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Policy Brief


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CO-DESIGN MOBILE-BASED DIGITAL SOLUTIONS FOR LOW EXTERNAL INPUT SYSTEMS

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Summary

The integration of digital technologies in agriculture, especially in low external input systems, presents significant opportunities for smallholder farmers, pastoralists, fishing and hunter-gatherer communities. These systems are knowledge-intensive, relying on local expertise to adapt to variable environmental conditions. However, traditional top-down interventions often overlook the specific needs of end users, leading to low adoption and limited impact.

Co-design is an iterative, participatory methodology that actively engages stakeholders—such as pastoralists, researchers, and developers—throughout the design process. This approach ensures that digital solutions are:

- **Relevant:** Tailored to the particular contexts of end users.
- **Usable:** Intuitive and accessible, even in low-digital literacy settings.
- **Sustainable:** Aligned with local practices and resource availability, fostering trust and long-term adoption.

By integrating local knowledge and external data and analytical systems (e.g., external databases, remote sensing, and artificial intelligence systems), co-design bridges the gap between local practices and digital innovation, creating tools that are both effective and culturally appropriate. For instance, in rangeland apps, local knowledge of rangeland conditions and remotely sensed rainfall distribution data can be combined to provide pastoralists with additional regularly updated information on the state of the vegetation in the rangelands.

Co-design is guided by principles emphasizing participation and inclusion. It capitalizes collaboration with users, involving frequent testing and feedback to iteratively refine digital solutions ensuring contextual relevance through immersion in local contexts. By fostering empowerment and trust, co-design enables users to shape solutions, building and ownership. Additionally, it supports adaptability to accommodate to end users´ needs, and finally aims to ensure scalability while retaining local relevance. This brief presents a co-design framework specifically for developing mobile-based digital solutions in low external inputs systems, with an emphasis on pasture-based livestock systems.

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Introduction

The rapid advancement of digital technologies is contributing to the transformation of agriculture, with a growing emphasis on mobile-based solutions across agricultural sectors. For low external input systems, particularly in smallholder and pastoralist settings, mobile solutions present unique opportunities. For example, in the knowledge-intensive pastoral livestock systems, pastoralists not only decide on the direction and timing of mobility, but also assess future resource availability. This approach allows them to plan grazing itineraries effectively and reserve pasture resources for times of scarcity. Access to accurate, timely information—such as pasture quality, water availability, and environmental factors—can improve resource-use efficiency and help pastoralists respond to climate challenges. As in these vast and marginalised areas, veterinary service provision is largely absent, other possible areas of purposeful use of mobile application could be by improving information access for disease diagnostics and treatments through mobile application. Yet, limited digital literacy, misaligned solutions, and restricted access to technology hinder the effectiveness of previous developed tools in remote areas[1,2].

Traditionally, agricultural research and development interventions have followed a linear technology transfer model, with limited design input from end-users like smallholder farmers or pastoralists. This top-down approach often produces tools that fail to meet users' specific needs, leading to low adoption and low impact[2]. Addressing this gap in the development of digital solutions requires co-design—an approach to engage diverse stakeholders, including local communities, throughout the design stages to ensure solutions are contextually useful (relevant to user needs), usable (intuitive and accessible), and sustainable (aligned with local practices and resource availability)[3]. Co-design enables local communities, researchers, and technology developers to incorporate users' knowledge and capacities, and to consider local context and cultural backgrounds in the development of digital solutions[3,4].

By engaging local communities in co-design, mobile tools in agriculture become more relevant, user-friendly, and effective

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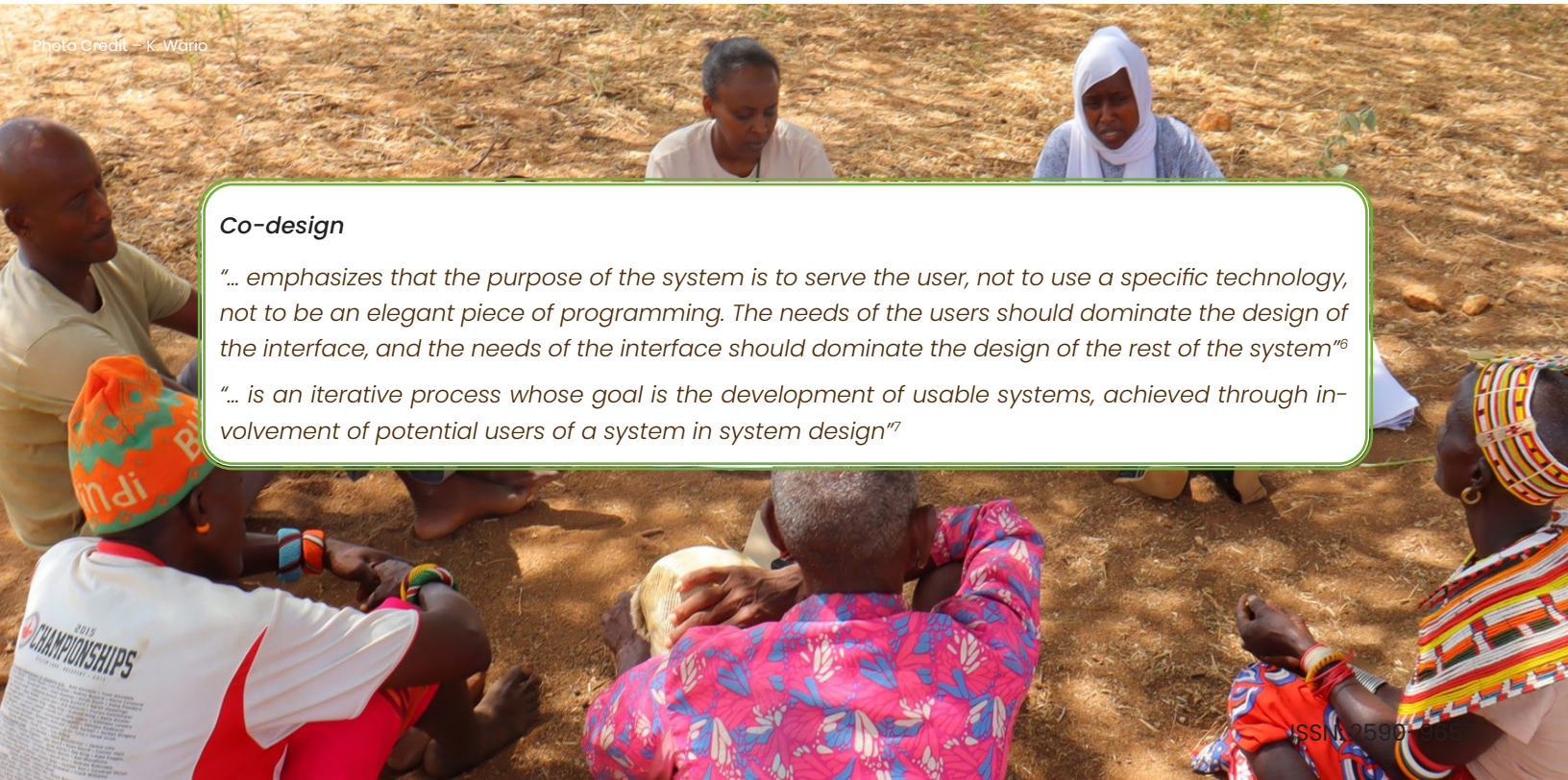
This brief presents a co-design framework specifically for developing mobile-based digital solutions in low external inputs systems, with an emphasis on pasture-based livestock systems. Drawing on case studies and theoretical insights, we illustrate how fostering collaboration among technology developers, pastoralists, researchers, and other stakeholders enables the co-design of digital solutions that are not only technically viable but also socially and culturally aligned with the needs of end users, here pastoralists.

Concept of co-design mobile-based digital solutions for low external input systems

A. What is co-design

Co-design employs an actor- and activity-oriented methodology emphasizing iterative, user-driven development of digital solutions. It synthesizes knowledge from multiple sources, including end-users, data from external databases, remote sensing, and/or artificial intelligence systems. This approach helps identify appropriate methods for integrating new digital solutions with existing local information and knowledge. This collaborative approach involves joint decisions on development, testing, evaluation, and refinement of Information and Communication Technology (ICT) applications.

Co-design goes beyond top-down user involvement by fostering an environment where stakeholders—researchers, developers, and end users—share insights and contribute meaningfully. Establishing this collaborative space requires innovative methods that support participation and facilitate communication among these different actors[5].



Co-design

"... emphasizes that the purpose of the system is to serve the user, not to use a specific technology, not to be an elegant piece of programming. The needs of the users should dominate the design of the interface, and the needs of the interface should dominate the design of the rest of the system"[6]

"... is an iterative process whose goal is the development of usable systems, achieved through involvement of potential users of a system in system design"[7]

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B. Why co-design for low external input systems

In many regions of the Global South, local actors have developed complex farming systems specifically adapted to their natural environment and based on locally available resources. Known as low-external-input systems, this way of farming is observed in small-scale mixed farming and pastoralism.

However, in the past and still today, subsidy programmes and development projects have promoted high-external-input practices and technologies in small-scale farming, that require much higher capital input and need more stable production conditions. This goes together with intensification through specialisation instead of diversification, dependency instead of autonomy, and transfer of technology instead of local innovation. The aim was to increase production by using high-potential crop varieties or breeds (often called "improved" varieties or breeds) and high levels of external inputs (e.g. mineral fertiliser, agrochemicals, hybrid seed). This way of farming is capital-intensive and requires inputs based on fossil energy. These inputs are used to maintain stable production conditions and to tailor them, for instance, to the requirements of the high-potential animal breeds, e.g. by constantly providing high-quality fodder, copious water, veterinary inputs and animal housing. Such production systems seek economies of scale (e.g. managing large farms with little labour) and can lead to high profitability if functioning infrastructure and economic systems are in place and if energy prices are low. However, their energy efficiency is usually low: the energy contained in the products is rarely higher and is often even less than the energy content of the fossil-fuel-based external inputs used in their production. For instance, in large-scale pig farming, ten units of support energy are needed to produce one unit of energy in the product (meat)[8].

Low-external-input systems are knowledge and information intensive: local actors use the knowledge they have gained from their experience in the locality to manage variability and uncertainty in the production environment

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In low-external-input systems, the energy input–output ratio is much more favourable: for instance, one unit of support energy is transformed into ten units of energy in the products (meat and milk) in pastoral systems[8]. A low-external-input farming system does not need much support energy to produce from locally available resources. It relies mainly on natural capital, while little physical and financial capital is needed. It can also deal with the persistent lack of infrastructure in many rural areas (e.g. poorly developed roads, power grids, markets and health, veterinary, educational, advisory, supply and financial services). However, such a system is knowledge intensive: it relies on knowledge gained from people's experience in the locality to deal with variability and uncertainty of the production environment.

Hence low-external input systems require deep knowledge of local conditions, enabling actors to adapt strategies, such as planting crops suited to microclimates or mixing crop varieties to secure production under adverse weather. Understanding these practices is essential for developing digital solutions that align with local decision-making and resource management. By integrating local knowledge and technology, co-design builds trust and empowers users, making tools practical, accessible, and sustainable. This enhances decision making in livestock management and helps to avoid losses caused by lack of information and thereby increased resilience of the system.

C. Key principles of co-design

Co-design is guided by principles that facilitate the development, communication and assessment of the process. Ten principles guide co-design for low-external-input systems:

1. **Participatory and user-centered:** Actively involve end users to ensure solutions meet their needs and preferences, leading to higher satisfaction and adoption rates[2,9–11].
2. **Establish a collaborative team:** Form a transdisciplinary team with expertise in local contexts and participatory methods. Include local facilitators, and community members that co-steer the process (acting as intermediaries) to ensure solutions are technically robust and contextually appropriate. This group would focus on implementing and supporting participatory strategies that account for the unique socio-economic, cultural, and ecological contexts of low external input systems. Common rules would be established jointly by the entire group. Establishing trust through transparency, respect, and consistent engagement is essential for fostering open dialogue and reducing hierarchies. By prioritizing equitable partnerships and valuing diverse perspectives, researchers, de-

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velopers and end users can co-create a supportive and collaborative environment.

3. **Iterative, incremental, and collaborative development:** Employ cycles of design, testing, and refinement with frequent prototypes and feedback, enabling users to visualize and shape the solution, ensuring continuous improvement and alignment with their expectations[2,9,12,13]. Early, continuous prototypes help users visualize and evaluate ideas, making the design more responsive to user feedback[9]. The aim is not simply to endorse a proposed solution, but to use the prototype as a provocation for further design directions and refinement[14].
4. **Context immersion and cultural inclusivity:** Immersing co-designers in the local context and understanding local practices to foster context relevant designs[2,11,13].
5. **Empowering through active feedback and engagement:** Develop and implement strategies specifically aimed at eliciting feedback from local actors, empowering them to voice their experiences and challenges. Incorporating their feedback into iterative designs reinforces trust and ensures solutions address on-the-ground realities[2,3,16,17].
6. **Local relevance with scalability potential:** While co-design for low external input systems centers on local needs, solutions should also consider potential scalability to similar contexts. This principle ensures digital solutions are adaptable and beneficial across a broader spectrum without losing their contextual relevance[2].
7. **Fostering inclusive and equitable participation:** Addressing gender, social norms, and power dynamics is crucial for ensuring that diverse voices are heard[2,4]. This includes sensitivity to cultural contexts, such as using the local language, involving female facilitators when appropriate, or organizing gender-segregated sessions. Efforts must aim to balance power dynamics by shifting from hierarchical, expert-led approaches to decolonized, collaborative attitudes that promote mutual respect and inclusivity[3,18,19].
8. **Capacity building and community-led sustainability:** Use existing structures for training, support, and dissemination[2,12]. This includes: **(a)** peer-assisted learning on digital-literacy. Peer-to-peer learning is considered an effective approach for helping end users understand the functionality of the co-designed digital solution[20]; **(b)** identifying and training local technicians (with IT experience) to maintain digital tools, reducing dependency on external developers for long-term sustainability; and **(c)** using existing community structures, such as cooperatives or pastoral networks, to spread awareness and support adoption of digital solutions.
9. **Adaptability and flexibility:** Maintain an adaptive mindset, recognizing that local

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communities are experts in their own context. Flexibility in the approach and willingness to pace the project according to community needs enhances project success[4].

10. **Contextual evaluation:** Digital solutions are evaluated with end-users in real contexts, observing their interactions and gathering feedback from early sketches to functional prototypes[9]. Establish methods and tools to co-assess the impacts and benefits of digital solutions, sharing results with end users to build confidence and further refining.

D. Stages of co-design

The co-design process involves several stages. While here they are described sequentially (Figure 1), they can (and often need to) be applied iteratively throughout the co-design process.

1. **Pre-Design - Collective Catalysing:** Identify key actors (users) and understand their information needs and challenges in relation to digital technologies.
2. **Design - Collective Understanding & Exploring:** Translate user requirements (context, boundaries, problem) into practical design solutions.
3. **Develop - Progressive Participatory Desing with `Co-Design Team´:** Develop the technical aspects of the mobile-based solution based on the refined prototype.
4. **Implement - Collective Doing & Learning:** Launch the mobile-based solution for use by the different actors and evaluate its effectiveness.

Figure 1. Stages in co-designing a mobile-based solution with pastoralists in Northern Kenya

Photo credits: F. Timado, Compwiz Creations, K. Sri, R. Roba

E. Recommendations for effective co-design

1. **Establish collaborative teams:** Form transdisciplinary teams with intermediaries having expertise in local contexts and participatory methods, as well as on developers' and

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ends users' needs.

2. **Iterative engagement:** Conduct multiple design and feedback sessions with end users to refine solutions.
3. **Flexibility in design:** Adapt timelines and processes to user needs.
4. **Empower local feedback:** Use tools that foster end users´ elicitation of actionable feedback.
5. **Peer learning:** Utilize existing structures for dissemination, training, and support.

F. Potential barriers

Co-designing digital tools in low external input systems face several challenges. Cost and time for context immersion, particularly in remote areas, are significant barriers. Language differences, trust issues, and infrastructure limitations, such as poor internet connectivity, further hinder adoption. Additionally, low digital literacy and resistance to technology, especially among older populations, can exacerbate these challenges[2,3,11].

To overcome these barriers, key principles in co-design described above need to be observed so that solutions will align with local practices. Tailored co-design methods and tools are essential for addressing the unique constraints of communities living in (often remote and resource-constrained) low external input systems4 by for instance offering simplified interfaces, and providing offline functionality.

Conclusion

By embracing co-design principles, digital solutions for low-external-input systems can achieve greater relevance, usability, and impact. This collaborative approach ensures that digital solutions are not only technically viable but also socially and culturally aligned. If well done, they constitute a tool to empowering smallholder farmers and pastoralists to manage resources efficiently, build resilience to climate challenges, and enhance productivity.

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