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How Robust Is Local Knowledge? The Role of *Pranata Mangsa* in Rice Production

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Abstract: The Bonokeling indigenous community of Banyumas District is still insisting on continuing its various traditions and local wisdom within various phases of life. One form of local wisdom possessed by the people of Bonokeling is the *pranata mangsa*, a calendrical system based on the apparent motion of the sun, which is widely used by Javanese farmers to determine planting times for agricultural commodities. This research was conducted in a bid to analyze the application of *pranata mangsa* and its impact on rice yield. In that respect, this qualitative-quantitative study uses primary data collected from interviews conducted among 50 farmers within the Bonokeling community and secondary data taken from the previous research and publications by related institutions. Data analysis used in the Wilcoxon signed-rank test. The result shows that there is no significant difference in the rice produced between farmers who used *pranata mangsa* and those who did not. This might probably be explained by increased uncertainty of the seasons due to climate change.
Keywords: local knowledge, pranata mangsa, *climate change*, *agriculture*, *cultural ecology*

1. Introduction

Climate change directly affects the agricultural sector regarding resources, infrastructure, production, food security, and farmer welfare. Climate fluctuations and variability, particularly extreme weather conditions, are among the major challenges and risks for crop production [1], [2]. Climate variability can be regarded as one type of stressor that may cause vulnerability and impact resilience [3]. According to the Ministry of Agriculture [4], climate change may exacerbate crop water deficit, shift in planting dates, reduction of area to plant and harvest, and higher risk of pest and loss by failure due to crop infestation.

Climate change has also impacted food crop agriculture in Central Java Province. As one of the country's major rice-producing parts, several counties that are centres of rice production have recorded 6-12 months with conditions ranging from dry to arid conditions [5]. This will undoubtedly affect rice production and food security both domestically and nationally. One such district in Central Java experiencing a declining trend in rice production is Banyumas. Over the past twelve years, rice production in the Banyumas has fluctuated, but with a general downward trend [6]. In terms of land area, there has been no significant change annually. Over the last ten years, the average annual rice production in Banyumas Regency has been 324,132.8 tons with an average land area of 63,656.6 hectares [6].

Small-scale farmers generally farm rice in Banyumas District with land ownership of less than 0.5 hectares [7]. The relatively traditional nature of rice farmers, combined with small land holdings, poses significant challenges in improving farmer welfare and capacity [8] regarding production and skills. Moreover, Banyumas District also hosts several indigenous communities vulnerable to climate change [9], [10]. An indigenous community or population is a native, originally, or first inhabitant of people in specific geographical areas and has ancestral origins combined with cultural identities and strong attachments to the land and environment [11], [12], [13].

One of the indigenous groups in Banyumas District is the Bonokeling community, centred in Pekuncen Village, Jatilawang Sub-district. The Bonokeling community upholds customs as the central pillar governing their social relationships and religious systems [14]. This community has strong familial bonds, and community leaders are closely connected to ancestral history. Most Bonokeling members are farmers who integrate tradition and customs into their agricultural practices. This local knowledge is embedded in various agricultural management practices, including rice farming.

Local or traditional knowledge, often referred to in the literature as traditional ecological knowledge, is understood as the accumulation of knowledge, practices, and beliefs that evolve with environmental changes and are passed down through generations [15], [16], [17]. Traditional knowledge can be

distinguished into two categories: knowledge inherited from generation to generation and shared by the majority of community members, and traditional knowledge acquired from individual experiences resulting from empirical observations by the community during their interactions with the environment [18]. Traditional ecological knowledge is a resource that contributes most to the adaptive capacity of the communities while facing external changes, especially those of climate change [19]; it complements scientific knowledge by providing practical experiences on living within ecosystems and responding to changes in those ecosystems [20].

One form of local knowledge used to determine planting seasons is pranata mangsa, a traditional Javanese belief system that guides the timing of planting and farming activities [21]. The Bonokeling community uses this to handle the uncertainty of seasonal patterns nowadays. This study analyses the effectiveness of using pranata mangsa in determining rice planting seasons on rice production in Pekuncen Village. The result is expected to provide useful information that will help improve farmers' adaptive capacity to climate change.

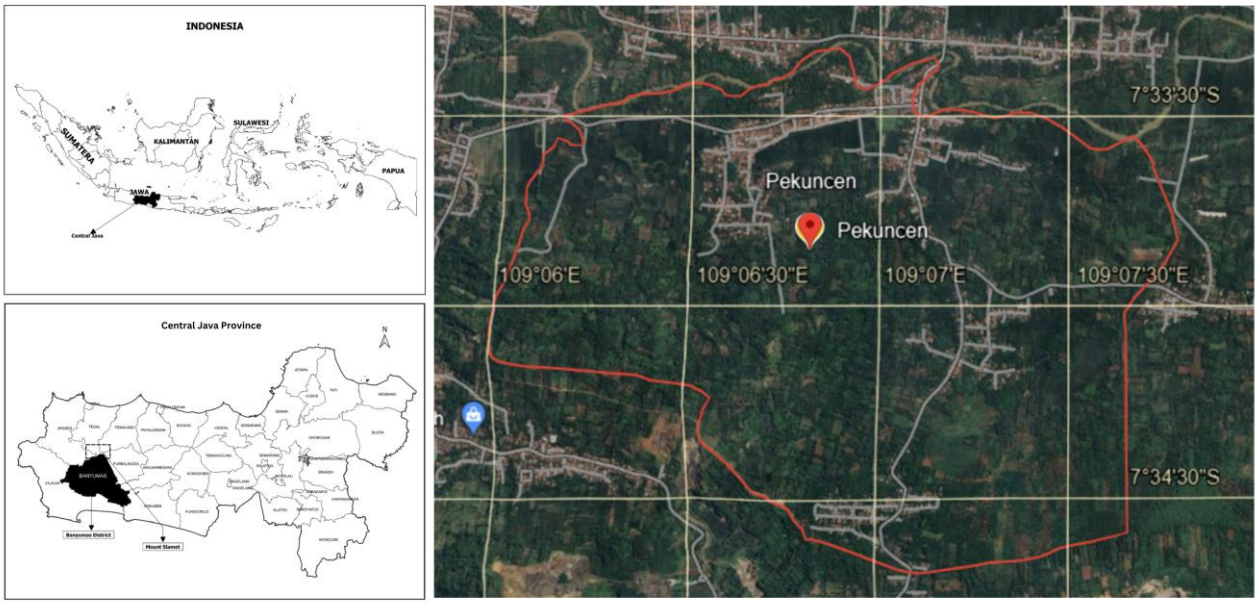

Figure 1. The Map of Pekuncen Village, Jatilawang Sub-district, Banyumas District, Central Java Province, Indonesia

2. Material and Methods

2.1. Study Area

This research was conducted in Pekuncen Village, Jatilawang Sub-district, Banyumas District, Central Java Province (Figure 1), from June to July 2024. Geographically, Pekuncen Village is located at coordinates 7°33'31"S 109°06'35"E. This location was chosen because it is the centre of the Bonokeling indigenous community. The area of Pekuncen Village reaches 4.9 km² with a population of 5,277 people. Rice is one of the staple crops that farmers in this area plant every year. The type of rice field in Pekuncen Village is rain-fed, with a total area of 65 hectares [22].

2.2. Data Collection

The research employs a case study approach, utilising qualitative and quantitative methods. The primary data will be obtained through interviews with 50 randomly selected farmers in the community of Bonokeling. It will use purposive sampling based on a specific criterion. For the respondents, a division can be made into those who are using prenatal manga as a reference for planting seasons and those not using it. The observational technique was also used to record information about rice farming and its application of prenatal manga in rice cultivation [23].

2.3. Data Analysis

After collecting qualitative data from field interviews, the data were reviewed, categorised, and filtered based on the research objectives. The qualitative data were then descriptively narrated to address the research aims. The quantitative data obtained were subsequently analysed and subjected to statistical testing to assess the impact of pranata mangsa on rice production. The Wilcoxon signed-rank test, also called the matched-pairs test, was used. The Wilcoxon signed-rank test is a non-parametric test used to compare two paired groups with ordinal or interval data that are not normally distributed [24], [25]. The following hypotheses were tested:

H0: $\mu X_1 - \mu X_2 = 0$, suggesting no significant difference in production based on the use of

pranata mangsa

Ha: $\mu X_1 - \mu X_2 \neq 0$, suggesting a significant difference in production based on the use of *pranata mangsa*

Testing criteria:

If the p-value is < 0.05, H0 is rejected and Ha is accepted

If the p-value is ≥ 0.05, H0 is accepted and Ha is rejected.

In this study, the impact of implementing prenatal mangsa on rice production is assessed by comparing respondents who apply prenatal mangsa with those who do not in their rice farming practices. The analysis focuses solely on the variable of prenatal mangsa implementation, while other variables affecting rice production are held constant (ceteris paribus).

3. Results and Discussion

3.1. Pranata Mangsa: An Overview

The history of pranata mangsa goes back a long time, thus linked to the many forms of traditional agricultural knowledge developed during the Majapahit and Mataram Kingdoms. The etymology of pranata mangsa is from the Javanese words pranata, which means rules, and mangsa, which means season or time. Thus, pranata mangsa is a seasonal calendar based on time and season, which are important to the Javanese people, especially farmers and fishermen. [26].

Pranata mangsa was introduced by the King of Surakarta, Sri Susuhunan Pakubuwono VII, in 1855 as a harvest calendar and system to organise agriculture [27]. The basic principle of pranata mangsa refers to the local cosmology, especially the annual north-south movement of the sun along the equator [27], [28]. The Javanese people are gifted with observing seasonal patterns, known as titen, where sharp observations of animal behaviours, plant developments, and natural environments are made. According to these indicators, the Pranata Mangsa calendar further divides the year into four main seasons and two minor seasons, ie, terang (bright), semplah (suffering), udan (rainy), and pangarep-arep (hopeful) [29].

The terang, or clear-skies season, lasts 82 days, while semplah, or hardship, lasts 99 days. Semplah is followed by the minor season of paceklik, a period of scarcity lasting 23 days. Then comes the udan, or rainy season, lasting 86 days, followed by pangarep-arep, 98 or 99 days, and finally the minor panèn season (harvest) in the last 23 days. The more correct pranata mangsa calendar is divided into 12 months or mangsa: kasa, karo, katelu, kapat, kalima, kanem, kapitu, kawolu, kasanga, kadhasa, sadha, and dhesta [30], [31], [32]. In Figure 2, the pranata mangsa calendar.

The basis of determination and the cycle and time computation are the main areas where the pranata mangsa calendar approach varies from the Gregorian calendar. First, direct measurements of the sun's position on Earth and weather patterns passed down through the centuries are the basis for the pranata mangsa calendar [28]. On the other hand, astronomical calculations that consider the Earth's axial tilt, revolution, and other celestial events provide the basis of the Gregorian calendar [33]. Second, the year is divided into 12 months (mangsa) by the pranata mangsa, with 23–43 days each month [34]. The Gregorian calendar, which likewise has 12 months, is comparable to this time division, but the number of days makes a difference. The Gregorian calendar has from 28 to 31 days; it also carries a leap year every four years [35]. Finally, on precision, the Gregorian calendar has been considered accurate because it has been scientifically calculated [36].

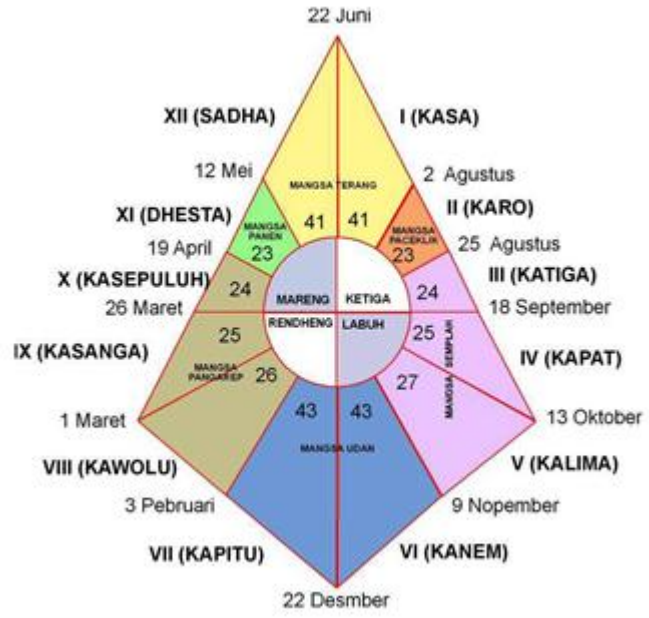

Figure 2. The *Pranata Mangsa* Calendar (Source:[27], [30], [32])

The practice of pranata mangsa continues today in some Javanese farming communities, including the indigenous people in Bonokeling. The belief system follows the timing for planting and harvesting activities based on observations of natural phenomena and seasonal changes [37]. Many also consider this belief outdated, but the community still keeps and passes it by word of mouth. Planting in harmony with the timing of pranata mangsa enables farmers to live in harmony with nature [34]. This system includes periods of fallow, where the land is left unexploited to restore its condition. The rotation of crops, as guided by pranata mangsa, is also seen as a mechanism to

enhance soil fertility [38], reduce pest and disease incidence [39], and foster a stable micro-ecosystem [40], [41].

Moreover, Pranata Mangsa is also utilised by farmers as a mechanism to mitigate risks and avoid high production costs [42]. Climate change-induced seasonal uncertainty has made it challenging for many farmers to determine optimal planting times, thereby increasing agricultural risks. The pranata mangsa is still relevant today, considering that it has been through many climate changes and technological improvements [43]. It is relevant because it is based on the experience and observations of past farmers, which coincide with present phenomena. Hence, pranata mangsa could guide farmers in understanding the pattern of the weather and the planting seasons accordingly [44].

3.2. The Application of Pranata Mangsa and Rice Production

Among the factors affecting rice production is accuracy in determining the planting time of the rice crop[45], [46], [47]. Choosing the right planting time and season can reduce the obstacles in planting and maintenance and lower the possibility of crop failure [45]. From the data gathered in interviews, it is determined that not all members of the indigenous community of Bonokeling use pranata mangsa to determine their planting time. Other members depend on other considerations, such as the planting calendar provided by agricultural extension workers, their observations, or imitation of the planting schedules adopted by other farmers.

Table 1. The Wilcoxon signed-rank test results

Respondent farmer groups	Average rice production (ton)	n	p value
Utilizing *pranata mangsa*	1.43	38	
Not utilizing *pranata mangsa*	1.40	12	
			0.333486

Significant α: 0,05%

Based on the results of testing by using the Wilcoxon/Mann-Whitney test, from Table 1, it is seen that the P-value is greater than 0.05, or it can be said that there is no significant difference in rice yield between rice farmers who use pranata mangsa and those who do not use it. The result is in line with the study of [48], which also found pranata mangsa was not a significant determinant of rice productivity. Climate change, which has been causing changes in weather variability and seasonal shifts, is suspected to be one of the factors that cause the traditional planting schedule determination using pranata mangsa to be less accurate [49]. This phenomenon is called "salah titen," or wrong observation triggered by weather and seasonal uncertainties. Recently, seasonal variability has been marked by changes in the onset of seasons and fluctuations in the intensity of seasonal rainfall [50]. In addition, the pranata mangsa passed down through generations experiences difficulty in maintaining accuracy because variations in interpretation from generation to generation result in the loss of precision.

Based on the results of the interviews, 36 per cent of the respondents mentioned that they no longer rely on pranata mangsa for planting seasons, while 64 per cent mentioned that they still do at present. The 36 people who are not using it said that pranata mangsa cannot be used for determining planting seasons due to the current unpredictability and dynamic shifts in weather patterns. This condition is based on the rainfall data of the Banyumas District. In 2015-2023, monthly variations in precipitation are significant [51]. The above condition is presented in Figure 3. Therefore, farmers must depend more on direct observations, such as monitoring natural indicators at the beginning of the planting season. Besides that, farmers also refer to advice from agricultural extension workers or other sources for decisions regarding planting season.

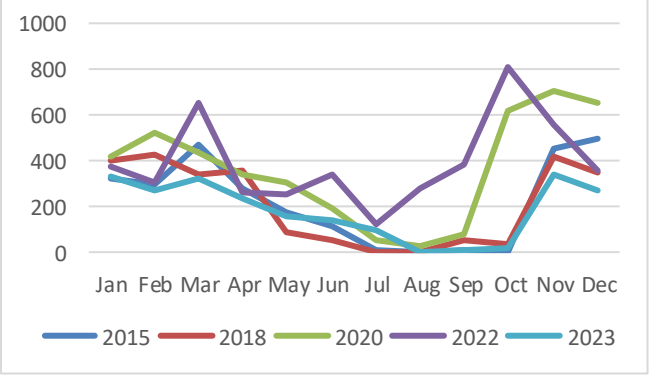

Figure 3. Average of Precipitation in Banyumas District (2015, 2018, 2020, 2022, 2023)

It may not directly influence the results, but pranata mangsa plays an important role in social life for maintaining traditional agriculture, preserving cultural heritage [36], and increasing the resilience of the indigenous community in Bonokeling. The local knowledge indirectly influences the rice yields, guiding farmers in more modern and scientifically informed ways of determining the planting times [52]. Further development of pranata mangsa can be done by integrating it with scientific approaches such as meteorology and modern agricultural practices [53]. Integrating pranata mangsa with scientific knowledge is expected to be useful in adjusting planting patterns, developing planting calendars, and selecting agricultural commodities by the climatic conditions of a region. It acts indirectly on adaptation and mitigation strategies against the adverse consequences of extreme hydrological events and thus may reinforce community resilience [27].

4. Conclusion

The Bonokeling community has close traditions in agriculture and still holds onto its norms and beliefs. Pranata mangsa is one sort of local wisdom still used by most of the communities in Bonokeling to predict planting time. However, statistical analysis using a Wilcoxon signed-rank test shows no significant difference in rice production between farmers who use pranata mangsa and those who do not. This could be because no significant difference in seasonal variability or shift may have occurred with climate change. From direct observations and oral traditions passed through generations, pranata mangsa is less precise in predicting the best times for planting rice. Whatever the case, pranata mangsa is an integral element in the community's social life in Bonokeling because of the place it occupies in their culture to reflect beliefs and knowledge relating to the interactions between natural systems and the divine. Integrating pranata mangsa with modern scientific knowledge could be a strategic approach to increasing its accuracy while preserving local knowledge, supporting traditional agriculture, and strengthening the resilience of indigenous communities.

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References

[1] G. Hoogenboom, “Contribution of agrometeorology to the simulation of crop production and its applications,” *Agric. For. Meteorol.*, vol. 103, no. 1–2, pp. 137–157, Jun. 2000, doi: 10.1016/S0168-1923(00)00108-8.

[2] W. R. Cline, *Global Warming and Agriculture: Impact Estimates by Country*. Peterson Institute, 2007.

[3] T. P. Purboningtyas, “Respon Rumah Tangga Petani Padi Terhadap Variabilitas Iklim: Studi Kasus Dua Desa Di Kabupaten Indramayu Jawa Barat,” Master Thesis, IPB University, Bogor, 2018.

[4] Ministry of Agriculture, *Adaptasi dan Mitigasi Dampak Perubahan Iklim Subsektor Hortikultura*. Jakarta: Kementerian Pertanian, 2022.

[5] N. Febrianti, “Analisis Fenomena Kekeringan Meteorologis Di Beberapa Daerah Sentra Produksi Padi Di Jawa Tengah,” *Pros. Semin. Nas. Penelit. Pendidik. dan Penerapan MIPA Fak. MIPA Univ. Negeri Yogyak.*, 2011.

[6] BPS Central Java, “Luas Panen, Produksi, dan Produktivitas Padi Menurut Kabupaten/Kota di Provinsi Jawa Tengah (Kuintal/Hektar), 2021-2023.” 2024. [Online]. Available: https://jateng.bps.go.id/indicator/53/463/1/luas-panen-produksi-dan-produktivitas-padi-menurut-kabupaten-kota-di-provinsi-jawa-tengah.html

[7] R. Satriani, A. Rosyad, and I. Widyarini, “Marketable dan Merketed Surplus Beras Di Kabupaten Banyumas,” *J. Ekon. Pertan. Dan Agribisnis JEPA*, vol. 5, no. 3, pp. 618–631, 2021.

[8] B. Budiyoko *et al.*, “Unlocking the sustainable livelihoods strategy for forest communities in the southern slope of Mount Slamet, Indonesia,” *Sustain. Debate*, vol. 15, no. 1, pp. 216–232, Apr. 2024, doi: 10.18472/SustDeb.v15n1.2024.52568.

[9] A. Aich, D. Dey, and A. Roy, “Climate change resilient agricultural practices: A learning experience from indigenous communities over India,” *PLOS Sustain. Transform.*, vol. 1, no. 7, p. e0000022, Jul. 2022, doi: 10.1371/journal.pstr.0000022.

[10] K. Thomas *et al.*, “Explaining differential vulnerability to climate change: A social science review,” *WIREs Clim. Change*, vol. 10, no. 2, p. e565, Mar. 2019, doi: 10.1002/wcc.565.

[11] S. Barlindhaug and J. Corbett, “Living a Long Way from Home: Communicating Land-related Knowledge in Dispersed Indigenous Communities, an Alternative Approach,” *Acta Boreal.*, vol. 31, no. 1, pp. 1–24, Jan. 2014, doi: 10.1080/08003831.2014.904619.

[12] R. Datta, “A relational theoretical framework and meanings of land, nature, and sustainability for research with Indigenous communities,” *Local Environ.*, vol. 20, no. 1,

pp. 102–113, Jan. 2015, doi: 10.1080/13549839.2013.818957.
[13] J. D. Ford, N. King, E. K. Galappaththi, T. Pearce, G. McDowell, and S. L. Harper, "The Resilience of Indigenous Peoples to Environmental Change," *One Earth*, vol. 2, no. 6, pp. 532–543, Jun. 2020, doi: 10.1016/j.oneear.2020.05.014.
[14] B. H. S. Purwana, Sukari, and Sujarno, *Sistem Religi Komunitas Adat Bonokeling di Desa Pekuncen, Kecamatan Jatilawang, Kabupaten Banyumas*. Yogyakarta: Balai Pelestarian Nilai Budaya (BPNB) Daerah Istimewa Yogyakarta, 2015.
[15] S. Aswani, A. Lemahieu, and W. H. H. Sauer, "Global trends of local ecological knowledge and future implications," *PLOS ONE*, vol. 13, no. 4, p. e0195440, Apr. 2018, doi: 10.1371/journal.pone.0195440.
[16] M. K. Nelson and D. Shilling, Eds., *Traditional Ecological Knowledge: Learning from Indigenous Practices for Environmental Sustainability*, 1st ed. Cambridge University Press, 2018. doi: 10.1017/9781108552998.
[17] W. F. Afrianto *et al.*, "Local Knowledge and Practice of Entomophagy in Datengan Village, Kediri, East Java, Indonesia," *Sriwij. J. Environ.*, vol. 7, no. 3, pp. 148–155, Dec. 2022, doi: 10.22135/sje.2022.7.3.148-155.
[18] J. P. Brosius, G. W. Lovelace, and G. G. Marten, "Ethnoecology: an approach to understanding traditional agricultural knowledge.," in *Traditional agriculture in Southeast Asia. A human ecology perspective.*, London: Westview Press, 1986.
[19] S. Boillat and F. Berkes, "Perception and Interpretation of Climate Change among Quechua Farmers of Bolivia: Indigenous Knowledge as a Resource for Adaptive Capacity," *Ecol. Soc.*, vol. 18, no. 4, p. art21, 2013, doi: 10.5751/ES-05894-180421.
[20] F. Berkes, M. Kislalioglu, C. Folke, and M. Gadgil, "Exploring the Basic Ecological Unit: Ecosystem Like-Concept in Traditional Societies," *Ecosystem*, vol. 1, no. 5, pp. 409–415, 1998.
[21] N. Khotimah, "Pranata mangsa and the sustainability of agricultural land resources management in Imogiri sub-district of Bantul regency," *IOP Conf. Ser. Earth Environ. Sci.*, vol. 338, no. 1, p. 012029, Nov. 2019, doi: 10.1088/1755-1315/338/1/012029.
[22] BPS Banyumas, "Kecamatan Jatilawang Dalam Angka 2023." 2023. [Online]. Available: https://banyumaskab.bps.go.id/publication/2023/09/26/2da322e5bf8bc3c6b01292c7/kecamatan-jatilawang-dalam-angka-2023.html
[23] O. A. Adeoye-Olatunde and N. L. Olenik, "Research and scholarly methods: Semi-structured interviews," *JACCP J. Am. Coll. Clin. Pharm.*, vol. 4, no. 10, pp. 1358–1367, Oct. 2021, doi: 10.1002/jac5.1441.
[24] N. Masruroh and W. Hariyanto, "Analisis Reaksi Pasar dan Kinerja Saham Sebelum dan Sesudah Pengumuman Pembelian Kembali Saham (Buy Back) Periode 2020 - 2022," *Innov. Technol. Methodical Res. J.*, vol. 1, no. 3, p. 17, Jan. 2024, doi: 10.47134/innovative.v1i3.60.
[25] R. Fibriafi and R. Ismawati, "Effect of Soybean, Rice Bran, and Seaweed Flour (Gracilaria sp) Substitution on The Acceptibility, Iron and Vitamin B12 of Brownies," *Media Gizi Indones.*, vol. 13, no. 1, pp. 12–19, 2018.
[26] H. O. Salsabila, "The Existence of Pranata Mangsa Calendar in the Midst of Global Climate," *Proceeding Int. Conf. Sharia Law*, vol. 1, no. 1, pp. 85–89, 2022.
[27] M. K. Zaki, K. Noda, K. Ito, K. Komariah, S. Sumani, and M. Senge, "Adaptation to Extreme Hydrological Events by Javanese Society through Local Knowledge," *Sustainability*, vol. 12, no. 24, p. 10373, Dec. 2020, doi: 10.3390/su122410373.
[28] S. Sobirin, "Pranata Mangsa dan Budaya Kearifan Lingkungan," *J. Budaya Nusant.*, vol. 2, no. 1, pp. 250–264, Sep. 2018, doi: 10.36456/b.nusantara.vol2.no1.a1719.
[29] A. Luthfiyana, "Studi komparatif prakiraan musim dalam penanggalan Jawa Pranata Mangsa dengan Badan Meteorologi Klimatologi dan Geofisika (BMKG) pada tahun 2015-2018 : studi kasus di Dusun Dadapan Desa Mangli Kecamatan Kaliangkrik Kabupaten Magelang," Undergraduate Thesis, UIN Walisongo, Semarang, 2019.
[30] Sindhunata, *Pranata Mangsa*. Jakarta: Kepustakaan Populer Gramedia bekerja sama dengan Bentara Budaya, 2011.
[31] M. H. Riza, "Sundial Horizontal dalam Penentuan Penanggalan Jawa Pranata Mangsa," *Ulul Albab J. Studi Dan Penelit. Huk. Islam*, vol. 2, no. 1, p. 119, Nov. 2018, doi: 10.30659/jua.v2i1.3016.
[32] R. D. Handayani, Z. K. Prasetyo, and I. Wilujeng, *Pranata Mangsa Dalam Tinjauan Sains*. Penerbit BRIN, 2023. doi: 10.55981/brin.691.
[33] I. P. Sari, "Analisa Pergeseran Kalender Gregorian Menjadi Kalender Dunia," *Al-Afaq J. Ilmu Falak Dan Astron.*, vol. 4, no. 1, pp. 20–31, 2022.
[34] S. Harini, Sumarmi, and A. G. Wicaksono, "Manfaat Penggunaan Pranata Mangsa Bagi Petani Desa Mojoreno Kabupaten Wonogiri,"

J. Inada, vol. 2, no. 1, pp. 82–97, 2019.

[35] M. Saifulloh, L. A. Farah, and J. Roesuldi, "Studi Komparasi Sejarah dan Aturan Kalender Tahun Masehi: Julian dan Gregorian," *AAL – AFAQ J. Ilmu Falak Dan Astron.*, vol. 4, no. 1, 2022.

[36] D. W. Febrianti, N. Rohmah, S. Almadini, and D. P. Sari, "Pranata Mangsa dan Dinamika Gerak Semu Matahari: Perspektif Ilmu Astronomi dan Kearifan Lokal Jawa," *Biochephy J. Sci. Educ.*, vol. 4, no. 1, pp. 30–36, 2024, doi: https://doi.org/10.52562/biochephy.v4i1.1063.

[37] N. P. N. E. Lestari, M. K. S. Budhi, and I. M. Suidarma, *The Subak Economy: Masa Depan Ekonomi Agraria Bali lewat Penguatan Lembaga Usaha Ekonomi Subak*. Bandung: Nilacakra, 2023.

[38] K. K. Shah *et al.*, "Diversified Crop Rotation: An Approach for Sustainable Agriculture Production," *Adv. Agric.*, vol. 2021, pp. 1–9, Jul. 2021, doi: 10.1155/2021/8924087.

[39] M. Jalli *et al.*, "Effects of Crop Rotation on Spring Wheat Yield and Pest Occurrence in Different Tillage Systems: A Multi-Year Experiment in Finnish Growing Conditions," *Front. Sustain. Food Syst.*, vol. 5, p. 647335, Jul. 2021, doi: 10.3389/fsufs.2021.647335.

[40] K. Hoeffner *et al.*, "Legacy effects of temporary grassland in annual crop rotation on soil ecosystem services," *Sci. Total Environ.*, vol. 780, p. 146140, Aug. 2021, doi: 10.1016/j.scitotenv.2021.146140.

[41] S. Ouda, A. Zohry, and T. Noreldin, "Crop Rotation Maintains Soil Sustainability," in *Crop Rotation*, Cham: Springer International Publishing, 2018, pp. 55–76. doi: 10.1007/978-3-030-05351-2_4.

[42] N. Witasari, "Astha Brata Dan Pranata Mangsa: Alam dan Relasi Kuasa Dalam Konteks Agraria Di Jawa," *Paramita Hist. Stud. J.*, vol. 25, no. 2, p. 225, Feb. 2016, doi: 10.15294/paramita.v25i2.5138.

[43] L. A. Kusuma *et al.*, "Traditional ecological knowledge and utilization of rice in Sukoharjo District, Central Java, Indonesia," *Int. J. Bonorowo Wetl.*, vol. 13, no. 2, Dec. 2023, doi: 10.13057/bonorowo/w130205.

[44] R. C. I. Prahmana, W. Yunianto, M. Rosa, and D. C. Orey, "Ethnomathematics: Pranatamangsa System and The Birth-Death Ceremonial In Yogyakarta," *J. Math. Educ.*, vol. 12, no. 1, pp. 93–112, Jan. 2021, doi: 10.22342/jme.12.1.11745.93-112.

[45] H. M. Safitri and A. D. Yulianto, "Dampak Masalah Jadwal Tanam Padi Terhadap Perubahan Sosial Masyarakat Di Desa Dukuhmencek Kecamatan Sukorambi Kabupaten Jember," *J. Agric. Socioecon. Bus.*, vol. 2, no. 1, 2019.

[46] P. A. J. Van Oort and S. J. Zwart, "Impacts of climate change on rice production in Africa and causes of simulated yield changes," *Glob. Change Biol.*, vol. 24, no. 3, pp. 1029–1045, Mar. 2018, doi: 10.1111/gcb.13967.

[47] U. Khanal, C. Wilson, V.-N. Hoang, and B. Lee, "Farmers' Adaptation to Climate Change, Its Determinants and Impacts on Rice Yield in Nepal," *Ecol. Econ.*, vol. 144, pp. 139–147, Feb. 2018, doi: 10.1016/j.ecolecon.2017.08.006.

[48] D. M. Mirza, "The Difference In Productivity of Rice Farmer As The Impact of Owl and Pranatamangsa Utilization," Undergraduate Thesis, Universitas Kristen Satya Wacana, Salatiga, 2016.

[49] O. Wihanjono and E. Nurjani, "Kajian Pengaruh Variabilitas Hujan Musiman dan Produktivitas Padi Sawah Tadah Hujan Di Kabupaten Purworejo, Provinsi Jawa Tengah," *J. Bumi Indones.*, 2013.

[50] J. L. McBride, M. R. Haylock, and N. Nicholls, "Relationships between the Maritime Continent Heat Source and the El Niño–Southern Oscillation Phenomenon," *J. Clim.*, vol. 16, no. 17, pp. 2905–2914, Sep. 2003, doi: 10.1175/1520-0442(2003)016<2905:RBTMCH>2.0.CO;2.

[51] BPS Banyumas, "Jumlah Curah Hujan dan Hari Hujan Menurut Bulan di Kabupaten Banyumas, 2023." 2024. [Online]. Available: https://banyumaskab.bps.go.id/id/statistics-table/1/NjA1IzE=/jumlah-curah-hujan-dan-hari-hujan-menurut-bulan-di-kabupaten-banyumas-2023.html

[52] W. Oktasari, "Peran Penyuluh Pertanian Dalam Adopsi Inovasi Budidaya Padi Metode SRI Berbasis Kearifan Lokal Pranata Mangsa di Kabupaten Purworejo," Master Thesis, Universitas Gadjah Mada, Yogyakarta, 2015.

[53] K. Hartomo, E. Sediyono, S. Yulianto, and S. Bistok, "Updated Pranata Mangsa: Recombination of Local Knowledge and Agro Meteorology using Fuzzy Logic for Determining Planting Pattern," *Int. J. Comput. Sci. Issues IJCSI*, vol. 9, no. 6, pp. 367–372, 2012.