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Analysis of Rainfall Data Compatibility from 1991 to 2020 with the Balinese Sasih Calendar in Bali Province

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ABSTRACT: This study aims to analyze the alignment between the traditional Balinese Sasih calendar system and observed rainfall data from BMKG across the Province of Bali for the period 1991–2020. Sasih, a form of local wisdom, has long been used by Balinese farmers as a guide for determining planting times. In this study, the Gregorian calendar was converted into the Sasih system to synchronize rainfall and rainy days data based on Sasih periods. Rainfall data were categorized according to BMKG classification standards for both monthly rainfall totals and the number of rainy days per month. A contingency table method was used to calculate the accuracy between Sasih-based predictions and observed BMKG data. The results show that the accuracy of Sasih in predicting the number of rainy days was higher (average 62%) than its accuracy in predicting total monthly rainfall (average 37%). This indicates that the Sasih calendar is more relevant in representing rainfall frequency rather than rainfall intensity. The spatial distribution of accuracy shows that highland regions such as Jembrana and Tabanan demonstrated better agreement compared to the southern coastal and central lowland areas. Although the overall accuracy is not optimal, these findings highlight the importance of integrating local knowledge systems like Sasih with modern climate data to support sustainable agricultural planning in Bali.

KEYWORDS: Sasih, rain data, Bali Province

I. INTRODUCTION

Agriculture in Bali is inseparable from the local wisdom of its people, including systems such as Subak, Wariga, Sasih, and others. Balinese agriculture is considered unique, as most of its activities are regulated and managed through the Subak system. Subak is a local farmer organization directly related to the management of paddy fields and irrigation water.[1].

Another form of local wisdom in Bali is the Sasih system, also referred to as *masa*, which means "month". *Masa* can be interpreted as a period of time within a year. A year is composed of 12 *masa* or months. These twelve *Sasih* are often grouped into two major categories: Lahru Masa and Rengreng Masa. *Lahru Masa* refers to the dry season, while *Rengreng Masa* represents the rainy season. [2]. Generally, Sasih serves as a traditional record or representation of weather and climate conditions in Bali, which includes the onset and duration of both rainy and dry seasons.

Rainfall is one of the most critical factors in agricultural activities, both in wetland and dryland farming systems. In general, the rainfall pattern in Bali follows a monsoonal type, characterized by one peak of the rainy season and one peak of the dry season. The peak of the rainy season typically occurs in December, January, and February, while the peak of the dry season usually falls in June, July, and August.

Although the overall rainfall pattern across Bali is relatively similar, the difference between regions lies in the timing of the onset of the rainy and dry seasons. This variability is one of the reasons why Bali has been divided into 20 new climate zones (Zona Musim), based on the BMKG climate normal data for the period 1991–2020. [3].

Since ancient times, traditional farmers in Bali have recognized rainfall patterns through the Sasih calendar. For the Balinese community, Sasih is deeply connected to all aspects of life, particularly agricultural activities. Each Sasih embodies certain characteristics or specific weather/climate conditions of that month. Generally, it is understood that Sasih Kanem and Sasih Kapitu represent the peak of the rainy season in Bali, while Sasih Kasa and Sasih Karo correspond to the peak of the dry season.

Each Sasih period typically lasts 30 days, following the duration of one lunar cycle (full moon to new moon). As a result, the Sasih calendar does not always align precisely with the Gregorian calendar months. For example, Sasih Karo does not always fall exactly in July—it may occur between July and August. This misalignment, according to Gede Marayana, the maker of the Balinese calendar, can lead to inconsistencies in rainfall characteristics when interpreted using the Gregorian calendar framework.

Until today, farmers in Bali continue to use the Sasih calendar in various aspects of their lives, especially in agricultural practices. One of its primary functions is to determine the planting period. For example, continuous rainfall over several days, which marks the arrival of Sasih Kalima, is traditionally seen as a signal for farmers to begin preparing their fields for cultivation. However, in recent years, this condition has often led to confusion, as rainfall occurring over several consecutive days no longer reliably indicates the beginning of the rainy season. This uncertainty may be caused by changing climate patterns and shifts in seasonal behavior.

The purpose of this study is to find the accuracy value of rainfall forecasts based on the Sasih calendar by comparing it with observed rainfall data from BMKG, and to produce a spatial distribution map that shows the level of Sasih suitability throughout Bali Province.

II. METHODS

This research was conducted from September 2024 to December 2024. The study area is located in Bali Province, which lies between 08°3'40" – 08°50'48" South Latitude and 114°25'53" – 115°42'40" East Longitude. Bali features a diverse topography and is surrounded by the sea. In general, the coastal areas are characterized by lowlands and beaches, while the central region consists of higher elevations, including mountain ranges and hilly landscapes.

The materials used consist of daily rainfall data from BMKG rainfall observation stations in Bali Province for the period 1991–2020, which represent various climatological regions across the island. Additionally, Sasih data were obtained from the Balinese calendar for the years 1991–2020.

Sasih data is a form of qualitative data that does not consist of numerical values, making it difficult to analyze using standard statistical methods. Therefore, an approach was applied to connect the traditional Balinese calendar system (Sasih) with the actual rainfall data recorded by BMKG. The following steps were undertaken to construct the analogy between Sasih and rainfall data: 1. Date Conversion, transforming BMKG rainfall dates (Gregorian calendar) into Sasih periods, 2. Data Grouping, categorizing BMKG rainfall data based on the corresponding Sasih periods (Example: all rainfall data from 1 January 2024 to 30 January 2024 are grouped into Sasih Kapitu, depending on the year and lunar phase), 3. Statistical Analysis, calculating the average rainfall per Sasih period across the 30-year time span (1991–2020), 4. Graphing and Tabulating, presenting the rainfall data by Sasih in the form of charts or tables, 5. Mapping the accuracy value of the comparison of Sasih with rainfall data.

The Rainfall data for each Sasih period were averaged over a 30-year period to obtain the Sasih Rainfall Normal. Descriptive statistical analysis of rainfall data was performed by calculating the mean. [6]. This average value was used to determine the general rainfall trend for each Sasih, based on long-term observational data. Accuracy testing was conducted to determine the extent to which the predicted rainfall categories based on the Sasih calendar align with actual rainfall data from BMKG observation stations. This process aims to assess the level of agreement or consistency between two distinct data sources: one derived from traditional knowledge, and the other from scientific and instrument-based measurements.

The method used to evaluate accuracy is the contingency table (also known as a confusion matrix), a statistical approach commonly applied in classification evaluations. This table compares the predicted rainfall categories based on Sasih with the actual rainfall categories from BMKG observations, covering both monthly rainfall totals and monthly rainy days counts. The resulting accuracy values were then visualized using mapping software, allowing for the generation of spatial maps showing the degree of agreement between observed rainfall data and Sasih-based predictions across Bali Province.

The accuracy of Sasih predictions relative to observed rainfall data was assessed using two approaches: 1. Accuracy based on the number of rainy days, and 2. Accuracy based on total rainfall volume. According to the BMKG climate bulletin, monthly rainfall totals are categorized into four groups: Low (0–100 mm), Moderate (101–300 mm), High (301–500 mm), and Very High (>500 mm). Meanwhile, the number of monthly rainy days is classified into three categories: Low (≤10 days), Moderate (11–20 days), and High (>20 days).[3]. These classifications were used as the basis for grouping rainfall data in the analysis of Sasih suitability with actual rainfall conditions.

RESULTS AND DISCUSSION

Based on rainfall data from the period 1991–2020, a total of 361 monthly data points were obtained using the Sasih calendar. These monthly rainfall data were then averaged across the 12 Sasih periods in a year over the span of 30 years, resulting in the calculation of the Normal Rainfall for each Sasih. Based on the rainfall normals for each Sasih period at several locations—Negara, Ngurah Rai, Karangasem, Buleleng, and Tabanan (Figure 2)—it was found that Sasih Kasa, Karo, and Ketiga (approximately corresponding to July, August, and September) represent the peak of the dry season in Bali. Conversely, the peak of the rainy season, according to the Sasih-based rainfall normal, occurs during Sasih Kanem, Kapitu, and Kaulu, which correspond roughly to December, January, and February, as shown in Figure 1.

Based on Figure 1, it can be observed that the sample locations generally exhibit a similar rainfall pattern, with the peak of the rainy season occurring at the beginning and end of the year, while the peak of the dry season falls in the middle of the year. The two main differences between locations lie in the onset of the seasons and the duration of each season.

The determination of the dry and rainy season periods is based on BMKG criteria. The onset of the dry season is defined as a 10-day period (dasarian) in which rainfall is less than 50 millimeters, followed by two consecutive dasarians with similarly low rainfall, meaning that monthly rainfall is less than 150 millimeters. In contrast, the onset of the rainy season is defined when rainfall during a 10-day period exceeds 50 millimeters, followed by two consecutive dasarians with similar or increasing values—thus, monthly rainfall exceeding 150 millimeters. [3].

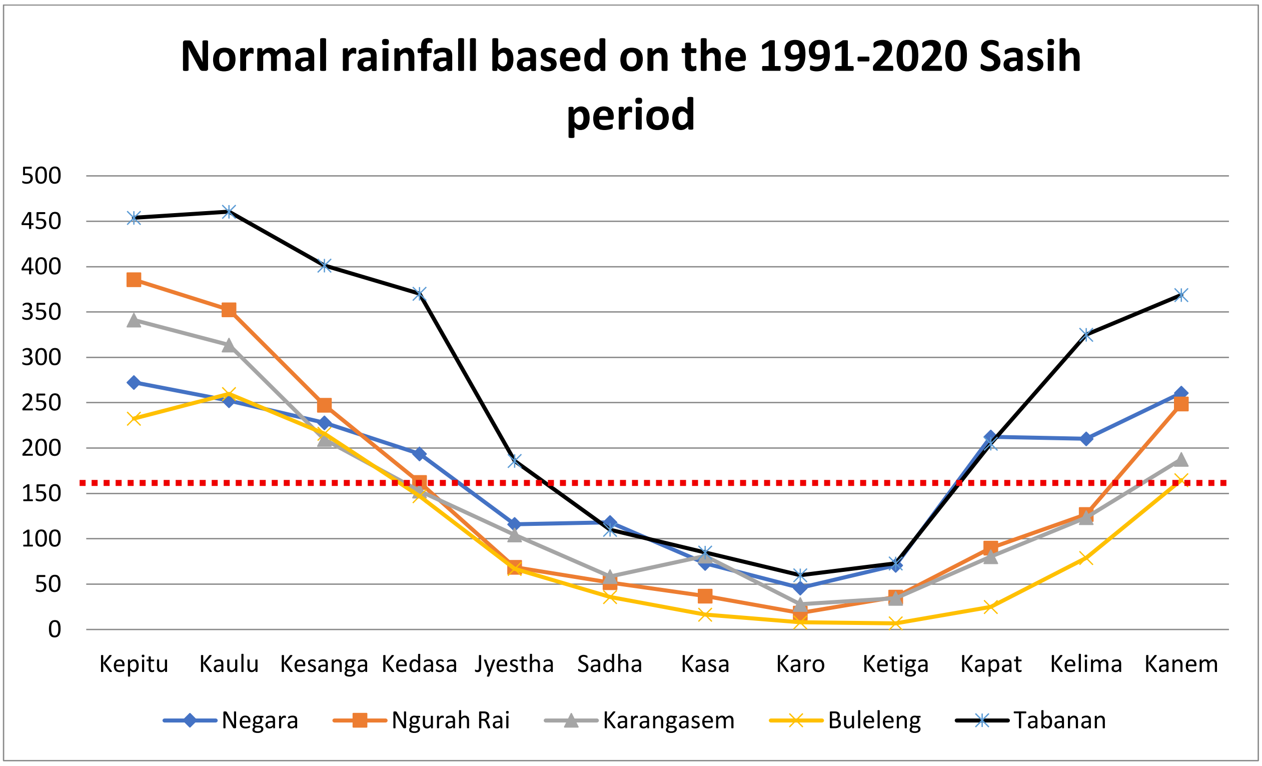

Figure 1. Normal Rainfall Based on the 1991-2020 Sasih Period

Referring to Figure 1, the boundary between the rainy and dry seasons as defined by BMKG is indicated by the red dashed line. Based on this boundary, it can be observed that Tabanan enters the dry season starting from Sasih Sadha through Sasih Ketiga, while Sasih Kapat already marks the onset of the rainy season. In contrast to Tabanan, the dry season in Buleleng appears to begin as early as Sasih Kedasa and extends until Sasih Kanem. A similar pattern is also observed in Tuban (Ngurah Rai), located in South Badung, where the dry season begins in Sasih Kedasa, with the peak of dryness occurring during Sasih Karo (approximately corresponding to August in the Gregorian calendar). The dry season in South Badung continues until Sasih Kelima, after which Sasih Kanem marks the transition into the rainy season.

A similar condition to Buleleng is also observed in Tuban (Ngurah Rai), South Badung, where the dry season begins in Sasih Kedasa, with the peak of the dry season occurring during Sasih Karo (which corresponds approximately to August in the Gregorian calendar). The dry season in South Badung continues until Sasih Kelima, while Sasih Kanem marks the transition into the rainy season.

The bar chart as in figure 2 below, illustrates the distribution of Sasih-based rainfall prediction accuracy across various observation stations. The x-axis represents accuracy intervals in percentage (%), while the y-axis shows the number of locations (stations) falling into each accuracy category. The data reveal that the majority of stations (54 locations) fall within the 40–50% accuracy range, indicating a moderate level of agreement between the Sasih-based predictions and the actual observed rainfall. Additionally, 13 stations achieved an accuracy between 50–60%, while only 1 station reached an accuracy of 60–70%.

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There are no locations with extremely low (below 30%) or very high (above 70%) accuracy values. This suggests that, while Sasih predictions show some level of alignment with observed rainfall, their ability to represent monthly rainfall quantitatively remains limited and clustered around moderate values.

The accuracy of Sasih in predicting rainfall volume can be considered very low. Based on the contingency table analysis, as shown in Table 1 below, using sample data from the Palasari rainfall station in Negara, an accuracy rate of only 37% was obtained. This indicates that only about one-third of the total months showed agreement between the rainfall category predicted by the Sasih calendar and the actual observed rainfall data.

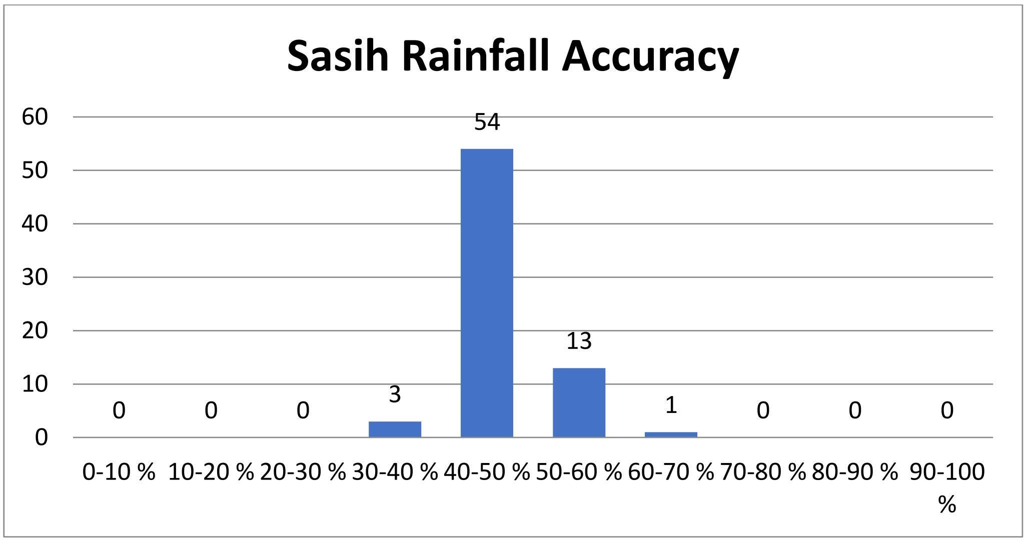

Figure 2. Sasih Accuracy Value Based on Rainfall Data

Table 1. Contingency table results for Sasih rainfall accuracy (1991–2020) at Palasari Station (Negara).

	Actual Rainfall				
Sasih Prediction	Low	Medium	High	Very High	Total
Low	53	36	2	0	91
Medium	69	73	17	0	159
High	36	56	11	1	104
Very high	1	13	4	0	18
Total	159	178	34	1	372

The spatial distribution map of Sasih accuracy values in Figure 3 illustrates the level of accuracy of the Sasih calendar system in predicting monthly rainfall categories based on observational data from BMKG rainfall stations across Bali Province. In general, the accuracy of Sasih predictions relative to actual rainfall data falls within the low to moderate range, with the majority of rainfall stations showing accuracy levels between 40% and 50%. This indicates that Sasih-based predictions of monthly rainfall amounts tend to be less precise quantitatively when compared to actual rainfall measurements from observation stations.

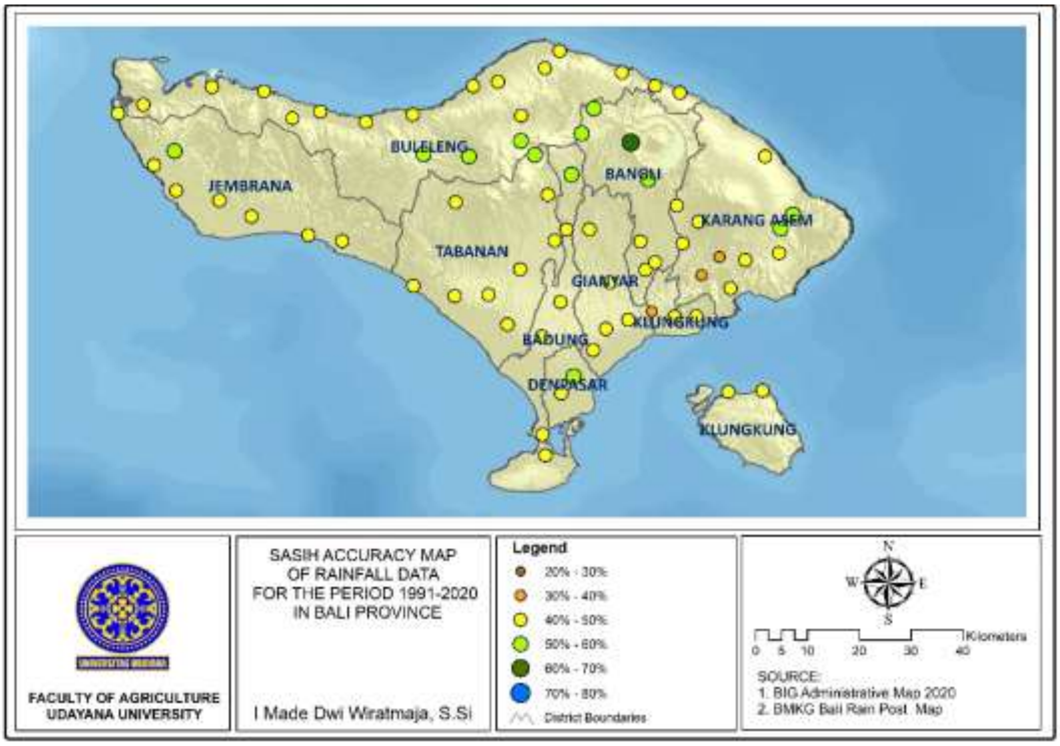

Figure 3. Map of the distribution of Sasih Accuracy Values Based on Rainfall Data

The low accuracy of Sasih predictions based on rainfall volume data indicates that the Sasih calendar is not yet fully capable of quantitatively representing the actual rainfall patterns during the analyzed time period. This low accuracy of Sasih in predicting monthly rainfall totals was also observed in other regions across Bali. The highest accuracy, at 41%, was recorded in Buruan (Tabanan), while the lowest, at 32%, was found in Sumberkima (Buleleng).

The bar chart as in figure 4 below, illustrates the distribution of Sasih accuracy in predicting the number of rainy days across observation stations. The x-axis shows accuracy intervals in percentage (%), while the y-axis represents the number of stations falling within each accuracy range. The data show that the majority of locations (59 stations) achieved an accuracy between 50–60%, indicating a moderate to relatively good agreement between Sasih-based predictions and the actual number of rainy days recorded. An additional 10 stations reached the 60–70% accuracy range, while only 1 station fell into the 40–50% range. No stations reported accuracy levels below 40% or above 70%.

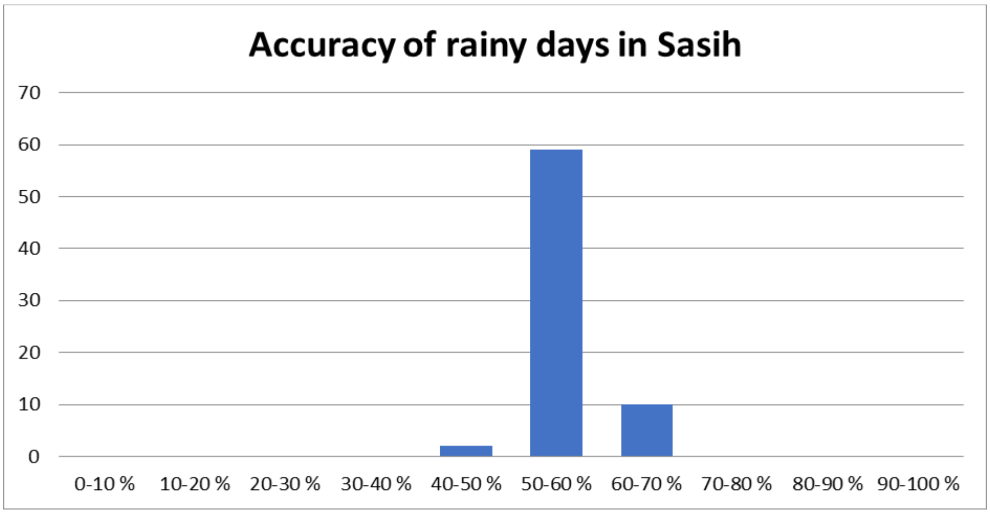

Figure 4. Sasih Accuracy Value Based on Rainy Days Data

The accuracy of Sasih in predicting rainy days can be considered moderate to relatively strong. Based on the contingency table analysis shown in Table 2 below, using sample data from the Palasari rainfall station in Negara, the overall accuracy was calculated at 62%. This means that more than half of the months showed a match between the rainy days category predicted by the Sasih calendar and the actual category recorded by BMKG observations. This indicates that the Sasih system still holds a moderate level of accuracy in reflecting the monthly rainfall patterns in Palasari (Negara), although the remaining 38% discrepancy may be attributed to changing climate dynamics or localized environmental factors.

Table 2. Contingency table results for Sasih rainy days accuracy (1991–2020) at Palasari Station (Negara).

	Actual Rainy Days			
Sasih Prediction	Low	Medium	High	Total
Low	149	23	0	172
Medium	96	92	9	197
High	5	13	1	19
Total	250	128	10	388

Although the accuracy rate of 62% suggests that Sasih remains relevant in predicting monthly rainfall frequency, the findings also highlight the need for further investigation to understand why Sasih-based predictions do not always align with observed conditions. The range of Sasih accuracy for predicting rainy days across locations varies between 40% and 63%, with the lowest accuracy found in Sanglah (Denpasar) and the highest in Melaya (Jembrana). These results can be considered fairly good, though not yet optimal—indicating that there is still room for improvement or adjustment of the Sasih model to better accommodate current climate variability.

The map presented in Figure 5 below illustrates that the accuracy level of Sasih-based predictions in representing rainy day categories varies across different locations. The dominant accuracy range lies within the 40%–60% category, indicating a moderate level of agreement. Several areas show relatively higher accuracy levels, reaching the 60%–70% range, particularly in Jembrana, northern Buleleng, and central Karangasem. This suggests that in these regions, the Sasih calendar still aligns reasonably well with the actual monthly rainy days patterns as recorded by BMKG. In contrast, lower Sasih accuracy levels are found in the northern and southern coastal areas of Bali, such as western Buleleng, southern Gianyar, southern Klungkung, and Nusa Penida.

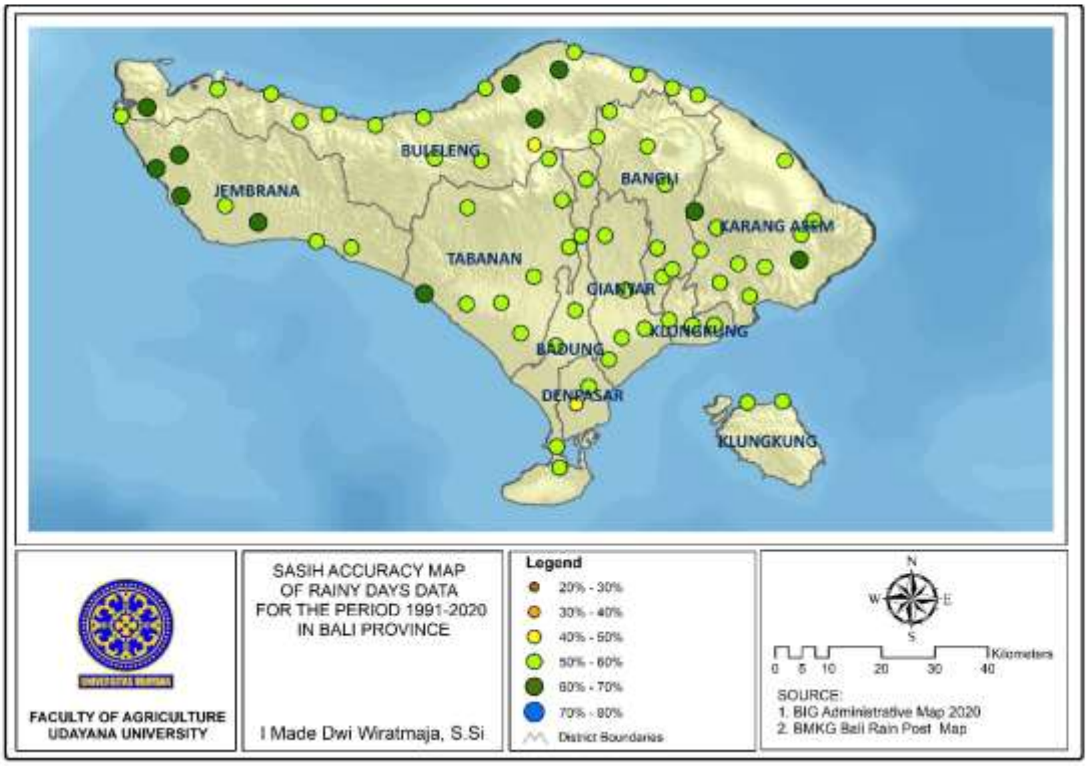

Figure 5. Map of the Distribution of Sasih Accuracy Values Based on Rainy Days Data

The spatial analysis of Sasih-based predictions for rainy day categories (Figure 5) shows a moderate level of alignment between traditional knowledge and observed climate data across most regions of Bali Province. The accuracy was assessed by comparing the Sasih-based classification of rainy periods to the observed number of rainy days recorded by BMKG rainfall stations from 1991 to 2020.

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A significant number of stations fall within the 40–60% accuracy range, indicating that the Sasih calendar is still moderately reliable for predicting the frequency of rainfall. This suggests that despite the evolution of local climate conditions, traditional indicators used in Sasih still hold empirical validity in identifying rainy periods.

Higher accuracy levels (60–70%) were observed particularly in Jembrana, northern Buleleng, and central Karangasem, areas characterized by highland or mountainous terrain. In these regions, the natural environmental cues used in traditional calendars (such as changes in wind, clouds, and animal behavior) are more pronounced and may align better with actual weather patterns. In contrast, lower accuracy levels (below 40%) were predominantly found in southern coastal areas, including southern Klungkung, Gianyar, and Nusa Penida. These regions may experience greater microclimatic variability or be more exposed to changing weather dynamics, such as coastal winds or sea-surface temperature anomalies, which are not captured in Sasih-based predictions.

The findings indicate that the Sasih calendar remains a useful reference for determining the onset and end of the rainy season, especially in areas with traditional farming systems and Subak-based irrigation. However, its application in lowland and coastal zones may require complementary meteorological inputs to enhance precision and reduce the risk of misaligned planting times. Thus, there is a clear need to promote integrated climate advisory systems, combining local ecological wisdom (like Sasih) with modern rainfall monitoring and seasonal forecasts. This hybrid approach could support adaptive agriculture in Bali amid ongoing climate variability and change.

CONCLUSION

The findings of this study reveal that the Sasih calendar continues to hold relevance in predicting rainfall frequency, particularly the number of rainy days, across various regions in Bali Province. The average accuracy of Sasih predictions for rainy days reached 62%, indicating a moderate level of agreement with actual BMKG observations. However, its accuracy in predicting rainfall volume was significantly lower, averaging only 37%, which suggests limited capacity in reflecting quantitative rainfall intensity. The spatial distribution analysis further shows that upland areas such as Jembrana, northern Buleleng, and central Karangasem tend to align more closely with Sasih predictions, while lowland and southern coastal regions, including Nusa Penida and southern Klungkung, exhibit lower levels of accuracy. These results highlight the importance of integrating traditional knowledge systems like Sasih with modern climate information, especially in regions where the performance of Sasih alone is insufficient. Overall, the Sasih calendar still offers value as a phenomenological indicator of seasonal patterns, but its predictive strength varies by location and should be supported by scientific data to ensure effective agricultural planning under changing climate conditions.

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