List of themes	Your choice (1,2,3)
Analysis of innovative practices and transition pathways	
Systemic innovation for agrifood systems transformation	2
Co-design methods and tools for agrifood systems	1
Coupled innovation processes for agrifood system change (reconnecting the dynamics of innovation in agriculture and food)	
Agrifood system management enhancing biodiversity	
Modelling for anchored agricultural system change	
Role of digitalization for enhanced agroecological systems	
Co-design of territorial scenarios for agricultural change with stakeholders	
Capacity building for scaling up change in agricultural systems	3
Managing climate risks in agrifood systems	
Considering resilience in farming system assessment and design	
Change in policies and advisory services to enhance the transition of agrifood systems	
Design at the territory level for sustainable and healthy agrifood systems	
Territory and value chain interactions for agrifood system transition	
Analysis of sociotechnical systems to drive agrifood system design	

T4E DESIGN APPROACH ENABLING DESIGN OF SUSTAINABLE FARMING SYSTEMS

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Introduction

Current intensive farming systems heavily use inputs, produce high yields, and have multiple negative side-effects on greenhouse gas emissions, biodiversity, farm income, and on soil and water quality (Kremen et al., 2012; Titttonell, 2023). Agro-ecological farming systems, by contrast, which are based on the theory of diversified farming systems, rely on “solutions” from the ecological processes in the production system and replace external inputs and/or labour by ecological processes. For example pest and disease are regulated by biology and soil fertilization through plant diversity. When compared to intensive farming systems, the agro-ecological systems need less inputs, produce other beneficial outputs next to food products, and have less negative impact on environment, biodiversity, climate and human health (Kremen et al., 2012; Petersen-Rockney et al., 2021; Tittonell, 2023). The further adoption of such ecological farming systems, however, faces huge challenges. To advance the uptake of such systems and/or diversification processes, we need to fill knowledge gaps, reduce the risk for the farmers and provide technologies facilitating the transition towards agro-ecological farming (Lamine et al., 2012)).

To address these challenges, the Synergia research program, financed by the Netherlands Organization for Scientific Research (NWO grant 17626), IMEC-One Planet and other private parties, aims to foster more ecology-based farming by using a new (re)design approach under the name “Technology for Ecology” (T4E). Within this program, new solutions are sought by interacting and cooperating with researchers from various disciplines as well as stakeholders. The research addresses three agricultural sub-systems, *viz*. greenhouse horticulture, dairy farming, and arable farming.

What is T4E

T4E is a multi-disciplinary bio-systems engineering approach aimed at the (re)design of the architecture as well as at the management of farming systems to achieve “integral sustainability”. This includes economic sustainability (for farmers, industry, society), maintenance and resilience of natural ecosystems and the support and services they provide to agricultural production as well as to society at large.

In this approach, the system to be re-designed extends beyond the farm and includes entities relevant for the design challenge at hand, e.g. natural environment, farms, suppliers, retail, consumers. It aims to include ecological solutions to functions (e.g. crop protection, biodiversity) where possible and identifies the need for and designs technologies to manage such an agro-ecological system for different local and regional circumstances.

The T4E design approach builds on general design approaches (Siers, 2004; Cross, 2008) and on experiences from applying the so-called RIO design approach (a Dutch acronym for ‘Reflective Interactive Design’) developed for animal husbandry systems (Elzen and Bos, 2019). Key parts of these approaches are a system analysis, an assessment of the needs of the key-actors and an identification of (key)functions that the new design should fulfil. The needs of the key-actors are described and quantified in so-called “briefs of requirements” that the new design should adhere to. The extended RIO approach also addresses the uptake of

new designs in future practices by adding an 'anchoring' stage to the RIO approach (Elzen and Bos, 2019). For T4E, we further adapted the RIO approach as follows:

1. 'Anchoring' will already get the attention starting from step B.
2. In step G, when collecting solutions, also nature technologies are included i.e. ecological and biological mechanisms. Such technologies are preferred in the design.
3. An extra iteration (Step K, L and M) is made to design technological (hardware) solutions for advancing the incorporation of the ecological mechanism from step H.

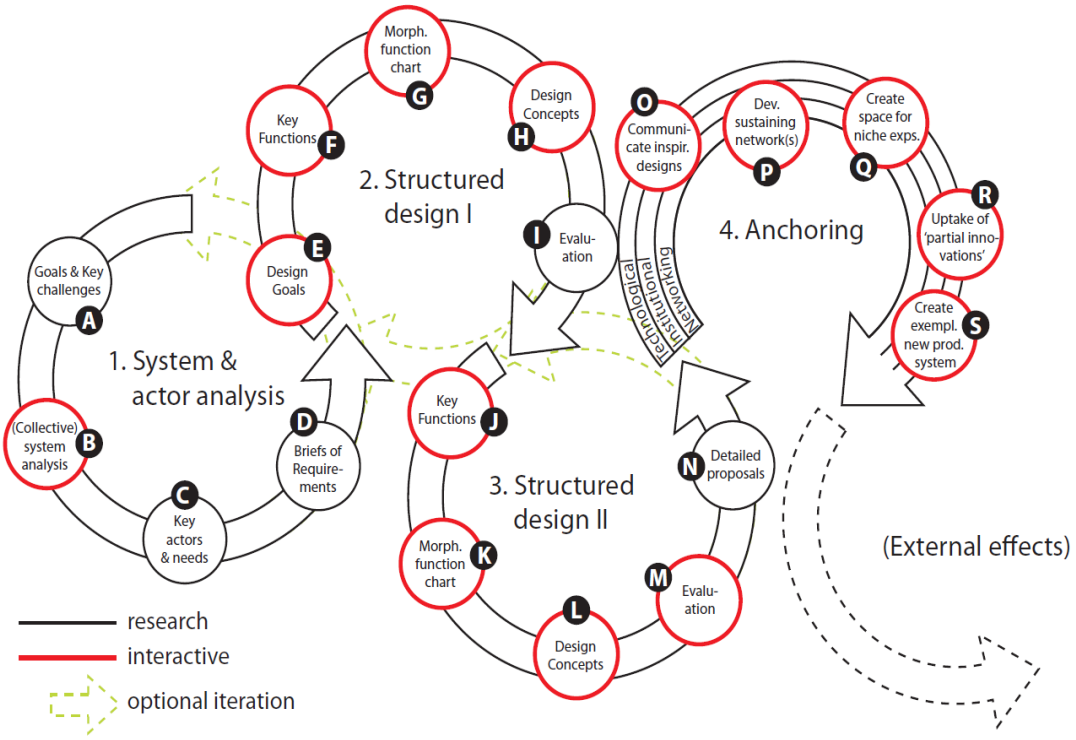


Figure 1. The steps of the extended RIO (Reflexive Interactive Design) approach which also includes anchoring of the design (Elzen and Bos, 2019)

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Demonstration of the approach

In the first phase of the Synergia program, the T4E approach was tested to assess and demonstrate its general applicability. PhD students from the Synergia program, all having different specialisms, combined their knowledge within one of the three use-cases (arable farming, greenhouse horticulture and dairy farming). They defined the main problems within each use-case and the main functions related to these problems (key-functions). Next, ecological mechanisms and technologies (hardware and practices) were identified that might serve as a solution for these key-functions. A list with requirements for redesign was produced to select the most suitable and promising solutions. By combining the best solutions for the key-functions, a redesign was accomplished.

Results and conclusions

Though the approach was carried out in a rather crude manner, each use-case group with PhD students was able to successfully produce a draft of a newly designed agro-ecological farming system. These systems featured 1) new ideas and innovative combinations of concepts and solutions based on ecological mechanisms and 2) various, partly novel, technologies to facilitate uptake of those mechanisms. It was also demonstrated that it is important not to seek solutions to single problems but to target an integral (re)design of a farming system. This

diminishes chances that new problems are created elsewhere and allows finding more optimal ecological solutions.

As an example, the redesign of the arable farming system focused on soil compaction, greenhouse gas emission, labour availability and water availability. The selected technologies to manage the system allowed for a diversity of crops under a Gantry system with semi-transparent solar panels which are adjustable in angle and with automated field operations. Energy and water are buffered. Pigs perform the “ploughing”, provide nutrients and reduce tubers from root crops after harvest of the main crop.

After the successful demonstration of the approach, the full T4E approach, including the involvement of stakeholders, will be carried out later this year for the dairy and arable use-cases.

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