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Geographic Information System – Based Spatial Information, distribution and demand analysis of Agricultural tools and machinery in Kubu Raya Regency, Indonesia

Ekawati[1*], Rahmatullah Rizieq[1] and Ajun Purwanto[2]

[1] *University of Panca Bhakti, Faculty of Agriculture, Science and Technology, Pontianak, Indonesia*
[2] *PGRI Pontianak University, Pontianak Indonesia*
[*]*Corresponding author:* ekawatiupb@gmail.com

Abstract

Ekawati, Rizieq, R. & Purwanto, A. (2025). Geographic Information System – Based Spatial Information, distribution and demand analysis of Agricultural tools and machinery in Kubu Raya Regency, Indonesia. *Bulg. J. Agric. Sci., 31*(4), 673–680

Agricultural mechanization plays a crucial role in enhancing productivity and efficiency in rice farming. This study, conducted in Kubu Raya Regency, West Kalimantan, evaluates the adequacy of agricultural machinery and the demand for key equipment, including hand tractors, power threshers, and combine harvesters. Using Geographic Information Systems (GIS), to analyze distribution patterns, the study highlights a significant disparity between the availability and demand for these machines, with several sub-districts facing acute shortages. The analysis, based on paddy field areas and production capacities, demonstrates that insufficient mechanization hinders efficient land preparation, harvesting, and post-harvest processing. The results indicate that the limited supply of modern agricultural machinery adversely affects rice productivity and farmers' profitability in the region. The findings underscore the urgent need for better allocation and distribution of agricultural machinery to promote sustainable agricultural development. This study offers critical insights for policymakers, to enhance agricultural efficiency, and improve farmer welfare in Kubu Raya Regency.

Keywords: Demand for Agricultural Machinery; Rice Production; Spatial Information; Rice Farming

Introduction

Agriculture is a key pillar in the economies of many countries worldwide, including Indonesia. The agricultural sector is the largest provider of employment. Most of the people working in the agricultural sector, are still traditional and household-scale in terms of land management (Harini et al., 2015; Xu et al., 2022). Family farming is economically incapable of supporting decent welfare on par with other sectors, in an atmosphere of free trade (Harini et al., 2015). In addition, the selection of agricultural commodities also determines the success of production and productivity of the agricultural sector, which will directly affect farmers' income levels (Chi et al., 2022). Government policies that support the improvement of farmers' welfare are needed, especially in the provision of agricultural inputs, such as fertilizers, pesticides, seeds, irrigation systems, and other agricultural machinery.

The use of agricultural machinery in rice farming is very important in helping farmers face the increasingly complex, and diverse challenges associated with modern agriculture (Katayama et al., 2015; Shin et al., 2013). Agricultural tools and machinery are needed for tillage, planting, harvesting, post-harvest, and processing. So the availability of appropriate agricultural tools and machinery in number and type is very important (Ma and Sun, 2020; Xu et al., 2022). The

use of agricultural tools and machinery has a positive impact on increasing production, the quality of agricultural production (Ekawati et al., 2018; Haryono et al., 2021; Iacomi and Popescu, 2015; Sims et al., 2016; Zhou and Ma, 2022) time efficiency, labor, costs, reducing yield losses, increasing added value (Iacomi and Popescu, 2015; Sims et al., 2016).

Kubu Raya District is one of the central production areas and food barns of West Kalimantan Province. In 2023, Kubu Raya Regency contributed 8.09% to the total rice production in West Kalimantan. However, during 2020 – 2023, there was a significant decrease in rice production from 107 589 tonnes in 2020, to 55 707 tonnes in 2023, or a decrease of 48.22% (BPS Kalbar, 2024). This decline in production in Kubu Raya Regency is the highest compared to other districts in West Kalimantan.

Much agricultural tools and machinery government assistance has been distributed under the management of UPJA/ farmer groups/farmer groups. During the 2017 – 2021 period, as many as 1848 units of two-wheeled tractors, and 168 units of four-wheeled tractors have been distributed in the West Kalimantan region (Kementerian Pertanian RI, 2022). It is not yet known whether the agricultural tools and machinery have been distributed, according to the needs of UPJA / Poktan/Gapoktan in each district in West Kalimantan. The distribution of agricultural tools and machinery assistance according to location needs is very important in optimizing the use of agricultural tools and machinery, to achieve increased productivity, efficiency, and welfare of farmers and maintain agricultural sustainability. This is following the results of the research (Mardinata and Zulkifli, 2014), that the average hand tractor can complete tillage 2.492 h/ha and in the rotating pattern is 4.651 h/ha, increasing rice productivity by 667 kg/ha (Suyatno et al., 2018), the combined harvester can save approximately 50% of labor use (Januarti et al., 2018) increasing at least 15% of farmers' opinion (Pundising et al., 2021).

The distribution of agricultural tools and machinery in Kubu Raya Regency has not been uneven, and has not been following the needs seen from the existence of a machine that has been distributed for one year, but has never been operated. The performance of existing agricultural tools and machinery is not optimal, many are in a damaged condition due to lack of maintenance, while economically UPJA as a management unit is feasible to cultivate (Ekawati et al., 2021; Santoso et al., 2018).

Geographic data plays a key role in understanding the distribution and needs of agricultural tools and machinery in different regions. GIS technology can provide deeper and more accurate information to support management decisions, that prioritize data-driven decision-making through the use of predictive models and geographic data (Purwanto et al., 2024; Purwanto and Paiman, 2024). GIS technology that focuses on spatial data strongly supports more efficient (Breus & Skok, 2021; Chi et al., 2022; Rounsevell et al., 2003), and sustainable UPJA management, in predicting the needs of agricultural tools and machinery, in line with the needs and challenges in the agricultural sector, to increase productivity and effectiveness of UPJA management over time (temporal).

The research is intended to overcome the lack of information with the main objective of calculating the coverage area, and the need for agricultural tools and machinery and mapping the status of agricultural tools and machinery adequacy at the Kubu Raya Regency level. This research uses Geographic Information Systems (GIS) to comprehensively present data (Breus and Skok, 2021; Pichura et al., 2023). The results of this study are expected to be the basis for policymakers in formulating sustainable agricultural development plans in Kubu Raya Regency.

Material and Method

Area

This research was conducted in Kubu Raya Regency, West Kalimantan from August to November, 2024. Astronomically, Kubu Raya Regency is located between 109° 03′ 11,48″ East Longitude to 109° 58′ 23,50″ East Longitude and 0° 13′ 47,16″ North Latitude to 1° 00′ 51,38″ South Latitude. Kubu Raya Regency area is shaped in land by 8,568 km^2 (856,8 ha). In terms of geographic position, Kubu Raya Regency has boundaries as follows: West – Natuna Sea; East – Ketapang Regency and Sanggau Regency; North – Mempawah Regency, Pontianak municipality, and Landak Regency; South – Kayong Utara Regency. The study area can be seen in Figure 1 below.

The data used in this study, are data on the area of rice fields in Kubu Raya Regency from 2022 and the data on the number of agricultural equipment and machinery (2-wheeled tractors, 4-wheeled tractors, transplanter and combine harvester) in Kubu Raya Regency from 2023. Sub-district coordinate data of farmers/farmer groups/Agricultural Machinery Service Business/ combined farmer groups, who own 2-wheeled tractors, 4-wheeled tractors, transplanters, and combine harvesters. The location of the selected sub-districts is carried out surveys, and field observations by taking a sample of farmer groups that have the complete agricultural tools and machinery to find out the problems, currently faced in the development of agricultural tools and machinery for food production activities, so that constraints in the development of agricultural tools

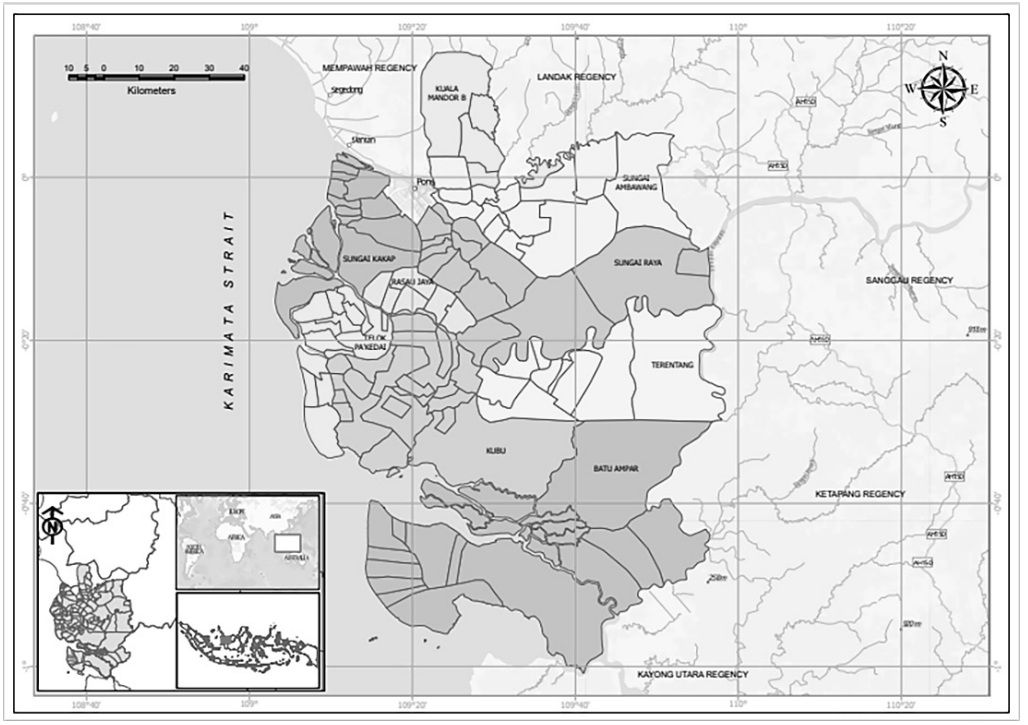

Fig. 1. Study Area

and machinery and solutions can be provided. The data obtained is then processed using ArcGIS Pro software, to produce distribution maps and priority maps of agricultural tools and machinery needs.

Data Analysis

Analysis of the calculation of the need for agricultural tools and machinery by comparing the total area of paddy fields, with the number of agricultural tools and machines, available in each Agricultural Machinery Service Business, farmer group, and analyzing how much the contribution of increasing the number of agricultural tools and machines to rice production in each Agricultural Machinery Service Business. The need for agricultural tools and machinery is calculated using the following formula (Asnawati, 2017):

$$\text{Total Needs of soil cultivation agricultural tools and machinery} = \frac{(LS \times CF)}{(Ka \times tE \times E)}$$

Total need for agricultural tools and machinery (Unit)
LS = Rice Field Area (ha);
CF = Factor Coefficient (assuming the value is 1);
Ka = Work Capacity (ha/h);
tE = Effective Working Day (Day);
E = Effective Working Hours (ha/day).

$$\text{The number of post-harvest agricultural tools and machinery needed} = \frac{(P \times CF)}{(Ka \times tE \times E)}$$

Total need for agricultural tools and machinery (Unit)
P = Paddy Field Production (ha);
CF = Factor Coefficient (assuming the value is 1);
Ka = Work Capacity (ha/day);
tE = Effective Working Day (Day);
E = Effective Working Hours (h/day).

For efficiency and ease in calculating the above formula, a simpler tool is used in GIS, namely Spatial Analyst Tools using the Map Algebra Tool.

Results and Discussion

Based on the primary and secondary data collected, the number of agricultural machinery available in Kubu Raya Regency, broken down by district, is presented in Table 1. All of the machinery was provided through government assistance, either from the central or regional government. Recently, this assistance has also been distributed through the allocation of funds from the proposals of national, provincial, and district-level parliamentary members. However, due to the nature of this assistance, the distribution of the machinery has been uneven, and in some cases, the equipment provided is not suited to the local conditions.

Table 1. The Distribution of Agricultural Tools and Machinery in Kubu Raya Regency 2017–2023

Sub District	Number of Agricultural Tools and Machinery Available (Unit)								
	HS	HT	PA	CV	MPR	PT	CH	RT	RMU
Batu Ampar	107	32	32	2	3	25	0	0	1
Kuala Mandor B	7	14	12	2	0	3	0	0	0
Kubu	32	34	18	2	1	20	1	0	0
Rasau Jaya	35	44	19	14	0	16	1	3	0
Sungai Ambawang	49	34	47	10	0	10	0	0	0
Sungai Kakap	149	76	88	23	14	57	12	2	0
Sungai Raya	89	65	68	20	4	64	3	0	0
Teluk Pakedai	19	20	21	3	1	15	0	0	1
Terentang	25	19	27	8	3	27	1	0	0
Total	512	338	332	84	26	237	18	5	2

Source: Simluhtan (2017-2023) and Primary Data (processed, 2024)
Description: HS (Hand Sprayer); HT (Hand Tractor); PA (Water Pump); CV (Cultivator); MPR (Mower); PT (Power Treasher); CH (Combine Harvester); RT (Rice Transplanter); RMU (Rice Milling Unit)

The overall spatial distribution of land cover in the study area can be seen in Figure 2. The results of the GIS analysis using ArcGIS Pro show that the spatial distribution identified eleven types of land cover in the study area, as seen in Figure 2 below. The rice fields span 54 937.91 ha, which accounts for 6% of the total area. The breakdown of this area across the nine sub-districts is presented in Table 2 below.

The distribution of agricultural machinery, especially hand tractors, power threshers, and combine harvesters, was identified as critical by Focus Group Discussions (FGD) in nine districts. These tools are indispensable for enhancing productivity and efficiency in rice farming.

Hand tractors are essential for efficient land preparation in rice farming, significantly enhancing productivity. They allow farmers to cultivate land faster and more effi-

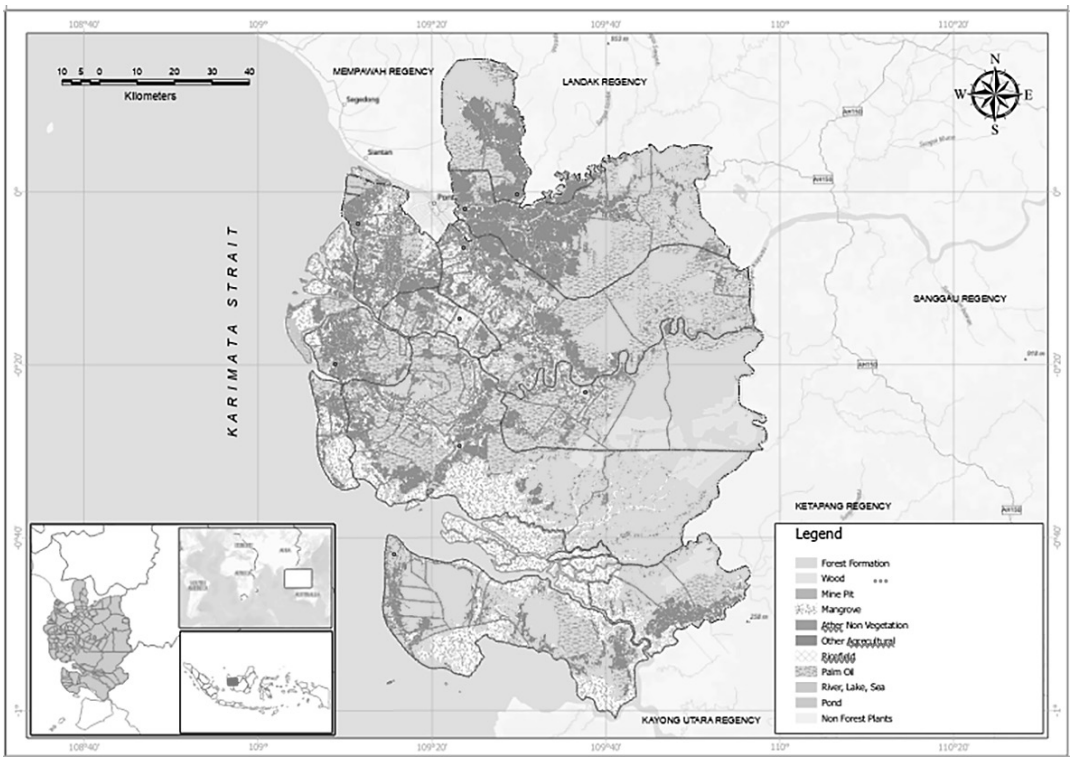

Fig. 2. Land Use Land Cover Study Area

Table 2. Needs Analysis of Agricultural Tools and Machinery

Sub District	Rice Field Area (Ha)	Hand Traktor (unit)		Power Treasher (unit)		Combine Harvester (Unit)	
		Availability	Needs	Availability	Needs	Availability	Needs
Batu Ampar	3554.60	32	272	25	121	0	26
Kuala Mandor B	314.58	14	24	3	11	0	2
Kubu	10289.98	34	788	20	350	1	75
Rasau Jaya	6585.06	44	504	16	224	1	48
Sungai Ambawang	597.03	34	46	10	20	0	4
Sungai Kakap	12257.80	76	939	57	417	10	89
Sungai Raya	14590.13	65	1117	64	497	3	106
Teluk Pakedai	4331.89	20	332	15	148	0	31
Terentang	2452.84	19	188	27	84	1	18
Total	54973.91	338	4209	237	1872	16	399

Tractor working capacity = 0.0544 ha/hour (Manik et al., 2014); Power treasher capacity 414 kg/hour (Suhendra et al., 2019); Actual performance capacity combine Harvester 0,574 ha/hour (Murjana et al., 2021).

ciently compared to traditional methods relying on manual labor. Studies highlight the importance of hand tractors in improving work efficiency. For instance, Fauzan (2020) demonstrated that the economic efficiency of rice farming is closely linked to the proper use of technology, particularly hand tractors, to maximize yields. This equipment enables faster land preparation, leading to higher productivity and increased harvests.

Moreover, hand tractors help reduce labor costs. Bakari (2019) found that manual labor could account for over 70% of total variable costs in rice farming. The use of hand tractors lowers farmers' dependence on manual labor, reducing operational costs and increasing profits, which in turn allows resources to be reallocated to other production areas. The uniform tillage achieved with hand tractors also improves soil conditions and promoting healthier plant growth, as noted by Santoso et al. (2022). Better soil conditions result in higher yields.

Power threshers efficiently separate rice grains from straw, which boosts productivity and enhances the quality of harvested rice. Musilah et al. (2021) demonstrated that power threshers reduce the time and labor needed for harvesting, which is particularly advantageous during periods of unpredictable weather. Khomsah et al. (2022) further emphasized that power threshers not only enhance technical efficiency, but also improve grain quality by minimizing physical damage during the threshing process.

The use of power threshers also reduces production costs by lowering labor requirements, as demonstrated by Suryandari and Rahayuningsih (2020). Arifin (2023) supported this finding, showing that efficiency gains from mechanized threshing have a positive impact on farmers' incomes. The improved grain quality achieved through the use of threshers, results in better market prices, ultimately improving farmers' economic well-being (Wahyuningsih et al., 2021).

Combine harvesters streamline rice farming by integrating several processes – cutting, threshing, and cleaning in a single step. This technology significantly reduces the time required for harvesting, as Durroh (2020) showed, enabling farmers to avoid losses caused by weather disruptions. Additionally, Prihantini (2024) found that combine harvesters positively correlate with increased farmer income.

In terms of harvest efficiency, combine harvesters reduce grain loss during harvest. Prayudhi et al. (2021) reported a grain loss rate of only 10.91% when using combine harvesters, much lower than the rate associated with manual methods. Reduced harvest losses contribute to higher yields and increased income for farmers, improving the overall economic viability of rice farming.

Demand for Agricultural Machinery

The demand for hand tractors, power threshers, and combine harvesters based on GIS analysis is presented in Table 2.

Based on Table 2, the demand for agricultural machinery (Alsintan) across nine districts in Kubu Raya Regency, reveals a significant gap between the availability and demand for key equipment, particularly hand tractors, power threshers, and combine harvesters. The demand for hand tractors is considerably higher than the available supply, with 4209 units needed across the regency, while only 338 are available. Districts with large rice fields, such as Sungai Raya and Sungai Kakap, exhibit the highest demand, requiring 1117 and 939 units, respectively. Despite having some tractors available (76 units in Sungai Kakap and 65 in Sungai Raya), these numbers fall far short of what is required. Similarly, Kubu district shows a demand of 788 units, but has only 34 available, highlighting the under-support of this district's large rice fields. This shortage of hand tractors is likely to

slow land preparation and negatively impact overall agricultural productivity.

The demand for power threshers also shows a similar shortfall, with 1872 units needed, but only 237 available across all districts. Again, Sungai Raya and Sungai Kakap have the highest demand at 497 and 417 units, respectively, but their available supply is only 64 and 57 units. Other districts, like Kubu and Rasau Jaya, also experience significant gaps, with Kubu requiring 350 units but only having 20 available. The availability of combine harvesters is even more critical, with only 16 units distributed across the nine districts, while the total demand is 399 units. Districts like Sungai Raya, Sungai Kakap, and Kubu, which require 106, 89, and 75 units, respectively, are severely under-equipped, further hampering their ability to conduct efficient harvesting operations. The lack of sufficient combine harvesters could significantly delay the harvesting process, increasing the risk of crop losses due to adverse weather conditions.

The overall shortage of Alsintan in Kubu Raya has a direct impact on rice productivity. Over the past five years, rice productivity in the region has fluctuated, peaking at 30.68 quintals per hectare in 2020, before declining to 29 quintals per hectare in 2022 and 2023. This productivity remains well below the national average of 52.85 quintals per hectare in 2023. Key factors contributing to this decline include the limited availability of modern agricultural technology and suboptimal land conditions. The lack of adequate machinery, especially in districts like Kubu, has resulted in inefficient farming operations and reduced productivity.

To address this issue, it is critical to focus on increasing the procurement and distribution of appropriate agricultural machinery. The adoption of modern tools and equipment would expedite farming processes, improve yields, and reduce labor costs. As noted by (Loko et al., 2022), inadequate mechanization is a major constraint on smallholder farmers, leading to delays and reduced cultivation. Similarly, (Chen et al., 2022) highlights that the adoption of agricultural machinery not only enhances production efficiency, but also lowers operational costs. Furthermore, timely mechanization is crucial for maintaining rice quality, as (Shen et al., 2023) points out, since delays caused by insufficient equipment can reduce the marketability of the crop.

The lack of modern machinery also hinders the adoption of improved agricultural practices, as (Putri et al., 2024) suggests that mechanization plays a critical role in increasing production. Inadequate mechanization widens the gap between attainable and potential yields, as (Bhandari et al., 2023) points out, and this situation exacerbates food insecurity, as has been noted by Aldillah (2016). Thus, addressing the shortage of agricultural tools and machinery is essential for improving rice productivity and ensuring food security in Kubu Raya. Investment in mechanization will not only boost yields, but also enhance the overall efficiency and sustainability of rice farming in the region.

Conclusion

This study underscores the crucial role of agricultural mechanization in boosting the efficiency, productivity, and sustainability of rice farming in Kubu Raya Regency, West Kalimantan. It highlights the significant demand for modern equipment, such as hand tractors, power threshers, and combine harvesters, which are essential at various stages of the farming process. However, there is a noticeable shortfall in the availability of these machines, resulting in delays in land preparation, harvesting, and reduced overall productivity. This shortage aggravates other challenges, such as labor deficits and unpredictable weather conditions, leading to lower rice yields and decreased farmer incomes. The adoption of advanced machinery not only improves operational efficiency but also enhances rice quality, increasing profitability and market competitiveness. Moreover, mechanization fosters sustainable agricultural practices by improving soil quality, expediting land preparation, and enabling more effective farm management. The study calls for policy initiatives to ensure a fair distribution of farming equipment across districts, which would help maximize productivity and support rural economic development. Closing these gaps is essential for achieving long-term food security and strengthening the agricultural sector's resilience in Kubu Raya Regency.

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Conflict of Interest

Our research contributes significantly to the field of agricultural technology and rural development. The manuscript has not been published or submitted elsewhere, and

all authors have approved the manuscript, and agree with its submission to Bulgarian Jurnal of Agricultural Science. We declare no conflicts of interest.

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