggests that the elements of futures in rural centres were divergent but specific.

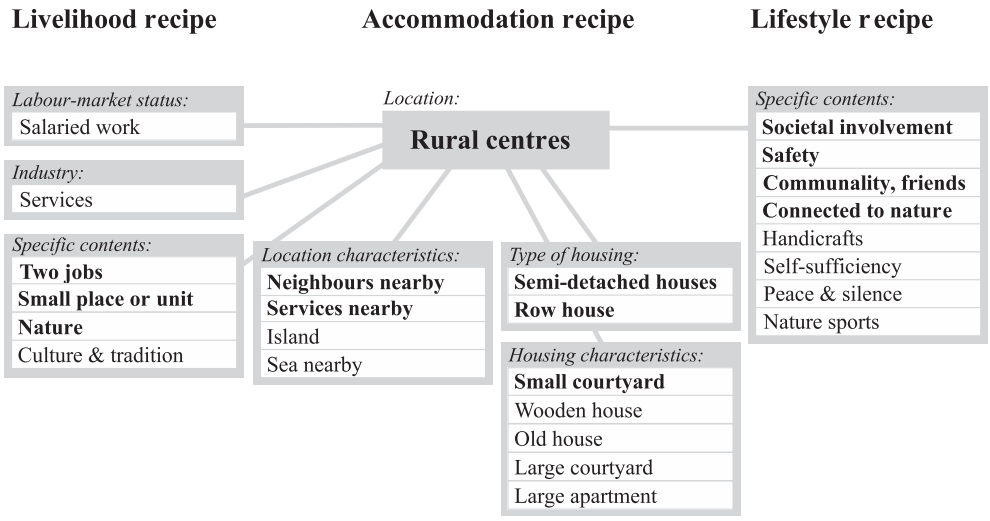

Fig. 4. The profile of rural centres in the dream futures by the youth (strong profilers in bold, weak profilers in regular font).

5.1.4. Futures in remote rural areas

The futures in sparsely populated and remote rural areas were profiled by entrepreneurial livelihood, traditional housing in the middle of the nature and very diverse lifestyles (Fig. 5). In the livelihood recipes of these regions, entrepreneurship was present as a must, which arises from the lack of salary-based jobs. Entrepreneurship was presented as an opportunity, which expresses freedom of choice. Pluriactivity similarly reflected a necessity for achieving a decent living and an opportunity to supplement the earning-orientation in the main job with a meaning-orientation in a subsidiary job. Also the primary sectors of agriculture, forestry and fishing, and manufacturing and sustainability were logically extensively present in the employment of these regions. Regarding the accommodation recipe, an island location (there are 168,000 lakes and a long seacoast in Finland) and various versions of wooden houses – villas, cottages, farmhouses, wooden houses, old houses – were emphasised in these truly rural futures. Nature and privacy were appreciated in housing also. The lifestyles recipes were most the diversified among all the regions and included as many as 12 profilers. Nature-related and space-related activities and lifestyles (hunting, fishing, freedom, a nature connection, animals, being alone, peace and silence) and human-related lifestyles (societal involvement, family life and safety) profiled these regions. Keeping busy with handicrafts or machines were also characteristic for the dreams attached to remote regions.

Considering these together, what was special about the futures in the deep countryside was the pronounced role of entrepreneurship together with nature-related housing and hobbies. Extensive rural space and remoteness are present in all the three recipes. Surprisingly, the futures in the remote rural regions had the largest number of profilers (28), which reflects the diversity of personal futures attached to these areas. The strong profilers – primary industries, pluriactivity, island location, traditional wooden houses, hunting & fishing – attach the core configuration of futures in remote rural areas to tradition.

5.2. Profiles of the youth dreaming of specific regions

Various regions had unique profiles in the dreams of the youth. Thinking of this the other way around offers new perspectives: can the youth be categorised into groups based on which region they would prefer in their dream futures in 2030? There was a statistically significant association between the type of the dream region and seven background variables (chi-square test, $p < 0.05$): the

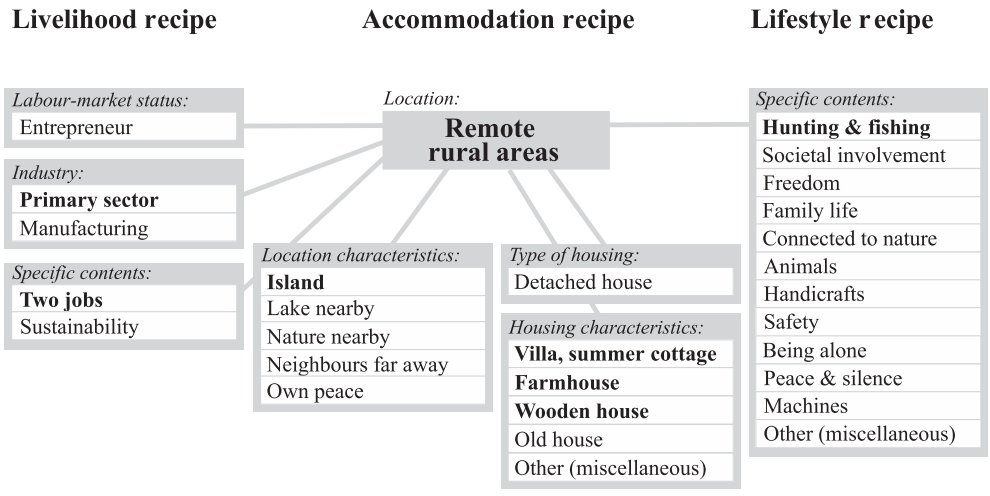

Fig. 5. The profile of remote rural areas in the dream futures by the youth (strong profilers in bold, weak profilers in regular font).

regional origin (birth and residence), demographics (age, family and children) and working-life association (working-life status and education). Gender did not discriminate between the regions. We also tested for the role of geographical regions (six cultural-functional areas: capital town region, south-western, central, eastern, western, northern) as a place of birth and as a place of residence. These geographical regions did not have a statistically significant association with the type of dream region, however, because all these geographic regions already included different types of urban and rural areas. As it appears that many background variables are associated with the target area of the dreams, the qualities of these associations are discussed next.

The analysis showed that the people who were interested in urban futures came from urban areas and tended to be rather young, single, students with elementary or high school education (Fig. 6). In addition to this, the unemployed and graduates were dreaming about urban futures, possibly for employment reasons. Urban-adjacent rural areas were in the dreams of rather young people with mostly urban backgrounds; many of these young people had families with children, an education and a job. Rural centres attracted people who came from intermediate or rural municipalities, who were somewhat older, had families with children and had a higher level of education. In working life they took various positions as employed, unemployed or being out of labour-force (mostly due to parental leave). Finally, those who attached their dreams to remote rural areas had a similar profile as the previous rural centres group except for the association to working life, in which they were often outside the labour-force (half of these had children) and had a lower education (elementary or vocational school). Generally, the profiles of the youth dreaming of specific regions may be depicted by a *life-cycle model*. Relatively young respondents without families, an education or a job were attracted by the opportunities of the cities. Somewhat older respondents with families and an education were attracted by the rural areas. This older group valued the safety, the appropriate balance between privacy and communality, the nature connection and their own property for various activities and for the spacious rural lifestyle. This harmony was broken only by the *role of origin*, as the place of birth and residence affected preferences in favour of the origin.

6. Discussion

In this research we have studied how rural areas profile in the futures dreams by young people in Finland. The timeframe of these manifestations of a good life was the year 2030; during the next 17 years covered by the envisaged time travel, the respondents move from younghood to adulthood. The results suggest that personal futures and rural areas were linked by multidimensional welfare. This welfare was comprised of the availability of diverse employment, housing and lifestyle opportunities. It was possible to abstract several universals regarding the positive contents of the livelihood, accommodation and lifestyle recipes attached to various types of rural areas, but heterogeneity of the dreams was a prominent feature of the personal micro-futures. Just as the psychology

Regional origin:	Destination of dreams:			
Place of birth:				
Urban municipality	Cities	Urban-adjacent		
Intermediate municipality			Rural centres	Remote rural
Rural municipality		Urban-adjacent	Rural centres	Remote rural
Place of residence:				
Urban municipality	Cities	Urban-adjacent		
Intermediate municipality			**Rural centres**	Remote rural
Rural municipality			Rural centres	**Remote rural**
Demographics:				
Age:				
18–24 years	Cities	Urban-adjacent		
25–30 years			Rural centres	Remote rural
Family status:				
Single	Cities			
Couple		Urban-adjacent	Rural centres	Remote rural
Children:				
No children	Cities			
Children		Urban-adjacent	**Rural centres**	Remote rural
Working life association:				
Working life status:				
Student	Cities			
Employed		Urban-adjacent	Rural centres	
Unemployed	Cities		Rural centres	
Outside labour-force			**Rural centres**	Remote rural
Education, highest completed:				
Elementary school	Cities			Remote rural
High school	Cities	Urban-adjacent		
Vocational school		Urban-adjacent		Remote rural
University of applied sciences			**Rural centres**	
University	Cities		Rural centres	

Fig. 6. The profile of the youth classified according to their dream regions (strong profilers in bold, weak profilers in regular font).

literature has explained, futures thinking tended to be rather positive and not very detailed (Rasmussen and Berntsen, 2014). Even though the frontline media and demographic trends in Finland as well as many other developed countries propose rather pessimistic futures for non-metropolitan rural futures, the youth observed a lot of opportunities to extract rural welfare. This setting is in line with the ideas of Eckersley (1999) and Rubin (2013) that the youth conceive their personal futures more positively than contemporary social futures. All types of rural areas had many attractive features for the youth.

Engagement of the findings with the existing literature results in four conclusions. Firstly, an idea of the good life by the vast majority of the youth is connected to manifestations of the *consumption countryside* (Marsden, 1999). The countryside was to be consumed especially through spacious, traditional, wooden housing styles and through communality, peace, tradition and various ways of consuming nature. These dominant profiles of the rural areas could be considered as manifestation of immaterial welfare and varied markets for togetherness, care, identity, peace of mind and convictions (Jensen, 1999). This finding confirms the results of several studies in which the main contribution of the rural areas in the lives of the youth as a whole is in residential and leisure activities (King and Church, 2013; Kupari, 2011; Ponnikas et al., 2014; Pöyliö and Suopajärvi, 2005). Against all odds, the ways in which to consume rural places were richer the further away one went from the cities. This mode of very diversified housing and lifestyles in remote rural areas was a contradictory finding which deserves more attention, as remote rural regions are attached with predominantly negative visions and labels in several studies (e.g. Ollila, 2008; Tuhkunen, 2007). This distinction may be partly explained by the approach, which identifies dreams of those interested in the specific region and not the position of all young persons. *Production countryside* with primary industries, manufacturing and self-employment were the most prevalent sources of livelihood only in the remote rural areas, where the local consumption or the urban proximity will contribute only marginally to employment in the Finnish circumstances (Eskelinen and Fritsch, 2009, 617). In this respect, the youth have a realistic view of the opportunity structures of different locations.

Secondly, different types of rural regions had distinctively *different positive profiles* in the dreams of the youth. Rural areas were not considered as a homogeneous idyll or highly heterogeneous mosaic of spots, but comprised distinctive basins of attraction with different profiles for different types of rural areas. The profile of attraction, by the *urban-adjacent rural* areas, includes the possibilities for taking advantage of the best parts of the urban and the rural. This is by being connected to jobs in the proximate city and by being able to enjoy spacious housing and varied home-based activities in a natural and peaceful environment. The profile was very different from the urban one and not seen as its extension or variant. Voluntary isolation featured in the dream life of these areas, when societal involvement was excluded from the profilers only in these areas, but own peace and being alone were included. Not surprisingly, prospects of these commuting regions look very promising and they could increase their population by a fifth before 2040 (Ponnikas et al., 2014, 24), as the youth will contribute to the urban sprawl. The attraction profile of these urban-adjacent areas could be synthesised as “the best places for cosy life”. The profile of attraction by the *rural centres* among the Finnish youth is based on the benefits of smallness and economies of proximity. The qualification as “the best places for small-scale life” emerges from communality, societal involvement, safety and nature, which profile as the attraction of these locations. *Remote rural regions* were characterised by the necessity and opportunity for entrepreneurship and pluriactivity. Nature and tradition were present in the livelihood (primary industries), accommodation (summer cottages, villas, farmhouses and wooden houses) and lifestyles (hunting, fishing, animals and handicraft). The profile of attraction in these areas could be named “the best places for self-made life”. In the Finnish context, nature nearby was an important element of a good life in all regions, including cities. At the general level, the match or fit between personal preferences and opportunities of the region are considered crucial for staying or leaving by the youth (Thissen et al., 2010; Tuhkunen, 2007; van Dam et al., 2002). The effectiveness of the rural, regional and municipal development policy could potentially benefit significantly by providing direct responses to the dreams of the youth on the basis of research contributions which profile regions for the future. So far, these kinds of contributions have been rare except for barometer surveys.

Thirdly, issues of history and time matter also in personal futures in terms of *origin* and *life cycle*. Being born or having lived in rural areas increased the likelihood of having a rural destination in the futures dreams and vice versa for the urban origin. This is in line with previous results, where roots and one's own experiences of a rural living (Feijten et al., 2008, 153; Stockdale et al., 2013, 254; Thissen et al., 2010, 432–433; van Dam et al., 2002, 468) or even specific type of a place (Stockdale et al., 2013, 254) enhances the attachment to the place and reduces out-migration intentions. Generally the past seems to have an effect on how young people think about the future just as the previous literature proposed (Brannen and Nilsen, 2007; Ono, 2003). For the future of rural areas this is a challenge, since an increasing share of the youth will be of urban origin. On the other hand, temporal aspects were present also in the form of the life cycle effect. Becoming older, having a family and having a profession seemed to increase the probability of rural futures, when the urban markets for education, for marriage and for early careers are not at demand any more. This is in line with previous research (e.g. Geist and McManus, 2008; Johansson, 2015). Along with urbanisation and concentration of educational institutions, the rural areas have an increasing disadvantage upon transitions from home to school, but on the basis of the stated preferences they have potential upon transitions from school to employment. Surprisingly, gender did not differentiate between dream destinations, whereas an exodus of young women from rural regions to cities is a historical trend (e.g. Bjarnason and Thorlindsson, 2006; Muilu and Rusanen, 2003). The distinction most probably arises from the difference between stated and revealed preferences, as women prefer rural locations equally to men but have limited chances to realise their dreams.

Fourthly, as a methodological solution for finding an appropriate level of abstraction, *the three recipes for livelihood, accommodation and lifestyle* was a feasible way to structure heterogeneous personal futures and to connect them with specific regions. This structuring provided a reasonable level of abstracting universals for the important aspects of personal futures. The recipes appeared relevant for the respondents, they formed compact tools for research and they appeared to be relevant for policy design. In trying to understand youth in research or attract youth in rural development, the elements of the three domains of livelihood, accommodation and lifestyle should be considered rather than just one of them – which is most often just livelihood (Morrison and Clark, 2011). On the other hand, the demand for nuanced variety in studying opportunities and choices upon youth transitions in terms of “employment, education/training, housing, physical accessibility, community participation, culture and leisure” (Dax et al., 2002, 169) could take this more compact and comparable form without losing important information, since the three domains may be filled with personal or place-specific substance matter.

In conclusion, a number of developed countries have observed

the lack of youth in the countryside and have tried to (re)connect young people with the countryside (King and Church, 2013, 67). Evidently, personal futures offers interesting insights for this effort. With this approach it is possible to produce future-oriented, systematic and rich knowledge as compared to extrapolation of demographic trends or place-specific case studies. All dreams will not turn into realities, as many people are unable to act in accordance to their working, housing or living desires (Coulter and van Ham, 2013; van Dam et al., 2002). However, the dreams provide some new avenues for studying rural preferences and for designing rural development policies for the future. Even though, these Finnish results should be generalised with caution due to the specific biophysical, economic, social and cultural fabrics of each country and location, as "local and regional responses are heavily influenced by the specificities of the context" (Dax et al., 2002, 164). However, these profiles still have relevance in many developed countries. It is possible to assess these place-based specificities in relation to the youth's preferences in a systematic way, through an appropriate level of abstraction along the lines of this study. However, it would be interesting to see the similarities and differences as well as their match in other contexts.

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III

EXPOSING THE ATTRACTORS OF EVOLVING COMPLEX ADAPTIVE SYSTEMS BY UTILISING FUTURES IMAGES: MILESTONES OF THE FOOD SUSTAINABILITY JOURNEY

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Exposing the attractors of evolving complex adaptive systems by utilising futures images: Milestones of the food sustainability journey

Tuomas Kuhmonen

Finland Futures Research Centre, Turku School of Economics, FI-20014, University of Turku, Finland

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ABSTRACT

This study aims at exposing the potential of futures images in anticipating and informing transitions of complex adaptive systems toward sustainability. Our case concerns the food system. The inherent properties of complex adaptive systems make the exact trajectories of these systems unforeseeable. However, since the systems unfold into a common direction, we can say something about the qualities of the milestones toward which these systems navigate. Attractors configure the evolution of complex adaptive systems. Since attractors are the most stable and robust elements in these systems, they are more feasible targets for foresight than the several variants that they configure and effectuate. We have depicted attractors of sustainable local food systems by futures images: through working with an appropriate level of abstraction, by leaning on a multi-perspective approach and by breaking the linear relationship between the present and the future. In this context they were sustainability-oriented trading and delivery systems, food cultures, product development projects, food brands and transparent food systems. We also located hot spots of structural change and agency within the food system. These insights may inform transition management efforts, but they must be updated frequently, since sustainable development is a journey.

1. Introduction

We live at the edge of two paradigms, two worlds with different logics and guiding stars. The socio-economic paradigm of the 20th century was characterised by orientations based on production, processing, division of labour, disintegration and material welfare. We suspect that the socio-economic paradigm of 21st century will navigate toward sustainable development, systems view, integration and immaterial welfare. Embodiment of the new paradigm gives rise to many system level changes, which have been anticipated by the scientific enterprise: studies on sustainability journeys and transitions are booming (Fuenfschilling and Truffer, 2014; Garud and Gehman, 2012; Geels and Schot, 2007; Genus and Coles, 2008; Hjorth and Bagheri, 2006; Holtz et al., 2008; Jørgensen, 2012; Kemp and Martens, 2007; Markand et al., 2012; Safarzynska et al., 2012; Vasileiadou and Safarzynska, 2010). The feeling of change has made us all hungry for knowing about these futures. In this orientation, empirical contributions for the alternative milestones and destinations are important.

The dominant designs of food, energy, transport and housing systems have several features that do not fit to the new paradigm (Geels et al., 2015, 2; Hinrichs, 2014, 152; Markand et al., 2012, 955; Ros et al., 2006, 193; Voß et al., 2009, 283). Consequently, they will face fundamental changes or transformations. We will take a closer look at the food systems. The problematic features of the 20th century food systems – partly depending on the point of observation – relate to the dominance by retailers and other intermediaries (Flynn and Bailey, 2014; Konefal et al., 2005), extensive processing, packing and cross-transportation fuelled by non-renewable energy (Hendrickson and Heffernan, 2002; McMichael, 2009; Wilson, 2015) together with long and non-transparent supply chains permitting unethical conduct and health risks (Blay-Palmer, 2008; Kjærnes and Torjusen, 2012). These features have come along with industrialisation, capitalisation, specialisation, concentration, spatial separation and globalisation of the food systems (Blay-Palmer, 2008; Jarosz, 2008; Oosterveer and Sonnenfeld, 2012; Palpacuer and Tozanli, 2008; van der Ploeg, 2010).

Many scholars anticipate that the 21st century food systems will facilitate sustainable development by "reconnecting" food, people and places as well as by integrating economic, environmental, social and cultural aspects of food (Fonte, 2008; Grauerholz and Owens, 2015; Kirwan, 2004; Lyson, 2004; Marsden, 2013). In this vein, manifestations of the new paradigm would be more locally governed sustainable food systems (Feenstra, 1997; Flynn and Bailey, 2014; Hinrichs, 2014), which may provide resilience and safety in a turbulent world with social, environmental and market-led crisis (Tendall et al., 2015). Consequently, the "food from somewhere" challenges the "food from nowhere" (Campbell, 2009) upon the paradigm shift and subsequent sustainability journey. At the 21st century, the new food systems may replace the

E-mail address: tuomas.kuhmonen@utu.fi.

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dominant regime, they may remain small and "alternative" or they may co-exist with the old regime in a tandem setting where starkly different global and local food systems emancipate. However, "even with public enthusiasm now for local and regional food, the twentieth century move to long distance food distribution has path-dependent elements that suggest caution about expecting a quick, uncomplicated or thorough transition" (Hinrichs, 2014, 149).

A major problem in foreseeing aspects of the paradigm shift or transition originates from the fact that alternative transition paths are difficult – if not impossible – to foresee. This is an inherent feature of complex adaptive systems (CAS). Complex adaptive systems have agency, which energises and directs their emergence and evolution and distinguishes them from "just" complex systems (Choi et al., 2001, 353). Food systems as many other social systems in developed market economies are CAS (Nesheim et al., 2015, 233): they unfold and self-organise without central command on the basis of non-linear and mostly local interactions among their heterogeneous elements (Byrne and Callaghan, 2014; Holland, 1995). For example, *Produit en Bretagne* as one of the oldest regional food brands in Europe is a "self-organised complex system in which the stakeholders and their interactions – either intuitively or via joint strategic actions – result in resilience accompanied by periodically renewed emerging properties showing the diverse quality characteristics of their products" (Perrot et al., 2016, 97). In the myriad of complex adaptive food systems, many novel constellations (innovations; practices, technologies, businesses) typically emerge as a response to the changed environment, making their detailed futures unforeseen.

However, the constellations in complex adaptive systems tend to accumulate around specific junctures or nodes called attractors (Gerrits, 2012, 157; Room, 2011, 130). While attractors are the most stable and robust elements of complex adaptive systems, they are more feasible targets of foresight than the several variants of detailed socio-economic systems that the attractors configure and effectuate. If we could foresee these attractors, then management of the transition with targeted research, development, business and policy actions becomes more productive. A way to anticipate these attractors within the food systems could rest on three premises. First, the dynamics of diverse food systems are unfolding along with social action (Chase and Grubinger, 2014, 1; Koc, 2010, 43). Second, transition-oriented social action is fundamentally teleological in nature (Smith et al., 2010, 444). Third, teleological social action is guided by objectives, ideals, visions and images (Bell, 1998). Consequently, futures images may frame and guide the sustainability journey (Beers et al., 2010, 725; Kemp and Martens, 2007, 9). According to Vasileiadou and Safarzynska (2010, 1178), images of the future are "expected to act as attractors for managing transitions, i.e. by creating expectations which attract support, actors, ideas and funding". By exercising disciplined imagination (Weick, 1989) to produce futures images, it could be possible to "jump" to the sketches of new realities across the diversity of unforeseen paths and bifurcation points. In this orientation, the "discipline" should come from the normative guideline of sustainability, and the "imagination" could come from the visionary and creative contribution of futures research methods. Identification of the becoming attractors in this way may unravel the mystery of the milestones of the sustainability journey of the local food systems.

Following this line of logic, this study aims at exposing the potential of futures images in anticipating and informing transitions of complex adaptive systems toward sustainability. This is illustrated by studying emerging sustainable local food systems in Finland. Transition of food systems toward sustainability will be discussed first in Section 2. The characteristics of complex adaptive systems and attractors are discussed in Section 3, whereas the potential of the futures images in the anticipation of attractors will close the theoretical-conceptual discussion in Section 4. Methods and materials of the analysis are presented in Section 5 and the results are reported in Section 6. Finally in Section 7, the findings are evaluated in terms of feasibility and benefit for the scientific enterprise and in practice for stakeholders struggling to anticipate and manage sustainability journeys.

2. The sustainability journey of food systems

Sustainable development is a widely used but fuzzy concept. In the broadest sense, it refers to intergenerational equality in meeting human needs and desires (Brundtland, 1987). In contextual and disciplined specifications, it often boils down to economic, environmental, social and cultural dimensions (Borch, 2007; Magee et al., 2013; Nielsen et al., 2010; Pezzey and Toman, 2002). These dimensions host the ideal that human needs should be met within the bounds of economic profitability, biological carrying capacity, social justice and cultural continuity. Sustainable development does not degrade the stocks of economic, environmental, social and cultural capital in their diverse contexts and scales. This makes it possible for the future generations to fulfil their needs by the services of these stocks. Over time, the goals of sustainable development have diversified to include good governance as an additional dimension (e.g. FAO, 2013) and recently the United Nations (2015) has defined as many as 17 sustainable development goals for 2030. Sustainable development is multidimensional.

Each social system, context and generation has its own sustainability concerns. As such, "sustainable development is an issue of complex systems" (Hjorth and Bagheri, 2006, 90) and could be conceived as an unending multidimensional, deliberate and reflexive process toward the socially constructed and temporally relevant ideal of sustainability in each context (Darnhofer, 2015; Forsell and Lankoski, 2015; Kemp and Martens, 2007; Koc, 2010; Oosterveer, 2014). Indeed, the change of the food systems toward sustainability is a journey, which "navigates" (Sage, 2014, 255) toward this ideal along thousands of milestones exhibiting different scales, scopes and temporalities. In studying these journeys and their milestones, we "have to work with complex and multi-layered notions of food systems and sustainability" (Flynn and Bailey, 2014, 117). Consequently, the transition of food systems toward sustainability may also proceed on four parallel tracks: economic, environmental, social and cultural serving the profit, the people and the planet (Ros et al., 2006, 193).

Various forms of "alternative" *food systems* – which also may take the form of networks (Watts et al., 2005) or hubs (Blay-Palmer et al., 2013) or movements (Grauerholz and Owens, 2015; Sage, 2014; Starr, 2010) – are our units of analysis and vehicles for sustainability journeys. Most of these alternative food systems have a local orientation: they reconnect producers and consumers through direct interaction (Forsell and Lankoski, 2015; Kirwan, 2004; Kneafsey et al., 2013). They also have a multidimensional sustainability orientation as they have "a commitment to the social, economic and environmental dimensions of sustainable food production, distribution and consumption" (Jarosz, 2008, 232) and "share values of economic and social solidarity, environmental conservation and opposition to the logic of the dominant food-system" (Darrot et al., 2015, 143). Many of them also have communal features (Feagan, 2007). So, it seems that the emerging food systems share some common elements or "attractors" around which the diversity organises. These local sustainability-oriented food systems include farmers' markets, food hubs, various short supply chains, community supported or shared agriculture, consumers' purchasing groups or organisations, community gardening, certification and labelling programmes, food box schemes, internet sales and much more, partly blurred by conceptual vagueness (Blay-Palmer et al., 2013; Cleveland et al., 2014; Feagan, 2007; Grauerholz and Owens, 2015; Le Velly and Dufeu, 2016; Parker, 2005; Watts et al., 2005).

It is important not to overstate the superior sustainability of these heterogeneous systems (Born and Purcell, 2006; Tregear, 2011), but their emergence along with either deliberate action toward sustainability (Blay-Palmer et al., 2013; Cleveland et al., 2014) or as a counteraction toward unsustainable features of the dominant regime (Allen et al., 2003; Hendrickson and Heffernan, 2002) point in this direction. Many of the contemporary alternative food systems, which co-exist under different brands, simultaneously promote several dimensions of sustainability (Table 1). Through the local food systems, sustainability operates at the

Table 1
Examples of alternative modern food systems by dimensions of sustainability.

Food system	Key contents and sources	Ordering of sustainability dimensions promoted
Farmers' markets, farm stands and farm shops	Makes it possible for the consumer to connect directly with the producer and/or the production site with no intermediaries while shopping. Is based on familiarity, habit, sentiment, values and attraction of fresh, high quality produce. Producers selling on these markets often come from small family farms and sell in small scale to get extra price and social experiences. Operates via direct interaction. (Chase and Grubinger, 2014; Grauerholz and Owens, 2015; Hinrichs, 2000; Kirwan, 2004; Wittman et al., 2012)	Economic, social, environmental, cultural
Organised local food hubs and other shortened supply chains (including public procurement)	Consisting of farmers/suppliers, a hub or pooling organisation and buyers. Suppliers often have to fill in certain criteria concerning farm size, farming system and distance/location. Large/public buyers may have a sourcing quota for local, organic and/or certified produce. Operates via hub/pooling. (Blay-Palmer et al., 2013; Cleveland et al., 2014; Darrot et al., 2015; Friedmann, 2007)	Economic, social, environmental
Community supported or shared agriculture	Local consumers pay for a share of the becoming (often organic) harvest for a set and fair price and get more or less produce depending on the harvest. As a result, the harvest risk is shared between producers and consumers, markets are secured for the producer, environmentally friendly production methods are often promoted and access to fresh, local produce is guaranteed for the consumers. Social and educational side-activities are common: field days, children's activities etc. Operates via communality. (Feagan, 2007; Fieldhouse, 1996; Grauerholz and Owens, 2015; Hinrichs, 2000; Kjærnes and Torjusen, 2012; Parker, 2005)	Social, environmental, economic
Consumers' purchasing groups or organisations	Consumers organise to purchase certain type of local food as a group, pool or organisation. Motivations may be mixed: ideological, political, spiritual, healthiness or related to various dimensions of sustainability (economic, environmental, social, cultural). Operates via social practice. (Fonte, 2013; Hendrickson and Heffernan, 2002; Sage, 2014)	Social, cultural, environmental, economic
Community gardening	Community gardening turn consumers into producers. This community-based resource management and seasonal production takes place in many contexts (cities, villages, schools; roofs, plots, yards, vacant lots), often as a neighbourhood activity. Reasons to participate vary a lot: access to food, health, social and environmental reasons. Operates via entrepreneurship and localisation. (Grauerholz and Owens, 2015: Jarosz, 2008; Lawson, 2005)	Social, cultural, environmental, economic
Certification and labelling programmes	Products, production techniques or producers may be connected to a certain place or region via labelling and/or certification. The consumers are accountable of the cultural (maintenance of heritage), social (cohesion of rural areas), environmental (low-input or organic systems) and economic (farmers' livelihood) consequences of buying these products. Operates via products. (Barham, 2003; Bell and Valentine, 1997; Kneafsey et al., 2013)	Cultural, social, environmental, economic

markets of economic viability, environmental integrity, social responsibility and equity, and cultural heritage. Clearly heterogeneous systems bring about heterogeneous outputs: the type and degree of sustainability achieved in the local food systems varies considerably within the ideal types and may include also drawbacks from the ideal (Blay-Palmer et al., 2013; Forsell and Lankoski, 2015; Bowen and Zapata, 2013; Hinrichs, 2000). In this article, we turn the lens the other way around by asking: which kinds of local food systems could best serve sustainability in its four dimensions. To that end, the horizon is set to the milestones of the sustainability journey in the near future, in a specific context. These milestones could be teased out in many different ways, as discussed next.

In Finland, which is a relatively large, developed northern country with a very low population density, the alternative food systems are at the stage of emergence. The corporate food regime with long supply chains is the well-established dominant design of the food system. The food trade is heavily concentrated and two food retailers share about 80% of the markets. During the last two decades, a number of various "directly from the producer" enterprises have started, many short-lived. During the last few years, a second generation of this genus has intervened in the markets, including farm shops, food hubs, food circles, web shops and public procurement of local food. However, their markets share is still negligible.

3. Complex adaptive systems and attractors

A key issue in studying the becoming manifestations of more sustainable local food systems in specific contexts, is the choice of a feasible research strategy, including especially guidance provided by an analytical framework. Many local food systems emerge from scratch along with interaction and networking by only a few key actors: as for example concerning AMAP Poisson fish-box scheme in France (Le Velly and Dufeu, 2016) or Taikei in Japan (Parker, 2005). Relatedly, *Actor Network Theory* (*ANT*) is a feasible tool for studying the first steps of a novel system (Steen, 2010) on the basis of relational ontology (Garud and Gehman, 2012). However, as we are interested in the qualities of these manifestations rather than the process of their emergence, it is not the best choice. *Multi Level Perspective* (*MLP*) is a reflexive structuration model (Ref. Giddens, 1984), which has been also used in food system studies (e.g. Hinrichs, 2014; Sutherland et al., 2015) based on the evolutionary ontology (Garud and Gehman, 2012). In this model, the hierarchical interplay of landscape level pressures, institutionalised regimes and novelty-generating niches bring about change of the system (Geels and Schot, 2007; Genus and Coles, 2008; Smith et al., 2010). However, temporal orientation of the MLP is rather past-based or present-based than being future-oriented in its empirical application (e.g. Geels, 2002; Sutherland et al., 2015) and in this service it provides little guidance for the qualities of alternative evolving futures (Vasileiadou and Safarzynska, 2010). A broader and more flexible evolutionary toolbox is needed.

Local food systems could be also conceived as *complex adaptive systems* (*CAS*). Complex adaptive systems are entities, which "exhibit coherence under change, via conditional action and anticipation, and they do so without central direction" (Holland, 1995, 38–39). They have numerous heterogeneous elements and non-linear connections (Room, 2011, 139); they are capable for learning based on experience and information along self-organisation (Holland, 1995, 9); and they are open in the sense that they exchange energy and information with their environment (Byrne and Callaghan, 2014, 26). Unlike "just" complex systems, complex adaptive systems have agency: capacity to change things and courses of events (Byrne and Callaghan, 2014, 193; Choi et al., 2001). The system is comprised by the individual elements and the systemic properties, and the resulting complexity is neither present in nor comprehensible by the individual agents of the system (Byrne and Callaghan, 2014, 4; Smith and Jenks, 2006, 13). The complex adaptive system is neither mechanical nor linear: it is an organic and non-linear system with feedback loops, disproportional effects, emergence and co-evolution. It is important to observe that agents in the social complex adaptive systems may not only follow some simple decision rules but

also create them (Koliba and Zia, 2011, 4; Ostrom, 2006, 115), giving rise to emergence. Concomitantly, qualitative novelties and unexpected structures may emerge along with the interaction and systems dynamics (Nicolis, 1995, 1–2); there is a "ghost in the machine" (Schiere et al., 2012, 344). Key concepts of the CAS are illustrated in Table 2. These qualities and dynamics manifest the ontology of becoming (Chia, 1999, 215), which serves our purpose extremely well.

Accordingly, we do not want to animate the complex behaviour of the actors (or agents) of the local food systems, but the various nodes or milestones toward which their behaviours are expected to navigate and accumulate. These nodes may be conceptualised by means of attractors. Complex adaptive systems typically have various types of *attractors*: "An attractor is something towards which a dynamical system evolves over time", a specific location in the state space (Byrne and Callaghan, 2014, 26–27). The attractors pull and capture the trajectories of the system elements within their power fields called basins of attraction (Kauffman, 1993, 176), also featured as "watersheds" (Room, 2011, 130). The attractors may represent temporal states of stability in the system (Gerrits, 2012, 157). Since the attractors actually limit the number of possible or feasible locations in the state space of the system or "box … space of possibilities" (Kauffman, 1993, 174), they are powerful descriptors of the potential milestones of a dynamical system "as not every system state is very likely in the future" (Gerrits, 2012, 156). They could be comprised by many kinds of "powers that pattern complexity" (Smith and Jenks, 2006, 13) in the social context: capabilities, preferences, ideologies, values, meanings, ideals, successful outcomes etc. On our teleological sustainability journey, the attractors correspond to envisioned contextual sustainability maxima.

Complex adaptive systems may *swap attractors*, which implies a bifurcation, a phase shift, a change in kind, a metamorphosis, a quantum change, an evolutionary change (Byrne and Callaghan, 2014, 27; Kauffman, 1993, 180; Miller and Friesen, 1984, 207–219) or, in our case, a travel of the system to the next milestone in the sustainability journey. Swapping occurs, when a "patterned behaviour of the system switches from one attractor to another" (Choi et al. 2001, 356). In the case of food systems, the "patterned behaviour" considers the practices of producing, processing, delivering and consuming food. Swapping is caused by a change in "control parameters" of the system (Byrne and Callaghan, 2014, 36), which are often configurative chokes of complex causation (e.g. consumption habits) rather than simple, separate variables. Swapping is hindered or resisted by saddle points that separate adjacent basins of attraction (Room, 2011, 135). These saddle points or frontiers may consist similar kinds of elements than the attractors, but their power field or logic works against those of attractors. At a more general level, this setting abstracts the structure–agency interplay where "structural inheritance" plays a role (Archer, 2000, 307–308). When the attractors energise agency of the system change, the saddle points are often historical remnants resisting changes and maintaining path dependency. Getting to know the saddle points of the local food system is important if one wants to enhance the power of the attractors.

In reality, complex adaptive systems evolve in partly unpredictable ways, but the attractors may also represent the milestones of intentional action to guide the evolution (Gerrits, 2012, 157). This is our case: multidimensional (economic, environmental, social, cultural) ideals of sustainability are set as the normative attractors in the complex adaptive local food system. If the contextual attractors and the saddle points of the system could be anticipated and extracted out of the multitude of possible system states, they would provide valuable information of the qualities of the system, also for teleological purposes of navigation and transition management. We will try to identify these locations by utilising futures images, which will be discussed next.

Table 2
Key elements of the complex adaptive systems (CAS).

Concept	Description
Attractor	Configurative location in a dynamical system toward which or around which, the system tends to evolve in the state space. CAS may have multiple attractors. In socio-economic CAS the attractors may be comprised by habits, routines, norms, dominant designs, preferences, ideals, innovations, demand trends etc. which turn specific locations in the system to more desirable, probable or common state spaces than others.
Basin of attraction	Wider state space around the attractors within which the micro-level dynamics of the CAS takes place. The effective power field of the attractor maintains the trajectory of the CAS within the basin of attraction. A watershed or valley around the attractor is a feasible topological metaphor for the basin of attraction.
Saddle point	A separator of adjacent basins of attraction and an obstacle for system change. Depending on the qualities of the CAS, the trajectory of the system may or may not cross the saddle. A mountain between watersheds or valleys (basins of attraction) is a topological metaphor for the saddle point.
Trajectory	Cumulative change of the evolving system in the state space. Some systems and their attractors are deterministic giving rise to precise predictability of the trajectories, whereas others are non-deterministic and lack this feature.

4. Futures images and CAS dynamics

Non-linear dynamics make the exact trajectories of complex adaptive systems highly unpredictable (Mackenzie, 2005). Even though the precise description and explanation of these systems escapes from us, it simultaneously opens up a "possibilization of the future" (ibid., 49). Truly many alternative configurations are possible and in social systems they may be pursued and promoted. Complex adaptive systems have agency (the "adaptive" in CAS). The agency may well be hidden from the agents (Holtz et al., 2008, 627–628) and exist "everywhere" in the system (Byrne and Callaghan, 2014, 193), but the agency may be also explicit, teleological and deliberate (De Haan & Rotmans, 2011, 99). Transition toward more sustainable and local food systems credibly happens only via intentional action. The ideals of sustainability or more specific long-term goals may inform the direction of the sustainability journey (Markand et al. 2012, 956). Having a shared understanding about the sustainability goals, may assist in the anticipation of the attractors of the sustainability journey.

Futures images are an ideal tool for this purpose: for envisioning, structuring, crystallising and parallelising divergent views through a process of extracting some alternatives available in the state space. A futures image is "an expectation about the state of things to come at some future time" (Bell & Mau 1971, 23), and we are interested in specific states of things ("maximum sustainability") at a specific future time ("in 2030"). While futures images are being cultivated with versatile epistemological basins (e.g. conceptual vs. empirical) and methodological guidelines (e.g. futures tables vs. participatory processes), they have a common role in serving goal and agenda setting, motivation, futures choices and innovation at the individual and collective levels (Bell and Mau, 1971, 21; De Smedt et al., 2013, 433; Vasquez, 1999, 344). Futures images contribute to guiding human behaviour (Rubin, 1998, 498) and thus "contribute to the creation of the shape of the coming future itself" (Bell, 1997, 86). However, if we want to adapt to or control alternative futures, we need to envision and formulate them first.

For futures images to serve a community in the navigation on a sustainability journey, they should envision desirable destinations and/or expose obstacles residing on the futures field (van der Helm, 2009, 99). In futures research, the alternative futures are often explored in terms of high or low desirability, possibility and probability (Amara, 1981; Masini, 2006). As we have a normative agenda, we strive for crafting desirable and possible futures of sustainable local food systems along with identification of obstacles for their realisation. These represent attractors and saddle point in the complexity literature, respectively. The ideal of sustainability gives rise to the "pull of the future", whereas drawbacks of the dominant corporate food regime facilitate a "push of the present" and cause much of the "weight of history" as rigidities,

path dependence and lack of vision on our way to plausible futures (Inayatullah, 2008, 8; Polak, 1973, 1). As the becoming attractors of complex adaptive system are fuzzy and difficult to anticipate, we look for broader representations of alternative futures rather than single point estimates. In this role, futures images have been observed to work well in distancing from the present (Beers et al., 2010, 726): "The mobilising power of simple images can impede understandings of complexity in (sustainability) problems". In this role, futures images are presumed to work better than scenarios, which focus on the trajectories rather than on the projected states of development (Slaughter, 2004, 103, 106).

This rather long elaboration of the research strategy provides several benefits for studying the milestones of sustainability journeys. First, by using futures images in tracing attractors of the complex adaptive local food system it becomes possible to avoid approaching futures in a way that rather replicates the rigidities and trajectories of the current system as "comparative statics" than assists in opening up new worlds. Navigation toward sustainability may take many other forms besides those alternative food systems described in Table 1. Second, the strategy serves at avoiding overwhelming reductionism by taking a more holistic view of the system wholes. Apart from this, finding the appropriate level of abstraction is primarily an empirical matter and, as such, one of the most challenging tasks in social sciences. Too narrow or broad a view both result in less meaningless insights – also concerning sustainability transitions (Rotmans and Loorbach, 2009, 190). Finally, the conceptualisation brings together several disciplines and strands of literature to work together for a common goal, which is expected to expose more effective transition management agendas than separate contributions. We will show how this strategy helps to draw insightful conclusions concerning policy measures, governance and management of sustainable local food systems and innovations needed for their realisation as well as concerning studies of sustainability journeys.

5. Methodology

Our analytical devices are targeted at the normative ideal of multidimensional (economic, environmental, social, cultural) sustainability and sharpened at the mid-term milestones of the sustainability journey of local food systems in Finland. In this quest, we will anchor ourselves to the field of science by two presumptions. First, the *ontology of complex adaptive systems* implies that the food systems will self-organise to conform some sensible configurations to meet their primary task of feeding people. They do not end up in chaos or randomness, but organise themselves around various attractors (Gerrits, 2012, 157), which are more robust and more possible to anticipate than the variants of the systems they effectuate. Second, the *evolutionary epistemology* – in the social domain – implies that systems adapt to their environments through a combination of trial-and-error learning and deliberate action (Aldrich and Ruef, 2006, 18–19; Plotkin, 1993, 248). In the social domain, the resulting "bookkeepers" of the accumulated evolutionary knowledge may be diverse social systems instead of biological species or phenotypes (Kovác, 2007, 65). Regarding our case, these dynamically stable containers of the evolutionary knowledge (Plotkin, 1993, 229, 244) are food systems that evolve to have an adequate fit within the economic, environmental, social and cultural environment to be functional entities. The food systems interact, compete and attract resources from the environment while maintaining a structure, coherence and boundary. If they fail, they release their resources to the environment to become reorganised into other wholes: different kinds of food systems. The systems are driven by their "genes", by the attractors. In the 20th century food systems these attractors were, among others: high-input agriculture; commodification, processing and packaging of food; logistic networks; supermarkets and food shopping. The 21st century sustainable local food systems organise around other kinds of attractors, to which part of the contemporary systems will swap.

Currently, *futures images* may present this organised complexity as coherent configurations. Futures images are our analytical models to probe the future in the exercise of "disciplined imagination" (Weick, 1989, 520), where the "discipline" comes from the normative stance of sustainability and the "imagination" comes from the need of creativity and envisioning in grasping representations of things to come. As we are interested in the futures images of sustainable local food systems, we have followed three principles in facilitating the empirical research process to assure the quality of the data. First, the deliberate part of the future of social systems resides within human minds (Bell, 1997, 174, 211). For this reason, the "imagination" part should come from actors that have "emotions, fears, hopes, personal history, and experiences, as well as … general views, values, and opinions shared by the society and the environment" (Rubin, 1998, 498) concerning local food. Second, sustainability is an ill-defined, vague, complex and fuzzy concept (Phillis and Andriantiatsaholiniaina, 2001) and partly unknown for the (local) food actors and stakeholders. For this reason, we made an extensive literature survey on the sustainability of local food (Kuhmonen et al., 2015) and refined the findings into key points of each sustainability dimension to be presented for the actors in the workshops. Third, in crafting alternative futures, the choice of appropriate level of abstraction is a key issue (Levins, 2006). The complex reality has to be compressed to make it manageable and comprehensible even with some aspects of it will be lost (Gerrits, 2012, 168). As we wanted to tease out specific images of the local food systems, we refined exemplary images for each dimension for the actors to have an idea of the feasible "flight altitude".

Since our images ask for envisioning, creativity and evaluation ("possible futures"), we used a participative method called *futures workshops* (Jungk and Müllert, 1987) for crafting the futures images. This social technology inspires imagination and reflection among and between the groups of participants, when each group first creates its own contribution and then complements the contributions of other groups. We first organised one national futures workshop, in which four national futures images were crafted (see Fig. 1). The images were instructed to maximise the economic, environmental, social and cultural sustainability, respectively, in about 2030. This approach broke down the intellectual monoculture of the dominant and alternative food systems, since the novel assemblages were to direct to specific kind of sustainability rather than to stick to evaluation of the sustainability contributions of the existing systems. In the second futures workshop, the research team (five persons) elaborated the output of the workshop to prototypic futures images for the four sustainable local food systems in Finland: Short Food Chain for economic sustainability, Green Food Chain for environmental sustainability, Fair Food Chain for social sustainability and Genuine Food Chain for cultural sustainability.

In the second stage, we organised four regional futures workshops to observe the special socio-economic and environmental circumstances and cultural characteristics of the large country. In each of these workshops, four region-specific futures images were crafted which maximise the four dimensions of sustainability in about the year 2030. After crafting the images, the obstacles for their realisation were identified. All workshops were organised in May–December 2015 and lasted for 3 h. In order to have diverse but topic-relevant participants, we used an expertise matrix and targeted invitations in recruiting participants to the workshops. A third of the nine participants of the national workshop represented alternative food systems, a third represented advisory and development organisations and a third represented academic food research; they also represented local, regional and national actors in equal shares. The affiliations of the 83 participants of the regional workshops were as follows: administration 7, agricultural and food business 17, NGOs 19, development and education 20 and research 20. Finally, the prototypic national futures images were calibrated utilising the contributions of the regional workshops. The empirical research process is synthesised in Fig. 1.

At the third stage, the outputs of the futures workshops were analysed by means of conventional content analysis without predefined categories (Hsieh and Shannon, 2005; Krippendorff, 2004) to expose the attractors and other qualities of the sustainable local food systems. This compression was an essential stage of arriving from the diverse manifestations of the CAS to their more robust elements, as discussed earlier. In this reconceptualisation of the futures images, we have considered the four dimensions of sustainability as basins of attraction, their elements as attractors and their barriers of realisation as saddle points in complex adaptive systems. Regarding the attractors, the content analysis resulted in identifying 370 elements of the original images, which were further compressed into 68 more abstract keywords. Regarding the saddle points, the content analysis resulted in 213 elements and 30 keywords. We have also taken a brief analysis of the futures images to locate the attractors and saddle points in terms of structure and agency (Archer, 2000; Giddens, 1984): where in the food chain and among which actors do the attractors and saddle points reside. The identified elements of the futures images are placed in the food chain (production, trading & delivery, consumption) and the resulting rankings of the origin of structural change and agency are presented in the results. We still would like to reiterate that even though this approach took multiple perspectives on the food futures within the sustainability frame, it still produced one set of possible futures within the state space of all the possibilities. We suspect that repeating the research process in other locations in Finland would have resulted in different manifestations of the complex adaptive food systems, but with rather similar attractors and saddle points, as envisaged by the inherent properties of the CAS.

6. Results

6.1. Interim results: futures images of the sustainable local food systems

The national and the regional futures images display a significant superficial diversity, which is typical for the method: different days, different participants, different futures. However, different representations of the four sustainability dimensions share several common logics and elements. As we do not have space to report all the 20 versions of the sustainable local food futures, we will introduce the final national futures images in Table 3 as an example of the outputs before proceeding to the analysis in proper.

6.2. Final results: mapping the futures images into complex adaptive system landscapes

In the state space of all possible configurations of the food systems, each of the sustainability dimensions will comprise of a basin of attraction within which the system will self-organise itself around specific *attractors*. These attractors are located by identifying the key contents of the various future images specifying each dimension. By means of content analysis, the 370 elements of the original images are compressed into 68 more abstract keywords, most common of which are listed in Table 4. The most common keywords in each dimension are the most powerful attractors within that basin of attraction. As we can see, the key attractors of the Short Food Chain for economic sustainability are reorganised trade and delivery methods, reorganised retail trade and reorganised ownership. Realisation of the futures images would come with and bring about novel configurations of these elements. In the Green Food Chain for environmental sustainability, the key attractors are self-sufficiency, development of new products and new production technology. Further on, the Fair Food Chain manifesting social sustainability will organise around transparent food chain, reorganised trading and delivery methods and certification of fair food. Finally, the Genuine Food Chain for cultural sustainability is attracted by new food culture, genuine food brands and food tourism. The very idea of sustainable development is of balanced, multidimensional progress (Brundtland, 1987, 6–7). Following this idea, the four basins of attraction or substantive sustainability dimensions – economic, environmental, social and cultural – would fuse together. In this case, the roles of the attractors are slightly different from the separate basins. The most powerful attractors are reorganised trade and delivery methods, new food culture and development of new products. A number of less powerful attractors also pattern the complexity.

The sustainability journey or swapping of attractors by the food systems toward sustainable local variants is resisted or hindered by *saddle points* or saddle frontiers. These are located by identifying elements in the state space that made the futures images impossible or difficult to realise before 2030. By means of content analysis, the 213 original elements are compressed down into 30 more abstract keywords, of which the most common are listed in Table 5. The most common keywords in each dimension are the most powerful saddle points separating the basins of attraction. The key issues resisting swapping to Short Food Chains are contemporary consumption habits, low profitability and concentrated food trade. The most significant powers to resist evolution of Green Food Chains are the lack of innovations, consumption habits and lack of appreciation. Development of Fair Food Chains is resisted by the concentrated food retailers and by the lack of the reorganiser and lack of appreciation of sustainable local food. Finally, Genuine Food Chains are resisted especially by the lack of know-how, lack of appreciation and contemporary consumption habits. These saddle points in the wide state space of food systems especially resist the specific sustainable local food systems from attracting more resources from the environment to develop and grow. Fusing of the basins of attractors into a single one representing

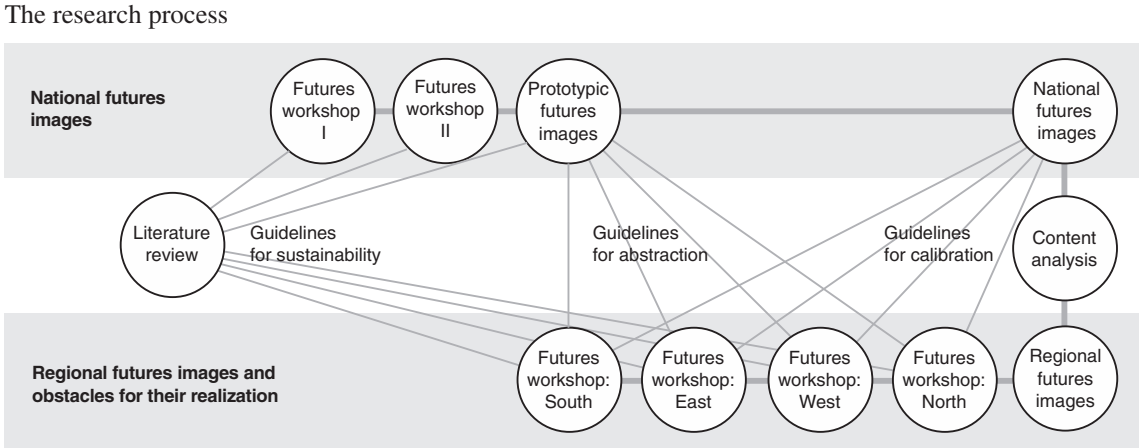

Fig. 1. The research process.

Table 3
Futures images of possible local food systems in Finland by 2030 - maximising each dimension of sustainability.

Short Food Chain for economic sustainability	Consumers and producers get bored with the dictatorship by the retail trade and unite their forces to bypass it. The short value chain is transparent, when identifiable food products pass directly from the producers to the consumers. Hundreds of local food cells facilitate direct interaction and feedback between producers and consumers. The producers guarantee the quality and safety of their products by their own name and face. A consumer may choose local products from the food cell or special products from the national web shop. A new co-operative of consumers and producers owns the web shop and some production sites. On Saturdays, food wagons gather together on market squares, where food is made, bought and enjoyed. The few ordinary markets sell mostly imported products like coffee, tea, olive oil and tropical fruit or top up the lacking local production in the main cities. The closer link between production and consumption reduces waste and the food cells recycle food packages. Less agricultural subsidies will be needed, since the lack of intermediaries and efficient organisation of the two delivery systems grant the producers and consumers with monetary benefits. The short chain maximises the common value added by producers and consumers within the food chain. Consumers buy 40% of their food from the local food cell, 40% from the web shop and 20% from ordinary supermarkets.
Green Food Chain for environmental sustainability	Global instability and climate change drive the worried citizens and policymakers for regional self-sufficiency. In the green chain, the environmental impacts of food are transparent through the geographical proximity of production and consumption. Maintenance of soil productivity, reduction of long-distance transportation and cutting of environmental damage are the guiding stars in the food chain. The environmental and food security risks of regionally concentrated "cheap food" production are recognised, valued and included in food prices. Food production and consumption are characterised by strong self-sufficiency. Inputs are mainly local or domestic and the nutrients are recycled; domestic bioenergy fuels heating, production and transportation. The food system reorganises into scales where nutrients and biomasses for food, feed and energy will circulate efficiently. New technology scans environmental risks and, together with various indicators, facilitates resource efficiency. Food is produced everywhere: in forests, city parks, roofs, balconies, large fields and small gardens. The green chain maximises the local environmental capital stock and its productivity in food production in the long run. 20% of the consumer food is self-produced, 60% comes from the local region (<100 km) and 20 % comes from further away.
Fair Food Chain for social sustainability	Acknowledgement of social inequality put responsibility and social justice to the core of food economy. In the fair chain, the social impacts of food are transparent trough certification. The certificate guarantees a lawful, just and ethical action by the stakeholders of the domestic food system. The terms of the certificate provide full-cost pricing of domestic food, including the costs of animal welfare, hired labour and farmer's inputs. Waste food is delivered for charity through contract organisations. Terms of the certificate require full transparency and traceability: the sites of production, the names of producers and their share in the selling price must be presented in the shop or in the product. In this way, the consumer knows the economic and social effects of her/his choices. The certificate is widely required in the public procurement of food. Several agricultural aid schemes, stamps and labels are fused with the certificate system, which reduces the need of subsidies and bureaucracy. The certificate system is maintained by a fund; members of the board are nominated half and half by consumer and producer organisations. The fair chain maximises the food-related social capital among the stakeholders. 80% of the domestic food that consumers buy is certified and 20% is not.
Genuine Food Chain for cultural sustainability	Food education and food enlightenment breed a new food culture. In the genuine chain, the food has a story of its history and life course. Food is born in skilful hands, in specific places and with transparent methods, which become known to the consumer. At the local level, this information comes directly from the producers; at the national level, it is obtained from the products, shops or producer's web pages; at the international level, its comes with the arctic brand. Food production and consumption as a historical and cultural issue is part of the basic education. The rise of the new food culture boosts food tourism and provokes the creative class to add magic for the genuine food. The nation, which has reached self-sufficiency in food in the middle of snow, rocks, swamps, waters and forests, is proud of its creation: the ethnic food of Finland. Many people become interested in indigenous breeds, species and varieties. The national food map is full of stories. Food exports and food tourism flourish as well as seasonal food. The food coming from a known source tackles potentially fake and dangerous food, which comes from unknown sources and is inspected only occasionally. The genuine chain maximises the food-related cultural capital. 95% of the domestic food purchased by consumers includes information concerning the producers and production sites, dates and methods, while 5 % remains without a history.

balanced multidimensional sustainable development will relocate the saddle points to some extent. The most powerful saddle points resisting this configuration are contemporary consumption habits, low profitability and the lack of appreciation.

6.3. Epilogue: the attractors and saddle points in a structure–agency setting

Analysis of the contents of futures images exposes a rich number of elements, which attract and resist reconfiguration of the food systems. By taking still a higher level of abstraction, these results are reanalysed by looking at the hot spots of attraction and resistance from the structure–agency perspective. This assists is targeting the actions of transition management. We first expose the attractors and saddle points in the *structure* of the food chain by asking, to which part of the food system do the elements of the new configurations belong (attractors) or to which part of the food system does the resistance originate (saddle points). Regarding the attractors, the sustainability journey asks for extensive changes in all main parts of the food system: production, trading & delivery and consumption (Table 6). In the Short, Fair and Genuine Food Chains, trading & delivery is most extensively affected, whereas in Green Food Chains this holds for production. There was some variation in the regional versions of the futures, but

Table 4
Top-10 attractors of the sustainable local food systems by basins of attraction, keywords in descending order according to frequency.

Short Food Chains for economic sustainability	Green Food Chains for environmental sustainability	Fair Food Chains for social sustainability	Genuine Food Chains for cultural sustainability	Fused food chains for multidimensional sustainability
New trading methods	Self-sufficiency	Transparency	New food culture	New trading methods
Reorganised retail	Product development	New trading methods	Food brands	New food culture
New ownership	Production technology	Certification	Food tourism	Product development
Food processing	Circular economy	Co-operation	Product development	Brands
Public procurement	Self-made food	Traceability	Food education	Transparency
Reorganised logistics	New trading methods	Reorganised retail	Food stories	Food tourism
Consumption habits	Consumption habits	Subsidies	New trading methods	Co-operation
Seasonal food	Legislation	Empowered producers	Food processing	Self-made food
Direct interaction	Organic food	Ethical conduct	Self-made food	Traceability
Societal change	Subsidies	Equity	Traceability	Self-sufficiency

the general tendency was rather similar. Regarding the saddle points, they originate rather equally from production, trading & delivery and consumption. While most of the extensive resistance for Short, Fair and Genuine Food Chains originates in trading & delivery, the Green Food Chains are most extensively resisted by production-related factors. To sum up, in the navigation toward the sustainability of local food systems, the whole food systems would face changes and most extensively within the trading and distribution subsystem.

Regarding the *agency*, we ask for the origin of the agency among key actors of the food systems. For the generation of the attractors of sustainable local food systems in general, the most extensive source of agency accrues to producers, followed by business firms (including retail trade), consumers, public bodies (policy makers and administrators) and NGOs (Table 7). The role of food producers is most significant across all four types of food chains, whereas the role of consumers as a source of agency is emphasised in Short and Green Food Chains and the role of business firms in significant in Fair and Genuine Food Chains. In general, the agency resisting these futures originates most extensively within the business firms (especially retail trade) but varies unsystematically between types of food systems. For Short and Green Food Chains, most extensive resistance comes from the consumers, whereas for Fair and Genuine Food Chains it comes from the business firms. Comparing the roles of the actors both as the origin of novelty and as the origin of resistance, the role of the producers turns clearly into a role of an innovator and change agent, whereas the roles of the consumers and business firms are more passive and resistant. Transition management efforts should be informed about these positions of the target groups.

7. Discussion and conclusion

This study aims at exposing the potential of futures images in anticipating and informing transitions of complex adaptive systems toward sustainability, with the consideration that we live at the edge of paradigm shift and are hungry for knowing about the new worlds. Our case is the food system. While it is plausible to say that "the" future cannot be predicted (Dator, 2007, 2) and "the" trajectories of the complex systems may not be foreseen (Levin, 2002, 17), we may still say something about the existence and qualities of alternative futures. If a paradigm shift toward sustainable local food systems will take place, a countless number of local sustainability journeys will commence. If we accept that food systems are complex adaptive systems, this has implications for studying their evolution. Intrinsically, we cannot foresee or predict their exact trajectories, since they unfold along with the inherent features of heterogeneity, nonlinearity and self-organisation of complex adaptive systems. There is a ghost in the machine.

However, since the systems share a common direction, we can say something about the qualities of the milestones toward which these systems navigate. "Every transition becomes coordinated at some point through the alignment of visions and activities of different groups" (Geels and Schot, 2007, 402). While attractors and saddle points are the most stable and robust elements of complex adaptive systems, they are more feasible targets of foresight than the several variants of detailed socio-economic systems that the attractors configure and effectuate. We have tried to figure out the ways to anticipate these kinds of milestones by futures images: through working with an appropriate level of abstraction and by breaking the linear relationship between the present and the future.

Our results suggest that sustainability-oriented trading and delivery systems, food cultures, product development projects, food brands and transparent food systems are the most powerful attractors of the emerging sustainable local food systems in Finland. The voices of the attractors vary according to the dimensions of sustainability. The economic sustainability journey navigates toward reorganisation of the consumer–producer interaction, the environmental sustainability journey toward geographically reconstructed circular and self-sufficient systems, the social sustainability journey toward transparent and certified co-operative food systems and the cultural sustainability journey toward emergence of a new food culture with genuine brands. These attractors are different from those of the 20th century corporate food system, which organised around manufacturing and processing to make food perishable, transportable and suitable for easy shopping. Furthermore the results suggest that the main source of innovation and organisation comes from the food producers and the main resistance comes from within the inert, institutionalised and locked corporate food regime; especially from the powerful retail trade and from the consumers who are habitualised to easy and cheap food. However at the same time our results add to the extensive literature on food systems by explicitly exposing some candidates for milestones of the sustainability journey, their locations in the food chain and the agency effectuating them, without taking a stance on any specific organisational form. This makes the findings applicable to several contexts irrespective of the contemporary state of affairs. We do not predict the evolution of the food systems or claim priority for certain kind of a system, but open up alternatives for "states of things to come at some future time" (Bell and Mau, 1971, 23) within the domain of sustainability transition. To the extent that we become aware of the future alternatives, our domain of possible choices becomes expanded (Slaughter, 1993, 290).

Based on the results, experiences and insights gained in this exercise, two lessons are justifiable. The first lesson is for the *scientific enterprise* struggling with appropriate frameworks and models to describe, explain and anticipate complex, dynamic and multidimensional phenomena. Our choice was to conceptualise the emerging and evolving sustainable local food systems as complex adaptive systems (CAS) and to chase the milestones of the sustainability journey by futures images. Following Vasileiadou and Safarzynska (2010), we took "complexity seriously" in transitions. This choice made it possible to identify both the pull of attractors and the resistance of saddle points. Application of the structure–agency setting made it possible to see in which parts of the system these where located and who was expected to energise them. We tried to avoid the "precision trap" of exact trajectories by abstracting to more robust attractors and saddle points of the systems. While sustainable local food systems have a myriad of variants, they

Table 5
Top-10 saddle points in the sustainable local food systems by basins of attraction, keywords in descending order according to frequency.

Short Food Chains for economic sustainability	Green Food Chains for environmental sustainability	Fair Food Chains for social sustainability	Genuine Food Chains for cultural sustainability	Fused food chains for multidimensional sustainability
Consumption habits	Lack of innovations	Concentrated food trade	Lack of know-how	Consumption habits
Low profitability	Consumption habits	Lack of organiser	Lack of appreciation	Low profitability
Concentrated food trade	Lack of appreciation	Lack of appreciation	Consumption habits	Lack of appreciation
Legislation, bureaucracy	Low profitability	Low profitability	Lack of co-operation	Legislation, bureaucracy
Price-driven choices	Environmental problems	International forces	International forces	Concentrated food trade
Lack of value premium	Lack of transparency	Lack of resources	Legislation, bureaucracy	International forces
Lack of effective demand	International forces	Lack of information	Lack of entrepreneurship	Lack of know-how
Lack of entrepreneurship	Societal policies	Corrupted price-image	Lack of resources	Lack of co-operation
Lack of know-how	Price-driven choices	Lack of value premium	Lack of organiser	Lack of innovations
Lack of returns to scale	Distorted support policy	Lack of co-operation	Lack of information	Lack of resources

Table 6
Hot spots of structural changes upon the sustainability journey of local food systems, ranking from highest (1) to lowest (3) according to the share as a location of attractors and saddle points.

	Short Food Chains for economic sustainability	Green Food Chains for environmental sustainability	Fair Food Chains for social sustainability	Genuine Food Chains for cultural sustainability	Fused food chains for multidimensional sustainability
Attractors:					
Production	2	1	2	2	2
Trading & delivery	1	2	1	1	1
Consumption	3	3	3	3	3
Saddle points:					
Production	3	1	2	3	2
Trading & delivery	1	2	1	1	1
Consumption	2	3	3	2	3

most probably organise around some central issues, as our stylised descriptions of the existing systems and the extant literature already suggests. Calibration to an appropriate level of abstraction is the key issue in detection of robust attractors and saddle points of complex socio-economic systems. In our view, this research strategy resulted in a more thick description of structures and governance than the ANT-based approach (Actor Network Theory) and more informed view on the alternative futures than the MLP-based approach (Multi Level Perspective). If wished, the contemporary alternative food systems may be considered as "niches" in the MLP and the futures images as "visions" serving their evolution in the future (Geels and Schot, 2007, 401). The visionary element in the MLP is rather undeveloped and could benefit from more explicit linkage to futures research.

Despite that, our findings are well in line with the research literature on alternative food systems (e.g. Forsell and Lankoski, 2015; Grauerholz and Owens, 2015) and conceptualisation of sustainability journeys (e.g. Markand et al., 2012), we still have the problem of external validity of our futures images. They comprise a small set of all possible and feasible mental representations of sustainable local food systems. Another study would bring about different kinds of manifestations. By leaning on the research literature and participative futures workshops it was possible to combine these categories of knowledge in the disciplined imagination exercise of crafting futures images. One way to improve validity of envisioning futures of complex socio-economic systems, followed in and illustrated by this study, is the reliance on multiple knowledge bases together with a multi-perspective and multidisciplinary approach representing various viewpoints, values, rationales, substances and sciences (Huutoniemi, 2014).

However, the unavoidably limited external validity of the images is not as crucial as the way in which they are used. We took a normative stance on sustainability as a "discipline", which guided the "imagination" of sustainability journeys. Sustainability, the future and the complex local food systems are all fuzzy concepts and our understandings about them will always be limited. We study journeys, futures in-the-making, about which our understandings evolve continuously. Next year many of us would possibly make different kinds of futures images. Also the concept of sustainable development evolves and has recently grown into a broad, multidimensional ideal, which emphasises contextual sensitivity in the formulation of the targets of the journeys (United Nations, 2015). This is the ultimate lesson of evolutionary epistemology and evolutionary learning: the futures images should be updated frequently. It is important to update the mental representations that chase the becoming milestones, because both representation and milestones are subject to change. In this way, futures images may serve social learning about the alternative futures (Kuhmonen and Kuhmonen, 2015) and transition management toward them (Nill and Kemp, 2009). "Even if you cannot bathe twice in the same river, one still tries to develop some robust representation of the river itself and some swimming heuristics" (Dosi et al., 2005, 271). This setting calls for foresight practitioners to regularly and systematically update their findings. Our findings also suggest that the analytical darkness in studying evolutionary complex systems could be reduced by carefully choosing a rather high level of abstraction: by targeting the foresight of attractors and saddle points of the possible representations of the future.

The second lesson is for the *stakeholders* struggling with anticipation and management of sustainability journeys of food systems with a long-term and strategic agenda. "The rationale behind transition management is that there are persistent problems for which there are no immediate solutions" (Rotmans and Kemp, 2008, 1006). The main challenges in transition management as a governance approach are related to the evaluation of alternative targets, to streamlining of the activities toward the targets and to finding effective tools to effectuate the targets (Turnheim et al., 2015; Voß et al., 2009). For all these concerns, futures images may help in the reflexive governance of "becoming". Sustainability may be a crosscutting bottom-line of the 21st century policies and the sustainability journeys need instructive milestones. Since policies promoting sustainability transitions are designed to work at various domains, scales and levels, they often remain broad, flat and un-instructive. For example, the Rural Development Programme for 2014–2020 in Finland – also financing local food projects – aims at "promoting

Table 7
Hot spots of agency upon the sustainability journey of local food systems, ranking from highest (1) to lowest (5) according to the share as a source of attractors and saddle points.

	Short Food Chains for economic sustainability	Green Food Chains for environmental sustainability	Fair Food Chains for social sustainability	Genuine Food Chains for cultural sustainability	Fused food chains for multidimensional sustainability
Attractors:					
Producers	1	1	1	1	1
Consumers	2	2	4	3	3
Business firms	3	3	2	2	2
Public bodies	4	4	3	4	4
NGOs	..	..	5	5	5
Saddle points:					
Producers	3	4	2	2	3
Consumers	1	1	3	3	2
Business firms	2	2	1	1	1
Public bodies	4	3	4	4	4
NGOs	..	..	..	..	..

bio-economy and, as part of it, practising agriculture that is economically, socially and ecologically sustainable and ethically acceptable" (MAF, 2014, 105). Obviously, explicating this statement into region and business specific futures images through participative methods would enhance social learning and innovations necessary for realising the aims of the programme (Voß et al., 2009, 283). In transition management of complex systems, one has to "try to find new attractors for the system by developing a sustainability vision" (Rotmans and Loorbach, 2009, 191). In the absence of this, also directionality failure may arise (Weber and Rohracher, 2012, 1042).

As a reflexive process, this approach serves policy design and delivery. Sustainability transition is essentially a continuous social learning process, where frequently updated futures images in various scales, contexts and temporalities are valuable tools. Based on this study, management of sustainability journeys – transition management – is related to policies, management practices and innovations that on the one hand promote sustainability-oriented trading and delivery systems, food cultures and product development projects (attractors) and on the other hand resolve the problems arising from contemporary consumption habits, inefficient organisation of local food systems, restrictive legislation and bureaucracy and dominant position of the retailers (saddle points). These issues, together with knowledge concerning the affected structures and sources of agency in the food chain, may assist in defining "arenas of development" (Jørgensen, 2012, 1003) and framing "system innovations" (Smith et al., 2010, 439) for managing sustainability transition. We believe that the attractors, saddle points and hot spots of structural change and agency also have some general applicability, since the "genes" of the food systems are less diversified than their "phenotypes". We suspect that repeating the research process in other locations in Finland would have resulted in different manifestations of the complex adaptive food systems, but would have rather similar attractors and saddle points, as envisaged by the inherent properties of the CAS.

As a conclusion, even after our contribution, proactive management of the sustainability journeys of complex systems remains a major challenge for scientists and practitioners. Combination of complexity, transition and futures research provides one avenue ahead in getting a holistic but meaningful grip of the evolution of these kinds of systems. A great deal of further research is needed both in the conceptual and empirical domains to anchor the research strategy better in various disciplines, scales, contexts and purposes. The paradigm shift at hand will keep us busy with framing and structuring issues for a while.

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Tuomas Kuhmonen is currently the Research Director at Finland Futures Research Centre, University of Turku, Finland. Previously, he has been a Professor of Agricultural Policy (University of Helsinki) and a Professor of Entrepreneurship (University of Jyväskylä). He has worked together with many governments, experts and stakeholders to learn about agricultural, food, rural and regional issues. His research interests include socio-economic transformations, policy studies, futures images and evolutionary epistemology.

IV

SYSTEMS VIEW OF FUTURE OF WICKED PROBLEMS TO BE ADDRESSED BY THE COMMON AGRICULTURAL POLICY

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Systems view of future of wicked problems to be addressed by the Common Agricultural Policy

Tuomas Kuhmonen

Finland Futures Research Centre, Turku School of Economics, FI-20014, University of Turku, Finland

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ABSTRACT

Public policies address societal problems. The problems chased by the Common Agricultural Policy (CAP) of the European Union (EU) have been persistent. The institutional and political economy reasons for this setting have been discussed widely, but the role of the problems lack robust analysis. This study contributes to an explicit understanding of the CAP problems as a system of wicked problems. Wicked problems escape simple and final solutions and form an interconnected 'jam', where each resolution generates a cascade of new problems and collateral damages.

The CAP problematics are analysed with the systems dynamics methodology, causal loop diagrams. A system of CAP problems was reconstructed based on the content analysis of survey data for 52 Finnish experts, representing various dimensions of the CAP in a balanced manner. Abstraction and categorisation of the 303 listed problems to be addressed by the CAP in the future resulted in 22 key problems under five domains (socio-environmental, spatial, policy, market, farming). The problems formed three agglomerations with reinforcing causal loops: the subsystems of competitiveness, sustainability, and heterogeneity. The full system of CAP problems comprised 114 causal links across all five domains. The problems also had varying positions in the network regarding connectivity and causation. For example, multidimensional sustainable development qualified as the most networked problem, free trade with divergent farming regulations was the most extensively wired driver problem, and competitiveness and incomes in agriculture was the most extensively connected dependent problem. Extending the time horizon from 2020 to 2040 indicates that the negative impact of climate change on food production capacity and food security would accentuate; otherwise, the CAP policy makers would be stuck with, more or less, path-dependent problematics.

The results confirm that CAP problems exhibit all ten properties of wicked problems and constitute a tightly wired and evolving complex adaptive system. Solutions to these types of problems should not be chased with a domain-specific approach, as spatial, farming, market, or environmental problems, but rather as networked, driver, dependent, and punctuated problems observing systems dynamics. This problem network status strongly affects the possibilities and feasible means to find better trade-offs between the problems; notably, complete solutions should not be expected due to the systemic and wicked properties of the CAP problems.

1. Introduction

Public policies chase societal problems (May and Jochim, 2013). The burning problems at the inception of the Common Agricultural Policy (CAP) of the European Union (EU) were striking: have a sufficient amount of food for the population at affordable prices and promote productivity growth, modernisation, and structural adjustment of the large agricultural sector (Tracy, 1989; Treaty of Rome, 1957). Over time, new concerns have emerged: how to cope with market imbalance and volatility, national exchange rates, environmental concerns, uneven territorial development, and cohesion of the enlarged EU (Feindt, 2010; Gorton et al., 2009; Josling, 2008a; Oskam et al., 2011; Swain, 2013; Tangermann and von Cramon-Taubadel, 2013). This enrichment of problems has contributed to the accumulation of the complexity of the CAP. Addressing these additional problems requires more measures and more internal heterogeneity to be considered, that then requires far more differentiation of the measures. The portfolio of problems underpinning the CAP has not been observed to decrease over time to make room for simplification and leaning of the policy (Burrell, 2009; Josling, 2008b). One possible reason for this situation is that the problems the CAP aims to resolve are wicked problems.

Wicked policy problems are different from tame problems because they have no final, definitive, and explicit solution (Rittel and Webber, 1973). Wicked problems are open to divergent and conflicting

E-mail address: tuomas.kuhmonen@utu.fi.

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arguments for resolutions and have causal relationships with other problems (ibid.). Various stakeholders generally disagree on both the nature of the problem and the best solution (Conklin, 2006; Roberts, 2000). A specifically important aspect of the wicked problems is their endogenous resolution space: a tentative resolution depends on the direction of approach for finding the resolution, creating new connected problems to be managed (Rittel and Webber, 1973). These characteristics are typical for CAP problems. For example, resolving the agricultural pollution and biodiversity problems through extensification would lead to new problems in agricultural productivity, trade balance, agricultural incomes, and subsidy budgets. Resolving those four problems through straightforward intensification would increase the severity of the environmental problems. Combining the aspects of extensification and intensification into 'sustainable intensification' (Godfray and Garnett, 2014) would add complexity and regulative burden to indicate sustainability. Omitting this sustainability regulation would leave the definition of the bargaining process to be created between the stakeholders of the food system, leading to perpetuating and escalating circles of argumentation between conflicting frames (Candel et al., 2014). This simple illustration suggests that many CAP problems cannot be definitively solved without conflict or collateral damage.

The faculty of explanation of the CAP problems and their persistence is rich. From the political economy perspective, for example, the dominant state-supported agriculture regime in developed economies is considered to occur because of constrained structural adjustment and declining comparative advantage of the farming sector (Anderson et al., 2013; De Gorter and Swinnen, 2002; Honma and Hayami, 1986). A rich array of social and environmental perspectives have suggested that long-term government intervention is required to manage market imperfections, externalities, and public goods (Blandford and Fulponi, 1999; Dibden et al., 2009; Hall et al., 2004; Pretty et al., 2001). In addition to these types of substantive domains, various institutional explanations have suggested that the complex political and decision-making configurations of the EU—in general—tend to breed incremental, reactive, and path-dependent policy changes (Garzon, 2006; Harvey, 2004; Kay, 2003; Lynggaard, 2007; Peterson and Bomberg, 1999; Thomas et al., 2008).

Path dependence is maintained by various self-reinforcing mechanisms that selectively afford and constrain future choices (Denzau and North, 1994; Mahoney, 2000; North, 1990). Concomitantly, the state-assisted agriculture regime of the CAP (Coleman et al., 1997; Daugbjerg and Swinbank, 2016), once opted for, is difficult to give up, and the policy interventions are partial reasons for the existence of the problems. Furthermore, what is considered a problem worthy of being addressed by the CAP is heavily dependent on the agendas and discretion of the key institutions joining the policy design process: the European Commission, the Council, the European Parliament, and the various stakeholder organisations surrounding them (Daugbjerg, 2009). The CAP problems are institutionally embedded social constructs, and this characteristic adds to their persistence.

All these valuable contributions provide insights on the institutionalisation and path dependence of the CAP support regime; however, they hardly expose the qualities and implications of the underlying system of interrelated problems. To say something about the future of any societal policy, one should be able to say something about the evolution of the problems the policy is expected to address. *This research makes a contribution to the explicit understanding of the CAP problems as a system of wicked problems*.

Although the evolution of the CAP targets, measures, and institutions have been extensively examined (e.g. Burrell, 2009; Grant, 2010; Oskam et al., 2011; Moyer and Josling, 2002), the systemic nature of problems underlying them has received less attention. Problem-setting, problem-framing, and problem-solving may have been configured and explained in many ways, but the complex system of problems to be addressed by the CAP continues to effectuate it and grant it with legitimacy.

Attribution of causes and consequences within the system is complicated and crucial. Complicated, because 'in a complex system the cause of a difficulty may lie far back in time from the symptoms, or in a completely different and remote part of the system … causes are usually found not in the prior events, but in the structure and policies of the system' (Forrester, 1969, p. 9). Important, because 'basing an intervention on a wrongly assumed cause and effect relationship is likely to produce an outcome very different from what we intended' (Neville and Dalmau, 2010, p. 29). The following is a primitive hypothesis scrutinised in this study: *the qualitative and systemic properties of the problems possibly represent one crucial reason for the lack of agenda-clearing solutions and for the path dependence of the CAP*.

To address these problematics, a brief review of the evolution of the CAP problems is first provided in Section 2 as an introduction to the substance. The properties of wicked problems are discussed in Section 3 to illustrate their general-level implications for policy evolution. The wickedness of the problems encountered by the CAP in the future is analysed based on systems dynamics methodology and views from Finnish experts, and these methods and materials are explained in Section 4. The results are reported in Section 5 and discussed in Section 6.

2. Short history of the CAP problems

In the early years, during the 1950s and 1960s, the main challenges to be addressed by the CAP were the stable provision of food at affordable consumer prices and modernisation of the backward and large agricultural sectors in the six original Member States (Tracy, 1989). CAP was also a welfare and income redistribution policy from the outset, making major reforms painful because of social and political repercussions (Spoerer, 2015). The early CAP facilitated food security and economic development, specifically. In this context, establishment of the common market was the ultimate goal in the 1960s (Fig. 1). Structural and regional problems were observed (e.g. Commission, 1968) but received minimal resources in the common policy starting in the 1970s. Targeted assistance to the less-favoured areas (LFA) was initiated in 1975. Protected internal markets and steady increases in agricultural productivity inevitably led to structural market imbalance and mounting surpluses towards the end of the 1970s and in the early 1980s (Commission, 1985). Mediterranean enlargements in the 1980s were the impetus for an upheaval of cohesion orientation in response to significant internal socioeconomic inequalities. During the first decades, the CAP institutionalised and acquired considerable autonomy as the first deeply integrated policy field in the EU.

The problematic consequences of these developments and enlargement of the EU was the impetus for decreased autonomy and increased integration of the CAP to a wider societal policy framework (Fig. 1). The escalating costs of market management and structural surpluses led to production restraint from the mid-1980s and later on—together with accumulating pressures in the multilateral trade negotiations (GATT/WTO)—to the first significant policy redirection: the MacSharry reform in 1992 (Commission, 1991).

The MacSharry reform initiated a lineage of policy reforms in which market balance was attempted by cutting internal prices and paying farmers direct payments in compensation: Agenda 2000, Fischler reform 2003, Health Check 2008, and CAP post-2013 (Commission, 1997, 2002, 2007, 2010). Environmental concerns were manifested in the CAP: first, as voluntary measures in 1987 and second, as obligatory agri-environmental schemes in 1992 (Feindt, 2010). Since the Agenda 2000 reform in 1999, addressing rural and environmental problems has become an integral and significant part of all incremental policy reforms. Eastern enlargements in the 2000s increased the internal diversity of the EU (Swain, 2013). The response to these enlargements has been increased flexibility in the delivery of the socio-structural measures and rebalanced payments between the Member States (Terluin et al., 2017). Effective market management has been replaced by risk

Fig. 1. Storyline of the CAP.

Table 1
Properties and consequences of wicked problems.
Source: Properties are adopted from Rittel and Webber (1973).

Property	Consequence	Example
1. Problems lack definitive formulation.	Problem formulation and problem resolution are intertwined.	A feasible resolution to food security depends on the definition of food security (Candel et al., 2014).
2. Solution has no stopping rule.	Resolution occurs because of external reasons, not from a final internal solution.	CAP reforms are concluded on the basis of few options under time pressure instead of complete scrutiny of all possible options (Tangermann and von Cramon-Taubadel, 2013).
3. Not true-or-false but good-or-bad solutions.	No universal and agreed evaluation criterion for the solution.	Costs and benefits of agricultural trade liberalisation differ among economic, social, environmental, and cultural evaluations (Batie and Schweikhardt, 2010).
4. No immediate and ultimate test of a solution.	Solutions have spill-over and lagging effects impossible to observe.	The increased flexibility allowed for the Member States in the application of the direct payments makes evaluating the exact impacts of the CAP reform impossible (Terluin et al., 2017).
5. Only 'one-shot' solutions are possible.	Solutions are partly irreversible and each trial-and-error would generate new sets of problems.	If coping with climate change is unsuccessful, the consequences could be catastrophic (FAO, 2016).
6. No enumerable set of potential solutions and permissible operations.	The conclusion is reached through imagination, judgement, and certainification, without a fixed choice set.	Steps towards more fair and transparent food systems have been diversified, iterative, and wobbly (Kuhmonen, 2017).
7. Problems are essentially unique.	Wicked problems may have similarities but they are essentially unique and contextual, escaping classification, and transference of solutions.	Agricultural biodiversity is highly contextual and asks for policy solutions that adapt to local biophysical conditions, farming practices, and competences (Siebert et al., 2006).
8. Every problem is a symptom of another problem.	Problems comprise an interlinked system in which removal of one problem may create new problems.	Agricultural externalities, farming practices, markets, technology, and policies comprise an interlinked system (OECD, 2015).
9. There are many explanations; choice of explanation determines the resolution.	Attitudes, values, and world views guide the choice of explanation among many alternative lines of argumentation.	Alternative paradigms and approaches to the sustainability of agri-food systems have a different focus (Lamine, 2015).
10. Wrong solutions are not tolerated.	Ideational world tolerates refutation, but malfunction in a real-life solution bears liabilities for the proponents of the solution.	Policy reforms that diminish European agriculture in the face of climate change would cause a political and civic crisis (FAO, 2016).

management.

Along the accumulated policy transformations, a part of the agricultural production incentives has been converted into policy compliance incentives, because the farmers' subsidies are conditional on following complex provisions. Increased internal heterogeneity of the EU and augmented environmental concerns have added to the diversity of the CAP measures and their delivery modes. The expansion of free trade and global food logistics has created new concerns related to a transparent, fair, ethical, safe, and sustainable food system (Daugbjerg and Swinbank, 2016). Policy efficiency, complexity, bureaucracy, and legitimacy have consequently had to observe new frontiers (Commission, 2005). In these ways, the CAP itself—policy design and delivery—has become a critical problem of the CAP; additionally, the multitude of substantive farm, consumer, environmental, regional,

trade, and budgetary concerns continue in spite of this (Kuhmonen, 2018).

3. Wicked problems

Wicked problems are complex junctures that escape univocal definitions and agreed solutions, unlike tame problems. The wicked nature of many public policy problems is an important reason for the incremental and path-dependent policies, politics-based resolutions, and persistence of the problems (McConnell, 2010, p. 358). Wicked policy problems are pernicious because they host complexity, uncertainty, and divergence (Head, 2008). Formulating the wicked problems, computing their solutions, conducting repeated trials, or monitoring their temporal repercussions is difficult (Norton, 2012). For example, agricultural trade liberalisation may be considered a wicked problem: liberalisation may create net benefits for the economies but comes with concomitant harmful distributional, political, and moral effects (Batie and Schweikhardt, 2010). Further, the understandings, definitions, and policies concerning food security exhibit so many manifestations and tensions that food security has been considered a wicked problem (Candel et al., 2014; Grochowska, 2014). According to the seminal work by Rittel and Webber (1973), wicked—malignant, vicious, tricky, aggressive—problems have ten specific properties listed and illustrated in Table 1.

On the one hand, the presence of all properties is naturally unequal in all wicked problems, but any truly wicked problem manifests all ten attributes (Rittel and Webber, 1973). On the other hand, 'wicked' is an easy label to stamp on any tricky question, causing confusion over the concept. Irrespective of these reservations, wickedness is consequential for understanding, describing and resolving these types of policy problems in three respects.

First, wickedness challenges the propagators of explicit, complete, and simple solutions to complex policy issues. Truly wicked problems ask for extensive discussion and contextual elaboration to formulate a feasible partial resolution or move towards a better compromise instead of a final and complete solution (e.g. Gamborg et al., 2014).

Second, wicked problems are multidimensional, multi-layered, multifaceted, and multidisciplinary in nature. A single science, level of analysis, or ideology is hardly capable of providing a feasible resolution (Norton, 2012). Consequently, versatile networks—instead of narrow hierarchies and specialised agencies—have been suggested for tackling wicked problems (Ferlie et al., 2010).

Third, an essential property of the wickedness is interconnectedness, where the problems induce each other. Each resolution generates a cascade of new problems. Only a systems approach is capable of illustrating the setting and uncovering the multitude of local resolutions and their repercussions within the system (Zellner and Campbell, 2015). This approach is illustrated next, in Section 4, with an empirical account of problems expected to be addressed by the CAP of the EU.

4. Methods and materials

The CAP problematics are addressed by *systems dynamics methodology* in this study. Systems dynamics aims to identify and model causal relationships between elements that interact within the boundaries of a certain entity (Forrester, 1968; Maani and Cavana, 2007; Sterman, 2000; Wolstenholme and Coyle, 1983). Systems dynamics methodology may facilitate multidimensional, multidisciplinary, and multifaceted studies by observing, for example, economic–-and–environmental–and–trade–and–spatial, micro–and–macro, producer–and–consumer issues. within the same framework; specifically, systems dynamics may deal with multiple simultaneous causalities by exposing various reinforcing and balancing feedbacks between the system elements. This core capacity allows for an illustration of inherent properties of complex adaptive systems (CAS): non-linear evolution through heterogeneous interactions, disproportional effects, and lack of central command or master rule (Byrne and Callaghan, 2014; Holland, 1995; Room, 2011). Multiple realities may live and evolve within this type of a system, which is also evident in the case of the CAP. Although governance of these types of systemic entities is challenging (Hoppe, 2011), 'systems dynamics is a method to enhance learning in complex systems' (Sterman, 2000, p. 4).

There are several methodological platforms for the specification of systems dynamics in empirical accounts, but for our purposes, *causal loop diagrams* provide an appropriate tool. Qualitative systems dynamics may be used to uncover the multitude of causal relationships within a certain system through a grounded approach (Lane, 2008; Wolstenholme, 1999). A causal loop diagram consists of variables and 'arrows' or causal links that indicate their mutual causal influences (Sterman, 2000, p. 138). Each causal link or arrow is attached with a positive (+) or negative (–) polarity.

A crucial part of this analysis is the identification of the feedback loops, in which an effect starting from a cause comes back to the cause. For example, if an increase in the competitiveness of agriculture increases the vitality of the countryside (a positive causal link) and an increase in the vitality of the countryside increases the competitiveness of agriculture (returning positive causal link), a positive reinforcing or amplifying feedback loop becomes established. Relatedly, if an increase in the agricultural production increases quotas and other restrictions on production (a positive causal link) and an increase of these restrictions decreases agricultural production (a negative causal link), that is, a negative balancing or stabilising feedback loop is established.

These feedback loops are powerful system elements because they contribute to specific dynamics of the system, for example, accumulation, balancing, decay, oscillation, and chaos. (Sterman, 2000). Nonlinear interaction may shift loop dominance over time (Richardson, 1995), and a variety of alternative narratives are openly available through studying the diagrams. Generally, using a causal loop diagram as a mapping tool is a powerful analytical device for discussing problem-driven narratives and policy design puzzles. The main challenge in crafting the diagrams is finding an appropriate level of abstraction, because 'modelling is the art of simplification' (Sterman, 2000, p. 166).

In this study, the key variables (problems) and their relationships were obtained through a survey. Based on the history of the CAP problems (Section 2), an *expertise matrix* was reconstructed to allow coverage of the substance and diverse views (data triangulation; Denzin, 1989). Participants for the survey were invited to represent one of the six key categories of CAP problems (agricultural production, consumption and foodstuffs, regions and rural areas, internal and external trade, environmental issues, and policy design and delivery) in such a way that representatives of 1) policy design and delivery bodies, 2) research and development organisations and 3) non-governmental and professional organisation were present in each of the six categories. These three types of organisations were screened for senior staff having a broad job description and falling into the six substance categories in a balanced manner. A prerequisite for the invitation was an observed experience and competence (publications, involvement, advocacy) regarding a specific dimension of the CAP problems. A total of 130 Finnish experts were invited for the electronic survey and 52 responded within three weeks in June 2016. Table 2 summarises the number of respondents according to the *ex ante* category of expertise and the self-reported expertise.

Obviously, the coverage and balance of expertise were satisfactory for the purposes of this study. Out of the 52 respondents, 19 represented policy design and delivery bodies, 16 represented research and development organisations, and 17 represented non-governmental and professional organisations. Representatives of the policy design and delivery bodies included the former permanent secretary, two director generals, and seven senior staff members of the Ministry of Agriculture and Forestry; director general of the Finnish Food Safety Authority; chairperson of the Agriculture and Forestry Committee in the Parliament of Finland; three senior specialists of the Permanent

Table 2
Ex ante main expertise and self-reported expertise of the respondents according to the CAP problem dimensions. Scale: 1 = no expertise … 5 = very good expertise.

Dimension of the CAP problems	Number of respondents (ex ante)	Self-reported expertise: average	Self-reported expertise: standard deviation
Agricultural production	11	4.2	0.9
Consumption, foodstuffs	8	3.6	1.0
Regions, rural areas	7	3.7	0.9
Internal and external trade	10	3.2	0.9
Environmental issues	7	3.7	0.9
Policy design and delivery	9	3.9	1.0
Total	52	3.6	1.0

Representation of Finland to the EU; head of unit of the Agency for Rural Affairs, and two heads of unit and one senior specialist of regional administrative bodies.

Representatives of the research and development organisations included seven professors, two research directors and five senior researchers of Finnish universities and research institutes, and two heads of unit of large private agricultural firms (banking, food). All these representatives were intimately working with various fields of agriculture and food: farm management, economics, agricultural policy, consumer issues, sustainability and environmental issues, rural issues, agricultural finance, food development, futures research, and developing countries.

Finally, representatives of the non-governmental and professional organisations included the president, vice president, three directors, head of research, three regional directors and one local chairperson of the Central Union of Agricultural Producers and Forest Owners (MTK); chairperson of the Women's Committee of the World Farmers' Association; the director general and director of the Finnish Food and Drink Industries' Federation (ETL); managing director of the Central Organization for Finnish Horticulture; regional director of the Finnish Home Economics Organization (Martat); managing director of the Rural Advisory Services (ProAgria), and senior specialist of the Finnish Association for Nature Conservation.

Experts from any Member State are aware of the CAP problems with some national emphasis. The special concern of Finland has traditionally related to observing the extreme northern natural conditions in the common policy, the wide application of the LFAs and agri-environmental schemes, and the possibility of paying national subsidies. This positionality limitation is noted; however, advancing to a full-scale EU-wide comparative study would be a risky engagement at this stage, that is, before testing the approach and methodology; in a later stage, such a study would be worthwhile.

In the survey, the respondents were first asked a to *identify a maximum of 10 significant EU level problems* to be addressed by the CAP in the future and *provide an argument* (cause or consequence) to justify the significance of each problem. The respondents named 303 problem–argument pairs, which were categorised by means of conventional content analysis without predefined categories (Hsieh and Shannon, 2005; Krippendorff, 2004). Content analysis is a standard abstraction and categorisation procedure for heterogeneous data sets to make them manageable. For example, one respondent identified 'progress of climate change' as a problem and presented an argument: 'progress of climate change will dry southern parts of the EU, which will lead to significant conflicts and adaptation problems and ultimately will change the territorial structure of the EU'. In this response, there is a positive causal relationship: progress of climate change → (+) internal heterogeneity. Notably, the same issue could be a cause or effect. Another respondent identified 'legitimacy of agricultural policy' as a problem and presented an argument: 'EU Member States differ in many respects and a one-truth-policy does not fit for all'. In this response, a negative causal relationship is revealed: internal heterogeneity → (–) legitimacy of agricultural policy. This type of iterative process resulted in 114 pairs of problems and their reasons. These causal relationships were further subjected to qualitative causal loop analysis to integrate them into the system of CAP problems.

Second, the respondents were asked to *evaluate the significance* of the problems at the EU level in the short run (up to 2020) and long run (up to 2040). A Likert-type scale was used: 1 = insignificant … 5 = very significant. This rating made it possible to differentiate between the temporal horizons of the identified problems, that is, to observe whether they would be degrading, stable, or upgrading from 2020–2040. This rating naturally excludes the potential invasion of novel problems within the time horizon. In this respect, the fixed portfolio of problems implies an underestimation of the complexity, unless some current problems are definitively solved before 2040.

5. Results

5.1. Key problems

The content analysis exposed 22 key problems to be addressed by the CAP (Table 3). These variables and their relationships configure the system under investigation. The problems are synthetic and feature a high level of abstraction because they are derived from 303 responses. *This general map of the CAP problems* may be characterised by five domains (plus a wild card option): socio-environmental, spatial, policy, market, and farming. While looking at the list, it is observed that none of the problems, even as a standalone subject, has a universally agreed criteria for a final solution, but all solutions can be seen as good or bad from specific points of view or stakeholder perspectives (property #3 of wicked problems in Table 1).

5.2. Reinforcing loops

The analysis of the relationships of the CAP problems and their causes exposes 11 bilateral or pairwise *reinforcing feedback loops.* These loops manifest recursive causality (Forss et al., 2011, p. 49). Observing their interconnections, these loops form three agglomerations: competitiveness, sustainability, and heterogeneity subsystems (Fig. 2). Due to immediate feedbacks, these three subsystems are important engines within the CAP problematics.

First, the competitiveness and incomes in agriculture and the farmers' commitment to and the attractiveness of agriculture consists of a robust positive reinforcing loop. Both problems form their own positive reinforcing loops with the vitality of the countryside, which forms a positive reinforcing loop with cohesion, equality, and transparency. Furthermore, competitiveness and incomes in agriculture form a positive reinforcing loop with exports of agricultural and food products. Consequently, an effort to address any of these problems or challenges will have positive repercussions and cascading effects on the whole subsystem.

Second, multidimensional sustainable development contributes to two negative reinforcing loops: one with the dominance of trade and big players in the food chain, and the other with free trade with divergent farming regulations. Consequently, multidimensional sustainable development is simultaneously a 'victim' of and a 'solution' to these two market-related problems. Furthermore, allowing free trade with divergent farming regulations will counteract the maintenance of food production capacity and food security, which simultaneously erodes free trade with divergent farming regulations. One positive feedback loop is also included in this subsystem, because multidimensional sustainable development and distributed local food and energy systems reinforce each other. Generally, these five intimately

Table 3
Key problems to be addressed by the CAP.

Problem	Domain and code	Abbreviation	Description
1. Possibility of a major crisis	Wild card (WC)	Crisis	Possibility of an institutional collapse, food shortage, civic crisis etc.
2. Progress of climate change	Socio-environmental (ENV)	Climate	Problems related to the increased variation of weather conditions, occurrence of extreme weather events (storms, floods, droughts) and altered natural preconditions.
3. Multidimensional sustainable development	Socio-environmental (ENV)	Sustainability	Problems related to the governance of the food chain and natural resources with fair, ethical, equal, responsible and transparent standards.
4. Multifunctional agriculture	Socio-environmental (ENV	Multifunctionality	Problems related to the simultaneous provision of market commodities and non-market public goods by agriculture.
5. Food production capacity and food security	Socio-environmental (ENV)	Food security	Problems related to the maintenance of agricultural capacity and relatedly national and EU food security.
6. Food safety	Socio-environmental (ENV)	Food safety	Problems related to the contaminated or fake food and spread of animal and crop diseases.
7. Internal heterogeneity	Spatial (SPA)	Heterogeneity	Problems related to the environmental, economic, social, political, cultural and religious differences within the EU.
8. Cohesion, equality and transparency	Spatial (SPA)	Cohesion	Problems related to the distribution of wealth, compensation, power and involvement within various socioeconomic systems and specifically the food system.
9. Vitality of the countryside	Spatial (SPA)	Countryside	Problems related to the maintenance of the economic and social fabric in the rural areas.
10. Distributed local food and energy systems in bio-economy	Spatial (SPA)	Local systems	Problems related to the provision of local food and local renewable energy (market access, profitability, incentives, information).
11. Budgetary pressures of the public sector	Policy (POL)	Budget	Problems related to the willingness and ability of the national governments and the EU to provide finance for agricultural issues.
12. Legitimacy of agricultural policy	Policy (POL)	Legitimacy	Problems related to the defining and agreeing on acceptable goals, means and resources for the agricultural policy.
13. Extensive regulation and bureaucracy	Policy (POL)	Regulation	Problems related to the complexity and inconsistency of the agricultural and food regulation.
14. Short-term and biased policy on subsidies and competition	Policy (POL)	Biases	Problems related to the contradictory, lacking or biased policy incentives and short-term policy fixes without a long-term or global view.
15. Free trade with divergent farming regulations	Market (MAR)	Trade	Problems related to free international trade while trading partners have divergent animal welfare, environmental, ethical, safety, employment and health standards and regulations.
16. Dominance of trade and big players in the food chain	Market (MAR)	Food chain	Problems related to the oligopolistic distribution of power to trade and logistic firms within the food chain and dominance of big food processors and traders.
17. Imbalance and instability of agricultural and food markets	Market (MAR)	Markets	Problems related to the increasing volatility, unpredictability and structural imbalances of the agricultural and food markets.
18. Exports of agricultural and food products	Market (MAR)	Exports	Problems related to the difficulty and necessity in finding profitable outlets for the EU production in the markets of third countries in face of stagnating EU demand.
19. Not cost-based, low producer prices	Market (MAR)	Prices	Problems related to farm-gate prices not covering production costs that observe animal welfare, environmental, ethical, safety and quality standards, biophysical circumstances and alternative labour remuneration options in varying circumstances within the EU.
20. Research, education, extension and improved competences	Farming (FAR)	Competence	Problems related to the improvement of the knowledge base and competences in the agricultural and food sector.
21. Competitiveness and incomes in agriculture	Farming (FAR)	Competitiveness	Problems related to the development of agricultural productivity, farm structures and agricultural incomes.
22. Farmers' commitment and attractiveness of agriculture	Farming (FAR)	Attractiveness	Problems related to the willingness and ability of current and potential farmers to commit themselves and invest in the farming business.

interlinked issues form the hard core of the trade-related and market-related sustainability problematics to be addressed by the CAP.

Third, internal heterogeneity within the EU reinforces short-term and biased policies on subsidies and competition, further increasing internal heterogeneity. Internal heterogeneity and the imbalance and instability of agricultural and food markets are the two components of a related positive reinforcing loop. Concomitantly, the vast internal heterogeneity of the EU is an impetus for critical market and policy problems and simultaneously accentuated by these same problems.

Addressing these three closed loop subsystems is of special importance in the management of the CAP problems because of their self-referential behaviours due to recursive causality. The feedback dynamics also manifest the wickedness of developing solutions for these problems. If one starts with, for example, the loop of three problems—competitiveness of agriculture, attractiveness of agriculture, and vitality of the countryside—one may ask when each or all of these problems will be addressed to a necessary degree and if they will be resolved. Addressing one of the problems causes disproportionate (non-linear) and lagging effects on the others (property #4 of wicked problems). Furthermore, no norm is observed for 'competitive agriculture', 'attractive agriculture', or 'vital countryside': there is no stopping rule (property #2 of wicked problems). Any major attempt to resolve the attractiveness problem in a final and definitive manner would be a partly irreversible undertaking that would generate new sets of, for example, budgetary and competition law problems: a second major attempt after a failed one could not be expected soon (property #5 of wicked problems).

5.3. Full system

Observing the *full system of CAP problems* creates a complex matrix even at this rather high level of abstraction (Fig. 3). There are 114 pairwise causal links in the system that host a rich portfolio of partial narratives. As it is impossible to highlight all the interconnections, two narratives are given for illustration.

First, strengthening multifunctional agriculture would improve the status of many other problematic issues: multidimensional sustainable development; food production capacity and food security; food safety; cohesion, equality, and transparency; vitality of the countryside; legitimacy of agricultural policy; competitiveness and incomes in

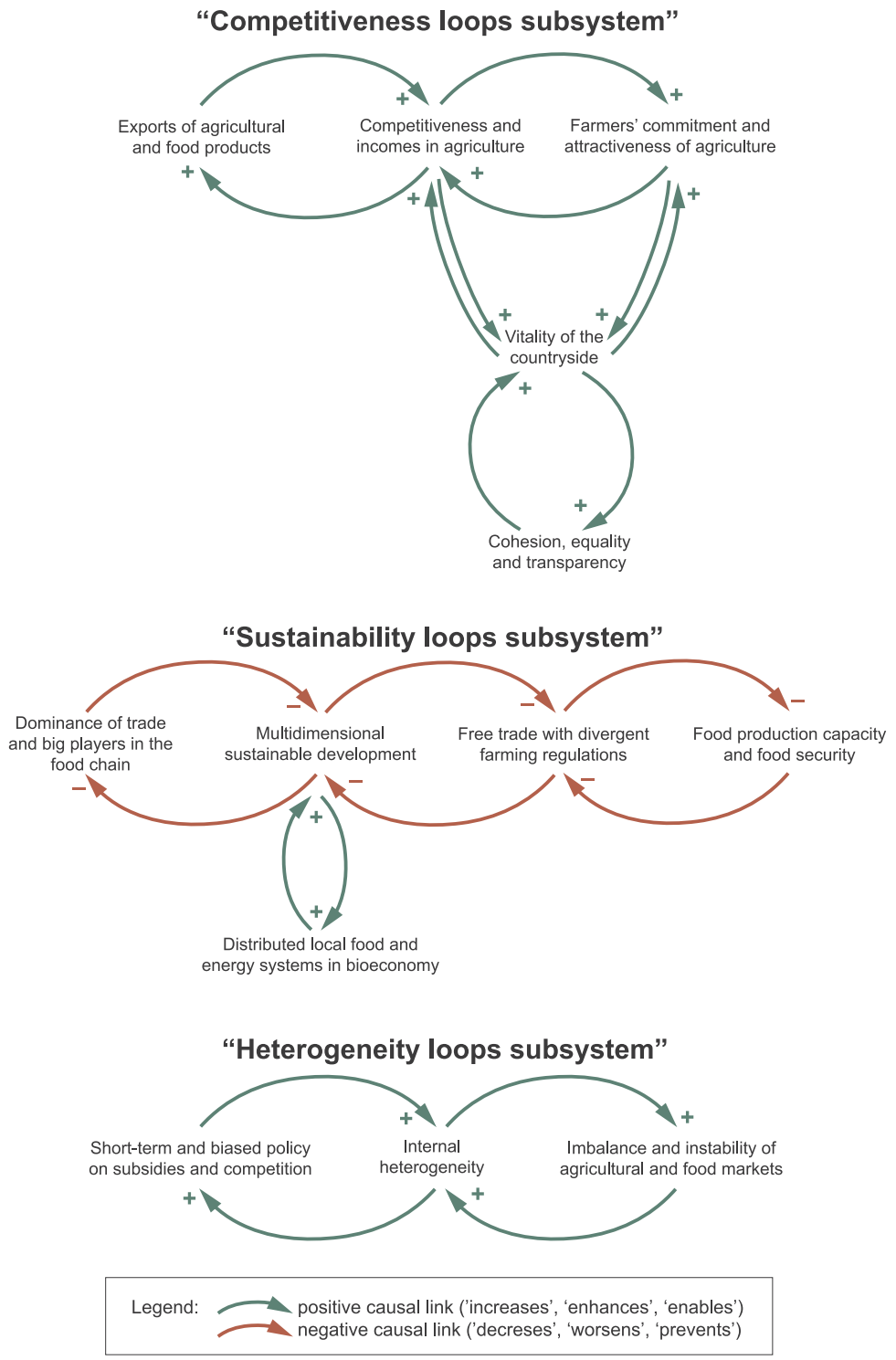

Fig. 2. Reinforcing bilateral loop subsystems within the CAP problems.

agriculture. Simultaneously, strengthening multifunctional agriculture would mitigate the progress of climate change and reduce the dominance of trade and big players in the food chain.

Strengthening multifunctional agriculture is hampered by the triumph of free international trade with divergent farming regulations. Problematics related to the multifunctional agriculture are observed to be critical to addressing many other CAP problems. Facilitating multifunctional agriculture is observed to be a multidimensional problem because of the direct causal links with all five domains: socio-environmental, spatial, policy, market, and farming. Consequently, an attempt to address multifunctionality problematics would require observing an immediate change in the status of ten directly related problems that exhibit five domain logics and policies.

Second, legitimacy of agricultural policy enhances the farmers' commitment to the farming business and the attractiveness of agriculture. Simultaneously, positive developments in other problematic issues would enhance legitimacy of agricultural policy: multidimensional sustainable development; multifunctional agriculture; cohesion, equality, and transparency; exports of agricultural and food products; and research, education, extension, and improved

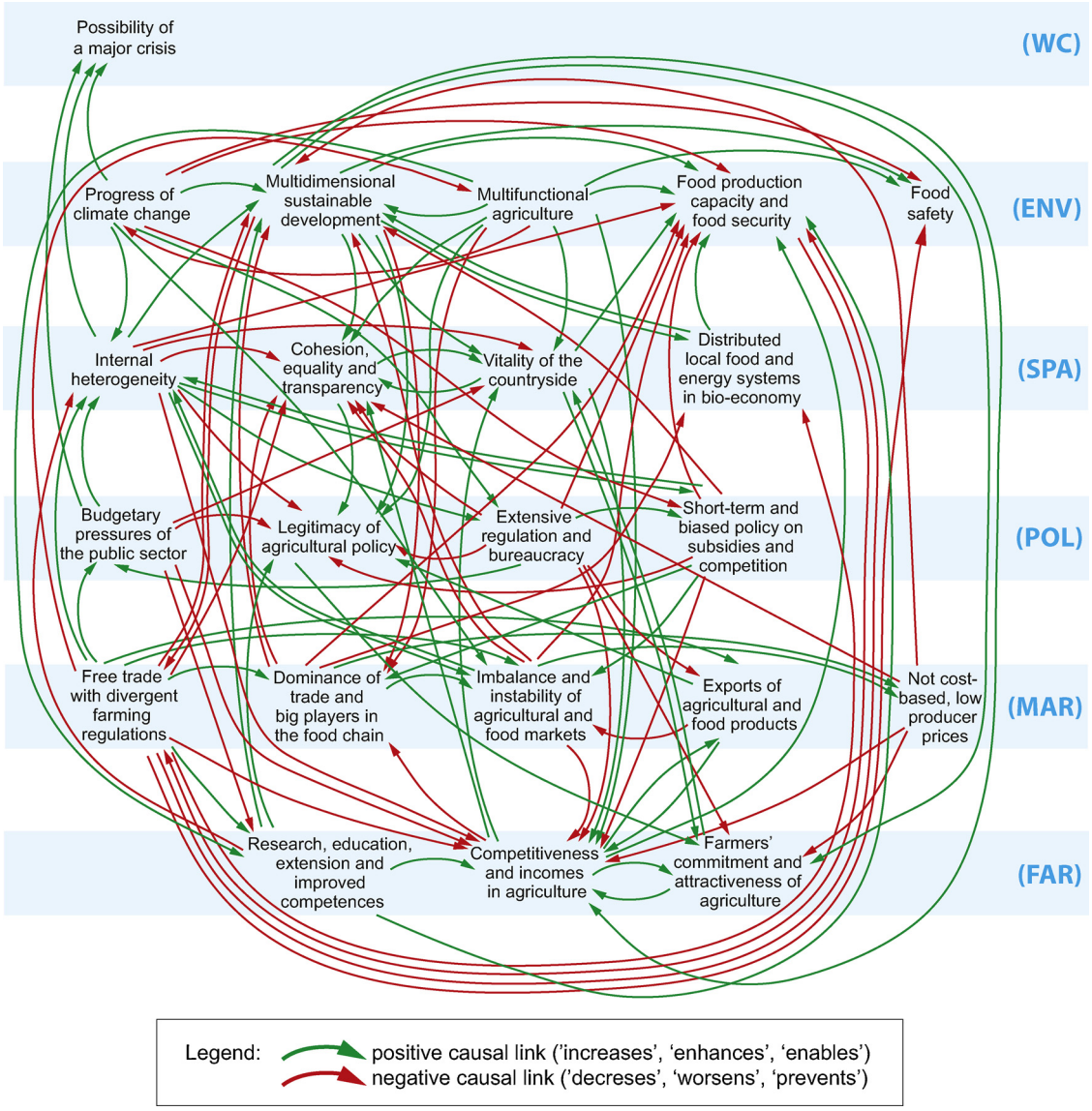

Fig. 3. Causal loop system of the problems underlying the CAP. Domain codes are given in Table 3.

competences. Many issues would erode legitimacy: internal heterogeneity, budgetary pressures of the public sector, extensive regulation and bureaucracy, and short-term and biased policy on subsidies and competition. In contrast with multifunctional agriculture, legitimacy is of more consequence than a cause within the web of CAP problems. However, in a manner consistent with the multifunctionality problematics, all five domains are directly involved with legitimacy problematics. Notably, these narratives are synthetic behavioural models of the system based on the experts' views on causality.

Obviously, the full system of CAP problems have certain general features. First, the problems are highly interconnected across multiple domains. Consequently, any attempt to resolve a problem is afforded and constrained by the status of other problems and will affect the status of other problems. *This is the hard core of wicked problems: they form a 'jam' and any change will affect the whole system as problems are symptoms of other problems* (property #8 of wicked problems).

Second, the problems also have varying positions as causes of other problems or as consequences of them. The problems form affording and constraining cascades. It is possible to start explaining and resolving a certain problem from many alternative locations on the map and create many narratives for the problem. The choice of the narrative affects the framing and contents of the resolution (property #9 of wicked problems). Section 5.4 further elaborates on this dual role, as a cause and a consequence.

5.4. Problem network status

The status of the problems within the systems varies in connectivity and causation. An arbitrary typology of the CAP problems, featuring them as 'networked', 'driver', 'dependent', and 'punctuated' problems, is presented in Fig. 4. On average, the problems were attached with 5.2 starting and arriving causal links. Problems with an above average number of starting and arriving causal links are labelled as *'networked problems'*. Three CAP problems representing three domains, qualify for this category: multidimensional sustainable development, internal heterogeneity, and the imbalance and instability of agricultural and food markets. Multidimensional sustainable development is the most extensively networked problem within the system. These networks are especially wicked problems due to their dual role and high connectivity. An attempt to address these tightly wired problems will set the whole system to move, but this possibility is severely preconditioned by preceding problems.

Problems with an above average number of starting causal links and below average number of arriving causal links are labelled as *'driver*

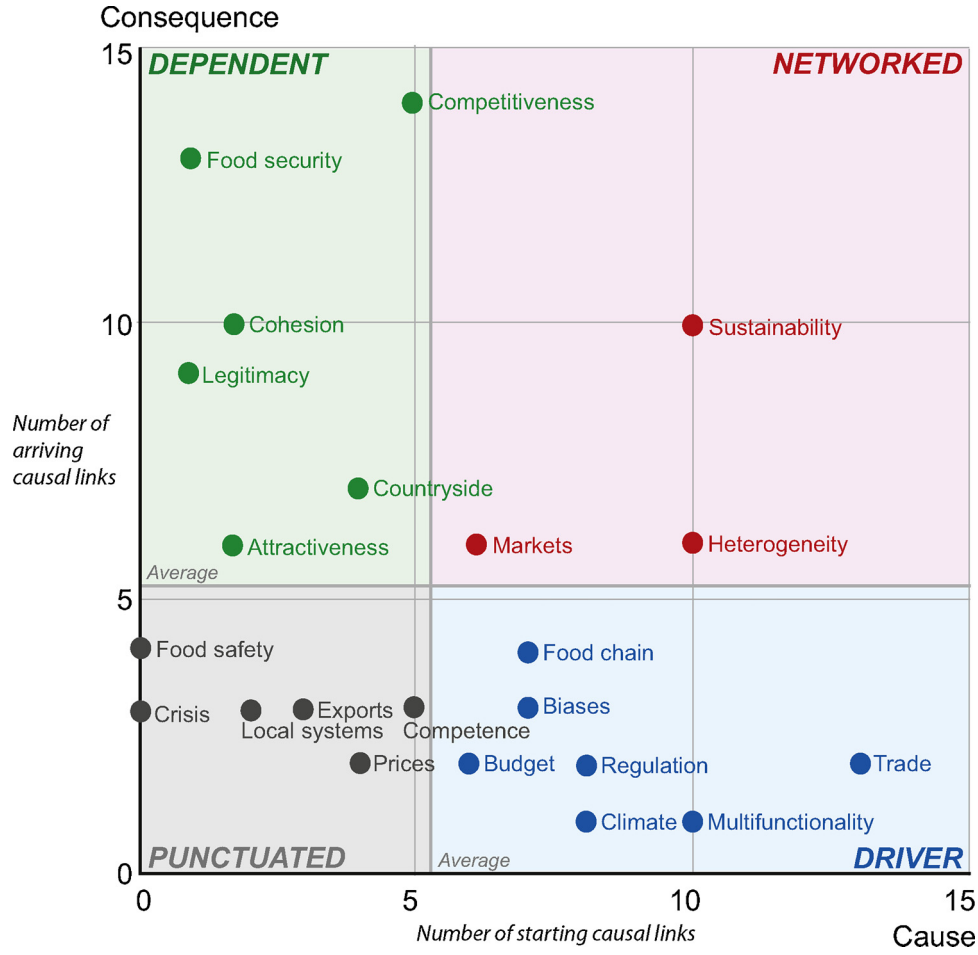

Fig. 4. Status of the problems as causes (number of starting causal links) and consequences (number of arriving causal links) within the system. Problem abbreviations are given in Table 3.

problems'. These problems are not tightly preconditioned by other problems but affect a high number of other problems. Seven CAP problems qualify for this category. Free trade with divergent farming regulations is the most extensively wired driver problem, with 13 starting causal links to the other problems. Within the market domain, the dominance of trade and big players in the food chain also has a driver problem status. Multifunctional agriculture and progress of climate change within the socio-environmental domain have a driver problem status. Further, three problems in the policy domain belong to this category: extensive regulation and bureaucracy, budgetary pressures of the public sector, and short-term and biased policies on subsidies and competition. Generally, addressing these problems will have extensive cascading effects within the system but few preconditions. Therefore, 'driver problems' offer feasible breaking points or 'leverage points' (Meadows, 2009, p. 145) to the system of CAP problems.

Problems that have a below average number of starting causal links and an above average number of arriving causal links are labelled as *'dependent problems'*. These problems are preconditioned by numerous other problems and do not have extensive causal impacts. Six CAP problems are labelled as dependent. Competitiveness and incomes in agriculture is the most extensively wired dependent problem with 14 arriving causal links from other problems. Another dependent farming domain problem is farmers' commitment to and attractiveness of agriculture. This category also consists of two spatial problems (cohesion, equality, and transparency; vitality of the countryside), one policy problem (legitimacy of agricultural policy) and one socio-environmental problem (food production capacity and food security). Attempts to address these dependent problems should observe the preceding problems because, for example, the enhancement of the vitality of the countryside is hardly possible without addressing sustainability and farming problems.

Finally, problems that have a below average number of starting and arriving causal links are labelled as *'punctuated problems'*, that is, relatively isolated problems within the network with few preceding and affected problems. Five CAP problems from four domains, fulfil these characteristics. Food safety holds a special position, with only arriving causal links. Two market domain problems are punctuated: exports of agricultural and food products and not cost-based, low producer prices. The problems concerning research, education, extension, and improved competences within the farming domain and distributed local food and energy systems within the spatial domain also have low connectivity and causality. Due to their isolated nature, these problems may be addressed by direct policy intervention without significant preconditions or repercussions. How easy this would be regarding politics and intervention design, is another issue.

As reported, the status of the problem within the network in terms of connectivity and causation will affect possibilities and feasible means of addressing it. The distribution of domain-specific problems across the four categories follows no specific rule or logic because each category includes problems from many domains. This result implies that each problem is—more or less—a unique case (property #7 of wicked problems). Solutions to the problems should not be pursued within a domain-specific approach, such as spatial, farming, or environmental problems, but with a system-based approach of networked, driver, dependent, and punctuated problems that cross these domains. This result also confirms that the formulation of the CAP problems and their

Table 4
Top–10 causal links to be addressed by the CAP: Weighted scores for 2020 and 2040.

Causal link	Score 2020	Score 2040	Change in score
1. Progress of climate change → (–) Food production capacity and food security	54.1	77.1	+23.0
2. Internal heterogeneity → (–) Cohesion, equality and transparency	53.0	50.1	–2.9
3. Short-term and biased policy on subsidies and competition → (–) Competitiveness and incomes in agriculture	46.2	44.0	–2.2
4. Extensive regulation and bureaucracy → (–) Farmers' commitment and attractiveness of agriculture	43.0	47.0	+4.0
5. Extensive regulation and bureaucracy → (–) Competitiveness and incomes in agriculture	41.0	41.0	0.0
6. Imbalance and instability of agricultural and food markets → (–) Competitiveness and incomes in agriculture	40.0	39.0	–1.0
7. Free trade but divergent farming regulations → (–) Competitiveness and incomes in agriculture	29.0	31.0	+2.0
8. Competitiveness and incomes in agriculture → (+) Food production capacity and food security	29.0	27.0	–2.0
9. Internal heterogeneity → (–) Legitimacy of agricultural policy	25.0	27.0	+2.0
10. Research, education, extension and improved competences → (+) Competitiveness and incomes in agriculture	24.0	27.0	+3.0

resolutions are intertwined, because every problem lacks a universal and context-free definition but only becomes meaningful through contextualisation (property #1 of wicked problems).

5.5. Temporal evolution

The problems will evolve over time and new problems will emerge from external reasons and along the attempts to resolve existing problems. Regarding the fixed set of defined problems, the experts rated the significance of the causal links they had identified in the short run (up to 2020) and in the long run (up to 2040). The previous results featured the population of identified causal links; however, this analysis includes the frequencies (number of experts who identified the causal link) and significance scores (scale 1–5). The significance scores are weighted by the frequency to obtain *weighted significance scores for 2020 and 2040*. The results indicate notable tendencies.

First, *the list of the most severe challenges to be addressed by the CAP in 2020 and 2040 is stable*. The top–10 list includes the same problems for both years, in an almost identical order (Table 4). Negative effects of the progression of climate change on food production capacity and food security is the most severe challenge to be addressed by the CAP in 2020 and 2040. This topic has become increasingly crucial over these 20 years, with an increase of 23 points (+43%) in the score. Changes in the other top–10 scores are marginal. Assuming that the experts' foresight is correct, these same problematic issues will continue for the CAP over the next two decades. Furthermore, competitiveness and incomes in agriculture is present in 30% of these most significant causal links for the future, implying it will be a key problem for the CAP for at least 80 years: 1960–2040.

Second, *problems from all five domains were present in the top–10 list*. The causal links included eight farm-based problems, four policy problems, three socio-environmental problems, three spatial problems, and two market problems as causes or consequences of each other. Apart from climate change problematics, competitiveness and incomes in agriculture, and attractiveness of agriculture will be challenged by many related problems: short-term and biased policies on subsidies and competition, extensive regulation and bureaucracy, imbalance and instability of agricultural and food markets, and free trade with divergent farming regulations. Internal heterogeneity will further challenge cohesion, equality and transparency, and legitimacy of agricultural policies. It is predicted that CAP policy makers will be unable to give up any domain but will have to work within a multidimensional policy space.

Based on the experts' views, the system of CAP problems will face a path-dependent and steady evolution without major revolutions. There would be some changes in the network status of the problems and, consequently, in the systems dynamics. An analysis similar to Fig. 4 was conducted with the weighted scores, concerning the starting and arriving causal links in the 114 pairwise relationships, and by looking at the change in the scores between 2020 and 2040 (Fig. 5). There are two significant changes in the problem network status. First, climate change would grow in significance as a cause. Second, food production capacity and food security would grow in significance as a consequence. Excluding these two socio-environmental problems, the system of problems would not face major changes before 2040.

The dynamics facilitating the new configuration of the CAP problems may be featured by the four quadrants in Fig. 5. First, certain problems increase in importance concerning starting and arriving causal links, namely, as a cause and as a consequence, and these could be called 'attractors' in the complex system (Room, 2011, p. 130), around which the evolution of the system will increasingly accumulate. This category includes all four spatial problems, all three farming problems, two policy problems (extensive regulation and bureaucracy, short-term and biased policy on subsidies and competition), and three socio-environmental problems (progress of climate change, multidimensional sustainable development, multifunctional agriculture). Accordingly, problematics around this set of 12 issues would accentuate in the period 2020–2040 and require more intensive management than is presently performed.

Second, two trade problems would increase as causes and decrease as consequences. Both problems are related to market conduct: free trade with divergent farming regulations and dominance of trade and big players in the food chain. These two problems would turn into more evident origins of other problems over time. Third, the imbalance and instability of agricultural and food markets would simultaneously become a more evident result and less of a cause of problem dynamics. Fourth, not cost-based, low producer prices would become less significant, as a cause and a consequence, together with the budgetary pressures of the public sector.

In addition to these 'downgrading' problems to be monitored, exports of agricultural and food products would decrease slightly as a consequence. The overall changes in the problem network status of the market problems are striking and suggest that market problems evolve towards either more evident causes of other problems or consequences of other problems. Finally, some problems become more dependent on the evolution of other problems without a change in the driver status. These four reactive issues are food production capacity and food security, legitimacy of agricultural policy, possibility of a major crisis, and food safety.

What then is a feasible set of policy choices in the context of observing the expected dynamics of the system of CAP problems as illustrated in Fig. 5? Obviously, there is a rich portfolio of historical and existing CAP measures with significant flexibility in application (Terluin et al., 2017). By contrast, this toolbox is primarily intended to address domain-specific environmental, spatial, or farming problems. Regarding the dynamics of the problems as a system, such a fixed and evident toolbox is observed to be narrow, non-reflexive, and potentially hazardous for adjacent problems. Essentially, the CAP problematics are a manifestation of a CAS of problems that characteristically maintain a considerable amount of self-organisation and autonomy through multiple non-linear feedbacks (Miller and Page, 2007; Room, 2011). To govern such a system (Hoppe, 2011), a systems dynamics toolbox could

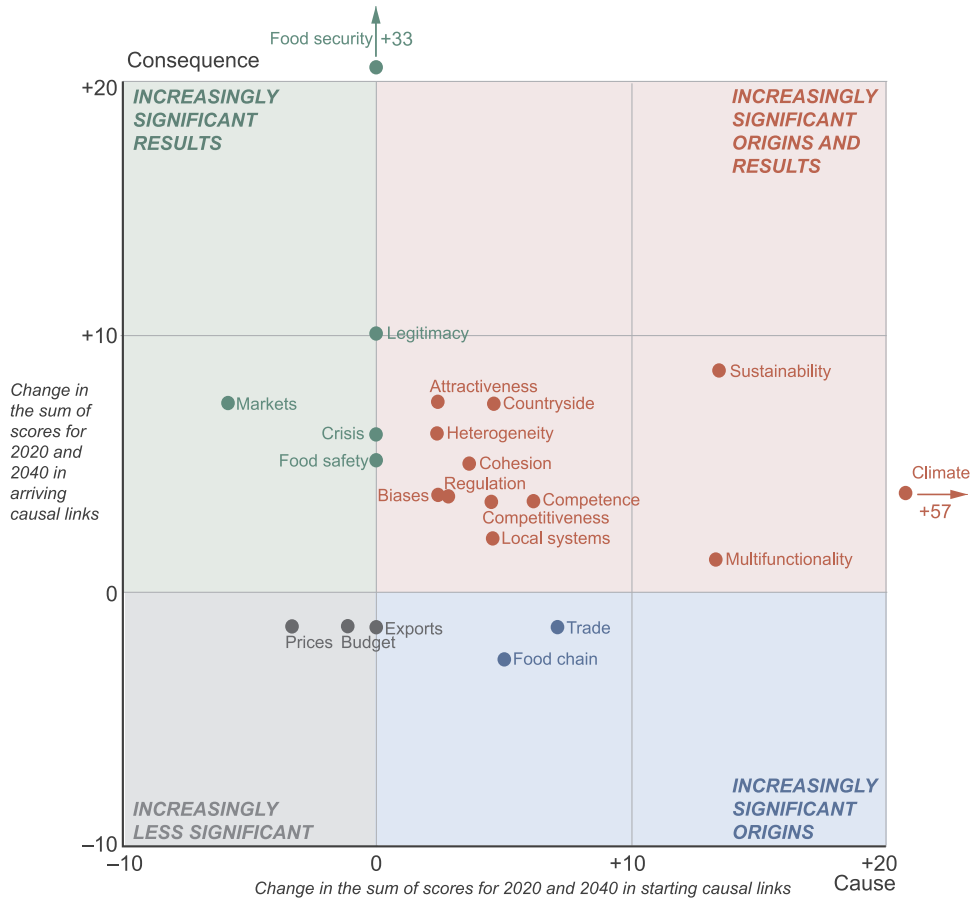

Fig. 5. Change in the status of the problems as causes (number of starting causal links) and consequences (number of arriving causal links) within the system from 2020–2040. Problem abbreviations are given in Table 3.

be enacted and evaluated through collaborative 'transdisciplinary imagination exercises' (Brown et al., 2010) across the domains, stakeholder groups, and fields of science (property #6 of wicked problems). Wrong solutions will still not be tolerated, for example, not observing the progress of climate change could cause an irreversible food crisis (property #10 of wicked problems).

6. Conclusion

At the general level, no obvious contradictions and needs for troublesome trade-offs among the CAP objectives are observed (e.g. viable food production, sustainable management of natural resources, balanced territorial development; Commission, 2010). As the problematics to be addressed by the CAP are examined more explicitly, a huge system of reinforcing and counteracting dynamics is uncovered. The observed complexity of the system of problems logically depends on the level of abstraction. The rather high level of abstraction in this study resulted in 22 key problems and with 114 causal links among these key problems. This complexity and connectivity would already make any policy problems rather complicated to address, but the CAP problems also fulfil all ten specific criteria of wicked problems. This setting has important implications for attempting to manage the CAP puzzle.

First, complete solutions for the CAP problems are extremely difficult to create. The existing problems are expected to live on for decades. From 2020–2040, climate change is expected to increase most as the origin of other problems and food security as the result of other problems; additionally, traditional concerns like agricultural incomes and vitality of the countryside remain. The CAP problematics will live on in various contexts, frames, and stakeholder views that maintain the diversity of meanings, definitions, explanations, and potential solutions. Many legitimate perspectives and access points to the system of CAP problems will surface, and their systemic nature will further curtail the possibilities for solving some problems definitively. 'Some people sooner or later may want to open debate or re-engage in contestation about the unsolved or only partially solved problem parts' (Hoppe, 2011, p. 9).

The CAP problems constitute a CAS that may not be resolved but managed. Multidimensionality, complexity, and the diversity of the CAP problems have increased so substantially that none of the extant problems can be resolved without creating new conflicts or collateral damages. As long as the CAP remains within the present scope, complete solutions should not be expected from scientists or policy makers. It is important to recognise that trade-offs between the problems to be addressed must be tolerated due to the quality of the problems. *In conclusion, approaches and tools should be searched and developed that observe the wicked nature of the CAP problems.*

Second, domain-specific solutions for the CAP problems are inadequate and possibly hazardous. Single-sided economic, environmental, spatial, social, or technological solutions are hardly capable of streamlining the portfolio of wicked CAP problems. There is a risk that the CAP will sustain a desperate hot-spot of competing standalone claims to resolve the complex puzzle of interlinked problems. Any attempt to resolve, for example, a certain environmental problem, will affect the status of many socio-environmental, spatial, policy, market, and farming problems. Therefore, the capacity of the environmental sciences and environmental measures remains limited and rather unidimensional, and one-sided environmental interventions may reinforce spatial, market, farming, or policy problems through direct and indirect causal links (FAO, 2016, p. 81). Individual system elements do not expose (even their own) systemic properties. *In conclusion, systemic*

understanding and a holistic approach is required to manage the CAP problematics in a balanced and productive manner.

This task requires multidimensional expertise and a collaborative, multi-perspective design process, or a 'transdisciplinary imagination' (Brown et al., 2010) that observes diversity of the problem system. 'Policy will have to be designed in a way that it serves several purposes and addresses multiple clients in the process' (Viaggi et al., 2013, p. 101). The role of science is to expand the systemic understanding of CAP problematics with novel and insightful contributions like fuzzy cognitive maps (Christen et al., 2015) or constellation analysis (Schäfer and Kröger, 2016). Various network-based approaches have been proposed to manage wicked problems better than traditional specialised, isolated, hierarchical institutions by engaging more views, options, and agencies (Ferlie et al., 2010). In this context, various boundary organisations which bridge worldviews, institutions, or domains may 'co-create new, transformational knowledge and shared understanding which may be critical to the innovation in the policy process' (Batie and Schweikhardt, 2010, p. 30). These types of approaches may be useful in adding systemic understanding and in finding feasible ways to manage the wicked CAP problematics.

Third, the system of CAP problems is a tightly wired and evolving 'jam'. The status of a problem within the system affects the possibilities and feasible means to address it. Networked problems (e.g. multidimensional sustainability) are critical for the configuration of the whole system and require an especially careful policy design to achieve a successful incremental resolution. Driver problems (e.g. free trade with divergent farming regulations) offer powerful and unconditioned breaking points for the system. Dependent problems (e.g. competitiveness and incomes in agriculture) may be addressed by directly targeted and indirect measures that resolve other problems. Punctuated problems (e.g. food safety) allow direct intervention. *In conclusion, an operating system of the CAP problematics should be capable of observing the network status of various problems.*

Following this line of reasoning, management (not solutions) of the CAP problems in a system dynamics framework could be based on the *connectivity-causation typology* with its four categories. For the networked problems critical in the system of problems, a transition management approach could be productive (Voß et al., 2009). This approach encourages induced innovations in various domains that push the whole system into new intended directions through incremental steps as the whole system may not be often reconfigured immediately due to 'persistent problems' (Rotmans and Kemp, 2008, p. 1006).

Many CAP problems—the problematics of advancing multidimensional sustainable development as the prime candidate—could be considered in this type of incubation system, which subjects them to systemic innovations for partial resolutions. The driver problems are potential targets for a focused policy intervention because they have extensive direct impacts on many other problems. These problems deserve a careful cost–benefit analysis that observes systemic effects. Driver problems have a key role in delivering short- and medium-term policy results for the public funds. The problems caused by free trade with divergent farming regulations were observed to be the prime candidate for this scrutiny process. A partial resolution of the dependent problems can be expected through alleviating their master problems in the two previous categories. This setting asks for a systemic impact analysis with a full observation of the dynamic interlinkages. The problem of competitiveness and incomes in agriculture would be the prime candidate for this treatment.

Finally, the punctuated problems could be addressed by targeted intervention. To some extent, they could even be left for the specialists, when in all other categories generalists are called for. Food safety was observed to be the prime candidate for this type of targeted process. Generally, this new policy design, analysis, and management framework could back the huge and growing number of disciplinary and case-specific studies and bind them together.

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V

TRANSITIONS THROUGH THE DYNAMICS OF ADAPTIVE CYCLES: EVOLUTION OF THE FINNISH AGRIFOOD SYSTEM

by Irene Kuhmonen and Tuomas Kuhmonen 2023

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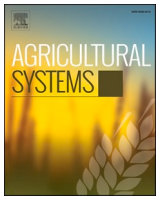


Transitions through the dynamics of adaptive cycles: Evolution of the Finnish agrifood system

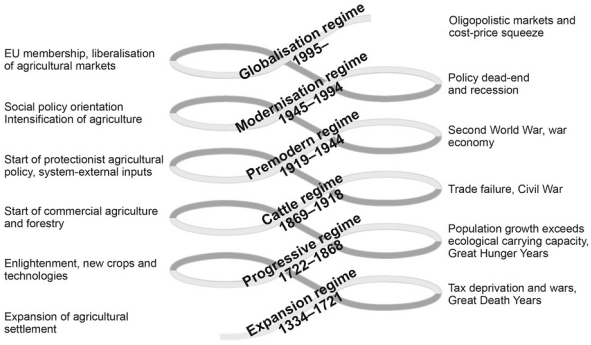
Irene Kuhmonen [a,*], Tuomas Kuhmonen [b]

[a] University of Jyväskylä, School of Business and Economics, P.O. Box 35, FIN-40014, Finland
[b] Finland Futures Research Centre, University of Turku, FIN-20014, Finland

HIGHLIGHTS

- A qualitative analysis of 700 years of Finnish agrifood system's history was conducted.
- Adaptive renewal cycles capture the regime shifts in the Finnish agrifood system.
- The elements of growth have turned to seeds of destruction during each regime.
- Regime shifts were driven by loss of resilience.
- Metabolic changes induced the most far-reaching regime shifts.

GRAPHICAL ABSTRACT



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ABSTRACT

CONTEXT: The escalating sustainability problems of the current agrifood regime call for a radical, systemic transformation. Such a transformation implies a move into a new stability domain, defined by a new set of systemic attractors. These transformations can be conceptualised as regime shifts.

OBJECTIVE: In this study, we explored the history of the Finnish agrifood system in order to learn from the past transformations of the system and to inform the current attempts to steer its development in a more sustainable direction.

METHODS: We conducted a qualitative analysis on literature discussing the history of the Finnish agrifood system by utilising the concept of the adaptive cycle, which captures the cyclicity of the evolution of social-ecological systems.

RESULTS AND CONCLUSIONS: We identified six regimes from the 14th century onwards: Expansion (1334–1721), Progressive (1722–1868), Cattle (1869–1918), Premodern (1919–1944), Modernisation (1945–1994) and Globalisation (1995–). During each regime, the evolution of the system organised around specific attractors which initially opened up new possibilities for the actors, but over time, the very same attractors became the main source of vulnerability in the system. Along with the system's maturation, path-dependency created rigidity, escalating sustainability problems and decreasing room for manoeuvre for the system's actors, concomitantly decreasing the system's resilience. When an external shock related to climatic conditions, economic turbulence or wars coincided with such a rigidity, the system collapsed, the consequences

* Corresponding author.
E-mail addresses: irene.a.kuhmonen@jyu.fi (I. Kuhmonen), tuomas.kuhmonen@utu.fi (T. Kuhmonen).

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of which span from food shortages to large-scale, deadly famines. The collapse of the old regime opened up the window of opportunity for a regime shift. The most profound regime shifts were related to changes in the system's metabolism and trade orientation.

SIGNIFICANCE: While the conservation phase of the adaptive cycle increases systemic vulnerabilities, it also offers an opportunity for systemic transformation. Allowing the adaptive cycle to play out on smaller scales—such as at the level of farm systems—helps to avoid collapse on the scale of the whole food system. The current agrifood regime in Finland indicates strong path-dependency and rigidity, manifesting a conservation phase, to be followed by release and reorganisation. This observation calls, first, for considering the resilience of the current system to anticipate a crisis and, second, for outlining alternative visions for the sustainable future of the agrifood system.

1. Introduction

During the past century, agrifood systems have undergone major changes globally. In the processes of modernisation, industrialisation and globalisation, locally oriented, more or less self-sufficient systems have transformed into systems tuned around relative competitive advantage, ever-increasing productivity fuelled by fossil and synthetic inputs, and dependence on the international trade of foodstuffs (McMichael, 2009; Oosterveer and Sonnenfeld, 2012; Kummu et al., 2020). While these developments have made it possible to feed a population that has more than quadrupled from 1920 to 2020, they have also contributed to a number of persistent problems, from biodiversity loss to environmental degradation and climate change, as well as social problems such as unequal nutrition and animal welfare issues (Pretty, 2008; Marsden and Morley, 2014; Eakin et al., 2017). To address these problems, it is of utmost importance to understand their systemic origin (Rotmans and Loorbach, 2009; El Bilali, 2018; Béné et al., 2019).

The shift towards a more sustainable future calls for a radical departure from the current ways of production and consumption within the agrifood system: a societal, systemic transformation. The questions of societal transformation are addressed within the field of transition studies, which explore causes, effects and processes related to the evolutionary dynamics of social systems (Geels and Schot, 2010; Loorbach et al., 2017; Ollivier et al., 2018; Köhler et al., 2019).[1] Understanding how and why systems undergo radical transformations calls for long-term historical analysis (Fraser and Stringer, 2009; Parsons and Nalau, 2016; Nicoll and Zerboni, 2020). Such an understanding can prove to be pivotal for the current attempts to steer the sustainability transition of our contemporary social systems (Garud and Gehman, 2012; Van Bers et al., 2019). However, the majority of transition studies in the field of agrifood systems as well as beyond them tend to be concerned with the dynamics of the present-day transition processes or limit their investigations to specific transition periods in history and the dynamics prevailing in those relatively short timeframes. Accordingly, Van Bers et al. (2019) argue that in order to navigate the transition of agrifood systems towards more sustainable pathways, far more empirical research is needed about (a) their historical transformations, and (b) the incremental vs. radical forms these transitions can take.

What constitutes a radical transformation of a social system remains ambiguous in the contemporary transition literature (Geels and Schot, 2007; Feola, 2015; Hölscher et al., 2018). Such transformations essentially relate to the stability of regimes, which can be seen as the dominant structural configurations of social systems prevailing across certain time periods. Regimes are characterised by stability and path-dependency anchored around strong social forces such as norms, routines, power relations and technologies (Loorbach et al., 2017). Regimes are path-dependent and resistant to change, but not immutable; thus, a regime shift – a significant change in the structural configuration, processes and functions of a system – can be seen to constitute a radical transformation, while incremental transitions may change some dimensions of the regime yet leaving their basic structures untouched.

Over the long term, the transition dynamics in social systems tend to take a cyclical form, as indicated by, for example, Schumpeter's cycles (Schumpeter, 1934) and Kondratieff's waves (Nefiodow and Nefiodow, 2017). Analysis of the macro-level development taking place within food systems (the food regime theory) has indicated that food systems are not in a state of constant flux, but they are characterised by multiple stability domains and consequent transformations (McMichael, 2009). In other words, social systems tend to spend considerable periods in a state of incremental developments that do not challenge the essence of the regimes, but these periods of stability are at times interrupted by events that reconfigure the structural foundations of the regimes.

A prominent framework for addressing both the cyclic nature of evolution of the social systems, as well as the multidimensional dynamics giving rise to It, is the concept of the adaptive (renewal) cycle (AC). The adaptive cycle is a heuristic model that captures the life cycle dynamics of social-ecological systems through phases of exploitation, conservation, release and reorganisation (Holling and Gunderson, 2002; Folke, 2006; Walker and Salt, 2006). As an integral part of resilience theory, it captures the dynamics occurring at multiple spatial and temporal scales across a system; this hierarchy of nested scales is referred to as panarchy (Holling and Gunderson, 2002). The theory holds that regime shifts take place as a result of a system exceeding resilience threshold—with resilience understood as "the capacity to absorb disturbance, to undergo change and still retain essentially the same function, structure, and feedbacks" (Walker and Salt, 2006: 32)—and entering a new regime or stability domain (Holling, 2001). The concept of adaptive cycle was originally coined within the field of ecology (Holling, 1986), and it was later adopted by social scientists to uncover and interpret development patterns of various kinds of social-ecological systems. In the context of agrifood systems, the adaptive cycles have been used to illustrate long-term transition dynamics observable in various geographical regions, as in the analysis of systemic lock-ins (Allison and Hobbs, 2004), spatiotemporal change dynamics and transformations (Vang Rasmussen and Reenberg, 2012; Winkel et al., 2016; Antoni et al., 2019), the resilience of local agroecosystems (Abel et al., 2006; van Apeldoorn et al., 2011; Tittonell, 2020) and agrarian soil use (Teuber et al., 2017) as well as industry restructuring (Sinclair et al., 2014).

In this study, our aim is to explore the long-term evolution and transition dynamics within an agrifood system. Our case concerns Finland, a developed country in Northern Europe. More specifically, we aim at identifying regime shifts from the history of the Finnish agrifood system, starting from the 14th century, as well as the conditions predating the radical changes of the system. Using the adaptive cycle heuristic as a theory of change in the Finnish agrifood system has significant value for revealing the key drivers and patterns of change across time, and the lessons learned might have value for other countries and agrifood systems as well, regardless of whether or not they have experienced similar transitions over time or have operated in similar regimes. Finland is an interesting target of investigations for a variety of reasons.

[1] The literature discussing large-scale changes of social systems uses both terms *transformation* and *transition*. The difference between the two is not clear-cut, but studies on social-ecological systems generally refer to *transformations* whereas the term *transitions* is commonly used by the socio-technical stream (Hölscher et al., 2018).

On the one hand, it serves as an example of the historical transformation trajectory observable across the Global North, with a changing metabolic basis of the agrifood system and the interrelated, escalating sustainability problems and increasing efforts to address them. On the other hand, the Finnish agrifood system has witnessed many periods of food-related vulnerability and crises, which are partly related to Finland's northern location at the edge of the bread-grain cultivation zone. To analyse the historical evolution of the Finnish agrifood system, we conducted a qualitative survey of the agrifood and historical literature within the framework of the adaptive cycle, depicting its development from the 14th century all the way to the present day. Our paper is organised as follows. In section 2, we discuss the theoretical background: the theory of complex adaptive systems and adaptive cycles, and how these theoretical frameworks can be utilised in analysing the transition dynamics of social systems. In section 3, we present our methodological approach. In section 4, we present our results concerning the identified regimes and regime shifts, as well as the system dynamics that have given rise to these shifts. In section 5, we discuss the relevance of our findings especially from the viewpoint of sustainability transitions.

2. The dynamics of adaptive cycles in social-ecological systems

Agrifood systems are a type of social-ecological system, but they are also complex adaptive systems (CAS). Complex adaptive systems are open systems that exchange matter, energy and information with other systems, lack central coordination and self-organise around systemic functions (Byrne and Callaghan, 2014; Boulton et al., 2015), such as food provision in the case of food systems (Hodbod and Eakin, 2015). These systems alternate between several equilibria or steady states (Holling and Gunderson, 2002; Folke, 2006). These alternative equilibrium states converge around attractors. The system dynamics take place within the power field set up by attractors, forming a basin of attraction (Kuhmonen, 2016). Depending on the system and the context, attractors can take various forms: norms, practices, technologies and so on. Basins of attraction are manifestations of a system's path-dependency, as they limit the possibilities towards which a system can evolve within a specific development trajectory (Kauffman, 1993). Thus, they can be conceived of as 'cups' or 'valleys' in which the system lives.

Within the transition literature and political economy, similar dynamically stable configurations of social systems are captured by the concept of regime. Here, the concept of regime depicts the patterned development trajectories of socio-technical systems featured by cognitive routines, regulations and standards, the interlinkages between lifestyles and technologies, sunk investments as well as path-dependencies related to investments in machines, infrastructures and competencies (Geels and Schot, 2007). In this way, the cyclical evolution of complex adaptive systems can be traced back to consecutive regimes (equilibrium or steady states) and regime shifts (transformations). According to resilience theory, a resilient regime remains within the state space defined by a set of attractors (Gunderson and Holling, 2002; Walker and Salt, 2006). When the system loses its resilience, typically resulting from an exogeneous shock coupled with internal vulnerability, the threshold delineating this state space—the 'cup' within which the system lives—is crossed, and the opportunity for a regime shift opens up (Walker and Salt, 2006). In this situation, the system may either return to its earlier steady state, defined by the same attractors as before, or reorganise around a new set of attractors (Gunderson and Holling, 2002).

The evolutionary dynamics of social-ecological systems underlying regime shifts can be conceptually modelled using the adaptive (renewal) cycle (AC; Fig. 1). The AC can be seen as a life cycle model entailing the imminent stages of birth, growth, maturation and decline. The equilibrium states or regimes – captured by a basin of attraction – form during the reorganisation phase (α), grow during the exploitation phase (*r*), stabilise during the conservation phase (K) and decline during the release phase (Ω) (Walker et al., 2002; Sundstrom and Allen, 2019). This sequence is indicative in the sense that not all systems at all cycles pass through all of the phases in consecutive order (Walker and Salt, 2006). According to this model, a regime shift is most likely to take place as a result of a systemic collapse taking place in the release phase, which opens up the window of opportunity for the system to reorganise towards a new stability domain. Thus, the 'front loop' consisting of exploitation and conservation phases represents incremental change, while a radical transformation and a regime shift can follow from the system entering the 'back loop', consisting of release and reorganisation phases.

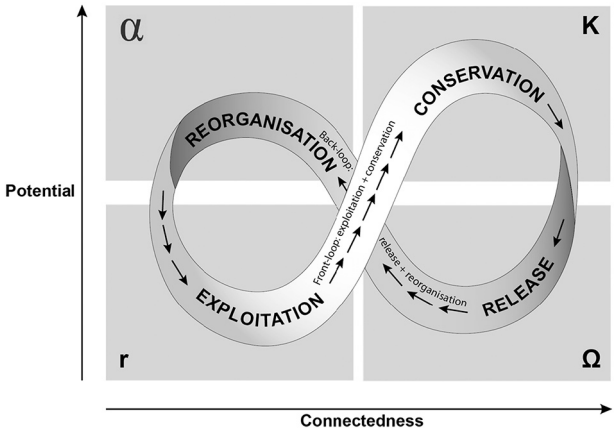

Fig. 1. The logic of the adaptive cycle (adapted from Gunderson and Holling, 2002, 34).

In the *exploitation phase* (r), new opportunities and resources are available for the system agents to exploit (Walker and Salt, 2006). This phase is marked by continuous accumulation of different forms of capital facilitated by self-reinforcing feedback loops between the system's components, which leads to accumulating resources, know-how and welfare (Renfrew, 1984; Gunderson and Holling, 2002; Walker and Salt, 2006; Fath et al., 2015; Faulseit, 2016). At the beginning of the exploitation phase, the system is weakly regulated and interconnected, but the connectedness of the system increases along with the system's growth (Walker and Salt, 2006). Due to these positive feedback loops, resources and power centralise to the hands of the most successful actors (Gunderson and Holling, 2002; Walker and Salt, 2006)—peripheralising less powerful actors (such as farmers within the food system; Kuhmonen, 2020).

Accumulation and centralisation of different forms of capital indicates a transition to the *conservation phase* (K) (Walker and Salt, 2006). The conservation phase typically means "a move toward more specialization and greater efficiencies or large economies of scale: bigger machines, bigger outputs, smaller costs per unit, larger profits over longer timeframes" (Walker and Salt, 2006: 77). Increasing connectedness creates rigidity within the system and slows down the system's growth rate (Gunderson and Holling, 2002; Walker and Salt, 2006). Acting otherwise becomes increasingly difficult, as the search for efficiency eliminates diversity and alternative ways of doing (Walker and Salt, 2006). Reinforcing feedbacks maintain the system's growth in the exploitation phase, but growth also creates unintended consequences. These can turn some of the reinforcing feedbacks to balancing feedbacks, which then resist change in a particular direction. As a result, the growth of the system eventually slows down, and path-dependency of the regime consolidates. The resulting centralised system is tuned around efficiency, has eliminated redundancy, and has its capital tightly bound into existing structures. The resilience of such a system is low, and that is why any external disturbance—such as drought, political unrest, major institutional change or economic recession, but also a relatively small disturbance—can push the system over a critical

threshold and cause a release phase (Allison and Hobbs, 2004; Abel et al., 2006; Walker and Salt, 2006; Chaffin and Gunderson, 2016; Hartel et al., 2015). In other phases of the cycle, the system is more resilient to such disturbances and is less likely to cross a critical threshold that could lead to collapse of the system.

In the *release phase (Ω),* natural, social and economic capital leak out of the system, which leaves room for uncertainty or even chaotic conditions (Walker and Salt, 2006). The conditions are favourable for the reorganisation and emergence of a new regime. During the *reorganisation phase* (α), the system converges either around the same attractors as before or around new ones, thus moving towards a new basin of attraction. Due to the loose organisation of the system, the reorganisation phase is favourable to the emergence of new actors, new modes of organisation and governance, and new kinds of networks between the actors (Walker and Salt, 2006; Fath et al., 2015). Resources released in the collapse of the previous regime are available to be harvested, but the process of reorganisation can benefit from receiving additional activation energy from the broader scales in the panarchy structure, or, in some cases, from beyond the focal system (Gunderson et al., 2002; Abel et al., 2006; Vang Rasmussen and Reenberg, 2012; Fath et al., 2015). The concept of panarchy refers to the hierarchy or embeddedness of nested scales (Holling et al., 2002): in the case of food systems, such scales could include global trade systems, national level food systems (which is the focus of inspection in this study), regionally organised supply chain systems and, finally, farm systems. The dynamics of adaptive cycles are affected by similar dynamics occurring both at the broader and lower levels of the system; at the broader level cycles tend to last longer than at the lower levels (Holling et al., 2002). The resulting pattern of interactions is called 'revolt and remember'. The term *revolt* refers to the faster renewal rate of smaller-scale systems affecting cycles at broader scales, whereas the term *remember* refers to the confining effect of how broader scales condition the options available for systems at smaller scales (Gunderson et al., 2002; Holling et al., 2002).

During the four phases, a system manifests diverging levels of connectedness, potential and resilience (Holling, 2001; Sundstrom and Allen, 2019). The concept of *connectedness* captures the amount and quality of interdependencies and feedback loops in the system (Holling and Gunderson, 2002). The degree of connectedness generally grows along with the maturity of the system through the organisation, structuration and institutionalisation of the behaviours of the system agents and their interactions (Walker and Salt, 2006). Connectedness peaks in the conservation phase and collapses in the release phase. The concept of *potential* refers to the options available for the system agents (Holling, 2001). In the conservation phase, the system is rich in resources but poor in options, whereas in the release phase there is a lot of latitude for improvisation, initiative and innovation (Fath et al., 2015). In a more abstract setting, potential can be seen to capture the oscillating power balance between structure and agency (see Giddens, 1984; Archer, 2000). A *resilient* system is able to navigate among these phases while retaining its ability to fulfil its systemic functions (Holling, 2001; Meuwissen et al., 2019). However, resilience or the capacity to adapt often weakens because of the growing rigidities during the conservation phase, which may cause the system to enter the release phase after losing resilience partly or completely (Walker et al., 2006).

In sum, in the light of the theory of resilience and adaptive cycles, a regime shift, representing a radical systemic change, is most likely to result from a collapse of the system of some magnitude. Such a collapse typically results from a loss of resilience, which drives the system over the threshold delineating the system's basin of attraction. Systems are most vulnerable and thus prone to lose their resilience at the late conservation phase of the adaptive cycle due to growing rigidity and (over)-connectedness of the system elements.

3. Data and methods

To depict the evolutionary dynamics of the Finnish agrifood system and identify its major regime shifts from the 14th century to the present day, we conducted a qualitative thematic analysis by reviewing literature on the history of the Finnish agrifood system. By 'agrifood system' we mean the whole system of production and consumption of food, including both its material and cultural dimensions that can assume different manifestations over time. Thus, the Finnish agrifood system is one that aims at feeding the population residing within the country's boundaries. We reviewed approximately 100 items from the literature, ranging from extensive accounts of the history of Finnish agriculture to detailed research reports concentrating on some specific aspects of the

Table 1
Literature referred to in the analysis by regime.

Regime	Literature
1. Expansion regime (1334–1721)	Huhtamaa and Helama, 2017; Jutikkala, 1958; Katajala, 2003; Korhonen, 2003; Korpela, 2012; Kuisma, 1997; Kylli, 2021; Lappalainen, 2021; Muroma, 1991; Mäkelä-Alitalo, 2003; Niemelä, 2008; Nummela, 2003; Orrman, 2003a; Orrman, 2003b; Rasila et al., 2003; Simonen, 1947, Soininen, 1961; Solantie, 2012; Voutilainen et al., 2020; Wilmi, 2003
2. Progressive regime (1722–1868)	Jutikkala, 1958; Heikinheimo, 1915; Huhtamaa and Helama, 2017; Jutikkala, 2003; Koponen and Saaritsa, 2019; Korhonen, 2003; Kotilainen and Rytteri, 2011; Kuisma, 1997; Kupiainen, 2007; Kylli, 2021; Metsähallitus, 2012; Mykrä, 2015; Niemelä, 2008; Niemelä, 2009; Rasila, 1961; Rasila et al., 2003; Simonen, 1947; Soininen, 1961; Soininen, 1974; Solantie, 2012; Tikkanen, 2019; Voutilainen, 2016; Voutilainen et al., 2020
3. Cattle regime (1869–1918)	Hjerppe, 1988; Heikinheimo, 1915; Huhtamaa and Helama, 2017; Häkkinen and Peltola, 2001; Jutikkala, 1958; Ihamuotila, 1979; Koponen and Saaritsa, 2019; Kotilainen and Rytteri, 2011; Kuisma, 1997; Niemelä, 2008; Niemelä, 2009; Ojala and Nummela, 2006; Peltonen, 2004a, 2004b; Peltonen, 2019; Rantatupa, 2004a; Rasila, 1961; Simonen, 1947; Vihola, 1991; Vihola, 2004a, Östman, 2004
4. Premodern regime (1919–1944)	Granberg, 1989; Hjerppe, 1988; Häkkinen and Peltola, 2001; Ihamuotila, 1979; Jutikkala, 1958; Koponen and Saaritsa, 2019; Kotilainen and Rytteri, 2011; Niemelä, 2008; Ojala and Nummela, 2006; Partanen, 2017; Peltonen, 2004a; Rantatupa, 2004b; Simonen, 1947; Vihola, 2004b
5. Modernisation regime (1945–1994)	Aakkula et al., 2006; Birge, 2017; Granberg, 1989; Granberg, 2004a, 2004b; Haapala, 2004; Hildén et al., 2012; Hjerppe, 1988; Häkkinen and Peltola, 2001; Jokinen, 1997; Kettunen, 1992; Kiander, 2001; Koistinen, 2009; Kola, 2002; Komiteanmietintiö, 1985; Komiteanmietintiö, 1987; Kuhmonen and Aaltonen, 1997; Kuhmonen and Niittykangas, 2008; Kuokkanen et al., 2017; Markkola, 2004; Muilu et al., 2016; Niemelä, 2004; Niemelä, 2008; Ojala and Nummela, 2006; Partanen, 2017; Raatikainen, 2018; Roiko-Jokela, 2004; Vepsäläinen, 2007; Vihinen, 2004; Waris, 1974; Ylivainio et al., 2015
6. Globalisation regime (1995–)	Aakkula et al., 2006; Aakkula and Leppänen, 2014; Ahokas et al., 2016; Arovuori, 2022; Arovuori and Karikallio, 2019; Berninger, 2018; Economydoctor, 2022; EU, 2020; Herzon et al., 2022, Hyvärinen, 2016; Jansik et al., 2021; Jokinen, 1997; Kaljonen, 2006; Kaljonen, 2011; Kaljonen et al., 2019; Kallio, 1997; Karhula et al., 2015; Karttunen et al., 2019; Kiander and Romppanen, 2005; Kivekäs et al., 2015; Koistinen, 2009; Kola, 2002; Koppelmäki et al., 2021; Kotilainen et al., 2010; Kuhmonen, 2018a, 2018b; Kuhmonen and Aaltonen, 1997; Kuhmonen et al., 2015; Kuhmonen and Siltaoja, 2022; Kuokkanen et al., 2017; Kuokkanen et al., 2018; Latvala et al., 2022; Kuosmanen et al., 2009; Lehikoinen, 2020; MAF, 2017; Markkola, 2004; Muilu et al., 2016; Niemi and Väre, 2019; Niskanen and Lehtonen, 2014; Ojala, 2006; Paloviita et al., 2017; Partanen, 2017; Parviainen and Helenius, 2020; Piipponen et al., 2018; Puupponen et al., 2022; Vainio, 2022; Valtioneuvosto, 2005; Vepsäläinen, 2007; Ylivainio et al., 2015; Yli-Viikari, 2019

system. The goal of the literature review was to produce 'data' to be used in the analysis described next. Table 1 summarises the literature used in the analysis per each regime.

The analysis proceeded in three stages. First, we identified the regimes and regime shifts on a coarse level. Second, we finetuned this initial understanding about the regimes by analysing the nature of the agrifood system in nine dimensions. Third, we analysed the temporal development of the regimes in terms of the adaptive cycle. In practice, the research process was iterative and moved back and forth between these stages: understanding about the dimensions of the systems as well as the phases of the adaptive cycle fed back to dating the regimes and regime shifts.

In the first stage, the aim of the analysis was to delineate the regime shifts, that is, those periods of time during which the system endured major changes, as well as the regimes that prevailed in between the regime shifts, during which the system developed on a specific path-dependent trajectory. The initial identification was based on narratives of a dominant idea configuring and delimiting the system dynamics within the agrifood system. While this step could only capture a coarse understanding of the system, it was necessary for building an initial framework about the timing of the regimes and the regime shifts in between.

In the second stage, we worked further with the initial regime framework to dive deeper into the dominant idea of each regime—in other words, this stage served to delineate the basin of attraction for each regime. This was done by analysing the nature of the system in nine dimensions. The dimensions included agricultural production, the main source of energy and nutrients, technology and production methods, food chains, culture and society, climate and environment, demography, international trade as well as agricultural and land use policies. Based on our reading of the historical literature, these dimensions captured the essential characteristics of the agrifood system in all times. These nine dimensions provided historical contexts and fitness landscapes for the regimes, as well as accounted for the structures, functions and processes of the system. This step also contributed to distinguishing between the consecutive regimes in more detail. Upon a regime shift, we expected to see changing contents in these dimensions. The detailed results of this analysis are given in Appendix A, which describes the dimensions of the system for each regime. For a brief presentation of the dimensions, see Table 2.

Third, the development of each regime was broken down into four phases of the adaptive cycle: reorganisation, exploitation, conservation and release. Identification of these phases was based on the indicators of system properties: resilience, connectedness and potential—as suggested in conceptualisations of adaptive cycles (Holling, 2001; Holling and Gunderson, 2002). During the adaptive cycle, *resilience* is at its lowest point in the late conservation phase, which makes a release phase more likely. In contrast, a similar amount of disturbance is less likely to make the system cross a threshold and collapse during the exploitation phase, where the resilience tends to be in its highest peak (Walker and Abel, 2002). Increasing complexity and *connectedness* within the system manifest a conservation phase, whereas in the release phase, these connections are broken to become rebuilt in the reorganisation phase. Source, contents and accumulation of *potential* are phase specific as well. The various forms of capital that become released in the release phase feed the exploitation phase. However, as some of the resources leak out of the system in the release phase (Holling and Gunderson, 2002), gaining resources from broader levels in the panarchy structure can be beneficial for the reorganisation process (Gunderson et al., 2002; Fath et al., 2015). There is also some empirical evidence suggesting that opportunities arising beyond the boundaries of the focal system may play a role in the process of reorganisation (Abel et al., 2006; Vang Rasmussen and Reenberg, 2012). The detailed results of this phase of analysis are presented in Appendix B, describing the systemic properties of each regime and phase of the adaptive cycle.

In addition to resilience, connectedness and potential, we also included two other indicators: type of the major feedback loops (reinforcing vs. balancing; Walker and Salt, 2006; Faulseit, 2016) and manifestations of agency (agency vs. structure; Archer, 2000; Lyon and Parkins, 2013). While these concepts are not the default analytical tools in studies of adaptive cycles within social-ecological systems, stabilisation of growth upon the turn of exploitation to conservation is connected with changing feedback patterns from self-reinforcing or amplifying feedbacks to stabilising or balancing feedbacks (Meadows, 2008; Fath et al., 2015). The growth in the exploitation phase is facilitated by self-reinforcing feedback loops, such as improved technology facilitating improved productivity, allowing again investments in technology. Balancing feedbacks dominate the conservation phase: ultimately, the consequences of growth may begin to 'eat away' at the prerequisites for growth—here the projected detrimental consequences of climate change to humanity perhaps serve as an extreme example.

Our rationale for including agency as an indicator of the adaptive cycle arises from the observation that the phase of adaptive cycle plays a role for exercising human agency (Westley et al., 2013). The findings of Lyon and Parkins (2013) on the relatedness of the adaptive cycle and the conceptualisation of cultural morphogenesis put forward by Margaret Archer (2000), among others, provide a signpost on analysing the comparative 'strength' of agency vs. structure in this setting. Lyon and Parkins argue that the adaptive cycle is a close match with the morphogenetic model, where actors are strongly bound by the structural constraints arising in the conservation phase, but through becoming aware of these constraints, they increasingly start to challenge them, and through reorganisation may contribute to transformation of the system. These ideas have not been widely adopted and tested in empirical research concerning adaptive cycles, but we see similarities in extant theorising of adaptive cycles especially in terms of the impacts of connectedness on the possibilities for (transformative) human agency. This is why we wanted to analyse the latitude for agrifood system actors to exercise their agency in the different phases of the adaptive cycle.

Table 2
Nine dimensions and five systemic properties underlying historical agrifood systems.

Dimension (D) or Property (P)	Description
D1. Agricultural production	Agricultural land use, main crops, new crops, self-sufficiency
D2. Main source of energy and nutrients	Types of energy and nutrient sources, local vs. external sources, new sources
D3. Technology and production methods	Main and new technologies in farming, evolution of mechanisation
D4. Food chains	Members of the food chain, evolution and structural change in the division of labour and markets
D5. Culture and society	Evolution of the nation state, settlement and employment structure, wars and societal reforms
D6. Climate and environment	Evolution of the climatic conditions, status of the environment and natural resources
D7. Demography	Pattern of population growth, farmers and landless people, migration
D8. International trade	Role and main patterns in imports and exports of agrifood products, trade balance
D9. Agricultural policies	Orientation and main measures of agricultural and land policies
P1. Resilience	Ability of a system to navigate the adaptive cycle, to tolerate disturbances, adapt and transform while retaining its essential functions
P2. Connectedness	Strength of internal connections and degree of internal control of a system
P3. Potential	Accumulated stock of various capitals (natural, economic, social, cultural) and capacities
P4. Feedback loops	Internal connections that control self-adaptation of a system contributing to either growth (self-reinforcing) or stability (balancing)
P5. Agency	Capacity of social actors to act intentionally, make deliberate choices and ultimately exercise power to affect social structures

4. Results: System dynamics of the Finnish agrifood system from 1334 to 2022

We identified six successive regimes from the 14th century to the present. The regimes can be conceptualised as multi-dimensional configurations of the agrifood system that are built around a few key attractors that condition the development of the social structure and organisation. The consecutive regimes are called the Expansion regime (1334–1721), the Progressive regime (1722–1868), the Cattle regime (1869–1918), the Premodern regime (1919–1944), the Modernisation regime (1945–1994) and the Globalisation regime (1995–). The regimes and main characteristics of their four phases (reorganisation, exploitation, conservation and release) are presented in Fig. 2 in the form of a continuously evolving adaptive cycle. In the following, the key features of each regime will be discussed.

4.1. Expansion regime: 1334–1721

The first cycle, the Expansion regime, was built on grain cultivation with varying degrees of self-sufficiency. It is considered to begin with a declaration by King Magnus IV of Sweden in 1334 and to last almost 400 years until 1721. The declaration stated that the uninhabited wilderness in the kingdom of Sweden, to which Finland belonged at the time, was to be colonised (Niemelä, 2008). This intent was promoted with exemption from taxes for the colonisers but had the ultimate aim of enlarging the tax base of the kingdom (Korpela, 2012; Huhtamaa and Helama, 2017). The following period was characterised by expansion of settlement further into the inlands (Simonen, 1947; Jutikkala, 1958; Soininen, 1961). Finland was inhabited by three geographically and culturally distinct populations. The western population practiced farming on permanent fields, the eastern population practiced mostly slash-and-burn agriculture and the Sámi people were hunters and gatherers. The Sámi people were slowly pushed towards the northern parts of the Scandinavian peninsula as the farming population spread out into their hunting lands.

Accordingly, the Finnish agrifood system during the Expansion regime was characterised by two distinct basins of attraction. (The hunter–gatherer system of the Sámi people should be considered a distinct system of its own, but as this study is focused on agrifood systems, it is not discussed in more detail here.) In the west, farming on permanent fields was based on fertilisation with cattle manure. The cattle foraged in the woods and meadows surrounding the villages, while the fields were reserved mainly for producing human food and horse feed, along with fibre plants needed for clothing (Nummela, 2003; Niemelä, 2008). The main role of the cattle was moving nutrients from the surrounding areas to the productive fields – for 1 ha of field, 3 ha of meadows were needed in terms of manure sufficiency (Korhonen, 2003). Animal protein was derived mostly from fish as cattle was malnourished in wintertime and only provided milk during the summer (Wilmi, 2003). Two varieties of grains – rye and barley – formed the backbone of the diets (Simonen, 1947; Wilmi, 2003; Niemelä, 2008).

The eastern system was based on slash-and-burn agriculture and the role of cattle was not as pronounced as in the west (Nummela, 2003; Orrman, 2003a; Niemelä, 2008). The nutrient economy in this system was based on releasing the nutrients bound to tree mass by fire. Once the burned land was utilised for a couple of harvests and some years of grazing, the trees were left to grow and reharvest the nutrients without further intervention. The slash-and-burn agricultural system was very productive and could sustain large families, but it also required a lot of labour force (Kuisma, 1997; Orrman, 2003a). The rotation times were very long, and the nature of the system was extremely expansive. It was also vulnerable to variation in weather conditions and could hardly sustain the population of the time. In fact, only the southern and western areas in Finland were self-sufficient in terms of bread grains (Orrman, 2003a). In other parts of the country, the livelihoods relied on a mixture of sustenance farming, hunting and fishing – especially fur animals were important trade items (Orrman, 2003a). In these areas the population also regularly relied on famine foods such as bread partly made of pine

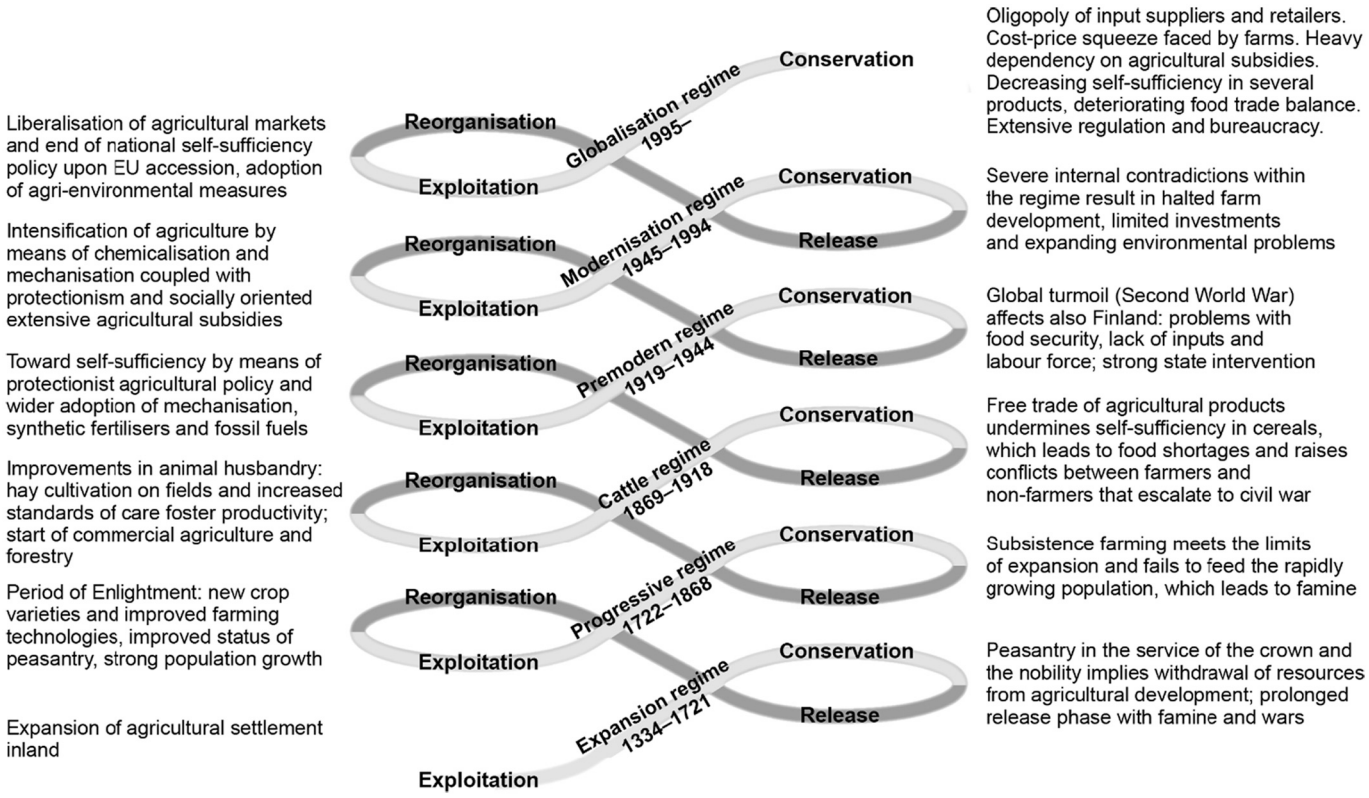

Fig. 2. Adaptive cycles in the Finnish agrifood system since the 14th century.

bark (Simonen, 1947; Orrman, 2003a; Kylli, 2021).

The exploitation phase of the Expansion regime was initiated by self-reinforcing feedback loops created by systemic potential, that is, abundant resources – available uncultivated land – together with population pressure and politics favouring colonisation (Jutikkala, 1958; Orrman, 2003a). This phase lasted until the 16th century. By then, the control of the state increased along with the power politics of King Gustav I to centralise state governance and to strengthen the kingdom's military rule (Jutikkala, 1958; Katajala, 2003; Niemelä, 2008). The web around peasant farmers tightened in relation to the crown (tax burden) and to the nobility (day labour), indicating increasing connectedness of the system and the beginning of the conservation phase. The consequences of these policies were harsh for the peasant farmers (Mäkelä-Alitalo, 2003; Korpela, 2012). Even though promotion of colonisation was continued, the strains imposed by heavy taxation, military service and numerous wars desolated farms and even some villages altogether (Simonen, 1947; Orrman, 2003b; Wilmi, 2003; Niemelä, 2008). The system was rigid, bureaucratic and control oriented (Lappalainen, 2021). The crown wanted farms to specialise in crop cultivation, and secondary or additional sources of livelihood – as important as they were – were not encouraged (Lappalainen, 2021). Growth-maintaining, self-reinforcing feedback loops based on expansionist policies were thus replaced by policies based on the deprivation of peasants, placing balancing feedback loops in the system. These hardships eventually culminated in a severe famine in 1695–1697, called the Great Death Years. The famine was triggered by extremely harsh weather conditions, called the Little Ice Age. This climatically unfavourable period lasted for several centuries (Huhtamaa and Helama, 2017 date the period to 1220–1650) and caused reoccurring harvest losses. During the Great Death Years, approximately 20%–30% of the Finnish population (originally half a million) was wiped out (Muroma, 1991; Voutilainen et al., 2020). Even though cold summers caused food shortages and famine all over northern Europe during this time, the destruction was most complete in Finland. During the Great Death Years, the inherent vulnerabilities of the Expansion regime, such as primitive farming technology, diets being built on only a few crops which were cultivated at the northernmost edge of their cultivation zone (Simonen, 1947; Solantie, 2012), materialised. By then, resilience of the system had declined in the conservation phase along with resources leaking to serve the crown and the nobility, coupled with a lack of secondary livelihoods. The remaining population was further burdened by continuing wars between Sweden and Russia until the early 18th century and thus prolonged the release phase of this cycle to last almost 30 years.

4.2. *Progressive regime: 1722–1868*

The peace between Sweden and Russia in 1721 meant that the easternmost parts of Finland were placed under the control of the Russian empire. The peace marked the possibility for the agrifood system to reorganise and finally embark on a new growth period. This regime is called the Progressive regime and it lasted almost 150 years until the late 19th century. The system had access to new system-external potential in the form of knowledge brought about by the Enlightenment (Niemelä, 2008), even though the basic nature of the agrifood system stayed untouched (Kylli, 2021) and thus the attraction basin was similar with the previous regime. This potential was translated into incremental improvements in the farming systems: new crop varieties (such as yellow turnip and potato), new farm animals (hens), new tools that allowed cultivation of heavier soils than before as well as developments in ditching and draining techniques (Simonen, 1947; Korhonen, 2003; Niemelä, 2008). The diffusion of knowledge and new innovations became possible through an increasing share of literate people and the establishment of university-level agricultural education during the late 18th century (Simonen, 1947; Niemelä, 2008). At the same time, the process of land parcelling enabled peasants to try out new farming methods on their own land, as peasants farming on common lands were tied by the opinion of the majority (Jutikkala, 1958; Saarenheimo, 2003). The 18th century was a climatically favourable period, and the population grew constantly in the exploitation phase of this cycle (Jutikkala, 2003; Voutilainen et al., 2020). This population growth pushed the government to legalise the establishment of crofts in the mid-18th century, which was earlier forbidden (although poorly supervised) so as to maintain large enough farms and a sufficient livelihood for the farm-based families (Kupiainen, 2007; Rasila, 1961). The establishment of crofts led to the expansion of farmed land, and the development of ploughing technologies led to the expansion of farmland to soils that were not cultivatable earlier (Niemelä, 2008). At the same time, the privileges of the nobility were abolished (Rasila, 1961; Niemelä, 2008). All these developments offered new opportunities for farmers and created self-reinforcing feedback loops that boosted the system's growth. From 1750 to 1850, the population quadrupled from 0.4 million to 1.6 million (Voutilainen et al., 2020).

In 1809, Finland became an autonomous part of the Russian empire, which marked the establishment of central state governance and, at the same time, the beginning of the conservation phase. Becoming part of Russia opened trade relations to the east in the form of butter exports and grain imports (Simonen, 1947). Butter exports allowed for the expansion of animal husbandry in the northern and eastern parts of the country and, at the same time, moved the emphasis of the population northwards and towards climatically less favourable areas (Solantie, 2012). The first agricultural organisations were founded in the 19th century both at the state and local level to develop farming methods (Niemelä, 2008). These were centrally managed and organised and did not lead to extensive grassroot involvement of farmers (Niemelä, 2008), which is also characteristic of the conservation phase.

The extensive farming style coupled with population growth gradually led to reaching the limits of the system. In the eastern areas, where slash-and-burn agriculture was practised, peasants started to complain about the decrease in forest base suitable for burning already in the mid-18th century (Jutikkala, 2003). The tragedy of the slash-and-burn technique was endogenous: it was so effective that it enabled significant population growth, which eventually made continuation of the whole system impossible due to its continuous demand of new areas to be burned. Thus, towards the end of this period, the eastern system based on slash-and-burn agriculture was gradually transformed into a farming system based on permanent fields (Saarenheimo, 2003; Niemelä, 2008). At the same time, the progression of land parcelling and the increasing value of timber made attitudes towards slash-and-burn more negative (Myllyntaus et al., 2002). In the western system, new fields were mostly cleared from meadows that had been previously used for feeding cattle (Wilmi, 2003; Saarenheimo, 2003). This led to reduced acreage for feeding the cattle and consequently to less manure, which was the key input for the whole agrifood system (Jutikkala, 2003; Niemelä, 2008). Towards the end of the period, the proportion of meadows to fields decreased from 3:1 to 2:1, implying severe scarcity of nutrients (Soininen, 1974; Jutikkala, 2003). Concomitantly, production capacity of grains stagnated while the population was becoming increasingly dependent upon them, resulting in a growing role for grain imports (Jutikkala, 2003). At the same time, finding a livelihood was difficult for landless people, who formed a significant part of the growing population (Voutilainen, 2016).

The vulnerabilities of the agrifood system were accentuated further when the availability of game animals no longer acted as a buffer for the fluctuations in crop yields. The eastern and northern populations were not self-sufficient in terms of bread grains but hunting and fur trading had provided important additional resources. Increasing population pressure, however, had led to overexploitation of numerous game and fur animals, as well as the persecution of large carnivores (Kunnas, 2018; Solantie, 2012; Tikkanen, 2019). In the 19th century, populations of species such as moose (*Alces alces*), deer (*Rangifer tarandus fennicus*), bear (*Ursus arctos*), wolves (*Canis lupus*), pine marten (*Martes martes*), squirrels (*Sqiurus vulgaris*) and whooper swans (*Cygnus cygnus*) declined

strongly, and some eventually went extinct (Metsähallitus, 2012; Mykrä, 2015; Tikkanen, 2019). Thus, strong balancing elements to the operative feedback loops were created in both the western and eastern systems when the limits of the local environmental carrying capacity were reached in terms of nutrients, the shrinking forest coverage and decrease in game animals as well as by the increasing amount of landless population. The resilience of the system was already weak, when extreme weather conditions caused harvest losses in the 1860s. The resulting Finnish famine, called the Great Hunger Years (1867–1868), was the last major famine in Europe killing 8% of the population (Voutilainen, 2016).

4.3. Cattle regime: 1869–1918

Within the historical literature on Finnish agriculture, the Great Hunger Years represent a threshold: a turn from "old agricultural model" towards a new one, based on new technologies, a reliance on cattle husbandry and the commercialisation of the agrifood system. The roots of these developments were manifold. Already during the Progressive regime in the 19th century, field grasses such as timothy and clover were introduced in Finland (Niemelä, 2008). They provided better yields than wild domestic grass species, but despite this, their adoption rate remained low until the end of the period. Farmers were initially reluctant to cultivate hay for the cattle on their best fields (Kuisma, 1997; Östman, 2004; Kylli, 2021). This changed dramatically after the Great Hunger Years and was strongly promoted by some agricultural experts of the time, who claimed that hunger in Finland would not end until cultivation of bread grains would cease once and for all (Simonen, 1947; Kuisma, 1997). The central innovation that formed the basin of attraction for the regime emerging after the famine in the late 19th century was cultivated grass for cattle feed, which enabled greater milk output of cows and paved the way to large-scale commercialisation of dairy production. This period is accordingly called the Cattle regime. This regime lasted about 50 years and was built on several developments forming self-reinforcing feedback loops. The key drivers were developments in ploughing technology and the processing of dairy products, the free trade of agricultural products and the rise of the forest industry, which were all related to the common development of industrialisation.

The Cattle regime is a good example of a socio-technical system, where the physical and social structuration of the system is anchored around specific technological solutions (Niemelä, 2008). The key technology in this system was the plough. Development in new plough technology was enabled by the improved availability and industrial-scale production of iron, which enabled adoption of grass as part of crop rotation on permanent fields instead of collecting hay from seminatural meadows (Östman, 2004). With the old-fashioned ploughs, terminating grass on permanent fields to give way to other crops was difficult and in itself prevented the adoption of grass as part of crop rotation. Another important technological innovation was a mowing machine that was suitable for harvesting grass from permanent fields, but not from seminatural meadows (Östman, 2004; Niemelä, 2008). Technological innovations were also introduced in the processing of dairy products, such as milk separators (Niemelä, 2008; Kylli, 2021).

Acquiring the new machines required financial resources from the farmers. Such resources were obtained by selling wood to the growing forest industry, as almost all farms owned forests (Simonen, 1947; Jutikkala, 1958; Niemelä, 2008). The emerging forest industry was thus an important source of system-external potential for the reorganisation of the agrifood system after the Great Hunger Years. The growth in the commercial value of timber meant the end of both slash-and-burn agriculture and the free grazing of cattle in woods, both considered destructive practices for forests (Heikinheimo, 1915). These two practices, coupled with the extensive demand for wood in construction and for energy, had resulted in large-scale destruction of mature forests in vast areas, especially in the southern parts of the country (Niemelä, 2008). Stronger differentiation between the agrifood system and the forestry system thus served the interests of both the emerging Cattle regime and the industrial forestry regime.

The new agricultural system was built around intensive animal husbandry and it expanded at an unprecedented speed. The number of cows doubled during the cattle regime (Simonen, 1947; Niemelä, 2008). Agricultural education and extension were institutionalised and became pivotal in spreading the technological innovations related to dairy farming (Vihola, 2004a). These developments contributed to the improved feeding and productivity of cattle – during the Cattle regime, the milk yield per cow more than doubled – which also encouraged farmers to take better care of their animals (Vihola, 2004a; Niemelä, 2008; Kylli, 2021). As a result, dairy products finally replaced manure as the primary output of cattle husbandry (Soininen, 1974).

At the same time, the global agrifood system was facing major changes. Cheap grain was flowing in from the new world (the US and Australia) and challenged the competitiveness of European bread grain production (Peltonen, 2019). This forced many European countries – including Finland – to seek new competitive advantage in animal husbandry and especially in dairy production. The import of grain was tax-free (Vihola, 2004a). In Finland this period is the first example of an agrifood system oriented towards the idea of comparative advantage in trade. However, the imported grains did not essentially challenge the subsistence farming of bread grains, but contributed to feeding the growing cities, industrial workers and landless people (Vihola, 2004a; Niemelä, 2008). The number of non-farm consumers had increased as a result of industrialisation: in 1910, 66% of employed people were farmers compared to almost 80% during the previous regime (Simonen, 1947; Ojala and Nummela, 2006). The building of the railway network and the growing importance of the monetary economy were integral for the growing role of grain imports in feeding the population (Vihola, 2004a). Finland exported butter but imported 60% of consumed bread grains and significant amounts of pork and eggs (Ihamuotila, 1979).

The exploitation phase of the Cattle regime was marked by various forms of self-organisation. The farmers established local agricultural organisations which were, unlike in the previous regime, controlled bottom-up (Jutikkala, 1958; Vihola, 2004a; Niemelä, 2008). Agricultural production and especially dairy production commercialised and self-organised into local cooperatives processing dairy products (Vihola, 2004a). Later on, centralisation increased throughout the agrifood system as it matured and marked the turning of exploitation phase into the conservation phase. This was manifested in the establishment of a central organisation within the central government (the agricultural administration *Maanviljelyshallitus* in 1892), among dairy cooperatives (the central cooperative Valio in 1905) and among farmers' organisations (farmers' union MTK in 1917), with the latter two remaining important actors in the field to this day.

The vulnerabilities of the Cattle regime related to the strategy of relying on the comparative advantage in the national food supply became apparent along with the growing global political instability that ultimately led to World War I. Due to this unrest, the global food trade started to flounder (Rantatupa, 2004). In 1917, Finland declared its independence from Russia. At the time, the domestic harvests were poor due to difficult weather conditions and grain imports from Russia stopped (Rantatupa, 2004; Niemelä, 2008). As a result, food shortages among the landless people emerged, intensifying the juxtaposition between the social classes (Häkkinen and Peltola, 2001; Rantatupa, 2004; Niemelä, 2008). Food shortages sparked conflicts that eventually led to the Civil War between land-owning farmers and landless people as well as industry workers in 1918. The release phase of the Cattle regime was chaos.

4.4. Premodern regime: 1919–1944

The Civil War left behind a deeply divided nation. Even though agricultural productivity had risen fast during the Cattle regime, the system had lost its resilience. The chosen free-market orientation in

agricultural policy entailed vulnerabilities that were related to fluctuations of food prices as well as varying availability of food products. These vulnerabilities had materialised during the global unrest. At the same time, the share of farmers in the population was decreasing due to emerging industrialisation, which meant that the interests of farmers and the interests of the growing consumer class had started to diverge.

In the reorganisation phase of the emerging regime, the young nation based its agricultural policy on the idea of self-sufficiency (Vihola, 2004b). During this regime, agricultural policies delivered social policy goals as much as they regulated food production. This was manifested, for example, in the case of crofters, as they became entitled to the land they farmed through redemption of their crofts. The basin of attraction for the Premodern regime formed around the promotion of self-sufficiency by means of small-scale farming and the clearing new fields, but also by mechanisation as well as the introduction of a completely new resource base: synthetic fertilisers and fossil energy.

Achieving self-sufficiency in food products was largely based on inputs that were, to a growing extent, imported from overseas: fertilisers, fuels, and, most importantly, animal feeds (Niemelä, 2008). Self-sufficiency was about achieving an equivalence between the food produced and food consumed, even though the agrifood system was paradoxically all but self-sufficient in terms of the inputs and the resource base that allowed such production. Synthetic fertilisers and fossil fuels had been introduced already during the Cattle regime but started to affect the composition of the system only during the Premodern regime. They served as the system-external resource that allowed the system to reorganise and grow after the release phase of the previous regime, accompanied by a 30% growth in the agricultural land (Niemelä, 2008). The exploitation phase of the Premodern regime was characterised by increased agricultural output – even to the extent of surpluses in the 1920s (Ihamuotila, 1979; Ojala and Nummela, 2006). Meeting the goal of self-sufficiency also required protectionism to prevent cheap imports of foodstuff from overseas. The bureaucratic apparatus to implement the policy objectives was based on customs duties, export subsidies, various kinds of regulations and finally agricultural subsidies (Ihamuotila, 1979). Surpluses of dairy products were significant in the 1930s and agricultural policies were initiated to regulate this development (Niemelä, 2008). These measures formed balancing feedback loops in the system and indicated the beginning of the conservation phase.

The Finnish economy and its agrifood system were strongly linked to the global economy, and despite the promising development witnessed during the Premodern regime, other kinds of development trajectories overseas affected Finland as well. The American economy was in a release phase in the 1930s, which triggered a global recession (Niemelä, 2008). The economic downturn hit especially hard on farmers who had invested and developed their farms and become indebted; many of these farms faced bankruptcies and forced sales (Rantatupa, 2004b; Niemelä, 2008). The system was recovering in the late 1930s, but the waves of the World War II struck Finland as well, and the country went to war with the Soviet Union in 1939. The war years in the 1940s (Winter War 1939–1940 and Continuation War 1941–1944) upset the system and caused a food shortage especially due to the limited supply of inputs, many of which had been imported, and by limiting the supply of labour and power: the men and the horses were away at war (Niemelä, 2008). The Finnish agrifood system was in crisis and the rather short (25 years) Premodern regime was in the release phase. Wartime policies succeeded in food rationing, however, and the population avoided full-scale famine.

4.5. Modernisation regime: 1945–1994

While the Premodern regime introduced the first steps towards a new fossil-fuelled metabolic basis for the agrifood system, this development was in full swing during the next cycle, which we call the Modernisation regime. The basin of attraction was organised around fossil fuels and nutrients together with the policy goal of maintaining the self-sufficiency of agricultural products (as during the Premodern regime) and embracing agricultural policy as a part of social policy through the aim of securing farmer incomes throughout the country and also on small farms. The reorganisation of the agrifood system after wartime was characterised by resettlement and strong striving for self-sufficiency. The peace treaty awarded half of the region of Karelia to the Soviet Union. The population coming from this area, representing 12% of the total population, was resettled all over Finland by splitting existing farms (Roiko-Jokela, 2004). Within a decade, 100,000 new farms (+50%) were established, 75,000 new houses were built, and a large amount of new farmland was cleared (Granberg, 2004b; Haapala, 2004; Roiko-Jokela, 2004). To encourage production and survival of farm livelihoods in all parts of the country, agricultural prices were regulated starting in the 1950s, and an extensive system of agricultural subsidies was introduced in the 1950s and 1960s (Kuhmonen and Aaltonen, 1997; Granberg, 1989, 2004a; Kola, 2002). Small farms and disadvantaged regions received additional subsidies (Kettunen, 1992). Food security improved and the population grew by 34% during the regime. Many new tractors and machines were sold to farms (the number of tractors on farms exceeded the number of horses in 1967; Waris, 1974), the use of chemical fertilisers was promoted even by subsidies ('agricultural billion'), and new crop varieties, animal breeds and farming techniques were adopted (Niemelä, 2004).

Strong growth in agricultural productivity was facilitated by the availability of system-external inputs in the form of nutrients and energy, enlarged farm and farmer populations, and the post-war reconstruction mentality, together with the adoption of production-oriented agricultural support policies and the progress of technology, mechanisation and chemicalisation of farming. The development pattern was the same as in other parts of the western world, relying on rapidly increasing productivity resulting from displacing human labour with financial capital in the form of synthetic inputs, fossil fuels and machinery. The application of chemical fertilisers released farming from the limitation set by the availability of manure, and applying pesticides allowed long monocultures, which reduced the need for fallowing, further promoting productivity growth (Aakkula et al., 2006; Niemelä, 2008; Kuokkanen et al., 2017). Productivity growth released large amounts of agricultural labour force to other sectors of society (Kuhmonen and Niittykangas, 2008). The development of technology boosted industrialisation, whereas the motorisation of the transportation system fuelled by fossil fuels promoted the centralisation and urbanisation of society. Productivity growth boosted specialisation throughout the food chain, as both production of inputs (energy and nutrients, machinery) and processing of products were peeled off from the farms to specialised processors and traders. Not only farms but also agricultural regions became specialised (north-eastern 'Cattle-Finland' and south-western 'Crop-Finland'), which reduced traditional mixed farming systems and ultimately meant a disconnection between cropping systems and animal farming systems (Granberg, 1989, 2004b; Markkola, 2004).

Following the growth of the agrifood system, already by the late 1960s the surpluses of several agricultural products had become established (Granberg, 2004b). An extensive system of policy measures to balance the food market was introduced: obligatory fallowing, slaughter and afforestation premiums, export subsidies, production quotas, establishment licences for animal units and so on (Komiteanmietintö, 1987; Kettunen, 1992; Kola, 2002). This restrictive balancing feedback marked the beginning of the conservation phase of the regime. Agricultural production was encouraged and restricted simultaneously with an extensive mix of policy measures. Upon the shift from the exploitation to the conservation phase, the number of farms, people employed in agriculture as well as food retail stores started to decrease (Koistinen, 2009; Granberg, 2004b; Muilu et al., 2016; Statistics Finland), which were all manifestations of the increasing centralisation throughout the agrifood system. At the same time, environmental problems started to become visible. Concerns about the excessive use of fertilisers causing eutrophication in both inland waters and the Baltic Sea emerged in the

1980s, while agriculture was later identified as the single most important cause of eutrophication (Jokinen, 1997; Aakkula et al., 2006; Ylivainio et al., 2015). The biological diversity of agricultural environments impoverished along with the intensification development (Vepsäläinen, 2007), which was not, however, a major public concern during this period. The decline took place especially through the discarding of meadows and traditional rural biotopes that used to play a major role in both feeding cattle and collecting hay during the Expansion and Progressive regimes (Birge, 2017; Raatikainen, 2018).

The conservation phase of the modernisation regime has been considered a 'period of helplessness' (Kuhmonen and Niittykangas, 2008, 27), as the internal connectedness increased alongside the consecutive introduction of new measures, which created new lock-ins and contradictions. For example, in the 1970s and 1980s about one half of the agricultural budget was used for encouraging production and about one third for cutting off production and for subsidised exports of the surpluses (Komiteanmietintiö, 1985). Incentives for farmers were mixed and farm development was halted due to restrictions. Agricultural investments had been in steady decline since the early 1980s, and from 1991 to 1994 as much as 22%–23% of the farmland lay fallow (Statistics Finland). Rapid industrialisation, urbanisation and post-industrialisation, which manifested in the development of a service economy, had emptied rural areas throughout the country (Vihinen, 2004). The regime was in a dead-end stage in terms of economy, ecology, markets and public spending, when it faced the consequences of the disintegration of the Soviet Union.

The disintegration of the Soviet Union in 1991 destroyed important trade relations. Along with the collapse of overheated financial markets, Finland was thrown into a severe economic recession lasting from 1990 to 1993, during which the GDP dropped by 13% (Statistics Finland). Even though the origins of this crisis were not related to the food system, the resilience of the food system was affected as the regime approached the release phase. Over 100,000 Finns reported hunger, and 'bread lines' made a return after decades of mounting welfare (Kiander, 2001). In the aftermath of this turmoil, Finns voted for EU membership in 1994. The expectation of EU membership set in motion the release phase of the Modernisation regime, as many policy instruments were abandoned or transformed to comply with the regulations of the EU (Kuhmonen and Aaltonen, 1997; Markkola, 2004). The Modernisation regime in Finland lasted almost 50 years, until 1994.

4.6. Globalisation regime: 1995 onwards

Finland's accession to the EU on 1 January 1995 initiated the Globalisation regime, which to date has lasted over 25 years. While the metabolic basis for this regime is built, as it was during the previous regime, on fossil fuels, on the policy level the system's basin of attraction relies, contrary to the previous regime, on the free trade of agricultural products within the European Union and selectively across its bordersas well as on the aim of retaining a fair self-sufficiency in food at the EU level rather than on the national level (Kuhmonen and Aaltonen, 1997). These goals are accompanied by objectives related to environmental sustainability and climate change mitigation, the role of which has grown stronger throughout the regime (Kuhmonen, 2018a; EU, 2020). Attaining these goals simultaneously requires extensive agricultural subsidies; without these subsidies the production would move away from less favourable areas, the Union's food sovereignty would decrease, and the environmental burden of agricultural production would increase.

The reorganisation of the Globalisation regime took place through the abandonment of the extensive national policy measures – which were favourable to small farms and disadvantaged regions – and the adoption of the measures of the Common Agricultural Policy (CAP). As a result, farm gate prices (the prices farmers receive from their products) were cut by about 40% overnight (Kiander and Romppanen, 2005). The transition period from 1995 to 1999 to level out the national subsidies and some remaining nationally funded long-term subsidies for northern agriculture alleviated the economic losses for farmers, however (Markkola, 2004). The transition period corresponds with the growth phase of the Globalisation regime. The growth of the system was based on farmers' changing investment behaviours – investments doubled during this period (Hyvärinen, 2016). Finnish farmers were introduced to a wide array of new subsidy schemes, such as the organic farming scheme that rapidly found a foothold within the Finnish agrifood system. CAP funds thus acted as the system-external potential that enabled the growth of the system.

Farm investments were boosted by both stick and carrot: farms had to grow in order to provide a living for the farm families, while the subsidy system also provided incentives for investments. Growth resulted in increasing productivity, specialisation and centralisation, from which the food industry and retail trade have greatly benefitted. The share of food processing and retail trade in consumer food expenses has grown at the cost of primary production (Kuosmanen et al., 2009; Kotilainen et al., 2010; Piipponen et al., 2018). From the beginning of the Globalisation regime, average farm size has grown from 22 to 51 ha (Natural Resources Institute Finland, 2022), while the number of farms has decreased by 55% (Natural Resources Institute Finland, 2022). The growth of farm size has been especially strong in animal husbandry (Economydoctor, 2022). At the same time, despite increasing farm size and productivity, the profitability of farming has been in constant decline throughout the whole period (average profitability ratio 0.55 in 2000–2007 and 0.40 in 2008–2019; full compensation for labour and capital in 1.0; Economydoctor, 2022), which manifests as an unescapable cost–price squeeze at the farmgate. Securing farm income through scale economies has been the standard solution to the decreasing prices of agricultural products, which has strengthened the trend of regional specialisation of production that started already during the Modernisation regime.

Despite the continuing trend of increasing productivity at the farm level, the growth phase of the Globalisation regime did not last long, and the system moved into the conservation phase already around the year 2000. During the conservation phase, centralisation and complexity within the system have increased, which can be observed through several balancing feedback loops limiting the growth of the system. These balancing feedbacks are observable as conflicting aims of system actors and trade-offs that create rigidity and unintended consequences through the system dynamics. For example, the redirection of agricultural support upon EU accession from production subsidies to area-based payments to counteract the productivist tendencies entailed two major consequences. First, by subsidising ownership of resources (farmland and animals), it resulted in elevated prices of agricultural land. This trend has contributed to the increasing debt burden of developing farms (MAF, 2017) and the difficulties of enlarging farmers to acquire new farmland especially in areas specialised in cattle husbandry, which the farmers have counteracted through clearing new fields from forests (Niskanen and Lehtonen, 2014; Huttunen, 2015) – a practice considered detrimental for both climate targets and nutrient leakages. Second, the new incentive logic, which made farmers subject to external control and on-spot checks, caused a cultural clash in terms of the basic ideology of farming between agricultural administration and farmers: whether it is about producing food or following subsidy prescriptions (Kaljonen, 2006). Despite the continuous attempts to decrease the bureaucratic burden related to agriculture, the complexity and multiplicity of agricultural policy objectives (some of which conflict with each other) have increased to the extent where simplification has itself become a policy objective (Kuhmonen, 2018a, 2018b).

The CAP sets significant environmental objectives that aim at controlling the negative externalities caused by agricultural production as well as at strengthening the public goods provided by agriculture, which are both enforced through prescriptions related to subsidy measures. Over the course of more than 25 years of membership, agriculture's negative externalities, especially those related to nutrient-loading

potential, have indeed diminished (Natural Resources Institute Finland, 2016), but reduced pollution potential only slowly translates into observable changes in water quality, and at the same time, climate change increases runoffs and thus counteracts these efforts (Aakkula and Leppänen, 2014). The CAP, however, is not a very effective tool in intervening in issues such as recycling nutrients throughout the food system or disengaging from the use of fossil inputs. The overarching trends of specialisation and centralisation of production are difficult to counteract through the measures offered by agri-environmental schemes, and thus the measures can, at best, only slow down the negative environmental developments such as declining agricultural biodiversity or dwindling carbon content in the soil (Herzon et al., 2022; Yli-Viikari, 2019). For these reasons, the agri-environmental policies are considered to have failed to meet their environmental targets (Kaljonen, 2011; Kuokkanen et al., 2018). These failures stem from the difficulty to resist the path-dependency of the contemporary regime (see Kuokkanen et al., 2017) with policy tools that are themselves an integral part of the regime.

While the Finnish agrifood system is still fairly self-sufficient in many products, the self-sufficiency rates have been in constant decline in several products, especially meat (Statistics Finland), and the diversity of domestic food production has decreased (Lehikoinen, 2020). The trade balance of agricultural and food products is negative and has been in a linear decline since accession to the EU: about −0.5 billion euros in 1995, −1 billion euros in 1998, −2 billion euros in 2008, and − 3 billion euros in 2017 (Niemi and Väre, 2019). The increasing concentration throughout the agrifood system has created oligopolistic markets, where the ownership of the input suppliers, food processors and wholesale trade has become more centralised and partly transferred to international operators and the power of trade has strengthened in relation to other actors (Muilu et al., 2016; Paloviita et al., 2017; Arovuori, 2022). Sanctions placed upon Russia in 2014 by the EU stopped eastern dairy exports and have ever since put further downward pressure on the prices of dairy products. Due to the tightening financial situation on farms, the increasing bureaucratic burden and the heated societal debate on the negative environmental impacts of farming and especially animal husbandry (Karhula et al., 2015; Puupponen et al., 2022), there are signs of an increasing abundance of mental health problems among farmers (Kivekäs et al., 2015). The Finnish agrifood system is very reliant on imported inputs (Lehikoinen, 2020; Jansik et al., 2021), especially fertilisers, the price of which has skyrocketed since the war in Ukraine started in 2022 (Latvala et al., 2022). The pressures for a fundamental reorientation of the agrifood system are increasing. The production-oriented approach of confronting sustainability problems as questions of agri-environmental management no longer suffices, and the scope of animal production and the need for a transition towards plant-based diets is under heated debate (Kaljonen et al., 2019). Yet geographically inclusive visions of alternative pathways for the system to embark on are scarce (Kuhmonen and Siltaoja, 2022).

5. Discussion

In this study, we set out to explore the long-term evolution and transition dynamics within the Finnish agrifood system. Through identifying the historical regime shifts, we aimed for our findings to increase understanding on the prerequisites for transformation and thus to help navigate the prospective sustainability transition in the agrifood system in Finland and possibly also in other contexts. By utilising the adaptive cycle as the organising theory for our analysis, we were able to trace the origins of the cyclical evolution pattern of the agrifood system and the recurring sustainability problems and crises. Specifically, we observed that sustainability problems were related to the very nature of the regimes: in essence, the attractors upon which they were built. The immanent stages of the cycle therefore provided a firm causal texture for the cyclical behaviour of the agrifood system.

Our analysis indicates that regime shifts in the Finnish agrifood system have occurred when the low resilience of the system in the late conservation phase has coincided with an external disturbance: extreme weather conditions, wars and an economic recession. The system had been exposed to such disturbances in other stages of its evolution, but for a disturbance to cause a system-wide collapse, the overall resilience of the system had to be low. For example, while the Little Ice Age caused reoccurring harvest losses throughout the country during the Expansion regime, a system-wide collapse was only triggered when the bad weather conditions coincided with the internal vulnerability of the system. However, not all of the regime shifts were transformative in terms of switching the attractors upon which the system was built. For example, the Expansion and Progressive regimes were built on rather similar attractors as were the Premodern and Modernisation regimes. However, the system never returned to same organisation or structure as before—the fitness landscape and the basin of attraction changed in all of the regime shifts observed here. As such, the 'transformability' of the regime shifts varied along a continuum rather than along a clear-cut incremental/radical duality.

When radical transformations within the Finnish agrifood system did take place, they required changes in the system's socio-metabolism (see also Fischer-Kowalski, 2011; Haberl et al., 2011). Such metabolic changes could be dated to the turn from the Progressive regime to the Cattle regime, where the system shifted from a meadow–field and slash-and-burn agriculture to field-based production, and to the transition from the Cattle regime to the Premodern regime, where the agrarian model transformed to an industrial one (Pichler et al., 2017). The shift from agrarian to industrial model could be depicted as a shift from the era of scarcity to the era of abundance. Upon this shift, the resource use changed from extensive and decentralised to intensive and centralised. During the era of scarcity, the inputs were mostly internal to the system. Livelihoods and nutrition relied on the surrounding nature and its resources. Relatedly, population growth implied increasing pressure on the local natural resources which could be observed in several developments especially in the 19th century: destruction of forests and extinction or near-extinction of several animal species, especially macro fauna. The era of scarcity prevailed until the mainstreaming of fertilisers, pesticides and energy, which were brought to the agrifood system from external sources. This change of socio-metabolism made it possible to decouple food production from the limitation set by the natural capacity of the system based on soil productivity and the availability of manure. When livelihoods and nutrition were released from the limits set by the local resource base, some of the pressures for exploiting them were also released (e.g., the need to clear more fields) – yet at the same time giving rise to new kinds of problems brought about by the adoption of fossil and synthetic inputs, such as overproduction and waste issues (including climate change, eutrophication and other forms of pollution).

Growth and its maintenance have been central questions for the Finnish agrifood system throughout the history of 700 years explored here. Not only has the population grown, but so has welfare and material consumption—exponentially so during the last 100 years. The growth orientation bears important implications for the observed system dynamics. The reorganisation taking place after the release phase can be based on existing resources—those that are released in the systemic collapse—but as, for example, Gunderson et al. (2002) and Fath et al. (2015) note, importing resources from broader scales in the panarchy structure may help, especially as some of the released resources tend to leak out from the system during the release phase. Our results imply that such activation energy has played a role in facilitating reorganisation towards a new growth phase. Such activation energy—originating either from higher hierarchical levels in the panarchy structure or from adjacent systems—has enabled reaching a growth track within the agrifood system. They have taken the form of knowledge and innovations originating elsewhere in Europe (Progressive regime), the commercial value of forests allowing investments in iron tools and farm machinery (Cattle regime), imported synthetic fertilisers and fossil fuels (Premodern and Modernisation regimes) and EU subsidies (Globalisation regime). At the

same time, the source of new potential is decisive for forming the basin of attraction that starts to define the development of the emerging regime, and later on contribute to the path-dependency of the established regime.

As well as igniting growth, the maintenance of growth tends to be the objective for system management and interventions – growth brings new opportunities to exploit, it is usually related to peaceful times, and growing systems tend not to collapse (Walker and Salt, 2006). At the same time, growth brings a system closer to its boundaries, which will eventually limit its growth by turning some of the positive, self-reinforcing feedback into negative, balancing feedback. These developments can be observed as sustainability problems that have accompanied the Finnish agrifood system throughout its history. Essentially, in the course of each regime's maturation, things that were initially desirable became detrimental from the viewpoint of the regime's sustainability. These included expansion of population and farmland during the Expansion and Progressive regimes (which contributed to growing the tax base but eventually led to reaching the carrying capacity of the system), reliance on comparative advantage in foreign trade during the Cattle regime (which allowed technological development and productivity growth within the sector but eventually created food shortage when the global trade channels choked up), reliance on the external inputs during the Premodern regime (that allowed productivity growth but led to food shortage during the war years) and reliance on protectionism, regulation and subsidies during the Modernisation regime (that secured both productivity and farmer incomes but blocked innovations and structural development as well as caused environmental damage).

Specialisation, centralisation, connectedness, regulation and complexity tended to increase within all six regimes along with their maturation. This implied that more system resources were needed for maintenance and legitimacy of the system (see also Renfrew, 1984; Faulseit, 2016). The growing rigidity and escalating sustainability problems observable during the conservation phase make a system vulnerable to external disturbances and lead to the loss of resilience. When an external disturbance such as a war, economic recession and harsh weather conditions coincides with an internal vulnerability such as tax deprivation, shortage of nutrients, overexploitation of natural resources or extensive dependence on global trade, the agrifood system crosses a critical threshold and dives into a release phase (see also Tubi, 2020). All the release phases during the history of the Finnish agrifood system observed here have taken place as a result of the system losing its resilience, the manifestations of this extending from the emergence of food help, with 100,000 Finns reporting hunger in the transition from the Modernisation regime to the Globalisation regime, to large-scale, deadly famines killing 20% to 30% of the population, as in the shift from the Expansion regime to the Progressive regime.

Despite the destructive nature of the crises, they were critical in opening up the window of opportunity for the transformation of the system (Young, 2010; Herrfahrdt-Pähle et al., 2020): the emergence of a new set of attractors and a regime shift. In other words, no regime shifts took place without crises. The elements of the newly emerging regime often originated from the sustainability problems of the dominant regime, which paved the way to discursive contests about the direction of the future developments. Interestingly, when the basin of attraction of the system changed profoundly, the new regime took an opposite direction from the old one in terms of trade orientation: from free trade to protectionism in the shift from the Cattle to the Premodern regime, and from protectionism to (EU-free) trade in the shift from Modernisation to Globalisation. The agency of actors determined to take the system in a new direction played a key role during the reorganisation phase. The role of single decisions and single decision-makers was also pronounced during the release phase, as it is these decisions that could determine whether the system was heading towards full-scale chaos or a milder disturbance (Fath et al., 2015).

Predating most of the radical transformations, the ingredients for the emerging regimes had already existed during the previous regime, but were unable to break through due to systemic rigidities. These rigidities of the conservation phase decrease the actors' room to manoeuvre and weaken their opportunities to manage the mounting sustainability problems. For example, despite the strong sense of a dead-end that was observable at the end of the Modernisation regime, the system actors were unable to deliberately lead the system towards transformation. The fight to keep the system in the conservation phase despite clear signs of weakening resilience can be detrimental for the outcomes when the system finally collapses. On the other hand, the resilience theory argues that allowing the adaptive cycle to play out at smaller scales of the panarchy can promote the resilience of the system at larger scales. Observations from the farm system level in Finland—the most critical subsystems for the resilience of the whole agrifood system—suggest that the renewal and transformation of farm systems is currently strongly constrained, which increases the vulnerability of the whole agrifood system.

The sustainability problems are the consequence of the open nature of complex systems such as agrifood systems: there is no one 'perfect' and conflict-free solution for the organisation of the system (Holling and Gunderson, 2002; Folke, 2006). The sustainability transition currently sought for implies a radical change in the metabolic basis of the agrifood system through a shift from fossil inputs to renewables. Such a transformation is likely to affect the resilience of the system as well. The contemporary constellation of the agrifood system – the Globalisation regime – is in the conservation phase: the system displays various signs of rigidity and lock-in, the system structure significantly limits actors' room to manoeuvre, the pressures for a radical transformation are mounting and the discursive contests about the future direction are becoming heated. To date, the current regime has proved to be resilient to shocks such as the Covid-19 pandemic (Meuwissen et al., 2021). However, the system is also approaching the carrying capacity of the Earth system especially in terms of multiple planetary boundaries (Steffen et al., 2015), which accentuates the need for systemic change. In the light of our analysis, it is not likely that such a change can be achieved without a crisis. One potential such crisis is currently gaining strength in the form of the Russian invasion of Ukraine and its consequences, which are being seen in the shortage of fossil energy and nutrients as well as the looming food crisis due to the cessation of food exports from Ukraine.

The results of this study make several calls for further research as well as highlight questions of relevance in the practical sphere of agrifood policies. First, we argue that in order to navigate the developments arising after the Globalisation regime, we need alternative visions about the elements of the regime, specifying the 'sustainability' of the sustainability transition sought for (Feola, 2020; Jensen, 2012; Meadowcroft, 2011), as well as delineating the pathways needed to attain such visions. Throughout the history of the Finnish agrifood system, both population growth and economic growth have led to reaching the limits of the system's carrying capacity. Objectives, policies and practices targeted at growth need critical scrutiny and alternative frameworks that are not centred around growth, since in the past the elements and drivers of growth have been the seeds of the sustainability and resilience crisis. It would be of utmost importance to explore the compatibility of post-growth and degrowth scenarios with the resilience theory, as it is the very growth that is a central part of the system dynamics but that also takes the system closer to collapse. The paradoxical finding about the impetus for a system's growth turning into seeds of destruction at the conservation phase also requires further research from different geographical contexts and different systems. Second, our results call for attention to strategies that build resilience, adaptive capacity and food security for both good times (as in the front loop of the adaptive cycle) and bad times (as in the back loop). Allowing the system to regenerate from within is a prerequisite for resilience. Developing policies for a post-fossil future and letting the farm systems transform accordingly instead of collapse would build resilience for the emerging regime

within the Finnish agrifood system. Third, we also point to the most obvious limitation of this study and suggest that quantifying the mostly qualitative findings of this study would shed more light on the system dynamics observed here.

6. Conclusions

In this study, we set out to explore the historical regime shifts that have taken place in the Finnish agrifood system from the 14th century to the present day by utilising adaptive cycles as the analytical device. The adaptive cycle accommodates the idea of changing stability domains within a social-ecological system, which can be conceptualised as regimes: the temporally stable modes of organisation of a system, organised around a set of (changing) attractors. We found that it is these very attractors that gave rise to the growth of the system, associated with the growth of both human population and agricultural production—and eventually, to its collapse. While growth tended to be a central goal for those managing the system, it also created unintended and unwanted consequences, such as rigidity and centralisation of resources into the hands of the few, as well as environmental problems ranging from resource depletion and loss of biodiversity to different forms of pollution, such as climate change and eutrophication. These unintended consequences weakened the system's resilience and made it prone to disturbances, such as extreme weathers, wars and economic recessions. The vulnerabilities originate from the same source as the system's growth: geographical expansion, (over)exploitation of local resources and reliance on externally sourced food products or inputs. After collapse following the materialisation of these vulnerabilities, the Finnish agrifood system has reoriented towards more or less different pathways. Changes in the system's energy and nutrient metabolism have implied more fundamental regime shifts than those related to changes in the policy orientation or introduction of new innovations of more incremental nature. Thus, while the release of the contemporary mode of organisation can have detrimental consequences for the system's capacity to deliver on its central function—feeding the people reliant on it—it opens up the window of opportunity for systemic renewal.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

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Appendix A. Central dimensions of the agrifood regimes in Finland

Dimension	Expansion regime (1334–1721)	Progressive regime (1722–1868)	Cattle regime (1869–1918)	Premodern regime (1919–1944)	Modernisation regime (1945–1994)	Globalisation regime (1995–)
Agricultural production	Main crops: barley and rye. Introduced: oats, buckwheat, beans, peas. Animal protein mainly from fish and dairy products, in smaller amounts meat from livestock and game. Famine foods are widely used (except for the best farming areas).	Increasing acreage. Main crop: rye. Expanding: oats. Introduced: yellow turnip, hemp, hens, potato, red clover, field grass. Famine foods are widely used (except for the best farming areas).	Increasing field acreage, two-thirds of which is used for fodder production. A very rapid growth of animal husbandry. Growing productivity of cattle: milk yield per cow doubles. Self-sufficiency in many products is declining, e.g. self-sufficiency in bread grains is 35%–40% in the early 1910s. Half of the cereals is rye. Increasing importance of potato. Introduced: sugar beet.	Increase in productivity and in cultivated acreage. Overproduction of some products. Increasing self-sufficiency in bread grains: from 60% to 90%. Milk remains important: half of the sales income in agriculture.	Increased productivity. Growth in the production of barley (becomes more popular than rye from 1951 and more popular than oats from 1977), pork and poultry. Decreasing grass area since 1958: more than 50% of the field area in the 1950s, 30% in the 1960s. Transition from horses to tractors releases 0.5 million hectares horse feed area. Gradual mounting of structural surpluses in several products.	Decreasing number of farms and increasing farm size. Production remains regionally specialised. Growth in the production of poultry continues. Growth of organic farming (2% of the field area in 1995, 14% in 2019).
Main source of energy and nutrients	Human and animal labour, wood; emerging local water and wind power. Naturally occurring nutrients from the meadows and forests are harvested with cattle (manure) or fire.	Human and animal labour, wood, local water and wind power. Naturally occurring nutrients from the meadows and forests are harvested with cattle (manure) or fire.	Human and animal labour, wood, local water and wind power, introduction of fossil fuels. Clover establishes and allows fixing nitrogen from the air. Introduction of synthetic fertilisers, but manure remains important.	Human and animal labour, wood, local water and wind power, fossil fuels, expansion of electricity network. Synthetic fertilisers, nitrogen fixing plants, fossil fuels, manure.	Electricity, fossil fuels, wood. Synthetic fertilisers, nitrogen fixing plants, manure.	Electricity, fossil fuels, wood; emerging heat pumps, local solar and wind power. Synthetic fertilisers, nitrogen fixing plants, manure, introduction of recycled fertilisers.
Technology and production methods	East: slash-and-burn. West: permanent fields, cattle; rotational farming (2 crops),	In the east slash-and-burn with shortening rotation times. In the west, meadow–field ratio	Lack of meadows was resolved by producing cattle fodder on fields instead of meadows, which was possible due	Regional specialisation of production: bread grains in the west and fodder elsewhere.	Deepening of regional specialisation of production. Adoption of agri-industrial model	Improved fertilisation practices. Large animal units after removal of restrictions: milking robots, automation.

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Dimension	Expansion regime (1334–1721)	Progressive regime (1722–1868)	Cattle regime (1869–1918)	Premodern regime (1919–1944)	Modernisation regime (1945–1994)	Globalisation regime (1995–)
	meadow–field ratio 3:1. Watermills and windmills for grinding grain in the west.	diminished from 3:1 to 2:1 (implies a lack of manure in southern Finland). Cattle fodder almost solely from meadows. Rotational farming (2–3 crops). Developments in ploughing technique allow cultivation of grass and heavy soils. Developments in ditching and draining.	to improved iron tools. End of slash-and-burn. Technological innovations in the processing of dairy products.	Early mechanisation: land engines, first tractors.	through intensification of production on all fronts: new crop varieties and breeds, synthetic fertilisers, herbicides and pesticides (resulting in fallowed fields to be less than 100,000 ha in 1950–1985), improved drainage, intensified tilling. Overfertilisation is established as a practice due to the history of a constant lack of nutrients. Decoupling of production and land capacity through external inputs. Expansion and development of tractors, harvesters and farm machinery.	
Food chains	In the best farming areas (south and west) subsistence farming, in other areas primitive exchange economy (especially furs). Grain forms the backbone of diets.	Subsistence farming, also exchange economy in the east and north. The limits of the local environment's carrying capacity are approaching with the current technology, which accentuates in the Hunger Years 1867–1868.	Commercialisation of agriculture, foundation of agricultural cooperatives. Reliance on comparative advantage in animal husbandry while importing grains. Increasing prices of agricultural products.	Recession in the 1930s hits especially developing farms. Increasing food prices. Self-sufficiency by the end of the period in terms of many products but not in terms of inputs.	Activities are divested of the farms to the specialised input industry and food industry. Expansion of domestic input and machine industry. Increased division of labour. Drastic decrease in the share of agricultural employment and GDP. Number of production, processing and trade units starts to decrease since the 1960s.	Number of production, processing and trade units decreases further. Strong centralisation in both ends of the food chain. Profitability of agriculture is in steady decline in the 2010s.
Culture and society	Living in villages, farming on common fields (west). Reformation of the church. Finland is part of Sweden. Centralisation of power to the King. Wars during the 1600s.	Change from densely populated villages to unified farms along with the Great Partition from 1750s onwards. Share of literate population increases, which enables agricultural extension and education. Weakening status of the nobility. From Swedish to Russian control in 1809.	Formation of agricultural organisations and cooperatives. Emerging industrialisation alleviates the situation of landless people and increases the importance of monetary economics. About two-thirds of population gains their livelihood from farming. Building of railway network. Economic recession in 1910s due to global unrest. Independence from Russia in 1917. Growing inequality between social classes escalates into the Civil War in 1918.	Strengthening of the national identity. Crofters become entitled to claim the land they farm. About 60–70% of population still gains their livelihood from farming. Global economic recession in 1929–1934 due to overheating of both agricultural and industrial markets. World War II spreads to Finland: Three interrelated wars in 1939–1945.	Reconstruction and war compensations as a national project. Establishment of 100,000 new farms for war refugees. The share of farm employment diminishes from 50% to 8%. Building of the welfare state. Urbanisation depopulates rural areas. From agrarian to industrial and from industrial to post-industrial service economy. A serious economic recession in 1990–1993 as the result of an overheated economy and collapse of trade with the Soviet Union.	Rising environmental awareness and sustainability concerns. Consumers are becoming increasingly detached from food production. Digitalisation and web-based interaction; rise of social media. The share of farm employment continues to decrease and is less than 3% in 2018.
Climate and environment	'Little Ice Age' 1450–1850. Yield losses on a regular basis. Local timber shortages due to slash-and-burn agriculture and cattle foraging.	Unfavourable climatic period continues. Vast destruction of mature forests, local timber shortages. Many game animal populations and	Strong decline of meadows and expansion of fields. Declined stocks of game animals; some species have disappeared. Better climatic conditions until the 1910s.	Meadows cleared to fields, grazing cattle in the forests decreases due to the rising value of forests and changes in the production system.	Eutrophication of surface waters due to excessive nutrient application and drainage of peatlands. Intensive application of pesticides. Declining biodiversity	Accelerating climate change due to the use of fossil fuels. Application of fertilisers and pesticides becomes controlled. Continued decline of biodiversity of agricultural areas due to

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Dimension	Expansion regime (1334–1721)	Progressive regime (1722–1868)	Cattle regime (1869–1918)	Premodern regime (1919–1944)	Modernisation regime (1945–1994)	Globalisation regime (1995–)
		large carnivores decline or go extinct.		Favourable climatic period in the 1930s.	of agricultural areas due to disappearing meadows and pastures. Growth of game animal populations.	decreasing grazing of cattle. Problems with soil quality.
Demography	Slow but fluctuating population growth, expansion of settlements into new areas. Population pressure especially in the slash-and-burn areas. Crop failures and small-scale famines are common but worst in the Great Death Years 1695–1696 (25%–30% dies).	Accelerating population growth (quadruples in 1750–1850) and regional expansion of the settlement (population growth boosted to strengthen military power). Population growth and harvest failures lead to large-scale famine in 1867–1868 (8% dies).	Strong population growth, emigration overseas. Share of farmers in the population starts to decrease. Rural landless population is double the land-owning population. Limited imports and crop failure in 1918 lead to food shortages and Civil War.	Steady population growth, expansion of city network.	Steady population growth. Fast urbanisation and rural depopulation.	Slow population growth. Growing immigration, foreign seasonal labour on farms.
International trade	Grain imports from Sweden and Baltic countries. Exports of butter from Western Finland.	Butter exports doubles (north, east). Free trade of grains in 1780–1809. Growing imports of grains during the 1800s (not enough manure for the new fields).	Free trade of grains since 1864. Exports of dairy products increases (also timber). Agricultural trade balance turns negative in the 1910s: dairy exports halts and imports of grains, pork and eggs increases. Import becomes difficult due to the First Word War.	Grain imports from the US removes the food shortage in 1919. Exports of dairy products (profitable until the 1930s) and eggs. Imports of fertilisers, feed and fuels increase. In the wartime, imports of grains.	Overproduction of agricultural products all over Europe. Imports of bread grains, subsidised exports of animal products and feed grains.	Decreasing self-sufficiency in several products, start of net imports in meat. Steady deterioration of the agricultural and food trade balance: negative trade balance grows by sixfold in 1994–2018.
Agricultural policies	Favourable policies for colonising new areas since 1300s. Independent farmers. Domestic production.	The Great Partition enables independent farming decisions and moderate growth of productivity. Establishment of crofts allowed since 1743. Both policies promoted clearing of new land and population growth (the number of crofts grows by tenfold in 1760–1860 contributing to 1/3 of the population growth).	Change in the policy focus from self-sufficiency to comparative advantage (animal products > crop products). First agricultural subsidies introduced. Increasing value of wood and forests; crofter issue becomes political.	Crofters gain independence: lots of small farms are established. Introduction of protectionist agricultural policies to guarantee self-sufficiency (especially in grains). Establishment of public grain storage in 1928. Start of complicated and contradictory agricultural subsidy policy.	Agricultural policy as a social policy, focus on small family farms. Development of agricultural income was detached from supply and demand. Increasing complexity and inconsistencies: restrictions on and support for production at the same time. Strict import protection (quotas, licences, levies, duties).	Adoption of the Common Agricultural Policy: common market, common finance, community preference. Abandonment of the concept of national self-sufficiency. Additional nationally funded subsidies. Heavy bureaucracy and control. Institutionalisation of agri-environmental policies.

Appendix B. Systemic properties of the agrifood regimes in Finland

Phase of the cycle	Resources (potential)	Connectedness	Resilience	Feedback loops	Agency
Expansion regime 1334–1721. Basin of attraction: Extensive mixed farming based on permanent fields and meadows in the west, slash-and-burn agriculture in the east.					
Exploitation 1334–1549	Land resources available to settle and clear new land.	Interdependency between peasant and the crown increases along with the willingness of the crown to collect more taxes.	Agricultural hardships are common, but no widespread famines.	Population pressure and politics favouring colonisation promote the expansion of settlements and cultivated areas.	Expansion of farming towards uninhabited areas is a private and family enterprise, supported by the crown.
Conservation 1550–1694	Provision of more taxes for the crown and services to the nobility by the peasants degrades the resource base. Harsh climate period cuts yields (Little Ice Age). Population base and tax	Centralisation of state governance (creation of the basis for a modern Nordic state). Specialised production of bread grains. Peasant are tied to serve two ends: to produce more food and to	Hunting for fur animals lead to their local extinction. Desolation of farms due to inability to pay taxes.	Wars and increased taxes put a burden on the peasant farmers and halts expansion. Overexploitation of fur animals limits livelihoods in the peripheries.	Deprivation of the peasants by the crown and by the nobility in the 17th century.

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Phase of the cycle	Resources (potential)	Connectedness	Resilience	Feedback loops	Agency
	revenues start to decline from 1570s onwards.	serve better the crown and the nobility.			
Release 1695–1721	Resources are both lost (wars, famines) and released (from fiefdoms).	Reduction of the fiefdoms releases established institutional relationships; nobility loses power and property.	High dependency on bread grains results in hunger. 25%–30% of the population dies due to famine during the Great Death Years 1695–1696; The Great Northern War in 1700–1721 increases losses.	The nobility and the crown lose control, focus is on survival.	Resourceless peasants are burdened by continuous wars.
Progressive regime 1722–1868. Basin of attraction: Extensive mixed farming based on permanent fields and meadows in the west, slash-and-burn agriculture in the east.					
Reorganisation 1722–1749	Period of enlightenment and appreciation of knowledge and innovations, new crop varieties.	Abolishment of the land ownership privileges of the nobility.	Peaceful and climatically favourable period.	Establishment of crofts and the adoption of new ploughing technologies promote expansion.	Improved opportunities for the peasants due to the right to establish crofts and better access to knowledge.
Exploitation 1750–1809	Basic Land Consolidation increases productivity and innovativeness. Strong population (and labour) growth. Reduced tax burden due to reorganisation of the military system. University-level agricultural education begins. First Finnish agricultural extension materials (people are becoming literate).	Increasing trade and exports of agricultural products. Free trade in cereals. Incremental innovations in farming techniques. Advisory organisations are founded.	The period is depicted as peaceful, although Central and Eastern Finland suffers from food shortages on a regular basis. Grain exports from south-west Finland.	Within the slash-and-burn system: high production capacity and demand for workforce promote population growth and expansion. Within the field farming system: Basic Land Consolidation, incremental innovations, establishment of crofts and decreased tax burden promote expansion and population growth.	Rights of the peasants are strengthened further. Basic Land Consolidation from the 1750s onwards allows farmers to make individual decisions about farming practices.
Conservation 1810–1865	The limits of expansion are approaching in land use.	Establishment of central governance along with the adoption of Russian rule. Centralisation of land ownership. New local farmers' unions are founded, but their management takes place top-down. First steps of regional specialisation. Growth of foreign trade, which leads to centralisation of wealth.	Population is growing and spreading northwards. Crop yields are decreasing due to nutrient problems. Cheap grain from Russia starts to flow in due to removal of customs; dependency on grain in diets grows further. Food security is increasingly sensitised to climatic fluctuations at the northern edge of grain production zone.	Population growth asks for expansion of fields in the west, which leads to competition between meadows and fields. Availability of manure limits the productivity of fields in the west. In the east, population growth asks for expansion of slash-and-burn agriculture which leads to diminishing forest cover. In both areas, the result is decreasing room for further expansion of agriculture. Increasing population also leads to increasing hunting pressure in the woodlands and disappearance of moose and deer.	Rural inequality grows especially in the western parts of the country due to population pressure and centralising land ownership; the situation of landless population is getting more difficult. Centrally established agricultural organisations do not lead to extensive grass-root involvement of farmers.
Release 1866–1868	The limits of production growth are met with the technology in use.	Existing production systems start to disintegrate.	8% of the population dies during the Great Hunger Years 1867–1868.	The capacity of extensive and grain-oriented farming to feed the people is at stake.	Peasants have a pressure to adopt new practices.
Cattle regime 1869–1918. Basin of attraction: Grass cultivation for cattle feed on permanent fields; reliance on comparative advantage in international trade.					
Reorganisation + Exploitation 1869–1904	Introduction of iron tools such as ploughs. Timber trade provides additional income for the farmers and enables investments in new technology. Milk production grows due to increased availability of cattle fodder. Agricultural education is institutionalised. Synthetic fertilisers and fossil fuels are introduced. New crop varieties and cattle breeding. From 1860 to 1900, number of employed in primary	Importance of international trade grows due to removal of customs. Exports of dairy products and imports of grain, pork and eggs.	Commercialisation of agriculture implies a trade-off between the commercial production and own consumption on the farms. Growing reliance on markets to maintain resilience of the food system.	Rotational farming practices, new plough technology, new knowledge, industrial-scale production of iron, new income sources and new markets for dairy products promote increasing productivity and specialisation.	Strong sentiment towards animal-based production systems instead of reliance on grain production. Local agricultural organisations and cooperatives are formed bottom-up.

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Phase of the cycle	Resources (potential)	Connectedness	Resilience	Feedback loops	Agency
	production grows from 0.5 m to 0.7 m.				
Conservation 1905–1917	Economic recession, unrest, poor harvests (bad weather) and imports of cheap grains undermine farm development.	Centralisation in the governance of the cooperatives. Dependence on international trade. Agricultural policies strengthen and lead to increasing food prices.	Global political instability manifests the vulnerabilities arising from the reliance on international trade. Harvest losses. Low self-sufficiency in other than cattle products.	Agricultural policies aim at regulating farmers' incomes and food supply, which results in food price increases and increasing tension between farmer and worker populations.	A more centralised, collective agency takes place.
Release 1918	Conflict over resource (land) ownership contributes to the start of the Civil War in 1918.	Dependence on international trade becomes a problem due to ceased imports resulting from the First World War.	Grain imports from Russia cease and self-sufficiency is low, which lead to shortage of food and unrest culminating in the Civil War in 1918.	Increased specialisation in cattle products and low self-sufficiency in other products leads to food shortages when import channels flounder.	Escalating conflicts between the farmers/ landowners and workers/ landless people.
Premodern regime 1919–1944. Basin of attraction: self-sufficiency in food driven by fossil energy.					
Reorganisation + exploitation 1919–1929	Fossil fuels and synthetic fertilisers become common. Mechanisation proceeds rapidly, e.g. combustion engines. Redistribution of land resources along with independence of crofters.	Adoption of protectionist agricultural policies in products reduces external connections and intensifies internal connections within the national food system. Extensive imports of feed, fuel and fertilisers.	Growth and intensification of production results in a change from food scarcity to occasional surpluses.	Promotion of small-scale farming and establishment of many small, independent farms.	Reorientation towards self-sufficiency. Crofters gain their independence and small-scale farming develops.
Conservation 1930–1938	Introduction of the agricultural support system.	Strengthening of the protectionist policies deepens internal connections within the national food system further; regional specialisation intensifies.	Turbulent time is characterised by forced sales, hardships and again recovery.	Introduction of policies to regulate production. Increased dependency on external inputs.	Farmers' economic situation is fluctuating; occasional farm failures.
Release 1939–1944	Resource base narrows due to wartime economy (labour, horses, machines).	Wartime economy and central regulation replace many commercial connections.	Food shortages during the war years due to decreasing imports of foodstuff and inputs accompanied by difficult weather conditions.	Limited availability inputs and labour in the war years (men were at war) lead to a decrease in animal production. This results in the decline of fertilisation (manure), which brings about food shortages.	Focus on survival.
Modernisation regime 1945–1994. Basin of attraction: self-sufficiency in food driven by fossil energy.					
Reorganisation 1945–1955	Oil, combustion engine, synthetic fertilisers. Reconstruction mentality, new farms become established and new agricultural land is cleared.	Policies aiming at self-sufficiency in products, extensive imports of inputs.	Recovery from the wartime economy and encouraging policies.	Establishment of many small, independent farms. Subsistence of refugees, national self-sufficiency, food security and social integration go hand in hand.	Resettlement of war refugees. Post-war reconstruction and clearing of new agricultural land. Strong reconstruction mentality.
Exploitation 1956–1969	Increasing use of fossil fuels, fertilisers, machinery. Agricultural subsidies, education and extension, plant and animal breeding. Increasing field acreage.	Agricultural policies to safeguard a comparative level and development of farm income in relation to other groups (cohesive or social agricultural policy).	Increasing productivity and crop yields. Self-sufficiency improves in products but deteriorates in inputs.	Clearing of new fields and intensification of production lead to increase of production and gradually to overproduction. Increasing input of fertilisers leads to increasing yields, which results in more money to be invested in more nutrient inputs and machinery.	Key role of farmers, input suppliers and advisory organisations in the adoption of new knowledge about input-intensive and machinery-based farming techniques. Farmers are 'safe' and indemnified by the state.
Conservation 1970–1989	The subsidy system becomes more extensive. Limitations in the possibilities to expand production. Decreasing field acreage.	Increasing specialisation both horizontally (production lines) and vertically (growing dependency on input suppliers and food processors). Institutionalisation of the extensive subsidy system.	Environmental problems accentuate especially in nutrient management. Farm development is halted.	Agricultural production is at the same time encouraged and restricted. Increasing application of fertilisers reduces the need for fallowing or using manure. This leads to weed problems which is alleviated by increased application of herbicides. The herbicides allow monocultures which promotes divergence between animal husbandry and crop cultivation. This results in the accentuation of environmental problems.	Very limited possibilities for farm growth, investments in productivity rather than in structural development.

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Phase of the cycle	Resources (potential)	Connectedness	Resilience	Feedback loops	Agency
Release 1990–1994	Policies limiting farm development are gradually relaxed in the anticipation of EU membership.	Old agricultural policies become gradually dismantled in anticipation of accession to the EU.	Part of the population suffers from hunger during the economic recession, demand for emergency food supply ('food help') increases.	Dead end: impossibility to expand production without effective market demand becomes obvious, increasing farm subsidies prove difficult, negative impacts of continuous intensification become visible, halted structural development of farms highlights low international competitiveness.	Farmers oppose EU membership.
Globalisation regime 1995–. Basin of attraction: maintenance of European production in global markets by means of subsidies.					
Reorganisation + exploitation 1995–1999	While producer prices are cut by 40%, a very extensive subsidy system becomes a new source of potential for agriculture.	Agri-environmental management institutionalises. Increasing centralisation in production, input supply, processing and retail trade. Introduction of extensive regulation and control of farming activities.	'Food help' institutionalises. Rise of organic farming and diversification of farm activities.	All obstacles for farm expansion and all specific subsidies for small farms are removed; average farm size increase by 1 ha/year (before EU accession 0.1 ha/year). Strong price cuts and constantly increasing input prices motivate farmers to increase the number of hectares as the subsidies are paid per hectare.	The number of small farms (1–20 ha) decreases by 36% in 1995–2000. The remaining farms start investing to grow or diversify supported by subsidies and released resources.
Conservation 2000–	Potential and resources are concentrated in the hands of a few (input suppliers, farmers, processors, retailers).	Heavy bureaucracy, high level of global interconnectedness, oligopoly in trade.	Climate change is established as a phenomenon and force field. Specialisation strategy replaces diversification strategy on developing farms. Reorientation at the farm level becomes difficult.	Incentives for owning the means of production grow further in relation to incentives to produce, which fortifies the centralisation of resources.	Power basin in the food chain lays increasingly in retail and input suppliers. Farmers' room to manoeuvre becomes limited between rising input prices, stagnating producer prices and high dependency on the agricultural support system. Mental health of farmers deteriorates.

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VI

SUSTAINABILITY-DRIVEN REGIME SHIFTS IN COMPLEX ADAPTIVE SYSTEMS: THE CASE OF ANIMAL PRODUCTION AND FOOD SYSTEM

by Tuomas Kuhmonen, Irene Kuhmonen and Arto Huuskonen 2024

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

Tuomas Kuhmonen [a,*], Irene Kuhmonen [b], Arto Huuskonen [c]

[a] Finland Futures Research Centre, Turku School of Economics, FI-20014 University of Turku, Finland
[b] Jyväskylä School of Business and Economics, FI-40014 University of Jyväskylä, Finland
[c] Natural Resources Institute Finland, FI-00790 Helsinki, Finland

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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

* Corresponding author.
E-mail addresses: tuomas.kuhmonen@utu.fi (T. Kuhmonen), irene.a.kuhmonen@jyu.fi (I. Kuhmonen), arto.huuskonen@luke.fi (A. Huuskonen).

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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

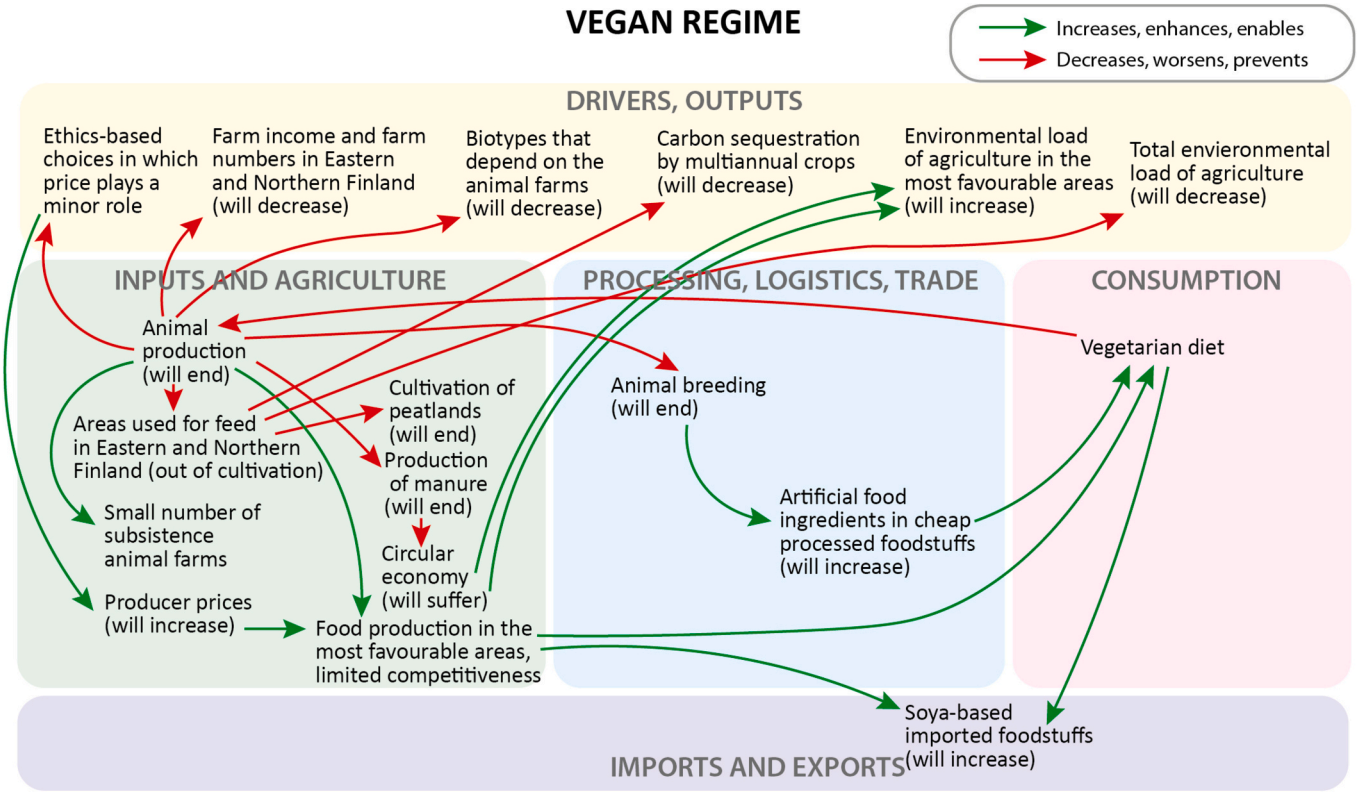

Fig. 1. An example of a Causal Diagram (Vegan regime).

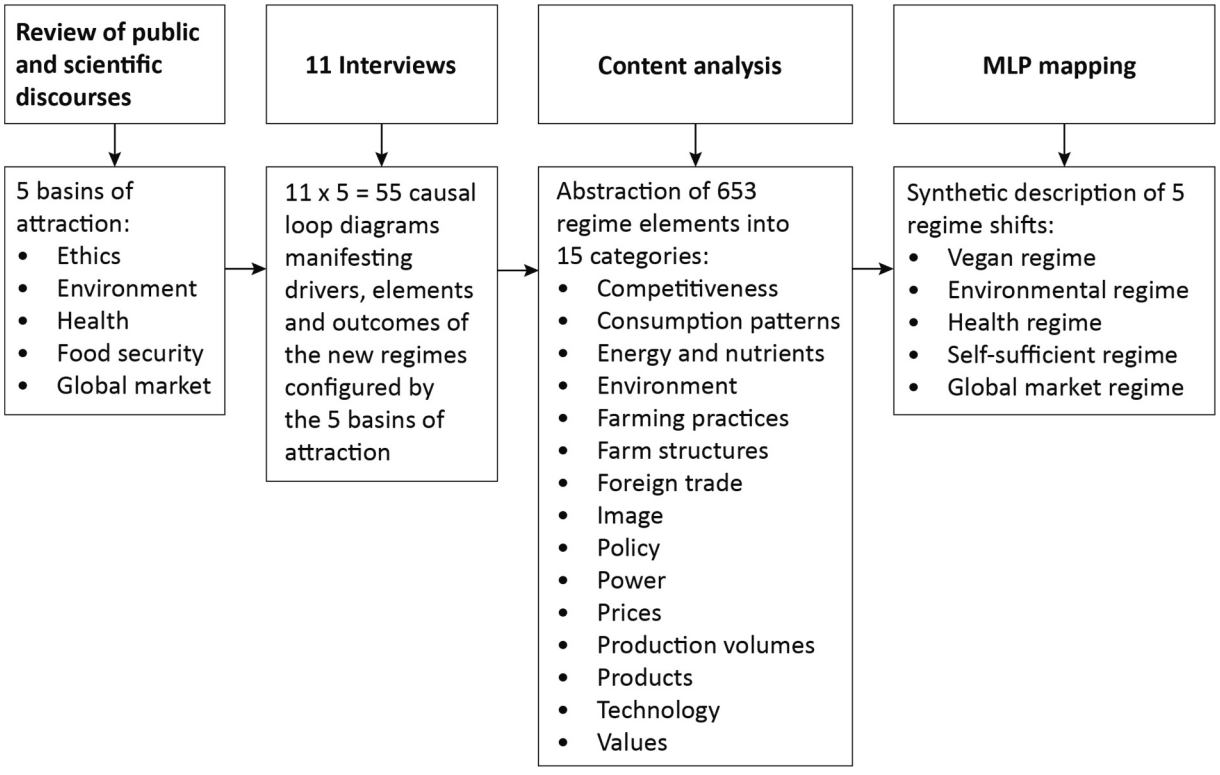

Fig. 2. Methodology of the study.

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

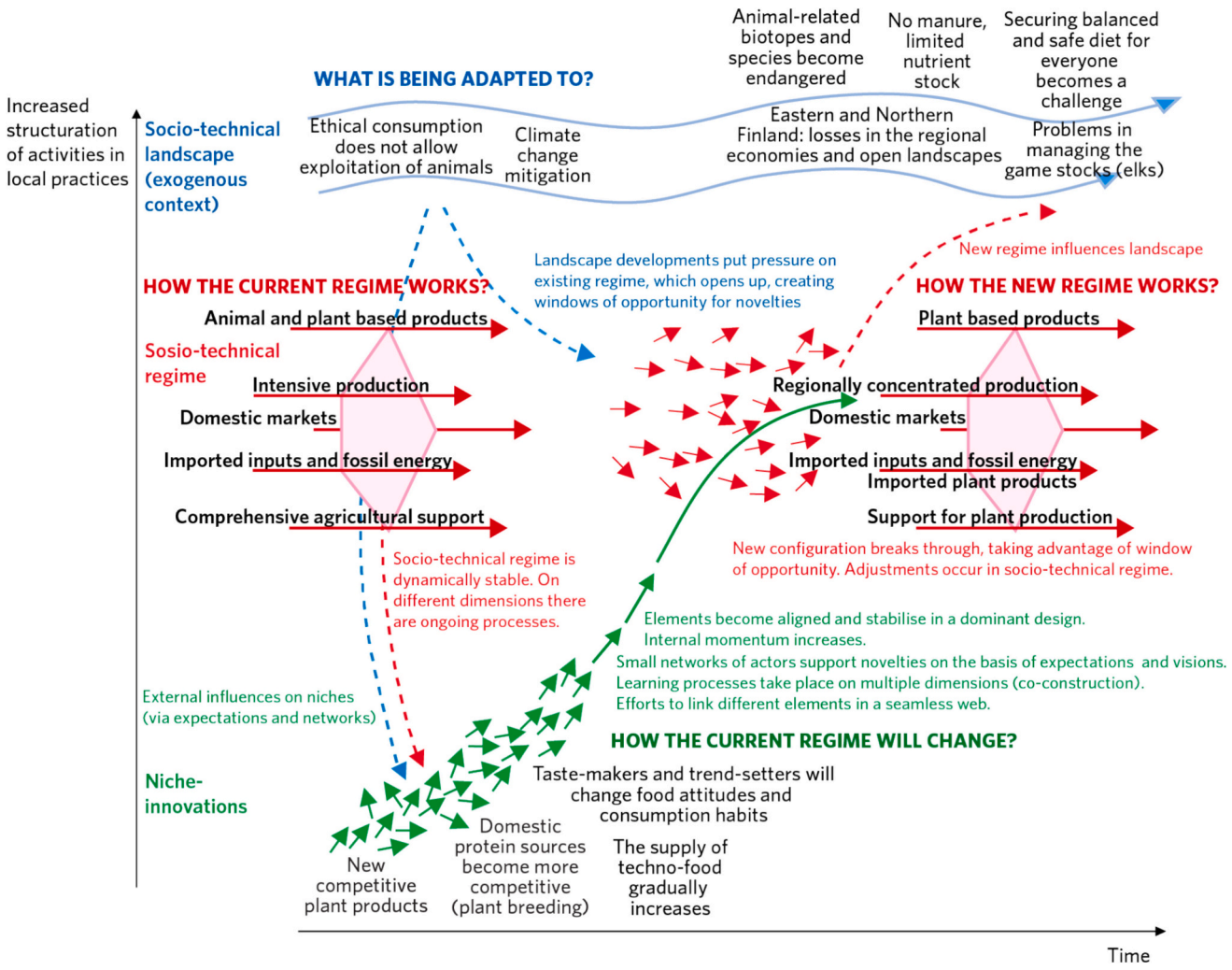

Fig. 3. MLP map of the regime shift from contemporary regime to Vegan regime.

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

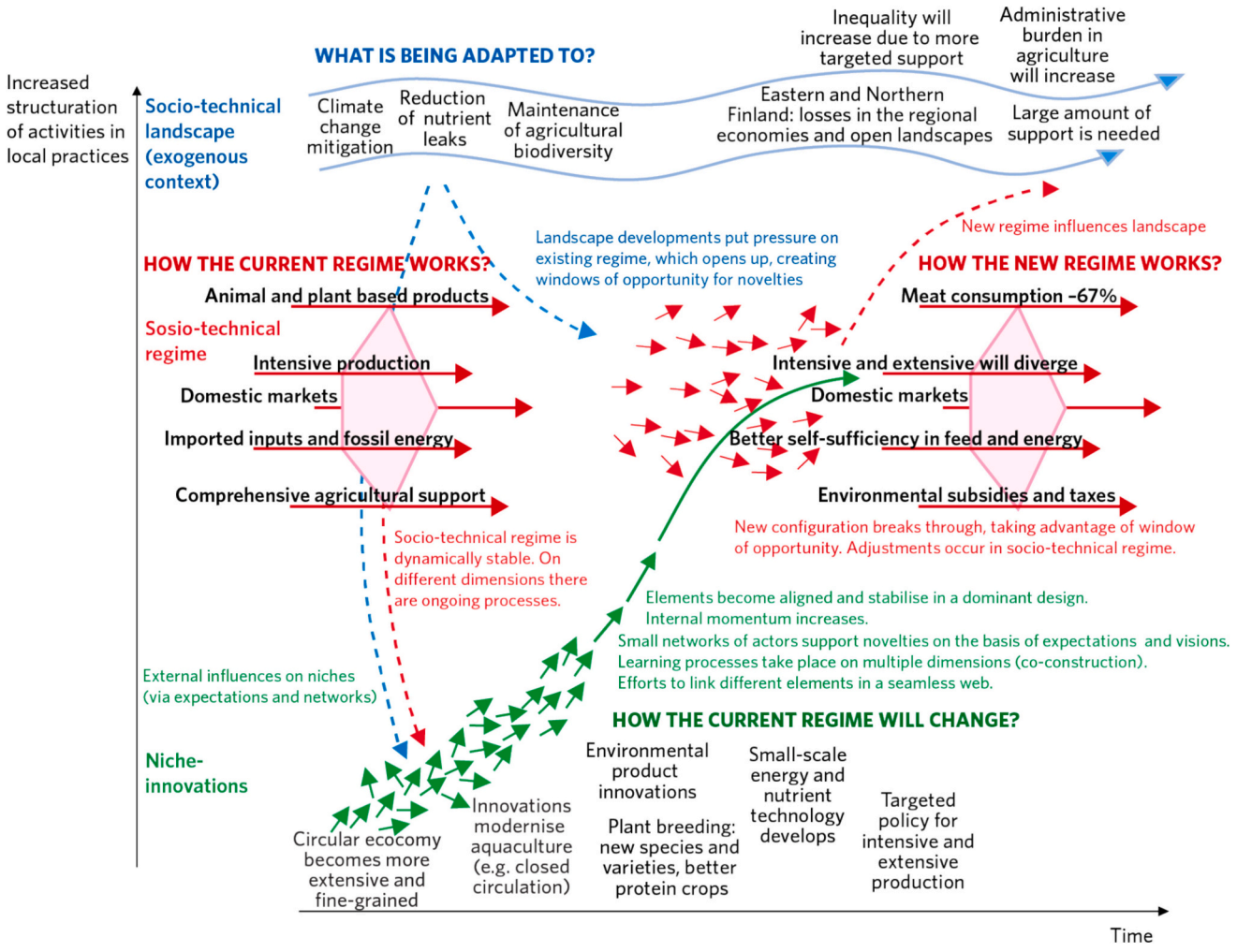

Fig. 4. MLP map of the regime shift from contemporary regime to Environmental regime.

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

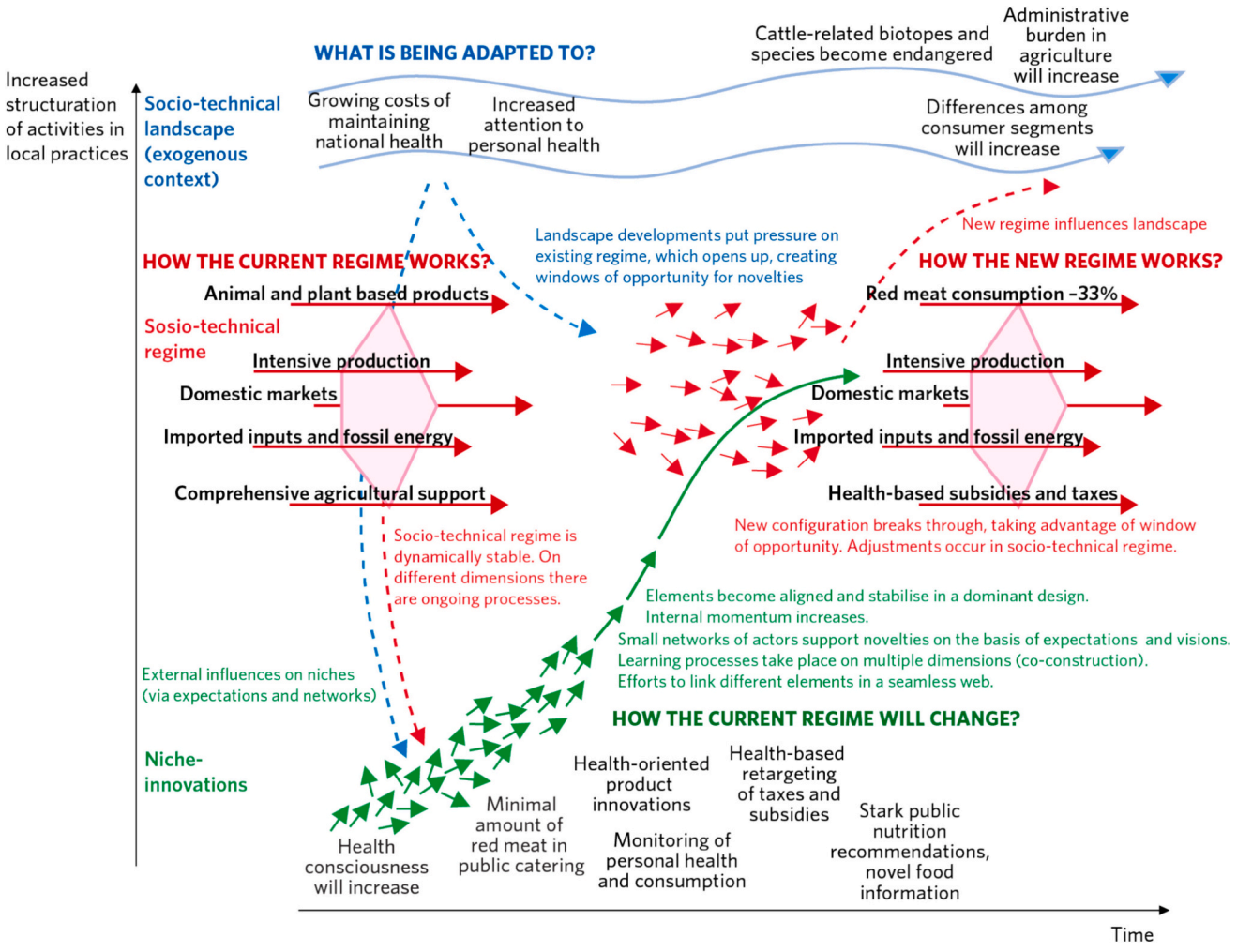

Fig. 5. MLP map of the regime shift from contemporary regime to Health regime.

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

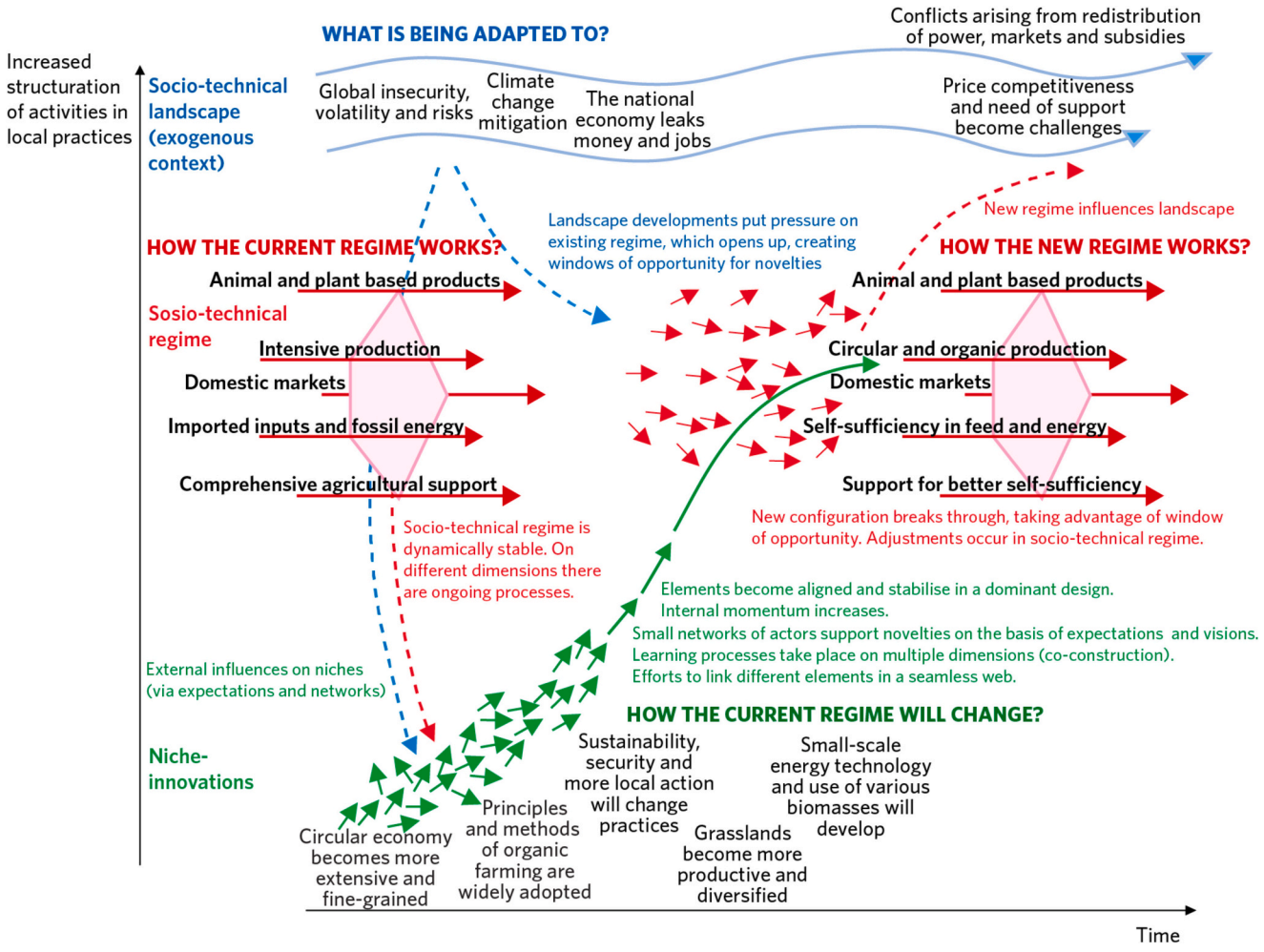

Fig. 6. MLP map of the regime shift from contemporary regime to Self-sufficient regime.

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

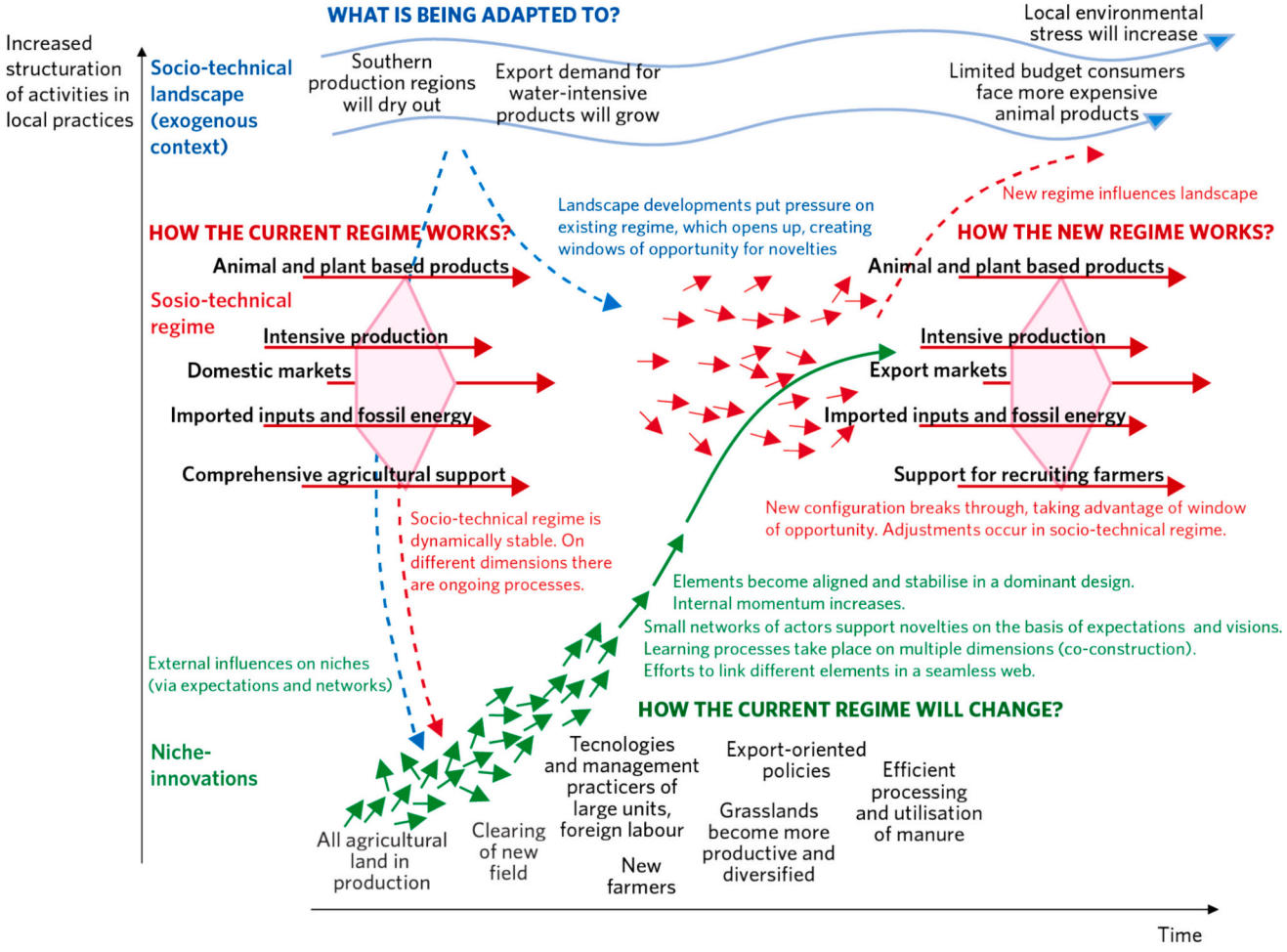

Fig. 7. MLP map of the regime shift from contemporary regime to Global market regime.

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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