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ANALYSIS OF DRYLAND AGROECOSYSTEM RESILIENCE FOR SUSTAINABLE AGRICULTURE IN PLAMPANG, SUMBAWA

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ABSTRACT: Dryland agroecosystem resilience is essential for sustaining agriculture in rainfed areas that are exposed to drought, land degradation, and socio-economic uncertainty. This review aims to analyze the concepts, dimensions, determining factors, and strengthening strategies of dryland agroecosystem resilience in Plampang District, Sumbawa Regency. A critical literature review was conducted by synthesizing peer-reviewed articles, institutional reports, and relevant statistical documents published mainly from 2019 to 2026. The synthesis focused on ecological, economic, social, institutional, and technological dimensions. The findings show that resilience is not determined solely by crop productivity, but also by soil health, water efficiency, livelihood diversification, crop-livestock integration, social capital, extension capacity, and climate-adaptive technology. The most relevant strategies include soil and water conservation, organic matter improvement, commodity diversification, use of climate information, and strengthening of farmer institutions. This article proposes an input-process-output-outcome-impact framework as a conceptual basis for developing dryland resilience indicators and guiding future empirical research in Plampang.

Keywords: Agroecology, Agroecosystem Resilience, Dryland Farming, Plampang, Sustainable Agriculture.

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INTRODUCTION

Dryland agriculture plays a strategic role in providing food, feed, and rural livelihoods. Nevertheless, this production system faces more complex ecological pressures than irrigated agriculture because it depends strongly on rainfall, has limited soil water availability, and is vulnerable to erosion, declining organic matter, and climate uncertainty. From an agroecological perspective, agricultural sustainability cannot be assessed only through short-term yield increases. It should also be viewed through the capacity of a system to maintain ecological, social, and economic functions repeatedly over time (Wezel et al., 2020). Strengthening dryland agroecosystem resilience ensures long-term agricultural sustainability.

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Resilience in farming systems is generally understood as the capacity of a social-ecological system to maintain core functions under disturbance, adjust management when conditions change, and transform when existing practices are no longer adequate. Recent reviews on farming-system resilience emphasize three major capacities, namely robustness, adaptability, and transformability (van der Lee et al., 2022). These capacities are particularly relevant for drylands because farmers are not exposed to a single shock only, but to the accumulation of climatic, market, labor, and policy pressures. Climate-risk resilience in farms therefore needs to be built through a combination of technology, institutions, diversification, and farmer learning rather than through one isolated intervention package (Pret et al., 2025).

In Indonesia, water management is one of the central issues in dryland agriculture. Studies on dryland water optimization show that water harvesting, water-saving irrigation, adaptive varieties, and adjustment of cropping intensity can improve productivity while anticipating climate change (Rejekiningrum et al., 2022). Reviews on dryland productivity also underline the need to improve water-use efficiency, strengthen soil conservation, develop drought-tolerant crops, and manage local resources in increasingly uncertain environments (Li et al., 2020).

Plampang District in Sumbawa Regency provides a relevant local context for examining these issues. Official statistics from Plampang District in Figures 2025 offer an initial basis for understanding villages, population distribution, supporting facilities, and local economic activities (Badan Pusat Statistik Kabupaten Sumbawa, 2025). At a broader scale, maize is a strategic commodity in Indonesia, including West Nusa Tenggara, and changes in harvested area and national maize production influence the orientation of dryland farming (Badan Pusat Statistik, 2025). The agricultural profile of West Nusa Tenggara also highlights the importance of food crops and livestock as regional economic pillars for sustainable agriculture (Badan Pusat Statistik Provinsi Nusa Tenggara Barat, 2024).

From a climate perspective, Nusa Tenggara frequently faces recurrent agricultural drought. Remote-sensing studies in the Nusa Tenggara Islands show that rainfall, solar radiation, and land-surface temperature strongly influence vegetation condition and drought diagnosis (Krisnawan et al., 2025). From a crop-management perspective, research on hybrid maize adaptation in West Nusa Tenggara drylands indicates that plant spacing and variety selection affect seed and biomass production (Syahruddin et al., 2023). These findings imply that strengthening resilience in Plampang should connect climate, soil, crop, livestock, and farmer-institution management.

Previous studies have discussed soil-water conservation, adaptive crop varieties, water harvesting, and integrated farming systems. However, studies that integrate ecological, economic, social, institutional, and technological dimensions to explain dryland agroecosystem resilience in Plampang remain limited. The scientific novelty of this article lies in its critical synthesis and conceptual framework that places resilience as a staged process from inputs and management practices to system outputs, adaptive capacity, and sustainability impacts. This framework supports sustainable dryland agriculture.

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Based on this gap, this article aims to: 1) analyze the concept and characteristics of dryland agroecosystem resilience; 2) identify the dimensions and determining factors of agroecosystem resilience in Plampang District; and 3) formulate strategies for strengthening resilience to support sustainable agriculture. The main question addressed is how dryland agroecosystem resilience can be understood conceptually and how its management strategies can be formulated contextually for Plampang.

METHOD

This article used a critical literature review approach. The review did not merely summarize previous findings; it examined conceptual linkages, strength of evidence, knowledge gaps, and practical implications for a local dryland context. This approach was selected because dryland agroecosystem resilience is a multidimensional concept that requires cross-disciplinary synthesis, including agroecology, soil science, agricultural climatology, farm-household economics, institutions, and climate-adaptive technology.

The literature sources consisted of international and national scientific articles, development-agency reports, and government documents. The search was directed to Scopus, Web of Science, ScienceDirect, Springer, SINTA, Garuda, Google Scholar, the Central Statistics Agency, and relevant policy documents. The main keywords included dryland agroecosystem resilience, farming system resilience, agroecology, conservation agriculture, integrated crop-livestock system, climate-smart agriculture, dryland farming Indonesia, Sumbawa, West Nusa Tenggara, Plampang, and sustainable agriculture.

The inclusion criteria were: 1) publications from 2019 to 2026 to capture recent developments, with exceptions for conceptual references that remain theoretically important; 2) sources discussing resilience, agroecology, drylands, soil-water conservation, crop-livestock systems, drought, or sustainable agriculture; 3) direct or indirect relevance to tropical drylands, Indonesia, West Nusa Tenggara, Sumbawa, or dryland management; and 4) availability of arguments, data, or frameworks that could be synthesized. The exclusion criteria were unclear publication sources, sources unrelated to agriculture or environmental management, and opinion papers lacking adequate conceptual support.

The review procedure consisted of four sequential stages. First, literature was identified by reading titles, abstracts, and keywords. Second, relevance screening was conducted by assessing topic fit and source quality. Third, concepts were extracted and grouped into ecological, economic, social, institutional, and technological dimensions. Fourth, critical synthesis was conducted by comparing evidence, identifying gaps, and formulating strategies and a conceptual framework for Plampang. The overall review flow that links these four stages is presented schematically in Figure 1, which serves as the operational roadmap of this synthesis. This systematic process ensured that the reviewed literature was integrated coherently to establish a comprehensive understanding of dryland agroecosystem resilience and its implications for sustainable agricultural development in Plampang.

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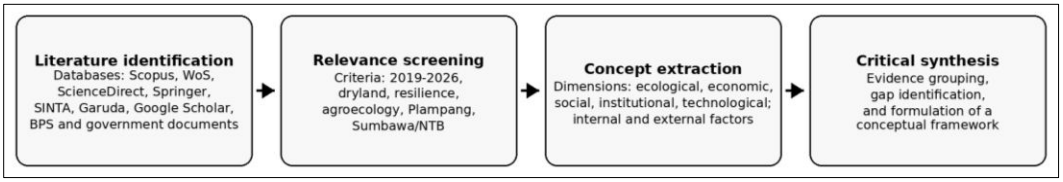


Figure 1. Critical Literature Review Flow Used in the Synthesis.

The synthesis was not designed to produce a quantitative resilience score. Instead, it formulated conceptual indicators that can be tested in future field research. The indicator framework considers the proposition that agroecosystem resilience under climate variability must be assessed through the relationship between ecological processes, household decisions, institutions, and adaptive management. This orientation is consistent with farming-system resilience frameworks that emphasize function, adaptation, and learning across scales (Meuwissen et al., 2019).

RESULTS AND DISCUSSION

Concept of Dryland Agroecosystem Resilience

A dryland agroecosystem is a social-ecological system in which biophysical conditions interact with farm-household decisions, social networks, markets, technologies, and policies. In such a system, resilience cannot be reduced to the ability of crop production to return to its previous level after a disturbance. Resilience should be understood as the capacity of the system to maintain key functions, adapt to gradual changes, and transform when old management patterns no longer support sustainability. Farming-system literature explains that robustness, adaptability, and transformability provide a useful basis for assessing resilience (Meuwissen et al., 2019; Tittonell, 2020).

In drylands, robustness can be observed through the ability of soil to store water, the availability of fodder reserves, the use of adaptive crop varieties, and the stability of household income. Adaptability appears in changes in planting calendars, crop rotation, mulching, variety selection, and farm-income diversification. Transformability occurs when farmers and institutions reorganize production systems toward integrated crop-livestock systems, agroforestry, collective water management, or more diversified value chains. Climate variability requires this broader understanding because dryland agriculture is influenced by both sudden shocks and slow-onset stresses (Cleves et al., 2022).

The concept of resilience is closely related to agroecology. Agroecology views agriculture as a system that depends on relationships among soil, water, organisms, people, and governance. Therefore, resilience strategies should move beyond input-intensive logic and toward resource-use efficiency, biomass recycling, biodiversity, local knowledge, and institutional learning. Agroecology has also been recognized as a pathway for building food-system security and nutrition while reducing vulnerability to external disruptions (Altieri & Nicholls, 2020; Bezner Kerr et al., 2021). This approach emphasizes the integration of ecological sustainability, social participation, and adaptive management in strengthening agroecosystem resilience.

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Characteristics of Dryland Agroecosystems in Plampang District

Plampang District is located in the dryland landscape of Sumbawa, where agricultural activities are strongly influenced by the alternation of rainy and dry seasons. Local statistical information indicates that agricultural planning in Plampang should consider village distribution, population, economic facilities, and production-support infrastructure (Badan Pusat Statistik Kabupaten Sumbawa, 2025). Such information is important because resilience is not only shaped by land and rainfall, but also by access to roads, markets, extension services, input supply, and local institutions.

Economically, maize is an important commodity for West Nusa Tenggara and Sumbawa. Maize can increase farmer income in favorable seasons, but it can also reduce resilience if the system becomes too monocultural and too dependent on one market commodity (Badan Pusat Statistik, 2025; Badan Pusat Statistik Provinsi Nusa Tenggara Barat, 2024). Excessive dependence on maize may increase vulnerability when rainfall is delayed, input prices rise, or farm-gate prices decline. Therefore, maize should remain important within the farming system, but it needs to be combined with legumes, fodder crops, livestock, and soil-restoring practices.

Ruminant livestock, particularly cattle, are important in the dryland agroecosystem of Sumbawa. Livestock can function as household savings, income sources, manure producers, and converters of crop residues into economic value. At the same time, dry-season fodder availability, manure management, and livestock health influence the extent to which livestock contributes to resilience. Integrated crop-livestock systems can produce crop yields comparable to specialized systems while improving nutrient cycling and resource efficiency (Peterson et al., 2020). Improved tropical forages can also generate environmental co-benefits by supporting livestock productivity and reducing pressure on land resources (Notenbaert et al., 2021).

Climate risk remains a key pressure. Remote-sensing evidence from Nusa Tenggara shows that drought diagnosis is strongly related to precipitation and surface conditions (Krisnawan et al., 2025). Crop studies in West Nusa Tenggara also show that variety and spacing management influence seed and biomass production in dryland maize systems (Syahruddin et al., 2023). These findings suggest that Plampang requires adaptive agronomic practices, soil-water conservation, climate information, and stronger institutions capable of supporting farmer decision-making under uncertainty.

Dimensions of Agroecosystem Resilience

The literature synthesis indicates that dryland agroecosystem resilience in Plampang can be examined through five interrelated dimensions: ecological, economic, social, institutional, and technological. These dimensions do not stand alone. The ecological dimension determines the basic capacity of land, the economic dimension affects household flexibility, the social dimension shapes collective action, the institutional dimension determines access to support, and the technological dimension influences farmers' ability to anticipate and respond to risks. To provide an integrated view of how these five dimensions translate into measurable resilience indicators, Table 1 summarises each dimension together

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with its key indicators and its specific resilience function. This framework provides a basis for assessing resilience and identifying priority areas for intervention.

Table 1. Dimensions and Key Indicators of Dryland Agroecosystem Resilience.

Dimension	Key Indicators	Resilience Function
Ecological	Soil organic matter, soil structure, erosion control, water storage, biodiversity, nutrient cycling	Maintaining the biophysical basis of production and reducing drought and erosion risk
Economic	Income diversity, stability of yields, access to markets, production costs, livestock assets	Reducing household vulnerability to crop failure and price fluctuation
Social	Local knowledge, farmer participation, mutual assistance, learning networks, adaptive capacity	Strengthening collective learning and community-based risk responses
Institutional	Farmer groups, extension services, village support, local policy, partnerships, access to finance	Connecting farmers with information, programs, markets, and innovation support
Technological	Climate information, adaptive varieties, composting, simple water harvesting, conservation practices	Improving anticipation, efficiency, and practical adaptation to dryland constraints

The ecological dimension is the foundation of resilience. Healthy soils have more stable structure, higher organic matter, better water-holding capacity, and more active soil biota. In drylands, organic matter improvement not only increases fertility, but also reduces vulnerability to short dry spells after rainfall. Agroecological approaches to resilience emphasize diversification, soil organic matter, water conservation, agroforestry, and co-creation of knowledge as mutually reinforcing elements (Diacono & Montemurro, 2023).

The economic dimension is related to the ability of farm households to maintain income when facing partial crop failure, lower prices, or higher input costs. Diversification is important because household income should not depend only on maize. Livestock, fodder crops, legumes, compost production, and local agribusiness can distribute risk. At a broader scale, dryland productivity under climate change is affected by water availability, vegetation dynamics, and land-use decisions (Wang et al., 2022). This approach strengthens household income stability while reducing farmers' vulnerability to market fluctuations and climate-related risks.

The social dimension is reflected in local knowledge, labor exchange, farmer participation, and willingness to adopt adaptive practices. Social capital is highly relevant because many dryland practices require collective coordination, such as water-structure maintenance, erosion control, communal grazing management, and group-based marketing. The institutional dimension determines whether innovation can reach farmers consistently. Farmer groups, extension agents, local government, village institutions, market actors, financial institutions, and universities need to form a support ecosystem. The technological dimension should be understood proportionally: useful technologies are not always expensive technologies, but technologies that are suitable for farmers' labor availability, risk perception, and local resources.

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Factors Influencing Agroecosystem Resilience

The determining factors of resilience can be grouped into internal and external factors. Internal factors originate from farm-household conditions and local resources, whereas external factors originate from climate, markets, infrastructure, and policy. Their interaction determines whether farmers can survive disturbances, adapt their management, and transform their livelihood systems. The resulting structure is presented in Table 2, which classifies the main components into internal, external, and linking factors, and identifies the implications of each group for resilience.

Table 2. Internal and External Factors Shaping Dryland Agroecosystem Resilience.

Factor Group	Main Components	Implications for Resilience
Internal	Land quality, water availability, labor, farmer knowledge, livestock ownership, household assets, local knowledge	Determines the initial capacity to maintain production and adjust farming practices
External	Climate variability, commodity prices, input prices, road access, extension services, credit, government programs	Determines the enabling or constraining environment for adaptation
Linking Factors	Farmer groups, market partnerships, climate information, collective water management, village-level planning	Connects household capacity with institutional and technological support

The first internal factor is land resources. Soils with low organic matter, poor structure, or steep slopes are more vulnerable to drought and erosion. The second internal factor is farmer knowledge. Farmers who can interpret seasonal signals, manage residues, select varieties, and prepare dry-season fodder have stronger adaptive capacity. The third internal factor is livestock ownership, because livestock can provide income buffers and nutrient resources. However, livestock only strengthens resilience when supported by adequate fodder and manure management.

The most dominant external factor is climate variability. When the onset of the rainy season shifts or rainfall pauses occur during crop establishment, planting failure risk increases. Maize prices, fertilizer prices, road access, extension services, and government support also determine whether innovations can be implemented economically. Climate-smart agriculture in Indonesia emphasizes the need to integrate productivity, adaptation, mitigation, and institutional support rather than treating climate adaptation as a purely technical matter (World Bank, 2021).

From an agroecological perspective, these factors should be managed as one system. A farmer may have strong knowledge but remain vulnerable when access to climate information, markets, or collective institutions is weak. Conversely, technology support may not generate resilience when soils are degraded and household income is highly dependent on one crop. Therefore, resilience strategies for Plampang should combine ecological restoration, livelihood diversification, institutional strengthening, and practical technology.

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Sustainable Agriculture as an Approach to Strengthening Resilience

Sustainable agriculture in drylands should be understood as an approach that balances productivity, resource conservation, farmer income, and social equity. In dry regions, sustainability is not only about increasing yield in one season, but also about maintaining the system so that it can continue producing under rainfall variability and economic uncertainty. Conservation agriculture provides principles and policy options for maintaining soil organic carbon, reducing disturbance, protecting soil cover, and diversifying crops (Francaviglia et al., 2023).

Diversification is the first principle. It can be implemented through maize-legume rotation, intercropping, fodder crops, and perennial plants in suitable parts of the landscape. Diversification expands income sources, improves nutrient cycling, reduces pest pressure, and increases biomass for livestock. The second principle is soil-water conservation. Terraces, contour planting, infiltration channels, mulching, minimum tillage, manure application, composting, and water harvesting can increase infiltration and reduce runoff. Reviews of dryland agricultural systems indicate that climate change will increase the need for integrated management of water, crops, soil, and institutions (Ahmed et al., 2022).

The third principle is the crop-livestock system. This system links crop production and fodder needs, enhances nutrient cycling, and strengthens household economic reserves. The fourth principle is the use of climate information. Forecasts of rainfall, rainy-season onset, dry spells, and drought risk can help farmers determine planting time, crop choice, and risk-management options. However, climate information becomes useful only when translated into practical guidance through extension services, farmer groups, and local decision-making processes.

Strategies for Strengthening Dryland Agroecosystem Resilience in Plampang

Resilience-strengthening strategies should be gradual and contextual. Not all innovations can be implemented at the same time by all farmers. A realistic strategy is to begin with low-cost practices, use local resources, and strengthen institutions so that innovation does not stop at demonstration plots. To translate this gradual logic into operational guidance, Table 3 sets out priority actions and expected contributions for each of the five resilience dimensions, ranging from ecological foundations to technological enablers.

Table 3. Strategies for Strengthening Dryland Agroecosystem Resilience in Plampang District.

Strategy	Priority Actions	Expected Contribution
Ecological Strategy	Soil-water conservation, manure and compost application, residue management, crop diversification, erosion-risk mapping	Improves soil health, water storage, and ecological stability
Economic Strategy	Diversification of commodities, fodder-based agribusiness, livestock strengthening, local market development	Reduces income risk and strengthens household reserves
Social Strategy	Farmer field schools, participatory demonstration plots,	Improves adaptive capacity and collective learning

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Strategy	Priority Actions	Expected Contribution
	farmer-to-farmer learning, documentation of local knowledge	
Institutional Strategy	Strengthening farmer groups, extension networks, village planning, partnerships with universities and market actors	Improves access to support, innovation, finance, and coordination
Technological Strategy	Simple rainfall gauges, seasonal forecast use, adaptive varieties, composting technology, participatory maps of erosion-prone fields	Improves anticipation and practical decision-making under climate uncertainty

Ecological strategy should be treated as the basis of resilience. Soil-water conservation needs to become a routine practice on fields that are prone to runoff, especially at the beginning of the rainy season when rainfall intensity can be high. Returning organic matter through manure and compost is important because Plampang has potential crop-livestock linkages. Residue management should be viewed not as waste handling, but as a mechanism for improving soil health and fodder availability.

Economic strategy should reduce the risk of relying on maize as the only income source. Maize remains important, but the system should provide space for legumes, fodder crops, compost, and livestock enterprises. This diversification is not simply adding more commodities; it builds economic buffers for years when maize yield or price declines. Social and institutional strategies are also necessary because dryland technologies often fail not because they are technically ineffective, but because they do not fit farmers' labor schedules, costs, risk perception, or local norms.

Technological strategy should emphasize local suitability. Climate-adaptive technology does not always mean expensive digitalization. Simple rainfall gauges, seasonal forecast information, participatory maps of erosion-prone land, adaptive varieties, and composting techniques can provide practical benefits. The key is to ensure that technology is accompanied by farmer learning, local institutions, and mechanisms for evaluating results after each season.

Conceptual Framework of Dryland Agroecosystem Resilience

This critical synthesis produces a conceptual framework of dryland agroecosystem resilience in Plampang consisting of five components: input, process, output, outcome, and impact. Inputs include land and water resources, labor, local knowledge, social capital, and policy support. Processes include agroecological practices, soil-water conservation, crop-livestock integration, commodity diversification, and farmer learning. Outputs include productivity, yield stability, input efficiency, household income, fodder availability, and organic matter. Outcomes are reflected in robustness, adaptability, and transformability. The final impact is sustainable agriculture, local food security, and improved farmer welfare.

The framework emphasizes that resilience does not emerge from a single technology. It is produced by interactions among resources, management

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practices, institutions, and learning feedback. For example, a water-harvesting pond is only a physical input when it stores water; it becomes part of a resilience process when managed collectively, linked to planting decisions, and evaluated after each season. Similarly, cattle become a resilience component when manure is returned to fields and dry-season fodder is planned systematically. The complete logic of this staged framework including how the five leveraging dimensions cut across all stages and how adaptive feedback returns from impact to input is visualised in Figure 2.

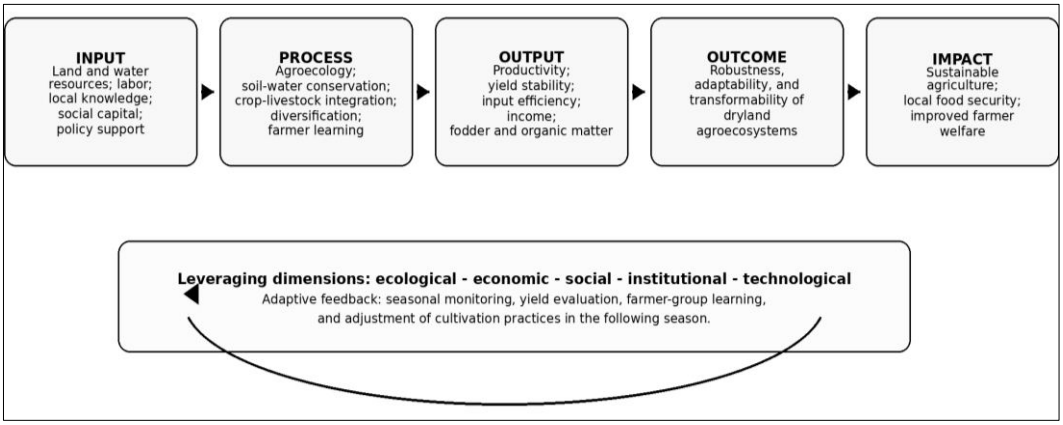


Figure 2. Conceptual Framework of Dryland Agroecosystem Resilience in Plampang District.

The novelty of this framework lies in the integration of five resilience dimensions and the staged relationship from input to impact. In future research, the framework can be translated into empirical indicators, such as soil organic matter content, enterprise-diversification index, residue-use ratio, access to climate information, farmer-group strength, fodder-reserve capacity, and income stability across seasons. Thus, Plampang can become a site for developing a dryland agroecosystem resilience model that is grounded in local evidence while remaining connected to global sustainable-agriculture discourse.

Policy Implications and Future Research Agenda

The first implication is directed to local government. Dryland agricultural programs should shift from seasonal input assistance toward long-term resilience investment. Such investment includes soil-water conservation, organic matter improvement, fodder management, collective water institutions, and village-level climate information systems. These programs can begin in villages with high drought and erosion risk and then be expanded through learning among farmer groups.

The second implication is directed to extension agents and farmer institutions. Extension should facilitate problem-based learning rather than only deliver technology packages. Relevant extension themes include adaptive planting calendars, residue management, composting, crop diversification, fodder management, and farm-cost recording. Strengthening farmer groups is essential because farmers need collective spaces to make decisions on water management, infrastructure maintenance, and joint marketing.

The third implication is directed to researchers. Empirical studies are needed to test Plampang agroecosystem resilience indicators based on the proposed conceptual framework. Future research can combine farm-household surveys, soil measurement, spatial drought analysis, institutional mapping, and farm-economic analysis. The combination of quantitative and qualitative data will help explain not only the level of resilience, but also the mechanisms that make the system stronger or more fragile.

CONCLUSION

Dryland agroecosystem resilience is a crucial foundation for achieving sustainable agriculture in Plampang District, Sumbawa Regency. Resilience is not only related to maintaining maize production, but also includes soil health, water efficiency, economic diversification, social capital, institutional capacity, and adoption of climate-adaptive technology. Within the framework of robustness, adaptability, and transformability, a resilient agroecosystem is a system that can withstand disturbances, adjust management practices, and transform toward a more diverse, efficient, and equitable system.

The major factors influencing resilience in Plampang include land condition, water availability, livestock ownership, farmer knowledge, labor, social capital, climate variability, commodity prices, infrastructure, extension, and policy support. Strategies for strengthening resilience should focus on soil-water conservation, organic matter improvement, crop and income diversification, crop-livestock integration, farmer-group strengthening, collective water management, and practical use of climate information. The input-process-output-outcome-impact framework proposed in this article can serve as a basis for developing resilience indicators and future field research. Through this approach, dryland agriculture in Plampang can be developed not only as a production system, but also as an adaptive and sustainable social-ecological system.

RECOMMENDATION

Future research should empirically test and validate the proposed input-process-output-outcome-impact framework through field-based studies. Further studies are also recommended to develop measurable resilience indicators, assess the contribution of each influencing factor, and examine the effectiveness of different resilience-strengthening strategies across seasons and farming conditions.

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