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Mapping Multidimensional Family Vulnerability in Indonesia Using Principal Component Analysis and K-Means Clustering

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ABSTRACT

Family vulnerability in Indonesia is shaped by interrelated economic, public health, and ecological conditions, yet its multidimensional structure, spatial distribution, and association with institutional support remain insufficiently examined. This study develops a composite Family Vulnerability Index using 2025 provincial-level data from Statistics Indonesia (Badan Pusat Statistik, BPS), integrating poverty, the Open Unemployment Rate (TPT), access to improved sanitation, access to improved drinking water, and the Indonesian Disaster Risk Index (IRBI). Principal Component Analysis (PCA) was employed to construct the composite index by integrating the multidimensional vulnerability indicators, while K-Means Clustering was used to classify provinces according to their vulnerability profiles. Pearson correlation and simple linear regression were subsequently applied to examine the associations between the Family Vulnerability Index and the marriage officiant ratio and divorce ratio. Quadrant analysis was used to identify priority regions based on the combination of family vulnerability and the marriage officiant ratio, with the mean of each indicator serving as the initial cut-off point. The clustering analysis identified three vulnerability categories: high vulnerability (3 provinces), moderate vulnerability (12 provinces), and low vulnerability (23 provinces). The Family Vulnerability Index was positively and significantly associated with the marriage officiant ratio ($r = 0.552$; $\beta = 5.283$; $R^2 = 0.304$; $p < 0.001$), indicating that provinces with higher levels of vulnerability tended to have higher marriage officiant ratios. However, this association should not be interpreted as evidence of a causal institutional response or as an indication that officiant provision is proportionate to regional needs. In contrast, the association between the Family Vulnerability Index and the divorce ratio was negative but not statistically significant ($r = -0.306$; $\beta = -2.482$; $R^2 = 0.094$; $p = 0.078$), indicating that provincial variation in divorce cannot be sufficiently explained by the vulnerability indicators included in this study. The quadrant analysis revealed substantial heterogeneity in vulnerability and institutional-support patterns across provinces. This study contributes a multidimensional provincial framework that combines PCA-based vulnerability measurement, K-Means classification, and institutional-support mapping to identify differentiated regional vulnerability profiles. The findings provide an empirical basis for preliminary, context-sensitive policy prioritization, while further research using household-level, longitudinal, and spatially explicit data is needed to directly assess family resilience and causal mechanisms.

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1. Introduction

The global crises of recent times have created increasingly complex challenges for the survival of families [1]-[4]. Economic shocks triggered by inflation, rising living costs, and uncertainty in the labor sector, compounded by the growing intensity of climate-related natural disasters and a range of public health threats, have eroded families' capacity to meet basic needs, safeguard their well-being, and sustain their social roles [5]-[9]. This phenomenon affects not only the economic dimension but also the stability of family relationships, the quality of parenting, and families' ability to withstand the accumulation of pressures that arise simultaneously [10]-[13]. In the face of this reality, families are required to develop adaptability and resilience so that they can continue to carry out their basic functions amid the ever-evolving dynamics of global crises.

As the most basic social unit, the family is also a key pillar of a harmonious and civilized society [14]-[16]. In Islamic teachings, this is realized through the concept of the *Sakinah-Maslahah* Family, namely a household founded on tranquility (*sakinah*) and love and compassion (*mawaddah wa rahmah*) that also delivers benefit (*maslahah*) to its members and the wider community [17], [18]. Therefore, the resilience of a *sakinah-maslahah* family is assessed not only by its ability to withstand economic, ecological, and public health pressures, but also by its capacity to adapt, maintain harmony, and sustain family functions amid change.

However, family resilience does not arise on its own. It is shaped by interrelated factors, namely economic, environmental, public health, and internal family dynamics [19]-[21]. Poverty and unemployment weaken families' ability to meet basic needs and heighten social and psychological strain [22]-[24], while limited access to adequate sanitation and clean drinking water, combined with high disaster risk, lowers quality of life and increases vulnerability to shocks [25], [26]. High divorce rates also signal challenges in preserving family integrity [27]-[29], which is why religious services, particularly marriage registrar (*kepenghuluan*) services, play an important role in strengthening family guidance before and after marriage [30], [31]. Given the interrelated nature of these pressures, family vulnerability needs to be measured multidimensionally to provide a more comprehensive picture of families in Indonesia.

Studies on family vulnerability that integrate economic, ecological, public health, and family dynamics indicators into a single composite index remain limited. Approaches that combine Principal Component Analysis (PCA) to construct the index with K-Means Clustering to group regions by their vulnerability characteristics are also rarely used [32]-[34]. Yet, a multidimensional approach is needed to map vulnerability comprehensively, identify priority regions accurately, and provide a basis for policies that strengthen family resilience [35], [36].

Based on these gaps, this study develops and analyzes a Family Vulnerability Index (FVI) for Indonesian provinces by integrating economic, public health, ecological, and family-related dimensions. Principal Component Analysis (PCA) is used to construct the index, K-Means Clustering to classify provincial vulnerability profiles, and association and quadrant analyses to examine the FVI in relation to the marriage officiant ratio as a proxy for institutional support and the divorce ratio as an indicator of family stability. Unlike conventional social, household, or disaster vulnerability assessments that typically focus on specific sectors or forms of exposure, the proposed FVI provides an integrated provincial-level framework linking multidimensional vulnerability with institutional support and family stability.

The concept of *Sakinah-Maslahah* is positioned as a normative and policy-oriented framework for interpreting family resilience rather than as a directly measured construct. Accordingly, the FVI identifies structural vulnerability conditions that may inform efforts to strengthen family resilience, while recognizing that *Sakinah-Maslahah* encompasses normative and relational dimensions requiring more direct household- or family-level measurement. Using 2025 secondary data from Statistics Indonesia (BPS), the National Disaster Management Agency (BNPB), and the Ministry of Religious Affairs, this study contributes a multidimensional, data-driven framework for mapping family vulnerability and identifying differentiated regional profiles and priority areas. The findings

may support context-sensitive policy planning by relevant stakeholders, although the implications remain preliminary because the analysis uses provincial-level cross-sectional data and does not establish causal relationships or directly measure household-level family resilience.

2. Method

This study employs a quantitative approach with a descriptive-exploratory design. The unit of analysis comprises 38 provinces in Indonesia, utilizing secondary data from 2025 obtained from Statistics Indonesia (BPS), the National Disaster Management Agency (BNPB), and the Ministry of Religious Affairs of the Republic of Indonesia. The research variables cover economic, public health, and ecological dimensions, as well as institutional support, proxied by the marriage registrar (penghulu) ratio, and family stability, proxied by the divorce ratio.

All data analyses were conducted using RStudio in four stages. First, Principal Component Analysis (PCA) was applied to reduce the dimensionality of the indicators and construct the Family Vulnerability Index. Second, K-Means Clustering was used to group provinces according to their vulnerability characteristics, with the optimal number of clusters determined through the Elbow Method and Silhouette Analysis. Third, Pearson correlation and simple linear regression were employed to examine the strength and direction of the relationship between the vulnerability index and both the penghulu ratio and the divorce ratio. Fourth, quadrant analysis was applied to determine priority regions for intervention based on the combination of vulnerability level and the penghulu ratio. The overall results were used to map family vulnerability across provinces, identify the characteristics of regional groups, and formulate contextual and well-targeted policy recommendations for strengthening family resilience.

3. Results and Discussion

This study analyzes the level of family vulnerability in Indonesia by constructing a Family Vulnerability Index that integrates economic, public health, and ecological indicators. The index is built from poverty, the Open Unemployment Rate (TPT), access to improved sanitation, access to improved drinking water, and the Indonesian Disaster Risk Index (IRBI). It is then used as the basis for grouping provinces through the K-Means Clustering method. The resulting clusters are examined in relation to the marriage officiant ratio and the divorce ratio to determine priority regions for intervention in strengthening the resilience families.

This mapping provides a comprehensive overview of the variation in family vulnerability across provinces, while also serving as an empirical foundation for formulating more targeted strategies to strengthen family resilience. The results of the provincial clustering based on the Family Vulnerability Index are presented in Fig. 1 below.

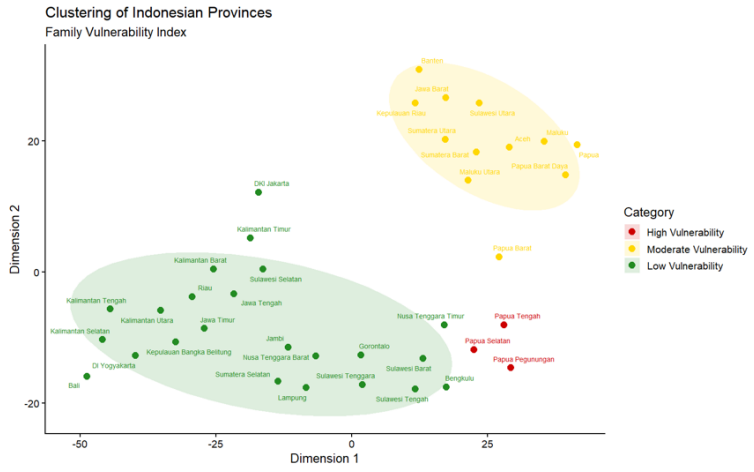

Fig. 1. Family vulnerability index

The results in Fig. 1 show the clustering of Indonesian provinces into three categories of family vulnerability: high, moderate, and low. The clustering was performed using the K-Means method (k = 3) based on the standardized, varimax-rotated scores of the two retained principal components (PC1 and PC2), derived from five indicators: poverty, the Open Unemployment Rate (TPT), access to improved sanitation, access to improved drinking water, and the Indonesian Disaster Risk Index (IRBI). The two components jointly explain 77% of the total variance, with PC1 accounting for 50% and PC2 accounting for 27%. Based on the rotated loading matrix, PC1 is primarily characterized by poverty (loading = 0.90), IRBI (0.79), and sanitation (−0.83), whereas PC2 is predominantly associated with TPT (0.89), followed by access to improved drinking water (0.58) and sanitation (0.37). These components provide a two-dimensional representation of provincial variation in the indicators used to construct the Family Vulnerability Index, while the K-Means algorithm identifies three groups based on the component scores.

Visually, the clustering results show a fairly clear separation among the three groups, marked by provinces that are relatively homogeneous within each category but heterogeneous between categories. This finding indicates that the K-Means method is able to identify distinct patterns of family vulnerability across provinces, thereby producing a representative regional classification based on the characteristics of the indicators used in this study.

The high vulnerability group consists of 3 provinces that form a distinct cluster, clearly separated from the other groups. This indicates that the provinces in this group have relatively more severe vulnerability characteristics than other provinces, and therefore require more intensive attention and policy intervention. In contrast, the moderate vulnerability group, consisting of 12 provinces, shows relatively homogeneous characteristics with provinces positioned close to one another, reflecting a medium level of vulnerability. Meanwhile, the low vulnerability group comprises 23 provinces scattered across an area distinct from the other two groups, reflecting relatively better family conditions in terms of the indicators that constitute the family vulnerability index.

This distinct separation between clusters shows that family vulnerability in Indonesia is not homogeneous but varies according to the socioeconomic conditions, public health, and ecological risks in each province. Accordingly, these mapping results provide an empirical basis showing that family strengthening strategies cannot be implemented through a one-size-fits-all approach, but must be tailored to the level of vulnerability and the specific characteristics of each region. These findings serve as an important foundation for formulating more targeted policies to strengthen family resilience, particularly in provinces classified as highly vulnerable.

To understand the relationship between family vulnerability and religious institutional support, this study analyzes the relationship between the Family Vulnerability Index and the Marriage Officiant Ratio at the provincial level. The analysis is conducted through a scatter plot visualization complemented by a linear regression line, and is then reinforced by Pearson correlation testing and simple linear regression analysis. The marriage officiant ratio is used as a proxy for the availability of marriage officiant services, which play an important role in marriage services, premarital guidance, and family development as part of efforts to strengthen family resilience. The visualization is presented in Fig. 2 below.

As shown in Fig. 2, there is a positive relationship between the Family Vulnerability Index and the Marriage Officiant Ratio, reflected in the upward slope of the regression line. In general, provinces with higher Vulnerability Index values tend to have higher marriage officiant ratios. However, the scatter of data points shows considerable variation, so this pattern does not hold uniformly across all provinces. For example, several provinces with relatively low vulnerability, such as Nusa Tenggara Timur and Bali, have fairly high marriage officiant ratios, while some provinces with higher vulnerability show lower ratios. This finding indicates that the distribution of marriage officiants is not determined solely by the level of family vulnerability, but is also influenced by other factors, such as population size, geographic characteristics, regional area, and officiant deployment policies in each region.

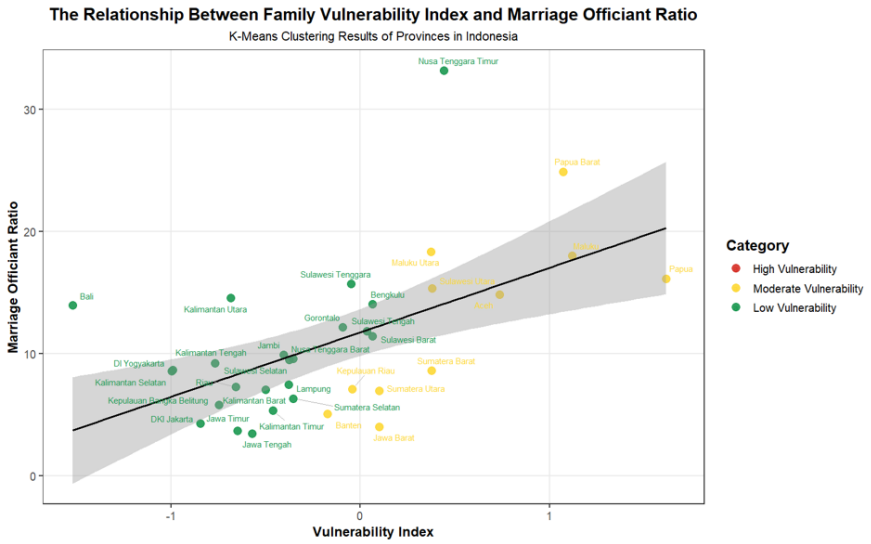

Fig. 2. Family vulnerability index and marriage officiant ratio

The Pearson correlation analysis showed a significant positive association between the Family Vulnerability Index and the Marriage Officiant Ratio at the provincial level ((r = 0.552), (p < 0.001)). The correlation coefficient indicates a moderate positive association, suggesting that provinces with higher family vulnerability scores tend to have higher marriage officiant ratios. Consistent with this finding, the simple linear regression analysis also identified a positive and statistically significant association between the Family Vulnerability Index and the Marriage Officiant Ratio ((\beta = 5.283), (p < 0.001)), with a coefficient of determination of (R^2 = 0.304). This indicates that the Family Vulnerability Index accounts for 30.4% of the observed variation in the Marriage Officiant Ratio within the fitted regression model. The remaining 69.6% of the variation is not accounted for by this model. However, these results demonstrate an association rather than a causal effect, and they do not establish why marriage officiants are distributed differently across provinces.

Overall, these findings indicate that provinces with higher family vulnerability scores tend to have higher Marriage Officiant Ratios. However, the present analysis cannot determine whether this pattern reflects a government policy response or other factors influencing the distribution of marriage officiants. The observed variation also suggests that the relationship between regional vulnerability and marriage officiant availability warrants further examination. Therefore, future planning of marriage officiant services could consider family vulnerability alongside population size, service demand, geographic accessibility, and administrative arrangements to support more context-sensitive and needs-based resource allocation.

Within the framework of family resilience, the findings of this study affirm that marriage officiants occupy a strategic position, not only as marriage registrars but also as key actors in strengthening family resilience through premarital education, family guidance, household conflict mediation, and post-marriage family support. Accordingly, strengthening the capacity and ensuring a more equitable distribution of marriage officiants, adjusted to regional vulnerability levels, is one relevant strategy for supporting the development of resilient, harmonious, and sustainable families.

Furthermore, to understand the relationship between family vulnerability and family dynamics at the provincial level, this study analyzes the relationship between the Family Vulnerability Index and the Divorce Ratio through a scatter plot visualization complemented by a linear regression line, which is then reinforced by Pearson correlation testing and simple linear regression analysis. The divorce ratio is used as an indicator representing the stability of family life, so the relationship between the two variables is expected to provide an overview of the link between family vulnerability and household sustainability. The relationship between the Family Vulnerability Index and the Divorce Ratio is presented in Fig. 3 below.

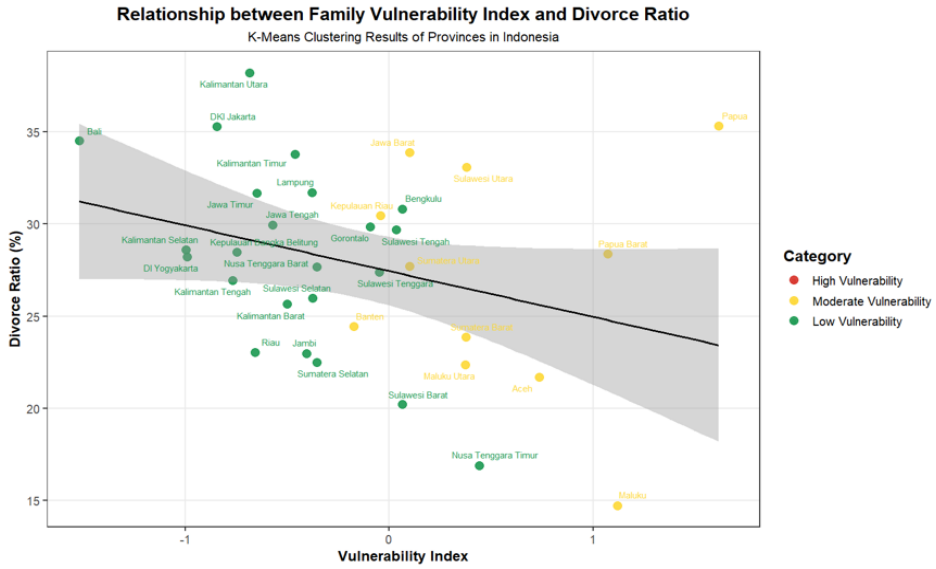

Fig. 3. Family Vulnerability Index and the Divorce Ratio

As shown in Fig. 3, the regression line indicates a negative relationship between the Family Vulnerability Index and the Divorce Ratio. Visually, provinces with higher vulnerability tend to have lower divorce ratios, although the scatter of data shows considerable variation across provinces. This relatively dispersed pattern indicates that the relationship between the two variables has not formed a strong pattern. For illustration, several provinces with low vulnerability, such as Bali, DKI Jakarta, and Kalimantan Utara, have high divorce ratios, while some provinces with moderate vulnerability, such as Maluku and Nusa Tenggara Timur, show relatively low divorce ratios. This condition indicates that the divorce rate does not always align with the level of family vulnerability constructed from economic, public health, and disaster risk indicators.

The subsequent statistical analysis reinforces this finding. The Pearson correlation test shows that the Family Vulnerability Index has a negative relationship with the Divorce Ratio ($r = -0.306$), but this relationship is not statistically significant ($p = 0.078$). This correlation coefficient indicates that the strength of the relationship between the two variables is weak, so there is not yet sufficient empirical evidence to state that changes in family vulnerability are directly related to changes in the divorce ratio across provinces.

The simple linear regression analysis shows a similar tendency. The regression coefficient of $\beta = -2.482$ indicates that each one-unit increase in the Family Vulnerability Index tends to be followed by a decrease in the Divorce Ratio of approximately 2.48 units. However, this relationship is also not statistically significant ($p = 0.078$), with a coefficient of determination of $R^2 = 0.094$, meaning that the Family Vulnerability Index explains only about 9.4% of the variation in the Divorce Ratio, while most of the remaining variation (90.6%) is influenced by other factors outside the model.

These findings suggest that the Family Vulnerability Index, as operationalized in this study, is insufficient on its own to account for variations in provincial divorce ratios. Previous studies have identified factors such as marital communication, educational background, age at marriage, psychological conditions, religious contexts, cultural values, and conflict-resolution practices as potential correlates of marital stability. However, these factors were not examined in the present study and therefore cannot be established as explanations for the observed pattern. Future research could incorporate these individual, interpersonal, and sociocultural factors to investigate more comprehensively how regional vulnerability relates to divorce patterns.

Within the framework of family resilience, the findings of this study imply that strengthening family resilience cannot focus solely on improving socioeconomic conditions or reducing disaster risk. Building resilient families also requires strengthening preventive and educational functions

through marriage guidance services, family counseling, religious guidance, and continuous post-marriage support. Accordingly, strategies for strengthening family resilience need to be designed comprehensively by integrating economic, social, psychological, and religious approaches, so as to address the various challenges faced by families in Indonesia more holistically.

To determine policy intervention priorities, this study maps each province into four quadrants based on the Family Vulnerability Index and the Marriage Officiant Ratio. The Family Vulnerability Index is used to represent the level of regional vulnerability, while the Marriage Officiant Ratio serves as a proxy for institutional support in marriage officiant services. The quadrant analysis used the mean values of the Family Vulnerability Index and the Marriage Officiant Ratio as cut-off points to classify provinces according to their relative positions on the two indicators. The mean was selected to distinguish provinces with values above and below the national average. However, this classification is sensitive to the choice of cut-off points, particularly for provinces with values close to the thresholds. Therefore, quadrant membership is interpreted as a relative classification rather than an absolute measure of policy priority. A sensitivity analysis using alternative thresholds, such as the median, can help assess the robustness of the resulting classifications. The policy intervention priorities are presented in Fig. 4 below.

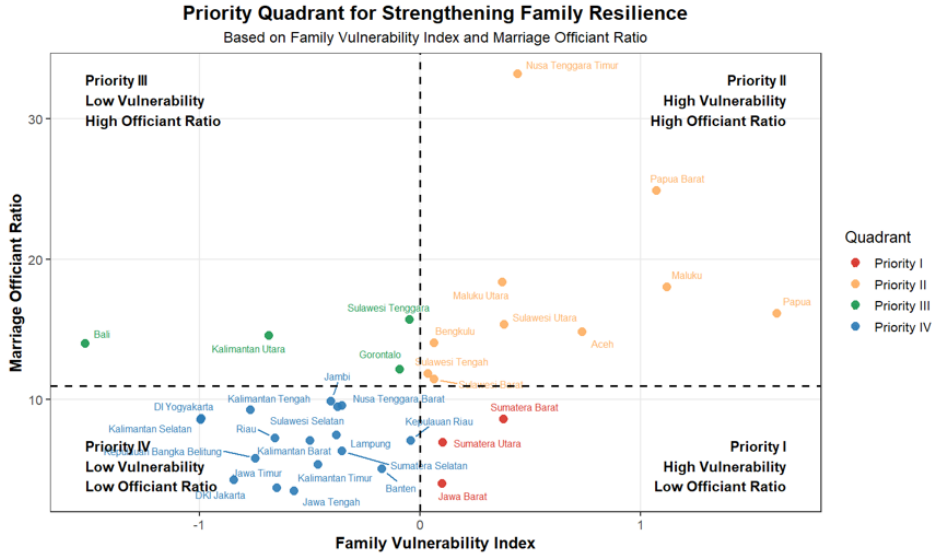

Fig. 4. Policy intervention priorities

Fig. 4 shows that provinces in Indonesia are distributed across four quadrants that reflect the combination of family vulnerability levels and the availability of marriage officiant services. Quadrant I is occupied by provinces with high family vulnerability but a relatively low marriage officiant ratio. Regions in this quadrant represent the highest intervention priority, as their substantial vulnerability burden is not yet matched by adequate marriage officiant service capacity. Provinces in this group include Sumatera Barat, Sumatera Utara, and Jawa Barat. This condition indicates the need to strengthen institutional capacity by increasing the number of marriage officiants, improving the quality of marriage guidance services, providing family counseling, and implementing more intensive family support programs.

In contrast to Quadrant I, Quadrant II consists of provinces with high vulnerability that are accompanied by a relatively high marriage officiant ratio, such as Papua, Papua Barat, Maluku, Maluku Utara, Aceh, Sulawesi Utara, Sulawesi Barat, Bengkulu, Sulawesi Tengah, and Nusa Tenggara Timur. This quadrant comprises provinces with relatively high Family Vulnerability Index scores and relatively high Marriage Officiant Ratios. However, the quadrant classification alone cannot establish whether marriage officiant services are adequate or effective in reducing family vulnerability. Further assessment incorporating population size, service demand, geographic accessibility, and service outcomes is needed to determine whether existing service provision

corresponds to regional needs. Policy efforts could therefore focus on evaluating service quality and accessibility, alongside the potential role of marriage guidance and family support programs.

Furthermore, Quadrant III represents provinces with relatively low vulnerability accompanied by a high marriage officiant ratio, such as Bali, Kalimantan Utara, Sulawesi Tenggara, and Gorontalo. This group shows generally better conditions, as it is supported by adequate marriage officiant service capacity. These regions can serve as a reference for best practices in the delivery of family services, so the policy direction for this group is oriented toward maintaining service quality, developing innovative family guidance programs, and strengthening collaborative networks with local governments and social-religious institutions.

Meanwhile, Quadrant IV includes provinces with low vulnerability that are also accompanied by a low marriage officiant ratio, such as DKI Jakarta, Jawa Tengah, Banten, Jawa Timur, Lampung, Kalimantan Timur, Kalimantan Selatan, Kalimantan Barat, Kalimantan Tengah, Riau, Sumatera Selatan, Jambi, Kepulauan Bangka Belitung, Nusa Tenggara Barat, Kepulauan Riau, and DI Yogyakarta. Although vulnerability in this group is relatively low, the limited marriage officiant ratio still requires attention so that it does not develop into a problem in the future. Therefore, policy for this group is directed toward preventive measures, through improving service quality, strengthening premarital education, and conducting periodic monitoring of family vulnerability dynamics in these regions.

This study uses provincial-level aggregated data; therefore, its findings cannot be directly generalized to individual families or households. The observed associations do not establish household-level relationships between family vulnerability, marriage services, and divorce. Future research using household-level data is needed to examine these relationships more directly.

4. Conclusion

A differentiated, region-specific approach may be more appropriate than a uniform intervention strategy, given the variation in vulnerability characteristics and institutional capacity across provinces. The proposed mapping can serve as a preliminary reference for the Ministry of Religious Affairs and other relevant stakeholders in identifying regions that warrant further assessment of marriage officiant availability, marriage guidance services, family counseling, and family support programs. However, decisions regarding resource allocation should also consider population size, service demand, geographic accessibility, and local conditions.

This study provides a multidimensional overview of provincial family vulnerability in Indonesia and preliminary empirical evidence to inform regional policy planning. Nevertheless, the findings should be interpreted cautiously given the ecological and cross-sectional nature of the data, the use of selected proxy indicators, and the potential sensitivity of the classifications to methodological choices. Further validation using household-level data and alternative analytical approaches is needed before the findings can support definitive policy decisions aimed at strengthening family resilience.

Supplementary Materials: No additional materials accompany this study

Author Contribution: All authors made equal contributions to this study, including conceptualization, data collection, methodology, formal analysis, visualization, and writing of the manuscript. All authors have read and agreed to the published versi.on of the manuscript

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Conflicts of Interest: The authors declare no conflict of interest.

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