Design of Complex Agroforestry Systems in the Netherlands

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Overall objective and research questions

Complex agroforestry systems (CAS) have received increased societal attention as a novel land-use system in Europe, and in the Netherlands especially[1–3]. CAS, (or food forests as they are popularly called) provide a multitude of edible products while mimicking the structure and function of natural forests, with a large diversity of trees, shrubs, and plants, fulfilling different niches in space and time and reflecting the increased complexity that is characteristic of natural forest succession[4]. Through mimicking the ecological processes of forests, CAS aim to achieve self-regulation and independence from (chemical) inputs that are common in conventional agriculture[4]. Research suggests that CAS have the potential to deliver healthy food, environmental services, spaces for recreation, education, and community building[1,5–7]. Until recently, CAS have been mainly implemented by citizens to contribute to ecosystem restoration while providing other services for private or nonprofessional use[1,5]. In the last two years there is an increasing interest to engage in CAS with economic objectives[8–10]. There are also growing societal expectations that CAS can play an important role in a transition towards regenerative food systems[2,5]. However, due to their novelty, complexity and long time spans inherent to tree-based systems, there is much uncertainty about the options for design and implementation of CAS which can provide the required services within economically viable business models[1,5]. Moreso, CAS can be designed and managed in many ways depending on stakeholder objectives as well as the social and biophysical context[11]. In order to move beyond the 'early adopters phase', there is a need for scientifically grounded practical know-how on economically viable complex agroforestry[12].

Currently, farmers lack relevant information regarding the selection and spatial and temporal arrangement of plants[13,14]. A recent inventory of information / knowledge needs among stakeholders done by Wageningen University & Research and the ReGeneration Foundation indicated urgent questions related to place-based planting schemes (selection and spatial/temporal arrangement of plants species, cultivars and rootstocks) for the ecological (mortality, productivity, nutrient and water cycling, pest and disease regulation), socio-cultural (values and preferences related to management, activities and outputs) and economic (labor requirements, product quantity and quality) performance of CAS[13]. These questions could be addressed by drawing together multiple scientific disciplines (functional ecology, forest ecology, agroecology, horticulture, landscape architecture) and scientific methods (e.g. action research, reflexive interactive design)[11,15,16]. For example, current ecological theory highlights the importance of niche complementarity for optimal functionality, which can be integrated in design by selecting plant combinations based on complementarity of functional traits[15]. My aim with this EngD is to gain insight into how biophysical, socio-cultural and economic contextual conditions and objectives translate into design decisions from farm level down to detailed planting schemes, and to contribute to decision-making tools that will enable professional CAS practitioners to oversee their options, based on the state-of-the-art scientific and methodological knowledge. Hence, the main research question is articulated as:

What plants (species, cultivar and rootstocks) and spatial and temporal arrangements achieve economic objectives within the biophysical, socio-cultural and economic context of complex agroforestry systems?

In answering this question, and as output of this EngD, I will:

1. Develop a CAS design framework
2. Design and implement planting schemes for five CAS pilot farms
3. Contribute to open-source CAS planning and decision-making tools

Co-financing for this project is provided by the ReGeneration foundation. The ReGeneration foundation was founded in 2022 with the aim of creating open-source knowledge for the next generation of land users who want to work professionally with complex agroforestry. To explore the potential to use and professionalize the multifunctionality of CAS in different contexts, Stichting ReGeneratie is co-creating five CAS pilot farms in the Netherlands as living labs in collaboration with landowners, future farmers, and various partners, including Wageningen University[17]. The farms have been selected by the foundation and within the next three years, the designs will be implemented. As EngD candidate, my responsibilities will be to:

1) document and map all design considerations and information inputs for these five pilots
2) translate the inputs from all stakeholders into contextualized designs, from zonation plan to detailed planting scheme, and implementations
3) select and make (a contribution to) the design of a set of open-source products on CAS decision-making

I will do this by integrating scientific knowledge from various disciplines with experiences from 'early adopters' in the field, by applying a participatory action research approach (PAR) and by drawing upon scientific engineering methods such as interactive, reflexive design[18]□[19], while building upon the CAS design framework I created as part of my MSc thesis (see Fig. 1 in Annex). A PAR approach is chosen for the potential of linking theory to practice, collecting both qualitative and quantitative data, achieving clear objectives and creating value with and for stakeholders[18]. In order to enhance the scientific robustness of the design and implementation of the five pilot farms, as well as the knowledge tools and communication materials I can draw upon scientific knowledge from functional ecology, agroecology, forest ecology, horticulture and landscape architecture. The field of functional ecology and agroecology can contribute relevant understandings of functional ecological traits (e.g. biotic facilitation and resource partitioning) and agronomical plant traits (e.g. labor requirements, product quantity and quality). This can serve as a bridge between the contexts and the selection/arrangement of plant species. From the field of forest ecology, I aim to distill strategies for mimicking succession[16]□[20]. Horticulture can provide knowledge on specific traits of cultivars and rootstocks, and inform design decisions for management (pruning, etc). From landscape architecture I aim to draw methodological skills to integrate these inputs effectively into spatial and temporal arrangements of plants, as well as methods to use software programs for communicating planting schemes effectively to stakeholders.

Suitability of the research question for EngD trajectory

This project is suitable for the EngD trajectory because the aim is to integrate applied and scientific knowledge into a new technology with high societal relevance and potential. The technology of complex agroforestry has the potential to offer solutions for the complexity of entangled sustainability issues that can be mindful of the ecological, the social, the cultural, the economic and the ethical, and the way these dimensions interrelate[21]. Therefore, the proposed research question aligns with the goal of the EngD program to solve sustainability challenges. Moreso, the EngD program provides the opportunity to draw from interdisciplinary knowledge and design skills through the flexibility in the educational component. In addition, the EngD allows for an interdisciplinary team of supervising and advisory researchers and practitioners (see annex) to provide additional support for integrating perspectives from different scientific backgrounds and linking these to practice. Since there is a lack of scientific research on the design and implementation of CAS in temperate climates, most of the knowledge still resides with early adopters in practice. The EngD program provides a unique opportunity to bridge the gap between science and practice by enabling me to gather knowledge from practitioners in temperate climates through the exposure component of the program. I can then integrate this knowledge to enhance the scientific robustness of the design and implementation of the five pilot farms and of the other tools and communication materials that are generated and shared via the open-source knowledge platform. This process can bring complex agroforestry to the next level of technological readiness[22]. CAS cannot be designed and tested in lab conditions, which means that research, development and deployment need to take place in the actual operational environment. The EngD program can make this possible in collaboration with the ReGeneration foundation through its pilot projects as living labs. Finally, the EngD

trajectory aligns with my personal motivation, knowledge, skills and network, while also providing me with the opportunity to develop myself further as a bridge between science and practice, linking complex design challenges to scientific research and informing practice with science-based knowledge (see attached motivation letter).

Potential for societal impact

This EngD project facilitates the transition to professionalized and prosperous CAS in the Netherlands, by providing insight to farmers and designers that want to start with or already practice CAS what options are viable in each step of the design and implementation process depending on their biophysical and socio-economical context and targets. In the short term, the EngD results in 5 planting schemes and implemented farms. In addition, the dissemination of the knowledge about the designs and implementation is guaranteed via the open source knowledge platforms of Foundation ReGeneration and their partner organizations such as Foundation Food forestry Netherlands, Agroforestry Netwerk Nederland and various research partners, to which I am well connected. Communication materials take shape as a series of factsheets, manuals and leaflets on the most prominent knowledge gaps covered during all phases of the design and implementation process. In addition, I contribute to open-source decision-making tools for farmers and designers, such as crop-selection, companion planting, successional planning and business model development tools. In the long term, after completion of the EngD, the five pilot farms will function as continuous learning landscapes that will provide additional insights on the long term viability of the design and implementation decisions through long term monitoring by the ReGeneration Foundation.

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Annex

Figure 1: The iterative, cyclic decision-making framework for designing food forests in the Netherlands (Van Eijk, 2021). The explored key elements of the framework were the steps in ring 1 and 2 with their corresponding plans, actions, maps and lists in ring 3 and 4. The steps are iterative and cyclical, visualized through the dotted arrows. The center ring of the framework visualizes step 0, surrounded by a

second ring of steps 1 to 5. The third ring shows the most relevant design aspects of each step. These aspects are elaborated in another surrounding fourth ring. As the design progresses the amount of detail increases concerning plant species selection, designing the spatial and temporal orientation of the vegetation on the maps as well as the concrete elaboration of the succession and management plans. In practice sometimes a step is moved back, which is indicated through the dotted feedback arrows.

Advisory board:

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