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Analysis of horticulture farmers' welfare from a sustainable development perspective

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Abstract

The horticultural sector in Solok Regency faces significant problems that undermine farmers' welfare, including restricted agricultural inputs, financial constraints, and ineffective distribution routes, all of which hinder the achievement of sustainable development goals in agriculture. This study investigates the influence of production, distribution, and social capital on the welfare of horticulture farmers in the sub-districts of Lembah Gumanti and Lembang Jaya, utilizing the Sustainable Livelihood Framework (SLF) to provide measures for resource optimization aimed at economic enhancement. This research employed route analysis within a probability sampling framework, especially proportionate cluster random sampling, to survey 236 farmers from a total population of 573, as calculated using Slovin's formula with a 5% margin of error. Quantitative data were subjected to descriptive analysis and Partial Least Squares-Structural Equation Modeling (PLS-SEM) to assess variable relationships. Results demonstrate substantial impacts of production, distribution, and social capital on farmers' welfare, underscoring their critical functions in augmenting income via enhanced output, effective distribution, and fortified social networks. The research additionally recognizes social capital as a driver of socio-ecological resilience and enhanced market access. The findings highlight the SLF's significance in enhancing the welfare of horticulture farmers by maximizing production, distribution, and social capital, hence promoting a resilient and sustainable agricultural model in Solok Regency. The broader implications indicate that SLF-based sustainable development strategies may tackle analogous challenges in various regions, strengthening economic and social resilience within agricultural communities against climate variability, market instability, and resource scarcity, thus providing essential insights for national agricultural policy development.

Keywords: Farmer welfare, Horticulture, Sustainable agriculture, Sustainable development, Welfare analysis.

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1. Introduction

The well-being of horticulture farmers is a crucial element in the overarching context of sustainable agricultural growth. In the agricultural sector, horticultural producers frequently encounter variability in crop yields attributable to climatic variations, pest infestations, and restricted access to advanced agricultural technologies that could improve productivity [1]. Furthermore, inadequate resources, including high-quality seeds, fertilizers, and contemporary agricultural machinery, pose substantial obstacles to attaining optimal productivity [2]. Dependence on intermediaries sometimes leads to farmers obtaining a diminished portion of the earnings. The absence of direct market access, inadequate transportation infrastructure, and insufficient post-harvest storage facilities frequently impede the distribution of horticultural products, potentially resulting in losses due to deterioration prior to reaching consumers [3]. The interconnected aspects of production and distribution are intrinsically related to the welfare of horticulture farmers, requiring targeted initiatives for enhancement.

Solok Regency, a significant area in West Sumatra Province, exhibits considerable agricultural potential, especially in horticulture. Data from the local Statistics Bureau indicates that Solok encompasses 35,510 hectares of horticulture land, with an output of 350,000 tons in 2022, facilitated by around 36,401 farmers, each averaging 1.1 hectares [4]. Notwithstanding this potential, the welfare of horticultural farmers in Solok remains comparatively poor at both national and regional levels. Horticulture farmers in Solok earn an average of Rp15 million annually, which is inferior to the wages of similar regions, such as West Java and Central Java, which are Rp25 million and Rp20 million, respectively. In West Sumatra, Solok is inferior to other regencies, such as Agam and Tanah Datar, which have averages of Rp17 million and Rp18 million, respectively [5]. The disparity between agricultural potential and farmer income in Solok indicates issues that extend beyond simple production volumes. The Farmers' Welfare Exchange Rate (NTKP) in Solok is 95.39, indicating that the revenues farmers obtain for their products are inadequate to pay production costs. This gap highlights the necessity of enhancing product quality and market accessibility, as superior horticulture items often command higher prices, and direct market access promotes increased income for farmers.

Current studies underscore the economic prospects of horticulture in Indonesia, particularly in areas such as Solok [6]. Nonetheless, a deficiency persists in the literature regarding a more profound examination of production variables, market structure, and the implementation of the Sustainable Livelihood Framework (SLF) in particular regions. Most studies have primarily concentrated on the overall potential of the horticultural industry, neglecting the specific production and distribution dynamics and the social capital elements within localized contexts, such as Lembah Gumanti and Lembang Jaya in Solok Regency.

This study seeks to address this gap by examining the interplay between production, distribution, and social capital in the horticulture sector of Solok. This research employs the SLF as a framework to examine the effects of production and market factors on farmer welfare, the role of social capital on agricultural practices and sustainability, and the interplay of these elements in shaping sustainable agricultural growth. The study's originality is attributed to its integrated methodology, merging social capital and SLF views, thus providing a more thorough understanding of the distinct challenges and opportunities encountered by horticultural farmers in Solok.

This project aims to identify and assess the roles of production, distribution, and social capital in enhancing farmer welfare and fostering sustainable agriculture in the Lembah Gumanti and Lembang Jaya districts. The SLF approach will analyze how these factors affect agricultural practices, resource accessibility, and the economic welfare of farmers. The study will identify the principal production and market determinants influencing horticulture productivity and profitability in Solok, therefore providing a foundation for informed policy-making and practices.

The implications of this work encompass wider sustainable development objectives. The findings may aid in poverty alleviation and sustainable agricultural development by offering insights on enhancing horticultural farmers' well-being through increased production efficiency, improved market access, and strengthened social capital. This correlates with the Sustainable Development Goals (SDGs), namely those concerning "No Poverty" and "Zero Hunger." Empowering local farmers through sustainable methods might potentially stimulate regional economic growth, enhance food security, and elevate living standards. Fundamental components for enduring agricultural sustainability.

This topic is of considerable urgency on both national and global scales. At the national level, agriculture in Indonesia constitutes the cornerstone of the economy, especially for rural people who predominantly depend on this sector for their sustenance. Challenges such as restricted access to agricultural technologies, insufficient market infrastructure, and volatile agricultural product prices render farmers, particularly horticulturalists, susceptible and impede their welfare enhancement. This research is essential for identifying production aspects and distribution systems that can enhance farmers' well-being, thereby facilitating the development of more effective improvement initiatives. The sustainability of agriculture has become increasingly critical worldwide due to climate change, population increase, and escalating food demands. This study, utilizing the Sustainable Livelihood Framework (SLF) approach, aims to provide answers tailored to local circumstances while also enriching the global literature on sustainable farming techniques applicable to diverse locales. The results of this research may serve as a policy framework for other developing nations with similar issues, thereby supporting the attainment of the Sustainable Development Goals (SDGs) at both national and international levels.

The study argument is on the innovative integration of social capital and the Sustainable Livelihood Framework (SLF) principles within the horticulture agricultural environment of the core areas of Lembah Gumanti and Lembang Jaya. This study seeks to elucidate the application of social capital as a mechanism to improve farmer wellbeing and promote sustainable agriculture. Additionally, it will examine the obstacles encountered by farmers in optimizing production, distribution, and social capital, and investigate alternative solutions to improve these areas to mitigate the hurdles. The

project aims to enhance our comprehension of social capital's role in sustainable agriculture and establish a basis for more successful local policy and intervention programs.

2. Theoretical Review

2.1. Farmer Welfare

Farmer wellbeing is a multifaceted topic influenced by access to financing, governmental regulations, agricultural methodologies, and market dynamics. Financial assistance, especially via loans and subsidies, is a crucial element in improving wellbeing, although its effects are not always clear-cut. Wibowo [7] discovered that agricultural loan distributions did not substantially affect farmer welfare, in contrast to previous studies associating loans with rural economic development. This indicates that the advantages of financial access are contingent upon contextual factors such as the economic landscape and the particular requirements of farmers. Government subsidies significantly contribute to alleviating poverty among farmers. Nonetheless, targeted subsidies, particularly those designated for impoverished farmers, may unintentionally diminish the welfare of non-recipient groups, indicating a necessity for more inclusive policy frameworks [8]. Furthermore, subsidies can lower input expenses and encourage investment in superior technology, which is particularly advantageous for farmers in economically limited environments [9].

Alongside financial measures, access to technology and market stability are essential for maintaining farmer wellbeing. Extension services facilitate the adoption of enhanced agricultural technologies, leading to increased yields and greater household wellbeing [10, 11]. Successful adoption frequently depends on the educational attainment and managerial competencies of farmers, underscoring the significance of capacity-building initiatives [12]. Simultaneously, fluctuating commodity prices intensify the susceptibility of smallholders, requiring measures such as price controls to safeguard their livelihoods [13]. Moreover, equal market access is crucial in influencing economic results for farmers [14]. Consequently, enhancing farmer welfare necessitates a holistic strategy that incorporates financial resources, well-structured subsidies, technology dissemination, and reliable market mechanisms. These features are especially vital in developing nations where agriculture is a principal means of subsistence, and future studies should persist in examining how these interconnected factors might be refined to promote sustainable rural development.

2.2. Sustainable Livelihood Framework/SLF

The Sustainable Livelihood Framework (SLF), developed by the UK Department for International Development (DFID), provides a comprehensive methodology for examining rural livelihoods through the integration of five fundamental forms of capital: natural, physical, financial, social, and human [15]. These capitals underpin livelihood strategies by affecting individuals' access to resources, economic instruments, networks, and knowledge [16]. Natural capital, including land and water, underpins agricultural output, whereas physical and financial capital enable economic activity and investments. Social and human capital, encompassing community networks and individual competencies, are equally vital in cultivating resilience and adaptive capacity in rural environments. The SLF considers the vulnerability environment, including external factors such as climate change and economic shocks that can disrupt livelihoods [17].

The framework advocates for participatory and context-specific techniques to alleviate vulnerability, as demonstrated by Zossou et al. [18], who emphasize the empowerment potential of participatory impact evaluations in customizing agricultural solutions to local need. Su et al. [19] assert that livelihood instability can be mitigated by comprehensive, diversified strategies that enhance the interaction among diverse capitals and institutional support. These observations validate the SLF's significance in poverty alleviation and sustainable development policymaking by providing a flexible framework for assessing and enhancing livelihood options in evolving contexts. The Sustainable Livelihood Framework (SLF) provides a comprehensive analytical approach for assessing and improving rural livelihoods by considering the dynamic interactions among five essential types of capital: natural, physical, financial, social, and human, within a context of vulnerability. The SLF is an essential instrument for guiding targeted, context-specific interventions for poverty alleviation and long-term resilience by integrating participatory techniques and acknowledging the structural and environmental elements that affect livelihood options.

2.3. Indicators of the Sustainable Livelihood Framework (SLF)

The Sustainable Livelihood Framework (SLF) serves as a structure to understand sustainable livelihoods through five key capitals: natural, social, physical, financial, and human. Natural capital includes essential resources like land, water, and forests that support human life by providing basic needs such as food and fuel. However, these resources require prudent management to ensure sustainability, as overexploitation due to population growth and human activities threatens their future availability. Sustainable management practices, including conservation, ecosystem restoration, and efficient use of water and land resources, are essential to maintain these resources long-term [20].

Social capital in SLF refers to the network of relationships and cooperation within communities, enhancing support during crises and expanding access to economic opportunities. Strong social ties allow community members to share knowledge and resources, ultimately increasing resilience and economic competitiveness. For example, in emergencies, robust social networks provide aid and community recovery support. Social capital fosters an inclusive, empowering environment where individuals can access opportunities that contribute to sustainable livelihoods [21]. Physical and financial capital also play vital roles in SLF. Physical capital encompasses infrastructure and equipment that aid agricultural production and distribution, such as irrigation systems, machinery, and transportation networks, all of which improve efficiency and broaden market access [22]. Financial capital grants access to economic resources and financial services that can be used for investment, insurance, or microenterprise development to support economic resilience. In the

context of sustainability, financial capital can also be allocated to environmental projects, reinforcing the balance between social, economic, and environmental aspects of development [23].

2.4. Horticultural Production

Horticultural production is essential in agriculture, contributing to food security, economic advancement, and environmental sustainability. The implementation of organic farming methods has become crucial to sustainable horticulture, emphasizing ecological equilibrium, biodiversity, and less reliance on synthetic inputs. These strategies enhance soil fertility and ecosystem health while reducing erosion and pollution, hence supporting the long-term sustainability of horticulture systems [24]. Organic methods enhance crop quality and productivity, addressing the increasing demand for fresh products Ram and Verma [24] while simultaneously bolstering resistance to climate stress via healthier ecosystems [22]. Simultaneously, technological advancements like LED illumination have demonstrated efficacy in decreasing energy use and enhancing crop growth, particularly in urban environments [25]. Furthermore, long-term-release fertilizers sourced from organic waste provide an environmentally sustainable alternative to synthetic inputs, enhancing productivity and diminishing the carbon footprint of horticulture [25].

In addition to environmental advantages, horticulture has significant socio-economic effects, especially for rural populations. Research indicates that horticulture activities enhance the income and savings of rural farmers, thus elevating their livelihoods [26]. Climate change is a significant concern, as variable rainfall and temperature patterns adversely affect crop yields and jeopardize food security [27, 28]. Addressing these challenges necessitates the use of climate-smart horticultural practices, including drought-resistant cultivars, efficient irrigation, and agroecological methods, to bolster resilience and improve ecosystem services [28]. Sustainable horticultural production, bolstered by organic practices, innovation, and adaptable solutions, is essential for enhancing food security and rural welfare while reducing environmental degradation.

3. Research Method

This research utilized a quantitative causal design to examine the direct and mediated impacts of production, distribution, and social capital on the welfare of horticulture farmers in Solok Regency, West Sumatra. The study employed a route analysis methodology, executed via Partial Least Squares–Structural Equation Modeling (PLS-SEM), to evaluate the linear associations among latent constructs, including mediating effects within the Sustainable Livelihood Framework (SLF). This method was selected for its ability to estimate complex causal models with multiple dependent and independent variables, particularly in scenarios involving non-normality and small to medium sample sizes.

The target population consisted of 5,713 horticultural farmers located in the Lembah Gumanti and Lembang Jaya sub-districts. A total of 236 respondents were chosen utilizing Slovin's technique with a 5% margin of error to guarantee statistical representativeness. A proportionate cluster random sampling method was employed to capture the diversity among sub-regional clusters, facilitating a balanced representation of farmers according to geographic and demographic dispersion. Primary data were gathered utilizing a standardized questionnaire derived from theoretical constructs and validated indicators. The questionnaire was disseminated electronically through Google Forms, utilizing a five-point Likert scale to assess respondents' perceptions of each latent variable.

The data analysis adhered to a bifurcated methodology. Descriptive statistics were calculated to analyze respondent profiles and average response values for each component. The structural model was subsequently evaluated using SmartPLS 4 software. The assessment of the measurement model (outer model) encompassed reliability testing (Cronbach's Alpha, Composite Reliability), convergent validity (Average Variance Extracted, factor loadings), and discriminant validity (HTMT ratio). The structural model (inner model) was assessed using bootstrapping techniques to determine the importance of path coefficients, mediation effects, and predictive relevance metrics such as R^2 and Q^2. This rigorous analytical methodology facilitated a thorough comprehension of the direct and indirect linkages influencing farmer welfare within the study context.

4. Results and Discussion

A study examining the well-being of horticultural farmers from a sustainable development viewpoint was carried out in the key horticulture centers of Solok Regency, specifically in the Lembang Jaya and Lembah Gumanti districts of West Sumatra, Indonesia. Renowned for their agroclimatic benefits, including cold temperatures, elevated altitudes, and fertile soil, these regions are optimal for cultivating crops such as potatoes, chilies, and strawberries. Lembang Jaya possesses superior market connectivity, whereas Lembah Gumanti encounters access difficulties in rural regions. Both districts, despite ample water resources, encounter market price volatility and necessitate enhanced farmer competencies for sustainable practices. This research offers critical insights into sustainable development techniques aimed at improving farmer welfare and environmental conservation.

4.1. Characteristics of Respondents

Alongside variable data, demographic information of respondents, specifically horticulture farmers in the Lembang Jaya and Lembah Gumanti districts of Solok Regency, was also gathered. The characteristics of the respondents encompass gender, educational attainment, and age distribution, offering a comprehensive profile of horticultural producers in the study area. The demographic features are illustrated in Table 1.

Table 1.
Respondent Characteristics.

Characteristics	sum	Percentage (%)
Gender		
Male	142	60.18
Female	94	39.82
Last Education		
Elementary School	42	17.92
Middle School	47	19.8
High School	125	53.01
University	22	9.27
Age		
19-38 Years	82	34.95
39-58 Years	119	49.99
59-78 Years	27	11.3

According to Table 1, respondent Characteristics: The majority of the 236 respondents are male, including 142 individuals or nearly 60.18%, while female respondents total 94 individuals (39.82%). The predominant educational attainment is high school graduation at 53.01%, followed by middle school graduates at 19.8%, elementary school graduates at 17.92%, and university-level education at a mere 9.27%. The majority of respondents, 49.99%, are aged between 39 and 58 years, followed by 34.95% who are aged 19 to 38 years, while the smallest group, 11.3%, consists of individuals aged 59 to 78 years. This data characterizes a demographic profile that is generally male and largely comprised of respondents with a high school education, primarily within the productive age range of 39 to 58 years. This provides insights into prospective behaviors or needs that may diverge from the broader population or prior studies with more uniformly dispersed age and education levels. This analysis can offer insights into the distinct preferences or needs of this specific group, which may be relevant for developing customized treatments, educational programs, or legislation.

4.2. Variable Overview

Latent variables that successfully undergo measurement model evaluation are validated to confirm that their indicators correspond with the research objectives. Indicators that do not fulfill standards are eliminated, retaining only those that are valid and dependable to represent the variables. This description delineates the qualities, dimensions, and interrelations of indicators within the construct, offering a thorough understanding and foundation for interpreting analytical results.

Table 2.
Respondents' Achievement.

Manifest Variable	Mean	TCR	Std. Dev.	Description
Production	3.93	78.59	0.793	Fairly Good
Distribution	3.93	78.55	0.78	Fairly Good
Social Media	3.72	74.35	1.08	Fairly Good

An analysis of production, distribution, and social capital variables within horticultural communities indicates a general rating of fairly good, with mean scores between 3.60 and 4.00, Total Respondent Achievement (TCR) ranging from 72.03 to 79.83, and standard deviations from 0.78 to 1.18. The results demonstrate reasonable satisfaction among respondents; nonetheless, certain areas necessitate additional focus. In production, it is essential to optimize land utilization and improve labor efficiency during peak harvest periods. Enhancing road infrastructure is crucial for optimizing the efficiency of produce distribution. Improving collaboration and community support can enhance collaborative efficacy among farmers concerning social capital. Recognizing these deficiencies reveals potential for improvement to increase productivity and the welfare of horticultural producers. The measurement of the variable from the manifest variable indicates the complete achievement of respondents regarding the distribution variable, specifically social capital, as follows:

Table 3.
Respondent Scores for Sustainable Livelihood Framework (SLF).

Manifest Variable	Mean	TCR	Std. Dev.	Description
Financial Capital	3.96	79.26	0.78	Fairly Good
Human Capital	3.95	79.07	0.78	Fairly Good
Natural Capital	3.97	79.41	0.78	Fairly Good
Physical Capital	3.97	79.41	0.78	Fairly Good

An examination of the four capitals within the Sustainable Livelihood Framework (SLF), Financial, Human, Natural, and Physical indicates that all variables attained a fairly good rating, with mean scores between 3.94 and 3.97, Total Respondent Achievement (TCR) ranging from 78.73 to 79.49, and a uniform standard deviation of 0.78. Although these findings suggest moderate satisfaction among participants, some areas require additional focus. In Financial Capital, it is

essential to improve accessibility and diversify income streams. Targeted training programs can consistently enhance individual capabilities within Human Capital. Concerning Natural Capital, it is imperative to ensure that current practices do not jeopardize the long-term viability of natural resources. In Physical Capital, discrepancies in respondent perceptions indicate a need for infrastructure enhancements in various locations. Recognizing these gaps presents opportunities to improve respondents' livelihoods and sustainability. The evaluation of Farmer Welfare through four manifest variables yields the following descriptive results:

Table 4.
Respondent Scores for Farmer Welfare.

Manifest Variable	Mean	TCR	Std. Dev.	Description
Farmer's Exchange Rate (NTP)	3.98	79.58	0.78	Fairly Good
Pendapatan Petani	3.97	79.32	0.78	Fairly Good
Kualitas Hidup	4.00	79.92	0.78	Fairly Good
Layanan Kesehatan	3.99	79.75	0.78	Fairly Good

The examination of four factors associated with farmer welfare, the exchange rate for farmers, along with income, quality of life, and healthcare services, suggests a fairly good level of satisfaction, with mean scores ranging from 3.96 to 4.01 and TCR values between 79.15 and 80.17. The findings, while largely favorable, underscore specific areas that require attention: stabilizing purchasing power, diversifying income sources, enhancing education and housing, and improving access to healthcare. The identified gaps indicate potential avenues to enhance the welfare and sustainability of farmers' livelihoods.

4.3. Structural Equation Model Analysis

The initial assessment emphasizes the loading factor, indicating the strength of the correlation between manifest variables and their corresponding latent constructs. Halder et al. [20] assert that indicators in reflective measurement models must be eliminated if their loading values (λ) are below 0.5, necessitating a subsequent recalculation of the model. Indicators with loading values (λ) greater than 0.5 are deemed valid. Indicators exhibiting high loading factors provide significant explanatory power for their related latent variables, while those with lower loading factors contribute little. Table 5 presents the respective loading values (λ):

Table 5.
Loading Factor of the Variables.

Exogenous Variable	Loading Factor			
	Production	Distribution	Social Capital	SLF
1	0.847	0.892	0.942	0.952
2	0.956	0.939	0.939	0.985
3	0.962	0.931	0.955	0.990
4	0.962	0.893	0.965	0.982
5	0.965	0.913	0.972	0.978
6	0.942	0.799	0.951	0.981
7	0.933	0.802	0.938	0.976
8	0.831	0.832	0.926	0.974
9	0.846	0.819	0.901	0.949
11	0.854	0.923	0.807	0.955
12	0.948	0.949	0.863	0.968
13	0.957	0.928	0.867	0.972
14	0.960		0.842	0.974
15	0.961			0.982
16	0.959			0.984

The examination of the Loading Factor values indicates that the variables Production, Distribution, and Social Capital all significantly contribute to the Standard Loading Factor (SLF), with Social Capital exhibiting the greatest consistency. Production exhibits a minor gap with SLF, averaging approximately 0.02-0.03, suggesting a close alignment. The Distribution demonstrates a significant gap, especially in variables 6, 7, and 9, indicating a reduced contribution to SLF relative to the other variables. Social Capital exhibits the narrowest gap, typically ranging from 0.01 to 0.03, indicating its robust alignment with the Sustainable Livelihood Framework (SLF) and establishing it as the most stable indicator. To enhance alignment with SLF, it is advisable to concentrate on improving the contribution of Distribution, whereas Production and Social Capital continue to serve as strong contributors with negligible gaps. Convergent validity evaluates the extent to which a construct explains the variance in its related items. The Average Variance Extracted (AVE) is a frequently utilized metric for assessing convergent validity. An AVE value of 0.50 or higher is typically regarded as the minimum acceptable threshold, indicating that the construct accounts for at least 50 percent of the variance in its constituent items. The convergent validity analysis produced the following findings.

Table 6.
Convergent Validity Test Results.

Variable	Average Variance Extracted (AVE)
Distribution	0.786
Farmer Welfare	0.952
Social Capital	0.890
Production	0.859
Sustainable Livelihood Framework (SLF)	0.949

The results of the convergent validity test presented in Table 6 demonstrate robust construct validity, as all variables surpass the AVE criterion of 0.5. Farmer Welfare exhibits the greatest Average Variance Extracted (AVE) at 0.952, followed by the Sustainable Livelihood Framework (SLF) at 0.949, Social Capital at 0.890, Production at 0.859, and Distribution at 0.786. Nonetheless, deficiencies persist: the model omits supplementary factors like policy support and environmental conditions, fails to examine causal relationships among variables (e.g., the direct impact of distribution and social capital on farmer welfare), and may encounter generalization constraints outside the study context. Future studies ought to address these elements to improve the Sustainable Livelihood Framework. Discriminant validity was assessed by three established methods: the Fornell-Larcker Criterion, cross-loadings, and the heterotrait-monotrait (HTMT) ratio, with HTMT recognized as the most rigorous way. In this research, all HTMT values were below the suggested threshold of 0.85, hence affirming discriminant validity. Consequently, HTMT was utilized to evaluate discriminant validity, with findings presented in Table 7.

Table 7.
Discriminant Validity Test Result.

	Distribution	Farmer Welfare	Social Capital	Production	SLF
Distribution					
Farmer Welfare	0.849				
Social Capital	0.821	0.864			
Production	0.848	0.883	0.844		
SLF	0.575	0.797	0.765	0.779	

The results of the discriminant validity test presented in Table 3 demonstrate that each construct shows sufficient discriminant validity, with the Square Root of Average Variance Extracted (AVE) values for each construct exceeding their correlations with other constructs. For instance, Farmer Welfare exhibits a value of 0.849, exceeding its correlations with other constructs, while similar trends are noted for Social Capital at 0.864 and Production at 0.844. This indicates that each construct accurately assesses its designated concept while differentiating itself from other constructs in the model. Nonetheless, the significant correlations identified between specific constructs, such as Farmer Welfare and Production (0.883), underscore a notable research gap; subsequent investigations could examine whether these associations suggest theoretical interdependence or possible redundancy among the variables. To address this issue, it may be necessary to refine or expand the definitions of variables to enhance the model's discriminant validity.

Table 8.
Composite Reliability Test Results.

Variable	Composite Reliability
Distribution	0.978
Farmer Welfare	0.997
Social Capital	0.986
Production	0.989
SLF	0.997

The findings from the composite reliability analysis indicate that all Cronbach's alpha coefficients for the construct variables surpass the 0.6 threshold, suggesting a satisfactory level of internal consistency. Additionally, the composite reliability values exceed the 0.6 threshold, further substantiating the reliability of the constructs. The composite reliability estimates exceed the corresponding Cronbach's alpha values, indicating that composite reliability provides a more precise evaluation of the internal consistency for each latent construct. The findings indicate that the five latent variables analyzed in this study, institutional factors, educational attainment, community participation, natural resource utilization, and poverty, demonstrate reliability. The chosen manifest indicators effectively reflect their corresponding constructs, confirming the strength and validity of the measurement model.

The R^2 values act as coefficients of determination, reflecting the extent to which the variance in the endogenous variables can be accounted for by the exogenous variables. In other terms, R^2 indicates the overall ability of the external constructs to explain the internal outcomes. According to the criteria set forth by Chachar et al. [22], a R^2 value of 0.67 is classified as substantial, 0.33 as moderate, and 0.19 as weak. This study identifies the endogenous constructs as institutional strength, education level, community engagement, utilization of natural resources, and poverty alleviation. The R^2 values for each construct are displayed in the table below, reflecting the model's explanatory adequacy.

Table 9.
Analysis of the Coefficient of Determination (R^2).

Variable	R Square	Adjusted R Square
Farmer Welfare	0.992	0.992
SLF	0.970	0.969

The data presented in the table indicate that production, distribution, and social capital account for 97% of the contribution to the Sustainable Livelihood Framework (SLF). The data shows that production, distribution, and social capital have a significant impact on the SLF. This suggests that the model's predictive accuracy can be categorized as robust. Additionally, the impact of production, distribution, and social capital on farmers' welfare is quantified at 99.2%. This value indicates a significant influence of these factors on farmers' welfare. The significance of the results was derived using bootstrapping to assess the effects, producing t-statistic values. When the t-statistic surpasses the critical z-values of 1.65 (for a 10% significance level), 1.96 (for a 5% significance level), and 2.58 (for a 1% significance level) in a two-tailed test, it indicates that the path coefficient is statistically significant. If the t-statistic does not surpass the critical z-value, then the path coefficient lacks statistical significance. This study accepts hypotheses at a significance level of 5%, corresponding to a critical value of 1.96. The projected path coefficients are detailed below:

Table 10.
Direct and Indirect Construct of a Variable.

Construct of Variable	Coefficient	ST. Dev	T-Value	P-Value
Direct Effects				
Production → Farmer Welfare	0.185	0.072	2.549	0.011
Distribution → Farmer Welfare	0.148	0.032	4.607	0.000
Social Capital → Farmer Welfare	0.021	0.008	2.599	0.010
Production → SLF	0.479	0.080	5.989	0.000
Distribution → SLF	0.414	0.068	6.129	0.000
Social Capital → SLF	0.121	0.025	4.747	0.000
SLF → Farmer Welfare	0.653	0.093	7.060	0.000
Indirect Effects				
Production → SLF → Farmer Welfare	0.313	5.517		0.000
Distribution → SLF→ Farmer Welfare	0.270	4.049		0.000
Social Capital→ SLF→ Farmer Welfare	0.079	3.525		0.000

The analysis indicates that production, distribution, and social capital have a significant impact on farmers' welfare, both directly and indirectly, as illustrated by the Sustainable Livelihood Framework (SLF). The direct effects of production (0.185, p=0.011), distribution (0.148, p=0.000), and social capital (0.021, p=0.010) on welfare are significant, with SLF demonstrating a substantial impact (0.653, p=0.000). SLF indirectly mediates the effects of production, distribution, and social capital, with coefficients of 0.313, 0.270, and 0.079 (p=0.000), underscoring its significant role. Nonetheless, gaps persist: the direct influence of social capital on welfare is constrained, suggesting its efficacy is enhanced through the Social Learning Framework (SLF), and the mechanisms for effective distribution necessitate additional investigation to improve welfare outcomes. The significant mediating role of SLF indicates the need for further investigation into its most impactful components. The results' significance was evaluated using bootstrapping to analyze effects via t-statistics. Path coefficients are deemed statistically significant when t-statistics surpass critical thresholds of 1.65 (10%), 1.96 (5%), or 2.58 (1%). This study accepts hypotheses at the 5% significance level, employing a critical value of 1.96. The estimated path coefficients are presented below.

Table 11.
Hypothesis Testing.

Construct of Variable	ST. Dev	P-Value
Direct Effects		
Production → Farmer Welfare	2.549	0.011
Distribution → Farmer Welfare	4.607	0.000
Social Capital → Farmer Welfare	2.599	0.010
Production → SLF	5.989	0.000
Distribution → SLF	6.129	0.000
Social Capital → SLF	4.747	0.000
SLF → Farmer Welfare	7.060	0.000
Indirect Effects		
Production → SLF → Farmer Welfare	5.517	0.000
Distribution → SLF→ Farmer Welfare	4.049	0.000
Social Capital→ SLF→ Farmer Welfare	3.525	0.000

The analysis indicates that production, distribution, and social capital have a significant effect on farmer welfare, both directly and through the mediation of SLF. Production (t=2.549, p=0.011), distribution (t=4.607, p=0.000), and social capital (t=2.599, p=0.010) significantly contribute to welfare enhancement, whereas SLF demonstrates a robust direct effect (t=7.060, p=0.000). SLF indirectly mediates these effects, enhancing the impact of production, distribution, and social capital. Nonetheless, gaps persist: the limited direct impact of social capital indicates a strong dependence on the Social Learning Framework for efficacy, and optimal distribution strategies necessitate additional investigation. The mediating role of SLF underscores the necessity of identifying particular components within SLF that most effectively enhance farmer welfare.

4.4. The Impact of Production, Distribution, and Capital on the Welfare of Horticulture Farmers in Lembah Gumanti and Lembang Jaya Subdistricts: A Sustainable Development Perspective through the Sustainable Livelihood Framework

This study demonstrates that horticulture production substantially improves farmer welfare via the Sustainable Livelihood Framework (SLF), which maximizes the advantages of heightened output. Increased yields enhance revenue and facilitate reinvestment in superior seeds, advanced tools, and improved infrastructure, consequently augmenting productivity and improving the management of livelihood assets, including human capital, technology, land, financial resources, and social networks. SLF enhances farmers' resilience by fostering diversification and adaptability to climatic and market variability [23]. Robust social connections provide access to market intelligence, collective expertise, and communal support, hence augmenting adaptive capacity [29, 30]. SLF amalgamates financial, social, and environmental aspects to guarantee enduring sustainability [31]. This study highlights the pivotal role of technologies such as IoT and AI, along with enhanced market access, in connecting horticultural productivity to multidimensional welfare, thereby strengthening social cohesion and promoting sustainable rural development [20]. This study distinctly investigates the effects of horticulture on farmer welfare through the Sustainable Livelihood Framework by incorporating economic, social, and environmental aspects. It underscores the significance of technologies such as IoT and AI in augmenting productivity and examines how improved market access fortifies social cohesiveness and adaptive ability, both essential for sustainable rural development.

The effective distribution of horticultural crops significantly influences farmer welfare, as mediated by the Sustainable Livelihood Framework (SLF) [32, 33]. Efficient distribution guarantees that produce arrives at the market fresh and in optimal condition, enabling farmers to obtain higher prices through quality-related price premiums [34]. The increase in income results from enhanced marketing channels and advantageous farm-gate pricing, indicating an improvement in financial and social capital within the Sustainable Livelihood Framework (SLF). This facilitates reinvestment in quality inputs, advanced technology, and improved farming practices, thereby enhancing agricultural productivity and sustainability [32]. Furthermore, effective distribution decreases losses associated with transport-related damage and lessens dependence on intermediaries that reduce profits. Enhanced market access, facilitated by efficient distribution, enables farmers to secure more equitable prices in local, regional, and national markets, thereby promoting economic stability and improved welfare. Efficient distribution networks are essential for improving the income and resilience of farmers, especially amid market fluctuations and economic uncertainties. Studies demonstrate that effectively managed distribution channels markedly enhance farmers' market access, subsequently increasing their profitability and overall welfare. Research conducted by Wijiono et al. [35] and Basuki et al. [36] indicates that timely and reliable market access correlates positively with enhanced farmer income and resilience to economic shocks. The findings highlight the significance of efficient distribution mechanisms in agricultural economies.

This analysis offers a new perspective on the influence of social capital in improving the welfare of horticultural farmers, utilizing the Sustainable Livelihood Framework (SLF). The findings indicate that social capital enhances access to resources and bolsters farmers' adaptability and resilience in the face of economic and environmental challenges. In this context, social capital, which includes networks, trust, and cooperation among farmers, enhances profitability by improving bargaining power and decreasing dependence on intermediaries [21, 37, 38]. The study emphasizes the importance of the interaction between social capital and other forms of capital within the Sustainable Livelihood Framework (SLF) for enhancing the adoption of new technologies and sustainable farming practices. This interaction fosters a more inclusive and adaptive livelihood model for horticultural farmers and supports a comprehensive approach to sustainable development.

The Sustainable Livelihoods Framework (SLF) underscores that social capital is an essential element that functions in conjunction with other capital types, including natural and human capital, to augment farmers' adaptive potential. In this context, social capital enhances the network among farmers and aids them in addressing numerous agricultural difficulties, including climate change and market price volatility. When farmers have robust networks, they may more readily exchange information on sustainable agricultural methods and disseminate knowledge regarding best practices, thereby enhancing crop yields and reducing environmental impacts. Prior research indicates that farmers possessing substantial social capital are more inclined to embrace innovative technology and sustainable farming methods, enhancing economic results while simultaneously aiding ecological conservation [16]. This highlights that the proper utilization of social capital can enhance the resilience and sustainability of agricultural systems, yielding long-term advantages for the welfare of horticultural producers.

This investigation is distinguished by its innovative use of the Sustainable Livelihood Framework (SLF) to evaluate the well-being of horticultural farmers in the key agricultural areas of Solok Regency, specifically Lembah Gumanti and Lembang Jaya. This study enhances comprehension of the interplay between production, distribution, and social capital in relation to farmers' welfare by incorporating SLF's economic, social, and environmental dimensions. This emphasizes the importance of social capital in enhancing resilience and adaptability when confronted with market and environmental

changes. Furthermore, the study provides important insights into the ways in which effective distribution networks and the application of technologies such as IoT and AI improve productivity, expand market access, and promote resilience within communities. The results contribute significantly to the existing body of knowledge regarding sustainable rural development and establish a basis for focused, sustainable strategies designed to meet the unique socio-economic and environmental requirements of horticultural communities in West Sumatra.

5. Conclusion

This research demonstrates that the welfare of horticultural farmers in Solok Regency is notably affected by production, distribution, and social capital as outlined in the Sustainable Livelihood Framework (SLF). Effective production management, coupled with efficient distribution, enhances farmers' income and strengthens their resilience to market uncertainties and environmental conditions. The SLF framework enhances productivity and allows farmers to utilize social capital through the establishment of networks and community support, thereby strengthening their bargaining power and decreasing reliance on intermediaries. This study demonstrates that social capital is essential for improving farmers' resilience, facilitating greater market access, and providing resources vital for sustainable agriculture. The relationship between social capital and factors of production and distribution enhances the economic resilience of farmers and fosters beneficial social outcomes through enhanced collaboration among them. This, in turn, enhances local agricultural sustainability and facilitates the attainment of sustainable development goals.

6. Recommendation

The government and relevant stakeholders should enhance support for agricultural infrastructure and technology to improve production and distribution efficiency in Solok Regency. This support may include enhancements to road infrastructure, the provision of contemporary agricultural tools, and improved market access to elevate farmers' income. Furthermore, the enhancement of social capital via the establishment of farmer groups or cooperatives can improve farmers' social networks and facilitate the exchange of knowledge regarding sustainable agricultural practices. Policies that support the SLF, including subsidies for distribution facilities and accessible credit assistance for farmers, are anticipated to enhance their welfare and foster sustainability within the horticultural sector.

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