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Tree-based intervention typologies and improvements in refugee displacement regions

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Abstract

Concern about deforestation in contexts of refugee displacement is substantial. Tree-based interventions (TBIs) are efforts to plant trees, conserve trees, and/or facilitate tree regrowth. TBIs are implemented by non-governmental organizations in refugee displacement contexts to address landscape-level deforestation, soil erosion, and biodiversity loss while providing livelihood opportunities to participants. Although humanitarian stakeholders recommend TBIs in refugee-hosting regions, the diversity of TBI models and associated strengths and weaknesses are not well understood. This research focuses on five TBIs implemented in a northwest Uganda refugee settlement that include large-acre woodlot planting, household-level planting of trees yielding short-term products, and conservation site establishment to protect indigenous tree species. Interviews and focus-group discussions with TBI staff revealed that each intervention makes trade-offs in navigating five key challenges associated with TBI implementation in a refugee context: Obtaining access to land, providing short-term livelihood benefits to participants, gaining equitable involvement by gender, achieving environmental conservation goals, and successfully engaging community members. Significant differences were found between the strategies of TBIs implemented at home sites when compared to TBIs implemented at community sites. While TBIs implemented at home sites are intended to provide participants long-term access to tree products with clear user rights and enable women to grow trees alongside ongoing domestic activities, TBIs implemented at community sites can achieve large-scale environmental goals and provide cash-based employment opportunities to participants. An applied integrated landscape approach is recommended to maximize inter-program collaboration and collective benefits across programs, while realizing sustainable TBI impacts within complex socioecological refugee displacement contexts.

Keywords: Tree-based interventions; Agroforestry; Refugees; Displacement; Humanitarian integrated landscape approach

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1. Introduction

Tree loss in refugee displacement regions is a global concern (Andreetti *et al*., 2024; Gianvenuti *et al*., 2022; Hassan *et al*., 2018; Leiterer *et al*., 2018). Declines observed in locations such as Daadab, Kenya (Braun *et al*., 2016), the West Nile sub-region of Uganda (Bernard *et al*., 2022; Nardi & Runnström, 2024), and refugee-hosting regions of Bangladesh (Rashid *et al*., 2021; Sarkar *et al*., 2023) warrant international attention. The magnitude and nature of tree loss differ based on contextual factors such as refugee and host-national population density (Black, 1994), variations in policies that enable or restrict refugee movement and natural resource access (Maystadt *et al*., 2020), and the extent and history of natural resource dependency among refugees and host-nationals (Black, 1994). In all cases, however, tree loss can exacerbate ongoing environmental challenges (Hagenlocher *et al*., 2012) and undermine tree-based livelihood opportunities for refugees and host-nationals (Grosrenaud *et al*., 2021).

Environmental and forestry programs in refugee-hosting regions have gained increasing attention from humanitarian organizations (European Union, 2022; Food and Agriculture Organization of the United Nations [FAO], 2023), and many include what are referred to as tree-based interventions (TBIs) (Duguma *et al*., 2019). TBIs focus on increasing and conserving tree and shrub cover and improving wood-use efficiency to reduce tree loss. TBIs in refugee landscapes can expand local food, medicine, and fiber production to supplement external aid (Tomkins *et al*., 2019), reduce energy poverty, and decrease the burden of labor for women through increased access to fuelwood (Watson, 2025), and address social conflict and gender-based violence associated with natural resource scarcity (Adam-Bradford, 2016). TBIs can also improve tree biodiversity conservation, increase shade provision, protect crops from wind damage, and enhance soil fertility (Grosrenaud *et al*., 2021).

Research indicates that tree cover reductions in regions of human displacement are driven largely by increases in demand for cooking fuel and building material (Hagenlocher *et al*., 2012), conversion of forests to cropland (Maystadt *et al*., 2020), and charcoal production, logging, or brick-burning (Naughton-Treves *et al*., 2007). Numerous studies have demonstrated the benefits of TBIs in addressing these drivers (Adam-Bradford, 2016; Grosrenaud *et al*., 2021; Moore *et al*., 2014; Nduwamungu & Munyanziza, 2013; Orr, 1985; Tomkins *et al*., 2019), but analysis of challenges and opportunities across TBI programs is lacking. Thus, prospects for increasing regional impact through program diversification and inter-organizational collaboration remain poorly understood.

This study addresses gaps pertaining to regionally integrated strategies by investigating five unique TBIs in northwest Uganda's Imvepi Refugee Settlement. Imvepi lies within Uganda's Terego District and is one of six settlements established by the Office of the Prime Minister (OPM) and the United Nations High Commissioner for Refugees (UNHCR) within the West Nile sub-region. Refugees in Imvepi are primarily from neighboring countries of South Sudan and the Democratic Republic of the Congo. Imvepi was selected for this study based on the strength of pre-existing relationships between the research team and settlement personnel, as well as the breadth of implemented TBI programs.

Research objectives are:

(i) To classify and describe discrete TBI programs within a single settlement
(ii) To characterize the organizations offering these programs
(iii) To highlight factors that enable or constrain TBI program success
(iv) To frame actionable strategies for improving programmatic impact and collaboration in regions of human displacement using an integrated landscape approach (ILA).

This study aims to provide valuable insights for enhancing TBI program efficacy and cooperation among humanitarian organizations in northern Uganda, as well as in other regions of the world where tree loss is addressed in the context of displacement.

1.1. Refugee TBIs

Efforts to reduce tree loss in refugee settlements date back to the early 1980s. In 1982, for example, UNHCR formed a consortium of non-governmental organizations (NGOs) to implement a forestry project for increased fuelwood supply and reduced environmental deterioration in the Luuq refugee camp, Somalia (Orr, 1985). A 2000 review of NGO-implemented environmental and forestry-based initiatives in African refugee contexts, or locations of refugee displacement, identified an increasingly diverse array of programming models, including woodlot establishment, provision of fuel-efficient woodstoves, environmental sensitization, and indigenous woodland management (Kakonge, 2000). In 2007, a UNHCR-backed environmental plan committed to a significant escalation of tree planting with a targeted nine million trees planted in human displacement regions across Asia and Africa (Caux, 2007).

Organizations such as UNHCR, international NGOs, and bilateral donors increasingly integrate environmental and forestry initiatives within policy and programming

recommendations. For example, European Union environmental guidelines for displacement contexts highlight forest ecosystem contributions to improved livelihood resilience and reduced social conflict (European Union, 2022). In 2023, FAO partnered with UNHCR and the Government of Uganda to develop a Forest Landscape Management Plan for the Bidibidi Refugee Settlement, which was to serve as a blueprint for forestry-focused plans in other refugee contexts (FAO, 2023). A recent UNHCR technical report highlighted tree planting and reforestation as core nature-based solutions for diverse displacement contexts, particularly when integrated with other initiatives such as urban farming and water resource management in camps and settlements (Ullal & Manoli, 2024). These documents underscore the increasing awareness in the sphere of international development that tree cover loss requires both a targeted and well-coordinated response across diverse stakeholders.

TBIs in refugee contexts are typically grouped into three categories: Tree planting, tree conservation, and facilitated resprouting of trees (Duguma *et al*., 2019). Tree planting is a central facet of TBIs in displacement contexts. One prominent strategy is the integration of woody perennial species and annual crops within farming systems, or agroforestry (Reij & Garrity, 2016). Agroforestry can yield a sustainable fuelwood source through annual tree pruning and maintenance, as well as provide access to the products and ecosystem services afforded by trees (Kay *et al*., 2021). Tree planting in refugee contexts can also take the form of plantation or woodlot establishment, with consolidated planting in defined areas to provide timber, fuelwood, and/or environmental services. Tree planting in refugee contexts requires special consideration for the protection of seedlings from animal or human damage, species selection in accordance with local environmental conditions and community preferences, and comprehension of local precipitation patterns to maximize survival (Ullal & Manoli, 2024).

Tree conservation using improved stove technology is a second dimension of TBIs in refugee contexts. Energy and infrastructure access in displacement contexts trail behind water, food, sanitation, health, and shelter in terms of funding and investment. Across global displacement regions, refugees often do not have adequate energy to cover basic electricity and cooking needs (Lehne *et al*., 2016). Furthermore, most refugees are in developing countries (UNHCR, 2025a), where rudimentary stoves are common and cause respiratory ailments, contribute to greenhouse gas emissions, and place significant demand on forest resources. Improved cookstove technology is central to TBIs in refugee contexts because it can reduce household fuelwood consumption by 20–30% (UNHCR, 2002). Lorena stoves are a popular and affordable option given their construction using locally available materials such as clay and organic materials (UNHCR, 2002). Another fuelwood conservation measure is the production of charcoal briquettes, molded from charcoal dust and other carbonized biomass materials, which burn as a cleaner and cheaper source of cooking energy (Mendum & Njenga, 2018).

A third common TBI strategy is farmer-managed natural regeneration (FMNR), which involves systematic management and pruning of existing indigenous shrubs and trees. Using coppicing to facilitate stump sprouts, FMNR can sustain highly productive tree and shrub cover across landscapes and help restore ecosystem diversity (Rinaudo *et al*., 2019). Following establishment, FMNR avoids challenges associated with reforestation, such as obtaining tree seeds and watering seedlings (Reij & Garrity, 2016). FMNR also maintains biodiversity and enables beneficiaries to practice conservation while managing trees for a variety of household products (Grosrenaud *et al*., 2021). In refugee contexts, FMNR is often paired with other enterprises such as apiculture for value addition and livelihood opportunities (Laird *et al*., 2021).

TBIs in refugee contexts ultimately reflect the unique challenges inherent to displacement. One is limited land access and land tenure insecurity (Adam-Bradford, 2016; Unruh, 1993). Refugee land holdings in encampments and settlements often are too small or marginal for extensive tree establishment (Grosrenaud *et al*., 2021). Some refugees access supplemental land through rental or lease agreements; however, these agreements and land use arrangements can change annually (Bohnet & Schmitz-Pranghe, 2019), thereby dissuading tree planting. Furthermore, displaced individuals often view their status as temporary and expect to return to their country of origin, potentially reducing interest in woody perennial investments (Black, 1994).

Another challenge is extreme socioeconomic distress, with refugees consistently experiencing higher poverty rates when compared to nearby host-national communities (Malik, 2023). Given the marginalization and food insecurity faced by refugees, a strong preference for planting fast-growing trees for economic return was a top priority among TBI participants in Cameroon (Moore *et al*., 2014), Somalia (Orr, 1985), and Uganda (Grosrenaud *et al*., 2021). Ensuring refugees realize livelihood benefits, either in the form of tree products or cash-earning employment opportunities, is an important TBI principle.

Gender is another important dimension of TBIs in refugee contexts, given that women head a significant

proportion of camp-based refugee households globally (Beltramo *et al*., 2023). As primary household-level agricultural producers and fuelwood harvesters, women are often disproportionately impacted by land and resource conflict (Kirabo *et al*., 2011), and exposure to sexual and gender-based violence when traveling long distances to harvest fuelwood is a major concern (Adam-Bradford, 2016; Kumssa *et al*., 2014). These factors underpin the importance of prioritizing the needs of refugee women in TBIs and engaging them in program design and implementation (Nduwamungu & Munyanziza, 2013). Participation by women also challenges existing gender roles, particularly in regions of sub-Saharan Africa where they are traditionally restricted from land ownership (Masters, 2021; Wel, 2012) as well as tree planting, which is often considered indicative of land ownership (Grosrenaud *et al*., 2021). In such locations, TBIs require careful navigation of norms to identify opportunities for equitable engagement and empowerment of women.

1.2. ILA

This study draws on ILA principles to interpret research results and synthesize participant-identified solutions into a set of strategic recommendations for collaborative tree-based humanitarian assistance programs.

An ILA framework draws on a range of concepts and tools to guide stakeholders and land managers in addressing various social, environmental, and economic challenges at the landscape scale. From an ILA perspective, the landscape is an appropriate spatial unit for addressing such challenges, given that environmental and human systems primarily interact at the landscape scale (Duncan *et al*., 2021). An ILA framework promotes multifunctionality in the development of holistic practices and policies and is particularly applicable to sustainable management of natural resources and climate change adaptation (Freeman *et al*., 2015). Landscape approaches are increasingly popular in tropical regions, given the complexity of existing sociopolitical systems and rich ecological diversity (Reed *et al*., 2017), and they are particularly relevant within refugee-hosting contexts in encouraging solution-building between actors at multiple levels in the provision of developmental and humanitarian services (Schure *et al*., 2022).

Five core concepts define ILA: (i) Multifunctionality, (ii) Interdisciplinarity/transdisciplinarity, (iii) Sustainability, (iv) Participation, and (v) Complexity (Freeman *et al*., 2015). ILA multifunctionality is defined as "achieving multiple objectives or functions at the same time" (Freeman *et al*., 2015, p.6). ILA transdisciplinarity avoids sectoral and siloed approaches through cross-sectoral, multistakeholder approaches. A healthy and productive landscape that holistically supports long-term environmental and human well-being amid changing social and environmental conditions underpins ILA sustainability. Relationship building is central to ILA participation, which includes both consultation and dialogue with landscape-level stakeholders and the promotion of two-way information exchange across multiple stakeholder groups, among whom power imbalances may exist. The predicate for ILA complexity is that comprehending contextual intricacies and nuance is essential when monitoring and documenting emerging processes and patterns at multiple scales (Freeman *et al*., 2015).

1.3. Refugee resettlement in Uganda

Uganda currently hosts 1.9 million refugees (Government of Uganda & United Nations High Commissioner for Refugees, 2025), which is the largest number by an African nation and the fourth largest globally (UNHCR, 2025b). In part, this is due to Uganda's proximity to countries enmeshed in protracted civil conflicts, namely, South Sudan and the Democratic Republic of the Congo (Titeca, 2022). Waves of violence following South Sudan's independence in 2011 continue to enkindle forced migration of South Sudanese refugees to northern Uganda (Titeca, 2022), where South Sudanese now comprise nearly 54% of Uganda's total refugee population (Government of Uganda & United Nations High Commissioner for Refugees, 2025).

Refugee settlement in Uganda is additionally occasioned by the nation's relatively liberal policies that provide refugees with freedoms of work and movement within the country (Blair *et al*., 2022). The centerpiece of Uganda's model is the Self-Reliance Strategy, which was designed jointly in 2002 by OPM and UNHCR to shift from a relief model of refugee engagement to a developmental strategy (Dryden-Peterson & Hovil, 2004). The Self-Reliance Strategy builds on Uganda's long-standing practice of distributing arable land within open settlements to refugees, with the goal of enabling refugees to produce their own crops, raise livestock, and/or maintain trees for self-sustenance (Kaiser, 2005). The adoption of liberalized refugee policies has earned Uganda praise from humanitarian bodies such as UNHCR and facilitated the movement of financial aid and international refugee response into the country (Betts, 2021).

Uganda's robust refugee response and unique policy of land distribution to refugees have created conditions for growth in the number of TBI programs across the nation's 13 refugee settlements. The presence of multiple and distinct TBI models operating within Ugandan refugee settlements offers an opportunity to compare programming models and explore organizations that

provide them, including relative strengths, challenges, and areas of collaboration. This research used a comparative case-study approach to understand how and why programs are designed and implemented, and to explore whether distinct TBI characteristics may bear distinct programmatic outcomes. Focus group discussions and analysis of initial results with staff of Ugandan TBI programs further informed the conversion of case study results into broad recommendations for successful and sustainable TBI programs and organizational collaboration in Uganda and other refugee displacement contexts.

2. Data and methods

2.1. Study context

Imvepi Refugee Settlement (Figure 1) is a 53.2 km^2 settlement that was formally established in 2017 to accommodate an uptick of refugees fleeing violence in South Sudan's Equatoria region (Barasa *et al.*, 2022). Imvepi's 74,804 residents are predominantly South Sudanese and are primarily of Kakwa, Kukuu, Madi, and Bari ethnicities. Refugees in Imvepi are 47% male and 53% female (Government of Uganda & United Nations High Commissioner for Refugees, 2025). Regional host-nationals are predominantly Lugbara, and the Terego District host-national population is approximately 230,000 (Hyde-Smith & Nyakana, 2021). While a proxy war between the governments of Sudan and Uganda contributed to significant regional violence throughout the 1990s and early 2000s, northwest Uganda is presently free of major conflict (Gidron, 2022).

Imvepi is located within shallow regions of the Albertine Rift. Soils are primarily clay loam, with native vegetation including grasslands and woodlands. The climate in the West Nile sub-region is tropical, with a bimodal rainfall pattern distributed between two rainy seasons (April–June and August–October). Annual precipitation is 1,250 mm on average, and mean temperatures range from 20°C to 30°C (Barasa *et al.*, 2022). Land cover in Imvepi and surrounding regions is historically categorized as wooded grasslands with dominant tree species including shea nut (*Vitellaria paradoxa*), *Combretum* spp., and stands of African fan palm (*Borassus aethiopum*) (van Breugel *et al.*, 2014).

2.2. Sampling and data collection

Five Imvepi TBI programs were purposefully selected based on program scale, intervention diversity, and willingness to participate. The first program is a Uganda-based TBI focused on the provision of tree seedlings and agroforestry training to refugee and host-national households. The second establishes large-scale teak woodlots, distributes tree seedlings to households, and constructs fixed-owner Lorena stoves within refugee and host-national kitchens. The third promotes household-based agroforestry and permaculture interventions, while the fourth focuses on food forest establishment. Finally, the fifth selected program centers on FMNR and apiary management.

Data were collected in organizational offices in Kampala, Arua City, and Imvepi in May and June 2023. Semi-structured interviews were conducted with nine administrative staff personnel from the selected TBI

Figure 1. Map of the Imvepi Refugee Settlement boundaries and its location in northwestern Uganda
Basemap sources: © OpenStreetMap contributors, © Esri (retrieved May 2025).

programs, including country directors and program managers. In addition, seven technical and local staff members were interviewed, including at least one staff member from each TBI program. Of the 16 TBI staff interviewed, 2 were female and 14 were male. Interviews collected detailed, descriptive information on specific programs, organizational characteristics, and strategies for navigating programmatic challenges. Topics specific to the semi-structured interview guide included organizational missions, geographic range of operations, number of TBI participants engaged, recruitment strategies, and funding duration, as well as core challenges, strategies, and opportunities for improving TBIs.

One TBI field site per program was visited to conduct in situ observations pertaining to the nature of interventions and stimulate additional inquiry based on semi-structured interview data. Visits lasted 30–40 minutes and involved documenting intervention features such as species composition, soil and water conservation practices, and ease of access by refugee and/or host-national participants. Secondary data were obtained from implementing NGOs in the form of web pages and program documents. Program documents included monitoring and evaluation reports, field manuals, annual reports, and project briefs. Webpage content and program documents were solicited from research participants at the time of the interview, though sometimes they were provided afterward by email. Webpage content for TBI programs was accessed and downloaded for content analysis, along with program documents and interview transcripts.

To enhance data richness and validity, a focus group discussion was conducted with eight Imvepi-based technical and administrative staff representing study organizations in May 2024. The focus group was held in Arua, a city located approximately 100 km from Imvepi, and travel stipends were provided to all attendees. Analyses of the interview transcripts and programmatic documents were presented to focus group participants. Between presentations, periods of structured and open dialogue occurred, with participants asked to comment on the findings, following the approach described by Lambert and Loiselle (2008). Participants were asked to verify the validity of initial research findings and/or contribute important elements that may have been missed through previous forms of data collection. Focus group attendee feedback was recorded using an audio device, transcribed, and integrated into the summative data analysis.

During the focus group discussion, a logic model (Savaya & Waysman, 2005) was used to define and operationalize a 5-year blueprint for achieving desired future TBI conditions and inter-organizational cooperation. Logic Models provide a framework for articulating short-term, medium-term, and long-term actions that are necessary for strategic change, as well as identifying assumptions and measurable inputs and outputs. Logic Model results represent the participant-identified programmatic actions and inter-organizational cooperation that are necessary for realizing long-term group-identified goals.

2.3. Data analysis

Interviews were recorded and transcribed to generate raw data, which were analyzed together with secondary data using ATLAS.ti version 23.2.2 (ATLAS.ti Scientific Software Development GmbH, Germany), a qualitative data analysis package for coding text data. Thematic analysis involved flagging and coding unique and/or recurring concepts across interview transcripts and program documents within ATLAS.ti, including organizational characteristics, activities, program strengths, and challenges. While an a priori set of topics, such as "gender" and "land access," were deductively selected and coded within texts based on review of pre-existing literature, other topics were inductively identified within the data to emphasize emergent themes. Initial coding of qualitative data thus involved a hybrid approach following Swain (2018), incorporating both theoretical and data-driven processes. Through axial coding, relationships and categories across initial codes were identified and organized.

A comparison table was created to facilitate the comparison of coded themes across programs. Comparison tables allow a researcher to synthesize long narratives by identifying similarities and differences between and within cases, based on the approach described by Goodrick (2014). Comparison tables are created following a process of text retrieval and coding by entering summarized information into table cells. In this case, an attribute table was used, or a table where rows, in addition to columns, represent properties of cases rather than the cases themselves. Comparison occurs by looking across columns as well as across rows to identify differences, associations, and trends according to attribute (Gibbs, 2007).

2.4. Ethical approval

Ethical approval for this study was obtained from the Institutional Review Board at the Virginia Polytechnic Institute and State University (23-283). The Research Ethics Committee at Bishop Stuart University in Mbarara, Uganda, also approved the study (BSU-REC-2023-73). Research clearance was also obtained through the Uganda National Council of Science and Technology (NS544ES). Permission to conduct research and operate within Imvepi was granted by the OPM in Uganda.

3. Results

3.1. TBI programs

Data analysis revealed six distinct TBI program categories: (i) Home-based agroforestry, (ii) Community-based agroforestry, (iii) Fuelwood efficiency, (iv) Woodlot planting, (v) Food forest establishment, and (vi) Community FMNR.

Home-based agroforestry TBIs distribute tree seedlings to refugee and host-national participants for planting near homesteads, along property boundaries, and/or integrated with home-based gardens. Tree species are selected based on compatibility with agricultural crops, or for fruit production, shade, or fuelwood. Some home-based agroforestry programs also include resource recovery and reuse training, which focuses on household soil and water conservation techniques such as repurposing kitchen graywater for irrigating trees and crops, digging trenches and bioswales to improve water absorption in soil, and composting to optimize water and nutrient availability. The goal is to extend the growing season to increase tree and crop survival rates during drought and unreliable precipitation.

Community-based agroforestry TBIs promote cropping in between newly established trees in timber woodlots on host-national land. Newly planted stands are divided into individual tracts, which refugees use for intercropping during a period of 2–3 years. Planting annual crops between juvenile timber trees is most common, but intercropping other tree and shrub species occurs as well. The goal is to increase agricultural production by accessing resources that are unused by timber trees in early stages of stand development, as well as reducing timber tree competitors. Community-based agroforestry is derived from *taungya*, an agroforestry system developed in the early 19th century in Myanmar as an efficient approach to rehabilitating forest cover and improving farmer livelihoods (Hemida *et al*., 2023).

Fuelwood-efficiency TBIs focus on improved access to biomass cooking fuel and enhancing the efficiency of cooking appliances to reduce demand for fuelwood. This includes the fixed-owner (Lorena) stove promotion. Artisans are trained to construct Lorena stoves inside refugee and host-national kitchens with locally sourced grass, sand, and clay. Recipients of stoves are involved in the stove construction process, providing them with a new skill set and the knowledge required to repair stoves in case of breakage over time. Fuel-efficiency programs also promote briquette production using carbonized tree twigs and crop residues, which are bound with soil. Briquettes are either for the purpose of home use or sale.

TBIs focused on woodlot planting involve establishing timber species on one hectare or more of land provided by host-national owners. Planting normally includes a small number of fast-growing timber species, predominantly teak (*Tectonis grandis*). NGOs hire refugees and host-nationals to establish and maintain woodlots for a 3-year period, after which management is transferred to host-national owners or local institutions. Management activities include weeding, trenching to exclude fire, and replanting where mortality occurs. In some cases, refugees can use pruned wood beyond the initial 3-year period.

Food forest establishment TBIs are two-to-three-acre projects designed using six permaculture layers: large tree canopy, small tree canopy, shrub, herbaceous, groundcover, and vining. Multiple layers and three-dimensionality mimic niche occupancy in natural forests and increase multifunctionality using diverse guilds that provide food, fodder, fiber, fuel, and medicine, as well as improve soil fertility. Food forests are planted on land provided by local institutions or host-nationals. Refugee and host-national farmer groups are hired to establish and maintain food forests for institutions, neighboring communities, and individual host-nationals. Soil and water conservation involves integrated water-harvesting structures (e.g., bioswales, boomerang, and half-moons) as well as manuring and mulching.

Community FMNR TBIs provide demonstrations where refugees and host-nationals are trained on systematic pruning and tree and shrub coppicing to encourage species regrowth. Apiaries and fruit trees are integrated to showcase short-term additive enterprise opportunities, which can provide sources of income before FMNR projects yield economic return. FMNR program participants receive apiary training and materials such as beehives, equipment for beehive maintenance, and honey bottling and marketing supplies. FMNR TBIs emphasize community management of conservation sites and apiaries, in particular, co-management between refugees and host-nationals.

3.2. TBI organizational characteristics

TBI organizational characteristics included five unique attributes: (i) Mission statements, (ii) Geographic range, (iii) Number of beneficiaries, (iv) Target beneficiaries, and (v) Funding duration (Table 1). TBI programs varied by mission statements and objectives published by the administering organization. Mission statements shape the nature of adopted program activities. Livelihood-oriented missions focused on activities providing short-term material benefits for participants. An environmentally focused missions focus on activities to support biodiversity

Table 1. Comparison of characteristics of organizations implementing TBIs across promoted activities

Tree-based interventions	Organizational characteristics				
	Programmatic mission	Geographic range	Number of participants/year	Refugee: host ratio	Duration
Home-based agroforestry	Gender responsiveness, food and energy security, sustainable ecosystems, resilient livelihoods	Settlement	190–300	70:30	4 years
Fuel-efficiency interventions	Energy security, reduced environmental degradation	5 districts	2,000	70:30	4 years
Community-based agroforestry	Energy security, reduced environmental degradation	5 districts	93	70:30	4 years
Community-based FMNR	Food security, sustainable natural resource use, and climate change adaptation	Settlement	667	70:30	3 years
Woodlots	Energy security, reduced environmental degradation	5 districts	1,040	70:30	4 years
Food forests	Resilience and economic development	13 districts	525	30:70	4.5 years

Abbreviation: FMNR: Farmer-managed natural regeneration.

conservation, carbon sequestration, and wind reduction. Common themes existing across the missions of all organizations include ecosystem resilience, human welfare, and host-national and refugee cooperation building. Other common themes are household nutrition, cooking energy security, reduction of environmental degradation, climate change mitigation, and regional economic development.

TBI programs also varied by geographic range and duration of implementation. Three organizations provide TBI programs in concentrated geographic areas. These organizations tend to focus on home-based agroforestry and community FMNR. Two organizations implement TBIs across larger ranges, spanning multiple refugee-hosting districts, and focus on woodlots, fuelwood efficiency programs, community-based agroforestry, and food forests. The largest organizational range covers 13 refugee-hosting districts, and the second largest operates in five refugee-hosting districts, including six refugee settlements. TBI program lengths also varied, with the average program length across organizations being 4 years. Three years is the shortest recorded program, whereas the longest is four and a half years. Three TBIs involve funding for pre-designated durations, whereas two organizations sought continuous funding through crowd-sourcing and additional grants or relied on annual contract renewal.

The food forest establishment TBI engaged the highest number of participants, recruiting a total of 2,355 refugees and host-nationals. One organization delivering a fuelwood-efficiency program reached an estimated 2,000 households per year. The woodlot establishment TBI involved more than 1,000 participants annually. The number of households trained in the community-based FMNR program totaled 2,000 over a 3-year period. Two organizations administering home-based agroforestry interfaced with approximately 150–300 households per year, while the community-based agroforestry TBI reached approximately 100 households annually. TBIs at four of five organizations aimed to engage 30% of host-nationals among recruited participants, though exact proportions varied due to the location of staff or programs. For instance, participants recruited for woodlot programs were often selected based on proximity to woodlot sites, which affected the proportion depending on proximity to refugee or host-national populations. Only one organization adjusted participant recruitment targets (30% refugee and 70% host-national participation) to accommodate a larger geographic range and refugee-hosting district mission.

3.3. TBI operational challenges

Distinct operational challenges emerged relative to five germane TBI challenges: (i) Land access, (ii) Participant livelihoods, (iii) Gender equity, (iv) Environmental conservation, and (v) Community engagement (Table 2). Land access is a common challenge for TBIs, particularly when engaging refugees whose primary landholdings are limited to plots granted by the OPM. Refugees do not technically own these plots, which rarely exceed 2,500 m^2, but are granted long-term tenure at no cost through land-use agreements negotiated by OPM, UNHCR, and local landowners. Although host-national TBI participants have larger landholdings, they also face land access limitations if a significant proportion of their acreage is under annual crop production.

One strategy for addressing land access challenges is to maximize the productivity of smaller land parcels through intensive application of soil and water conservation practices. Such practices include greywater harvesting and composting, as well as tree establishment on even the smallest and most marginal refugee plots. Another strategy is to negotiate access to external tracts of host-

Table 2. Comparison of TBI strategies in response to key operational challenges across promoted activities

TBIs	Operational challenges				
	Land access	**Short-term livelihoods**	**Gender**	**Environmental conservation**	**Community engagement**
Home-based agroforestry	Maximize participant land use	Tree products for use and sale	TBIs complement household tasks, and women engage at home	Shade and windbreak; soil and water conservation	Local staff hired; community meetings convened
Fuel-efficiency interventions	Maximize efficient tree use	Stove construction training	Reduced firewood demand	Tree conservation	Local staff build stoves, train neighbors
Community-based agroforestry	TBI establishment on host/institutional land	Improved crop yields; tree poles for use and sale	Women gain external land access	Soil fertility and crop protection	Local staff hired; mixed refugee–host groups formed
Community-based FMNR	TBI establishment on host/institutional land	Integrated agroforestry for tree products; Apiary establishment	Apiary training; female leadership roles groups	Biodiversity preservation; pollination	Local staff hired; local leaders engaged; mixed refugee–host groups formed
Woodlots	TBI establishment on host/institutional land	Cash-for-Work income; timber for landowner/ institution	Gender thresholds; female staff hired; cash earnings for women	Carbon sequestration; microclimate adaptation	Local staff hired; community meetings; community leaders engaged
Food forests	TBI establishment on host/institutional land	Cash-for-Work income; tree products for landowner/ institution	Gender thresholds; female staff hired; cash earnings for women	Diverse species planted; soil and water conservation	District leaders engaged; local staff hired; radio outreach

Abbreviations: FMNR: Farmer-managed natural regeneration; TBI: Tree-based intervention.

national or institutional land for TBI implementation through signing Memoranda of Understanding (MOU) with local landowners and regional and national governmental officials or other relevant stakeholders. For example, one community FMNR program negotiated MOUs to enable groups of refugee and host-national farmers to use one-acre plots of land for FMNR, agroforestry, and beekeeping activities, which are then left to the host-national landowner after programming concludes. A third strategy involves establishing TBIs on publicly available or institutional land. For example, food forests and woodlots are often established on land granted by schools, district offices, and even as green corridors alongside roads.

Providing short-term income and livelihood opportunities to incentivize TBI participation is of high organizational importance, given refugee and host-national socioeconomic insecurity. One TBI livelihood strategy is to distribute tree seedlings that yield short-term tree products for sale or home use. In certain TBI programs, for example, participants harvest the fruits of papaya (*Carica papaya*) and mango (*Mangiferus indica*) or cut tree poles from species such as senna (*Senna siamea*) or melia (*Melia volkensii*) for home construction or sale at UGX 5,000 (equivalent to USD 1.37) per pole. Even within conservation-oriented community FMNR sites, fast-producing fruit trees along boundaries encourage participants to regularly visit and maintain sites. In addition, community-run apiaries in FMNR sites provide an income source during the early stages when new trees do not yet render sufficient marketable yield.

Cash-for-Work (CfW) is another model for incentivizing TBI participation, particularly with respect to food forests and woodlots. CfW provides cash payments to refugees and host-nationals for TBI activities such as land preparation, tree planting, and maintenance. CfW is an important supplementation to food and humanitarian aid, particularly for youth and women, and can lead to longer-term livelihood opportunities when participants use payments as seed money to open shops or purchase poultry and livestock. Finally, a third livelihood strategy identified across TBI programs is building participant skillsets and employment opportunities through training on the construction and maintenance of fuel-efficient woodstoves.

Ensuring equitable access to TBIs by women is imperative, though programs differ in how this is achieved. Home-based agroforestry programs encourage women to integrate TBIs with domestic activities such as cooking,

cleaning, and childcare. For example, participants learn how to irrigate trees using greywater from household activities. Fuel-efficiency interventions such as briquette production and Lorena stove construction reduce the amount of time women spend searching for fuelwood away from the homestead. TBIs such as woodlot plantings, community-based agroforestry, food forest establishment, and community FMNR, by contrast, require women to leave the homestead. These programs, however, focus on empowering refugee and host-national women by improving land access and providing income. To ensure equitable representation by gender within TBIs, most programs set thresholds when recruiting participants, aiming for a minimum of 50% participation by women. However, some programs fall short on gender targets because women often find it difficult to travel from the homestead for any length of time. All organizations also intentionally include women as community-based staff.

Environmental degradation in refugee-hosting contexts is a significant challenge addressed by TBIs. Like gender equity, associated strategies differ. Small-scale, intensive approaches to soil and water conservation implemented by home-based agroforestry and food forest establishment TBIs address climate change impacts experienced by participants due to increasing short and unpredictable precipitation. TBIs include instruction on water management structures such as bioswales, trenches, and bench terracing to improve growing conditions and soil health. Biodiversity is another conservation priority. For instance, one home-based agroforestry TBI program raises and distributes indigenous tree species such as desert date (*Balanites aegyptiaca*), tamarind (*Tamarindus indica*), and sausage tree (*Kigelia Africana*) to participants.

Biodiversity conservation and wildlife habitat preservation are major priorities for community FMNR programming, which trains participants to manage and protect diverse indigenous tree species within FMNR plots. FMNR programming draws on local ecological knowledge of indigenous tree benefits to encourage community use of medicinal and/or edible non-timber forest products during tree regrowth. Biodiversity is a major challenge for woodlot establishment TBIs, with most plantations growing one or two species of fast-growing, non-native timber trees. Often this is due to the preference of landowners who decide which trees are planted on their land and may reject species perceived as slow-growing. Woodlot establishment TBIs instead focus on larger-scale environmental benefits associated with plantation establishment, such as carbon sequestration, wind modification, and microclimatic improvements.

TBI programs employ various strategies to achieve participant uptake of promoted activities, which is a prerequisite for program success. All programs hire local staff members to help identify and mobilize participants. Program informants highlighted the importance of local staff in facilitating communication with TBI participants in local languages within both the refugee and host-national communities. Local staff, in some cases, implement TBIs on their homesteads to create demonstration sites, inspiring neighboring participants to adopt TBI activities. Several programs intentionally engage local district-level leadership in the planning and execution of TBIs to ensure activities align with broader goals in the operational context. This prepares local districts to continue activities in the absence of formal programming and organizational support. Hosting community meetings is a common strategy for engaging local leadership and increasing TBI participation. Some programs emphasize community dialogues at the outset of activities to set appropriate land boundaries and foster community approval. Others implement dialogues mid-way through an intervention to identify participant preferences and brainstorm future directions. Radio programming also helps build community awareness and support for TBIs, providing updates on project progress, future activities, and best practices for implementation.

3.4. Focus group discussion and logic model

Focus group and logic modeling resulted in five prominent solutions to support overall TBI success and longevity: (i) Integrate TBIs, (ii) Coordinate across TBIs, (iii) Maximize use of funds, (iv) Build relationships, and (v) Monitor and evaluate. Salient discussion topics included selecting tree species favored by participants, offering home-based agroforestry programs focused on intensive water and soil conservation management, and hosting community meetings to ensure planned activities match participant-driven goals. Participants leading community-based interventions highlighted the importance of engaging local landowners and clan representatives in addition to the OPM and district governmental officials when arranging land access to avoid a sense of coercion or disregard among landowners and achieve mutually beneficial arrangements. Significant impediments to successful TBI program implementation in Imvepi included insufficient funding, short funding durations, and increasingly harsh environmental conditions for tree establishment and maintenance. The focus group discussion and logic model results were distilled into five prominent solutions.

4. Discussion

The results of this study highlight the significant differences between TBIs, particularly between home-based and community-based programs. Home-based

TBIs tend to focus on agroforestry applications and fuelwood efficiency, whereas community-based TBIs emphasize food forest establishment, woodlot planting, community-based agroforestry, and community FMNR. Aside from one fuelwood efficiency program, home-based TBIs are implemented by organizations with a localized, settlement-based geographic scope and engage a smaller number of participants. In contrast, most community-based TBIs are implemented by programs with broader, district-level geographic coverage that engage larger numbers of participants. One explanation is that large-scale organizations are better positioned to negotiate land access and establish MOUs with governmental stakeholders. Organizational mission statements also appear to influence the scale and nature of TBIs. Home-based TBIs are implemented by organizations whose mission statements emphasize gender responsiveness and household-level food and energy security, whereas mission statements among organizations implementing community-based interventions generally highlight regional and even global goals, including climate change mitigation, reduced natural resources degradation, and regional economic development.

Strategic responses to operational challenges also differ between home-based and community-based TBIs, with each intervention making important trade-offs to achieve programmatic missions. Home-based TBIs may attain longer-term land access and potentially greater TBI permanence by implementing activities on participant home plots; however, it can be constrained by the small size of plots, particularly among refugees. In contrast, community-based TBIs can achieve larger-scale impacts by linking participants to external tracts of land. TBIs on community land, however, may face constrained tenure given the short-term nature of land access agreements.

Home-based TBIs can build short-term livelihood opportunities by supplying participants with fast-growing tree species that yield products for which participants have clear ownership and user rights. These products may be more or less financially valuable depending on participant proximity to local markets, but they can address household-level food security and building material needs. However, user rights to products grown within community-based TBIs can be murky or restricted to only host-national landowners. To compensate, community-based TBIs instead emphasize livelihood opportunities in the form of CfW payments and apiary establishment.

Concerning gender, home-based TBIs are responsive to the needs of women by integrating TBIs with ongoing domestic work at the home site. Conversely, community-based TBIs draw women away from home in a manner that can be inconvenient, but at the same time may empower them and challenge gender norms through increased access to land and cash-earning opportunities. Home-based TBIs promote environmental conservation through household-level soil and water conservation practices, though they can fall short of large-scale environmental goals achieved by community-based TBIs such as mass carbon sequestration, wildlife habitat protection, and microclimate adaptation. Achieving biodiversity goals is a challenge for home-based and community-based treeplanting programs alike when participants perceive indigenous and/or diverse species to be slow-growing and at odds with supporting short-term livelihood opportunities.

Finally, community engagement strategies such as hiring local staff and conducting community dialogue meetings are common across home-based and community-based TBIs. Home-based TBIs can encourage local staff to utilize their homes as TBI demonstration sites, providing visual evidence to support the uptake of TBIs among neighbors. Local staff is well-positioned to continue promoting TBI activities in the absence of formal programs. Community-based TBIs more often boost community uptake through radio programming and align activities with district-level governmental initiatives in a way that ensures cohesion with ongoing environmental projects and encourages district-level adoption of projects when TBIs conclude.

Findings indicate that home-based and community-based TBIs address both human and environmental health goals, each with associated strengths and weaknesses. That individual TBI programs make trade-offs in balancing unique goals need not be problematic when programs are viewed collectively through the perspective of an ILA, which calls for "the engagement of multiple stakeholders across sectors to better negotiate trade-offs and maximize synergies within the landscape" (Reed *et al*., 2017, p.481). In the context of an ILA framework, diverse stakeholders can collectively contribute to finding synergies, identifying joint objectives, and accounting for gaps among individual actors (Reed *et al*., 2016).

ILA frameworks can be most impactful when contextualized and connected to problem-solving within a specific landscape. One method of operationalizing an ILA is to bridge general ILA principles with stakeholder action items as part of an adaptive and iterative process to achieve landscape-level change (Freeman *et al*., 2015). Five actionable TBI solutions identified during logic model planning align with general ILA core concepts. Examining the interplay is an opportunity to build pathways between grounded, applicable TBI recommendations and broader socioecological outcomes at the landscape scale.

Several TBI programs in Imvepi integrate activities to better account for service gaps. For example, home-based agroforestry programs often promote fuel-efficiency practices among participants to amplify impact by reducing fuelwood demand or encourage FMNR alongside agroforestry and woodlot planting to support the retention of indigenous tree species and biodiversity. TBI programmatic integration aligns with ILA multifunctionality. Multifunctionality can be a significant advantage for TBI programs operating in refugee contexts where the availability of environmental and livelihood interventions falls significantly below demand. The most successful programs may be those catering to multiple human and environmental health needs by blending diverse TBI activities and compensating for weaknesses associated with distinct intervention types. Program integration recognizes that trade-offs and hard choices by individual stakeholders within a given landscape are realistically unavoidable, but wherever possible, "win-win" outcomes are promoted where stakeholders simultaneously achieve multiple goals. Such program diversification may be enhanced through program planning exercises to review the spectrum of available TBI activities and rank activities in accordance with specific program objectives and priorities (Freeman *et al*., 2015).

TBI programs in Imvepi exhibit inter-organizational coordination through various avenues. One example is mutual procurement or provisioning of planting stock. One organization in this study established a tree nursery between refugee settlements and signed seedling provision MOUs with other organizations, while another established a relationship with the UNHCR and the National Forest Authority, which allowed tree seedling supply from the National Forest Authority nurseries to other TBI programs. Two home-based agroforestry TBIs shared permaculture training materials and conducted joint training with organizational staff and participants. TBI staff currently co-attends relevant livelihood and environmental sector meetings within Imvepi. Inter-program TBI coordination corresponds to ILA transdisciplinarity. Trade-offs within individual programs across a landscape can be reconciled by improving inter-organizational coordination, where diverse stakeholders strategically fill gaps left by another (Freeman *et al*., 2015). Additional coordination opportunities identified during focus group deliberations include establishing a settlement-based coalition of TBI implementing programs to facilitate knowledge exchange and coordinating activities with non-TBI–focused sectors such as education, health, and sanitation to broaden programming impact.

TBI programs optimize sustainability by maximizing the use of meager funds to achieve lasting impact beyond 3–5-year funding cycles. Among TBIs in Imvepi, one relatively low-cost means of supporting uptake and permanence is to emphasize participant training. Training provides participants with important and marketable skills such as the ability to construct Lorena stoves and prune resprouted trees. These skillsets can lead to livelihood opportunities in the case of refugee repatriation. Tree seedling survival is also critical for improving TBI efficiency, as planted seedlings face a range of threats, including ruminants, drought, fire, depleted soil, and species compatibility. Addressing these challenges involves using thorny shrub species for live fencing, digging fire lines to protect seedlings, promoting water harvesting and compost, ensuring species suitability, as well as selecting socially and culturally acceptable designs that are desired by program beneficiaries. Maximizing TBI funding intersects with ILA sustainability. Strengthening resilience and reducing vulnerability are viewed as critical to supporting the longevity of a landscape to provide environmental services in the context of climatic and sociocultural change (Freeman *et al*., 2015). Future sustainability opportunities include establishing community-managed tree nurseries within refugee contexts to reduce costs associated with seedling transportation and emphasizing FMNR as an important alternative for achieving tree regrowth without incurring seedling procurement, planting, and management expenses.

There is a strong precedent for wide TBI relationship-building with refugees, local host-nationals, international organizations, and governmental officials when interventions are planned and enacted. Strong relationships with local leaders at the district, sub-county, and village levels facilitate land access and set the stage for local leadership bodies to adopt and maintain TBI strategies. For these reasons, several TBI programs in this study linked participant groups to local government infrastructure and staff. Another critical dimension of relationship-building is fostering TBI partnerships between refugees and host-nationals. Developing mutually beneficial relationships and land access arrangements between refugees and host-nationals can enable ongoing land access following program conclusion. Such examples reflect ILA participation. Outcomes are expected to be strongest in ILA applications when participation across diverse stakeholders is highly collaborative, iterative, and flexible (Freeman *et al*., 2015). Recommended opportunities to bolster participation are refugee and host-national workshops on the process of drafting formal, written land access agreements to facilitate and protect both parties in cooperative land use arrangements for TBI engagement.

TBIs in Imvepi engage in joint TBI monitoring and evaluation with various stakeholders such as international

agencies, funding bodies, and government partners to increase capacity and critical evaluation. TBI programs implemented by large organizations often are in a better position to conduct monitoring if they already employ personnel specifically for the purpose of conducting monitoring and evaluation. Examples of program dimensions that are collaboratively evaluated include seedling survival, livelihood benefits, and community approval of TBIs. Monitoring and evaluation parallels ILA complexity. In complex refugee-hosting regions, significant intellectual, financial, and human resources are required to effectively monitor and evaluate TBIs, making it a relatively underdeveloped programmatic aspect. Landscape-oriented monitoring and evaluation frameworks, tools, and indices, and participatory approaches that empower and engage program beneficiaries are needed to effectively understand the complex social and environmental factors affecting program outcomes at different scales (Reed *et al*., 2016). Developing holistic measures of tree health and TBI programmatic success beyond solely measuring seedling survival rates could add important insight into the environmental suitability of selected species, as well as reasons why and whether participants choose to maintain planted species.

Bridging key ILA concepts with stakeholder-identified TBI solutions clarifies key pathways for initiatives to pursue multifunctional, transdisciplinary, participatory, sustainable, and complex responses to social-environmental challenges in refugee-hosting landscapes. Additional research on regional TBI coalition building and coordination is warranted, and may benefit from exploring approaches implemented in other prominent humanitarian sectors, such as water, hygiene and sanitation, nutrition, and education. Furthermore, although TBI programs involved in this study represent various TBIs undertaken within the context of a Uganda refugee settlement, ideal strategies and outcomes may look quite different in self-settled or closed-camp refugee-hosting contexts. Tailored applications of an ILA framework within diverse humanitarian contexts are recommended.

5. Conclusion

As tree-cover loss accelerates in diverse regions of refugee displacement, TBI programs are an increasingly common facet of humanitarian organizations focused on human and environmental health. TBIs are especially critical in developing regions where refugees and host-nationals alike depend upon trees and forests for multifunctional livelihood benefits and ecosystem services. While studies on the strengths and challenges of individual TBIs in refugee contexts exist, comparative analysis across multiple, distinct TBI program models does not. This study identified and compared five discrete TBI programs in the Imvepi refugee settlement located in Northwest Uganda to reveal differences and similarities, to highlight enabling or constraining factors for TBI program success, and to frame actionable TBI solutions for improved programming in regions of human displacement through the application of an ILA.

Results indicate that the goals and strengths of TBI programs in navigating service provision differ, particularly between programs implemented at home sites compared with those implemented at community sites. Home-based TBIs maximize household-level environmental benefits, accommodate participation by women, and yield tree products with clear user rights, while community-based TBIs can offer settlement-wide environmental benefits, provide empowerment opportunities to women, and cash-earning opportunities to refugees and host-nationals alike. Logic modeling with TBI staff revealed opportunities to boost effective provisioning at the landscape level through service coordination and flexibility between programs, as well as between TBIs and local community-based and governmental stakeholders well-situated to adopt and promote TBIs in the absence of external support. Application of an ILA framework positions TBI programmatic diversity as an asset, with distinct approaches collectively responding at different scales to major intersecting challenges in refugee contexts, including extreme poverty, malnutrition, and intensified climate change impacts.

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Conflict of interest

The authors declare that they have no competing interests.

Author contributions

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Ethics approval and consent to participate

Ethical approval for this study was obtained from the Institutional Review Board at the Virginia Polytechnic Institute and State University (23-283). The Research Ethics Committee at Bishop Stuart University in Mbarara, Uganda, also approved this study (BSU-REC-2023-73), and research clearance was also obtained through the Uganda National Council of Science and Technology (NS544ES). Written consent was obtained from each individual participating in semi-structured interviews and the focus group discussions.

Consent for publication

Participants provided written consent and agreed to the publication of non-identifying data collected during the semi-structured interviews and focus group discussion.

Availability of data

Data are available from the corresponding author upon reasonable request.

Further disclosure

Initial research findings were presented at academic conferences: October 2025, Kigali, Rwanda, 6th World Congress on Agroforestry, Agroforestry programs in regions of refugee displacement: Strategies and trade-offs in addressing livelihood and environmental challenges; June, 2024, Stockholm, Sweden, International Union of Forest Research Organizations (IUFRO) World Congress 2024, Characteristics of tree-based interventions in a Uganda refugee settlement; November, 2023, Nairobi, Kenya, 5th International Congress on Planted Forests, Comparing tree-based interventions in a northwest Uganda refugee settlement; October 2023, Sherbrooke, Canada, 3rd World Conference on Forests for Public Health, tree-based interventions in a northwest Uganda refugee settlement.

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