The 2024/2025 Subject Area Revision at the Department of Biosystems and Technology

The Research Strategic Perspective

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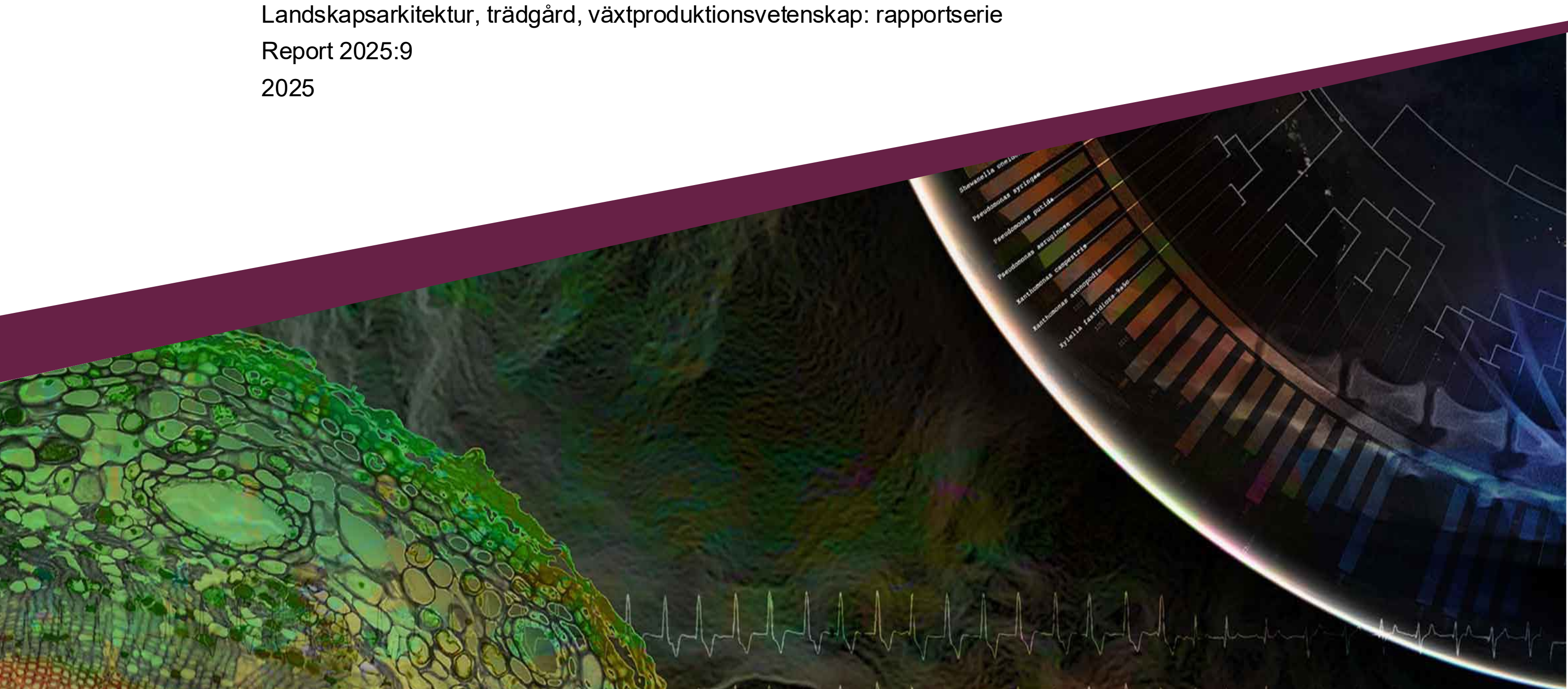
Swedish University of Agricultural Sciences, SLU
Dept of Biosystems and Technology
Landskapsarkitektur, trädgård, växtproduktionsvetenskap: rapportserie
Report 2025:9
2025



The 2024/2025 Subject Area Revision at the Department of Biosystems and Technology. The Research Strategic Perspective

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Editor:	Lars Mogren, SLU, Department of Biosystems and Technology
Publisher:	Swedish University of Agricultural Sciences, Faculty of Landscape Architecture, Horticulture and Crop Science
Year of publication:	**2025**
Place of publication:	**Alnarp**
Copyright:	All featured images are used with permission from the copyright owner.
Title of series:	Landskapsarkitektur, trädgård, växtproduktionsvetenskap: rapportserie
Part number:	2025:9
ISBN:	978-91-8046-953-1 (printed version)
	978-91-8046-954-8 (electronic version)
DOI:	https://doi.org/10.54612/ a.5rv6cthcqg
Keywords:	Agroecology, Animals, Biosystems engineering, Cropping systems, Food and Nutrition Security, Horticulture, OneHealth, Research strategy, Resilience, Sustainable food systems, Value networks

Abstract

The Research Strategic Analysis of the Department of Biosystems and Technology (BT) at the Swedish University of Agricultural Sciences (SLU) presents a forward-looking framework to strengthen the department's research excellence, interdisciplinarity and societal relevance. Conducted by the Research Strategic Consortium (RSC) during End of December 2024 to Start of November 2025, the analysis responds to the SLU Faculty of Landscape Architecture, Horticulture and Crop Science's directive to consolidate and future-proof the department's subject areas.

Five candidate areas suggested by the Heads of Department (HoDs), namely Agroecology, Animal-Centred Environments, Horticulture, Integrated Crop Production and Technology/Biosystems Engineering, were systematically assessed through a structured process including key term extraction from national and international policy documents, SWOT analyses, consequence and risk evaluations and AI-assisted scoring. The analysis considered both short-term (1.5 years) and long-term (15 years) horizons, reflecting alignment with SLU's upcoming Quality and Impact evaluation and the Swedish Government's 2024 research proposition. Based on the 10 documents identified as central to the research strategic analysis, sustainability, resilience, food and nutrition security as well as crisis preparedness were identified as central domains. This is also underpinned by the societal urgency. In addition, scientific excellence, internationalization and innovation were extracted as critical assets from the Governmental Research Proposition. The RSC agreed on the term "uniqueness" as a fundamental asset for the subject development within academia, SLU and the LTV-faculty as such. The RSC identified three prioritized subject areas for 2025–2040:

1. Agroecology: advancing sustainable, participatory and technology-integrated food systems;
2. Animal-Centred Environments: pioneering ethical, AI-based animal welfare and behaviour research;
3. Horticulture: developing resilient, circular and rural/periurban/urban food systems for edible horticultural produce using a system-oriented holistic approach.

Technology/Biosystems Engineering is positioned as a cross-cutting enabler supporting these research areas through digital innovation and systems integration.

The following names are suggested as names for the future subject areas: (1) Responsive Animal Environments; (2) Agroecological Production Systems; (3) Edible Horticulture.

Agroecological Production Systems covers the sustainability and practical feasibility of diversified agricultural (including both crops and animals) and horticultural production systems, targeting holistic system-level assessments of sustainability combined with detailed studies of resource (e.g. land, nutrients) use efficiency and interactions between plants, soil, microorganisms, animals and humans (both as producers and as users of the delivered products).

The Animal-Centred Environments research area focuses on the interplay between animal physiology, production and welfare, integrating sensory and digital monitoring technologies to advance health, behaviour and sustainable housing systems in livestock environments.

Edible Horticulture focuses on the sustainability, resilience and contingency of horticultural value networks for edible products, addressing the entire system from resource use and production at various scales of intensity and mechanization/automation to post-harvest handling, distribution and consumption. The research area integrates plant physiology (esp. stress physiology), ecology, microbiology, technology and systems analysis to develop climate-smart, circular and resource-efficient food systems for edible horticultural produce in rural, peri-urban and urban contexts, with strong emphasis on food and nutrition security, food safety and crisis preparedness.

The suggested subject areas are justified by their strong alignment with the LTV faculty's strategic priorities (LTV-faculty Faculty board, 2021) in sustainability, resilience, food and nutrition security and One Health/One Welfare. Together, Agroecological Production Systems, Animal-Centred Environments and Edible Horticulture consolidate BT's scientific strengths into coherent, systems-oriented and technology-enabled research areas. This configuration enhances academic excellence, internationalization and innovation while ensuring societal relevance and long-term impact, thereby strengthening the faculty's strategic profile and future research capacity.

The remaining issues to act upon in order to translate this strategic analysis to action are: The subject area names must be discussed and consolidated amongst the department's employees

1) A formalized research strategy incl. operational plan and actions
2) Its translation of the research strategy into a funding strategy
3) A list of infrastructure needs, incl. description of their purposes, urgency as well as, a priority list and description of consequences of needs not-met
4) A deeper analysis of needs to reach scientific excellence in the outlined subject areas
5) A talent and competence plan to populate the three future subject areas integrated with biosystems engineering to be successful, incl. identification of keystone competences, staff rejuvenation in balance with research and teaching needs
6) A comprehensive road map for translation, incl. time plan and funding allocation plan

The report underscores BT's strong scientific potential, robust interdisciplinary networks and access to advanced research infrastructure, while highlighting challenges such as fragmented funding, limited experimental facilities for animal studies and the need for enhanced digitalization and communication. Recommended actions include launching centres of excellence, investing in infrastructure and digital capabilities and strengthening policy and stakeholder engagement.

In summary, the analysis provides a strategic, evidence-based foundation for BT's future organization, ensuring excellence, internationalization and measurable impact across academia, industry and society.

Keywords: Agroecology, Animals, Biosystems engineering, Cropping systems, Food and Nutrition Security, Horticulture, OneHealth, Research strategy, Resilience, Sustainable food systems, Value networks

Sammanfattning

Den forskningsstrategiska analysen av SLU Institutionen för Biosystem och Teknologi (BT) presenterar ett framåtblickande ramverk för att stärka institutionens forskningsexcellens, tvärvetenskaplighet och samhällsrelevans. Analysen genomfördes av institutionens forskningsstrategiska konsortium (Research Strategic Consortium, RSC) under slutet av december 2024 till början av november 2025 och svarar på LTV-fakultetens direktiv om att konsolidera och framtidssäkra institutionens ämnesområden.

Fem kandidatområden, nämligen agroekologi, djurcentrerade miljöer, hortikultur, integrerad växtproduktion och biosystemteknik, föreslogs av institutionens prefekter; några av dessa (t.ex. Integrerad växtproduktion) existerade inte som ämnesgrupp vid institutionen. Samtliga utvärderades systematiskt genom en strukturerad process som omfattade extrahering av nyckelbegrepp från nationella och internationella policydokument, SWOT-analyser, konsekvens- och riskbedömningar och AI-assisterad poängsättning. Analysen beaktade både kortsiktiga (1,5 år) och långsiktiga (15 år) tidshorisonter, vilket återspeglar fokus på SLU:s kommande utvärdering rörande forskningens kvalitet och nytta (KoN) och den svenska regeringens forskningsproposition 2024. Baserat på 10 dokument med central bäring för den forskningsstrategiska analysen identifierades hållbarhet, resiliens, livsmedels- och näringstyrgghet samt krisberedskap som centrala områden. Detta underbyggs också av samhällets brådskande behov. Dessutom extraherades vetenskaplig excellens, internationalisering och innovation som kritiska tillgångar utifrån regeringens forskningsproposition. RSC enades om termen ”unikhet” som en grundläggande tillgång för ämnesutvecklingen inom akademin, SLU och LTV-fakulteten som sådan. RSC identifierade tre prioriterade ämnesområden för de kommande 15 åren (2025-2040):

1. Agroekologi: befrämjande av hållbara, deltagardrivna och teknikintegrerade livsmedelssystem;
2. Djurcentrerade miljöer: banbrytande etisk, AI-baserad forskning om djurs välbefinnande och beteende;
3. Hortikultur: utveckla motståndskraftiga, cirkulära och rurala/periurbana/urbana livsmedelssystem utifrån en systemorienterad, holistisk ansats.

Biosystemteknik positioneras som en tvärgående (horisontell) möjliggörare (*enabler*) som stöder dessa forskningsområden genom digital innovation och systemintegration.

Följande namn föreslås som namn för de framtida ämnesområdena: (1) Responsiva djurmiljöer; (2) Agroekologiska produktionssystem; (3) Hortikulturella värdenätverk för ätliga produkter.

”Agroekologiska produktionssystem” omfattar hållbarhet och tillämpbarhet hos diversifierade produktionssystem inom jordbruk (både växter och djur) och trädgård, med sikte på holistiska systemoreinterade utvärderingar av hållbarhet kombinerat med detaljerade studier av t

Forskningsområdet ”Djurcentrerade miljöer” fokuserar på samspelet mellan djurens fysiologi, produktion och välfärd och integrerar sensoriska och digitala övervakningsteknologier för att främja hälsa, beteende och hållbara inhysningssystem i lantbruksdjurens miljöer.

”Hortikulturella värdenätverk för ätliga produkter” fokuserar på hållbarhet, motståndskraft och beredskap i hortikulturella värdenätverk för ätbara produkter. Den bygger på en holistisk systemansats från resursanvändning och produktion i olika skalor av intensitet och mekanisering/automatisering till hantering efter skörd, distribution och konsumtion. Forskningsområdet integrerar växtfysiologi (särskilt stressfysiologi), ekologi, mikrobiologi, teknologi och systemanalys för att utveckla klimatsmarta, cirkulära och resurseffektiva

livsmedelssystem för ätbara trädgårdsprodukter på landsbygden, i stadsnära och urbana miljöer, med stark betoning på livsmedels- och näringstrygghet, livsmedelssäkerhet och krisberedskap.

De föreslagna ämnesområdena motiveras av att de ligger väl i linje med LTV-fakultetens strategiska prioriteringar inom hållbarhet, resiliens, livsmedels- och näringstrygghet samt One Health/One Welfare. Tillsammans konsoliderar ”Agroekologiska Produktionssystem”, ”Djurcentrerade miljöer”, och ”Hortikulturella värdenätverk för ätliga produkter” BT:s vetenskapliga styrkor till sammanhängande, systemorienterade och teknikstödda forskningsområden. Denna konfiguration höjer vetenskaplig excellens, internationalisering och innovation samtidigt som den säkerställer samhällsrelevans och långsiktig påverkan, vilket stärker fakultetens strategiska profil och framtida forskningskapacitet.

Följande uppgifter som inte omfattas av uppdraget till denna analys återstår att lösas:

1. En formaliserad forskningsstrategi inklusive operativ plan och åtgärder
2. Dess översättning av forskningsstrategin till en finansieringsstrategi
3. En förteckning över infrastrukturbehov, inklusive en beskrivning av deras syfte, angelägenhetsgrad samt en prioriteringslista och beskrivning av konsekvenserna av att behoven inte tillgodoses
4. En djupare analys av behoven för att nå vetenskaplig excellens inom de beskrivna ämnesområdena
5. En talang- och kompetensplan för att fylla de tre framtida ämnesområden som är integrerade med biosystemteknik för att bli framgångsrika, inklusive identifiering av nyckelkompetenser, personalföryngring i balans med forsknings- och undervisningsbehov
6. En omfattande färdplan för översättning, inklusive tidplan och plan för fördelning av finansiering.

Rapporten understryker BT:s starka vetenskapliga potential, robusta tvärvetenskapliga nätverk och tillgång till avancerad forskningsinfrastruktur, samtidigt som den lyfter fram utmaningar som fragmenterad finansiering, begränsade experimentella anläggningar för djurstudier och behovet av förbättrad digitalisering och kommunikation. Rekommenderade åtgärder är bland annat att lansera kompetenscentrum, investera i infrastruktur och digital kapacitet samt stärka samverkan med avnämare, politiker och andra beslutsfattare.

Sammanfattningsvis ger analysen en strategisk, evidensbaserad grund för BT:s framtida organisation, som säkerställer spetskompetens, internationalisering och mätbar påverkan inom akademin, näringslivet och samhället.

Nyckelord: Agroekologi, Biosystemteknik, Djur, Forskningsstrategi, Hållbara livsmedelssystem, Hortikultur, Livsmedels- och näringstrygghet, Odlingssystem, OneHealth, Resiliens, Värdenätverk

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Abbreviations

AI	Artificial intelligence
BT	Department of Biosystems and Technology
CEA	Controlled environment agriculture
CoARA	the European Coalition for Advancing Research Assessment
FNS	Food and nutrition security
HoD	Head of Department
HIR	The Rural Economy and Agricultural Society – Intensive Extension Service
ICP	Integrated Crop Production
IFOAM	International Federation of Organic Agriculture Movements
IMS	Department of People and Society (Institutionen för Människor och Samhälle)
ISHS	International Society of Agricultural Sciences
LAPF	Department of Landscape Architecture, Planning and Management (Institutionen för landskapsarkitekur, planering och förvaltning)
LCA	Life Cycle Assessment
LTV	Faculty of Landscape Architecture, Horticulture and Crop Science
PLF	Precision Livestock Farming
RSC	Research Strategic Consortium
RISE	Research Institutes of Sweden
SAFE	SITES Agroecological Field Experiment
SDG	Sustainable Development Goal
SITES	Swedish Infrastructure for Terrestrial Ecosystem Science
SLU	Swedish University of Agricultural Sciences
SWOT	Analysis of strengths, weaknesses, opportunities and threats
ToR	Terms of Reference
TRLs	Technology Readiness Levels
VSB	Department of Plant Protection Biology (Institutionen för växtskyddsbiologi)

Definition of identified key terms

Term	Definition	Reference
Agroecology	The integrative study of the ecology of the entire food system, encompassing ecological, economic and social dimensions	(Francis et al., 2003)
Artificial intelligence	"Artificial Intelligence is the science and engineering of making intelligent machines, especially intelligent computer programs. It is related to the similar task of using computers to understand human intelligence."	(McCarthy, 2007)
Biodiversity	an attribute of an area and specifically refers to the variety within and among living organisms, assemblages of living organisms, biotic communities, and biotic processes, whether naturally occurring or modified by humans	(DeLong, 1996, Swingland, 2013)
Circular bioeconomy	"an economic system, in which biomass and substances contained therein are used consecutively by biomass producing, processing and consuming sectors, resulting in a balanced exchange between the bioeconomy and the environment, where substances neither deplete nor accumulate".	(Jander et al., 2025)
Climate change adaptation	a dynamic, context-specific and inherently socio-political process through which individuals, communities and institutions respond and adjust to actual and anticipated climate impacts by reducing risk, addressing vulnerability and its structural drivers and integrating climate considerations into broader development pathways. It aims to safeguard human dignity, equity and the right to survival within acknowledged ecological, social and governance limits	(Amorim-Maia and Olazabal, 2025)
Climate smart agriculture	Encompasses practices and technologies that improve agricultural productivity (food security),	(Lipper et al., 2014)

	enhance resilience to climate change (adaptation) and reduce greenhouse gas emissions (mitigation)	
Climate transition	Here used to describe the fundamental shift in global economic, social, and technological systems to achieve net-zero greenhouse gas (GHG) emissions, aligning with the Paris Agreement's goal of limiting warming to 1.5°C	(ICPP, 2023)
Competitiveness	the ability of an economic unit (*e.g.,* company, farm, cluster, region, or country) to achieve and sustain its objectives within a given competitive environment by effectively deploying its internal resources and capabilities while responding to external conditions, constraints and rival actions	(Listra, 2015)
Contingency	*Philosophical (modal) definition*: An event is contingent if it occurs in the actual world but fails to occur in the majority of nearby possible worlds under the same relevant initial conditions.	(Drékalovic, 2014)
Crisis preparedness	An active, continuous and anticipatory process through which actors develop capacities to foresee, cope with and manage potential crises and their consequences before they materialize; *in a broader sense*: it encompasses socially embedded, planned, predominantly non-structural and enabling measures that build collective capacities for effective response and recovery, while accounting for uncertainty, residual risk and the need for adaptation and learning.	(Staupe-Delgado and Kruke, 2018)
Digital transformation	Highlights the integration of digital technologies like IoT, AI and data analytics into agricultural systems for better decision-making and efficiency	
Ecological intensification	The environmentally friendly replacement of anthropogenic inputs and/or enhancement of crop productivity, by including regulating and supporting ecosystem services management in agricultural practices.	(Bommarco et al., 2013)
Food security	is defined when all people, at all times, have physical and economic access to sufficient safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life.	(FAO, 2002)

Emergency storage	A system of storing essential agricultural products, such as grains, to ensure food availability during crises or war	
Genomics	Plays a pivotal role in developing stress-resistant and high-yield crop and livestock breeds, adapting to changing climatic and environmental conditions	
Grain production	The cultivation and harvesting of cereals like maize, wheat, barley, rice, rye and oats, which form a significant part of the food supply	
Green transition	"…a process towards a new development model that ensures environmentally sustainable and fairer societies. It is a necessity to address the human-induced climate change emergency, environmental degradation (water, land, forests, atmosphere) as well as the loss of biodiversity…"	(ETF, 2022)
Innovation	Emphasis on technological and methodological advancements to improve agricultural efficiency	
Innovation ecosystem	Refers to the network of stakeholders, including researchers, farmers and industries, working collaboratively to develop and implement innovative solutions	
Input supplies	Essential materials and resources like fertilizers, seeds and fuel required for agricultural production, often imported	
Knowledge transfer	Bridging the gap between research and practical implementation in farming communities	
Local production	Refers to the generation of goods within a proximate territorial context, characterized by reduced supply-chain length and strong territorial embeddedness, and is conceptually associated with environmental quality, local development, and enhanced perceptions of product quality. - Territorial proximity: The concept is anchored in shorter geographic and temporal distances between production and consumption, which consumers associate with the idea of "local." - Supply chain reduction: A primary attribute evoked is the shortening of the supply chain, indicating territorial and logistical closeness as a defining feature.	(Merlino et al., 2022)

	- Multidimensional values: Beyond geography, the notion includes sustainability and local development (*i.e.,* environmental and socio-economic aspects) and perceived food quality (*i.e.*, freshness, genuineness) as salient elements in consumers' perceptions.	
Precision agriculture	Refers to technology-driven farming practices that optimize inputs (*e.g.,* water, fertilizers) and maximize yields while reducing environmental impact	
Precision livestock farming	Refers to the use of sensor technologies, algorithms, real-time monitoring and automated systems to continuously track and manage livestock, their products and the farming environment in order to support informed decision-making and control of individual animals.	(Berckmans, 2017)
Productivity	Efforts to increase output while optimizing resource use	
Regional distribution	Decentralized storage and supply of grains across various regions to ensure accessibility and reduce risks in emergencies	
Resilience	Building a robust agricultural system to withstand environmental and economic challenges	
	Addresses the ability of agricultural systems to withstand and recover from environmental, economic and social disruptions	
	The capacity of a system to absorb disturbance and reorganize while undergoing change so as to still retain essentially the same function, structure and feedbacks and therefore identity, that is, the capacity to change in order to maintain the same identity	(Ge et al., 2016)
Self-sufficiency	Increasing domestic food production to reduce dependency on imports	
Self-sufficiency	The ability of a country or region to produce enough food independently to meet its population's needs during supply chain disruptions	
Sustainability	the principle of maintaining the resource base and productive capacity necessary to secure the well-being of future generations, by balancing present welfare gains with the long-term conservation of critical and irreplaceable natural resources in line	(Kuhlman and Farrington, 2010, World Commission on Environment and

	with the intergenerational equity framework articulated in the Brundtland Report. In the current context, the term focuses on social, economic and environmental sustainability in agricultural and horticultural practices as the cornerstone of modern agricultural/horticultural research, focusing on long-term ecological balance, resource efficiency and reducing environmental footprints	Development (WCED), 1987)
Sustainable intensification	the goal of increasing agricultural productivity without negatively impacting the environment or depleting natural resources	(Cassman and Grassini, 2020, Pretty, 1997)
Turn-over inventory	A dynamic storage system where stock is regularly rotated to maintain freshness and quality while keeping reserves available	

1. Preface

As the deputy Head of Department of Biosystems and Technology, I recognize the importance of transparent, inclusive and forward-looking processes in shaping our academic future. This research strategic perspective has been developed independently by the Research Strategic Consortium under the lead of prof Beatrix Alsanius together with colleague professors and subject area leaders (profs Georg Carlsson, Jean Yong, Assoc. profs Thomas Prade, Rebeka Zsoldos), associate extension professor Malin Hultberg and young scientists (senior lecturers Anna Karin Rosberg, Maria Vilain Rörvang, assoc. senior lecturer Oleksiy Guzhva) as well as the head of department PhD Hanna Sassner. This strategic research perspective reflects thorough analysis and broad staff engagement in response to the reorganization mandate. The analysis itself was firmly grounded in fundamental documents and standards set by the Swedish government, international organizations and leading academic bodies, ensuring both compliance and relevance to current policy directions.

Innovative methods, including structured strategic frameworks, participatory staff involvement and advanced digital tools such as AI-supported scenario and risk assessments, were employed to achieve transparency and data-driven prioritization. These forward-thinking procedures have enabled a dynamic alignment with institutional goals and evolving societal research needs.

I sincerely thank all contributors for their dedicated work, which provides a strong foundation for our department's continued development within the changing landscape of our university.

Lars Mogren, PhD
Deputy head of Department for Biosystems and Technology

2. Mandate to the Research Strategic Consortium

The research strategic consortium (RSC) is an advisory group to assist the head of department (HoD). This working group acts for strategic development of the research environment at the Department of Biosystems (BT). The consortium's assignment is based on the items identified by all BT staff members to meet the strategic goals set for 2021-2025 by the management board at the Swedish University of Agricultural Sciences (SLU)[1] (SLU Styrelsen, 2020), the Faculty of Landscape Architecture, Horticulture and Crop Science (LTV)[2] (LTV-faculty Faculty board, 2021) and operational and action plan at the Department of Biosystems and Technology[3].

2.1 Background

The Department of Biosystems and Technology currently comprises five subject areas: (i) Animal Environment and Building Function, (ii) Technology and Digitalization for Animal and Plant Production, (iii) Microbial Horticulture, (iv) Horticultural Production Physiology and (v) Cropping System Ecology. A preliminary subject revision was conducted in 2023 by the departmental management and subject area leaders, resulting in an internal management analysis that was discussed with the Faculty Board.

The analysis identified significant synergies across subject areas, particularly in conceptualizing and assessing entire production chains within agricultural and horticultural systems. Integrating expertise across subjects enables the study of complex and interlinked systems, such as crop-livestock integration, comparisons between field and controlled environments and interactions between urban and rural production contexts. A systems-level approach would enhance interdisciplinary

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[1] SLU strategy 2021-2025: https://internt.slu.se/globalassets/mw/org-styr/styr-dok/1-verksamhetsstyrning-organisation/strategi-slu-2021-2025.pdf

[2] LTV faculty strategy 2021-2025: https://internt.slu.se/globalassets/mw/riktade/ltv/strategiprocess-2021-2025/ltv-strategy-2021-2025.pdf

[3] Dept of Biosystems and Technology, Operational plan: https://arbetsplats.slu.se/sites/BT/Delade%20dokument/strategi/BT%20OPERATIONAL%20PLAN%202022-2026%20FINAL.pdf; Action plan: Handlingsplan final version 2022-2026 (Autosaved).xlsx

collaboration and generate stronger scientific and societal impact, which is not yet reflected in the current subject structure.

The department's 2022–2026 strategy emphasized building critical mass and excellence within subjects while strengthening interdisciplinary capacity for holistic studies of integrated systems. Continued development is needed to communicate the department's societal relevance in sustainability, One Health/One Welfare, resilience, food security and food safety. Also, development efforts are imperative to better integrate these themes into education. Strengthening competences in systems analysis, sustainability assessment and publication output in high-impact journals remains a priority.

BT has access to advanced infrastructure for environmental monitoring of animals and plants, including microbiological laboratories and digital analytical tools. There is strong potential to develop unique infrastructures based on existing resources such as SITES Lönnstorp, greenhouses, polytunnels and the phytotrone. However, experimental facilities for animal studies in Alnarp are lacking, though collaborations with nearby farms provide compensatory opportunities. Likewise facilities for near-commercial in- and outdoor experiments within horticultural research are lacking and depending on collaboration with producers dedicated to and supporting research. Strategic investments in equipment and recruitment of complementary expertise are key to consolidating BT's research platform.

Common themes identified across BT include environmental factors influencing plant and animal production, product quality and the use of byproducts as new substrates or energy sources. These align with broader faculty research areas in sustainability, One Health, and One Welfare. The One Health perspective emphasizes the interdependence of human, animal and ecosystem health, with synergies identified particularly with the Department of Biomedical Science and Veterinary Public Health as well as Plant Protection Biology (VSB). The One Welfare framework further connects animal welfare, human wellbeing and the environment, creating opportunities for collaboration with LTV-departments, such as Work Science, Business Economics, Environmental Psychology (IMS) and Landscape Architecture, Planning and Management (LAPF).

BT's research increasingly addresses circularity in agri- and horticultural systems, including biomass refining, biogas production and the use of alternative growing media. These initiatives are strategically important for sustainable development and holistic system assessments of circularity, resource efficiency and resilience.

Given BT's core focus on biological systems and technology, a reorganisation aligned with biosystem-based structures would strengthen cross-disciplinary integration and collaboration. Horticulture remains a unique and defining element of BT's profile and should be retained in future subject designations.

2.2 Terms of reference (ToR) given by the BT Head of department to the RSC

As a strategic working group for research within BT, the RSC was given the opportunity to address the results and input of the staff workshop and asked to assist in the background analysis and suggestions of new subject area proposals to guide the HoD-group in its decisions.

The mandate to the RSC was divided into three parts, namely

1. Identification of three future subject areas at the department through
    a. Identification of buzzwords or mission statements to be used to define and rank the alternatives, based on the outcome of the first staff workshop?
    b. Identification of the possible future subject areas: working name (*work name*)
    c. Description of the suggested scope of each proposed subject area (*kort beskrivning av ämnesomfattning och ämnesfokus*)
2. Justification of the suggested subject areas' connections to SLU/LTV's mission and strategy according to the LTV-proposal and depiction of aspects within the subject area being in the forefront of future research agenda?
3. List of remaining issues for discussion regarding name, demarcations or scope and suggestions on how to proceed to solve them.

2.3 Conditions

2.3.1 Language

The report must be written in English with a summary of the report in Swedish.

2.4 Miscellaneous

The following documents are fundamental for the subject area review:

- Decision of the LTV faculty's decision on subject area review, taken Dec 15, 2021 (SLU.ltv.2021.1.1.1.1-771)[4]
- Development plan for the LTV faculty's subject areas 2023-2026[5]

[4] expediering-av-beslut-i-fn-ltv-2021-12-15_--122-oversyn-av-amnesomraden-slu.ltv.2021.1.1.1-7712.pdf

[5] utvecklingsplan-for-ltv-fakultetens-amnesomraden-2023-2026.pdf

3. Initiatives preceding the RSC assignment

The Head of Department (HoD) group at the Department of Biosystems and Technology (BT) arranged a workshop on Dec 4, 2024, involving all employees to develop the strategy and to address concerns with respect to research, teaching and education as well as human resource issues in the light of the subject area revision. This workshop employed a World Café approach to create a participatory and inclusive atmosphere to drive change and to establish ownership of the change process. Two stations ("tables") dealt with the research perspective of the subject area revision (tables X1 and Y1). The basic scenarios for each of the two tables had been designed by the HoDs (table X1: Plants, Animals, Technology; table Y1: Horticulture, Agroecology, Biosystems engineering) and aspects to consider were provided to each of the tables to generate innovative ideas and to sketch on solutions. Staff perspectives on change with respect to research were gathered in three steps. Apart from the group facilitator who stayed at the same table during all three steps, group members rotated between each step. The output from the two tables was summarized by the HoD (Appendix 1).

Based on the summaries, the process at the two tables considered concerns of change rather than collective solutions. Consequently, the outcome could not be used as a stepping stone for the RSC to take on the research strategic process. The RSC therefore based their assignment on an alternative approach.

4. Procedures and Limitations

To develop the future research strategy, RSC members set their formal positions aside viewing the potential of future subject areas through the lenses of outcome and impact in line with needs and gaps identified by national, European and international propositions, reports and strategy papers. The current mission of the department and involved thematic areas served as a basis for this work. Two guiding time scenarios were defined, namely time frames for

i. Strategy longevity: 15 years (*i.e.*, time period until next subject area revision) and
ii. Months until the onset of the next quality and impact evaluation conducted by SLU, after transition to the new organization (21 months), implying that the new subject areas ought to have the potential for scoring at an excellent level in order to make use of potential benefits awarded to excellent subject areas.

In addition, BT's HoD framed 45 academic staff members (according to the LTV faculty board's directive) allowing a maximum of three subject areas implying a reduction in number of subject areas from five to three. BT's HoD also handed in a list of potential combinations of subject areas (Appendix 2). The RSC extracted five main alternatives from this list, namely Agroecology, Animal centred environments, Horticulture, Integrated crop production, Technology/Biosystem engineering.

The RSC process exclusively considered the subject area revision from a research strategic perspective. It did not take human resource aspects (*e.g.,* individual choices of group affiliation), potential group sizes, existing cultures and code of conduct in current subject areas nor consequences for teaching into account.

4.1 Workflow and time plan

The RSC received an informal invitation to develop the research strategic agenda on Dec 16, 2024, followed by a formal statement on Jan 9, 2025. The RSC conducted the analysis as a side assignment to their usual work commitment and met 14 times. The time frame for the future research strategy was set on Jan 9, 2025, setting this date as the baseline date for the strategic work documents, implying uncertainties regarding national propositions and reports that had not been passed by the Swedish Parliament at that point of time. Table 1 presents an overview of the workflow within the RSC. The development was based on four distinct phases, displayed in Figure 1.

Table 1. Overview of workflow and activities within the RSC's subject revision process from a research strategic perspective

Date	Theme	Comment
Dec 6, 2024	Impressions on Dec 4 workshop	Discussion of road map
Dec 18, 2024		
Jan 9/10, 2025	Deciphering future research realities	Scoring of key terms; key terms alignment to different key areas
Jan 20, 2025	Preparation of workshop Jan 27	
Jan 27, 2025	Staff workshop	Input of potential research topics to five key areas
Apr 28, 2025	SWOT analysis; Discussion of the 1st draft of the report;	
June 2, 2025	Identification of three recommended areas	Start of consequence and risk analysis
June 9, 2025	Presentation of the RSC report at the BT monthly meeting	
June 12, 2025	Finalizing consequence and risk analysis	
July 3, 2025	Discussion candidate areas	Discussion of outlined text, bracing to Biosystem engineering
Aug 8, 2025	Executive summary	Publication and submission to BT staff Aug 22, 2025
Sept 15, 2025	Report revision	
Nov 3, 2026	Final report submitted to RSC members and HoD	
Nov 13. 2025	Final report revision	Published Dec 18, 2025

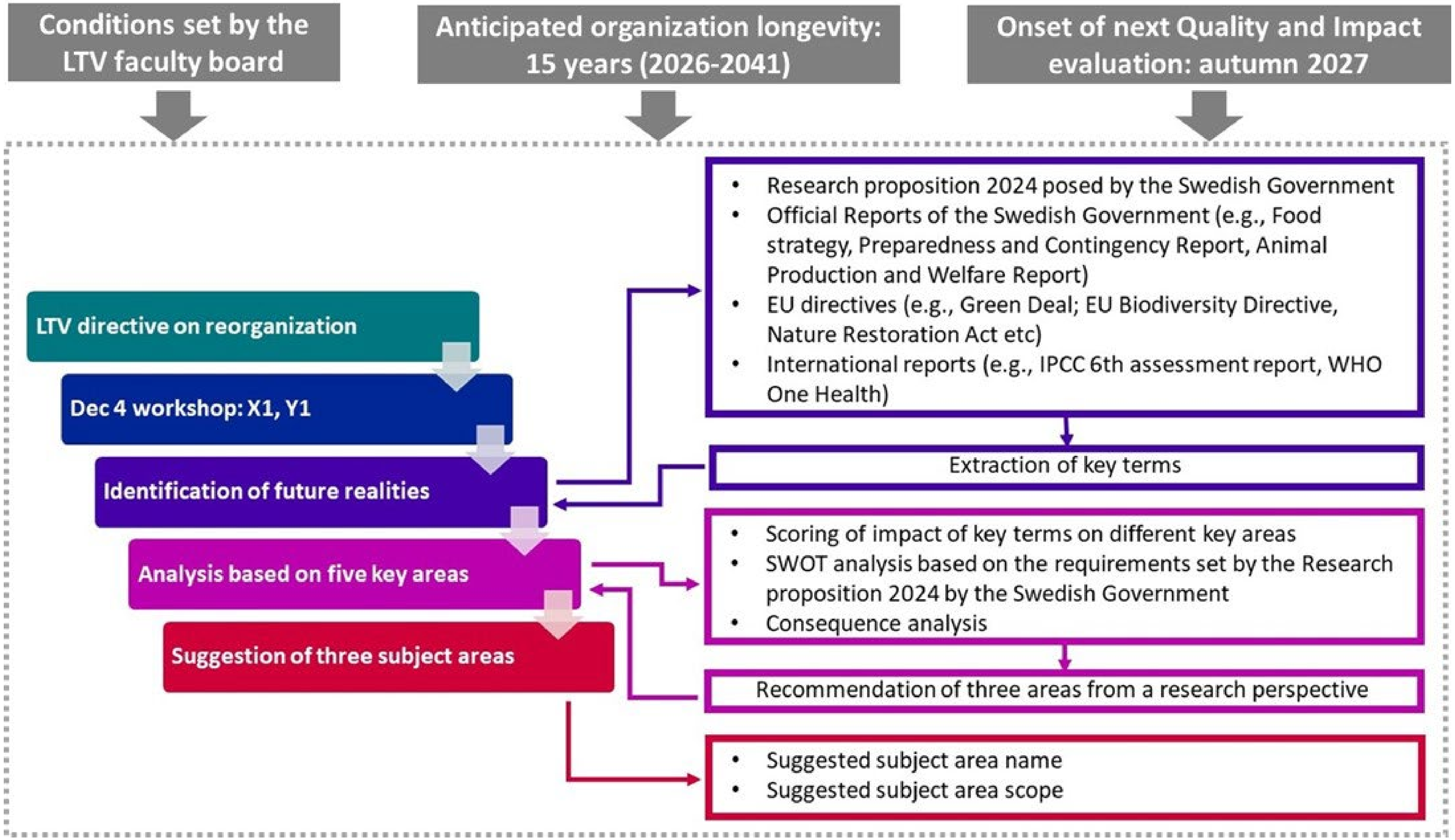

Figure 1. Framework and phases of the subject area development process from a research perspective

4.2 Current situation analysis

The subject area revision took place in a period of multiple changes on all societal levels. The current subject area revision based on the political decision on change taken and requested by the LTV faculty board is of course affecting how research needs to be organized. But also the expectations set by policymakers (focusing on impact and outcome) and evaluations of impact performed by research councils and foundations (considering interactivities between objectives and outcomes, between objectives and impact as well as between outcome and impact; Figure 2) are subject to a major shift in paradigm. To demonstrate outcome[6], changes in knowledge and understanding, skills, conditions, behaviour or attitudes need to be monitored and evaluated. The domain "impact" is assessed through changes in societal outcomes (*e.g.,* environmental, socio-economic or public health), behaviour or policies and institutional frameworks. This change in paradigm requires a fundamentally different mind-set and project set-up and is already introduced into national and European research calls. This shift also affects the mode of knowledge transfer, using a range of approaches for outreach and creation of synergies (e.g., participatory and interactive approaches alongside with traditional science publication in open access peer reviewed journals).

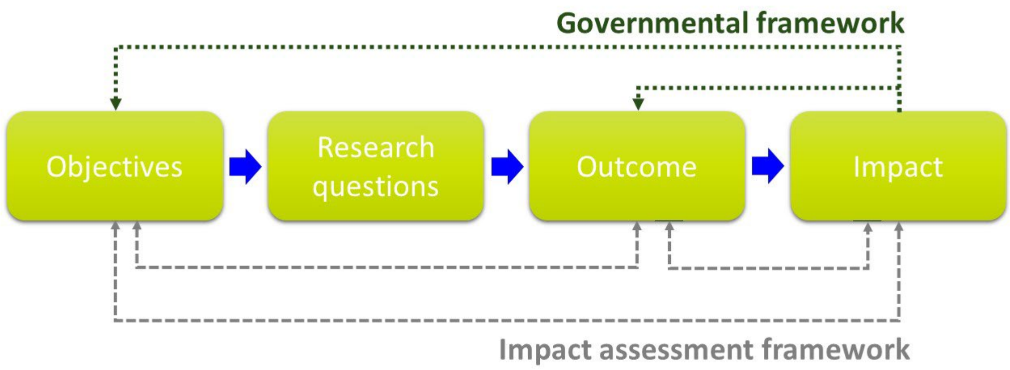

Figure 2. Project organization in the light of frameworks set by the government and research councils.

An additional change in waiting is the upcoming reform to evaluate research, individual researchers' merits as well as the performance of research institutions. SLU recently declared its commitment to comply to the framework of CoARA, the European Coalition for Advancing Research Assessment (https://coara.eu/). Given

[6] It is worthwhile to highlight the differences in the distinctions "output", a quantitative measure on project achievements, *e.g.*, indicated through number of stakeholders addressed, products released, timeliness, satisfaction or quality and "outcome" which comprises the dimension of change.

that the declaration of commitment is followed up by an action plan, evaluation of merits will be widened from monitoring citation performance to recognition of a larger diversity in contribution to science and society as well as activities (*e.g.,* science communication and public outreach, software engineering, leadership, teaching/mentoring). As this process is not concluded yet, it is not possible to bring in explicit research strategic assumptions with respect to the subject area revision.

4.2.1 Guiding documents

SLU's mission is stated in detail in the SLU regulation (1993:221) giving a clear mandate to several of the research areas considered under the umbrella of the Department of Biosystems and Technology

> "1 a § Lantbruksuniversitetet bedriver forskning samt utbildning på forskarnivå, avancerad nivå och grundnivå inom jord- och trädgårdsbruk, landskapsplanering, livsmedelsproduktion, naturvård, skogsbruk och vedråvarans förädling, fiske och vattenbruk samt veterinärmedicin och husdjursskötsel. Dessutom bedriver Lantbruksuniversitetet fortlöpande miljöanalys."

In addition, the RSC considered the following national and international documents in order to decipher future realities, research needs and gaps of knowledge (Table 2).

Table 2. Guiding documents used for extraction of key terms

Document	**Year**
National documents	
Research proposition 2024 of the Swedish Government	2024
The Swedish Food Strategy	2017
Preparedness and Contingency Report	2023
Animal production with high competitiveness and good welfare	2024
Strategy for a environment free of toxic compounds	2020
European documents	
EU Green Deal	
EU Biodiversity Directive	
EU Nature Restoration Act (2024/1991)	2024
International documents	
IPCC Climate Change 2022: Impacts, Adaptation and Vulnerability	2022
WHO One Health Initiative	2023
EAT Lancet Commission "Our Food in the Anthropocene: Healthy Diets From Sustainable Food Systems"	2019

4.2.2 Guiding documents limitations

Several of the national guiding documents are currently under revision (*e.g.*, National Food Strategy 2.0) or have not yet passed the Swedish Parliament (*e.g.*, Research proposition 2024) leading to uncertainties. Very recent legislation on the European level have not gained legal force in Sweden yet but will be highly relevant in a very near future (EU Nature Restoration Act). Again others, such as the EAT Lancet Report, are highly debated.

4.2.3 Extraction of key terms from guiding documents

From these documents, the 10 most important key terms were extracted using artificial intelligence-based tools. Queries, AI based tool as well as outputs are listed in Appendix 3. Extracted key terms were discussed from the perspective of the various disciplines which resulted in a list of definitions presented in Appendix 4 and grouped into parameters and outcome indicators. Leading key terms from the national Research proposition 2024 are

- Excellence
- Innovation and
- Internationalization.

Outcome indicators from the remaining documents were grouped in four dimensions, related to either sustainability, resilience, digitalization and miscellaneous as displayed in Table 3.

Table 3. List of extracted and grouped key terms

Sustainability related	**Resilience related**	**Digitalization related**	**Miscellaneous**
Sustainability	Resilience	Digital transformation	Innovation
Climate transition	Crisis preparedness	Climate smart agriculture	Knowledge transfer
Climate adaptation	Self-sufficiency	Precision agriculture	Translation to practice
Green transition	Local production		
Circular bioeconomy	Food security		
Sustainable intensification	Regional distribution		
Genomics (stress resistance)	Input supplies		

4.3 Brief definition of key areas for the perspective of the discipline

To provide common ground, the five key areas identified by the HoD (Appendix 2) are briefly described below from the perspective of the discipline. NB! At the point of evaluation, the key area "Integrated Crop Production" is not an existing subject area at BT, but a potential area launched by the HoD.

4.3.1 Agroecology

Agroecology is a multi-faceted concept and has been given a threefold definition as a scientific discipline, a political/social movement and a set of practices (Wezel et al., 2009). Different definitions occur, but a widely accepted and used definition of the scientific discipline is the one that describes "agroecology as the integrative study of the ecology of the entire food system, encompassing ecological, economic and social dimensions"(Francis et al., 2003). Research in Agroecology is broad and interdisciplinary, with the aim to generate holistic understanding of problems and possible solutions for sustainable food production systems. Examples of agroecological research questions include how soil fertility and crop resilience towards abiotic and biotic (weeds, pests and diseases) stress can be preserved or improved by animal-crop integration and cropping system diversification. It also emphasizes the implementation of new knowledge and how this can be improved by including concerned actors, often farmers and their knowledge and experience in the research process. Although the discipline agroecology covers a very wide range of study systems and entry points for solutions or improvements, most agroecological research shares a common criticism to the agricultural systems that currently dominate production in high-income countries, *i.e.* intensive, large-scale and input-dependent; often referred to as industrialized agriculture (Carlsson, 2019).

The interdisciplinarity and participatory dimensions of Agroecology (emphasizing *e.g.,* farmers' experiential knowledge and multi-actor collaborations to jointly identify problems and guide actions for the transition to more sustainable food systems) have been described in a framework of 13 agroecological principles and ten elements of agroecology (FAO, 2018, Wezel et al., 2020).

4.3.2 Animal-centred environments

The field of animal-centred environments stands as a robust and interdisciplinary research domain, integrating sensory, cognitive and physical considerations to optimize conditions for animals in various contexts (Ducrot et al., 2024). This area fosters novel advancements by combining cutting-edge technologies, innovative research methodologies and ethical frameworks, ensuring that both scientific inquiry and practical applications align with, or improve, the welfare of animals (Webber et al., 2022). The fundamental principle of this research is that decision-making both in research processes and practical implementations must prioritize animals' species-specific needs and motivations. By extending this perspective across all domains of animal research, the field establishes a structured ethical framework based on relevance, impartiality, welfare and consent. This approach not only enhances the credibility and impact of research but also drives a paradigm shift toward truly animal-centred scientific and practical advancements, reinforcing its role as a transformative force in welfare, sustainability and ethical research practices.

4.3.3 Horticulture

"Horticulture is the art, science, business and technology of cultivating and using plants to improve human life. It involves both the production of food and non-food products and services. Horticulturists create global solutions for safe, sustainable, nutritious food and plan, develop and construct healthy, restorative and beautiful environments" (Doyle, 2017). *Horticulture as a discipline* is multidisciplinary and based on technology, biology and economy. It is thus a biological engineering discipline. Horticulture as a branch includes cropping systems, cultivation process and system management of horticultural crops (edible/food[7] and non-edible/ornamental[8]) for production of high quality and safe products and stretches over the entire value network including resources and their use, production, processing distribution and consumption. Four decisive characteristics distinguish horticulture from other areal branches, (*e.g.,* agriculture) (Alsanius et al., 2021):

(i) Horticulture is characterized by high-input intensity and high turnover per unit cropping area.
(ii) Horticultural produce is of high quality and high value.
(iii) Adaptation and optimization of all production factors for the demands of the crop allow for precision planning of the crop and thus timing of harvest allowing for optimal positioning on the market. These first three assets allow for maximized profits.
(iv) Horticultural products are aimed for fresh consumption with no or minimal processing. Thus, quality and safety of horticultural produce must meet the market demands with respect to quantity and quality. Consequently, actions must be taken to maintain and safeguard horticultural products post-harvest.

Given horticulture's biological engineering discipline nature, the role of production factors and their interactions are key for successful production and for

[7] Vegetables, fruit, berries, grapevine, nuts, medicinal plants, herbs, mushrooms (in- and outdoors)
[8] Annual and perennial herbaceous plants, bulbs, cut flowers, shrubs, trees for in- and outdoor use

robust provisioning of people with horticultural products. This requires an understanding of crop physiological and ecological processes along the horticultural value chain to produce and maintain safe and nutritious produce of high quality with minimized environmental impact (Alsanius et al., 2023).

4.3.4 Integrated crop production

The term “Integrated crop production” (ICP) replaces the term “All plant group” used previously in the reorganization process.

"Integrated crop production" is the term used to describe a holistic and sustainable approach to managing agricultural and horticultural systems for animal feed, food and ornamental production, including both indoor and open field cultivation at different spatial and temporal scales. It covers a range of crop production approaches, from low to high input systems and conventional to organic production. It refers to the type and sequence of crops (rotation) grown over space and time, the practices using current available technologies and the components of crop production. The system's productivity is paramount, along with environmental, social and economic sustainability. Practices to consider include crop diversification, water use and management, nutrient management, soil management (incl. soil fertility and health) and weed control.

4.3.5 Technology/ Biosystems engineering

The subject area Technology is currently referred to as “Technology” or “Biosystems engineering”.

The subject of Technology is very broad and therefore this description will focus on the more defined area of Biosystems engineering and Agrotechnology. Biosystems engineering is a multidisciplinary field that emphasizes applications in agriculture, ecosystems and food science. The field focuses on developing environmentally sustainable engineering solutions to address society's ecological challenges. Biosystems engineering combines core principles from traditional engineering disciplines with knowledge from non-engineering fields to create holistic and sustainable approaches. The more applied field of Agricultural technology, or Biosystems Engineering involves the application and evaluation of technology in agriculture, horticulture and aquaculture to enhance yield, efficiency and profitability. Biosystems Engineering encompasses a wide range of products, services and applications that improve various agricultural input and output processes. The development of agrotechnology is driven by advancements in agricultural science, agronomy and agricultural engineering. These innovations have resulted in practical solutions that address challenges in modern agriculture, enabling more efficient resource use, sustainable farming practices and improved food security.

In the current practice at the Department of Biosystems and Technology, the subject includes research regarding technical systems within both agriculture and horticulture. Above all, the interaction between animals, plants, environment and humans is studied in the context of environmental impacts and climate change in systems for a sustainable and economically competitive production. Within the subject field, interdisciplinary research is carried out with a focus on technology development within the topics of systems analysis (including cropping and machinery systems as well as applied statistics) and building technology (building materials and building design).

Within the topic of systems analysis, research aims at improving production systems within agriculture and horticulture including post-harvest and energy conversion processes (energy balances, life cycle assessment, soil organic carbon modelling, systems dynamic modelling, nutrient balances, techno-economic assessments, GIS-based data and inventory, machinery simulations, intermediate crops, applied statistics). Furthermore, applications of biomass for various purposes in the new bioeconomy (food, feed, materials, energy) are investigated.

Within the topic of building technology, research topics include agricultural and horticultural production of food including animals, feed, raw materials for energy and industrial purposes, i.e. stables, storage, greenhouses and other production buildings. Specific research areas are lighting and energy efficiency in agricultural buildings.

4.4 Scoring of key terms in relation to key areas

Two score steps were used. The first step related to the value of terms for the different key areas, identifying the ones used as indicators vs. outcomes. In the second step, the current presence of key terms in the five areas was assessed. The key terms were scored in groups of two for agroecology, animal-centred environments, horticulture and technology/biosystems engineering and in a group of nine for integrated crop production, using scores from 1-3, with 1 indicating the lowest level of establishment/potential/risk and 3 meaning very well established/high potential/high risk. Table 4 displays the top 10 agricultural keywords, outcomes as well as indicators, identified from the background literature (see Table 2, Table 3). This scoring exercise guided the SWOT analysis (chapter 4.5), SWOT-pairing (chapter 4.6) and the assessments of consequences and risks (chapter 5).

Table 4: Top 10 agricultural keywords, outcomes and indicators scored for each of the five potential research environments from an impact assessment perspective. NB! In the international literature, the term "agriculture" often also comprises horticulture.

Impact assessment parameter	**Terms**
Top 10 agricultural keywords	Innovation, Food, Environment, Agriculture, Research, Climate, Policy, Farming, Resources, Food Security
Outcomes	Industrial collaboration, Translation to practice, Precision agriculture, Climate smart agriculture, Sustainability, Digital transformation, Resilience, Circular economy (agricultural wastes to resources to allow resource efficiency), Climate adaptation, Self-sufficiency/preparedness, Green transition, Innovation, Competitiveness, Productivity, Sustainable intensification, Knowledge transfer, Food supply, Grain production, Crisis preparedness, Input supplies, Storage infrastructure, Food security
Indicators	Innovation ecosystem (stakeholders that work collaborately to find innovative solutions), Genomics (stress resistance, high yield adaptations), Climate transition, Interdisciplinary collaboration (agriculture/horticulture, technology, economics, ecology), Biodiversity, Emergency storage, Turn-over inventory (*omsättningslager*), Regional distribution

4.5 SWOT analysis

The five key areas were screened in a two-step-process through a set of questions addressing strengths, weaknesses, opportunities and threats (SWOT) (Appendix 3) with (i) expert assessment in pairs, (ii) followed by commenting by all other RSC members. The answers were merged before screening and analyzing using AI-based tools. The texts were then critically analyzed and corrected, if needed, by the experts. These texts served then for the AI-managed

- SWOT-pairing (internal vs external criteria; Strengths x Opportunities, Strengths x Threats; Weaknesses x Opportunities, Weaknesses x Threats) and for the
- Analysis of consequences and risks.

An executive summary with the main outcomes of the analysis precedes each subchapter, followed by details in running text for the committed readership.

4.5.1 Agroecology

Box 1: SWOT analysis - executive summary for "Agroecology"

Strengths

- Interdisciplinary and participatory by design, enhancing research relevance
- Strong alignment with SDGs and SLU's strategic sustainability goals
- High potential for impactful research on resilient, low-input food systems
- Strong networks: local engagement and international collaboration
- Access to unique assets like SAFE and Alnarp Agroecology Farm

Weaknesses

- Low visibility and recognition of agroecology in the Swedish context
- Interdisciplinary work is time-consuming with uncertain outcomes
- Digitalization remains underdeveloped in agroecological research
- Case study focus can limit reproducibility and comparability
- Lack of unified strategy delays institutional development at SLU

Opportunities

- Rising interest in resilience, food security and climate adaptation
- Digital tools offer new paths for innovation and system analysis
- New EU funding streams support agroecological transformation
- Strong potential for cross-department and cross-sector collaboration
- Increasing student interest can strengthen research capacity

Threats

- Shift in funding focus may deprioritize sustainability research
- Competing fields overshadow agroecology without naming it
- Viewed by some as ideological or critical of intensive agriculture
- Lack of digital integration risks making research seem outdated
- Fragmented efforts weaken SLU's positioning in the field

Strengths

Agroecology is an emerging but increasingly recognized research field, offering several strengths that align with academic excellence, innovation and interdisciplinary collaboration. Its transdisciplinary and participatory nature (involving collaboration with stakeholders, farmers and multiple scientific domains) sets it apart from many other fields, creating unique opportunities for integrative research and societal relevance.

A key strength lies in agroecology's alignment with global agendas, such as the Sustainable Development Goals (SDGs) and SLU's own strategic ambitions. The field's emphasis on sustainable, resilient and locally adapted food systems offers significant potential to address ecological, economic and social challenges in food production, especially through reduced input dependency and systems-level thinking.

Methodologically, agroecology demonstrates rigor and originality, employing mixed-method and participatory approaches. While such methods may not be entirely unique, the innovative combination of techniques enhances the originality and applicability of the research (particularly when embedded in field-based experiments, systems analysis and sustainability assessments). The SITES Agroecological Field Experiment (SAFE; where SITES is the abbreviation for Swedish Infrastructure for Terrestrial Ecosystem Science), Alnarp Agroecology Farm and SLU’s master’s program in Agroecology are valuable assets that support both empirical inquiry and student involvement.

The research area also benefits from strong interdisciplinary ties within SLU, across subject areas at BT but even more so across departments at the LTV faculty and collaboration with national organizations and practitioners. Existing international networks, including collaborations across Europe, Latin America and Africa, further strengthen its potential for internationalization, research exchange and innovation. SLU’s connections with organizations like Agroecology Europe, FAO and the International Society for Horticultural Sciences underscore its global relevance.

Agroecology’s ethical fundament, rooted in food sovereignty and environmental stewardship, adds further legitimacy. Moreover, opportunities for digital innovation, such as incorporating robotics, drones and sensor technologies into diversified production systems, offer promising directions for bridging agroecology with sustainable intensification.

Given the competitive international landscape with an increasing focus and positioning in agroecology, SLU’s challenge lies in carving out a distinct niche of excellence. Strengths such as biodiversity and soil health, particularly in relation to horticulture, are identified as key contributions. The presence of influential international scholars and increased funding opportunities (*e.g.,* Horizon Europe, Formas) further support the field’s strategic development.

In summary, agroecology at SLU combines scientific rigor, societal relevance and interdisciplinary innovation, positioning it as a field with strong potential for impactful and distinctive research.

Weaknesses

While agroecology holds substantial promise as a research field, several weaknesses currently limit its potential, particularly within the Swedish context. One primary challenge is its relatively low visibility and recognition in Sweden, despite increasing interest. This lack of awareness among stakeholders and students makes it difficult to build a critical mass of research activity and public engagement.

In addition, students face uncertainties regarding career pathways, which may hinder recruitment into the field.

A central methodological weakness lies in the complexity of interdisciplinary and participatory research. Although these approaches are core to agroecology and offer long-term value, they are often time-consuming, entail uncertain research outcomes and can make it difficult to produce high-impact publications in conventional academic outlets. Moreover, the participatory nature of agroecological research, while enabling strong connections to practice, poses challenges in terms of scientific reproducibility and generalizability, especially when based on case studies specific to local contexts.

The integration of digital technologies in agroecological research remains underdeveloped. This presents both a weakness and an opportunity, as the lack of existing digitalization frameworks limits comparative research and innovation, especially in data management and meta-analysis. Improved openness in data handling could significantly enhance the field's analytical power and international standing.

Another issue is the difficulty in upscaling agroecological innovations, which are often developed in niche or small-scale settings. Translating these to broader food systems involves navigating political, economic and institutional barriers, such as market pressures, retail system realities and policy inertia. This presents a strategic and structural bottleneck that must be addressed to enhance the relevance and scalability of agroecological research.

Despite a strong intellectual community, there is still a need to clarify and strengthen the strategic positioning of agroecology at institutions like SLU, where it remains a relatively new field. Fragmentation within and across departments can hinder cohesive development, while the limited institutional infrastructure may delay the establishment of a centre of excellence or other long-term initiatives.

In sum, key weaknesses of agroecology as a research area include limited visibility in Sweden, methodological and strategic challenges in interdisciplinary and participatory research, insufficient digital integration, difficulties with upscaling innovations and structural barriers to attracting researchers and students. Addressing these issues is essential for realizing the full potential of agroecology in contributing to sustainable food systems.

Opportunities

Agroecology is well-positioned to respond to emerging global challenges and policy shifts, offering a range of opportunities for scientific, societal and institutional advancement. The increasing focus on preparedness, national self-sufficiency, resilience and food security opens new avenues for agroecological approaches that emphasize diversified, low-input systems and sustainable land use. However, worthwhile to note, small-scale and low-input systems do not replace the needs of large-scale approaches, but act in parallel to them. These areas align closely with climate adaptation and mitigation and green transition agendas, enhancing the field's policy relevance and societal value.

Digitalization and technological innovation present particularly promising yet underexplored opportunities. Integrating tools such as drones, sensors, robotics and autonomous systems into diversified agroecological systems could significantly improve system monitoring, management and scalability. Moreover, the application of big data and open data management could support comparative analyses and meta-studies, enhancing the empirical robustness of agroecological research. This integration may also offer a unique scientific niche at the intersection of agroecology and sustainable intensification.

The field also benefits from strong potential for interdisciplinary collaboration, both internally at SLU and externally. Active and potential partnerships with departments such as IMS, LAPF, VSB and Economics create a fertile environment for cross-cutting research. Within BT, collaboration with the technology group offers additional synergies, particularly in the development of methodological innovations.

In terms of funding and institutional development, opportunities are expanding through initiatives such as the European Partnership on Agroecology, which foreground interdisciplinary and impact-oriented research. National and international funding trends increasingly emphasize sustainability, systems thinking and stakeholder involvement, all core strengths of agroecology.

Additionally, the field enjoys strong student interest and growing academic engagement, providing a strong base for future capacity-building. Agroecology's emphasis on co-creation of knowledge and stakeholder participation enhances its societal legitimacy and offers effective pathways for knowledge transfer and impact, particularly in the context of sustainable food production and rural development.

Finally, agroecology's relevance to a broad range of policy, industrial and societal domains, including food safety, animal welfare and environmental health, positions it as a vital contributor to future food system transformation. Its integration into preparedness and contingency planning further underscores its strategic importance in addressing the multifaceted challenges of the 21st century.

Threats

Despite its growing relevance, agroecology as a research field faces several significant threats that could limit its development and long-term impact. One of the primary concerns is the potential shift in political and funding priorities, where the focus on preparedness and national contingency may overshadow broader sustainability goals. While agroecology is well-aligned with resilience and food security, failure to explicitly position it within these emerging agendas risks marginalizing the field in policy and funding landscapes.

Another threat arises from competing research fields, including those focusing on sustainability, ecology and food systems, that engage in agroecologically relevant work without adopting the term "agroecology." This creates a risk of dilution or invisibility, particularly when these areas receive greater recognition, resources or institutional support. Moreover, interdisciplinary collaborations at other universities and within SLU may unintentionally bypass agroecology as a named or distinct field.

Perceptions of agroecology as ideological, being too critical of industrial agriculture or positioned against technological advancement, also pose challenges. Such views can hinder its acceptance among policymakers, funders and more traditional academic disciplines. The association with niche or “old-fashioned” production systems may further reinforce skepticism, despite evidence of innovation within the field. To counter this, agroecology must demonstrate its compatibility with modern scientific standards and its openness to hybrid approaches, including those associated with sustainable intensification.

Another threat is the lag in digital integration. If agroecology does not embrace technological tools such as sensors, robotics and data analytics, it may be seen as outdated or scientifically limited, weakening its competitiveness in a rapidly evolving research environment. Relatedly, the field has yet to fully address data management practices, limiting the reproducibility and scalability of findings and preventing broader meta-analytical work.

Institutional fragmentation and the relative newness of agroecology at SLU also pose internal challenges. The lack of a consolidated research strategy or centre of excellence makes it harder to coordinate efforts, secure funding and attract long-term investments. Although there is strong student interest, uncertainty about career paths and limited visibility of agroecology among stakeholders in Sweden may restrict its appeal and slow the recruitment of new researchers.

In sum, to mitigate these threats, agroecology must assert its relevance within preparedness, embrace digital/technical innovation, bridge ideological divides and develop a cohesive institutional presence supported by robust communication and research strategies.

4.5.2 Animal-Centred Environments

Box 2: SWOT analysis - executive summary for "Animal-Centred Environments"

Strengths

- Strong interdisciplinary foundation across animal and digital sciences
- Links ethics, sustainability and productivity in animal systems
- High-impact international collaborations and networks
- Unique human capital with diverse academic expertise
- Backed by strong funding and policy-relevant research outputs

Weaknesses

- Lacks harmonized methods and scalability for real-world use
- Gaps in knowledge on animal senses and emotional well-being
- High-tech tools are costly and lack field-ready validation
- No dedicated animal facilities within the hosting faculty
- Limited participatory and interdisciplinary communication

Opportunities

- Advances in AI and sensors boost welfare and behavioural insights
- Rising relevance of One Health and ethical farming models
- New topics like biophilic housing and cognitive welfare emerge
- Scope for collaboration across SLU and international partners
- Alignment with sustainability agendas boosts funding potential

Threats

- Researcher attrition and economic constraints on infrastructure
- Ethical concerns over surveillance and selective welfare use
- Public trust risks due to misinformation and shifting values
- Global crises may sideline welfare for short-term priorities
- Future funding hinges on shifting policy and political will

Strengths

The research field of animal-centred environments demonstrates significant academic and practical strengths rooted in its interdisciplinary foundations. It bridges well-established domains such as animal welfare, behaviour, movement science and precision livestock farming (PLF), while incorporating cutting-edge methodologies including movement modelling, computer vision, sensor technology and environmental monitoring. This integration supports both original and applied research with high ethical standards, enhancing the field's academic rigor and societal relevance.

Despite being relatively niche within animal science, the field benefits from robust institutional expertise and infrastructure. Its uniqueness stems from perceptual studies to improve animal well-being and combining digital technologies as well as biomechanical insights to offer a novel interface with many other disciplines. These crossovers position the field to explore uncharted but impactful links between animal and cropping systems and land use, sustainability and ethical production systems.

The research area is distinguished by a strong international orientation and potential for further global engagement. Established collaborations with industry, advisory bodies and sustainability-focused initiatives, such as regenerative agriculture, support application-driven innovation. The field also holds strategic value in the light of emerging legislation on competitive and welfare-oriented animal production.

Notably, the animal-centred environment domain benefits from unique human capital: interdisciplinary teams with diverse expertise not widely represented elsewhere at SLU or internationally. These teams are equipped to deliver high-impact outcomes, including enhanced animal welfare and productivity, improved worker safety, ethical farming practices and contributions to climate resilience and food security.

Current projects and publications underscore the academic depth and innovation within the field. Furthermore, the availability of funding from major Swedish and European research bodies and a growing emphasis on digitalization and sustainability fortify its position as a future-oriented and high-potential area. Its anchorage in international regulatory and academic networks further strengthens its legitimacy and long-term relevance.

Weaknesses

Despite its strong interdisciplinary and innovative potential, the research area of animal-centred environment faces a number of internal and structural limitations that constrain its development. A major challenge lies in the lack of harmonized methodologies and the difficulty in scaling, validating and achieving appropriate Technology Readiness Levels (TRLs), particularly when addressing the complex interface between intensive and extensive animal husbandry systems. Short-term study designs and difficulties in balancing competing research goals further limit long-term impact and resilience to climate and environmental pressures.

Significant knowledge gaps persist, especially in the documentation and validation of animal senses, species-specific needs and emotional and cognitive well-being. Research has traditionally overemphasized productivity metrics, with limited focus on animal-centric technology, longitudinal studies and working animals. Integration of stakeholder perspectives and ethical considerations also remains underdeveloped, particularly in low-resource contexts.

Methodological constraints are further exacerbated by the high cost and complexity of advanced technologies, limited access to real-time behavioural data, lack of standardized welfare metrics and general resistance to adopting new digital tools. These factors contribute to issues of data reproducibility, accessibility and geographical bias. Interdisciplinary collaboration, particularly with BT subject areas, is seen as a promising but underutilized avenue to address these technological and methodological weaknesses.

A major structural limitation is the absence of dedicated animal facilities within the LTV faculty, which restricts the on-site ability to conduct experimental research essential for both behavioural and technological development and poses logistical and financial challenges to accessing such experimental facilities at other SLU campuses/sites. Financial constraints make it unlikely that new facilities will be prioritized, raising the need for strategic collaboration within SLU to access shared infrastructure.

Barriers to entry for new researchers include technical, academic and financial challenges. While research outputs are disseminated through seminars and advisory boards, broader engagement through participatory methods and interdisciplinary communication strategies remains underdeveloped but essential for future impact.

Opportunities

The animal-centred environment research field stands at a promising intersection of emerging technological, ethical and societal trends, offering substantial opportunities for interdisciplinary growth, innovation and impact. The increasing integration of digital technologies such as Precision Livestock Farming (PLF), AI, biometric tools and wearable sensors opens new avenues for tracking and enhancing animal welfare and production outcomes. These advancements facilitate the development of dynamic models and longitudinal data analytics, enabling deeper insights into animal behaviour, emotional well-being and environmental interactions.

The growing relevance of One Health and One Welfare frameworks, alongside societal shifts toward ethical and sustainable farming, provides a strong foundation for expanding the field's influence. Collaborative sustainability assessments and contributions to holistic system design, particularly when aligned with agroecology and other BT subject areas, enhance the field's relevance to pressing global challenges such as climate adaptation, biodiversity loss and food security.

Underexplored research topics present additional growth potential. These include the documentation and validation of animal senses, species-specific needs and emotional and cognitive well-being. Additionally, ergonomic design in extreme environments, biophilic animal housing, human-animal interaction ergonomics and the emotional and cognitive dimensions of animal welfare. Investigating synergies between welfare and production, as well as incorporating energy efficiency and emissions reduction strategies, would strengthen the field's contribution to sustainable intensification.

There are compelling opportunities for interdisciplinary collaboration, both within SLU and beyond. Collaborations with technology-focused researchers in the BT area can support development of novel tools and methods, while partnerships with existing ethics-focused groups and departments can reinforce the normative foundation of animal-centred approaches.

Although no specific new funding streams have been identified, current funding trends increasingly prioritize interdisciplinary, outcome-oriented research that addresses global sustainability challenges. This creates favourable conditions for funding success when aligned with digitalization, resilience and ethical farming goals. The field is also well-positioned to contribute to national strategies such as the Swedish food strategy, by promoting healthier ecosystems, enhanced animal well-being and resilient farming systems.

Ultimately, the animal-centred environment field has strong potential to contribute to climate resilience, reduce the environmental footprint of livestock systems and improve animal and human well-being, if it continues to evolve through strategic interdisciplinary integration and a clear articulation of its unique value.

Threats

The research field of animal-centred environments, while innovative and interdisciplinary, faces a range of external and systemic threats that may hinder its development and long-term impact. Key risks include competence leakage as researchers shift fields, as well as broader economic constraints that affect institutional priorities, research funding and infrastructure investments. Resistance to change within both academic and agricultural sectors further complicates the implementation of novel methodologies, particularly those that prioritize ethical and sustainability outcomes over productivity metrics.

Externally, the field is vulnerable to ethical and regulatory scrutiny, especially around the use of surveillance technologies, selective welfare practices and broader concerns about animal use in agriculture. Shifting societal attitudes and misinformation may also challenge public trust, with a risk that animal welfare is perceived as secondary to economic or production-oriented priorities. These dynamics can negatively affect both research legitimacy and the acceptance of scientific outcomes among stakeholders.

At a global level, escalating geopolitical instability, environmental crises and misinformation threaten to deprioritize sustainability, biodiversity and welfare concerns in favour of short-term, crisis-driven responses. This broader shift may reduce the perceived urgency or relevance of research that centers animal well-being within systemic change frameworks.

Although no immediate threat from competing research fields is noted, the field's continued relevance depends heavily on alignment with national and international policy agendas, such as the Swedish food strategy. While there is potential for increased funding aligned with welfare, sustainability and holistic production goals, this remains contingent on political will and long-term policy support.

Encouragingly, the field does not currently suffer from a lack of skilled researchers or declining interest. Moreover, it shows resilience against rapid obsolescence due to technological change. However, to maintain momentum, the field must actively navigate institutional politics, public perception and shifting funding landscapes while strengthening its ethical foundation and societal relevance.

4.5.3 Horticulture

Box 3: SWOT-analysis: Executive summary for "Horticulture"

Strengths

- Diverse methods, *e.g.,* metagenomics, transcriptomics, aquaponics, light studies
- Strong infrastructure: laboratories, greenhouses, SITES, Trädgårdslabbet, Lönnstorp
- High-impact themes: sustainability, resilience, food and nutrition security incl. food safety, climate change adaptation
- Strong global links: ISHS, EUFRIN, IFOAM, ERASMUS, top academic partners
- Cohesive subject identity with high interdisciplinary collaboration

Weaknesses

- Currently limited, fragmented funding hampers long-term research stability
- Gaps in subfields: ornamentals, nurseries, crop stress physiology
- Outdated equipment and lack of modern experimental greenhouses
- Weak communication strategy limits societal and policy impact

Opportunities

- Demand for resilient, self-sufficient, climate-smart food systems
- Digital tools and AI enable smart modelling and systems research
- New niches: peat-free media, renewable inputs, circularity in production systems, crop diversification
- Cross-disciplinary synergies in sustainability and food security
- Funding momentum from EU green transition and policy initiatives

Threats

- Horticulture may be overshadowed by protein and staple crop focus
- Volatile funding and shifting policy may deprioritize the field
- Ethical risks from peat use and sustainability perception gaps
- Shortage of skilled researchers limits long-term capacity building
- Selective focus by other institutions may limit broad partnerships

Strengths

Horticultural sciences at SLU represent a strategically important and dynamic academic field, grounded in methodological rigor and interdisciplinary collaboration. The subject group applies a wide range of advanced techniques, including metagenomics, transcriptomics, MALDI-TOF and phenotypic profiling, alongside cutting-edge technologies in microbiology, hydroponics, aquaponics, biological water purification as well as decontamination and light-environment interactions. Research is conducted within a well-equipped infrastructure, including

BLS2/3 labs, N^{15} facilities, photosynthesis systems, greenhouses, phytotrons, tunnels and field stations such as SITES Lönnstorp and "Trädgårdslabbet".

The field is uniquely positioned within SLU's organizational structure and contributes to Sweden's food strategy, particularly in addressing low food self-sufficiency, sustainable crop production and urban climate adaptation. Horticulture encompasses both edible and ornamental plants, reinforcing its relevance to public health, urban ecosystems and biodiversity. Researchers regularly contribute to high-impact journals and are recognized through keynote invitations and strong citation metrics, despite horticulture-specific journals typically having lower impact factors.

The subject enjoys strong national and international networks, with partnerships involving prominent universities (*e.g,*, Wageningen, Copenhagen, Université Laval, Humboldt university as well as Free University Berlin) and participation in scientific societies (ISHS, IAFP, FEMS, DGG) as well as networks (EUVRIN, EUFRIN, COST actions). Collaborative ties to policymakers (FHM, SJV, SLV, MSB, FOI, SVA) and EU lobby groups ensure societal relevance and influence. National collaborations with growers and horticultural food companies, The Rural Economy and Agricultural Societies and industry organizations enable research that is practice-oriented and innovation-driven.

Research themes align with key societal challenges, focusing on sustainability, climate resilience, digitalization, food safety and green transitions. The subject group's strong identity and coherence within SLU is a major strength and care must be taken to avoid fragmentation through organizational changes. Interdisciplinary collaboration is already active within SLU and there is strong potential to deepen this further with other BT subject areas and departments at LTV.

Despite limitations in dedicated funding for horticulture, substantial funding opportunities exist through Formas, Vinnova, EU programs and various foundations. Continued effort is needed to reposition horticulture within broader research narratives to unlock greater investment. Overall, horticultural sciences at SLU are uniquely positioned to contribute to major research, policy and societal goals and their continued development is vital to both the university and national interests.

Weaknesses

While horticultural sciences at SLU are well-established, several weaknesses currently limit the field's long-term sustainability, research impact and organizational resilience. One of the most significant challenges is the limited availability of substantial, long-term funding. The SLF provides restricted support and few funders offer large-scale grants. This combined with a generally high teaching load makes it challenging for researchers to maintain momentum and continuity in research efforts.

In terms of research coverage, certain critical subfields are underdeveloped. Some researchers are the sole academic representatives within their specialties, which creates a vulnerability in capacity. Ornamental plant and nursery research is currently deprioritized, despite its significance. Similarly, crop stand physiology, particularly stress physiology, requires a stronger focus. The lack in crop stand modelling is particularly worrying given the fact that timing of production to markets is a prerequisite in horticultural produce and a smooth integration into AI related questions. The research often focuses on a narrow set of target crops, making it difficult to translate results across the wide diversity of species used in horticultural production.

Technological integration is another concern. Infrastructure limitations, particularly aging laboratory equipment and outdated greenhouses, further constrain experimental capability. Although core methods are scientifically robust, the lack of state-of-the-art facilities, especially regarding crop production physiology, diminishes competitiveness and restricts opportunities for innovation.

From a process perspective, the transition from factor-based to outcome-oriented research is still ongoing and needs to be accelerated to remain aligned with future societal and funding expectations. Research approaches also vary widely, ranging from case studies to generalist studies, depending on available funding, which can make synthesis and broader applicability more difficult. Research is mainly published in open access journals displaying methodologically transparent, open data.

Additionally, the level of intellectual cohesion across the subject group varies, with some projects being deeply collaborative while others remain siloed. This variability is common given the nature of the topics but may limit the ability to develop unified strategic directions. Communication and outreach also need modernization. Despite growing societal relevance, horticultural research outcomes often do not reach intended audiences due to information overload and a lack of tailored communication strategies. Incorporating participatory approaches and collaborating with departments that have experience in stakeholder engagement could significantly improve research uptake.

Opportunities

The horticultural sciences at BT are positioned to seize several significant opportunities driven by emerging global trends, technological advancements and evolving funding landscapes. Climate change, coupled with new legislation aimed at mitigating environmental impacts, presents a unique opportunity for horticulture to play a key role in sustainability and adaptation research. Likewise, societal concerns around food security, national self-sufficiency and contingency preparedness are rapidly gaining attention, creating demand for research that aligns with horticulture's strengths. These areas not only have societal relevance but also present an opportunity for a paradigmatic shift in research focus, moving from narrow, traditional research questions to broader, systems-oriented approaches that consider resilience, sustainability and integrated food systems.

Within the horticultural field itself, several underexplored topics present exciting opportunities for growth. These include horticultural food security, circularity in horticulture inputs, production systems based on renewable resources (*e.g.,* peat-free growing media, but also energy) and crop diversification. These topics align well with global sustainability and resilience goals, offering entry points for impactful, interdisciplinary research that can drive significant societal change.

The ongoing technological revolution, particularly in artificial intelligence (AI) and digitalization, offers a wealth of new opportunities. Horticulture is based on digital technology already today, both in research and practice, but the advent of AI-based tools and digitalization 2.0 could revolutionize how data is gathered, analysed and applied in horticultural systems. The integration of AI with horticultural crop and systems modelling offers a particularly strong opportunity for growth and collaboration with other BT subject areas. There is significant potential to revitalize and expand this area of research through advanced modelling approaches, including descriptive, dynamic and generative methods.

Collaboration across departments and faculties within SLU and externally is another key opportunity. Strong interdisciplinary interactions with departments like IMS, VSB and VF at LTV and with other faculties such as NJ and VH, create a strong foundation for developing interdisciplinary research initiatives. The current and future funding landscape, including EU calls from Horizon as well as national initiatives launched by Formas and VR, provides an excellent platform for horticultural research to clearly define its niche and ensure its contribution to broader research agendas.

Ultimately, horticultural sciences at SLU have substantial opportunities to address societal challenges like food security, sustainability, climate change adaptation and resilience, all while strengthening their relevance and impact through interdisciplinary collaborations and strategic alignment with emerging funding initiatives.

Threats

Horticultural sciences at SLU face several potential threats that could affect the field’s growth and long-term impact. One of the key external threats is the potential overshadowing of horticultural research by the societal focus on protein and staple crops, which are gaining global attention due to the need for sustainable food production. As the focus shifts toward these crops, research on fruits and vegetables may be seen as less urgent, even though it remains crucial for food security and human health.

International universities and research institutes have well-established internationally renowned horticulture research. Collaboration opportunities with these institutions are available but could be more strategic.

Another threat to the field is the volatility of academic funding, which can fluctuate depending on political and societal priorities. Changes in research focus may divert funding from horticultural projects.

Ethical concerns, particularly regarding sustainability and biodiversity aspects, also pose challenges.

A key threat to the field's future is the shortage of skilled researchers. Horticulture spans multiple areas and if long-term funding is not secured, it could struggle to attract and retain necessary talent.

4.5.4 Integrated crop production

Box 4: SWOT analysis: executive summary for "Integrated Crop Production"

Strengths

- Academically rigorous with high-impact publications in top-tier journals
- Strategic relevance for sustainability, resilience and food security
- Potential for innovation through method integration across systems
- Strong individual expertise in agricultural and horticultural domains
- Opportunities for international collaboration and EU-funded projects

Weaknesses

- Lack of a clear scope and uniqueness weakens strategic focus
- Insufficient research infrastructure and outdated equipment
- Limited critical mass and high teaching load constrain development
- Field not well established at BT or nationally in Sweden
- Absence of postharvest perspective limits sustainability scope

Opportunities

- Alignment with global shifts toward sustainable food systems
- Technological advancements support cross-system innovations
- Potential for interdisciplinary collaboration across faculties
- New funding opportunities with a sustainability focus available
- High relevance for policy, climate adaptation and preparedness

Threats

- Strong competition from established national and SLU research groups
- Lack of funding, equipment and skilled personnel limits growth
- High risk of low researcher recruitment due to limited visibility
- Political and funding shifts may deprioritize the research area
- Weak institutional support hampers field's long-term viability

Strength

ICP represents a holistic and sustainability-driven approach to crop cultivation that integrates agricultural and horticultural systems across different spatial and temporal scales. Within the academic landscape, it demonstrates several key strengths that underscore its relevance and potential as a future-oriented research area. It is firmly grounded in academic excellence, drawing on rigorous methodologies, ethical standards, interdisciplinary collaboration and effective communication, all of which support the production of high-impact research. Notably, ICP-related studies have been published in leading journals such as *Science*, *Nature* and the *Journal of Cleaner Production*, indicating both scientific quality and international visibility.

As a conceptual framework, ICP is strategically aligned with pressing global challenges (*e.g.,* food security, environmental sustainability and biodiversity conservation). Its comprehensive systems-level focus, encompassing crop diversification, soil and water management, nutrient use and integrated farming practices, allows it to address a wide spectrum of sustainability and resilience objectives. Although individual methodologies within the field, such as intercropping or crop rotation, are well-established, their thoughtful integration within ICP provides a platform for innovation. This synthesis of methods opens up opportunities for developing novel, climate-smart cropping systems tailored to specific ecological and socio-economic contexts.

ICP also benefits from access to research infrastructure such as the SITES Lönnstorp facility and a pool of individually skilled researchers with strong competences in both agricultural and horticultural domains. These resources provide a foundation for advancing field-based studies and experimental design. Moreover, the potential synergies emerging from the combination of agricultural and horticultural expertise may foster unique methodological developments, particularly in integrating system components across disciplines.

On the international stage, ICP has considerable potential for research collaboration and project development. Existing connections through EU-funded initiatives and ongoing engagement with global sustainability networks provide a promising basis for future internationalization. While the field is still evolving, especially in Sweden, where it is not yet well established, its conceptual clarity and alignment with sustainability imperatives suggest that it could grow into a distinctive and impactful area of research. In sum, ICP stands out through its academic rigor, relevance to societal and environmental goals and capacity to foster innovation through interdisciplinary integration and methodological synthesis.

Weaknesses

Despite its conceptual appeal and alignment with sustainability goals, Integrated Crop Production (ICP) faces several critical weaknesses that challenge its development as a strong and competitive research area. A central issue lies in the difficulty of establishing cohesive, multidisciplinary research teams capable of addressing the broad and integrative nature of ICP. Although the theoretical foundation for merging agricultural and horticultural systems is sound, its practical implementation is hampered by entrenched disciplinary silos and the reductionist structure of education and research training. As a result, the field remains unestablished within the institution and lacks a clearly defined scope and uniqueness, particularly in comparison to more specialized and well-funded initiatives both within SLU and at other Swedish research institutions.

The fusion of agricultural and horticultural research under the ICP umbrella leads to conceptual fuzziness and dilution of disciplinary strengths, notably the loss of the postharvest perspective critical to horticultural systems. This weakens the potential for addressing environmental and social sustainability comprehensively. Furthermore, ICP is highly species-dependent, making the reproducibility and generalizability of findings variable and limiting the intellectual cohesion across studies. Methodological challenges also persist due to outdated or insufficient infrastructure, especially regarding horticultural research facilities and a lack of suitable soils and field equipment for robust experimental work.

Resource constraints represent a major bottleneck. Current funding for horticultural research is limited. While integration with agriculture might theoretically broaden funding opportunities, the restrictions regarding funding of specifically horticulture cropping systems by certain funders remains a considerable barrier. This fusion alone is not seen as a viable solution without a parallel shift in research paradigms and clearer thematic focus. The lack of critical mass in terms of researchers, technical staff and equipment, combined with strong national and institutional competition, makes it difficult for a small group to establish visibility or achieve research excellence. In addition, knowledge transfer mechanisms remain underdeveloped and are typically more effective for established and specialized research areas, limiting ICP's engagement with policymakers and end users.

Overall, the ICP research area suffers from a lack of strategic focus, insufficient infrastructure, weak institutional anchoring and limited capacity to attract talent and resources. Without substantial investment in staff development, methodological innovation and clearer thematic definition, the field's potential remains largely unrealized.

Opportunities

ICP offers several opportunities for growth and development, particularly in light of global shifts toward sustainable agriculture, climate adaptation and food system resilience. The field is well-positioned to contribute to emerging paradigms such as circular production systems, sustainable intensification and preparedness in food security. When well-structured and clearly communicated, research within ICP has the potential to yield high-quality publications and attract targeted funding, particularly in regions such as Europe, Australia and East Asia where there is increased interest in sustainability-oriented agriculture.

There is considerable opportunity to explore underdeveloped or currently fragmented topics within ICP. One such area is the integration of agricultural and horticultural crops within the same production systems to promote crop diversification. While similar studies are already underway elsewhere, adapting and contextualizing this research to specific environments or cropping systems could lead to meaningful innovations. However, the field must carefully consider whether such diversification alone is sufficient to justify a distinct research area, or whether broader thematic integration is needed.

Technological advancement provides another avenue for development. Precision agriculture technologies, including sensor-guided machinery and GPS-enabled systems, are becoming more accessible and can be applied across both agricultural and horticultural systems. These tools could foster methodological innovation within ICP by enabling more precise, data-driven management of cropping systems. Still, many of these technologies are not novel in themselves and their successful deployment in ICP would depend on creating added value through context-specific application and cross-disciplinary integration.

ICP also presents interdisciplinary collaboration opportunities. Interfaces with areas such as systems analysis, sustainability assessment and digital agriculture could foster innovation, provided that sufficient institutional support and collaborative frameworks are established. While interdisciplinary work is promising, realistic integration remains a challenge in a landscape dominated by established, specialized research networks.

From a societal and policy perspective, ICP has significant potential impact. System-level comparisons of crop rotations and production models could inform policies related to sustainable agriculture and climate adaptation. To realize this potential requires a clear research focus and paradigm shift, particularly in defining what “integration” truly means within ICP. Importantly, the current absence of postharvest considerations limits ICP's ability to address the full sustainability and resilience spectrum.

In sum, while ICP’s opportunities are substantial especially with respect to sustainability, resilience and methodological innovation, they will require strategic refinement, institutional commitment and a clearer articulation of the field’s unique contribution.

Threats

While conceptually aligned with emerging agricultural and sustainability challenges, ICP faces several external and internal threats that could significantly hinder its development and long-term viability as a competitive academic research area. A key risk is the persistent lack of stable funding, compounded by insufficient access to modern facilities, equipment and specialized personnel. Many instruments and research infrastructures are outdated, particularly for horticultural field and greenhouse experiments, limiting the potential to conduct cutting-edge experimental research. Cutting-edge crop physiological equipment is not existing. Furthermore, high teaching responsibilities among existing staff exacerbate the difficulty of building a critical mass for research excellence.

The field is also vulnerable to strong competition from well-established research groups and networks, both within SLU and at other Swedish universities and institutes. Organizations with a clearer specialization and greater institutional support, such as HIR and other national research actors, dominate areas that overlap with ICP. As ICP lacks a clearly defined identity and remains relatively unanchored institutionally, it struggles to assert itself in an already crowded research landscape. This threat is intensified by shifts in academic funding policies and political priorities, which are increasingly volatile and may not favour broad, interdisciplinary fields without a strong track record or distinct research focus.

Another pressing concern is the limited attractiveness of ICP to new researchers and students. The field currently suffers from a lack of academic reputation at BT and insufficient visibility within the broader research community. This undermines its ability to attract skilled researchers and doctoral candidates, particularly when more specialized and better-resourced fields offer clearer career pathways. The combination of high teaching loads, limited funding and weak institutional anchoring poses a significant barrier to developing a thriving research environment.

4.5.5 Technology/ Biosystems engineering

Box 5: SWOT analysis: Executive summary for Technology/Biosystems engineering

Strengths

- Strong expertise in modelling, life cycle analysis (LCA) and sustainability methods
- Access to advanced tools and digital simulation platforms
- High relevance to climate resilience and bioeconomy goals
- Interdisciplinary networks and ties to farming stakeholders
- National funding access and growing international visibility

Weaknesses

- Limited researcher base and recruitment challenges
- Underdeveloped integration of social sustainability aspects
- Fragmented collaboration across technological subfields
- Low academic identity in niche agricultural tech areas
- Slow innovation uptake and methodological coherence gaps

Opportunities

- Growing demand for circular and climate-resilient solutions
- Biorefinery and urban farming innovations gaining traction
- Emerging technology (AI, sensors) supports novel applications
- New policy directions may unlock targeted research funding
- Test beds and policy labs can boost applied research output

Threats

- Competition from larger, better-funded research institutes
- Lack of targeted calls for agri-tech infrastructure research
- Talent attrition due to limited career development paths
- Public concerns on ethics may reduce political support
- Risk of research losing relevance without tech integration

This research area encompasses systems analysis and building technology.

Strengths

Systems analysis is a methodologically mature and growing research subgroup, well-established in the academic community. It exhibits strong competence in life cycle assessment (LCA), techno-economic evaluation and systems modelling. The group applies these methods primarily to agricultural biomass production systems and biorefinery approaches, integrating environmental and economic dimensions. Key assets include advanced modelling tools and newly acquired software/hardware, as well as expertise in soil organic carbon modelling and intermediate crop applications, which are now part of national climate strategies. The subgroup has high interdisciplinary integration and strong connections to the farming community, creating potential for impactful applied research. Internationalization is also a strength, given the global relevance of resource efficiency and biorefinery concepts. The ability to assess sustainability and resilience in diversified agricultural systems further enhances its contribution to climate adaptation and circular bioeconomy strategies. The group also has competence in statistical methods, weed management and sustainable crop rotations.

Building technology, while more narrowly focused, presents a unique academic profile through its emphasis on agricultural buildings, a relatively underexplored domain in building research. Strengths lie in building energy efficiency, lighting and indoor climate management, including emissions in stables. Methodologically, the group excels in energy dynamic simulations and integrated digital tool use. Although there is a shortage of senior staff, the unit benefits from standard and advanced analytical tools, enabling in-depth environmental performance assessments. Notably, the group’s research on rooftop greenhouses and energy-efficient stable design has high potential impact in both sustainability and resilience domains. Opportunities for stronger international positioning exist, especially through the integration of horticultural systems and by leveraging the growing global interest in sustainable farming infrastructure.

Both subgroups benefit from a strong interdisciplinary environment and reasonable access to national funding. While systems analysis enjoys deeper international academic integration, building technology shows strong promise for broader international relevance through increased focus on novel applications and stakeholder engagement.

Weaknesses

The technology research area, while possessing significant strengths, faces several structural and methodological challenges that constrain its full academic and societal impact. These weaknesses are apparent in both systems analysis and building technology, albeit with different emphases.

Systems analysis has a primary orientation toward national-scale studies and limited critical mass of researchers pose constraints to its international impact. Social sustainability dimensions are underdeveloped and integration with other technological fields (particularly within building technology) should be strengthened. Recruitment is hindered by a lack of candidates with specialized methodological training.

Building technology suffers from an underdeveloped academic identity, especially concerning agricultural buildings, which are not a central focus in national or international research funding. There is a general lack of senior expertise, compounded by slow hiring processes. Technological innovation is underexploited, with limited modelling capabilities that integrate energy efficiency with sustainability assessments. Strong competition from other departments and research institutes (*e.g.,* RISE) further dilutes its position. Although the field holds promise in areas such as rooftop greenhouses, these topics are not yet well supported structurally or financially.

Overall, both subfields face challenges related to methodological coherence, research integration and resource limitations (especially in building technology) and competence acquisition. These factors collectively hinder the realization of excellence and innovation in this research area.

Opportunities

The technology research area, consisting of systems analysis and building technology, is well positioned to capitalize on a range of emerging trends, interdisciplinary avenues and societal needs. Both subfields have strong potential to contribute meaningfully to sustainability, resilience and innovation within agricultural and environmental systems.

Systems analysis benefits from increasing global attention to the bioeconomy, circularity and sustainable intensification, which creates a demand for advanced, flexible and predictive modelling. The biorefinery approach, in particular, offers transformative potential for diversified domestic production of proteins, plant nutrients and renewable energy. It is, however, dependent on the lead of other departments. Opportunities also lie in bridging the gap between research and implementation by aligning research outputs with innovative machinery systems and practical applications. Alongside the availability of targeted funding in areas such as cropping systems, feedstock processing and biobased product development, further internationalization of the research scope enhances its future impact. Cross-disciplinary collaboration (*e.g.,* building technology and environmental sciences) could enrich holistic sustainability assessments and integrate social, economic and environmental perspectives more fully.

Building technology is uniquely positioned to contribute to the green transition through research on energy-efficient, low-emission agricultural buildings, including advanced animal housing and post-harvest systems. Technological advancements (*e.g.,* AI, sensor technologies) and new building materials offer pathways for innovation within the context of climate adaptation and resource efficiency. Rooftop greenhouses and related systems represent a promising area for cross-sectoral collaboration, with the potential to reduce food loss, improve urban agriculture and enhance preparedness in food systems as well as collaboration across BT. Despite current funding limitations, opportunities may grow within bioeconomy-aligned calls and through strategic partnerships with actors such as

RISE. Establishing policy labs and test beds could further support experimental and applied research in this domain.

Both subfields would benefit from stronger integration, for instance by combining systems analysis with building technology to assess and design resilient infrastructure for diversified production systems. The field as a whole stands to play a critical role in shaping sustainable agriculture and food systems through improved energy use, emission reduction and circular resource flows, while contributing to broader policy and industrial shifts in climate resilience and food security.

Threats

Despite promising areas for development, the technology research area faces several external and internal threats that may limit its long-term impact and competitiveness. These challenges vary between the two subfields, but commonly involve issues of capacity, competition and structural support.

Systems analysis is threatened by a gap between theoretical research and practical implementation, highlighting the need for stronger validation and application frameworks. Although the field is growing, it risks being overshadowed by more established research in forestry, which continues to attract a disproportionate share of national research funding. Competence leakage by staff moving to better-funded and more technologically integrated institutions also poses a threat, especially if investments in methodological innovation are not prioritized.

Building technology is even more vulnerable due to its limited academic size, declining number of researchers and marginalization within both the broader university and external funding bodies. Political and institutional focus on actors like RISE, which benefits from higher salaries, broader expertise and coherent institutional networks as well as extensive technological platforms, intensifies the competition for both talent and visibility. Externally, the lack of targeted research calls for agricultural buildings and the general preference for research in residential or commercial buildings, reduces funding opportunities. Internally, welfare-related controversies concerning animal housing design can challenge public and political support. However, such dilemmas also offer important areas for ethical inquiry and invite for collaboration with other SLU sites and departments. Technological stagnation and limited interdisciplinary integration further weaken the field's ability to adapt to evolving research priorities.

Both subfields face the overarching threat of talent attrition and limited recruitment pipelines, particularly in building technology. While systems analysis is attracting more researchers, the lack of applied technology development may reduce its relevance in innovation-driven contexts. Without strategic investment in novel methodologies, validation infrastructure and collaboration mechanisms, the field risks losing ground to more agile and well-resourced competitors.

4.6 SWOT-pairing consequence analysis

SWOT-pairing is a strategic tool that transforms SWOT analysis from static evaluation into actionable planning. It involves systematically matching internal factors (strengths, weaknesses) with external factors (opportunities, threats) to identify four strategic responses. Strengths x Opportunities (SxO) strategies use strengths to exploit opportunities, enabling proactive growth. Strengths x Threats (SxT) strategies apply strengths to mitigate threats, preserving stability. Weaknesses x Opportunities (WxO) strategies address weaknesses to leverage opportunities, supporting capability development. Weakness x Threats (WxT) strategies aim to minimize weaknesses and avoid threats, ensuring risk containment. This pairing guides to craft targeted responses based on the organization's position and environment. The process promotes a structured approach to aligning capabilities with contextual demands, leading to informed, prioritized strategies. SWOT-pairing is particularly useful in dynamic contexts where both internal readiness and external forces shape outcomes. By translating analysis into direction, it enhances strategic clarity and organizational adaptability.

4.6.1 Agroecology

Box 6: SWOT pairing: executive summary for "Agroecology"

Strengths × Opportunities

- Transdisciplinary approach fits funding trends supporting impact-oriented research
- Participatory methods align with rising demand for inclusive food system innovation
- International networks position SLU to lead in global agroecology partnerships
- Field-based assets (SAFE, Alnarp) ideal for tech integration like drones and sensors
- Alignment with SDGs enhances relevance in climate adaptation and food security

Strengths × Threats

- Niche identity risks dilution by broader fields lacking agroecology's ethical lens
- Participatory methods may be undervalued in traditional academic evaluation systems
- Global relevance may weaken if policy agendas shift away from sustainability
- SLU's interdisciplinary assets risk fragmentation without stronger coordination
- Ethical grounding may be misperceived as ideological, reducing policy influence

Weaknesses × Opportunities

- Low digital capacity can be improved through collaboration with tech-driven units
- Limited visibility in Sweden could be addressed through student-led outreach efforts
- Complexity in methods could attract funding focused on transdisciplinary challenges
- Career uncertainty for students can be mitigated via new networks and internships
- Lack of meta-analysis capacity can be solved via open data and digital tools

Weaknesses × Threats

- Poor digital infrastructure risks falling behind in precision agriculture research
- Fragmentation across departments may hinder creation of a cohesive research agenda
- Low recognition in Sweden could lead to loss of funding and policy engagement
- Difficulty publishing participatory research may reduce academic competitiveness
- Perceived ideological stance could alienate traditional funders and stakeholders

Strengths × Opportunities

Agroecology at SLU is uniquely equipped to capitalize on emerging opportunities thanks to its core strengths. Its transdisciplinary and participatory nature resonates with the evolving priorities of major research funders, who increasingly seek impact-driven, interdisciplinary science. International collaborations and institutional assets like the SAFE and Alnarp farms provide strong platforms for the integration of emerging technologies (*e.g.,* drones, sensors and robotics) into research and education. Moreover, agroecology's alignment with the Sustainable Development Goals (SDGs) enhances its appeal in policy and sustainability discourses, positioning SLU as a potential leader in agroecological innovation and education.

Strategic implication: SLU should intensify efforts to frame agroecology within global innovation narratives and proactively seek leadership roles in transnational partnerships and consortia.

Strengths × Threats

Despite its strengths, agroecology is vulnerable to marginalization. Competing disciplines may attract more visibility and funding while engaging in similar research under broader or more neutral terms like "sustainable food systems." The field's participatory ethos, while methodologically rich, is often at odds with conventional academic performance metrics. Additionally, the ethical framing of agroecology may be misperceived as antagonistic to mainstream agricultural science or technological advancement, limiting its policy and institutional appeal. SLU’s lack of a clearly defined institutional identity in agroecology amplifies this vulnerability.

Strategic implication: Agroecology must actively assert its scientific legitimacy, emphasize its compatibility with innovation and invest in building a cohesive institutional profile.

Weaknesses × Opportunities

Agroecology's current weaknesses, particularly in digital capacity, institutional coherence and national visibility, can be strategically addressed through the field’s strong alignment with opportunity areas. The growing importance of digital agriculture presents a chance to embed technological innovation within agroecological frameworks. Student enthusiasm and academic interest can support visibility campaigns, while the inherent complexity of agroecology may be a strength in the context of funding programs that prioritize systemic, interdisciplinary work. Creating structured internship pathways and career development frameworks can mitigate student uncertainty, while open data strategies can enhance transparency, comparability and scientific influence.

Strategic implication: SLU should leverage cross-departmental and external partnerships to address digital gaps, support student pathways and develop open-data infrastructures.

Weaknesses × Threats

If unaddressed, existing weaknesses may compound the threats facing agroecology. The lack of digital infrastructure may cause the field to lag behind more technologically advanced areas of agricultural research. Organizational fragmentation and the absence of a strategic centre could limit cohesion and effectiveness. Visibility gaps within Sweden risk marginalizing agroecology in national policy and funding contexts. The difficulty of publishing interdisciplinary, participatory research in high-impact journals can undermine academic credibility, while lingering perceptions of ideological bias may further hinder acceptance among policymakers and mainstream academia.

Strategic implication: Proactive institutional development (incl. a centre of excellence, strong internal coordination and communications strategy) is essential to mitigate structural vulnerabilities and protect agroecology's long-term viability.

4.6.2 Animal-Centred Environments

Box 7: SWOT pairing: Executive summary for "Animal-Centred Environments"

Strengths × Opportunities

- Interdisciplinary methods can support new digital welfare tools
- Strong networks enable scaling of ethical, tech-based solutions
- Global engagement aligns with sustainability policy priorities
- Unique teams can lead innovation in biophilic animal housing
- High-impact research fits emerging One Health frameworks

Strengths × Threats

- Policy relevance buffers against shifting political priorities
- Strong ethics may counter public distrust in surveillance tech
- International links reduce isolation in geopolitical crises
- Unique expertise at risk from researcher attrition trends
- Existing legitimacy helps resist competing research agendas

Weaknesses × Opportunities

- Method gaps could be addressed via BT tech collaborations
- Missing facilities may be offset through SLU infrastructure sharing
- Gaps in animal cognition data align with new research frontiers
- Low participatory engagement could improve via ethical farming goals
- Weak standardization invites funding for harmonized solutions

Weaknesses × Threats

- Methodological issues may worsen under funding constraints
- Lack of real-time data may limit response to societal critiques
- Facility shortages impair resilience amid institutional shifts
- Poor communication raises risk of public or policy misalignment
- Barriers to entry may shrink the talent pipeline over time

Strengths x Opportunities

To advance the research field of animal-centred environments, strategic SWOT pairings can effectively guide future research directions. By leveraging its strengths against emerging opportunities (S × O), the field can consolidate its position as a leader in ethical and technologically advanced research. The integration of precision livestock farming (PLF), sensor-based welfare tracking and movement modelling offers strong potential for exploring emotional and behavioural states in diverse production settings. This can be further enriched by linking with frameworks like One Health and agroecology, promoting holistic and sustainable approaches. The field's interdisciplinary teams and strong ethical grounding also position it well to attract funding aimed at digitalization and resilience, while enhancing its influence through global collaboration.

Strengths x Threats

Simultaneously, core strengths can be used to counteract external threats (S × T). Ethical and scientifically rigorous practices can help pre-empt societal scepticism surrounding surveillance technologies and animal monitoring. The field's strong international orientation and established academic legitimacy enable it to weather shifting political priorities and regulatory uncertainties. By leveraging its unique human capital and cross-sector partnerships, the field can mitigate institutional resistance to change, maintaining relevance and adaptability in a volatile research and policy environment.

Weaknesses x Opportunities

To address current weaknesses using emerging opportunities (W × O), the field should prioritize collaborations with technology-focused researchers to overcome limitations in methodology, scaling and technology readiness levels (TRLs). The growing availability of interdisciplinary and impact-driven funding creates space for developing longitudinal, animal-centric research tools that integrate stakeholder perspectives and ethical considerations. Topics such as emotional welfare, ergonomic design and energy efficiency represent underexplored areas that could increase research impact and applicability.

Weaknesses x Threats

Finally, weaknesses can be managed to reduce exposure to external threats (W × T). A lack of dedicated animal facilities, for example, can be addressed through strategic partnerships within SLU, allowing access to shared infrastructure. Resistance to novel methodologies and risks from misinformation may be mitigated by improving interdisciplinary communication and public engagement strategies. Standardizing methodologies and emphasizing ethical transparency will be crucial to maintaining legitimacy in the face of regulatory and societal scrutiny. These adaptive strategies will help ensure the field's sustained contribution to welfare, sustainability and climate resilience goals, even amidst external uncertainty.

4.6.3 Horticulture

Box 8: SWOT pairing: Executive summary for "Horticulture"

Strengths x Opportunities

- Strong infrastructure enables rapid uptake of digital and AI-based horticultural tools
- Advanced methods support innovative systems for climate-smart, low-input production
- International networks can scale impact of circular and resilient food systems research
- Policy engagement enhances capacity to influence sustainability legislation uptake
- Interdisciplinary identity aligns with transdisciplinary funding and global challenges

Strengths x Threats

- High research quality helps counteract marginalization in crop-focused policy shifts
- Global reputation can mitigate risk from competitive pressure by external institutions
- Strategic partnerships offer stability amid volatile national funding priorities
- Relevance to national food security can reduce risk of deprioritization in agendas
- Internal cohesion provides resilience against external fragmentation or shifting trends

Weaknesses x Opportunities

- Gaps in subfields could be addressed via funding in emerging sustainability themes
- Fragmented funding can be leveraged into targeted project-based innovation niches
- Outdated facilities highlight areas for investment through green transition programs
- Weak data sharing could be improved using open science and digital infrastructure calls
- Communication gaps can be tackled with outcome-oriented, participatory research formats

Weaknesses x Threats

- Reliance on short-term funding amplifies risks of policy or priority fluctuations
- Lack of dedicated researchers leaves subfields exposed to long-term skill shortages
- Outdated infrastructure reduces ability to respond to fast-moving tech developments
- Poor integration of subfields weakens systemic approaches to societal challenges
- Limited societal outreach increases vulnerability to public and policy neglect

Strengths × Opportunities

The interplay between existing strengths and external opportunities offers a dynamic pathway for growth and strategic advancement within horticultural sciences at SLU. The field's robust methodological base, including advanced genomic, microbiological and systems-oriented techniques, provides the technical foundation necessary to engage meaningfully with emerging research priorities such as AI-driven crop modelling, digital phenotyping and precision horticulture. The strong food safety focus offers unique possibilities for benchmarking and international collaboration. The research area's scientific depth is complemented by a well-developed infrastructure and access to experimental sites that can support the development and deployment of climate-smart and low-input production systems.

Importantly, the field's strong presence in international networks (*e.g.,* ISHS, EUFRIN, IFOAM) and collaborative ties with world-leading institutions (*e.g.*, Wageningen, Copenhagen) provide conduits for scaling its research globally and increasing its visibility in transnational initiatives. These connections align well with broad-based funding calls under the EU Green Deal, agroecological transition frameworks and global food security initiatives.

Furthermore, horticultural sciences are uniquely positioned to contribute to emerging cross-cutting themes such as circularity, biodiversity and sustainable intensification, especially through areas like cropping systems based on renewable inputs (*e.g.,* peat-free growing media), resource-efficient systems and crop diversification. By aligning its internal capacities with these externally driven agendas, the field can reinforce its role as a thought leader in sustainable agricultural research, while also securing strategic resources for long-term development.

Strengths × Threats

The intersection of strengths and threats presents a dual dynamic: while horticultural sciences at SLU are resilient in many respects, they must remain agile and strategically proactive to mitigate potential risks. One of the major threats is the risk of marginalization due to shifting research and policy priorities that increasingly favour protein-rich or staple crops. However, the field's strong academic output, interdisciplinary scope and societal relevance equip it with a solid foundation to resist such marginalization.

International visibility, bolstered by frequent participation in global forums and strong academic partnerships, acts as a safeguard against external competition. These collaborative ties not only bring prestige but also help ensure continued integration into high-level research agendas. Similarly, horticultural sciences' embeddedness in national policy structures (*e.g.*, collaborations with SJV, SLV, FHM, MSB, AMV) positions it as an active contributor to national resilience and food security and helps insulate the field from short-term political or economic volatility.

Internal strengths such as interdisciplinary identity and cohesive subject leadership further contribute to the field's stability. These assets ensure that even as external environments shift, the core competencies of the field remain aligned with both institutional strategy and broader societal needs. Nevertheless, vigilance is needed to ensure that these strengths are not passively relied upon but actively deployed in strategic decision-making and communication efforts.

Weaknesses × Opportunities

This pairing reveals a particularly productive space for transformation. The weaknesses identified, such as underdeveloped research subfields, aging infrastructure and limited funding streams, can be repositioned as strategic entry points for growth when aligned with the right external opportunities.

For example, emerging policy agendas related to sustainability, green innovation and food system resilience offer new funding opportunities that could support the revitalization of neglected areas like stress physiology, ornamental horticulture and nursery systems. Similarly, fragmented funding structures, while limiting in scope, may incentivize agile and focused research programs that excel within niche innovation spaces, especially when aligned with outcome-oriented research models.

The growing emphasis on open science, participatory research and digital transformation also presents opportunities to modernize internal practices. Strengthening data sharing, increasing reproducibility and adopting digital infrastructure could not only address current process limitations but also enhance transparency and collaborative capacity. Communication shortcomings (*e.g.,* weak outreach; limited public visibility) could be mitigated through strategic investments in science communication, stakeholder engagement and co-creation approaches, particularly in partnership with other BT and LTV departments that excel in these areas.

Weaknesses × Threats

The interaction between weaknesses and threats marks the most critical zone of vulnerability. The most pressing concern is the compounding effect of short-term funding models and political or institutional shifts in research focus. A heavy reliance on project-based grants not only creates instability but also limits strategic continuity and capacity development, especially in light of the consistent, but even more accentuated competition for public and private research resources.

Moreover, the shortage of specialists in key subfields threatens the sustainability of knowledge transfer and disciplinary depth over time. As horticultural sciences span a wide range of areas (from pre- and postharvest physiology to landscape ecology) the risk of bottlenecks or knowledge loss becomes significant in the absence of long-term recruitment and career development strategies.

Infrastructure deficiencies, particularly outdated greenhouses and laboratory instruments, constrain the ability to conduct innovative, technology-driven experiments. This technical lag makes it harder for the field to remain competitive in research areas that depend on cutting-edge facilities, especially those linked to digitalization and AI integration.

Fragmentation between related research themes (*e.g.,* horticultural technology vs. crop physiology) weakens systems-level approaches and reduces the effectiveness of interdisciplinary collaboration. This structural disconnection hinders the field's capacity to generate holistic responses to complex societal challenges such as climate resilience and urban food production. Lastly, weak communication strategies increase the risk of societal and policy invisibility, which may over time reduce the field's access to funding and institutional prioritization.

Proactive strategic planning focused on infrastructure renewal, researcher development, better integration of subfields and enhanced communication is essential to mitigating these compounded risks.

4.6.4 Integrated Crop Production

Box 9: SWOT pairing: Executive summary for "Integrated Crop Production"

Strengths × Opportunities

- High-impact methods can support cutting-edge sustainability research
- Interdisciplinary strength aligns with system-based funding calls
- International networks can amplify strong academic outputs
- Methodological integration matches circular economy research trends
- Strong individual expertise can drive innovation in new tech areas

Strengths × Threats

- High academic rigor can counter reputational risks and competition
- Established methods can mitigate reliance on outdated infrastructure
- Existing collaborations may buffer against volatile funding shifts
- High-impact research can attract scarce funding despite resource limits
- Clear communication skills can address confusion over field identity

Weaknesses × Opportunities

- New funding sources could support modernization of research facilities
- Interdisciplinary projects can help build missing critical mass
- Technological trends may attract external partnerships or investment
- Sustainability focus offers a path to define a clearer research niche
- International calls can boost reputation and attract young researchers

Weaknesses × Threats

- Undefined scope increases vulnerability to competition and funding loss
- Lack of facilities limits ability to respond to technical advancements
- Weak reputation hinders recruitment and training of new researchers
- Fragmented research identity amplifies challenges in policy relevance
- High teaching load restricts strategic focus and research development

The interplay between the identified strengths, weaknesses, opportunities and threats in ICP reveals critical pathways to academic excellence and challenges that must be managed strategically.

Strengths × Opportunities

Strengths paired with opportunities indicate that ICP's well-developed methodological approaches and interdisciplinary expertise provide a solid foundation for advancing sustainability and circular economy research. The research area's potential to international collaborations amplify its academic impact positioning ICP favourably to secure system-oriented funding and participate in cutting-edge innovation. The alignment between ICP's methodological integration and emerging trends in precision agriculture and circular production systems highlights a natural synergy that can enhance research relevance and societal impact. Moreover, strong individual expertise within ICP can facilitate innovation by adopting new technological tools driving further development and recognition.

Strengths × Threats

Conversely, strengths confronted by threats demonstrate that while ICP's academic rigor and potential to collaborations offer resilience against reputational risks and funding fluctuations, these strengths alone may be insufficient. The presence of well-established competing research groups poses a significant challenge, especially for a small team balancing heavy teaching duties. Additionally, although the research methodologies are robust, the outdated physical infrastructure threatens to undermine ICP's ability to remain at the technological forefront. Effective communication is also crucial to dispel confusion around the ICP field's identity, thus maintaining competitive visibility.

Weaknesses × Opportunities

The pairing of weaknesses with opportunities suggests that targeted efforts to secure new funding could address critical gaps such as outdated facilities and insufficient critical mass. Leveraging interdisciplinary projects and emerging technological trends can build momentum to overcome the current fragmentation and elevate ICP's profile. A clear sustainability focus may help define a distinctive niche, enhancing the field's appeal to funders and young researchers. Furthermore, increasing engagement with international funding calls can improve reputation and attract talent, thereby addressing some existing human resource limitations.

Weaknesses × Threats

However, the interaction of weaknesses and threats signals several vulnerabilities that could impede ICP's development. An ill-defined research scope increases exposure to competition from better-established fields. The lack of modern facilities and research equipment limits ICP's responsiveness to fast-evolving methodologies, potentially rendering its outputs obsolete. Weak academic reputation and a heavy teaching burden further hinder recruitment and research capacity building. Fragmentation within ICP risks reducing its policy relevance and overall impact. Addressing these internal challenges is critical to ensure sustainability and growth in a competitive academic landscape.

4.6.5 Technology/ Biosystems engineering

Box 10: SWOT pairing: Executive summary for "Technology/Biosystems engineering"

Strengths x Opportunities

- Systems analysis can leverage growing global interest in bioeconomy and sustainability.
- Advanced modelling tools in systems analysis align with the demand for predictive modelling.
- Building technology's energy-efficient building expertise supports green transition goals.
- Rooftop greenhouses and sustainable infrastructure could be developed with AI and sensor technologies.
- Cross-disciplinary collaboration between systems analysis and building technology fosters sustainable infrastructure design.

Strengths x Threats

- Systems analysis's global relevance in biorefinery could mitigate the risk of being overshadowed by other research.
- Strong interdisciplinary connections in systems analysis may buffer risks of methodological fragmentation.
- The international presence of systems analysis can counterbalance the threat of competition from forestry research.
- Building technology’s expertise in agricultural buildings can address the marginalization within broader building research.
- Interdisciplinary strength in both subgroups can defend against competition from well-funded institutes.

Weaknesses x Opportunities

- The limited international engagement of building technology can be overcome by focusing on sustainable agricultural infrastructure.
- Systems analysis can expand into social sustainability dimensions to align with the growing interest in circular bioeconomy.
- Building technology's lack of senior expertise can be addressed through strategic international partnerships and targeted funding.
- Increased focus on novel applications in energy-efficient buildings can enhance building technology’s international standing.
- Systems analysis can integrate more cross-disciplinary collaboration to address societal challenges in sustainability.

Weaknesses x Threats

- Limited critical mass of researchers in systems analysis could worsen its international impact, compounded by a risk of competence leakage.
- The narrow academic identity of building technology risks declining visibility, especially with strong competition from other institutes.
- Slow recruitment processes in building technology exacerbate the threat of talent attrition and limited growth.
- Underdeveloped technological innovation in building technology limits its capacity to adapt to evolving research priorities.
- Methodological coherence issues in both subgroups may diminish competitiveness, especially in applied research.

Strengths x Opportunities

The field's strengths lie in its methodologically mature research base and capacity for integrated sustainability assessments. Systems analysis demonstrates advanced expertise in life cycle assessment (LCA), techno-economic modelling and environmental systems modelling, while building technology contributes niche but high-potential knowledge in energy efficiency, indoor climate control and low-emission design for agricultural buildings.

These strengths are well aligned with emerging global opportunities. There is increasing policy and societal demand for climate-adaptive, resource-efficient systems, especially in agriculture/horticulture and food production. Global interest in the circular bioeconomy, resilient infrastructure and biorefinery development provides fertile ground for international positioning. The area's strong stakeholder engagement, including ties to farming communities and national policy frameworks, enhances its ability to translate academic outputs into real-world solutions. Advances in digital tools, AI and sensor-based monitoring also provide a technological landscape well-suited for innovation-driven research that builds directly on existing competencies.

Strengths x Threats

The area's internal strengths provide some resilience against significant external threats. Strong methodological foundations and a growing international research network position the field well in the face of rising competition from sectors like forestry or urban sustainability, which currently attract a larger share of funding. Moreover, the ability to conduct integrated assessments combining environmental, economic and technological dimensions supports the development of robust responses to reputational risks, such as debates around food vs. fuel or animal welfare in housing design.

Continued investment in stakeholder engagement, practical validation and international collaborations will be essential to ensure that core strengths remain relevant amid shifting policy landscapes and funding priorities.

Weaknesses x Opportunities

Several internal limitations, such as a fragmented academic identity, limited senior capacity and underdeveloped integration of social sustainability constrain the field's potential. However, these weaknesses can be effectively addressed by aligning with external opportunities and talent recruitment.

For example, current funding streams focused on sustainability, food systems and the green transition offer strategic entry points for building new interdisciplinary collaborations. The development of test beds, policy labs and stakeholder-oriented research environments could compensate for current gaps in infrastructure and applied validation. Furthermore, recruiting strategically in data science, socio-technical systems and digital agriculture could strengthen methodological coherence and broaden the field's appeal to funders and collaborators. In the institutional context, the area lacks links and scientific foundation to the topics and needs critical to horticulture. This needs substantial attention but also inhabits large opportunities for development.

Weaknesses x Threats

The combined effect of internal and external limitations presents significant strategic risks if not addressed. Talent attrition, particularly in building technology and the lack of targeted funding for agricultural infrastructure research weaken the field's ability to sustain long-term growth. Structural marginalization within the university and intense competition from well-resourced institutions (*e.g.,* RISE) further limit visibility and influence. Technological stagnation, limited interdisciplinary integration and weak recruitment pipelines exacerbate these threats.

Without coordinated efforts to enhance institutional support, invest in cross-cutting methodologies and actively cultivate strategic partnerships, both subfields risk falling behind more agile and better-funded competitors. Addressing these challenges is critical for preserving and expanding the field's capacity to shape future sustainable systems.

4.7 Structured analysis through the lens of academic excellence, internationalization, innovation and uniqueness

This chapter provides a strategic assessment of five research areas (Agroecology, Animal-Centred Environments, Horticulture, Integrated Crop Production and Technology/Biosystems Engineering) framed through four critical dimensions: academic excellence, internationalization, innovation and uniqueness. These dimensions serve as guiding criteria for evaluating both the current performance and future potential of each field within SLU's research ecosystem.

The analysis reveals a dynamic landscape marked by methodological rigor, international collaborations and responsiveness to global challenges such as climate change, food security and sustainability. At the same time, it surfaces critical disparities in institutional visibility, infrastructure and thematic coherence across fields. While some areas possess a strong academic identity and clear international recognition, others require sharper strategic positioning and reinvestment to fully realize their potential.

By identifying disciplinary strengths, gaps and opportunities for interdisciplinary integration, this chapter supports evidence-based decision-making at the leadership level. It highlights where targeted investments, capacity building and institutional branding can enhance SLU's academic impact, global engagement and societal relevance. The aim is to inform strategic development toward a more resilient, competitive and mission-aligned research profile.

4.7.1 Agroecology

Box 11: Agroecology through the lens of academic excellence, internationalization innovation and uniqueness

Academic Excellence

- Employs rigorous, mixed-method and participatory research designs
- Aligns with SDGs and SLU's strategic sustainability ambitions
- Utilizes field-based infrastructures like SAFE and Alnarp Farm
- Supports a master's program linking research with student learning
- Faces challenges in high impact publishing due to complexity

Internationalization

- Collaborates with partners in Europe, Latin America and Africa
- Engages with FAO and Agroecology Europe on global initiatives
- Participates in international funding schemes like Horizon Europe
- Emphasizes transdisciplinary methods suitable for global contexts
- Risks dilution as other fields absorb agroecological themes

Innovation

- Integrates systems thinking with stakeholder-driven approaches
- Promotes field-based experimentation and co-created knowledge
- Lacks digital integration in areas like sensors and big data
- Opportunity to link with robotics and precision agriculture
- Challenges in balancing participatory methods with output

Uniqueness

- Combines sustainability with ethics and food sovereignty
- Emphasizes plural knowledge systems-scientific and traditional
- Distinct in connecting science, practice and social justice
- Perceived as ideological or outdated by some stakeholders
- Needs stronger branding to assert identity and relevance

Academic Excellence

Agroecology at SLU demonstrates considerable alignment with contemporary standards of academic excellence. The research is methodologically rigorous, utilizing mixed-methods and participatory approaches that are both empirically grounded and theoretically informed. While challenges remain regarding publication in high-impact journals, partly due to the complexity and contextual specificity of participatory research, the field excels in producing societally relevant, interdisciplinary knowledge that addresses grand challenges related to food systems, biodiversity and sustainability.

Key academic assets include:

- Field-based infrastructures like the SITES Agroecological Field Experiment (SAFE) and Alnarp Agroecology Farm.
- A dedicated master's program that fosters research-based learning and student engagement.
- Contributions to strategic research agendas such as the SDGs and SLU's sustainability goals.

However, the lack of a consolidated institutional strategy and low national visibility constrain its ability to build a cohesive academic identity and attract top-tier researchers and students. Strengthening internal coherence and improving external academic visibility will be crucial for enhancing scholarly output and institutional prestige.

Internationalization

Agroecology at SLU benefits from a robust international orientation, exemplified by:

- Collaborative networks across Europe, Latin America and Africa.
- Engagement with global institutions such as the FAO and Agroecology Europe.
- Participation in international partnerships and funding initiatives, including Horizon Europe.

These linkages position agroecology as a globally relevant field capable of contributing to transnational sustainability agendas, particularly in the Global South. The transdisciplinary and participatory nature of the field further facilitates international collaboration, as it resonates with global development paradigms emphasizing inclusivity and local adaptation.

Nevertheless, the threat of terminological fragmentation, where overlapping research domains address agroecological themes without adopting the term, risks undermining its identity and visibility in global academia. Clearer positioning and strategic branding are essential to maintain leadership in the international agroecological discourse.

Innovation

Agroecology is inherently innovative in both methodological and conceptual terms. It pushes disciplinary boundaries by:

- Integrating systems thinking with stakeholder co-creation.
- Promoting field-based experimentation and transdisciplinary collaboration.

- Addressing innovation not only through technology but also through social, institutional and ecological paradigms.

Digital innovation, however, remains an underdeveloped frontier. While the potential to integrate robotics, sensors, drones and big data is acknowledged, the field currently lacks the infrastructure and frameworks to capitalize on these technologies. Strengthening these capacities presents a critical opportunity for transformative innovation, especially in connecting agroecology with sustainable intensification and precision agriculture.

Moreover, while valuable for deep innovation, the complexity and time demands of participatory research can reduce academic throughput and publication frequency. Overcoming these methodological trade-offs through strategic design and hybrid research models will enhance innovation without compromising scientific integrity.

Uniqueness

Agroecology's most compelling characteristic is its uniqueness in combining ecological sustainability with social justice, food sovereignty and ethical commitments. Unlike conventional agronomic disciplines, agroecology:

- Embeds normative principles (*e.g.,* environmental stewardship, equity).
- Actively bridges science and practice, engaging farmers, policymakers and communities.
- Offers a pluralistic knowledge system, integrating traditional, scientific and local knowledges.

This makes agroecology distinctively positioned to lead transformative food system research. Its emphasis on place-based, participatory experimentation and its grounding in holistic sustainability create a value proposition not easily replicated by adjacent fields.

Nonetheless, perceptions of ideological bias and lack of scalability threaten its credibility. Addressing these challenges through strategic communication, data-driven outcomes and demonstration of compatibility with digital and modern approaches is key to defending its unique academic niche.

4.7.2 Animal-Centred Environments

Box 12: Animal-Centred Environments through the lens of academic excellence, internationalization innovation and uniqueness

Academic Excellence

- Integrates welfare science with digital and environmental research
- Produces high-impact studies with strong ethical orientation
- Supported by major Swedish and EU academic funding bodies
- Balances basic and applied research across key disciplines
- Faces gaps in methods, scaling and long-term infrastructure

Internationalization

- Engaged in global networks for welfare and sustainability
- Contributes to EU and global policy-aligned research goals
- Linked to international frameworks like One Health, One Welfare
- Collaborates with industry and advisory bodies across borders
- Faces risks from geopolitical and funding instability

Innovation

- Employs AI, sensors and modelling for welfare monitoring
- Advances longitudinal and real-time animal data analytics
- Explores new welfare dimensions like cognitive well-being
- Bridges tech with behaviour for future-ready applications
- Constrained by costs, tech readiness and adoption barriers

Uniqueness

- Combines animal welfare with digital and ecological insights
- Features expertise not widely found at SLU or globally
- Explores ethical, perceptual and biophilic animal housing
- Offers novel links to land use, climate and sustainability
- Stands out for normative focus in animal-centred research

Academic Excellence

The field of animal-centred environments at SLU demonstrates a high degree of academic excellence, driven by strong interdisciplinary integration, methodological innovation, and societal relevance. The subject area bridges established disciplines such as animal welfare, behaviour, and movement science with advanced technological domains including computer vision, sensor systems, and environmental monitoring. This convergence enables a rich methodological framework for both basic and applied research addressing the complex needs of animals in agricultural systems.

The field's academic standing is further supported by its ethical foundations and alignment with key policy agendas, including sustainability, digital transformation, and animal welfare legislation. Research is increasingly positioned to inform future-ready livestock systems through scientifically rigorous, welfare-driven approaches. However, structural barriers, such as limited access to nearby dedicated animal research facilities, a lack of long-term infrastructure, and fragmented methodological standards, hinder the full realization of the field's academic potential. Targeted investments in experimental capacity and research continuity will be essential to elevate this emerging domain to its next stage of academic and societal impact.

Internationalization

The field is characterized by a strong international orientation, evidenced by its global academic and industry collaborations and its integration within international regulatory frameworks. This positioning supports both scientific exchange and policy-relevant contributions, particularly considering evolving animal welfare legislation and sustainability agendas.

Participation in cross-border initiatives like regenerative agriculture and connections to broader frameworks such as One Health and One Welfare further reinforce its global engagement potential. While international partnerships are a strength, ongoing threats such as geopolitical instability and shifting policy priorities underscore the importance of proactive engagement with international funding and research agendas.

Innovation

Innovation is a defining characteristic of the field. The integration of digital technologies (*e.g.,* PLF, AI, biometric tools, wearables) enables novel approaches to real-time behavioural monitoring, longitudinal data analysis and the development of dynamic environmental models. These innovations contribute to a more holistic understanding of animal welfare and system sustainability.

Moreover, the field opens underexplored avenues such as biophilic animal housing, human-animal interaction ergonomics and emotional and cognitive dimensions of welfare. Nevertheless, innovation is currently constrained by limited TRLs, cost barriers and low adoption rates of novel technologies within the agricultural sector.

Uniqueness

The field's distinctiveness lies in its interdisciplinary teams and research topics that are not widely represented either within the SLU or globally. Its unique interface between animal science, environmental monitoring and technological innovation enables contributions to areas such as climate resilience, ethical farming and land use sustainability.

The emphasis on animal perception, ethical considerations and participatory methods, although still underdeveloped, adds a normative and humanistic dimension rarely found in adjacent domains. While there is no immediate competition from neighbouring fields, the continued distinctiveness of the research area depends on its ability to align with national strategies and clearly articulate its value proposition in global academic and policy discourse.

4.7.3 Horticulture

Box 13: Horticulture through the lens of academic excellence, internationalization innovation and uniqueness

Academic excellence

- Methodological sophistication: advanced techniques, for fundamental and applied research at the cutting edge.
- Strong access to advanced infrastructure supports high-quality experimentation and empirical rigor.
- solid publication record with high citation rates and frequent contributions to top-tier journals.
- Active participation in national policymaking bodies

Internationalization

- Active participation in collaborative networks alongside formalized partnerships with top institutions
- International visibility and exchange through engagement in international programs, joint PhD supervision, frequent keynote
- Success in securing EU and international grants reflects recognition beyond national boundaries and aligns with broader research agendas.

Innovation

- Integration of biology, technology and socioeconomics facilitates novel approaches to complex challenges
- Emphasis on emerging areas (*e.g.,* circularity in horticulture, cropping systems based on renewable inputs and AI-enabled crop modelling
- Research themes align closely with pressing global challenges

Uniqueness

- Strategic national role: addresses Sweden's low self-sufficiency in food and supports the development of resilient, sustainable production systems as well as food safety in horticultural commodities
- Institutional anchoring with a unique space within SLU's academic structure, a strong interdisciplinary identity
- Broad societal contribution (edible and ornamental plant research) extending beyond conventional agricultural roles.

Academic excellence

The academic field of horticultural sciences at SLU demonstrates a high degree of academic excellence, driven by methodological depth, strong infrastructure and societally relevant research. The subject area employs a broad array of advanced and integrative methodologies, including metagenomics, transcriptomics, enzymatic and phenotypic profiling, as well as aquaponics and light environment studies (physiological, ecological), that enable high-quality research across both fundamental and applied domains. These approaches are complemented by a well-established infrastructure comprising BSL2/3 laboratories, isotope facilities, photosynthesis instrumentation and experimental sites such as SITES and Trädgårdslabbet. Moreover, the field's capacity to generate high-impact outputs is evident in its robust publication record, high citation rates and consistent contributions to internationally recognized journals. Research is not only academically rigorous but also highly aligned with national and global policy agendas, as evidenced by active engagement with governmental agencies and policy institutions. Nonetheless, academic excellence is moderated by structural challenges, including limited long-term funding, gaps in certain subfields (such as ornamental horticulture and stress physiology) and outdated equipment in some areas. These limitations suggest the need for strategic reinvestment to fully realize the field's potential.

Internationalization

In terms of internationalization, horticultural sciences at SLU are firmly embedded within a global network of academic and professional collaboration. The field maintains active involvement in prominent international platforms such as the International Society for Horticultural Science (ISHS), EUFRIN, EUVRIN and IFOAM, which enhances visibility and facilitates cross-border knowledge exchange. Collaborations with leading institutions (including, but not restricted to Wageningen University, Copenhagen University, Université Laval, Humboldt University, Free University Berlin, Free University Brussels) reflect both the field's reputation and its strategic commitment to academic mobility. International engagement is further reinforced through ERASMUS exchanges, joint PhD programs and regular participation in high-level conferences, often as invited speakers. These activities not only foster academic diplomacy but also help position horticultural sciences as a key contributor to global research efforts in food and nutrition security incl. food safety, sustainability and climate resilience. While the internal environment is supportive, increasing external competition from other research institutions selectively investing in horticulture underscores the importance of maintaining a proactive international profile and deepening existing alliances.

Innovation

Innovation is a defining characteristic of the field, underpinned by a systems-oriented, interdisciplinary approach to solving complex societal and environmental challenges. Research themes such as sustainable production systems, water efficiency, climate adaptation, crop diversification and sensor-based food safety management in rural and urban settings considering various levels of scale and system management approaches, illustrate the subject's responsiveness to emerging global priorities. The field is particularly well positioned to lead innovation in areas such as circularity in horticulture, production systems based on renewable inputs and the integration of low-input methods. Moreover, there is considerable potential to leverage digital transformation, particularly AI, data-driven modelling and precision horticulture technologies, to develop smarter and more adaptive horticultural systems. The combination of technological capacity and sustainability focus gives horticultural sciences a competitive edge in contributing to agroecological transitions and green innovation frameworks. However, realizing this potential depends on resolving current limitations, including the fragmentation between sub-disciplines (notably between horticultural technology and plant physiology) and the need to modernize experimental facilities. Addressing these constraints through targeted investment would enable more holistic, systems-level innovation.

Uniqueness

Finally, horticultural sciences at SLU possess a distinct uniqueness within both the university and the broader national research landscape. The field plays a strategic role in addressing Sweden's low food self-sufficiency and contributes directly to the resilience and sustainability of local food systems, especially through research on fruit, vegetables, ornamentals and landscape plants. As the second-largest branch of area-based crop production in Sweden, horticulture has unique relevance to both human nutrition and climate adaptation. Within SLU, the field maintains a singular position in terms of its interdisciplinary identity and strategic anchoring within the LTV faculty, with no competing internal subject areas. This uniqueness is further reinforced by strong internal cohesion and integration with other biological and technical disciplines. However, the field's distinct value risks being obscured by shifting research agendas that increasingly favour protein and staple crops. Additionally, there is a need to more assertively communicate horticulture's societal contributions, especially in urban greening, biodiversity and sustainable food production, to ensure its continued visibility and relevance in policy and research funding contexts.

In conclusion, horticultural sciences at SLU stand out as a research area characterized by academic depth, international engagement, innovative capacity and a uniquely strategic role in addressing both national and global challenges. To further strengthen its position, the field would benefit from targeted investments in infrastructure, expanded funding pathways and enhanced communication strategies that more effectively convey its relevance and transformative potential.

4.7.4 Integrated Crop Production

Box 14: Integrated Crop Production through the lens of academic excellence, internationalization innovation and uniqueness

Academic Excellence

- High-impact publications possible when research is well-defined
- Rigorous, interdisciplinary methods support scientific quality
- Ethical standards and system thinking enhance research integrity
- Academic output limited by staff shortages and teaching load
- Undefined scope weakens strategic focus and research excellence

Internationalization

- Strong thematic fit with global sustainability and food security goals
- Opportunities for EU and international research collaboration exist
- Field alignment with international policy priorities is promising
- Weak institutional visibility hinders global recognition
- Lacks anchoring in global academic networks and consortia

Innovation

- Integration of methods supports systems-based innovation potential
- Precision tech offers new tools for field and greenhouse applications
- Cross-application of horticultural tech to ag systems is promising
- Outdated equipment and funding gaps constrain innovation capacity
- Broad scope dilutes focus needed for strong innovation outcomes

Uniqueness

- Integrated crop production lacks a clearly defined, distinctive research identity
- Agricultural-horticultural integration is not a novel concept
- Missing postharvest scope weakens system-level distinctiveness
- Overlap with existing fields reduces perceived originality
- Needs sharper thematic framing to stand out academically

Academic Excellence

ICP demonstrates a solid foundation for academic excellence. It benefits from rigorous methodological approaches, interdisciplinary collaboration and adherence to high ethical standards. Potential publications in high-impact journals highlight the academic relevance of the field when well executed. However, several limitations hinder the realization of sustained excellence. These include a lack of critical mass, insufficient access to modern research infrastructure and a high teaching burden, which together constrain the capacity to maintain competitive research output. Furthermore, the absence of a clearly defined research scope limits the strategic alignment necessary for developing a robust academic profile.

Internationalization
ICP holds substantial potential for international collaboration, particularly through EU-funded initiatives and alignment with global sustainability goals. The thematic relevance of ICP to pressing global challenges (*e.g.,* food security, climate adaptation and sustainable intensification) positions it well for transnational research agendas. Nonetheless, this potential is not yet fully realized due to limited institutional anchoring, a fragmented research identity and insufficient visibility in international networks. Without clearer specialization and stronger branding, ICP may struggle to establish itself as a preferred partner in competitive international collaborations.

Innovation
The integrative nature of ICP provides a platform for methodological and applied innovation. Especially when supported by digital tools and precision technologies, combining established practices such as intercropping and crop rotation within broader systems frameworks creates opportunities for new insights and applications. There is also promise in applying technological advances across horticultural and agricultural domains. However, the field's innovation capacity is tempered by the lack of advanced facilities, funding gaps and limited ability to develop new research methodologies internally. Innovation may also be constrained by the field's broadness, which risks diluting focus rather than sharpening it.

Uniqueness
At present, ICP lacks a clearly articulated unique value proposition. Although conceptually appealing the integration of agricultural and horticultural systems is neither new nor inherently distinctive unless paired with clearly defined and original research questions. The absence of the postharvest dimension, an integral part of horticultural systems, further limits the field's ability to offer a comprehensive and distinctive research agenda. Without greater thematic specificity and strategic positioning, the perceived uniqueness of ICP remains low both nationally and internationally, especially when compared with more focused or specialized research areas.

Thus, this analysis highlights the need for strategic investment, clearer thematic focus and institutional support to strengthen ICP's position across these four academic dimensions.

4.7.5 Technology/ Biosystems Engineering

Box 15: Technology/biosystems engineering through the lens of academic excellence, internationalization, innovation and uniqueness

Academic Excellence

- Systems analysis excels in life cycle assessment and techno-economic evaluation.
- Building technology demonstrates expertise in energy dynamics and climate management.
- Strong interdisciplinary integration with farming and environmental sciences.
- Research in sustainability and resilience contributes to agricultural systems' advancement.
- Methodological maturity in both subgroups, though limited by researcher capacity.

Internationalization

- Systems analysis holds global relevance in bioeconomy and sustainability.
- Building technology's focus on agricultural infrastructure has growing international appeal.
- Opportunities for international collaborations in sustainability and climate adaptation.
- Limited global engagement in building technology due to niche focus on agricultural buildings.
- Systems analysis needs broader internationalization to enhance global research impact.

Innovation

- Advanced modelling tools and software enhance systems analysis capabilities.
- Energy dynamic simulations drive innovation in energy-efficient agricultural buildings.
- Research in rooftop greenhouses contributes to urban agriculture innovation.
- Technological innovation in building design underdeveloped, limiting impact.
- Cross-disciplinary collaboration could amplify innovative solutions in both fields.

Uniqueness

- Systems analysis offers unique expertise in biorefinery and agricultural sustainability.
- Building technology is distinct for its focus on agricultural buildings and resilience.
- Niche focus on sustainable, energy-efficient agricultural infrastructure stands out.
- Systems analysis' methodological approaches are unique but need broader application.
- Agricultural building research lacks academic identity, limiting visibility and impact.

Academic Excellence
The technology research area demonstrates robust academic excellence through its methodological sophistication and thematic relevance. Systems analysis is well-established with recognized competence in life cycle assessment, techno-economic evaluation and systems modelling. It contributes significantly to sustainability research, especially in biomass production and biorefinery systems and plays a strategic role in national climate agendas. Although building technology is more narrowly focused, it offers rigorous expertise in energy performance, indoor climate control and environmental simulations specific to agricultural infrastructure. Together, these subfields support high-quality, interdisciplinary research outputs relevant to both scientific advancement and applied problem-solving in agri-environmental contexts. The horticultural context however needs substantial attention.

Internationalization
The field exhibits meaningful international engagement, particularly through systems analysis, which operates within globally relevant frameworks tied to resource efficiency, circular economy and climate adaptation. Ongoing participation in EU-funded projects and cross-border collaborations further enhances its international visibility. Building technology currently lags in this regard but holds untapped potential for international growth through emerging themes such as sustainable food systems, urban agriculture and climate-resilient infrastructure. Future opportunities exist to increase global relevance through policy-oriented collaboration, shared testbeds and integration into international research networks addressing sustainability transitions.

Innovation
Innovation capacity is evident across both subfields, with systems analysis leading in predictive modelling, environmental impact assessment and design of resilient agricultural systems. Its work on biorefineries and circularity contributes to transforming agricultural inputs into diversified, low-carbon outputs. Building technology shows strong innovation potential in smart infrastructure, energy-efficient stable design and digital monitoring systems, though these are currently underexploited. Greater integration of sensor technologies, AI and new materials offers avenues for novel applications. Combined, the area has the capacity to shape sustainable practices in food production and rural infrastructure through scalable, research-driven solutions.

Uniqueness
The distinctive value of the technology research area lies in its integration of systems-level modelling with applied agricultural infrastructure design, an

uncommon but strategically important combination. While systems analysis offers deep methodological tools for assessing sustainability, building technology introduces a rare academic focus on agricultural buildings, which remain underrepresented in the broader built environment discourse. This pairing provides a unique platform for developing holistic approaches to sustainability, bridging production, infrastructure and policy in the context of food security and environmental resilience.

5. Assessments of consequences and risks

The assessment of risks was based on the output from the SWOT analysis and conducted for each of the five key areas. The key areas were ranked from the perspective of the SWOT-pairing and screening for academic excellence, internationalization, innovation and uniqueness, as particularly highlighted in the Swedish Government's research proposition 2024/2025. The ranking was performed for a short-term (1.5 years) and long-term (15 years) perspective where the short-term lens was selected regarding the next Quality and Impact evaluation at SLU and the long-term lens for the anticipated duration of the new organization, i.e. until the next reorganization. The 15-year-perspective needs to be treated cautiously, as these outcomes are based on the input at one specific point in time and do not consider changes and developments that occur overtime, within the discipline and key area as well as in the surrounding society, legislation and policy decisions. It does not take into account new allocations in infrastructure or dynamics in research area specific funding. It thus offers a tool to proactively achieving organizational and discipline goals.

5.1 Assessment through the lens of the SWOT-pairing

The assessment of consequences and risks is presented in a grid with three scores: low (1, green), moderate (2, orange) and high (3, red) for either their probability to occur and impact. Five combinations with decreasing significance were identified, namely (i) critical, (ii) significant, (iii) manageable, but recurrent, (iv) closely monitored and (v) low priority issues.

Table 5. Definition of risk classes (Prob=Probability)

Prob	Impact	Risk class		Definition
		High probability, high impact risks	Critical	These risks represent urgent challenges that are both likely to materialize and potentially damaging to the field's long-term development. They demand immediate strategic attention
		Moderate Probability, High Impact Risks	Significant	These risks are moderately likely to occur but would have a significant impact if realized. They should be closely monitored and actively managed.
		High Probability, Moderate Impact Risks	Manageable, but recurrent	These risks are highly likely to arise but, while serious, tend to have localized or recoverable impacts. They require responsive but not necessarily structural interventions.
		Moderate Probability, Moderate Impact Risks	Monitor closely	These risks should be observed regularly to ensure that they do not escalate. Mitigation may be achieved through incremental adjustments rather than comprehensive strategy shifts.
		Low probability, moderate impact risks	Low priority	These risks are unlikely but should still be acknowledged, especially if the internal or external environment changes.

Risk matrices for strategic planning are presented in a short- and a long-term perspective.

5.1.1 Agroecology

SWOT Pairing	Consequence / Risk	Probability	Impact
S × O	Missed opportunity to lead international agroecology networks		
	Failure to integrate digital tools into research platforms		
	Underuse of participatory strengths in funding applications		
	Inability to scale SAFE and Alnarp assets for global innovation		
	Insufficient emphasis on SDG alignment in institutional strategy		
S × T	Dilution of agroecology identity by broader sustainability discourses		
	Devaluation of participatory methods in traditional academic publishing		
	Marginalization due to shifting policy/funding priorities		
	Internal fragmentation limits strategic positioning		
	Ethical framing misperceived as ideological, limiting credibility		
W × O	Failure to capitalize on digitalization partnerships		
	Inadequate response to student interest lowers recruitment potential		
	Missed chance to align complex methods with interdisciplinary funding calls		
	Lack of internship and career paths discourages student retention		
	Limited data openness hinders research comparability and impact		
W × T	Technological lag leads to declining scientific competitiveness		
	Organizational fragmentation hinders coordinated responses to threats		
	Continued invisibility within Sweden reduces policy influence		
	Persistent publication challenges affect academic legitimacy		
	Perceived ideology discourages engagement from funders and policymakers		

1. **High-Probability, High-Impact Risks (Critical)**
    - **Dilution of identity**
      Agroecology at SLU faces vulnerability from identity dilution within broader sustainability discourses. Competing frameworks risk overshadowing agroecology's distinct methodological and ethical foundations.
    - **Technological lag**
      Simultaneously, a technological lag, especially in adopting digital tools, threatens scientific competitiveness and future funding eligibility.
    - **National invisibility**
      Additionally, national invisibility limits influence over Swedish policy and funding mechanisms, exacerbating the risk of institutional marginalization. Without coordinated action, these risks could significantly hinder agroecology's strategic growth.

2. **Moderate-Probability, High-Impact Risks (Significant)**
    - **Failure to integrate digital innovation**
      The failure to integrate digital innovation, despite available partnerships and infrastructure, poses a missed opportunity to modernize agroecological research and education.
    - **Marginalization due to shifting policy and funding priorities**
      Similarly, marginalization due to shifting policy and funding priorities is a growing concern, especially without active engagement in national and European research agendas.
    - **Insufficient emphasis on SDG alignment**
      Insufficient emphasis on SDG alignment in institutional strategies may further reduce global relevance and access to transnational funding streams.

3. **High-Probability, Moderate-Impact Risks (Manageable but Recurrent)**
    - **Participatory and interdisciplinary methods**
      A high probability exists that the participatory and interdisciplinary methods core to agroecology may be undervalued in conventional academic publishing. This limits visibility in high-impact journals and poses a reputational risk, even if its direct impact on funding or partnerships is moderate.
    - **Organizational fragmentation**
      Additionally, organizational fragmentation without stronger internal coordination may hamper SLU's ability to scale initiatives or present a unified research agenda.

4. **Moderate-Probability, Moderate-Impact Risks (Monitor Closely)**
    - **Internal fragmentation**

There is a moderate risk that internal fragmentation will persist, weakening cross-departmental synergies and reducing the field's institutional coherence.

- **Ideological bias**
  Likewise, continued perceptions of ideological bias may discourage engagement from certain funders or policy actors. Although not catastrophic, these risks cumulatively erode agroecology's credibility and access to broader networks.

5. Low-Probability, Moderate-Impact Risks (Low Priority)

- **Underused participatory strength**
  Less urgent, but still relevant is the underuse of participatory strengths in grant applications. While the probability is low, failure to fully leverage these methods may reduce competitiveness in interdisciplinary funding calls. The impact is moderate, particularly in positioning SLU as a leader in transformative research.

5.1.2 Animal-Centred Environments

SWOT Pairing	Consequence / Risk	Probability	Impact
S × O	Missed opportunity to lead in digital animal welfare innovation		
	Underutilized global networks for sustainable impact		
	Failure to align with policy trends (*e.g.,* One Health)		
	Lack of follow-through on biophilic housing innovations		
	Limited scaling of high-impact research due to inaction		
S × T	Researcher loss weakens unique human capital		
	Public backlash to surveillance tech undermines ethics narrative		
	Policy shifts deprioritize animal welfare frameworks		
	Reduced global cooperation due to geopolitical instability		
	Erosion of field legitimacy by faster-growing adjacent disciplines		
W × O	Lack of tech-readiness prevents capitalizing on funding calls		
	Infrastructure limits collaboration and project execution		
	Slow uptake of participatory and cognitive welfare methods		
	Failure to standardize methods loses credibility and funding		
	Poor integration of new interdisciplinary partnerships		
W × T	Methodological flaws worsen under financial constraints		
	Inability to provide real-time data hurts legitimacy		
	Facility shortages hinder adaptability and long-term growth		
	Poor communication exacerbates public/policy distrust		
	Entry barriers discourage new researchers and reduce innovation		

1. High-Probability, High-Impact Risks (Critical)

- **Methodological and infrastructure gaps**
  The absence of standardized methods and limited access to appropriate research facilities pose major constraints. These weaknesses undermine the

field's ability to respond to digitalization and sustainability-focused funding calls, risking scientific stagnation.

- **Financial constraints amplifying weaknesses**
  Persistent funding limitations are likely to deepen existing methodological flaws, particularly in relation to the adoption of advanced technologies and real-time data systems. This undermines research credibility and limits influence on policy and public discourse.

2. Moderate-Probability, High-Impact Risks (Significant)

- **Ethical and public trust risks**
  Surveillance-based welfare technologies may provoke ethical concerns if not paired with transparent, participatory approaches. Public backlash could undermine the field's moral authority and derail implementation efforts.
- **Lack of method standardization and real-time responsiveness**
  Inconsistent welfare metrics and limited data agility may reduce scientific legitimacy, particularly in fast-evolving policy contexts. This can lead to missed opportunities in regulation and public funding alignment.

3. High-Probability, Moderate-Impact Risks (Manageable but Recurrent)

- **Infrastructure and collaboration bottlenecks**
  Ongoing facility shortages and fragmented infrastructure limit the capacity to execute interdisciplinary or large-scale projects, slowing progress and weakening global competitiveness.
- **Talent pipeline challenges**
  Barriers to entry for early-career researchers, such as technical demands, unclear career pathways and limited mentorship, may diminish innovation and continuity, which in turn affects the long-term resilience of the field.

4. Moderate-Probability, Moderate-Impact Risks (Monitor Closely)

- **Slow uptake of emerging welfare approaches**
  The delayed integration of participatory and cognitive welfare methods limits the field's relevance to contemporary societal and scientific concerns, diminishing its adaptive potential.
- **Underutilization of interdisciplinary partnerships**
  Coordination challenges reduce the effectiveness of collaborations, restricting knowledge exchange and hindering the field's ability to shape cross-sector innovation agendas.

5. Low-Probability, Moderate-Impact Risks (Low Priority)

- **Geopolitical and policy volatility**

Although less likely, international instability or a shift in policy priorities could deprioritize animal welfare research, restricting global cooperation and diminishing the field's visibility in sustainability frameworks.

5.1.3 Horticulture

SWOT Pairing	Consequence / Risk	Probability	Impact
S × O	Underutilization of international networks and policy engagement		
	Delayed adoption of digital and AI tools despite infrastructure readiness		
	Internal research cohesion not fully leveraged for transdisciplinary funding		
S × T	Marginalization of horticulture due to focus on protein/staple crops		
	External competition from institutions with selective horticultural focus		
	Volatile public/political support affecting funding stability		
W × O	Subfield gaps left unaddressed due to misaligned funding priorities		
	Missed funding linked to digital transformation and sustainability programs		
W × T	Lack of succession planning in vulnerable or solo-subfield areas		
	Aging infrastructure limiting access to high-tech experimentation		
	Fragmentation between subfields weakening systemic solutions		
	Ineffective communication reducing societal/policy influence		
	Project-based funding structure limits long-term strategic research		
	Failure to reposition horticulture within broader food security narratives		

1. High-Probability, High-Impact Risks (Critical)

- **Volatile funding and political shifts**
  The field's dependency on fragmented, short-term and project-based funding makes it highly vulnerable to fluctuations in national and EU

research agendas. As political priorities shift (*e.g.,* protein crops or tech-centric innovation while maintaining an action leverage perspective) horticultural sciences may struggle to maintain consistent funding, jeopardizing strategic continuity and staffing. The impact on research depth and programmatic coherence is potentially severe.

- **Lack of succession in specialist subfields**
  Several research areas are maintained by single or very few individuals, creating critical knowledge continuity risks. As these individuals approach retirement or leave academia, the lack of succession planning poses a high likelihood of knowledge loss and capability gaps, especially in ornamental plant research, stress physiology and nursery systems.
- **Project-based funding undermines strategic focus**
  Reliance on multiple small-scale grants limits the ability to pursue ambitious, long-term goals. High administrative overhead and lack of strategic alignment between projects can dilute the subject area's impact and reduce its attractiveness to early-career researchers and strategic partners.

2. Moderate-Probability, High-Impact Risks (Significant)

- **Marginalization due to shifts toward protein and staple crops**
  As national and international research frameworks increasingly prioritize protein security and staple crop systems, there is a risk that fruit, vegetable and ornamental research will receive less attention. If horticultural sciences are not effectively framed within the broader context of food and nutritional security, their strategic value may be underestimated.
- **Fragmentation between subfields weakens systems innovation**
  The current disconnection between horticultural technology, physiology and systems modelling impedes interdisciplinary solutions. Without integration, the ability to address complex sustainability challenges holistically (*e.g.,* circularity, climate adaptation or biodiversity) is compromised.
- **Ineffective communication reduces visibility and influence**
  The field has yet to fully adapt to modern outreach expectations. Without proactive, outcome-oriented and participatory communication strategies, horticultural research may fail to resonate with policymakers, funders and the public, which leads to underutilization and reduced funding prospects.
- **Failure to reframe horticulture in broader food and nutrition security narratives**
  Horticulture's role in food system resilience, nutrition and urban sustainability is not always recognized in mainstream agricultural discourse. If these contributions are not strategically articulated, the

subject risks being left out of cross-sectoral policy and funding opportunities.

3. High-Probability, Moderate-Impact Risks (Manageable but Recurrent)

- **External competition from institutions with targeted horticulture focus**
  While SLU is a leader in horticultural sciences, other universities (especially in Europe) are developing niche excellence in selected horticultural topics. This increases competition for both funding and global visibility. Strategic partnerships and clear value propositions will be essential to stay competitive. Other European countries invest into research structures for solving pressing horticultural obstacles; Sweden's reluctance to recognize and invest into such potential may leave Swedish horticultural research behind.
- **Aging infrastructure limits competitiveness in technological research**
  Many of the field's experimental facilities, incl. greenhouses and lab instrumentation, are not state-of-the-art. This limits the capacity to attract collaborative partners or conduct cutting-edge digital and climate-smart research, even where conceptual or methodological expertise is strong.

4. Moderate-Probability, Moderate-Impact Risks (Monitor Closely)

- **Underutilization of international networks and policy engagement**
  While the field is well connected internationally, there is a risk that these relationships are not fully leveraged for strategic influence, joint funding applications or long-term positioning. Strengthening structured partnerships and integrating them into institutional strategy would improve impact.
- **Missed opportunities in digital and green transition funding**
  There is significant alignment between horticulture and emerging digital, climate and sustainability research themes. If the field does not actively pursue these opportunities through repositioning, consortia building or proposal writing it may miss out on critical funding and innovation potential.

5. Low-Probability, Moderate-Impact Risks (Low Priority)

- **Delayed adoption of innovation despite strong infrastructure**
  Although infrastructure is sufficient to support digital transitions, institutional inertia or lack of technical personnel may delay the adoption of innovations like AI or automation. This could cause temporary setbacks in competitiveness, particularly in grant applications or industry collaborations.

- **Underleveraged interdisciplinary identity for funding appeal**
  The field's strong internal cohesion and interdisciplinary orientation are valuable assets. If these strengths are not strategically framed to respond to complex challenge-based funding calls (*e.g.,* One Health, resilience, circular economy), the field may fail to fully exploit its competitive advantages.

5.1.4 Integrated Crop Production

Consequence / Risk	**Probability**	**Impact**
1. Competition from well-established research groups limiting growth		
2. Insufficient funding restricting modernization of facilities		
3. Fragmented research scope weakens ICP's academic and policy impact		
4. Heavy teaching loads reduce time for research development		
5. Weak academic reputation deters recruitment of skilled researchers		
6. Rapid technological advancements risk obsolescence of current methods		
7. Confusion over ICP identity limits funding and stakeholder support		
8. Potential neglect of crop diversity in favor of commodity crops		
9. Limited critical mass reduces capacity for innovation and specialization		
10. Lack of interdisciplinary harmonization weakens collaboration potential		

1. High-Probability, High-Impact Risks (Critical)

- **Competition with well-established research groups**
  ICP faces severe strategic threats from competition with well-established research groups, which can limit its ability to attract funding and visibility. The small team size in combination with limited institutional support exacerbates this challenge.
- **Insufficient funding for infrastructure modernization**
  Outdated facilities hinder methodological progress and weaken the capacity to meet emerging scientific standards. Similarly, the lack of critical mass restricts specialization and limits ICP's ability to form competitive, innovative research clusters. This undermines both research output and collaborative potential.

2. Moderate-Probability, High-Impact Risks (Significant)

- **Fragmented research scope**
  A fragmented research scope poses a substantial threat by diluting ICP's identity, weakening policy relevance and hampering its ability to present a coherent value proposition to funders.
- **Weak academic reputation**
  Likewise, a weak academic reputation diminishes ICP's attractiveness to top researchers and collaborators. This makes it difficult to build a robust talent pipeline. Also, it undermines efforts to expand research capacity and limits long-term strategic growth.

3. High-Probability, Moderate-Impact Risks (Manageable but Recurrent)

- **Heavy teaching load**
  Heavy teaching loads are a persistent issue that significantly reduces the time available for research development, grant writing and collaboration. While not as immediately damaging as other risks, the cumulative impact on productivity and staff morale is considerable and can hinder institutional growth over time.
- **Aging Infrastructure Limits**
- **Competitiveness in technological research**
  Many of the field's experimental facilities, especially greenhouses and lab instrumentations, are not state-of-the-art. Advanced instruments for cutting-edge studies in integrated crop production is absent. This limits the capacity to attract collaborative partners or conduct cutting-edge digital and climate-smart research, even where conceptual or methodological expertise is strong.

4. Moderate-Probability, Moderate-Impact Risks (Monitor Closely)

- **Technological obsolence**
  The risk of technological obsolescence arises from the rapid pace of innovation in precision agriculture and data-driven research. While ICP's broad crop focus offers some resilience, the absence of updated infrastructure makes it increasingly difficult to adapt.
- **Confusion over ICP's identity**
  Similarly, confusion over ICP's field identity may limit recognition in interdisciplinary funding calls, reducing its competitiveness.
- **Potential crop diversity neglect**
  The potential neglect of crop diversity as funding shifts toward commodity systems also threatens ICP's integrated systems approach, although this risk is contextual and policy-dependent.
- **Limited interdisciplinary harmonization**

Finally, limited interdisciplinary harmonization continues to inhibit the formation of cohesive research initiatives, weakening the collaborative appeal of ICP in large consortia.

5. Low-Probability, Moderate-Impact Risks (Low Priority)

This category currently presents no significant risks identified as low in probability and moderate in impact, suggesting that the most pressing threats to ICP are concentrated in more probable and impactful areas requiring immediate strategic attention.

5.1.5 Technology/Biosystems Engineering

Consequence / Risk	Probability	Impact
Methodological coherence issues weakening competitiveness in applied research		
Rooftop greenhouses benefiting from AI and sensor technologies		
Cross-disciplinary collaboration fostering sustainable infrastructure		
Interdisciplinary strength defending against competition from institutes		
Systems analysis leveraging global bioeconomy interest		
Advanced modelling tools aligning with demand in *systems analysis*		
Systems analysis being overshadowed by forestry research		
Interdisciplinary connections in *systems analysis* mitigating fragmentation		
Systems analysis expanding into social sustainability		
Systems analysis facing competence leakage due to limited critical mass		
Cross-disciplinary collaboration addressing societal sustainability in *systems analysis*		
Building technology contributing to green goals		
Building technology's expertise in agricultural buildings mitigating marginalization		
Interdisciplinary strength defending against competition from institutes		
Building technology overcoming limited international engagement		
Building technology addressing senior expertise gap with partnerships		
Novel applications enhancing *building technology's* international standing		
Building technology's narrow academic identity causing visibility decline		
Slow recruitment processes in *building technology* leading to attrition		
Underdeveloped technological innovation limiting *building technology* adaptation		

1. High Probability – High Impact Risks (Critical)

- **Limited critical mass and competence leakage**
  The limited critical mass in Systems analysis coupled with the risk of competence leakage poses a serious threat to its international visibility and ability to retain key expertise.
- **Liability issues in advanced modelling tools**
  While the use of advanced modelling tools aligns well with demand, dependency on this strength becomes a liability if not continuously supported through infrastructure investment and skill renewal. Finally, the opportunity for cross-disciplinary collaboration addressing societal sustainability also entails risk if not institutionalized, given its importance to the group's relevance.

2. Moderate Probability – High Impact Risks (Significant)

- **Concurrent research areas with higher political and thus funding support**
  The risk of systems analysis being overshadowed by forestry research, which receives greater funding and political support, could dilute its influence unless it continues to diversify and globalize its research focus.
- **Building technology's narrow academic identity**
  Similarly, building technology's narrow academic identity, if unaddressed, may lead to long-term visibility decline. Promising but under-leveraged areas (*e.g.,* novel applications in building technology) could remain underdeveloped if not structurally supported. The subgroup's limited international engagement further exacerbates this risk.

3. High Probability – Moderate Impact Risks (Manageable, but Recurrent)

- **Recruitment process pace**
  Slow recruitment in building technology contributes to talent attrition and reduced momentum.
- **Methodological coherence**
  Meanwhile, methodological coherence issues, especially in interdisciplinary projects, can erode competitiveness in applied research without clear frameworks and shared standards.

4. Moderate Probability – Moderate Impact Risks (Monitor Closely)

- **Expansion into social sustainability analysis and**
- **Closing capacity gap for senior expertise for building technology**
  The latter one might be conducted via partnerships. Failure to address these issues may impede long-term integration with societal needs and diminish leadership capacity.

5. Low Probability – Moderate Impact Risks (Low Priority)

Risks such as interdisciplinary strengths defending against competition or Building technology mitigating marginalization are currently buffered by existing strengths. While these should be revisited periodically, they are not immediate strategic concerns.

5.1.6 Risk matrices

Figure 3 displays the risk matrices for the short- and long-term perspective. They indicate the shift in risks and risk manageability over time, unless no new assets in terms of intellectual capacity, funding, facilities and equipment are introduced. The only research area which over time shows a low capacity to manage the displayed risks and keeps a high-risk score, is the key area "Integrated Crop Production". The position of the four remaining key areas changes gradually over time. The key areas "Agroecology" and "Technology/Biosystems engineering" move over time from moderate risk manageability and moderate risk scores (1.5-year perspective) to high manageability and low risk scores (15-year perspective). "Animal-Centred Environments" moves from low-risk manageability and high-risk score in a 1.5-year perspective to moderate risk manageability and risk scores within the 15-year horizon, while horticulture diverts from are high risk manageability-low risk score position within the short-term to a moderate risk manageability-moderate risk score in the long-term perspective. This may be explained the highlighted needs for research infrastructure renewal and academic fragmentation.

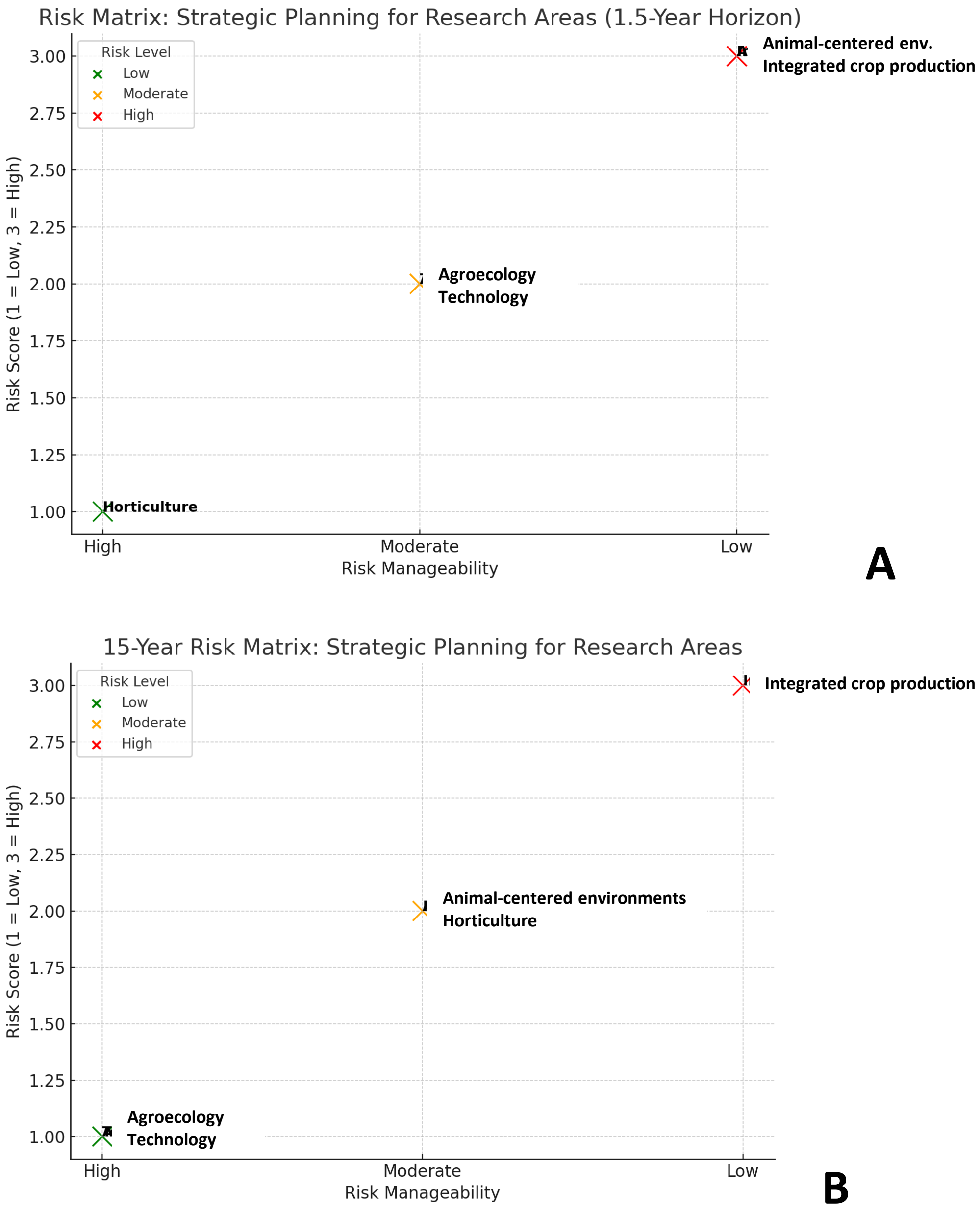

Figure 3. Risk matrix for the five screened key areas. A: short-term perspective (1.5 years); B: long-term perspective (15 years).

5.2 Rankings

5.2.1 Through the lens of SWOT-pairings

1.5-year-perspective

The criteria focus on near-term deliverability, visibility, alignment with funding and policy priorities and capacity to mobilize outputs that resonate both academically and societally.

Ranking list

- 1. Horticulture: Strong internal capacity with well-matched, fundable opportunities
- 2. Animal-Centred Environments: Unique ethics-tech fit with scalable, global relevance
- 3. Agroecology: Visionary and resilient, but slower to activate in short term
- 4. Technology: High modelling potential, but fragmented and uneven across subgroups
- 5. Integrated Cropping Systems: Lacks clarity and pairing strength for rapid impact

Summary

1. Horticulture: Score 1 (High Impact Potential) Horticulture stands out with a highly actionable SWOT matrix. Its strengths, namely cutting-edge methodologies, robust infrastructure and strong international and policy ties, are directly paired with immediate opportunities in climate-smart production, circular systems and digital innovation. Importantly, its weaknesses (*e.g.,* fragmented funding) are solvable through targeted investments and strategic communication. It shows the greatest readiness for visible academic and societal outcomes within the short 1.5-year timeframe.

2. Animal-Centred Environments: Score 1 (High Impact Potential) This area combines ethical urgency with technical innovation, making it a strong contender for short-term impact. Its SWOT pairings show clear alignment between internal expertise and emerging global frameworks *(e.g.,* One Health). While methodological and infrastructural gaps exist, they are well-paired with fundable, innovation-driven opportunities like precision monitoring and ethical tech development. Public and policy relevance enhances its immediate visibility and traction.

3. Agroecology: Score 2 (Moderate Impact Potential) Agroecology has high long-term impact potential due to its normative framework and global engagement, but the SWOT pairings reveal slower short-term activation.

While there is a solid match between participatory methods and global sustainability narratives, weaknesses like institutional fragmentation, digital lag and ideological perceptions require deeper restructuring. Its strength lies in systemic thinking, but time and coordination are needed to convert potential into rapid outcomes.

4. Technology/Biosystems engineering: Score: 2 (Moderate Impact Potential) The systems analysis subgroup has promising pairings, namely advanced modelling tools, policy relevance and interdisciplinary strength. However, building technology exhibits serious weaknesses (low staffing, limited visibility) that slow collective momentum. Internal fragmentation dilutes the overall impact potential. Some short-term gains are possible through focused initiatives in sustainable infrastructure and energy-efficient systems, but impact is less cohesive compared to the top two.

5. Integrated Cropping Systems: Score: 3 (Low Impact Potential) ICP suffers from unresolved weaknesses that are poorly matched with actionable opportunities. The SWOT analysis shows a lack of strategic direction, infrastructure gaps and an unclear research identity. All of which constrain the capacity for rapid academic or societal outcomes. While some isolated strengths exist, the field lacks the coherence and specialization necessary to respond effectively to funding or policy shifts in the near term.

15-year-perspective

Based on the SWOT pairings for each research area and their capacity to leverage strengths, address weaknesses, seize opportunities and mitigate threats, the scoring below considers the potential to achieve high scientific and societal impact within a 15-year perspective. The scoring follows a three-level scale: with 1 = High potential, 2 = Moderate potential and 3 = Low potential. The basis for this assessment is based on the data input in January 2025 and does not take changes within the discipline or the surrounding society and framework into account.

Ranking list

- 1. Animal Centred Environments: High Potential (Score: 1): Interdisciplinary, policy-aligned strengths; Ethical innovation potential; Scientific novelty, societal relevance
- 2. Agroecology: High Potential (Score: 1): Participatory, transdisciplinary science; SDG and policy alignment; Strong growth, resilient foundations
- 3. Technology: Moderate Potential (Score: 2): Innovation in bioeconomy, modelling; Fragmented identity, coherence gaps; Researcher attrition risks

- 4. Horticulture: Moderate Potential (Score: 2): Strong research, global ties; Climate-smart, AI opportunities; Outdated infrastructure, low outreach
- 5. Integrated Cropping Systems: Low Potential (Score: 3): Solid methods, academic networks; Identity and visibility issues; Facility constraints limit growth

Summary

1. Animal Centred Environments, Score: 1 (High Potential). This area is exceptionally positioned due to its interdisciplinary strengths, alignment with global policy frameworks like One Health and the potential for ethical innovation in animal welfare and digital tools. Its strong networks and policy relevance mitigate threats, while its unique positioning adds both scientific novelty and societal relevance. Despite infrastructure gaps, its trajectory toward high impact is clear.
2. Agroecology, Score: 1 (High Potential). Agroecology combines participatory methods, transdisciplinary science and alignment with global sustainability goals. It has a clear policy and academic fit with international frameworks like the SDGs. While digital infrastructure and ideological perception present challenges, its strong foundational opportunities and resilience give it excellent growth and impact potential.
3. Technology, Score: 2 (Moderate Potential). Technology, especially through systems analysis and building technology, is rich in innovation and global relevance in areas like bioeconomy, green infrastructure and modelling. However, its fragmented identity, internal coherence issues and researcher attrition risks diminish its scalability and integration across disciplines, placing it in the moderate impact zone.
4. Horticulture, Score: 2 (Moderate Potential). Horticulture is strong in research quality, infrastructure and global partnerships, with promising opportunities in climate-smart systems and AI. However, outdated facilities, weak outreach and internal fragmentation inhibit the realization of its full societal and scientific potential.
5. Integrated Cropping Systems, Score: 3 (Low Potential). While academically competent with solid networks and system-based methods, Integrated Cropping Systems suffers from a lack of clear identity, limited facilities and weak visibility. The interplay of these issues severely constrains its future development, making it less likely to emerge as a high-impact area within 15 years.

5.2.2 Through the lens of academic excellence, internationalization and uniqueness

1.5-year-perspective

The criteria focus on near-term deliverability, visibility, alignment with funding and policy priorities and capacity to mobilize outputs that resonate both academically and societally.

Ranking list

- 1. Horticulture – 1: High readiness for societal and scientific visibility
- 2. Animal-Centred Environments – 1: High tech and ethics synergy fuels rapid impact
- 3. Agroecology – 2: High relevance but slower due to participatory complexity
- 4. Technology – 2: Strong foundation, slower execution due to fragmentation
- 5. Integrated Cropping Systems – 3: Needs redefinition to enable meaningful progress

Summary

1. Horticulture stands out with strong academic foundations, advanced infrastructure and significant policy relevance. Its interdisciplinary nature, high-impact research and global partnerships place it at the forefront of innovation and international visibility. While some internal challenges remain, its strategic value and transformative potential are unmatched.
2. Animal-Centred Environments demonstrates a powerful mix of ethical relevance, technological innovation and global alignment. Its interdisciplinary structure and alignment with One Health/One Welfare frameworks make it uniquely positioned for high-impact work. Strategic infrastructure investment could rapidly accelerate its scientific reach.
3. Agroecology excels in systemic thinking, participatory research and sustainability leadership. Its international partnerships and normative uniqueness make it highly competitive. The field would benefit from clearer institutional positioning and enhanced digital capacity, but its alignment with SDGs gives it strong upward potential.
4. Technology, particularly in systems analysis and agricultural infrastructure, shows solid academic and innovation merit. However, its current fragmentation and the need for applied validation hinder short-term transformative potential compared to the top three.

5. Integrated Cropping Systems lags in all four dimensions due to unclear research identity, limited innovation and weak uniqueness. It requires significant strategic refocusing and capacity-building to become a high-impact area.

15-year-perspective

The scoring and narrative evaluation of the five research areas is based on their potential to achieve high scientific and societal impact within a 15-year perspective. The assessment draws from the combined insights into academic excellence, innovation, internationalization and uniqueness. The basis for this assessment is based on the data input in January 2025 and does not take changes within the discipline or the surrounding society and framework into account.

Ranking list

- 1. Animal Centred Environments – 1: Animal welfare innovation; Ethical, climate relevance; Interdisciplinary policy fit
- 2. Agroecology – 1: Transdisciplinary, global partnerships; Social, environmental justice; Holistic, systemic model
- 3. Technology – 2: Innovation in systems; Subfield imbalance; Talent, coordination gaps
- 4. Horticulture – 2: Urban, climate relevance; Food and nutrition security relevance; Academic fragmentation; Outdated infrastructure
- 5. Integrated Crop Production – 3: Conceptual, methodological rigor; Undefined strategic focus; Limited impact capacity

Summary

1. Animal Centred Environments – Score: 1 (High Potential). This field leads in impact potential due to its cutting-edge integration of animal welfare science and digital innovation. Its alignment with One Health, ethical frameworks and climate resilience makes it scientifically robust and societally relevant. Unique interdisciplinary teams, strong policy fit and international collaborations further reinforce its transformative capacity. While infrastructure gaps exist, the field's momentum is undeniable.

2. Agroecology – Score: 1 (High Potential). Agroecology offers high-impact potential through its transdisciplinary methods, global partnerships (*e.g.,* FAO, Horizon Europe) and commitment to social and environmental justice. It is well-positioned to shape sustainable food systems. Despite tech-related limitations and ideological perceptions, its holistic, site-based model and systemic focus make it crucial for long-term change.

3. Technology – Score: 2 (Moderate Potential). This field holds strong promise, particularly in systems analysis and sustainable infrastructure. It brings innovation in modelling, biorefineries and AI applications for agriculture. However, uneven development between subfields, talent leakage and internal fragmentation reduce its trajectory toward seamless, long-term high impact. With targeted coordination and investment, it could evolve into a high-impact field.

4. Horticulture – Score: 2 (Moderate Potential). Horticulture is academically sound and strategically relevant for sustainable and resilient food systems. It shows high societal value, particularly for urban greening and climate adaptation. However, outdated facilities, fragmented subfields and under-communicated societal value hold it back from achieving full impact. With modernization and strategic outreach, it could climb higher.

5. Integrated Crop Production – Score: 3 (Low Potential). While conceptually valuable and methodologically rigorous, this field lacks a clear identity, strategic focus and sufficient infrastructure. Its limited visibility, undefined niche and insufficient critical mass reduce its capacity to influence science or policy at scale. It risks being overshadowed by more focused and better-integrated areas.

5.3 Risk mitigation

This chapter categorizes key risks by probability and impact to prioritize strategic responses for each of the key areas. High-probability, high-impact risks are addressed first, reflecting their urgency and potential to disrupt long-term viability. Subsequent sections cover moderate to lower-probability issues that, while less immediate, still require coordinated action.
The goal of this analysis is to provide clear, action-oriented guidance for safeguarding and advancing key areas at SLU. By linking risks to strategic implications and practical recommendations, it supports informed decision-making around future research directions, institutional investments and policy engagement. In doing so, the Department of Biosystems and Technology and SLU can reinforce its role as a national and international leader in innovation and education.

5.3.1 Agroecology

Agroecology at SLU stands at a strategic crossroads. As global food systems face increasing pressure to become more sustainable, resilient and inclusive, agroecology offers a timely and transformative research paradigm. Its strengths in transdisciplinarity, participatory methods and alignment with the Sustainable

Development Goals (SDGs) position it well to address complex challenges across agricultural, environmental and social domains.
However, a structured risk analysis reveals that this potential is counterbalanced by several critical vulnerabilities. These include the dilution of agroecology's identity within broader sustainability discourses, a lag in digital integration, low national visibility and institutional fragmentation. Without targeted intervention, these risks may undermine SLU's ability to lead in the evolving agroecological landscape.

Action-oriented recommendations for Agroecology

Secure institutional positioning

Risks addressed: Dilution of agroecology's identity, technological lag, national invisibility and policy marginalization

1. Define and Defend Identity
   - Create a common identity for *Agroecology at BT*, clearly describing how agroecological research is comprising at BT and how it is conducted. NB! BT does not cover all aspects of agroecology. We define the niche within which we are strong.
   - Use agroecology more systematically in internal and external communications, based on our own identity description: *Agroecology at BT*.
   - Launch a branding initiative to clarify agroecology's scientific identity distinct from generic sustainability discourses.
   - Create a dedicated SLU Agroecology web platform showcasing people, projects and impact.
2. Invest in Digital Integration:
   - Form strategic coalitions within BT (across subject areas, to collaborate with experts in technology and digitalization), targeting innovative uses of digital technologies in accordance with agroecological principles (*e.g.,* solar-driven robotics to operate within diversified cropping systems).
   - Form inter- and transdisciplinary consortia with both academic and non-academic partners, to integrate AI, robotics and sensor technologies into fieldwork.
   - Embed digital modules in agroecology curricula and pursue targeted innovation funding.
   - Apply for research funding where existing infrastructures and platforms such as SAFE (SITES Lönnstorp), the Alnarp Agroecology Farm and the SLU and Sparbanken Skåne center for sustainable primary production are used as testbeds or living labs for innovative integration of digital technologies.
3. Boost National Engagement:
   - Initiate a national outreach and visibility campaign targeting ministries, funders and academic networks.

- Submit position papers and white papers to influence national funding agendas.
- Use our internal identity definition (first bullet point under “Define and Defend Identity” above) to position ourselves in these campaigns.

Falling behind in international funding and policy relevance
Risks addressed: Missed digital integration opportunities, Funding misalignment with shifting policy agendas, Insufficient emphasis on SDG alignment

1. Digital-Opportunity Matchmaking:
    - Proactively identify and co-develop calls with digital partners (*e.g.,* Horizon Europe, Vinnova), using strategic coalitions as described above (first bullet point under “Invest in Digital Integration).
    - Create pilot projects integrating digital tools into agroecological experiments (*e.g.,* SAFE and the Alnarp Agroecology Farm), *e.g.,* with funding through Partnership Alnarp (see also fourth bullet point under “Invest in Digital Integration).
2. Policy and SDG Alignment:
    - Map agroecology’s research themes directly onto SDG targets in strategic documents.
    - Include SDG and policy alignment criteria in all major research proposals.

Erosion of scientific visibility and institutional coherence
Risks addressed: Devaluation of participatory methods in publishing, Internal fragmentation

1. Increase critical mass and research education in Agroecology
    - Strategically apply for grants that target PhD student recruitment within the Agroecology domain where BT is strong (see first bullet point under “Define and Defend Identity”).
2. Publish Strategically:
    - Establish internal review groups focused on enhancing interdisciplinary manuscripts.
    - Target high-impact interdisciplinary journals and foster international co-authorship.
3. Improve Internal Synergy:
    - Set up an SLU Agroecology Steering Committee to align projects and resources.
    - Host regular internal retreats or cross-departmental research seminars.

Compromised external trust and internal efficiency
Risks addressed: Perceived ideological bias, Persistent institutional fragmentation

1. Neutralize Bias Perception:

- Emphasize scientific rigor and innovation in public messaging and academic proposals.
- Engage with mainstream agricultural scientists in joint publications and panels.

2. Coordinate Efforts:
   - Develop a shared agroecology research roadmap with clear roles, objectives and success metrics. Ensure that this roadmap aligns with the internal identity (*Agroecology at BT*).

Missed funding opportunities and weakened competitiveness
Risk addressed: Underuse of participatory methods in grant applications
1. Grant Writing Optimization:
   - Create a participatory methods toolbox for inclusion in proposals.
   - Train research staff on integrating co-creation and systems thinking into funding applications.
   - Use strategic coalitions (see first bullet point under "Invest in Digital Integration").

5.3.2 Animal-Centred Environments

The research field of animal-centred environments is gaining increasing relevance at the intersection of sustainability, ethics and technological innovation. Positioned within broader agendas such as One Health and digital transformation in agriculture, the field offers significant potential to shape future animal welfare systems. Its unique strength lies in combining interdisciplinary expertise, ethical commitments and global networks to develop new models for animal housing, care and interaction that align with both scientific standards and societal values.

However, as the field evolves, it faces a complex landscape of opportunities and risks. Emerging policy priorities and technological developments offer new entry points for funding and innovation, but they also expose critical vulnerabilities. Key challenges include gaps in standardized welfare metrics, limited access to experimental infrastructure and a lack of real-time data capabilities. These issues threaten not only research effectiveness but also public trust and long-term credibility.

This risk-focused analysis highlights the strategic tensions currently shaping the field. It identifies where existing strengths can be leveraged and where structural weaknesses may constrain progress. Importantly, it reveals how external threats (*e.g.,* political shifts, ethical controversies and institutional fragmentation) could disrupt momentum if not addressed proactively.

By focusing on the internal and external factors that condition future success, this analysis provides a foundation for informed strategic decision-making. It aims to support the development of resilient, scientifically robust and ethically sound pathways for advancing animal-centred environments in an increasingly complex and demanding research ecosystem.

Action-oriented recommendations for Animal-Centred Environments

1. Strengthen Methodological Readiness and Standardization

Risks Addressed: Methodological flaws, lack of standardization; Loss of credibility and funding due to inconsistent methods; Missed opportunities in policy-relevant research

- Develop and adopt standardized welfare metrics across research units
- Invest in digital systems for real-time monitoring and data integration
- Create national/international working groups for harmonizing research protocols

2. Expand and Optimize Research Infrastructure

Risks Addressed: Inability to capitalize on funding due to lack of facilities; Infrastructure bottlenecks limiting collaboration; Facility shortages impair long-term growth

- Form joint infrastructure agreements (*e.g.,* with SLU and partner institutions)
- Prioritize infrastructure investment strategically to support grant planning
- Map available infrastructure to improve access and coordination across teams

3. Mitigate Ethical and Public Trust Risks

Risks Addressed: Public backlash to surveillance tech; Inability to provide real-time data undermining legitimacy; Poor communication exacerbating public/policy distrust

- Include ethics and participatory design in all technology development phases
- Build transparent, inclusive stakeholder engagement strategies
- Establish communication protocols that reflect public values and sensitivities

4. Sustain and Develop Human Capital

Risks Addressed: Barriers to entry shrinking the talent pipeline; Researcher attrition threatening expertise continuity; Institutional gaps in supporting early-career researchers

- Create structured entry pathways: mentorship, fellowships, career development plans
- Improve technical support and onboarding processes to help new researchers integrate smoothly and contribute effectively.

- Provide incentives for interdisciplinary team retention and leadership development

5. Activate Strategic Interdisciplinary and Global Partnerships
Risks Addressed: Underutilization of interdisciplinary opportunities; Reduced cooperation from geopolitical shifts; Collaboration limits due to infrastructure and coordination gaps

- Establish formal consortia aligned with One Health and sustainability frameworks
- Take leadership roles in international research and policy fora
- Collaboratively target global funding opportunities and shared research challenges

6. Improve Internal and External Communication
Risks Addressed: Poor communication undermines public/policy support; Shifts in public sentiment or policy deprioritization; Inadequate visibility in interdisciplinary and policy spaces

- Assign communication leads or knowledge brokers within large projects
- Develop stakeholder-aligned messaging, emphasizing transparency and benefits
- Conduct scenario planning and foresight exercises to stay ahead of public/policy shifts

5.3.3 Horticulture

The risk landscape for horticultural sciences at SLU is shaped by a dual imperative: to protect existing strengths while transforming internal weaknesses into opportunities for renewal. Critical risks, particularly those related to funding stability, human resources and subfield sustainability, require targeted strategic responses. These include succession planning, infrastructure upgrades and cross-disciplinary integration. At the same time, positioning horticulture within high-level policy frameworks (*e.g.,* food security, green transition) and investing in strategic communication and outreach are essential to mitigating moderate and emerging risks.

By proactively addressing these risks, horticultural sciences can continue to function as a nationally and internationally significant research domain, contributing to sustainable agriculture and areal cropping systems, climate resilience and food system transformation.

Action-oriented recommendations for Horticulture

1. Secure Long-Term Funding and Strategic Research Continuity

Risks addressed: Volatile funding, short-term projects, marginalization in research agendas

- Develop a dedicated funding strategy aligned with EU Green Deal, agroecology transitions and national food security initiatives.
- Establish internal seed funding mechanisms to bridge gaps between external grants and enable long-term research continuity.
- Increase presence in large-scale transdisciplinary consortia (*e.g.*, Horizon Europe, Formas Policy labs) by highlighting horticulture's role in climate, food and nutrition security and resilience.
- Nominate honorary doctor candidates in LTV calls.
- Engage actively in lobbying and research-policy dialogues to embed horticulture into national strategic research agendas.
- Engage in leading positions in international networks (*e.g.*, ISHS, EUVRIN, IAFP, APS)
- Transform the research mindset from a strongly action-driven perspective to a "mental-model"-approach (Meadows, 2008).

2. Invest in Infrastructure Modernization

Risks addressed: Aging facilities, limits on technological competitiveness

- Prioritize renovation of experimental greenhouses and laboratories, ensuring readiness for sensor technologies, automation and AI. Also replace outdated and broken lab instruments, respectively, asap.
- Apply for infrastructure-focused funding programs (*e.g.,* Formas, EU structural funds) with clear sustainability and digitalization themes.
- Create shared core facilities at Alnarp that promote interdisciplinary use and attract collaborators within and beyond SLU.

3. Strengthen Human Resource and Succession Planning

Risks addressed: Lack of succession in subfields, skill shortages, solo researcher vulnerability

- Map critical expertise areas (*e.g.,* stress physiology, ornamental and nursery horticulture) and prioritize them in recruitment strategies.
- Develop early-career researcher pipelines, including PhD positions, postdocs and tenure-track roles in vulnerable subfields.
- Establish mentorship and knowledge transfer programs to secure continuity across generations of researchers.

4. Enhance Integration Across Subfields and Disciplines

Risks addressed: Fragmentation, weak systemic approaches, limited impact in challenge-driven funding

- Facilitate regular interdisciplinary workshops and research retreats to integrate horticultural technology, crop physiology, systems ecology and modelling.
- Create cross-cutting transdisciplinary project themes (*e.g.,* circularity in horticulture, urban food systems) that unite disparate expertise into collaborative efforts.
- Encourage co-authorship and joint funding proposals across research groups in-house and with high impact research groups within and outside SLU, on a national and international level to deepen integration and shared ownership.

5. Expand Strategic Communication and Outreach

Risks addressed: Ineffective communication, under-recognition of societal relevance

- Develop a communication strategy targeting policymakers, funders, industry stakeholders and the public to frame horticulture within the food, health and climate discourses.
- Implement participatory research models with growers, municipalities and civil society to boost co-creation and relevance.
- Strengthen presence in policy advisory platforms and public science communication forums, including SLU's own institutional channels (*e.g.*, Future Food, Urban Future, OneHealth).

6. Maximize International Collaborations and Visibility

Risks addressed: Underutilized networks, increasing external competition

- Activate dormant or underleveraged international collaborations, particularly in ISHS, EUFRIN and IFOAM networks.
- Pursue formalized strategic partnerships with top horticulture-focused institutions (*e.g.,* Wageningen, Copenhagen, Laval, Davis, Cornell) for co-supervision, infrastructure sharing and coordinated funding applications.
- Support researcher mobility programs and sabbaticals to strengthen global exposure and facilitate joint publications and research projects.
- Create and establish "dream teams" for collaboration

7. Align with Emerging Digital and Green Transition Opportunities

Risks addressed: Missed alignment with funding, underused infrastructure potential

- Create internal working groups focused on digital horticulture, sensor systems, AI modelling and data-driven sustainability practices.
- Integrate open data and reproducibility principles into project planning and publications to increase scientific transparency and funding competitiveness.

- Promote digital literacy training among researchers to ensure readiness for AI and modelling-intensive projects.

5.3.4 Integrated Crop Production

To ensure long-term competitiveness, ICP must address critical structural and strategic challenges. Outdated infrastructure limited critical mass and high teaching loads hinder research innovation and responsiveness to emerging trends. Clearer identity and interdisciplinary alignment are essential to enhance policy relevance and secure funding. Strategic actions should focus on modernizing facilities, strengthening talent recruitment and reducing the teaching burden to free capacity for high-impact research. Defining a coherent research narrative will counter fragmentation and boost visibility, while targeted communication and international engagement can enhance ICP's reputation and stakeholder influence. Active participation in global consortia and interdisciplinary projects will further position ICP at the forefront of sustainable, systems-based agricultural research. By linking these efforts directly to identified risks, ICP can better align its strengths with future opportunities and safeguard against threats, ensuring its leadership in tackling complex agri-food system challenges.

Action-oriented recommendations for Integrated Crop Production

1. Strengthen Infrastructure and Research Capacity

Risks addressed: Insufficient funding restricting modernization of facilities; Rapid technological advancements risk obsolescence of current methods; Limited critical mass reduces capacity for innovation and specialization; Weak academic reputation deters recruitment

- Pursue targeted infrastructure grants
- Establish a shared core facility model
- Develop a hiring plan to attract early-career researchers

2. Define and Communicate a Coherent Research Identity

Risks addressed: Fragmented research scope weakens academic and policy impact; Confusion over ICP identity limits funding and stakeholder support; Weak academic reputation deters recruitment; Potential neglect of crop diversity in favour of commodity crops

- Form a strategy group to define a unifying research narrative
- Update communication platforms to reflect ICP's focus
- Engage in targeted science-policy dialogue

3. Reduce the Impact of Teaching Load on Research Output

Risks addressed: Heavy teaching loads reduce time for research development; Weak academic reputation deters recruitment

- Negotiate teaching relief for research-active staff
- Expand use of TAs or postdocs in teaching
- Leverage digital tools for teaching

4. Amplify International and Interdisciplinary Collaboration
Risks addressed: Competition from well-established groups; Lack of interdisciplinary harmonization; Weak academic reputation deters recruitment; Fragmented research scope weakens academic and policy impact; Limited critical mass reduces capacity for innovation and specialization; Confusion over ICP identity limits funding and stakeholder support

- Actively participate in international consortia
- Launch interdisciplinary seed funding schemes
- Host thematic workshops to build alignment

5. Build Reputation Through Visibility and Impact
Risks addressed: Weak academic reputation deters recruitment; Fragmented research scope weakens academic and policy impact; Competition from well-established groups; Confusion over ICP identity limits funding and stakeholder support; Limited critical mass reduces capacity for innovation and specialization

- Strategic publication in high-impact journals
- Nominate researchers for awards and panels
- Develop case studies to showcase societal relevance

5.3.5 Technology/Biosystems Engineering

The research area Technology/Biosystems Engineering, comprising the subgroups Systems Analysis and Building Technology, plays a vital role in advancing sustainability, resilience and innovation within agricultural and environmental systems. Both subfields contribute essential expertise: (i) Systems analysis through methodological leadership in modelling, life cycle assessment and biorefinery evaluations and (ii) Building Technology through specialized research on energy-efficient, low-emission agricultural infrastructure.

Despite their respective strengths, the area faces significant structural and strategic challenges. Systems analysis is constrained by limited critical mass, underdeveloped integration of social dimensions and a strong national orientation. Building Technology, while holding a unique niche in agricultural construction, contends with an underdefined academic identity, insufficient international visibility and slow recruitment processes. Both groups also encounter growing competition from more technologically equipped and better-funded institutions.

At the same time, rising global interest in circular bioeconomy, sustainable infrastructure and climate-smart agriculture presents substantial opportunities. Leveraging these trends will require enhanced interdisciplinary collaboration, investment in methodological innovation and proactive internationalization strategies.

This analysis assesses the strategic positioning of the Technology research area using SWOT pairings and structured risk evaluation. It aims to identify actionable pathways and structural priorities to guide the selection and development of scientifically successful future research directions.

Action-oriented recommendations for Technology/Biosystems Engineering

1. Strengthen Critical Mass and Expertise

Risk addressed: Systems analysis competence leakage, Building Technology slow recruitment, Lack of senior expertise in Building technology, Limited critical mass in Systems analysis, Methodological coherence issues, Underdeveloped technological innovation in Building technology; Building technology's visibility decline

- Prioritize strategic recruitment targeting profiles in modelling, social sustainability and energy-efficient infrastructure.
- Establish joint PhD/postdoc programs to promote interdisciplinary training and build research continuity.
- Engage in visiting scholar exchanges to strengthen senior academic presence and research mentorship.
- Diversify methodological approaches through competence recruitment or internal education and development
- Define strategic research areas that support group uniqueness and increase competitiveness against *e.g.,* the Department of Energy and Technology, SLU Uppsala. This could involve areas that focus on technology and systems analysis applications within horticultural and agricultural production.
- Develop new bioeconomy approaches that combine existing expertise in technological applied in crop production, building and horticultural technology in areas we the group has the potential to become excellent and a unique class leader.

2. Advance Methodological Innovation and Integration

Risk addressed: Methodological coherence issues, Social sustainability underdeveloped in Systems analysis, Advanced modelling tools dependency, Underdeveloped technological innovation in Building technology, Competence leakage, Technological stagnation

- Develop shared methodological frameworks for holistic sustainability assessment.
- Create an internal "method lab" to pilot new tools integrating LCA, energy modelling and digital technologies.

- Invest in continuous training programs on AI, sensors and system dynamics.

3. Expand Internationalization and Visibility

Risk addressed: Building technology's limited international engagement, Being overshadowed by forestry research, Limited global presence of Systems analysis, Narrow identity in Building technology, Visibility decline in Building technology

- Form international consortia around green agricultural infrastructure and circular bioeconomy themes.
- Target international funding (*e.g.,* Horizon Europe) with applications in food-energy-water systems.
- Enhance digital presence and dissemination of models and case studies.

4. Foster High-Impact Interdisciplinary Collaboration

Risk addressed: Cross-disciplinary societal sustainability gaps, Methodological fragmentation, Underdevelopment in technology related to horticulture, Technological stagnation in Building technology, Implementation gap in Systems analysis, Relevance risks due to weak validation

- Launch flagship projects linking Systems analysis and Building technology (*e.g.,* climate-resilient farms).
- Create cross-functional teams focused on rooftop greenhouses, smart buildings and circular resource flows.
- Establish a stakeholder co-design platform to align research with practical needs and enhance relevance.

5. Secure Structural and Financial Support

Risks addressed: Marginalization of agricultural building research, Competition from better-funded institutes, Technological innovation underexploited, Weak validation of applied research; Talent attrition due to better offers elsewhere

- Advocate for dedicated funding streams for agricultural infrastructure in climate and bioeconomy programs.
- Develop living labs/testbeds for rooftop greenhouses, animal housing and integrated energy systems.
- Forge partnerships with RISE and similar institutions to share platforms without compromising academic autonomy.

6. Identification of three prioritized future subject areas

Guiding principles for the identification of the three potential future subject areas were based on

- Three key issues highlighted in the research proposal 2024, namely excellence, innovation and internationalization
- Criteria of successful research departments as elaborated by Ekvall (1989)
- Areas of responsibility as defined by the SLU regulation (REF) as well as
- Uniqueness within the SLU landscape of subject areas.

In addition, the potential projects suggested by the department staff at the workshop on January 27, 2025 was considered (Appendix 5). Appendix 5 delivers all themes suggested and a brief analysis of their potential in terms of the grand global challenges and outcome/impact parameters posed by the governmental research strategy and the international standards within academic research environments. Worthwhile to underline that these short analyses for each research priority are exclusively based on the wording of the suggested theme; no project synopses nor follow-up interviews were performed.

The research strategic perspective was considered. In this context, excellence in science was defined as

Rigorous Methodology	Thorough and methodical research based on well-established principles; reliable, valid and reproducible results
Innovation and Originality	New/novel ideas, approaches or perspectives; pushing the boundaries of knowledge; contributing originality to the field
Significant Impact	important problems addressed; valuable and validated solutions offered; advances in understanding with a broad, lasting impact on the academic community or society as a whole
Ethical Standards	Integrity and ethical responsibility in the conduct of research; openness; proper citation practices, no plagiarism

Interdisciplinary Collaboration	Transdisciplinary collaboration, adding different perspectives and expertise to tackle complex problems
Clear Communication	Communicating findings effectively through scholarly publications, presentations, novel knowledge transfer approaches across scientific and societal boundaries or other means. This ensures that research can be shared, critiqued and built upon by others in the field as well as implementation and enables societal and policy change.

6.1 Recommended priority areas

Recommended priority areas are:

1. Agroecology
2. Animal-Centred Environments
3. Horticulture

Each area shows high potential for short-term (1.5 years) and long-term (15 years) excellence, societal relevance and scientific leadership. Details regarding the scored assets are displayed in the evaluation matrix below (Table 5). The prioritized areas are described in section 7.3 through 7.5. The descriptions are limited to the presentation of the subject and key areas with examples of research issues relevant in a 20-year period. They do not present a roadmap, nor a strategic presentation of outcomes, such as anticipated publications, pathways for innovation, SLU internal, national or international collaborations. However, all of the prioritized areas are planned to perform on a high research quality level to meet the criteria set by the research proposition of the Swedish Government.

Table 6. Evaluation matrix (✓ indicates positive alignment with the evaluation parameters. The number of ✓ displays the strength of alignment. × depicts absence of alignment. Prioritized key areas are mentioned in alphabetical order, in bold font). ROI: return of investment

Area	Academic Excellence	Inno-vation	Internatio-nalization	Uniqueness	Short-Term ROI	Long-Term Potential
Agroecology	✓✓✓	✓✓	✓✓✓	✓✓✓	✓✓	✓✓✓
Animal-Centered Environments	✓✓✓	✓✓✓	✓✓✓	✓✓✓	✓✓✓	✓✓✓
Horticulture	✓✓✓	✓✓✓	✓✓✓	✓✓✓	✓✓	✓✓✓
Integrated Crop Production	✓✓	✓	✓	×	×	✓
Technology (as standalone)	✓✓	✓✓	✓	×	×	✓ (as support)

6.2 Full Strategic Evaluation

6.2.1 Executive summary

Prioritized areas

1. Agroecology

Academic Excellence: Mixed-methods, participatory, field-based research. High rigor; limited only by visibility and publication complexity.

Innovation: Systems thinking, co-created knowledge. Opportunities to integrate AI, robotics and big data.

Internationalization: Strong ties to FAO, EU, Latin America and Africa. Threatened by term dilution; needs stronger branding.

Uniqueness: Combines sustainability, ethics and social justice. Potential global leader in digital agroecology.

2. Animal-Centred Environments

Academic Excellence: High-impact work across animal welfare, sensor technology and ethical farming. Challenges include infrastructure and methodology gaps.

Innovation: Leading in AI-driven welfare tools, emotional behaviour analysis and biophilic housing design.

Internationalization: Deeply embedded in One Health/Welfare frameworks. Well-positioned in European and global research agendas.

Uniqueness: Ethical, digital and perceptual focus on animals. Unique talent base at SLU.

3. Horticulture

Academic Excellence: Strong empirical and fundamental research with advanced infrastructure. Needs reinvestment in underfunded subfields.

Innovation: Renewable inputs to cropping systems (*e.g.,* peat-free), circularity in horticulture, AI-modelling and urban resilience.

Internationalization: Active in international contexts (global level) with top academic partners.

Uniqueness: Central role in food self-sufficiency and urban green systems. Anchored and strategic within SLU.

Non-Prioritized Areas

Integrated Crop Production

- Lacks unique identity and visibility.
- Conceptually strong, but institutionally fragmented.
- Recommended as a platform within Agroecology and Horticulture.

Technology / Biosystems Engineering

- Valuable as an enabling field (not thematic).
- Should support digital, infrastructural and modelling needs of the top 3 areas.

6.2.2 Strategic evaluation

Agroecology presents SLU with a unique opportunity to lead globally in participatory, systems-based approaches to sustainable agriculture. It excels in methodological rigor through mixed-methods and field-based infrastructures like SAFE and Alnarp Agroecology Farm. While publication complexity and low visibility in Sweden present challenges, these can be addressed through digital integration and strategic communication. International collaborations with FAO and Agroecology Europe and alignment with SDGs strengthen agroecology's internationalization. Its combination of ethics, food sovereignty and social justice anchors its uniqueness and positions it as a transformative force in food system research.

Animal-Centred Environments harnesses digital innovation and ethical frameworks to address emerging questions in animal welfare. The integration of welfare science with technologies such as AI, sensors and behavioural analytics enables a pioneering approach to real-time, emotional and cognitive monitoring of animals. The field benefits from international networks and policy alignment with One Health and One Welfare but faces structural gaps in infrastructure and methodological harmonization. Its normative and perceptual dimensions make it a unique area of excellence at SLU, well-positioned to lead in ethical, tech-enabled animal welfare research.

Horticulture stands out for its mature research ecosystem, combining methodological sophistication with societal relevance. It supports Sweden's food self-sufficiency and offers advanced capacities in circularity in horticulture, digital crop modelling, renewable inputs and food safety. Although suffering from underfunded subfields and outdated infrastructure which pose risks, its interdisciplinary strength, strategic anchoring within SLU and integration into global research networks secure its role as a key player in climate-resilient, urban as well as rural and sustainable food systems at different scale and production approach.

Integrated Crop Production has strong conceptual relevance and methodological potential but lacks strategic cohesion. It blends agricultural and horticultural practices with an emphasis on system-level approaches. However, it suffers from low visibility, unclear identity and a lack of in-house high-grade facility and instrumentation which is a precondition for advanced research on integrated crop production. Its broad scope, while inclusive, dilutes its distinctiveness. ICP is better positioned as a supporting platform integrated within agroecology and horticulture, where its tools and principles can amplify research impact.

Technology/Biosystems Engineering contributes valuable enabling functions through its expertise in systems analysis, life cycle assessment and building design. While it lacks a central academic identity, especially in agricultural buildings, it offers essential support to agroecology, animal environments and horticulture through predictive modelling, digital infrastructure and sustainability analysis. Framing this area as a cross-cutting enabler ensures relevance without overextending its current institutional capacity.

6.3 Animal-centred environments

6.3.1 Suggested name

Responsive Animal Environments

6.3.2 Description of the scope

The subject area Animal-Centred Environments operates at the intersection of animal welfare science, digital innovation and ethics, offering a forward-looking framework for research and development in livestock systems and other animal contexts. Its scope spans the full spectrum from fundamental research on animal perception and behaviour to applied solutions for welfare-enhancing design and policy guidance.

Central to this area is the use of advanced technologies (including AI, sensor networks, behavioural analytics, real-time monitoring systems) to assess animals' emotional, cognitive and physical states in context-specific environments. These tools support novel, data-driven approaches for evaluating and adapting environments in a way that respects animals' species-specific motivations and welfare needs.

The subject area contributes to addressing urgent societal and global challenges related to animal welfare, sustainable food systems and climate resilience, while supporting key policy frameworks such as One Health and One Welfare. It also engages actively with international research networks, ensuring global relevance and alignment.

From a methodological standpoint, the field advocates for harmonised welfare assessment models, interdisciplinary collaboration and normative frameworks that guide responsible innovation. Its unique focus on the perceptual and ethical dimensions of animal-environment interaction positions it as a strategic field of excellence at SLU, well-placed to lead in developing technologies and practices that enable ethically sound, scientifically robust and socially acceptable animal management systems.

Strategic Relevance and Research Priorities

The scientific theme Animal-Centred Environments directly responds to national and international calls for more sustainable, resilient and ethically robust food systems. It aligns with the UN Sustainable Development Goals, EU's Green Deal, Farm to Fork Strategy and Swedish national priorities for food security, climate adaptation and animal welfare. Also, this theme addresses emerging challenges in animal agriculture through research that is both technologically innovative and ethically grounded.

Amid rising demands for food, environmental constraints and growing societal expectations for animal welfare, there is a pressing need for science that supports systems transformation while maintaining biological, economic and social resilience. Furthermore, the need for crisis preparedness in response to zoonoses, climate shocks and/or supply chain disruptions places animal health and welfare as integral components of system-wide stability and response.

This subject area supports and strengthens SLU's contributions to sustainability science, One Health/One Welfare and future food systems, offering a distinctive niche that integrates animal welfare with high-tech innovation and policy relevance.

Priority Research Areas

- **Technologies for Real-Time Welfare Monitoring**
  Development and integration of AI, sensor platforms and behavioural analytics for continuous assessment of animals' cognitive and emotional states in farm environments.
- **Welfare-Driven Resilience in Livestock Systems**
  Designing adaptive animal environments that buffer animals from environmental, climatic and systemic stressors to support health, productivity and stability under uncertain conditions.
- **Ethical and Perceptual Frameworks for Animal Inclusion**
  Exploring frameworks that position animals as sentient stakeholders in food systems; advancing normative science around welfare, consent and moral consideration in husbandry and research.
- **Infrastructure and Method Harmonisation**
  Development of standardised, scalable tools and protocols for cross-species, cross-system welfare evaluation to support harmonised data collection, policy comparability and international benchmarking.
- **Animal-Centred Crisis Preparedness**

Identifying vulnerabilities in animal housing, transport and welfare under crisis scenarios (*e.g.,* heatwaves, pandemics, feed shortages) and designing contingency-ready environments.

- **Sustainable Intensification through Animal-Centred Design**
  Combining welfare-enhancing design with productivity and environmental impact goals, ensuring that intensification strategies remain aligned with ethical and biological thresholds.
- **Contribution to Food and Nutrition Security**
  Evaluating how welfare-centric animal environments contribute to product quality, safety and trust in food systems, reinforcing consumer confidence and long-term system integrity.

3.3 Bracing “Animal-centred environments” to “Technology/Biosystems engineering”

The subject area Animal-Centred Environments provides a highly relevant and integrative platform for embedding Technology and Biosystems Engineering into a forward-looking, welfare- and sustainability-driven research agenda. Although Technology/Biosystems Engineering did not emerge as an independent subject area, its role is fundamental in developing adaptive, intelligent and ethical systems for animal care and production. This includes both digital innovations in monitoring and environmental automation and physical design aspects related to building systems and infrastructure.

A critical technological interface lies in the design of animal housing environments, where biosystems and architectural engineering intersect. Research on new sustainable and resilient building materials, energy-efficient ventilation and lighting and climate-adaptive structures will be essential to support animal health and welfare under changing environmental conditions. Furthermore, principles of biophilic design, originally applied in human architecture, can be explored to enhance animal environments by incorporating elements that mimic natural settings, improve sensory stimulation and reduce chronic stress.

Technology in this context is not only an enabler of precision and productivity but also a driver of welfare, environmental performance and resilience. As such, identifying both the shared and species-specific engineering needs across different animal systems is vital. This ensures that biosystems research continues to evolve in close collaboration with animal science, design research and sustainability disciplines, forming a cohesive and impactful part of this new academic theme.

7.4 Agroecology

7.4.1 Suggested name

Agroecological Production Systems

7.4.2 Description of the scope

Agroecology defined as "the integrative study of the ecology of the entire food system, encompassing ecological, economic and social dimensions" (Francis et al., 2003) has a too wide scope for a single subject area of 15-25 academic staff. In the frame of a BT subject area, agroecology should therefore focus on the sustainability and practical feasibility of diversified agricultural (including both crops and animals) and horticultural production systems. Even with this limited scope, agroecology at BT targets holistic system-level assessments of sustainability, combined with detailed studies of resource (*e.g.,* land, nutrients) use efficiency and interactions between plants, soil, microorganisms, animals and humans (both as mangers of the production system and as users of the delivered products).

The core of the subject area is to assess the sustainability of crop production in different settings: arable cropping systems (in both conventional and organic management), mixed farming systems (with crops and pastures for multiple purposes, *e.g.,* food, animal feed, bioenergy and biomaterials), market gardens or other systems for vegetable production. Field experiments, both on research stations and in farmers' fields and multi-criteria assessment tools are central research methods. Key factors of study include crop diversity at different levels (crop rotational diversity, inclusion of legumes, species mixtures/intercrops, cover crops and perennial crops) and management intensity (*e.g.,* soil tillage, fertilization/organic amendments, weed control, irrigation and post-harvest handling). Outcomes include productivity (crop yield per unit area), product quality (*e.g.,*, nutrient content), resource use efficiency (*e.g.,* land, nutrients), environmental impact (*e.g.,* greenhouse gas emissions, nutrient losses), soil health (changes in soil biology, organic matter and nutrient contents, soil structure), ecosystem services (focus on provisioning, regulating and supporting services) and profitability. System-level sustainability assessments are achieved by multi-criteria decision support tools such as DEXiPM (Pelzer et al., 2012), MASC (Sadok et al., 2009), SMART (Schader et al., 2016) and TAPE (Mottet et al., 2020). The focus on assessing the diversity, ecological interactions and sustainability of systems for food production suggests that *Agroecological Production Systems* could be a suitable name of the subject area.

Background

Agroecology as a science, a movement and a set of practices (Wezel et al., 2009) has a long history, but has recently become more visible (Wezel et al., 2020).

Although different definitions are used depending on geographic and disciplinary/professional context, agroecology is widely recognized for its transdisciplinary and sustainability-oriented approaches. The model for sustainable food production is often pictured as small-scale farming based on high crop diversity, supported by local knowledge and management practices adapted to the uniqueness of the place and where the plant and animal products provide healthy food for the local community. As Fischer et al. (2024) summarize the agroecological view on sustainable agriculture: "the model farmer is a smallholder who produces for subsistence, but probably also for (local) sale and who is tightly connected within their local farming community. The farm is diverse with a range of different crops produced, possibly in agroforestry systems. Farming is labour intensive with minimal use of external inputs. Crop seed is generally produced on the farm or in the local community and to a minimal extent, the farmer is dependent on large input suppliers or supermarkets."

A common feature of Agroecology is the opposition against modern industrial agriculture, which is criticized for environmental and social problems caused by the focus on commodity crops grown on large homogeneous fields with fertilizer and pesticide inputs to maximize productivity (Carlsson, 2019, Fischer et al., 2024). Agroecology also questions technology-based approaches such as synthetic inputs, precision agriculture and gene-editing techniques, as these are viewed as standardized solutions in commodity-based industrial agriculture and therefore interconnected with unsustainable farming practices (Fischer et al., 2024). Even though agroecology emphasizes the combination of plants and animals in integrated systems for sustainable and circular production, scientific literature within agroecology often focuses on "the narrow topic of crop production on farms" (Fischer et al., 2024).

Strategic relevance and research priorities

The aversion against costly (financially, energy-demanding or dependent on rare materials) technologies and the limited focus on animal production (especially regarding animal ethics) present gaps in "mainstream" agroecology, gaps that can be explored and covered by an Agroecology subject area at BT. Moreover, a clear conceptual and epistemological divide exists between the "agroecology" and "sustainable intensification" paradigms and how they tackle the challenges for sustainable agriculture and food security (Bernard and Lux, 2017, Fischer et al., 2024). This is an area where agroecology at BT can develop a unique position where the strengths of agroecology and sustainable intensification can be combined in innovative research, at the same time as the limitations of each paradigm are critically considered and debated.

As agroecology aims to optimize food production based on natural processes and ecosystem services and with minimum input dependency, it offers a model for resilience against drastic input shortages and infrastructure disruptions. The emphasis on diversified production systems is also promoted as a strategy for adaptation to climate change (Wezel et al., 2020). Among on the 13 principles of agroecology (Wezel et al., 2020), the emphasis on species and economic diversity, social values and diets show clear links with food and nutrition security. Agroecology as a social movement also overlaps with food sovereignty, which implies a focus on fair power relations between farmers and food system actors and a more explicit emphasis on nutrition security than the productivity approach to food security which is typically represented in sustainable intensification (Wezel et al., 2020). Thus, agroecology targets the entire range of challenges of sustainability, resilience and food and nutrition security. At the same time it offers solutions that are complementary to the focus in horticulture on high-value, nutrient-dense food produced under controlled, resource-intensive conditions.

Animal health, crop-animal integration and diversification of both plants and animals are key components represented in the principles of agroecology (Wezel et al., 2020). Nevertheless, Agroecology tends to focus more on crop production than on animals (Fischer et al., 2024) and has been criticized for representing an anthropocentric view on animals as resources rather than as sentient beings with inherent values, *i.e.* neglecting the implications of animal ethics in the discourse on sustainable food production (Agell, 2022, Katikaridis, 2025). As animal ethics and welfare are generally under-explored in agroecology, there is large potential to fill these gaps and simultaneously develop uniqueness and scientific excellence through collaboration between the BT subject areas Agroecology and Animal-Centred Environments.

In summary, an agroecology subject area at BT (*Agroecological Production Systems*) complements and synergizes with the other two prioritized subject areas; Animal-Centred Environments and Horticulture. Agroecology uses principles of co-creation, diversity, fairness, health, input reduction, participation, recycling, resource governance and social values as approaches in the sustainability–resilience–food and nutrition security nexus. Representing solutions based on local knowledge and adaptation to site-specific conditions (distinguished from the solutions based on optimization of growth conditions in Horticulture) and bringing methodologies for sustainability assessments of food production systems (including animals), agroecology also has large potential for unique collaborations across the BT subject areas that lead to research excellence and innovations. While the interdisciplinary and holistic framing of agroecology can be perceived as overlapping with the two other subject areas, agroecology at BT has all possibilities to build excellence in its own subject (*e.g,,* diversification, ecological interactions and sustainability assessments of food production systems) and at the same time form unique and innovative collaborations with Animal-Centred Environments and Horticulture. Lastly, the capacity and openness to explore the gaps between agroecology and sustainable intensification and to investigate digital technologies that support Agroecological production system, will further strengthen the subject area uniqueness and excellence – see chapter 7.4.3. below.

Priority research areas

Sustainability assessment of diversified cropping systems

Impacts of different crop diversification practices (intercropping, strip cropping, diversified crop rotations, integration of legumes, cover crops and perennial crops, agroforestry) on *e.g.,* crop yields, resource use efficiency, ecosystem services, labour inputs and profitability.

Plant-animal-microbe-soil interactions

Impacts of crop diversification and animals-crop integration on soil microbial community composition and functional diversity, nutrient acquisition and losses, greenhouse gas emissions, soil quality and fertility, etc.

Co-creation and co-assessment of innovative production systems

Defining research questions based on participants needs, *e.g.,* about innovative ways to integrate ley (with or without animals) in arable cropping systems, increased production and consumption of legumes or the practical implementation of crop diversification practices. Answering the questions through *e.g.,* on-farm experiments and participatory workshops together with concerned stakeholders.

Integration of production systems

Design and sustainability assessments of *e.g.,* agroecological farming systems (arable and horticultural crops, animals-crop integration), circular systems (crop residues and biproducts used as resources), arable-horticulture interactions and synergies, urban-rural interactions and synergies.

One health

Holistic investigations of how the production system affects the health of soil, plants, animals, humans and the environment.

Sustainable production for sustainable nutrition

Using the one health concept to investigate how dietary patterns, shaped by free choice or by guidelines based on environmental impact and/or human nutrition and health considerations, influence the choice and management of plants and animals in the food production and implications on food system sustainability and resilience.

7.4.3 Bracing “Agroecology” to “Technology/Biosystems engineering”

As describe above, agroecology represents scepticism to technology-based solutions such as precision agriculture, which is a central approach in sustainable intensification. The divide between agroecology and sustainable intensification has been further described by Fischer et al. (2024): “Both discourses claim to have the solution to agricultural sustainability but are largely inexplicit about their guiding assumptions and their own limitations and rarely engage with research in the other discourse".

The aversion towards modern technologies alongside with a lack of focus on productivity "making it impossible to establish whether enough food can be produced in the proposed diversified farming systems" (Fischer et al., 2024) critically limit the potential to scale and implement agroecological approaches beyond the niche of already convinced actors. These limitations can be effectively addressed by bracing Agroecology to Technology/Biosystems Engineering, which can be achieved at BT regardless of subject area structure.

Key research areas where agroecology at BT has potential to excel by bridging the gap to technology are:

Autonomous machines for management of diversified cropping systems

Holistic assessments of the efficiency (productivity, economic and energetic balances, labour savings, use of rare materials) of solar-driven camera-assisted robots for crop establishment and mechanical weed control, also assessing the implications for managing intercrops (including agroforestry), cover crops or other complex systems such as agrivoltaics.

Remote sensing to support holistic/integrated management

For example, assessing how fixed or drone-carried cameras/sensors (spectral range depending on objective/question) can guide spatiotemporal optimization of *e.g.,* fertilization, control of weeds, pests or diseases, moving grazing animals or harvesting the crop; implications for complex systems such as agroforestry, agrivoltaics, intercrops and cover crops. Adaptation/modification/development of cameras and sensors to distinguish *e.g.,* crop and weed identity in species mixtures; evaluation of AI-assisted quick and purpose-optimized data analysis to support autonomous machines or management decisions.

AI- or simulation-assisted planning

Evaluating the capacity of AI and simulation-based modelling to generate precise and reliable plans for the management of complex systems, such as spatiotemporal optimization of different crops and timing of different operations (sowing/planting, fertilization, weed control, harvest) in multi-species open-field or indoor fruit and vegetable production, agrivoltaics or multi-species strip cropping in arable fields.

Advanced analyses of productivity and food and nutrition security

Using systems analysis (*e.g.,* LCA or multi-criteria assessment tools) combined with linear programming or dynamic modelling of big/complex data sets to analyse the productivity (land use, labour and energy inputs), environmental impacts and nutrient supply in relation to dietary health; evaluating different scenarios for the primary food production (*e.g.,* comparing examples of agroecological systems and systems designed according to sustainable intensification) and their compliance with sustainability, resilience (*e.g.,* response to input shortages and climatic shocks) and food and nutrition security.

6.4 Horticulture

6.4.1 Suggested name

Edible horticulture

6.4.2 Description of the scope

Executive summary

Edible horticultural science, covering fruits, vegetables (incl. legumes), nuts, herbs, sprouts, medicinal plants and fungi, must be repositioned as a core research area within the sustainability–resilience–food and nutrition security (FNS) nexus. Traditionally seen as a niche sector producing luxury commodities, this framing overlooks its critical role in combating malnutrition, enhancing climate-resilient food production, supporting urban food systems and strengthening crisis preparedness.

Edible horticulture produces high-value, nutrient-dense food, often under controlled, resource-intensive conditions optimized through stress management. Yet, challenges persist in resource efficiency, biodiversity loss prevention, circularity and technological integration across production and value networks.

Meeting global nutrition and sustainability goals requires advancing edible horticulture into a systems-based, interdisciplinary science. The displayed approach is based on the needs depicted by national and international documents on sustainability, resilience, FNS as well as crisis preparedness. Priority research areas include but are not limited to (see detailed description):

- Multi-omics for nutrient-rich, stress-resilient crop design
- Controlled environment agriculture (CEA) for reliable, high-quality food production decoupled from geography and season
- Digitalization, robotics and AI for predictive system stability, early hazard detection and supply chain optimization
- Circular bioeconomy models integrating waste valorization and renewable energy
- Socio-technological systems ensuring equitable access to nutrition under socio-economic and environmental volatility

In the face of escalating systemic shocks such as climate extremes, pandemics and/or geopolitical disruptions, resilient, diversified and technologically integrated edible horticultural systems are essential to stabilize nutrition supplies and food system performance. This requires transdisciplinary research linking horticulture, biosystems engineering, public health and sustainability science to design future-proof, nutrition-secure food systems.

Detailed description

Horticultural science, with specific emphasis on edible commodities (fruit, vegetable incl. legumes, nuts, herbs and sprouts, medicinal plants, mushrooms) is at core of the "sustainability-resilience-FNS"-nexus. Given its high level of precision during pre- and post-harvest as well timing with respect to market aspects, it closely connects to the food-water-energy nexus. Academic horticultural programs have traditionally emphasized on horticulture as a niche crop production sector, with its branch specific production management and value networks. Horticultural produces were viewed as luxury commodities ("the cherry on the cake"). While valuable, this framework neglects the critical role of edible horticultural crops in:

- Combating malnutrition and diet-related disease
- Enhancing climate-resilient food production
- Supporting local and urban food systems
- Strengthening public health and crisis preparedness (Alsanius and et. al., 2025).

Thus, horticulture as an academic discipline and edible horticulture as a research area must transit on a fundamental level, rethinking and redefining its basic approaches (Figure 4). In contrast to modification and replacement of actions or inputs ("events") commonly adopted in horticultural research seeking quick fixes, this innovative approach challenges existing mental models (Meadows, 2008) governing horticultural production and produce at core. It allows to picture the basic underlying mechanisms and their impact on intermediate and outcome layers. Figure 5 presents a model to view edible horticulture within the framework of the nexus, the outer conditions posed by society and the impact of insecurities of different origin, longevity, intensity and depth.

The scope of the subject area is to reposition edible horticultural science as a central research and educational priority and to develop it with respect to today's and future realities and needs. Edible horticulture considers high value, high quality produce produced with high level of input means (incl. energy) and available upon market demand, irrespective of season, climate and site. Horticultural production actively implements the balance between positive and negative stress to optimize biomass production and yield as well as exterior and nutritional quality. Thus, substantial challenges are posed through a changing climate, resource use efficiency, diversity (crop diversity, biodiversity, nutritional diversity, diversity in preferences across populations and seasons), crop loss and food waste reduction, maintained quality under inferior conditions, storage, land use.

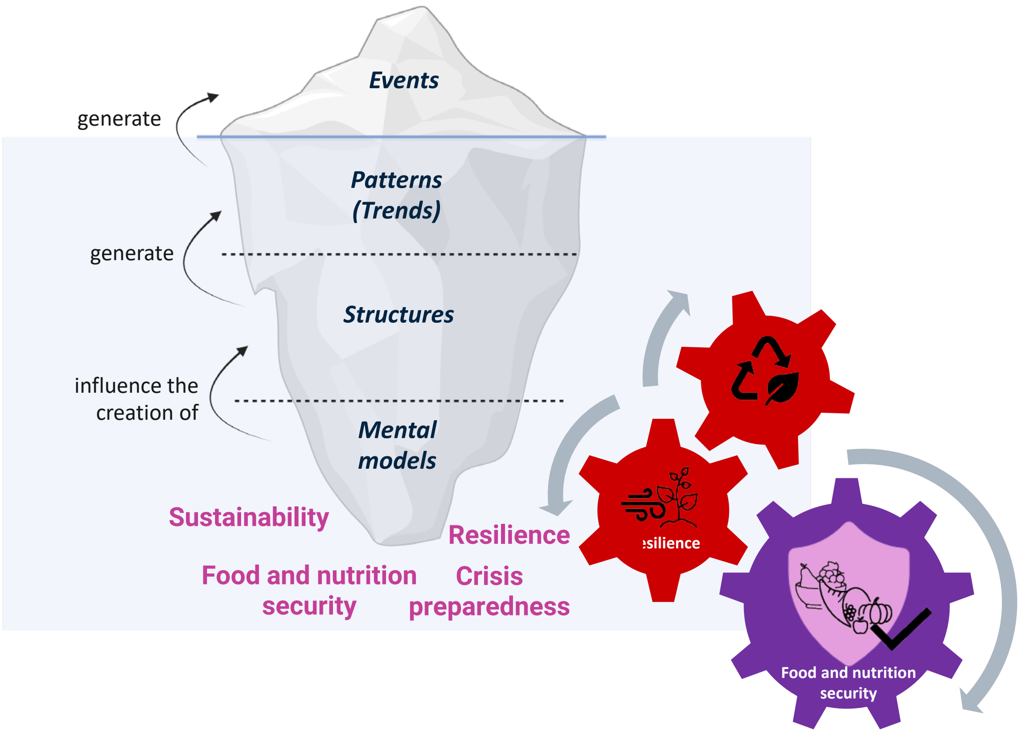

Figure 4: Redesign of the edible horticulture within a systems thinking approach based on the "Sustainability – Resilience - Food and Nutrition Security"-nexus. (Iceberg illustration according to Meadows (2008; arrangement and modifications: B. Alsanius)

Apart from the transition of the nutritional perspective, important trends in development are from linearity to circularity in horticulture and from finite to renewable resources, prevention of biodiversity loss within the production system and the surrounding nature, digitalization and robotization of production and distribution as well as retail, including early warning systems to alert on hazards and instabilities, novel energy sources to cover energy needs and prevent power system shocks as well crisis preparedness with respect to all parts of the value network (inputs, production, distribution, retail and consumption). Edible horticulture pursues a systems-based approach and integrates biology, technology and ecology related to horticultural value networks (from farm to colon) to the grand global challenges and collaborates with social, economic (market and consumer), environmental and medical sciences as well as logistics.

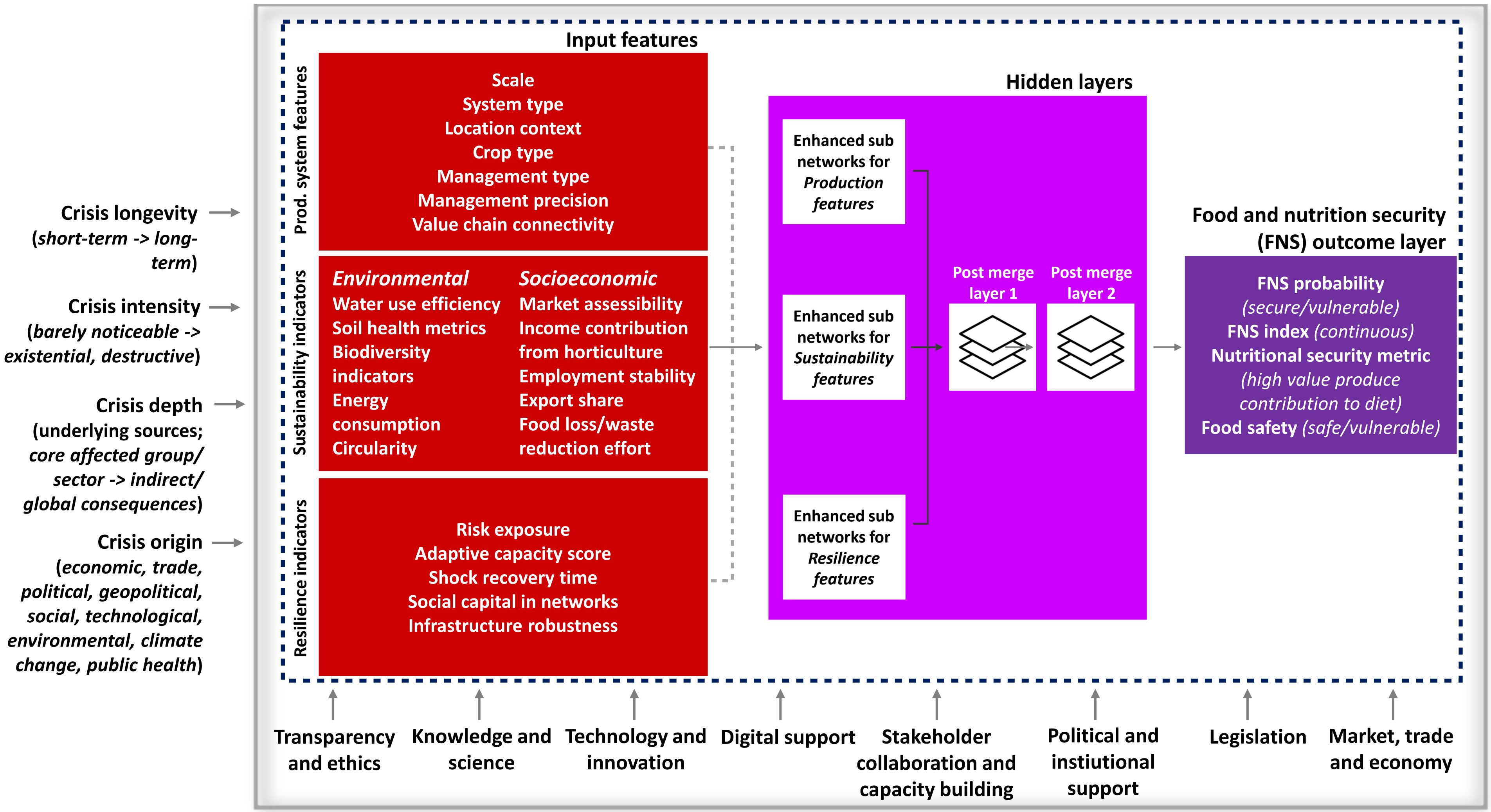

Figure 5: Model to approach the subject edible horticulture based on framework documents. The model is displayed as a multi-layer neural network integrating horticultural value networks into the framework of the "Sustainability - Resilience - Food and Nutrition (FNS)"-nexus as embedded into the framework of societal conditions and challenges posed by instabilities (crisis, insecurities). (Model development and illustration: B. Alsanius).

In detail, it

(i) uses sustainability as a guiding principle,
(ii) establishes edible horticultural food systems as a central pillar of agricultural and food science research,
(iii) prioritizes interdisciplinary research linking horticulture (and horticultural food) to public health, climate adaptation and food security in a politically and climatically highly volatile context,
(iv) develops dedicated research programs on resilient, sustainable and nutrition-focused horticulture,
(v) provides policymakers and stakeholders with cutting-edge evidence-based knowledge to support their informed decision-making process and
(vi) engages into the societal discourse to promote availability, accessibility and affordability of nutritionally important food items for diverse populations in times of insecurities and crisis.

As described in Figure 5, this basic concept allows modular approaches, selecting scenario-based study systems and allowing translation into other parallel systems. This maximizes output, outcome and impact. Prioritized research areas within the four challenging dimensions (sustainability, resilience, FNS and crisis preparedness) are listed below.

Food and nutrition security

Edible horticulture is central to achieving global FNS. While staple crops address caloric sufficiency, only horticultural crops provide the micronutrients, dietary diversity and bioactive compounds essential for preventing malnutrition, supporting immune function and reducing the burden of non-communicable diseases (Keatinge et al., 2011, Boeing et al., 2012, Yahia et al., 2019). Despite their critical role, edible horticultural crops remain underprioritized in research, policy and technology development, but also in consumers' prioritization (Mason-D'Croz et al., 2019). The scientific challenge for edible horticulture is to evolve beyond conventional production science into a cutting-edge, systems-level discipline that fuses genomics, controlled environments, digital technologies, circular bioeconomy principles and resilience engineering, explicitly oriented toward global FNS. The future of nutrition security depends not only on producing more biomass, but on producing smarter: designing horticultural systems that are nutritionally optimized, resource-efficient, technologically integrated and fundamentally resilient in the face of complex global challenges. At the Dept of Biosystems and Technology as well as at the LTV-faculty there is a strong stakeholder network in terms of Partnership Alnarp and implemented in ongoing projects in synergy with stakeholder industry. This means that there are very good opportunities for quick capitalization of the paradigm shift (Figure 4, Figure 5). Examples for these challenges are

- Multi-omics for nutrition-driven crop design integrating genomic, metabolomic and phenomic datasets that connect genotype, stress physiology and environmental inputs to bioactive compound accumulation, nutrient density and post-harvest stability.
- Precision controlled environments for nutrient engineering irrespective of cropping site to meet climatic variability with optimized for yield, shelf life and high nutritional quality. Predictive models for nutritional value chains linking production, post-harvest handling and logistics to nutritional quality at the consumer level. The perishability and sensitivity of edible horticultural commodities demand new modelling approaches.
- Circular bioeconomy and metabolic resource efficiency, closing nutrient loops through valorized biowaste and renewable energy and input means with maintained or enhanced nutritional integrity
- Resilience design for food and nutrition security in times of crisis and insecurity embedding redundancy, modularity, diversity and adaptive capacity into nutrition-sensitive value networks. This considers scale of production, closeness to consumer, crisis origin, depth, intensity and longevity.

Sustainability

The escalating demands for nutritional security, climate resilience, biodiversity preservation, resource circularity and systemic crisis preparedness place edible horticulture at the core of advanced food system sustainability science. The sector's unique characteristics, namely year-round availability of nutrient-dense, perishable, often resource-intensive produce, cultivated under stress-optimized conditions adapted to the crop's demands, present both grand challenges and frontier research opportunities. The transition from a fragmented approach, testing the replacement of individual practices or input means to a systems-based approach is key. Examples for these challenges are:

- Stress-responsive, resource-efficient crops for complex systems, using multi-omics to design crops with optimized nutritional properties, stress-resilience and resource use efficiency as well as balancing between environmental (incl. water) footprints and yield as well as phytonutrient profile stability across the horticultural value network
- Circularity and biodiversity conservation in high-performance horticulture, meeting the dual challenges of intensive production demands and environmental stewardship (*e.g.,* diversity in terms of biodiversity, crop diversity, nutritional diversity and diversity of preferences and needs, biodiversity metrics across production systems and scale; valorization of horticultural side stream resources)

- Digitalization, robotics and predictive sustainability intelligence, such as AI-enabled early warning systems for biotic, abiotic and societal hazards adventuring food safety, crop quality and food system stability; autonomous production and distribution technologies safeguarding sustainability and biodiversity in the production environment; digital systems linking value networks for edible horticultural commodities to environmental monitoring, supply chain logistics and nutritional quality
- Energy transition and resilient decoupled food systems, meeting vulnerabilities in today's energy grid (availability, accessibility, affordability, shocks)
- Socio-technological systems for nutrition accessibility and equity, expanding the discourse of sustainability in horticultural production beyond environmental sustainability to socio-economic metrics. This topic opens for a transdisciplinary approach involving public health, consumer and market science, for development of interventions as well as the understanding of resilient food systems and crisis response infrastructure.

Resilience

The frequency of systemic shocks occurring as individual or cascading events (*e.g.,* climate extremes, geopolitical instabilities, energy-related challenges, pandemics not limited to covid) has exposed the inherent fragility of global food systems. At the same time, nutrition insecurity and biodiversity loss are intensifying. In the Swedish context, a majority of edible horticulture produces have been subject for import during a long time. Given the fact that these commodities are an essential pillar of a healthy diet, food system resilience is key.

In this context, the critical functions of edible horticultural crops in buffering food systems against individual and/or cascading shocks, diversifying production landscapes and production scale as well as stabilizing nutrition supplies in crisis scenarios need attention. They need a transdisciplinary approach. Examples for these challenges to be tackled are:

- Embedding resilience into the entire value network in edible horticulture (*e.g.*, optimization of crops, cropping systems and management to withstand single or multiple stressors without compromising yield, exterior or nutritional quality; systems modelling for simulating adaptive capacities and identification of leverage points)
- The dilemma of CEA in terms of resilience infrastructure
- Predicitive technologies and early warning systems for sustainability, nutritional quality and public health hazards (food safety)
- Biodiversity integrated resilience across scales (*e.g.*, agroecological models to develop long-term adaptive capacity of horticultural cropping systems

which are often based on monoculture; circular design for sidestream valorization to support regenerative production cycles).

6.4.3 Bracing "Horticulture" to "Technology/Biosystems engineering"

The scope described in the previous section illustrates the close integration of technological questions into edible horticulture. For clarity, the main links between edible horticulture and technology/biosystems engineering are summarized below. Edible horticulture is central to addressing intertwined sustainability, resilience and nutrition challenges. Technology and biosystems engineering are critical enablers to:

- Transform edible horticulture into a systemically resilient, resource-efficient, biodiversity-positive and nutrition-optimized food system component
- Provide the technological basis ensuring year-round, site independent and crisis-robust production and distribution of nutritionally valuable edible horticultural commodities
- Integrate advanced digital, biological and engineering innovations into scalable, equitable food system solutions.

Strategic research programs must prioritize these interdisciplinary, technology-driven domains to position edible horticulture as a keystone of future-proof, sustainable food systems. The cross-cutting issues on crisis preparedness and system stability embedded across all core domains as a response to geopolitical, environmental, energy or health-related shocks were identified with respect to technology/biosystems engineering involvement and summarized at the end of this chapter.

Food and nutrition security

Technology/biosystems engineering focus: Nutrient availability, quality preservation, diversification of supply and system stability

Area	Research challenges
Multi-omics for nutrition-driven crop design	Integration of genomic, metabolomic and environmental datasets to enhance bioactive compound content, nutrient density and post-harvest stability
Precision controlled environments for nutrient engineering	Technological development of sensor-integrated, site-independent growth systems for optimized nutritional profiles
	Technological development of environmental control strategies and facilities balancing yield, shelf-life and nutritional integrity (*e.g.,* produce optimized storage facilities incl. packaging systems)
Predictive nutritional value chain modelling	Creation of dynamic models linking production, post-harvest handling, logistics and consumer-level nutrient availability for prediction of optimized handling
	Creation of real-time systems to mitigate nutrient degradation across extended, complex supply chains
Circular bioeconomy for nutrition and resource optimization	Engineering of biowaste valorization technologies contributing to both resource efficiency and food system stability

Sustainability

Technology/biosystems engineering focus: Resource efficiency, environmental stewardship, circularity, biodiversity preservation and technological transformation of production systems

Area	Research challenges
Stress-responsive, resource-efficient crop systems	Metrics and modelling for availability and optimized resource use efficiency of input means (water, nutrients, energy) as well as climate control
Circularity and biodiversity conservation	Systems design and modelling for valorization of horticultural side-streams and biowaste

in high-performance horticulture	Dynamic modelling of biodiversity in high-performance horticulture
Digitalization, robotics and predictive sustainability intelligence	Development of AI-enabled environmental and crop monitoring systems
	Development of autonomous production platforms safeguarding environmental sustainability
	Development of digital decision-support systems linking production with environmental indicators and nutritional outputs
Energy transitions in decoupled horticultural food systems	Energy-efficient, decentralized production units resilient to grid vulnerabilities
	Low-carbon, climate-neutral horticultural production technologies
Socio-technological systems for sustainable nutrition accessibility	Cross-disciplinary research integrating technology-driven interventions to ensure equitable access to sustainable, nutrition-rich horticultural products

Resilience

Technology/biosystems engineering focus: Systemic robustness, adaptive capacity, redundancy, biodiversity integration and buffering against shocks

Area	**Research challenges**
Resilience-by-design for edible horticultural systems	Dynamic modelling for crop optimization strategies to maintain yield, external and internal quality under multi-stressor scenarios (individual and cascading), incl. machine learning
	Systems modelling tools to simulate value network vulnerabilities, adaptive pathways and recovery mechanisms
Dilemma controlled Environment Agriculture (CEA) as resilient infrastructure	Engineering solutions for: • Energy-autonomous, modular and adaptive controlled environments • Integration of resilience metrics (redundancy, flexibility, diversity) in urban and peri-urban CEA systems

	• Mitigation of CEA dependency on centralized, fragile energy or input supply systems
Predictive technologies and early warning systems for systemic resilience	Development of AI-driven real-time hazard detection sensors/systems for biotic, abiotic and societal disruptions impacting edible horticulture
	Development of digital twins for real-time system simulation, vulnerability assessment and proactive response planning
Biodiversity-integrated resilience across scales	Biosystems design for agroecological models embedding edible horticulture in biodiverse landscapes
	Dynamic modelling on genetic and species diversity to buffer against ecological and economic shocks
	Modelling and biosystems design for circular valorization pathways to enhance ecological regeneration and system stability

Cross-cutting issues: Crisis preparedness and system stability

Technology/biosystems engineering focus: Systemic robustness, adaptive capacity, redundancy, biodiversity integration and buffering against shocks

Area	**Research challenges**
Resilient, decentralized production networks	Design of modular, distributed edible horticultural systems reducing supply chain dependency and increasing crisis response flexibility
Energy-autonomous and resource-efficient controlled environments	Mitigation of production vulnerabilities to energy supply shocks and climate extremes
Real-time early warning and system monitoring platforms	Integration of biosensors, AI and predictive analytics for rapid hazard detection, including food safety and nutritional security risks
Adaptive value network modelling under instability scenarios	Scenario-based systems analysis for proactive adjustment of edible horticultural supply chains in response to crises of varying origin, intensity and longevity

6.5 Recommended Actions (2025-2026)

- Create centres or platforms for Agroecology, Animal-Centred Environments and Horticulture (*e.g.,* transdisciplinary science and research platform, PhD school).
- Modernize infrastructure in horticulture and digitize agroecology.
- Position SLU in EU/UN agroecological and animal welfare innovation spaces.
- Frame Technology as an enabling cross-cutting strategy, not a primary theme.

6.6 Justification of suggested subject areas with respect to the LTV strategy

This chapter presents a justification for the selection of prioritized and non-prioritized research areas in alignment with the LTV Faculty's strategic objectives during 2021-2025 (LTV-faculty Faculty board, 2021). Emphasis is placed on each area's potential to contribute to sustainable societal development, digital innovation and interdisciplinary collaboration, *i.e.,* the core pillars of the faculty's mission. The prioritization reflects the unique strengths, societal relevance and future leadership potential of selected areas, while non-prioritized fields are repositioned as supportive platforms to enhance strategic coherence and resource focus.

6.6.1 Strategic synthesis

The strategic synthesis is displayed in Table 7.

Table 7. Strategic synthesis for the prioritized and non-prioritized key areas from the perspective of the LTV-faculty's strategy 2022-2025. (✓ indicates positive alignment with the evaluation parameters. The number of ✓ displays the strength of alignment. × depicts absence of alignment.) ICP: Integrated Crop Production.

Strategic Focus	Agroecology	Animal-Centred Environments	Horticulture	ICP	Technology
Multidimensional sustainability	✓✓✓	✓✓✓	✓✓✓	✓	✓
Digital society integration	✓✓	✓✓✓	✓✓	×	✓✓
Transdisciplinarity and co-creation	✓✓✓	✓✓✓	✓✓	×	✓✓(supportive)
Unique SLU identity	✓✓✓	✓✓✓	✓✓✓	×	×
Cohesive research and teaching environment	✓✓	✓✓	✓✓✓	×	×
Strategic leadership potential	✓✓✓	✓✓✓	✓✓	×	×

6.6.2 Details on alignment of prioritized and non-prioritized key areas with the LTV-faculty’s strategy 2022-2025

Proritized areas

1. Agroecology

- Sustainability Focus (Focus Area 1): Agroecology directly addresses multiple UN SDGs and engages deeply with environmental, economic and social sustainability. Its system-based, ethical and participatory approach perfectly aligns with SLU's “next step for sustainable development.”
- Transdisciplinarity and Collaboration: Agroecology thrives at disciplinary interfaces (*e.g.,* ecology, sociology, technology), responding to the LTV strategy’s emphasis on collaborative, co-created and interdisciplinary work with societal actors.
- Digital Potential (Focus Area 2): Its openness to AI, robotics and data integration supports SLU’s ambition to lead in digital transformation of sustainable agriculture.

- Campus and Societal Anchoring: Agroecology's visibility can be strengthened through living labs and campus development, as envisioned in the strategy's campus objectives.

2. Animal-Centred Environments

- One Health/Welfare (Focus Area 1): Animal welfare, particularly emotional and perceptual dimensions, advances SLU's holistic sustainability goals and societal relevance in food systems and health.
- Digital Integration (Focus Area 2): Pioneering use of AI and sensor technologies positions this area as cutting-edge in digital innovation which is a strategic imperative for LTV.
- Societal Engagement: Strong connections with global policy (*e.g.,* One Welfare) and ethical discourse exemplify SLU's commitment to knowledge exchange with societal actors.
- Uniqueness and Strategic Identity: Its distinctiveness enhances SLU's reputation as an expert authority, fulfilling strategy goals under both One SLU and external collaboration.

3. Horticulture

- Resilience and urban sustainability (Focus Area 1): Circular systems, production systems based on renewable inputs and urban green infrastructure make horticulture crucial to climate adaptation and food security which are key themes in SLU's sustainability agenda.
- One Health (Focus Area 1): Merging value network of edible horticultural commodities into the One Health focus advances SLU's holistic sustainability goals and societal relevance in food systems and health.
- Digital integration (Focus Area 2): Digital solutions already are "business as usual" in commercial horticulture; Pioneering use of AI and sensor technologies positions this area as cutting-edge in digital innovation poses a strategic imperative for LTV.
- Transdisciplinary potential: Engages in health, urban design, climate and food systems which is clearly aligned with SLU's integrative mission.
- Campus and physical environment expertise: LTV's unique role in physical planning and green environments directly supports campus development, with horticulture a practical and research-driven showcase of that.
- Educational anchor: As one of SLU's distinct subject areas, it supports cohesive education and research environments, a core aspect of "One SLU."

Non-Prioritized Areas: Reasons for Deprioritization

1. Integrated Crop Production (ICP)
    - Lack of strategic clarity: Despite conceptual relevance, ICP suffers from fragmented institutional presence and lacks a distinct academic identity, limiting its potential to lead as an independent strategic area.
    - Duplication and dilution: It overlaps thematically with agroecology and horticulture but without the unique systems framing or stakeholder engagement that otherwise would align more directly with transdisciplinary goals in the LTV strategy.
    - Strategic fit as a platform: The recommendation to embed ICP within agroecology and horticulture supports SLU's approach of strengthening cohesive environments (One SLU) while still preserving valuable knowledge and practices.

2. Technology/ Biosystems Engineering (as standalone)
    - Not thematically anchored: As a field, it lacks alignment with the LTV faculty's unique societal mandate (*e.g.,* ethics, landscape, quality of life). While technically important, it doesn't represent a mission-driven focus area.
    - Best suited as enabler: It aligns with supporting the digital society focus area but not as a strategic domain in itself. Instead, its role is to enhance the prioritized areas' digital infrastructure, modelling capabilities and system analysis.
    - Resource constraints: The current lack of infrastructure and critical mass limits its ability to fulfil the faculty's goals in external funding, education development, or cross-campus collaboration as a lead area.

7. List remaining discussion issues to translate the analysis to action

The present report describes the research strategic analysis for future successful research areas at the Department of Biosystems and Technology. It provides the basis for a formalized research strategy, For translation of the strategic analysis to action, the following steps are necessary:

1) The subject area names must be discussed and consolidated amongst the department's employees
2) A formalized research strategy incl. operational plan and actions
3) Its translation of the research strategy into a funding strategy
4) A list of infrastructure needs, incl. description of their purposes, urgency as well as, a priority list and description of consequences of needs not-met
5) A deeper analysis of needs to reach scientific excellence in the outlined subject areas
6) A talent and competence plan to populate the three future subject areas integrated with biosystems engineering to be successful, incl. identification of keystone competences, staff rejuvenation in balance with research and teaching needs
7) A comprehensive road map for translation, incl. time plan and funding allocation plan

8. Answers to the ToR

1. Identification of three future subject areas at the department through

a. Identification of buzzwords or mission statements to be used to define and rank the alternatives, based on the outcome of the first staff workshop?
The first staff workshop did not provide any buzzwords or define a specific ranking of alternatives.

b. The buzzwords extracted from documents central to the department are

Research strategy related	Excellence, Innovation, Internationalization, Uniqueness
Sustainability related	Sustainability, Climate transition, Climate change adaptation, Green transition, Circular bioeconomy, Sustainable intensification, Genomics (resistance to stress)
Resilience related	Resilience, Crisis preparedness, Self-sufficiency, Local production, Food security, Regional distribution, Input supplies
Digitalization related	Digital transformation, Climate smart agriculture, Precision agriculture
Miscellaneous	Innovation, Knowledge transfer, Translation to practice

c. Identification of the possible future subject areas: working name (*work name*)
Animal (*Animal centred environments*)
Agroecology (*Agroecological production systems)*
Horticulture (*Edible horticulture*)

d. Description of the suggested scope of each proposed subject area
Agroecology in broad sense entails studies of the ecology of entire food systems, but in the frame of a subject area the focus is on sustainability and practical feasibility of diversified production systems. Agroecological principles of *e.g.* recycling, input reduction, soil health, biodiversity and synergy are applied in holistic system-level assessments of sustainability

and detailed studies of resource use efficiency (e.g. land, nutrients) and interactions between plants, soil, microorganisms, animals and humans (both as mangers of the production system and as users of the delivered products).

The Animal-Centred Environments subject area explores the complex interactions between animal physiology, behaviour, production efficiency, and welfare in modern livestock systems. It integrates sensory perception, cognitive responses, and health indicators with digital monitoring technologies (e.g., sensors, computer vision and AI-driven analytics) to assess and improve animal welfare. The scope also includes the design and evaluation of sustainable and resilient housing systems that support species-specific needs, reduce environmental impact, and contribute to ethically grounded animal production.

Horticulture encompasses high intensity and quality value networks for edible and ornamental crops and produce, often perishable, for direct consumption or consumed after minimal processing. The crop, its abiotic and biotic demands as well as production goal set the frame for management factors and optimization of the horticultural production environment. The suggested research area focuses on edible produce. Edible Horticulture explores sustainability, resilience and contingency of horticultural value networks for edible produce. It addresses the entire system from resource use and production at various scales of intensity and mechanization/automation to post-harvest handling, distribution and consumption. The research area integrates plant physiology (esp. stress physiology), ecology, microbiology, technology and systems analysis to develop climate-smart, circular and resource-efficient food systems for edible horticultural produce in rural, peri-urban and urban contexts, with strong emphasis on food and nutrition security, food safety and crisis preparedness.

2. Justification of the suggested subject areas’ connections to SLU/LTV's mission and strategy according to the LTV-proposal and depiction of aspects within the subject area being in the forefront of future research agenda?

The proposed subject areas are justified by their strong alignment with the LTV faculty’s strategy, which emphasizes sustainability, resilience, food and nutrition security, One Health/One Welfare and societal relevance. Agroecological Production Systems, Animal-Centred Environments and

Edible Horticulture collectively address pressing global challenges through systems-oriented, interdisciplinary and technology-integrated research while building on BT's existing scientific strengths and infrastructure. The prioritization supports academic excellence, internationalization and innovation, and enhances the faculty's strategic profile by fostering unique, future-oriented research environments capable of delivering measurable impact across academia, policy and practice.

3. List of remaining issues for discussion regarding name, demarcations or scope and suggestions on how to proceed to solve them.
    - The subject area names must be discussed and consolidated amongst the department's employees
    - A formalized research strategy incl. operational plan and actions
    - Its translation of the research strategy into a funding strategy
    - A list of infrastructure needs, incl. description of their purposes, urgency as well as, a priority list and description of consequences of needs not-met
    - A deeper analysis of needs to reach scientific excellence in the outlined subject areas
    - A talent and competence plan to populate the three future subject areas integrated with biosystems engineering to be successful, incl. identification of keystone competences, staff rejuvenation in balance with research and teaching needs
    - A comprehensive road map for translation, incl. time plan and funding allocation plan.

Acknowledgements

The authors thank all BT staff members for their engagement and input during workshops and for individual or spontaneous discussions on the analyses. We also owe thanks to Lise Lykke Steffensen for her input and fruitful discussions.

Appendix 1

Research strategy output (Tables X1 and Y1) from the staff workshop on subject area revision on Dec 4, 2024 as summarized by the HoD

X1 (1)

- POSSIBLY A WOBBLY START IN THE BIG PLANT GROUP
  - *Due to strong personalities and loads of opinions!*
- POSSIBLE NAME OF THE "PLANT" GROUP:
  AGRICULTURAL AND HORTICULTURAL PLANT PRODUCTION
  - *Important that Horticulture is visible in the "plant" subject area*
  - *Wording matters - Perhaps rethink our department name?*
  - *Use Acronym?*
- "PLANTS", "ANIMALS" AND "TECHNOLOGY" NOT UNIQUE AT SLU→ AGROECOLOGY IS MORE UNIQUE
  - *What makes plant research at LTV/BT unique at SLU? Answer: Integrated plant production system with Agriculture and Horticulture crops.*

Production Systems
Production Technology
(Important key words)

Positivt med Hort+Agroek+tech grupper, men viktigt att Agroekologi tidligt inkluderar storskalighet och olika odlings-djurhållningssystem, även inomhus, t.ex Agroekologisk produktionssystem eller något sånt.

Tror Agroekologi med växt & djur ihop kan vara ett sätt att kunna "lobba" för att få tillbaks djur till Alnarp, vilket skulle vara positivt för både LMP & forskningen.

Måste jobba med psykologisk trygghet för att omorganisation ska fungera oansett hur den blir. (Helene).

1(3)

X1 (2)

- ONE PLANT AREA ALIGNS WITH STAKEHOLDERS VIEW ON PLANT PRODUCTION
  - *The devision between agriculture and horticulture is artificial, not relevant in practise*
- DIFFICULT TO FOCUS WHEN WE INCLUDE "EVERYTHING"
  - *We want to solve all problems*
- "NOT FIT TO MEET SOCIETAL CHALLENGES, INSTEAD

→Align to societal challenges & our relevance on how to meet/ contribute when we profile & organize ourselves
→Will benefit funding and thus, sucess

OR

→Three new areas:
- *All Plant/Horticulture*
- *Agroecology and Agrotechnology*
- *Animal Centered Environments*

→Key words:
Food securety
Resilience
Adaption

2(3)

X1 (3)

- ONE PLANT GROUP WOULD BENEFIT LAB WORK
  - *Better knowledge on equipment*
  - *Some specialized analyses that could benefit all subject groups*
  - *Inspire each other to apply "new" methods in own research*
- CURRENT STAFF COMPOSITION MIGHT CHANGE DURING 5 YEARS - SHOULD NOT HAVE TOO MUCH INFLUENCE
  - Animalgroup is small but in a very positive mode!
- GOOD TO RENEW HORTICULTURE AREA INTO LARGER PLANT FOCUS
- NEW POSSIBILITIES TO COLLABORATE ACROSS 3 SUBJECT AREAS

→ Because of increased openness and flexibility between groups (e.g. where people sit)
→ If we choose to be more open & flexible
→ New funding sources (national/international)
→ Increased critical mass in each group
→Because we will be more in each group, we get to know eachother etc... = Fuel
- *Stimulates scientific debate/depth*

"PRO'S"

Y1

- UNIQUE GROUP (NATIONALLY) (H,A)
  - Exists in no other universities in Sweden
- STRATEGIC USE OF (SHRINKING) RESOURCES (H,A,T)
  - No doubling of functions
- AVOID INTERNAL COMPETITION (H) (BETTER CONTROL)
- MORE COLLABORATION (H), (A) (MORE CONTACT)
  - Use infrastructure together (all groups)
- MORE PEOPLE CAN FOCUS ON RESEARCH (H)
  - Use infrastructure together (all groups)
- NEW RESEARCH TOPICS INTEGRATING ANIMALS AND CROPS (H, A, T)
- IF TECHNOLOGY GROUP, A PROFESSOR CAN BE RECRUITED

H: HORTICULTURE
A: AGROECOLOGY
T: TECHNOLOGY

WHY?

HORTICULTURE | AGROECOLOGY | BIOSYSTEMS ENGINEERING

1(2)

"CONS"

Y1

- REDUCE VISIBILITY OF ANIMAL RESEARCH (DUE TO EXPLICIT NAME?)
  - No visibility depending on how Agroecology is defined
- TO KEEP "UNIQUE" ↔ EXCLUDE/SKIP OTHER RELEVANT GROUP?
- LESS POSSIBILITIES FOR INTER-GROUP COLLABORATIONS BECAUSE OF FEWER GROUPS
- UNEVEN SIZE OF THE GROUPS(?)
- RISK OF LOOSING COMPETENCE
  - →People retire
  - →People changing to another department
- PROBLEM WITH MERGING GROUP WITH DIFFERENT CULTURE
  - Horticulture
    - Unique group at SLU, Alnarp
    - Avoid competition
    - Strategic allocation of resources
    - Suggested - Biosystem engineering?

2(2)

Appendix 2

List of potential combinations of subject areas leading to three candidate areas

Alternative subject area[9] combinations as suggested by the HoDs

1	2	3
Horticulture	Agroecology & animal centred environments	Biosystems engineering/Agrotechnology
	OR	
Horticulture	Animalergonomics + building function	Biosystems engineering / Agrotechnology
Integrated plant production systems	Agroecology & Animal centred environments	Biosystems engineering/Agrotechnology
	OR	
Integrated plant production systems	Animal centred environments	Biosystems engineering/Agrotechnology
	OR	
Integrated plant production systems	Animalergonomics & building function	Biosystems engineering/Agrotechnology
Integrated plant production systems	Animal centred environments	Agroecology and agrotechnology
OR		
Horticulture	Animal centred environments	Agroecology and agrotechnology
Integrated plant production systems	Animal centred environments	Biosystems engineering/Agrotechnology
		OR
Integrated plant production systems	Animal centred environments	Agroecology and agrotechnology

[9] NB! Some of the potential candidate areas are not existing at the Dept at the time of evaluation (*e.g.*, Integrated plant production systems, agrotechnology). No outline of these key areas was provided.

Appendix 3

List of questions used as a basis for the SWOT analysis

Strength

What are the key strengths of this research field in terms of academic contribution? (=*What is the potential for excellence? Rigorous methodology, innovation, originality, significant impact, ethical standard, interdisciplinary collaboration, clear communication?)*

How well-established is the research field in the academic community?

How unique is the research area? (and What are the unique selling points?)

What unique methodologies or approaches are being used in this research area?

What is the potential for innovation and internationalization within the research area?

What is the potential for internationalization (research collaboration, co-publication, exchange)?

How well established are branch collaborations and what is the potential for further development?

Does the research area engage in digitalization research within its domain of responsibilities?

What are the most invaluable resources or assets the research area has at its disposal?

What unique talents do our employees or teams possess (specialized knowledge / skill sets / experience / reputation)?

What high-impact outcomes in sustainability are associated with this field?

What high-impact outcomes in resilience are associated with this field?

What high-impact publications or influential researchers are associated with this field?

What funding sources are available for research in this area?

How well-supported is the research field by interdisciplinary collaboration?

How well is the research field anchored in international networks or policymaking bodies?

Weaknesses

What are the main challenges or limitations within this research field?

Are there any gaps in the existing body of knowledge that need to be addressed?

Are there any methodological or technical limitations hindering progress in this area?

How well is the research field suited to comply to the upcoming shift from factor or process to outcome oriented research?

Is there a lack of sufficient funding or resources for research in this field?

Are there issues with the accessibility or reproducibility of research findings?

What is the intellectual cohesion within the research field?

What are the factors that ultimately keep the research area from being excellent? What are the biggest bottlenecks?

What processes need most improvement?

What barriers exist for new researchers or students entering this field?

Are research outcomes reaching the end user? (Knowledge transfer to the scientific community, professionals, regulatory bodies and policymakers, extension, education)

Opportunities

What emerging trends or new developments could create opportunities for growth in this research area?
Are there untapped or underexplored topics within this field that could lead to significant discoveries?
What interdisciplinary opportunities exist for collaboration with other research areas or departments?
How can advancements in technology or methodology be leveraged to push the boundaries of research?
How can the new realities posed by funding bodies push research boundaries and collaborations?

Are there new funding sources or grants available to support research in this area?

What are the potential societal, industrial, or policy-related impacts of research in this field?

What are the potential of sustainability, resilience, food security, preparedness/contingency, green transition, climate adaptation, sustainable intensification impacts of research in this field?

Threats

What are the potential risks or external factors that could negatively impact this research field?

Are there competing research fields that could overshadow or replace this area of study?

How might changes in academic funding or political support affect the future of this research area?

Are there ethical concerns or public controversies that might limit the credibility or acceptance of research in this field?
How vulnerable is this field to changes in technological or methodological advancements that could make current research obsolete?
Could there be a shortage of skilled researchers or a lack of interest in pursuing this area of study?

Appendix 4

Themes for research projects falling under the five different research domains, suggested by the BT department staff members during the workshop on January 27, 2025. Each list is followed by a short analysis viewing the suggested themes from the perspective of the four underlying dimensions (sustainability, resilience, food and nutrition security, crisis preparedness) and the four outcome/impact areas (excellence, innovation, internationalization, uniqueness). **NB! this analysis is purely conducted on the basis of the suggested titles. No summaries or synopses for the different themes were available and follow-up discussions occurred. Therefore, this analysis does not provide any basis for institutional discussions within the framework of the reorganization process.**

Appendix table 5-1: Themes for projects suggested for "Agroecology"

1	Poplar trees and pig production - animal welfare and wood plus biogas production
2	Animal grazing in orchards
3	Balancing biological soil health and economic performance
4	Environment or food security – trade-offs between environmental and social sustainability
5	Working equine welfare in sustainable global food production systems
6	Reduced waste and better resource utilization in combined agri-horto-field vegetable production system.
7	Intercropping X with X for in organic farming systems Ecosystem services of X crop Perennial and annual integrated cropping systems Nutrient efficiency in X crop / nutrient cycles
8	Small scale animal husbandry for self-sufficiency and crisis preparedness
9	Agroforestry and pig production- enrichment for pigs kept outdoors
10	Integrated animal grazing and soil enhancement in the crop rotation
11	Possibilities for ecological intensification
12	Agroecological crop rotations to improve soil health to reduce incidence of plant pathogens in field and in storage.

Overarching themes	
1	Integration of systems
2	Sustainability and environmental health
3	Soil health and nutrient cycles
4	Animal welfare and integration
5	Diversity in cropping and land use
6	Resource efficiency and crisis preparedness

Summarizing analyses of the suggested themes

The proposed agroecology research portfolio demonstrates strong interdisciplinary coherence and strategic alignment with global priorities in sustainability, resilience, food security and crisis preparedness. The twelve project themes collectively cover a wide spectrum of agroecological innovation from integrated crop–livestock–forestry systems and circular resource management to soil health, animal welfare and socio-economic trade-offs. Several projects (*e.g.,* poplar–pig biogas integration, agroforestry with outdoor pigs and waste-efficient agri-horti-vegetable systems) exemplify high potential for excellence and innovation through their systemic coupling of production, energy and welfare dimensions. Others, such as balancing soil health and farm economics or assessing trade-offs between environmental and social sustainability, bring conceptual depth and international relevance, fostering dialogue between ecological performance and socio-economic viability. Unique contributions include attention to working equine welfare in global food systems and small-scale animal husbandry for crisis preparedness. They both extend agroecology's scope into underexplored ethical and resilience-oriented domains. Collectively, the projects combine experimental rigor with applied relevance, offering opportunities for cross-sectoral collaboration and real-world impact.

The overarching research themes, system integration, sustainability, soil health, animal welfare, diversity, resource efficiency and renewable energy, provide a cohesive framework that amplifies the projects' individual strengths. Together they establish a research environment characterized by scientific excellence, conceptual innovation and high internationalization potential. The program's distinguishing feature lies in its holistic approach: linking soil and ecosystem health to ethical animal use, circular bioresource flows, and preparedness for systemic shocks. This synthesis positions the agroecology portfolio as a distinctive and globally competitive initiative capable of advancing the transition toward resilient, low-input, and ethically grounded food systems.

Appendix table 5-2: Themes for projects suggested for “Animal-centred environments”

1	Integrated aquaponic systems in horticultural production
2	Smellwell - the link between emotions and olfaction to ensure positive welfare
3	Extract new proteins for animal feed
4	Development of a tool to assess Sustainability in the equine secto
5	Defining organic standards for aquaponic systems
6	Integrating more animals into current agricultural and horticultural systems in southern Sweden – increasing the circular bioeconomy
7	Growing more protein rich crops for utilising in animal feed
8	Human work environment and animal environment hand in hand
9	Integrated sunparks and animal grazing management
10	Systems perspectives on the animals roles in sustainable production systems
11	Farm staff working environment improvements that willl increase the sustainability of stable buildings and animal welfare.
12	Include animal welfare in the environmental assessment of livestock systems throughout EU
13	How to transition from industrial meat production to integrated extensive animal farming
14	Sound environment analysis of animals and farmers
15	Drones as a tool to assess and manage animal health and welfare in extensive grazing systems
16	Proposal of recommended distances between organic animal production and crop production for directed subventions
17	Improve rotational grazing practices
18	one welfare - identifying and quantifying tradeoffs between animal, soil, and environmental welfare and productivity?
19	landscape planning for human and animal welfare
20	How to reach 100% of domestic feed production
21	Measuring disease susceptibility within animal welfare – What are the true thresholds? Comparing different building systems from a OneHealth perspective
22	Animal-motivation-based innovations (can be mechanics, sensors an technology)
23	Human - animal interaction management improves one welfare
24	Better use of agricultural byproducts
25	Finding the balance between animals, agriculture, and horticulture - What can be done for better resource efficiency?
26	What is actually animal welfare today?
27	Understanding the perceptual needs of animals to ensure welfare and production

Overarching themes	
1	Integration of animals into farming systems
2	Animal welfare and well-being
3	Human-animal interaction and welfare

4	Sustainability and resource efficiency
5	Protein and feed production
6	Tools and standards development
7	Systems thinking and balance

Summarizing analyses of the suggested themes

The individual project themes collectively demonstrate a sophisticated and forward-looking interpretation of animal-centred environments, where animals are considered active participants in sustainable systems rather than passive production units. Across the twenty-seven themes, research emphasis ranges from sensory and emotional welfare to technological innovation, spatial design and systemic resilience. Projects such as "Smellwell" (linking olfaction and emotions), "sound environment analysis" and "animal-motivation-based innovations" stand out for their high innovation potential, introducing new methods for sensory-based welfare design and intelligent monitoring. Themes addressing "human–animal interaction", "work environment" and "One Welfare trade-offs" combine biological and social sciences yielding strong excellence potential through interdisciplinarity and societal relevance. Internationally oriented projects such as the "transition from industrial to extensive systems", "aquaponic standards" and "landscape planning for human and animal welfare" reflect the programme's capacity for transnational collaboration, policy alignment and adaptation across diverse agro-ecological and cultural contexts. Conceptual inquiries into "what constitutes animal welfare today" and the "perceptual needs of animals" add critical uniqueness, reinforcing the scientific and ethical depth of the portfolio and advancing the discourse on how animal well-being defines environmental quality.

At the macro level, the overarching themes provide a coherent strategic framework that integrates welfare, sustainability and systems thinking into a unified research vision. The "integration of animals into farming systems" and "animal welfare and well-being"-themes anchor the programme's ethical and ecological foundation, while "human–animal interaction and welfare" extends its scope into social sustainability and participatory design. "Sustainability and resource efficiency" alongside "protein and feed production" link animal welfare with circular bioeconomy transitions and global feed sovereignty creating strong opportunities for international collaboration. "Tools and standards development and systems thinking and balance" provide the methodological and conceptual backbone necessary for policy impact and long-term resilience. Collectively, these themes exhibit high excellence potential through interdisciplinary coherence, strong innovation in welfare metrics and sensory ecology, global internationalization through alignment with One Welfare and One Health frameworks and marked uniqueness in redefining the animal's role from resource to sentient co-designer of sustainable environments. This framework positions the "animal-centred environments" agenda as a distinctive, internationally relevant research domain at the forefront of ethical and ecological transformation in food and farming systems.

Appendix table 5-3: Themes for projects suggested for "Horticulture"

1	The potential of farm animals in an vegetable rich crop rotation.
2	The use biogas digestates as fertilisers
3	In the face of a crisis: System analysis on crop demands, dietary needs and systems
4	Local organic vegetable production - current status and future opportunities
5	Functions of microorganisms for spil health in horticultural production systems
6	Horse manure as a sustainable horticultural substrate
7	Gap between consumption and local production
8	Food waste prevention
9	Automatisation to detect pathogen volatiles to minimise disease in long-term vegetable storage
10	Scoping sustainability practices in horticulture

11	Sensor-based climate regulation
12	Utilisation of waste transformation
13	Changing arctic climate: sustainability, food availability and adaption from traditional to modern food provisioning in horticulture
14	Combination of varied organic resources for increased resilience in horticultural production
15	Sensor-based surveillance of plant pathogens in green house production
16	Can we subsidise local vegetable production for crisis preparedness?
17	Development of peat-free growing media
18	Identifying and evaluating local resources for alternative fertilizers as a source for greenhouse production, *e.g* rooftop greenhouses
19	Develop sustainable cropping system including both arable crops and horticulture and even tree
20	Designing horticultural production in the light of the EU restoration act
21	Definition of local production? System analysis of cities self-sufficiency rates. (also good for agroecology)
22	Looking into how to make harvesting of, e.g. kales more ergonomically easy from a worker perspective
23	Advanced lifting systems with crop feedback- loops (for detection of plant diseases, pathogens etc)
24	Investigating the economic sustainability of large horticultural systems
25	Sensor based surveillance of horticultural food quality and safety
26	Sustainable management of market gardens
27	Horticultural food insecurity: dilemmas in an age of crisis; scenario approach from identification to policy lab
28	Safe or green: navigating between public health and environment in green transition in horticulture

Overarching themes	
1	Sustainability in horticultural systems
2	Resource efficiency and waste utilization
3	Technological innovations in horticulture
4	Local production and crisis preparedness
5	Soil and microorganism health
6	Economic and social sustainability
7	Policy and system design

Summarizing analyses of the suggested themes

The individual horticultural project themes collectively illustrate a dynamic and forward-looking research agenda that positions horticulture as a cornerstone of sustainable, resilient and circular food systems. Together, they span biological, technological and socio-economic dimensions and connect soil health, resource efficiency and digital innovation with human and environmental well-being. Projects such as "automation for detecting pathogen volatiles", "sensor-based climate regulation" and “smart surveillance of plant pathogens and food quality” stand out for their innovation potential combining precision horticulture with advanced sensor and data technologies to enhance productivity and biosecurity. Equally strong are themes focused on excellence and societal impact including the study of microorganisms for soil health, peat-free growing media and horticultural food insecurity, which integrate ecological science and governance to strengthen long-term system sustainability. Several projects demonstrate significant internationalization capacity, particularly those addressing urban self-sufficiency, crisis preparedness and climate adaptation in arctic and temperate systems creating pathways for transnational collaboration and comparative research. Distinctive uniqueness emerges from studies exploring waste reuse, organic resource combinations and ethical dilemmas in the green transition which reframe horticulture as both an ecological and societal innovation platform.

At the macro level, the overarching horticultural themes provide a coherent strategic structure that unites scientific excellence with systemic innovation. “Sustainability in horticultural systems” and “soil and microorganism health” form the biological and ecological foundation of the programme, while “resource efficiency and waste utilization” translate circular economy principles into practice. Technological innovation drives modernization through automation, smart monitoring and climate regulation. Local production and crisis preparedness address the social and policy dimensions of food security and resilience. The inclusion of “economic and social sustainability” ensures that technological progress is grounded in human welfare and labour quality, whereas “policy and system design” situates horticultural research within broader frameworks such as the EU Green Deal and Restoration Act. Collectively, these overarching themes demonstrate high excellence potential through interdisciplinarity, strong innovation through integration of digital and ecological methods and notable internationalization by addressing global sustainability and food system challenges. Their uniqueness lies in framing horticulture not only as a production sector but as a living infrastructure, an adaptive, knowledge-intensive system that bridges ecological restoration, technological advancement and human well-being within the broader sustainability transition.

Appendix table 5-4: Themes for projects suggested for “Integrated Crop Production”

1	Nutrient efficiency in horticultural and agricultural systems
2	More resilient crop production
3	Nutrient rich residues
4	Trade-offs between productivity and sustainability in crop production systems
5	Similar to horticulture and agroecology research ideas
6	Identify and quantify synergies in integrated agricultural and horticultural production systems
7	Circular plant nutrients
8	Designing a vegan farm
9	Locally produces field vegetables
10	High tech horticultural systems for better resource efficiency and crisis management.
11	Developing circular practices to increase the readily available food production
12	Sustainable use of horticultural residues in energy production
13	Climate change resilient food production
14	Sustainable intensification - closing the gap: resource efficient use of plant biomass in multiple use biosystems
15	Nutrient efficient varieties
16	Outdoor - indoor gradient: technology - efficiency - productivity – circularity
17	Aquaponics

Overarching themes	
1	Nutrient efficiency and circularity
2	Sustainable and resilient systems
3	Integrated and multi-use systems
4	Local and vegan-oriented farming
5	High-tech and innovation-driven solutions
6	Climate change and crisis preparedness
7	Sustainability in agroecology and horticulture

Summarizing analyses of the suggested themes

The individual project themes within Integrated Crop Production collectively demonstrate a cohesive and forward-looking research portfolio aimed at transforming crop systems into circular, resilient and technologically adaptive production models. Together, they emphasize nutrient efficiency, system integration and the sustainable intensification of food production while maintaining environmental integrity. Projects such as "nutrient efficiency in horticultural and agricultural systems", "trade-offs between productivity and sustainability" and "climate change resilient food production" show strong excellence potential through their scientific depth, interdisciplinarity and societal relevance, addressing global challenges in resource management and adaptation. High levels of innovation emerge in technologically oriented themes such as "high-tech horticultural systems for resource efficiency" and "crisis management, nutrient-efficient crop varieties, outdoor–indoor gradient systems" and "aquaponics", which combine digital tools, controlled-environment systems and circular resource flows to increase productivity and stability. Internationalization potential is evident across themes focused on resilient crop production, local vegetable systems and circular food practices which link regional food autonomy to global adaptation strategies. Uniqueness arises from projects that extend integrated crop production into new conceptual spaces, such as "designing vegan farms, energy use of horticultural residues" and "quantifying synergies between horticulture and agriculture". These define an ethically grounded, multifunctional vision for future food systems.

At the macro level, the overarching themes establish a strategic framework that situates integrated crop production at the intersection of ecological integrity, technological advancement, and social responsibility. "Nutrient efficiency and circularity" provide the scientific foundation, focusing on the recirculation of plant nutrients and the closure of material loops across production systems. "Sustainable and resilient systems" and "climate change and crisis preparedness" extend this to a broader resilience framework, integrating ecological, climatic and socio-economic dimensions. "Integrated and multi-use systems" advance multifunctionality, linking field crops, in- and outdoor horticulture and energy systems into cohesive production landscapes, while "high-tech and innovation-driven solutions" ensure that circular principles are supported by cutting-edge digitalization and automation. Themes on "local and vegan-oriented farming" and "sustainability in agroecology and horticulture" reflect a social and ethical expansion of the field, bridging ecological science with changing dietary and policy priorities. Collectively, these overarching themes demonstrate strong excellence potential through their interdisciplinarity and scientific coherence, high innovation through the convergence of biological and technological systems, and significant internationalization through their applicability to global food security and climate adaptation efforts. Their uniqueness lies in redefining integrated crop production as a holistic, circular and resilience-oriented framework. They link resource efficiency, technological intelligence and ethical sustainability into a unified model for future agricultural systems.

Appendix table 5-5: Themes for projects suggested for "Technology/Biosystems Engineering"

1	Nutrient efficiency
2	Weed management in cropping systems
3	New sustainable building materials integrated into animal stables

4	Anything monitors things, *e.g.,* volatiles in a vegetable storage, weeds with a drone
5	New sustainable building materials from crops
6	No technology - removing technology to investigate what technology is needed (spark creativity in tech development)
7	Technology gradient in food production systems: multi criteria system analysis
8	Technology in times of crisis - what happens
9	Developing technologies for mechanical weed management in row/spacial intercropping
10	High tech drone supported precision vegetable field production.
11	How to efficiently harvest crops grown in row/spacial intercropping
12	Light and production environment: from animal to crop, from indoor to outdoor, from single purpose to multipurpose systems, from diversity to function
13	Technology for complex systems
14	Resilient technology - technical solutions that can bounce back
15	Sensors for diversified and integrated food production systems
16	Animal-motivation-based innovations to improve work environments for both animals, humans and production
17	From a systems analysis: What are all income sources within a farm
18	Building design for optimised food production
19	LCA for biodiversity impacts in agricultural and horticultural systems within Northern Europe
20	Agriculture as energy producer - combining technologies
21	Efficient irrigation systems

Overarching themes	
1	Technology for efficiency and resilience
2	Sustainable materials and practices
3	Integration of systems and multipurpose design
4	Technology gradient and minimalism
5	Monitoring and precision
6	Sustainability and environmental impact
7	Systems analysis and economic integration
8	Work and environment optimization

Summarizing analyses of the suggested themes

The individual project themes within Technology/ Biosystems Engineering collectively present a highly interdisciplinary and application-oriented research agenda focused on designing, evaluating, and adapting technologies for sustainable and resilient agri-food systems. Projects such as "technology for complex systems", "LCA for biodiversity impacts" and "efficient irrigation systems" display strong excellence potential through their methodological rigor, combining systems analysis, environmental modelling and engineering design to address both productivity and sustainability goals. High levels of innovation are evident in themes like "mechanical weed management in intercropping, drone-supported precision vegetable production" and "resilient technology", where automation, robotics and adaptive system design are used to enhance efficiency and robustness. Many of the projects carry strong internationalization potential, particularly those addressing “weed management,” “crisis-resilient technologies” and “agriculture as an energy producer” as they respond to global challenges and dilemmas of food security, renewable energy and technological adaptation under climate stress. The portfolio’s uniqueness lies in its breadth and reflexivity: alongside advanced engineering work, projects such as “no technology – removing technology to evaluate necessity”, “light and production environment gradients” and “animal-motivation-based innovations” push the boundaries of conventional engineering by incorporating behavioural, ecological, and ethical perspectives into technology design, thus redefining what “appropriate technology” means in sustainable biosystems.

At the macro level, the overarching themes provide a clear strategic framework that positions technology as both an enabler of efficiency and a driver of ecological and social resilience. “Technology for efficiency and resilience” encapsulates the programme’s commitment to adaptive, low-impact engineering solutions that maintain productivity under changing environmental and socio-economic conditions, while “sustainable materials and practices” advance circular design principles through bio-based and renewable materials. The themes of “integration of systems and multipurpose design” and “monitoring and precision” highlight the sector’s evolution toward data-driven, multi-output systems where sensor networks, automation and artificial intelligence enable precise, resource-conscious management. “Technology gradient and minimalism” and “work and environment optimization” add a reflective and human-centred dimension, challenging the assumption that more technology always equals better performance and emphasizing ergonomics, animal welfare and system balance. “Sustainability and environmental impact” and “systems analysis and economic integration” ensure that the technical innovations are grounded in environmental ethics, economic realism and policy relevance. Collectively, these overarching themes demonstrate strong excellence potential through interdisciplinary coherence and applied relevance, high innovation through the fusion of engineering, ecology, and informatics and significant internationalization through global alignment with sustainable development and climate adaptation priorities. Their uniqueness lies in reframing technology itself as a living, adaptive system, *i.e.,* a system that is simultaneously efficient, reflexive and ethically attuned to the complex realities of sustainability and resilience.

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