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Systematic Mapping and Meta Analysis of Maize Soybean Intercropping Studies in Indonesia

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Abstract. Soybean is an important food commodity in Indonesia because it is the main raw material for tofu and tempeh, two major protein sources widely consumed by the population. However, domestic soybean production remains far below national demand resulting in heavy dependence on imports. In contrast maize is increasingly preferred by farmers due to its higher productivity and a more stable economic value. Therefore, maize–soybean intercropping has emerged as a promising strategy to improve land-use efficiency while increasing soybean production without reducing maize cultivation. This study systematically mapped and synthesized maize–soybean intercropping research in Indonesia and conducted a meta-analysis of Land Equivalent Ratio LER values reported across studies. Literature searches using Scopus, Web of Science, and Google Scholar identified 179 eligible publications published between 1978 and 2023. Most studies focused on agronomic factors such as variety selection spacing arrangement and fertilizer management. Meta-analysis showed average LER values of 1.47 ± 0.046 for maize–soybean intercropping and 1.36 ± 0.081 for maize–mung bean intercropping indicating advantages over monoculture systems. However, inconsistencies in methodology and reporting standards limited study comparability and sustainability assessments. Future research should integrate ecological, social, and long-term economic indicators alongside standardized reporting frameworks to strengthen evidence-based intercropping recommendations nationally for sustainable agriculture.

Keywords: Intercropping; Land Equivalent Ratio; Maize; Soybean; Systematic Mapping.

1. BACKGROUND

Soybean plays a crucial role in Indonesian food systems because it is the main ingredient used in traditional foods such as tofu and tempeh (Ministry of Trade Indonesia, 2022; BSN-Badan Standardisasi Nasional, 2012). Despite its importance, domestic soybean production has consistently failed to satisfy national demand (FAOSTAT, 2023). Indonesia imports large quantities of soybean annually, creating vulnerability to international market fluctuations and supply instability.

Several factors contribute to low soybean productivity in Indonesia. Agricultural land conversion, declining soil fertility, unstable soybean prices, and lower profitability relative to competing crops all discourage soybean cultivation (Figure 1). In contrast, maize production has expanded rapidly due to higher yields, government support programs, and stronger market demand. Farmers therefore increasingly prioritize maize cultivation over soybean production.

Intercropping systems have long been proposed as a strategy to improve land productivity and diversify production systems. Intercropping refers to the cultivation of two or more crops simultaneously on the same land during part or all of their growth cycle (Raza et al., 2022). In maize–soybean intercropping systems, maize acts as the dominant cereal crop while soybean functions as a legume capable of contributing biological nitrogen fixation.

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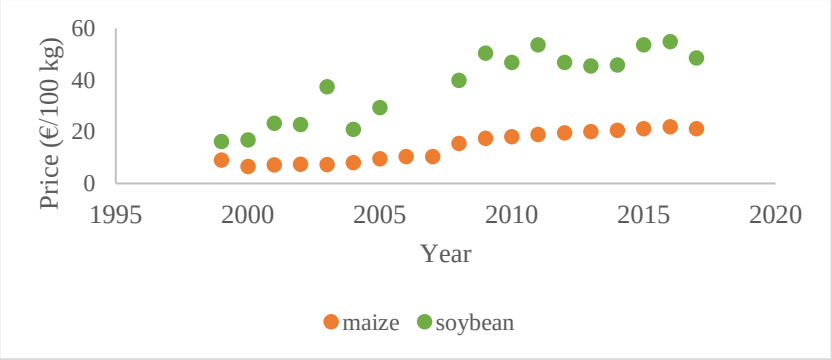

Figure 1. Price of soybean and maize per 100 kg from year 1999 until 2017 in Jambi Province (BPS Jambi, 2022). Soybean price fluctuated more than maize price.

Numerous studies have demonstrated that intercropping systems can improve resource-use efficiency by optimizing the utilization of sunlight, water, nutrients, and growing space. Additional benefits include improved soil fertility, weed suppression, reduced pest pressure, increased biodiversity, and improved resilience against climate variability. Consequently, maize soybean intercropping has become one of the most widely studied intercropping systems in tropical agricultural regions (Zulfahmi et al., 2023).

Land Equivalent Ratio (LER) is one of the most frequently used indicators in intercropping studies because it measures the relative land-use efficiency of intercropping compared with monoculture systems. An LER value greater than one indicates that intercropping requires less land area to achieve equivalent production compared with sole cropping.

Although maize–soybean intercropping research has expanded considerably in Indonesia during recent decades, no comprehensive synthesis has previously summarized the methodological approaches, agronomic factors, and overall intercropping performance across studies. Therefore, this study aimed to systematically map maizesoybean intercropping literature in Indonesia and evaluate overall LER performance through metaanalysis.

2. THEORETICAL REVIEW

Intercropping systems have been widely studied in sustainable agriculture because they increase ecological interactions among plant species. According to ecological theory, crop species with contrasting growth habits may utilize environmental resources more efficiently when grown together than when cultivated separately.

Maize and soybean possess complementary characteristics that make them suitable for intercropping systems (Mardian et al., 2020). Maize is a tall cereal crop with high nitrogen demand and strong competitive ability for light. Soybean, meanwhile, is a shorter legume crop capable of fixing atmospheric nitrogen through symbiotic relationships with Rhizobium

bacteria. This complementary interaction may reduce competition and improve overall productivity (Anggraeni et al., 2020).

Previous global meta-analyses have demonstrated positive effects of cereal legume intercropping on yield stability and land-use efficiency. Xu et al. (2020) reported that maize soybean intercropping increased nitrogen-use efficiency compared with monoculture systems. Similarly, Yu et al. (2015) found that temporal niche differentiation contributed significantly to increased LER values in annual intercropping systems.

In Indonesia, intercropping research has mainly focused on agronomic optimization such as planting density, row arrangement, fertilizer application, and varietal selection (Sija et al., 2020). However, broader sustainability indicators including biodiversity, soil biological health, carbon sequestration, and farmer adoption behavior remain less explored.

3. METODE PENELITIAN

This study followed the systematic mapping framework developed by the Collaboration for Environmental Evidence (CEE) (Collaboration for Envrionmental Evidence, 2015). Literature searches were conducted between August and September 2023 using Scopus, Web of Science, and Google Scholar databases. Search terms included combinations of keywords such as “soybean”, “maize”, “corn”, “intercropping”, “Indonesia”, “kedelai”, “jagung”, and “tumpangsari”. Additional exclusion terms such as “skripsi”, “diploma”, and “undergraduate thesis” were used to minimize inclusion of non-peer-reviewed documents.

Studies were included if they met the following criteria:

a. Conducted in Indonesia.
b. Investigated maize–soybean or maize–mung bean intercropping systems.
c. Reported empirical field or survey data.
d. Were available as journal articles, conference proceedings, graduate theses, or institutional publications.

Each study was reviewed and coded according to publication year, location, methodological approach, agronomic variables studied, yield reporting, LER values, and additional ecological or economic indicators. Land Equivalent Ratio (LER) values were extracted directly when reported. For studies that provided complete yield information but did not report LER, values were calculated using the standard formula:

$$LER = \frac{Y_{maize}}{M_{maize}} + \frac{Y_{soybean\ or\ mungbean}}{M_{soybean\ or\ mungbean}} \qquad \text{(i)}$$

Y = yields in the intercrop
M = yields in sole crop

Meta-analysis was conducted using RStudio. Exploratory analysis included descriptive statistics and visualization of publication trends. Linear mixed-effects models were selected because they better accounted for between-study variability and repeated observations within studies (Alonzo & Pepe, 2007).

4. RESULTS AND DISCUSSION

A total of 179 publications fulfilled the inclusion criteria. The earliest identified study was published in 1978, although publication frequency remained relatively low until approximately 2012. After this period, intercropping research activity increased substantially, reflecting growing interest in sustainable agricultural intensification. Most studies were conducted on Java Island, particularly in West Java, Central Java, and East Java (Figure 2). Additional studies were identified from Sumatra, Sulawesi, Bali, and West Nusa Tenggara. This geographic concentration reflects both the importance of maize and soybean production in Java and the stronger research infrastructure available in these regions.

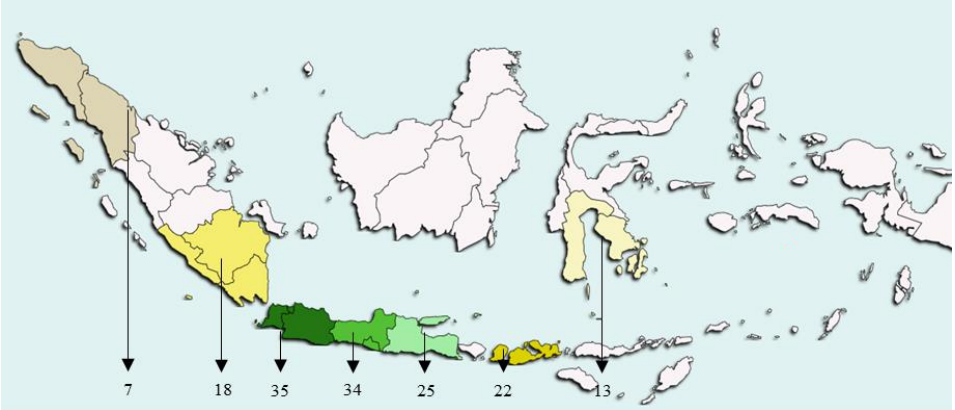

Figure 2. The distribution of maize-soybean intercropping study locations in Indonesia.

Field experimentation dominated the literature, accounting for 161 studies. Survey-based approaches represented only a small proportion of publications. Experimental studies primarily evaluated agronomic treatments such as spacing arrangement, fertilizer application, planting schedule, varietal selection, and cropping density. Soybean variety was one of the most frequently investigated factors because researchers aimed to identify varieties tolerant to shading and competition under intercropping conditions. Spacing arrangement was also widely studied because maize canopy structure strongly influences soybean access to sunlight.

Out of the 179 included studies, 117 reported yield or LER information. However, reporting quality varied considerably. Several studies reported only intercrop yields without monoculture controls, while others reported LER values without sufficient yield information for verification (Table 1). Meta-analysis showed that maize–soybean intercropping generally

produced LER values greater than one. The average LER value of 1.47 ± 0.046 indicated substantial land-use efficiency advantages compared with monoculture systems. Maize–mung bean systems also showed positive performance with average LER values of 1.36 ± 0.081.

Table 1. Detailed composition of publications on reporting the LER and yield.

Yield Reported for	Yield only	Yield & LER	LER only
Both species in both systems	5	41	
One species in both systems			
soybean in both systems	7		
maize in both systems	2	4	
mung bean in both system	1		
One species in both systems & the other species only in intercropping			
soybean in both systems - maize in intercropping		2	
maize in both systems - soybean/mung bean in intercropping	2	3	
Both species in intercropping	26	5	
One species in intercropping			
soybean in intercropping	5	1	
maize in intercropping	4	2	
LER only			7

These findings are consistent with global intercropping literature demonstrating that cereallegume combinations often improve productivity through complementary resource utilization. Differences in canopy structure, rooting depth, and nutrient acquisition likely contributed to the positive intercropping effects observed. Beyond agronomic indicators, some studies also investigated economic performance (Figure 3). Reported indicators included production costs, gross revenue, benefit-cost ratio, and labor efficiency. Several studies demonstrated that intercropping could improve farmer profitability, particularly under conditions of limited land availability.

Nevertheless, important research gaps remain. Ecological indicators such as soil microbial diversity, biodiversity enhancement, carbon dynamics, and long-term sustainability were rarely investigated. Similarly, social dimensions including farmer perceptions, labor dynamics, and adoption constraints were substantially underrepresented. Another major issue identified in this review was the lack of standardized reporting. Many publications failed to report important methodological details such as planting density, fertilizer rates, planting dates, and monoculture control yields. This inconsistency reduced transparency and limited opportunities for more robust quantitative synthesis.

5. CONCLUSION

Maize soybean intercropping research in Indonesia has increased substantially over the past decade, particularly in relation to agronomic optimization and land use efficiency. Meta-analysis results consistently demonstrated positive LER values above one, confirming that intercropping systems generally outperform monoculture systems in terms of land productivity.

However, substantial heterogeneity among studies and inconsistent reporting standards remains important limitations within the existing literature. Most studies focused primarily on short-term agronomic performance, while ecological sustainability and socioeconomic dimensions remained insufficiently explored.

Future research should adopt standardized reporting frameworks including complete yield data, planting density, fertilizer application, and management details. Researchers should also expand investigations into ecological resilience, farmer adoption behavior, and long-term sustainability outcomes in order to support more holistic agricultural development strategies in Indonesia.

DAFTAR REFERENSI

Alonzo, T. A., & Pepe, M. S. (2007). Development and evaluation of classifiers. In *Methods in molecular biology* (Vol. 404). https://doi.org/10.1007/978-1-59745-530-5_6

Anggraeni, L., Trisnaningsih, U., & Wahyuni, S. (2020). Pertumbuhan dan hasil sembilan kultivar kedelai (*Glycine max* (L.) Merrill) dalam sistem tanam tumpangsari dengan jagung manis (*Zea mays* Saccharata Strut). *Agroswagati Jurnal Agronomi, 8*(1), 28–36. https://doi.org/10.33603/agroswagati.v8i1.4057

Brooker, R. W., Bennett, A. E., Cong, W., Daniell, T. J., George, T. S., Hallett, P. D., Hawes, C., Iannetta, P. P. M., Jones, H. G., Karley, A. J., Li, L., McKenzie, B. M., Pakeman, R. J., Paterson, E., Schöb, C., Shen, J., Squire, G., Watson, C., Zhang, C., & White, P. J. (2015). Improving intercropping: A synthesis of research in agronomy, plant physiology and ecology. *New Phytologist, 206*(1), 107–117. https://doi.org/10.1111/nph.13132

BSN–Badan Standardisasi Nasional. (2012). *Tempe: Persembahan Indonesia untuk dunia*. PUSIDO BSN. https://bsn.go.id/uploads/download/Booklet_tempe-printed21.pdf

BPS Jambi. (2022). *Average producer prices of food crops (rupiah/quintal), 2015–2017* [Data set]. https://jambi.bps.go.id/indicator/36/567/1/rata-rata-harga-produsen-tanaman-pangan-.html

Collaboration for Environmental Evidence. (2015). *Systematic maps: Instructions for authors*. EE Journal. http://www.environmentalevidence.org/journal

Demie, D. T., et al. (2022). Mixture × genotype effects in cereal–legume intercropping systems. *Frontiers in Plant Science, 13*.

Directorate of Food Crops Horticulture and Estate Crops Statistics. (2022). *Analysis of maize and soybean productivity in Indonesia (The result of crop cutting survey)* (Vol. 5203029). BPS-Statistics Indonesia.

https://www.bps.go.id/publication/2022/12/16/9e87d65dae851717a1af5784/analisis-produktivitas-jagung-dan-kedelai-di-indonesia-2021.html

Food and Agriculture Organization of the United Nations. (2023). *FAOSTAT: Crops and livestock products*. https://www.fao.org/faostat/en/#data/QCL

Lithourgidis, A. S., Dordas, C. A., Damalas, C. A., & Vlachostergios, D. (2011). Annual intercrops: An alternative pathway for sustainable agriculture. *Australian Journal of Crop Science*, *5*(4), 396–410.

Mardian, I., Suriadi, A., & Barat, L. (2020). Optimalisasi lahan dengan usaha tani tumpangsari kedelai dan jagung pada lahan sawah beriklim kering Kabupaten Bima (Intercropping of soybean and maize for land optimization on farming system in low lands with dry climate in Bima Regency). In *Prosiding Seminar Nasional Lahan Suboptimal ke-8 Tahun 2020* (pp. 556–564).

Ministry of Trade Indonesia. (2022). Analisis perkembangan harga kedelai. In *Analisis perkembangan harga bahan pangan pokok, barang penting, ritel modern, dan e-commerce di pasar domestik dan international* (pp. 43–52). Pusat Pengkajian Perdagangan Dalam Negeri. https://bkperdag.kemendag.go.id/referensi/download_analisishbp/eyJpZCI6ImZmUVwvWDc4TTRyaHBSYmMrbzdHQXJRPT0iLCJkYXRhIjoiV0NoMSJ9

Raza, M. A., Yasin, H. S., Gul, H., Qin, R., Mohi Ud Din, A., Khalid, M. H. B., Hussain, S., Gitari, H., Saeed, A., Wang, J., Rezaei-Chiyaneh, E., Sabagh, A. E., Manzoor, A., Fatima, A., Ahmad, S., Yang, F., Skalicky, M., & Yang, W. (2022). Maize/soybean strip intercropping produces higher crop yields and saves water under semi-arid conditions. *Frontiers in Plant Science*, *13*, Article 1006720. https://doi.org/10.3389/fpls.2022.1006720

Sija, P., Sugito, Y., Suryanto, A., & Hariyono, D. (2020). Radiation use efficiency of maize (*Zea mays* L.) on different varieties and intercropping with mungbean in the rainy season. *Agrivita*, *42*(3), 462–471. https://doi.org/10.17503/agrivita.v42i3.2665

Xu, Z., et al. (2020). Intercropping maize and soybean increases efficiency of land and fertilizer nitrogen use: A meta-analysis. *Field Crops Research*, *246*, Article 107661. https://doi.org/10.1016/j.fcr.2019.107661

Yu, Y., et al. (2015). Temporal niche differentiation increases the land equivalent ratio of annual intercrops: A meta-analysis. *Field Crops Research*, *184*, 133–144. https://doi.org/10.1016/j.fcr.2015.09.010

Zulfahmi, Syarif, A., & Dwipa, I. (2023). Productivity of several soybean varieties (*Glycine max* L.) based on pruning of corn (*Zea mays* L.) leaves. *Jurnal Pembelajaran dan Biologi Nukleus*, *9*(2), 219–231. https://doi.org/10.36987/jpbn.v9i2.4682