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GIS-based land suitability and core-plasma partnership for sustainable cattle farming in South Lembor, Indonesia

HAMZA H. WULAKADA[1,♥], AGUS A. NALLE[2], FADLAN PRAMATANA[3], YOHANES FISHER KEON[4]

[1]Department of Geography Education, Universitas Nusa Cendana. Jl. Adisucipto, Kupang 85001, East Nusa Tenggara, Indonesia. Tel./fax.: +62-380-881085, ♥email: hamza.wulakada@staf.undana.ac.id

[2]Department of Animal Husbandry, Universitas Nusa Cendana. Jl. Adisucipto, Kupang 85001, East Nusa Tenggara, Indonesia

[3]Department of Forestry, Universitas Nusa Cendana. Jl. Adisucipto, Kupang 85001, East Nusa Tenggara, Indonesia

[4]Department of Political Sciences, Universitas Nusa Cendana. Jl. Adisucipto, Kupang 85001, East Nusa Tenggara, Indonesia

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Abstract. *Wulakada HH, Nalle AA, Pramatana F, Keon YF. 2025. GIS-based land suitability and core-plasma partnership for sustainable cattle farming in South Lembor, Indonesia. Intl J Trop Drylands 9: 135-147.* Domestic beef production in Indonesia currently only meets about 45% of the total demand. In West Manggarai District, East Nusa Tenggara Province of Indonesia, South Lembor Sub-district is designated to produce beef to anticipate the growing demand from tourism in the nearby Labuan Bajo. This study aims to explore the potential of cattle livestock development through land suitability analysis and partnership model design for beef cattle farming in the South Lembor. This research integrated GIS-based method (a systematic approach to analyze spatial data using Geographic Information Systems (GIS) to solve problems and gain insights from geographic patterns) and focus group discussion to capture stakeholders' perspective. The findings propose a core-plasma partnership entity as a model for design development, with Benteng Dewa Village in South Lembor Sub-district, identified as a focal point for advancing the livestock sector. The spatial analysis delineates the core zone 943.94 ha for grazing pasture, 459.59 ha for forage plantation, and the plasma zone of 276.29 ha, and optimizes the buffer zone in other villages within South Lembor Sub-district (1,528.66 ha) to support activities in the core zone. This study suggests in the introduction of a core–plasma partnership model in East Nusa Tenggara which connects core companies with local farmers to ensure technology transfer, financial access, and sustainable market integration.

Keywords: Core-plasma partnership, design development, East Nusa Tenggara, GIS-based, livestock model

INTRODUCTION

Indonesia's beef consumption per capita remains among the lowest in Asia, averaging only around 2-2.7 kg annually, far below the FAO's recommendation of 33 kg per capita (Chafid 2022; Astiti et al. 2023; Islami et al. 2025). Demand continues to rise with a growing population and increased income, with estimates of national consumption to reach more than 764,000 tons by 2025. Retail prices are relatively high, ranging from IDR 120,000-160,000 per kilogram, creating disparities between consumer access and domestic supply (Mubarok et al. 2024). Current production is estimated at about 570,000 tons, fulfilling only 45% of national demand (Firdayati et al. 2024; Sunyigono et al. 2024). This persistent deficit underscores the failure of self-sufficiency programs and forces reliance on imports (Smith et al. 2018; Danasari et al. 2023). Contributing factors of such gaps include high slaughter rates of productive females, weak integration with other agricultural commodities, and unsustainable production systems (Kandachar and Halme 2017; Agus and Widi 2018).

Demand for beef is further stimulated by the tourism sector, particularly in East Nusa Tenggara (ENT), where Labuan Bajo serves as a Super Priority Tourism Destination (Kapa 2015; Rahmayani et al. 2022). South Lembor Sub-district, West Manggarai District, has been designated for cattle development to meet the rising demand, considering that the majority of the population in South Lembor are cattle breeders, with a population of 4,261 cattle in 2023 and a grassland area of 14,743.04 Hectares (Nur et al. 2023). The success of livestock enterprises depends heavily on access to sustainable feed resources, which account for up to 70% of production costs (Indonesian Ministry of Agriculture 2014; Gwiriri et al. 2019). Forage availability, therefore, represents a key limiting factor for scaling up beef production in ENT. Despite its designation as a development zone, no previous study has combined GIS-based land suitability analysis with participatory approaches to design livestock development strategies in South Lembor.

The ENT region is ecologically vulnerable, characterized by dryland ecosystems with low rainfall, frequent droughts and variable soil fertility (Kuswanto et al. 2019a, b; Mukkun et al. 2021). Climate change intensifies these challenges, reducing pasture quality, limiting water availability, and heightening the risks of land degradation (Stavi et al. 2022; Slayi et al. 2024). Local communities have responded with adaptive measures such as mixed crop–livestock systems, rotational grazing, and diversification of livestock species (Niranjan and Bose 2020; Riptanti et al. 2022). Sustainable strategies for rangeland management, including integrating trees and legumes, are increasingly recognized as critical for maintaining productivity in drylands (Assani et al. 2024). Given these challenges, Geographic Information Systems (GIS) emerge as a vital tool to map biophysical characteristics of a region such as slope, vegetation, and soil conditions, supporting the allocation of land for pastures, forage plantations, and integrated crop–livestock systems (Parracciani et al. 2024; Praptiwi and Lesik 2025). GIS-based approaches also facilitate climate risk mapping and adaptive planning, enhancing resilience at both community and regional levels (Ngongo et al. 2023; Parlato et al. 2024).

Besides land suitability assessment, innovative institutional models are needed to strengthen smallholder farmers’ capacity. The core–plasma partnership offers a viable solution for resource-scarce regions like ENT. In this system, core companies provide improved breeding stock, finance, technology, and access to markets, while smallholder farmers (plasma) contribute land and labor (Widiati et al. 2019). This partnership improves efficiency, reduces transaction costs, and enhances bargaining power (Qin et al. 2021). It also promotes climate adaptation by facilitating access to resilient breeds, water conservation, and sustainable practices (Lu et al. 2024). Unlike contract farming, which often disadvantages smallholders (Bellemare 2018; Mao et al. 2021), the core–plasma model emphasizes profit-sharing, knowledge transfer, and more equitable risk distribution (Alary and Gautier 2023). Successful applications in Sulawesi and other regions show that such models can raise income, stabilize supply, and integrate smallholders into formal value chains (Dedu et al. 2023; Harifuddin et al. 2023).

This research aims to analyze land suitability and design a core–plasma partnership model for sustainable beef cattle farming in South Lembor. By integrating GIS-based spatial analysis with participatory stakeholder engagement, the study seeks to identify optimal zones for grazing, forage plantations, and community-based plasma areas, thereby providing a replicable framework to enhance livestock productivity, farmer livelihoods, and regional food security.

MATERIALS AND METHODS

Study area

The research was conducted in the South Lembor Sub-district (119^{0}52’57.8” E - 120^{0}18’48.5” E; 8^{0}41’23.3” S - 8^{0}52’2.6” S) of West Manggarai District, East Nusa Tenggara Province, Indonesia (Figure 1). South Lembor Sub-district has an annual mean temperature ranging from 18 to 27°C and an annual precipitation range of 1373-3182 mm (Fick and Hijman 2017). These climatic factors provide favorable conditions for beef cattle farming, influencing animal health, productivity, and economic viability. Temperatures exceeding 30°C can lead to significant challenges, including heat stress, which adversely affects cattle performance by reducing feed efficiency and increasing susceptibility to diseases (Lees et al. 2019; Wankar et al. 2024). Effective management strategies, such as environmental modifications and nutritional adjustments, are crucial for mitigating heat stress, thereby emphasizing the importance of maintaining temperatures within the optimal range (Lees et al. 2019). Sufficient rainfall fosters the growth of high-quality forage that is critical for the feeding of beef cattle. Optimal moisture conditions lead to improved pasture productivity, thereby enhancing the profitability of cattle farming operations (Addis et al. 2021). This is particularly important, as quality forage directly correlates with the health and growth rates of beef cattle, thereby reducing the need for supplementary feeding costs that can otherwise erode farm profitability. West Manggarai District, which is closely associated with Labuan Bajo, has a considerable market potential due to its tourism activities, which in turn increase the demand for meat.

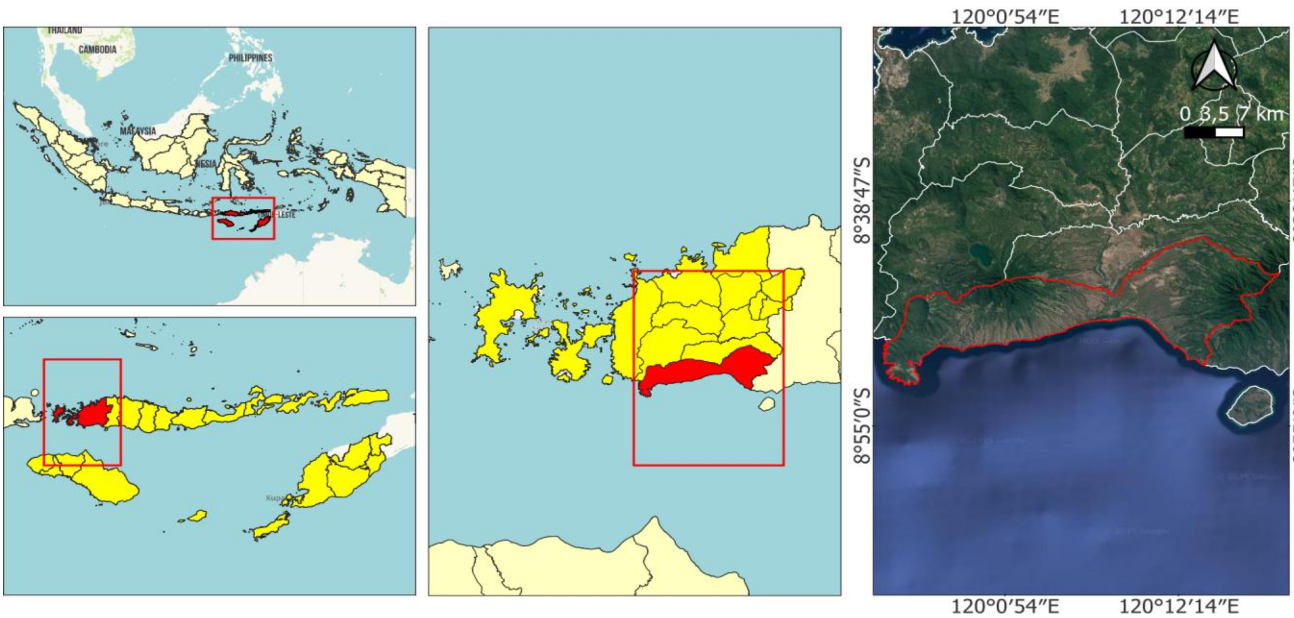

Figure 1. Map of study area in South Lembor Sub-district, West Manggarai District, East Nusa Tenggara Province, Indonesia

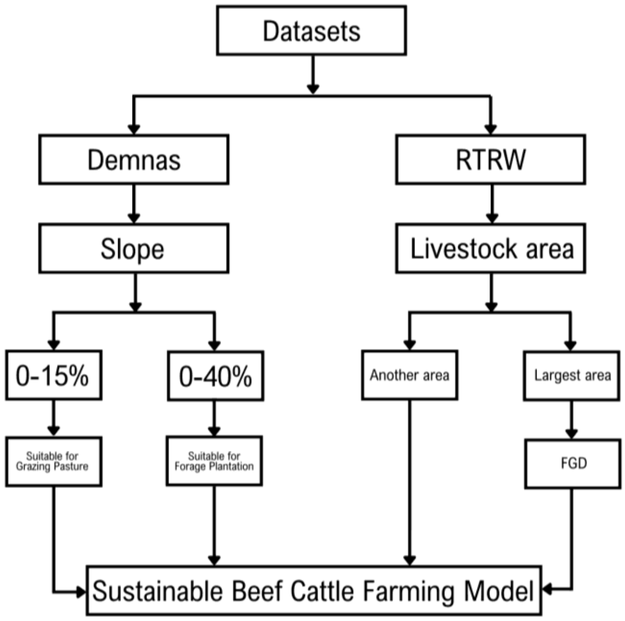

Figure 2. Analytical framework of the study to spatially allocate and design a sustainable beef cattle farming model in South Lembor Sub-district, West Manggarai District, East Nusa Tenggara Province, Indonesia

Analytical framework

This study utilized a socio-economic analysis by combining spatial analysis and Focus Group Discussion (FGD) (Figure 2).

Spatial analysis

In general, to assess the potential of livestock sector in South Lembor using GIS tools (ArcMap 10.8.2), several basic data are required including land spatial allocation based on the Regional Spatial Plan (*Rencana Tata Ruang Wilayah*/RTRW) of West Manggarai District (Santoso and Prasetiyono 2018), and slope gradient generated from the Digital Elevation Model National (DEMNAS), with a resolution of 8.25 m (Figure 2). One of the primary advantages is that DEMNAS can be used to assess topographical features crucial for livestock management, such as slope and elevation, which significantly influence water drainage and forage availability, thereby impacting accessibility for grazing animals (Aristin and Purnomo 2021). For instance, a detailed elevation model can help identify suitable grazing lands that are not prone to erosion or waterlogging, thereby improving the sustainability of livestock farming systems (González-Quintero et al. 2019). This aligns with findings by Li et al. (2024) regarding the importance of understanding local geographical factors in dryland farming. Furthermore, integrating DEMNAS into livestock models can facilitate effective land-use planning by allowing farmers to optimize the placement of infrastructure, such as water sources, feeding stations, and housing for livestock. By understanding how landscape features impact livestock behavior and health, interventions can be tailored to improve animal welfare and productivity (Firmansyah et al. 2022). For example, strategically placing water sources in alignment with the natural topography can minimize travel distance for livestock, promoting better hydration and reducing stress (Ahmed et al. 2022).

Slope values were classified using the Reclassify Spatial Analyst Toolbox in ArcMap to delineate the suitable area according to the criteria. Understanding the slope values associated with livestock models has significant implications for optimizing livestock management and ensuring environmental sustainability in various terrains, particularly in regions such as Indonesia's drylands. Research indicates that sloped terrains present unique challenges and opportunities for livestock farming. For instance, studies have demonstrated that grazing on slopes can influence soil compaction and health, particularly in relation to livestock densities (Blanco-Sepúlveda et al. 2024). Increased compaction can adversely affect vegetation cover and soil fertility, which are crucial for providing adequate forage for grazing livestock. The ecological dynamics on slopes also play a critical role in livestock planning. Locations on steeper slopes may be less hospitable for livestock due to an increased risk of erosion and runoff, which can wash away essential nutrients (Pittarello et al. 2021). Research by Pittarello et al. (2021) highlights how slope and proximity to buildings can effectively separate areas based on livestock site-use intensity, guiding farmers to make informed decisions about pasture use. Thus, maintaining optimal slope angles can foster better livestock productivity while minimizing landscape degradation. Vegetation management strategies that incorporate slope data can help foster beneficial plant-animal interactions, promoting healthier pastures and ensuring the long-term productivity of the farming systems (Sunardi et al. 2025).

GIS tools effectively assess land suitability for livestock farming and are widely used by various researchers (Qiu et al. 2017; Balew et al. 2022; Rana and Moniruzzaman 2023a, b). This allows for potential assessment and development based on land suitability, current regional conditions, and the socio-cultural context of the population in South Lembor District, West Manggarai District (Santoso and Prasetiyono 2018; Agustine et al. 2023). Furthermore, environmental variables were integrated according to the criteria and technical standards established by the Indonesian Ministry of Agriculture (2014) for the potential development of livestock areas, specifically areas with an optimal slope for forage plantations of 40%. For grazing pastures, the recommended slope is 15%. This criterion is also supported by Mano et al. (2024), who indicate that areas with a slope less than 15% significantly increase the capacity for healthy forage growth, which is essential for livestock nutrition. Higher slopes are often associated with increased soil erosion and reduced water retention, leading to less favorable grazing conditions. Slopes exceeding 15% can lead to substantial soil degradation, resulting in a decrease in both the quality and quantity of forage available for grazing livestock (Severoğlu and Gullap 2020; Hartono et al. 2024). The management of slope gradient is vital for the welfare of cattle, as well as for reducing soil erosion and improving pasture quality. Research has shown that grazing pressures are higher in areas with gentler slopes, as these conditions support more robust forage growth, thus providing better nutrition for the cattle (Zhang et al. 2018).

Maintaining lower slope gradients helps enhance soil health and water retention capabilities, which are critical for sustainable beef production systems (Dahal et al. 2018).

Focus group discussion

The socio-economic and livestock potential areas obtained were then developed into models that could encompass the entire sub-district area under a sustainable development system. Several livestock sector models were developed through Focus Group Discussions (FGDs) with the community centered on Benteng Dewa Village, which has the most significant potential in the livestock sector, as guided by the local government. The FGD participants included community figures (seven individuals), village government representatives (two individuals), and livestock breeders (33 individuals). The rationale of the selection of respondents was based on community figures who influence village policies, village government as decision-makers, and livestock farmers, as all households in Benteng Dewa Village have livestock. The FGD implementation followed the Standard Operating Procedure for Focus Group Discussions from the Indonesian Government (49/SOP/2500/01/2022). Careful participant selection is crucial. Foraker et al. (2022) emphasized the importance of appropriate participant demographics, arguing that ensuring diverse representation can enhance the robustness and richness of the data collected. FGDs allow participants to discuss and debate various topics, thereby generating a range of insights that statistical methods might overlook. As noted by Krampe et al. (2021), FGDs enable researchers to explore participant perceptions about complex topics, making it possible to uncover themes that emerge from group discussions rather than predetermined questions. The interactive nature of FGDs encourages participants to build on one another's responses. This interaction often leads to the emergence of new ideas, challenges, and collective sentiments. Okafor et al. (2022) highlighted that discussions among cattle producers revealed not only their individual opinions but also a range of emotive themes that could contribute to a better understanding of responsible practices within the industry. The back-and-forth dialogue actively engages participants and promotes a richer data set than solitary interviews. The livestock model agreed upon by stakeholders in the FGD was proposed to the Investment and Integrated One-Stop Services Agency (*Dinas Penanaman Modal dan Pelayanan Terpadu Satu Pintu*/DPMPTSP) as a form of investment transparency for investors who wish to collaborate with the community.

RESULTS AND DISCUSSION

Livestock potential areas in South Lembor Sub-district

The beef cattle population in South Lembor Sub-district totalled 4,261 individuals, with Nanga Lili Village was the largest with 2,041 individuals, while Modo Village having the smallest with 31 individuals, and no cattle present in Surunumbeng and Benteng Tado Villages (BPS-Statistics of Manggarai Barat District 2023). According to the technical recommendations for developing livestock areas (Indonesian Ministry of Agriculture 2014), various technical requirements and criteria exist for forage gardens and grazing pastures. The establishment of technical criteria and standards is anticipated to enhance the quality of forage plantations for livestock and grazing pastures, supply superior forage for livestock, and convert temporarily uncultivated or neglected land into productive forage for livestock (Rao et al. 2017; Moyo and Ravhuhali 2022). Figure 3 provides additional details regarding the suitable locations for livestock development.

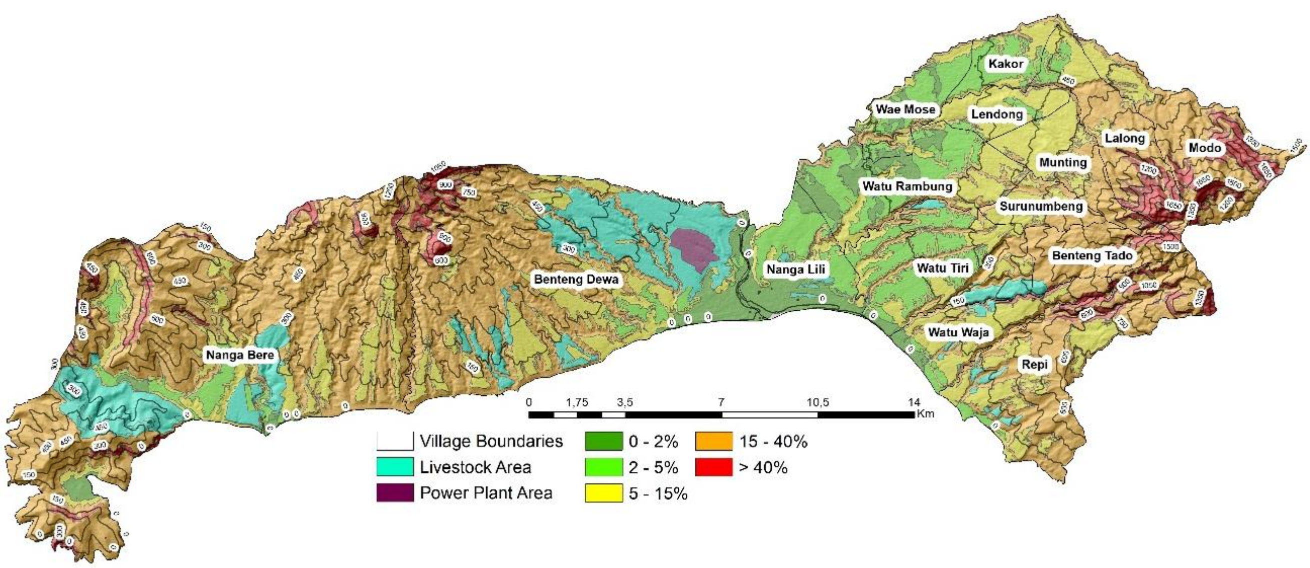

Figure 3. Potential areas for livestock development in South Lembor Sub-district, West Manggarai District, East Nusa Tenggara Province, Indonesia, based on slope. Slopes of 0-15% can be developed into grazing pastures, and slopes of 15-40% can be developed into forage plantations

Table 1. Potential of forage productivity in South Lembor Sub-district, West Manggarai District, East Nusa Tenggara Province, Indonesia

Village	VA (Ha)	LA (Ha)	LVA (%)	PLA (%)	PFP (Ha)	PGP (Ha)	POFP (Ha)
Benteng Dewa	8,049.80	1,679,84	20.87	52.07	1,679.84	1,010.66	669.18
Benteng Tado	898.92	26.40	2.94	0.82	22.53	-	22.53
Nanga Bere	10,801.25	1,172.11	10.85	36.33	1,172.11	342.07	830.04
Nanga Lili	1,365.52	55.26	4.05	1.71	55.26	55.26	0
Repi	2,968.63	72.75	2.45	2.26	72.75	21.57	51.18
Watu Tiri	2,197.92	172.15	7.83	5.34	161.83	85.23	76.60
Watu Waja	1,140.12	47.34	4.15	1.47	44.18	33.56	10.62
Total	36,389.91	3,225.95	53.14	100.00	3,208.50	1,548.34	1,660.16

Note: VA: Village Area, LA: Livestock Area based on RTRW, LVA: Percentage of livestock area per village Area (LA/VA), PLA: Percentage of potential livestock area (LA/ Total LA), PFP: Potential Forage Plantation (Slope value 0-40%), PGP: Potential Grazing Pasture (Slope value 0-15%), POFP: Potential only to be used as a forage plantation (PFP-PGP with Slope value > 15-40%)

Based solely on slope, South Lembor Sub-district has potential land for developing grazing pastures (slope 0-15%) at 14,778.76 hectares and forage plantations (0-40%) at 34,381.55 hectares. Based on this result, the land suitable for livestock production as specified in the West Manggarai RTRW needs modifications for developing extensive livestock operations or permanent zones (Metternicht 2018; Zhang et al. 2019). If a site with an allotment configuration beyond the livestock zone has been neglected and uncultivated for a prolonged period, local farmers may utilize natural resources, such as grass, to meet the forage requirements for livestock (Nelson et al. 2017; Prasetyani et al. 2023). If the area is utilized and administered according to its spatial allocation, local breeders are prohibited from reusing it. Consequently, it is essential to consider spatial allocation patterns in extensive and permanent growth to optimize and sustain cattle advancement (Widiatmaka et al. 2016). Table 1 presents information concerning the prospective regions for animal fodder production in the South Lembor Sub-district.

There are seven villages with livestock sector in South Lembor Sub-district: Benteng Dewa, Benteng Tado, Nanga Bere, Nanga Lili, Repi, Watu Tiri, and Watu Waja. The largest livestock area is located in Benteng Dewa, encompassing 1,679.84 hectares, which accounts for 52.07% of the total. In contrast, the smallest area is found in Benteng Tado, measuring 26.40 hectares, which accounts for 0.82% of the total. When analyzing data from the livestock sector about the village administration area, Benteng Dewa exhibits the highest percentage at 20.87% of the village area, while Repi shows the lowest rate at 2.45%. Benteng Dewa possesses significant potential for enhancing forage productivity for livestock, with a development area suitable for a forage plantation spanning 1,679.84 hectares. This includes areas well-suited for conversion into grazing land, encompassing an area of 1,010.66 hectares. Referring to the Table 1, the slope gradient criteria suitable for use in forage plantations areas, based on the allocation of space for the livestock sector, are in Nanga Bere Village, with an area of 830.04 Ha, and then followed by Benteng Dewa Village with 669.18 Ha. Smith et al. (2018) noted that natural resources, including land area and its utilization, rainfall, access to animal feed, and economic resilience, are key determinants of the sustainability of beef production. The development of this potential is essential due to the significant demand for beef in Indonesia. Additionally, the supply and production aspects present substantial opportunities to be structured to satisfy market needs (Agus and Widi 2018; Astiti et al. 2023). Chafid (2022) indicates that the anticipated production and consumption of beef and buffalo from 2022 to 2026 will consistently face a deficit, indicating an inability to satisfy market demand. According to his projections, Indonesia is expected to face a deficit of 307,321 tons of beef and buffalo by 2026. The burgeoning population and economic advancement within society significantly contribute to the heightened demand for meat, driven by an escalating inclination towards consuming high-quality protein sources (Milford et al. 2019).

The substantial potential coupled with elevated market demand is essential for expanding livestock production in the South Lembor sub-district (Sodiq et al. 2019). Smith et al. (2018) noted that natural resources, including land area and its utilization, rainfall, access to animal feed, and economic resilience, are key determinants of the sustainability of beef production. With a potential area of 1,548.34 hectares for grazing pasture and 1,660.16 hectares for forage plantations in South Lembor, it could help address the deficit if appropriately managed. Utilizing grazing pastures and forage plantations offers an alternative approach to addressing the challenges of climate change in the livestock sector of dryland areas (Assani et al. 2024). Implementing well-managed grazing systems can significantly enhance soil health, leading to increased biomass production and improved carbon sequestration (Zhou et al. 2017). Sustainable grazing practices can enhance soil carbon storage, a crucial step in mitigating the effects of climate change while also improving pasture productivity (Zhou et al. 2017). Such practices also help maintain forage quality and availability, which are crucial for livestock health, especially under the stresses associated with climate variability. The integration of grazing animals within forage plantations promotes biodiversity. Livestock can help control wildlife risks by reducing flammability through the consumption of dry and dead vegetation (Li and Jiang 2021). This function is particularly beneficial in the context of increasing wildfires driven by climate change. Additionally, maintaining diverse forage species can yield multiple ecosystem services, enhancing both resilience and productivity in grazing systems (Putri et al. 2022). The importance of adapting grazing management to the dynamic conditions driven by climate change. Shifts in plant community composition influenced by hydrological changes necessitate adaptive grazing strategies that account for variations in precipitation and forage availability (Oles et al. 2017). This adaptability is critical as climate patterns become increasingly unpredictable, impacting the timing and quality of forage for livestock.

Effective management practices are essential for maximizing forage productivity, which directly influences livestock feeding costs. Jobirov et al. (2022) state that the availability of well-managed pastures can significantly decrease feed costs in beef cattle farming, particularly when the price of supplementary feed is taken into account. By utilizing free or low-cost forage resources, farmers can increase their profitability in beef production (Jobirov et al. 2022). Additionally, Insúa et al. (2019) highlight that GIS technology for monitoring pasture growth enables precision in managing forage availability, allowing for optimal grazing and enhanced herd performance (Insúa et al. 2019). The synergistic relationship highlights the importance of integrating high-nutritional forage varieties into pasture management strategies to maximize livestock production (Gultekin et al. 2021). Expanding forage areas and integrating perennial forage crops result in enhanced environmental benefits and economic viability (Kulshreshtha et al. 2016). Shifting from annual crops to perennial forages not only enhances carbon sequestration but also improves soil health, which can yield long-term economic benefits for cattle farmers. This shift enables them to rely less on external feed sources, ultimately resulting in lower production costs (Kulshreshtha et al. 2016).

Design of the development of cattle farming in South Lembor

Benteng Dewa Village has the highest proportion of designated livestock land among other villages in South Lembor Sub-district. Therefore, this village possesses the potential to evolve into a hub for livestock sector activity within South Lembor Sub-district. Based on further assessment of livestock sector in Benteng Dewa Village, the potential areas are distributed across a minimum of three locations (Figure 4). The first area encompasses a substantial grassland area of 1,403.53 hectares (Area I in Figure 4), which includes a designated power station site covering 168.39 hectares (Area I in Figure 4). If energy-producing activities are well managed, they are expected to serve as a supplier for the electrification of facilities and infrastructure in the livestock sector.

The livestock areas II and III of Benteng Dewa Village are smaller and fragmented with total extent of 276.29 Ha. The area I is suggested as the central focus for developing the livestock sector center. The area I is situated in one of the hamlets closest to the transportation network connecting to Nanga Lili Village (Lokesha and Mahesha 2017). Additionally, following the Indonesian Ministry of Agriculture (2014) criteria, regions II and III are characterized by slope values conducive to forage plantations. The first area features a more extensive distribution of suitable grazing pasture, encompassing 943.94 hectares (with a slope value of 0-15% in Area I, Figure 4), which represents approximately 67% of the total area. Land unsuitable for grazing area development can be utilized to cultivate legume forage, thereby contributing to the provision of livestock feed sources (Hassen et al. 2017). The provision of legume forage is crucial in addressing the forage requirements of livestock (Phelan et al. 2015; Kebede et al. 2016). Approximately 459.60 hectares are available for development as legume forage. For the development of livestock sector areas, various models can be implemented based on the stakeholders' capabilities, while also adapting to the region's physical and ecological conditions. These include intensive livestock farming (Eijrond et al. 2019), semi-intensive models (Amiri et al. 2022), extensive livestock farming (Cameroni and Fort 2017; Fort et al. 2017), and integrated livestock-crop models (Osak and Hartono 2016; Septiadi et al. 2022). In the development of the livestock sector, engaging multiple stakeholders in business or investment can involve various models. These include vertical integration (Crespi and Saitone 2018), circular farming (Herrera et al. 2023), cluster farming (Kuivanen et al. 2016), contract farming (Bellemare 2018; Ruml et al. 2022), cooperative farming (Nosov et al. 2020), agrosilvopastura (Adnani et al. 2018), pasture-based farming (Macdonald et al. 2017), core plasma partnership (Widiati et al. 2019; Anggraini et al. 2023), feedlot operations (Flores et al. 2017), organic farming (Wolde and Tamir 2016), community-based farming (Mueller et al. 2015), precision livestock farming (Bianchi et al. 2022; Kleen and Guatteo 2023), and rotational grazing (Jordon et al. 2023).

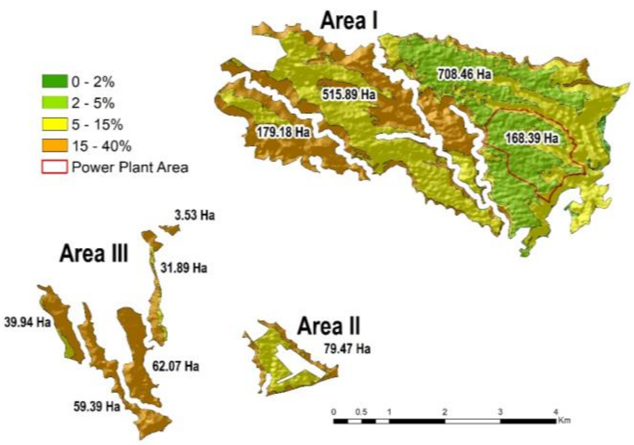

Figure 4. Potential area for cattle farming development in Benteng Dewa Village, South Lembor Sub-district, West Manggarai District, East Nusa Tenggara Province, Indonesia

The results of FGDs revealed that core-plasma model is the most scalable and sustainable cattle farming model in South Lembor Sub-district. It was proposed that Benteng Dewa Village can be developed through a core-plasma partnership, and at the same time makes this village a core-plasma zone by designating area I as the core zone while the remaining areas are classified as the plasma zone. The allocation of livestock areas in alternative villages may serve as a protective buffer zone (Figure 5). The development model is suitable given the community's receptiveness to the company as a catalyst for economic growth in Benteng Dewa Village. The community anticipates advancing the beef cattle enterprise, as each household possesses a minimum of four beef cattle. Engagement with the community is essential for the company's acceptance, contingent upon reaching a consensus through thoughtful discussion with the entire village populace. These results are also based on the socio-economic conditions of the Benteng Dewa community, which comprises small-scale livestock farmers who require intervention from a company that can bridge the gap.

The core-plasma partnership represents a dynamic relationship between breeders and livestock companies, or entities across various sectors, wherein livestock companies serve as the core and breeders function as the plasma (Widiati et al. 2019). The collaboration between the core and plasma regions facilitates technology transfer from the core to the plasma zone (Suarda et al. 2020). The limitations of the community that require intervention from core companies as investors make the core-plasma partnership model a novelty in the ENT region, which is dominated by dryland areas. Core companies typically have better access to resources and advanced technologies that small-scale farmers may lack, including improved breeding stock, veterinary care, and efficient feeding regimes. Collaborations enable plasma farmers to adopt these technologies, thereby enhancing livestock productivity, profitability, and improving meat quality (Ilham 2020). The core-plasma model also enhances market access for smallholder farmers by directly linking them with larger markets, thereby helping to ensure fair prices for their livestock. This relationship can help stabilize incomes for small-scale farmers by reducing the risks typically associated with traditional market transactions (Zimmermann et al. 2024). Policies promoting fair trading practices between core companies and small-scale farmers are essential for the sustainability of these partnerships (Ilham 2020). In addition, small-scale farmers have a chance to benefit from training programs organized by core companies that focus on animal husbandry, disease management, and effective marketing strategies. These training initiatives create an environment of continuous improvement and education, enabling plasma farmers to manage their operations more independently (Habimana 2024). Collaborations implemented through the core-plasma model can also foster environmentally friendly practices. Core companies often promote sustainable farming techniques that align with local ecology while supporting the economic viability of small-scale operations (Semin and Kislitsky 2023). Techniques such as rotational grazing can enhance pasture quality and reduce land degradation. Core-plasma partnerships can strengthen advocacy efforts for small-scale farmers at both the regional and national levels. Core companies can leverage their influence to advocate for supportive policies that create a favorable business environment and ensure fair regulations that assist small-scale livestock operations (Morris et al. 2023).

Management of the core plasma zone is advised to be undertaken by large or medium-scale livestock enterprises or companies from other sectors to bolster the livestock industry (Wulandari et al. 2023). This area will provide resources and infrastructure for livestock production, encompassing beef cattle breeding and the processing of livestock products (Hasanah et al. 2024). The plasma core zone purchases production outputs from the plasma and buffer zones at predetermined prices (Ismiyah 2023). The plasma core zone offers livestock sector enterprises guidance, development, and support, ensuring efficient production in both the plasma and buffer zones (Suarda et al. 2020). The plasma and buffer zone comprises breeders, groups of breeders, combinations of breeder groups, or livestock cooperatives that convert the available inputs into products required by the core company (Suhendar and Sukardi 2022). This zone functions as both a seller and supplier of production products at predetermined prices (Wulandari et al. 2018). The buffer zone functions similarly to the plasma zone, mitigating the most severe risks associated with livestock sector activities within the core plasma zone (Bernabucci 2019). The most concerning scenario is that climatic factors and extreme climate changes may influence the availability of food and water in the core plasma zone, potentially affecting industrial activities in that region (Gaughan and Cawdell-Smith 2015; Sejian et al. 2015). The buffer zone is a proposed solution to facilitate industrial activities within the plasma core, ensuring its continued operation (Rojas-Downing et al. 2017). The buffer area may include feed providers, nurseries, fatteners, or product processing industries, all of which have agreements integrated into the core plasma zone.

The core-plasma collaboration aims to influence several factors through investment activity by offering mutual advantages of the core, plasma, and buffer; enhancing plasma's role in technology, finance, institutions, and beyond; expanding the economic scale of plasma to achieve efficiency; and elevating the quality and competitiveness of plasma products. The allocation of profits and risks in the core-plasma partnership is established based on service contributions and working capital proportions, as mutually agreed upon by both parties in the agreement (Wulandari et al. 2018; Widiati et al. 2019; Suarda et al. 2020; Anggraini et al. 2023). The contributions of each party, the costs of production inputs (such as feed, seeds, medicines, vaccinations, and vitamins), and the prices of the produced goods are collectively established and documented in the agreement (Suarda et al. 2020). The product's pricing is determined by the production cost and the quality specified in the contract (Anggraini et al. 2023).

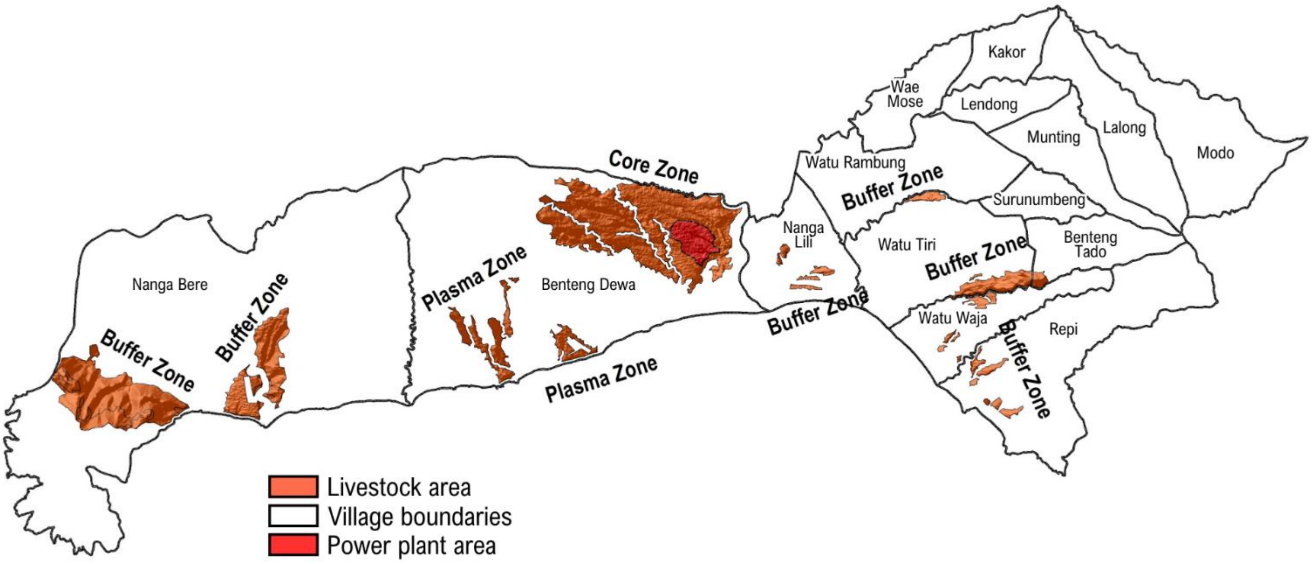

Figure 5. Core-plasma partnership design model of cattle farming in South Lembor Sub-district, East Nusa Tenggara Province, Indonesia

In executing the fundamental plasma partnership across each zone, the integration of livestock and crops can be employed to ensure that no resources are wasted, fostering a mutually beneficial system that promotes sustainable, circular agriculture. According to Nur et al. (2023) in the West Manggarai Agricultural Master Plan for 2023-2043, the agricultural-livestock integration strategies that can be pursued in West Manggarai District include combining cattle with rice, corn, and vegetable crops, as well as integrating livestock with fruit crops. The integration of crop and livestock systems represents the optimal utilisation of local resources, thereby promoting the sustainability of agricultural practices (Martin et al. 2016). The crop and livestock systems integration utilises byproducts from agricultural production as inputs or advantages for other agrarian endeavours (Yang et al. 2022). Agricultural waste serves a dual purpose, functioning as forage for livestock, while the residual feed and manure generated from livestock operations can be repurposed as fertiliser for agrarian endeavours (Baiyeri et al. 2019; Yue et al. 2022). The application of livestock manure has the potential to enhance soil quality while simultaneously decreasing the reliance on sodium and phosphorus fertilisers (Yagüe et al. 2016; Almeida et al. 2019; Rayne and Aula 2020; Vanotti et al. 2020). Integrating crop and livestock systems yields greater profitability than traditional methods (Mendonça et al. 2020; Vinholis et al. 2021). Thus, the development of the core-plasma partnership model is expected to address the challenges faced by the livestock sector in dryland areas, amid the increasing demand for meat consumption at local, regional, and national scales, which is anticipated to result in a deficit.

The core-plasma partnership model, centered on Benteng Dewa Village, optimizes the core zone 943.94 ha (67%) for grazing pasture, 459.59 Ha (33%) for forage plantation, optimizes the plasma zone 276.29 ha, and optimizes the buffer zone in other villages within the South Lembor Sub-district (1,528.66 Ha) to support activities in the core zone. Core-plasma partnerships serve as an alternative bridge for communities to access a viable market for livestock products through an agreement between the buffer zone and the plasma zone, with the core zone being bound by a mutual need for economic sustainability. Core companies are crucial for ensuring economic growth among small and medium-sized farmers. Schemes involving other core companies, such as contract farming, may be an option, but the various significant drawbacks that can occur are highly detrimental to farmers. Ruml and Qaim (2021) found that smallholder farmers frequently express dissatisfaction with their contracts, despite potential economic benefits, due to ongoing issues related to mistrust and the opaque nature of the agreements. When farmers lack clear information about pricing mechanisms, quality expectations, and payment terms, their ability to navigate these contracts effectively is hampered, creating a precarious situation regarding their income stability. While initial studies indicate that contract farming can lead to increased incomes, the long-term prospects may not be as positive due to potential exploitation by larger firms (Wu et al. 2020). The pricing mechanisms often favor contract companies, leaving farmers vulnerable to fluctuations in market prices and input costs, which can jeopardize their financial stability over time. In contrast, core-plasma models often provide a more equitable distribution of benefits, fostering better long-term relationships between farmers and their cooperatives or plasma partners. In addition, Bellemare (2018) argues that the initial costs associated with meeting contractual obligations (such as purchasing specific inputs or adhering to quality standards) can be substantial. Additionally, if market conditions change, farmers may find themselves locked into unfavorable contracts, leading to reduced profitability compared to non-contract farming scenarios. Bellemare and Novak (2017) also highlight that, particularly in dynamic market conditions, farmers may find themselves earning less than expected, which can impact their overall welfare. Contract farming can sometimes create a false sense of security about stable prices, ultimately leading to greater financial distress during downturns. Contract farming can exacerbate existing inequalities within rural communities, particularly when wealthier farmers or agribusinesses dominate the market. This tends to push smallholder farmers to the periphery, leaving them with fewer opportunities for advancement in the agricultural sector. Ncube (2020) emphasizes the need for policies that empower smaller-scale producers to negotiate equitable contracts, thereby mitigating these effects and ensuring fair access to resources. Thus, the potential land suitable for livestock farming in South Lembor could help reduce the supply-demand deficit for beef, both regionally and nationally, if it is managed appropriately. The proposed core-plasma partnership model can help bridge the gap between small- and medium-scale farmers, ensuring economic growth. Land management can also help reduce production costs, particularly the cost of providing forage. Proper feed management can also be a comprehensive step in addressing climate change. Participation in contract farming can lead farmers to become reliant on contract partners for critical decisions, effectively reducing their autonomy in making choices related to production practices (Dubbert et al. 2021). This decreased autonomy can undermine traditional agricultural practices, as farmers may feel pressured to conform to the specifications set by contracting companies, potentially leading to a homogenization of farming methods at the expense of local practices and knowledge. Additionally, the complexity and potential lack of clarity in contract terms present challenges for farmers engaged in contract farming. Mao et al. (2021) discuss how incomplete contracts can lead to "hold-up" situations, where contracts do not adequately cover all contingencies, leaving farmers exposed to various risks, such as market volatility and changing production conditions (Mao et al. 2021). This contrasts with the core-plasma model, which typically emphasizes more transparent and comprehensive agreements to mitigate risks.

One notable study is the implementation of core-plasma partnerships in Sulawesi. In this partnership, the core company provides essential resources and supports intensive farming operations, while the plasma farmers manage the actual farming processes and contribute labor and land (Dedu et al. 2023). The core company supplies input materials, including feed, veterinary services, and training on best management practices. This support is crucial for smallholder farmers who often lack the financial leverage and technical skills necessary to invest in modern farming techniques (Dedu et al. 2023). Further explanation in the research, core companies facilitate a direct line to markets, enabling plasma farmers to sell their produce without being subject to generalized market volatilities. This steadiness helps prevent income loss and provides farmers with more predictable cash flows, which are necessary for sustainable operations (Dedu et al. 2023). The collaboration has shown improved income levels for plasma farmers compared to independent farmers outside the partnership. Dedu et al. (2023) noted that the average revenue per farmer participating in the core-plasma system was significantly higher due to better production practices and guaranteed market access. The analysis indicated a favorable R/C (Revenue to Cost) ratio, often exceeding the threshold showing profitability, thereby confirming the economic viability of such partnerships (Dedu et al. 2023). Another example of the application of the core-plasma partnership model in Indonesia's beef cattle sector, particularly in its dryland areas, can be found in the collaboration between the Maiwa Breeding Center (MBC) and local farmers in Sulawesi (Harifuddin et al. 2023). This partnership effectively demonstrates how integrating different farming operations can enhance productivity and sustainability in livestock farming within challenging environments. The core company, MBC, supplies high-quality breeding cattle to local farmers. This supply enables farmers to enhance the genetic quality of their herds, which has a positive impact on overall productivity in terms of meat yield and growth rates (Harifuddin et al. 2023). Farmers receive training in cattle management practices, nutrition, and veterinary care from MBC. This educational support enhances farmers' skills, allowing them to effectively manage their investments and improve herd productivity. Research indicates that educated farmers are more likely to adopt better farming practices and manage risks associated with livestock operations (Harifuddin et al. 2023). A profit-sharing in a core-plasma partnership model based on the production outcomes achieved. This arrangement incentivizes farmers to optimize their cattle management practices, thereby improving profitability while ensuring that the core company has a vested interest in the success of participating farmers (Achmad 2024). Harifuddin et al. (2023) note that the core companies facilitate access to markets for beef products produced by farmers in the partnership. By linking farmers to local markets and buyers, the core company ensures that farmers receive fair prices for their livestock, thus stabilizing their income and enhancing their ability to invest in their farms (Rohani et al. 2020). The core-plasma partnership structure enables shared risks, where the core company helps absorb variations in feed costs or provides backup support during times of drought or disease outbreaks. This safety net is crucial for smallholder farmers who often lack sufficient financial reserves (Tameno et al. 2021).

Overall, this study has several limitations, including the omission of other variables that may not have been fully considered, such as the potential impact of climate change and the reliance on stakeholder willingness. One of the most immediate effects of climate change is the alteration of environmental conditions that affect the health of livestock (Auma and Badr 2022). Auma and Badr (2022) highlight that extreme temperatures directly impact the immune systems of livestock, making them more susceptible to diseases, which can lead to increased mortality rates. Similarly, the negative consequences of climate change on the quality of feed crops and the availability of water resources are crucial for maintaining livestock health and production levels (Pham-Thanh et al. 2020). These challenges are exacerbated by the anticipated increase in the frequency and severity of livestock disease outbreaks, particularly in low-income countries that are most vulnerable to such shifts. Furthermore, the global food supply chain is susceptible to the impacts of climate change. Godde et al. (2021) indicate that adaptation measures will be required across various levels, from farm management to institutional frameworks, to safeguard livestock production. This reflects the systemic nature of the challenges posed by climate change, where direct impacts on animal health and feed availability are interlinked with broader socio-economic conditions. Climate change is also shown to produce fluctuations in precipitation and an increase in extreme weather events, leading to degraded pastures and reduced forage availability. Climate-induced aridification leads to degradation of grasslands, posing significant challenges to livestock health, growth, and survival. Khurshid et al. (2023) further note that climate change can disrupt the delicate balance necessary for livestock growth and reproduction, severely impacting farmers' livelihoods. The community is generally very receptive to corporate involvement and wants this model to be implemented, as it significantly contributes to economic growth, with the note that there is a joint agreement from all of society, including in facing the challenges of climate change.

Conclusion, the core-plasma partnership livestock model, centered on Benteng Dewa Village, optimizes the core zone (943.94 ha) for grazing pasture and 459.59 Ha for forage plantation. It optimizes the plasma zone (276.29 ha) and the buffer zone in other villages within the South Lembor Sub-district (1,528.66 Ha) to support activities in the core zone. This model was proposed to the DPMPTSP of West Manggarai District to attract investors who want to become core companies and, together with the community, develop the livestock sector, leveraging the main market opportunity of tourism activities in the Labuan Bajo DPSP area. This study has several limitations, including the omission of other variables that may not have been fully considered, such as the potential impact of climate change and the reliance on stakeholder willingness. Further studies could be conducted to validate the model if a core company is willing to invest in this area. Another possible study would be to examine the impact of climate change on this model, including its strengths, weaknesses, and challenges.

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