ORIGINAL ARTICLE

Geospatial Clustering Pattern of Blood Type Diversity Among Voluntary Blood Donor in Bojonegoro, Indonesia

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ABSTRACT

Introduction: Blood service is responsible for ensuring the volume of blood supply is sufficient to gratify the demand, and Indonesia is no exception as a country with immense population. The diversity of ABO blood groups influenced by a myriad of factors. Understanding these multifaceted influences is essential for comprehensively analysing the geographic clustering patterns of blood type. This study aimed to describe the spatial variation in blood donation based on allelic distribution of ABO blood group in population. **Materials and methods:** This study analysed 45,096 voluntary blood donors in Bojonegoro, Indonesia who successfully donated whole blood at least once in 2022-2023 at the Red Cross Indonesia (IRC). Donors were geographically grouped according to their districts of residence. The data used to create the geospatial distribution arounds Bojonegoro administrative area and collected routinely by Bojonegoro Blood Donation Units Using QGIS 2.34.2. **Results:** The distribution of blood donor mapped 28 districts and spread out expected geographical factor such as the distance and ease of access to Blood Donation Unit. The prevalence of A, B, AB and O blood types are 22.56%, 31.02%, 6.74% and 39.40%, respectively. The most dominant subdistrict for all blood types is Bojonegoro, while the lowest is Kedewan. **Conclusion:** The analysis identified Bojonegoro has highest donors for all blood types, while blood type O shows highest prevalent among A, B and AB blood type, reached 39.40%. The most remote area contributes adequate amount of blood due the demographic and geographic condition.
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INTRODUCTION

Most blood donation studies have focused on individual-level characteristics as donors (1–3). Blood donor pre-selection criteria are designed to allow only eligible individuals to donate while preventing the risk of Transfusion Transmissible Infections (TTIs) (4,5). Donors who meet the required health and safety standards are permitted to give blood. Blood donation is a crucial act of saving lives, but it must be voluntary and cannot be compelled by those in need(6). In some countries, blood donors are classified into voluntary donors and replacement donors, where family members donate on behalf of a patient (7,8).

Human blood plays a critical role in modern medical procedures for save and extend life (6,9,10). Blood service responsible for ensuring the volume of blood supply is sufficient to gratify the demand, and Indonesia is no exception as a country with big population. In Indonesia, the non-profit charitable organization responsible for collecting and distributing the national blood supply called as Palang Merah Indonesia (PMI) or Indonesia Red Cross (IRC). IRC operates based on guidelines that stipulate blood donation as a voluntary act, accessible to individuals in good health, aged 17 years or older, and weighing at least 50 kg (11–14).

Indonesia covers a large area (1,916,906.77 km2) and consists of many islands, amounting to 16,056(15). Because of the large numbers and the geographical variability, the number of blood donors in each region varies considerably. It has been suggested that the proportion of blood donors in Indonesia depends on the different population groups and should cover up to 2% of the population (10,14).

The demographic characteristics of blood donor populations are dynamic and changeable, mirroring

shifts in the demographics of the overall population, adjustments to donor selection criteria, and periodic donor recruitment strategy (16–19). Comprehending shifts within the blood donor population offers crucial insights for monitoring donor recruitment and contextualizes observed trends in donor distribution among both new and returning blood donors (20,21). This data serves as valuable evidence for designing programs aimed at encouraging donors to contribute more regularly. Additionally, it informs strategies to recruit and retain first-time blood donors, who play a vital role in offsetting the loss of donors who cease donation voluntarily or due to illness.

Limited research has explored community-level disparities in blood donation. The demographic and environmental characteristics of neighbourhoods, communities, cities, and counties could potentially impact the prevalence of blood donors, repeat donors, and accessibility to donation facilities within a particular area (22–24). Understanding these variations is crucial for developing targeted strategies to increase blood donation rates and ensure equitable access to donation services across diverse communities.

The diversity of ABO and Rh blood groups varies across different regions in the world, influenced by a myriad of factors including geography, population history, customs, race, culture, and ethnicity (22,25,26). These factors represent the core genetic makeup of populations, as well as dietary habits and other cultural practices. As populations migrated and interacted over centuries, genetic admixture occurred, leading to unique blood group distributions in various regions (4,27). Additionally, environmental factors such as disease prevalence may have exerted selective pressures, further shaping the distribution of blood types (28). Understanding these multifaceted influences is essential for comprehensively analysing the geographic clustering patterns of blood type diversity and their implications for healthcare and population genetics.

Bojonegoro Regency is an area located in the East Java Province, situated at coordinates 7°09'09"S 111°53'13"E/7.1525°S 111.8869°E/-7.1525; 111.8869., with a distance of approximately 110 km from the provincial capital, Surabaya. The topography dominated by hilly terrain in the south (South Limestone Mountains) and north (North Limestone Mountains), flanking the lowlands along the Bengawan Solo River, a fertile agricultural area. The average land surface in Bojonegoro Regency is relatively low, ranging from 25m to 500m above sea level with an average slope of less than 2%. The rainfall in this region is generally uneven, ranging from 1,500 mm to 2,500 mm per year (15).

The area of Bojonegoro Regency is around 230,706 hectares with a population of 1,363,058 people in 2023. Administratively, this region is bordered by Tuban Regency to the north, Madiun, Nganjuk, and Jombang Regencies to the south, Lamongan Regency to the east, and Ngawi and Blora Regencies (Central Java Province) to the west. Bojonegoro Regency is divided into 28 districts, comprising 9 districts in the west area, 8 in the north area, 6 in the south area, and 5 in the west area of Bojonegoro (29).

Bojonegoro regency is an area supported by mostly village like areas in the west, south, and east direction. The west area of Bojonegoro is easily accessible and become the national route from Central Java Province to East Java Province. This area surrounded nine districts, Margomulyo, Tambakrejo, Ngraho, Purwosari, Padangan, Kasiman, Gayam, Malo, Kedewan. The west area has similar access with the east direction, and has become the primary route for nearby regency and narrowed to Surabaya. This area is divided into five distrrict; Kanor, Baureno, Sumberrejo, Kepohbaru, and Kedungadem. The busiest area of Bojonegoro Regency is located in the North direction and supported by eight districts. These districts are Trucuk, Kalitidu, Bojonegoro, Kapas, Balen, Dander, Ngasem and Sukosewu. Bojonegoro in the south direction surrounded by six districts; Ngambon, Bubulan, Sugihwaras, Sekar, Gondang, and Temayang (15,29).

Understanding the geospatial clustering pattern of blood type diversity among blood donors is crucial for ensuring effective and targeted blood donation campaigns, and optimizing blood supply management systems (16,30). Blood type diversity refers to the distribution and prevalence of different blood types within specific geographic regions (31). This diversity can vary significantly based on factors such as population demographics and environmental influences (23,32,33). Bojonegoro is a regency with diverse socio-geographic characteristics, including densely populated urban centers and remote rural areas. Previous studies have shown that geographic factors such as accessibility, population density, and proximity to donation centers influence donor distribution and blood availability (23,31). These variations may also correlate with the uneven prevalence of certain blood types, which is influenced by both genetic factors and population structure (29). A geospatial approach to understanding donor characteristics, including blood group distribution, is essential to identify high and low concentration areas and to develop targeted outreach and supply management interventions.

In Bojonegoro, blood stock not obtained equally from 28 districts. The distribution of blood component supply around 11 hospitals in Bojonegoro and also needed by hospitals outside the regency, especially for rare blood groups. The blood distribution for transfusion in those hospitals require different travel times, from minutes to hours. Consequently, the current mapping of voluntary blood donors according to blood type diversity has not

yet proven effective in maintaining a stable blood supply and ensuring timely distribution.

By examining the geospatial clustering patterns of blood type diversity among blood donors in Bojonegoro, researchers can gain insights into regional variations in blood supply and demand dynamics, identify areas with specific blood type supply and needs, and develop strategies to address these needs effectively. This study sets the stage for exploring the geographic clustering patterns of blood type diversity among blood donors and highlights the importance of such analyses in public health and blood transfusion medicine. Our aims in the paper to describe the spatial variation in blood donation based on allelic distribution of ABO blood group in population.

MATERIALS AND METHODS

This study analysed 45,096 municipalities in Bojonegoro, Indonesia and calculated a donor rate for each of these municipalities, defined as the ratio of inhabitants who successfully donated whole blood at least once in 2022-2023 at the Red Cross Blood Service. Data collection using secondary data provided by Bojonegoro Blood Service Units and donors already confirmed as voluntary donor by filling out the informed consent form. Donations in outer area were not included in this study. As blood donation in Indonesia is restricted to persons between 17 and 65 years, only the population figure in this age group in the denominator was included when determining the donor rate and calculating both crude and population-weighted donor rates.

Donors were geographically grouped according to their village of residence. This data was collected by filling out the pre-donation form and checking personal identification during blood donation. Some donors registered as temporary residence but stayed in Bojonegoro for times to study and work. The data used to create the geospatial distribution arounds the Bojonegoro administrative area and collected routinely by Bojonegoro Blood Donation Units. All the subjects were blood groups A, B, AB, and O with respect to positive rhesus and donated their blood on IRC in Bojonegoro and mobile units. The population shared the same culture, positive Rh across all samples, and local language. In order to visualize the geographic distribution of blood type diversity among blood donor in Bojonegoro, QGIS 2.34.2 was applied. The data performed in numeric and percentage (Table 1) and analyzed statistically using chi-square test.

Ethical Clearance

This study was approved by Research Ethics Committee, STIKES Guna Bangsa Yogyakarta No. 062/KEPK/III/2024.

RESULTS

We assess 45,096 voluntary blood donors during 2022-2023 who came to IRC and scheduled mobile unit around the area. The distribution of blood donors in Bojonegoro is shown in Table I and performed geographically in Figure 1. The present study was assumed to assess the allelic distribution of ABO blood groups in Bojonegoro Regency. The result showed that the O blood group is the most prevalent reached 39.4% followed by B and A blood groups respectively (31.02% and 22.56%), while AB is the rarest blood group (6.74%). The study showed a different distribution of each blood group prevalent among 28 districts and grouped into four categories following Indonesia Blood Donor Services Guideline; prodigious (over 500), considerable (201-500), adequate (11-200), and deficient (less than 10). According to the categories, no area listed as deficient for all blood types, while adequate, considerable, and prodigious of blood types across different areas showed blood type A was found in 8, 14, and 6 areas, while blood type B was present in 7, 11, and 10 areas. Meanwhile, blood type AB was relatively rare, being identified in only 26, 1, and 1 area. In contrast, blood type O was observed in 5, 11, and 12 areas. Those number follow the adequate, considerable, and prodigious, respectively.

Table I: ABO Blood Group Distribution by Donor Recidency

Donors Recidency	Total	A (%)	B (%)	AB (%)	O (%)
Balen	2707	553(20,43)	869(32,10)	165(6,10)	1111(41,04)
Baureno	2265	452(19,96)	735 (32,45)	147(6,49)	924(40,79)
Bojonegoro	8517	1923(22,58)	2636(30,95)	619(7,27)	3304(38,79)
Bubulan	284	62(21,83)	83(29,23)	21(7,39)	116(40,85)
Dander	3126	738(23,61)	976(31,22)	198(6,33)	1209(38,68)
Gayam	1183	293(24,77)	360(30,43)	71(6,00)	457(38,63)
Gondang	503	111(22,07)	156(31,01)	30(5,96)	205(40,76)
Kalitidu	2276	529(23,24)	699(30,71)	143(6,28)	897(39,41)
Kanor	1962	415(21,15)	573(29,20)	123(6,27)	847(43,17)
Kapas	2742	629(22,94)	806(29,39)	206(7,51)	1099(40,08)
Kasiman	683	161(23,57)	209(30,60)	49(7,17)	264(38,65)

CONTINUE

Table I: ABO Blood Group Distribution by Donor Recidency (CONT.)

Donors Recidency	Total	A (%)	B (%)	AB (%)	O (%)
kedewan	145	31(21,38)	53(36,55)	13(8,97)	48(33,10)
Kedungadem	1704	403(23,65)	518(30,40)	116(6,81)	654(38,38)
Kepohbaru	1560	345(22,12)	502(32,18)	93(5,96)	619(39,68)
Malo	835	178(21,32)	280(33,53)	52(6,23)	323(38,68)
Margomulyo	234	43(18,38)	83(35,47)	13(5,56)	95(40,60)
Ngambon	504	125(24,80)	158(31,35)	42(8,33)	179(35,52)
Ngasem	1510	330(21,85)	479(31,72)	116(7,68)	584(38,68)
Ngraho	1206	278(23,05)	369(30,60)	103(8,54)	454(37,65)
Padangan	1449	304(20,98)	485(33,47)	111(7,66)	541(37,34)
Purwosari	1005	244(24,28)	294(29,25)	71(7,06)	391(38,91)
Sekar	519	111(21,39)	186(35,84)	30(5,78)	190(36,61)
Sugihwaras	936	227(24,25)	282(30,13)	54(5,77)	373(39,85)
Sukosewu	1200	292(24,33)	350(29,17)	81(6,75)	475(39,58)
Sumberejo	3148	671(21,32)	1005(31,93)	184(5,84)	1281 (40,69)
Tambakrejo	1113	302(27,13)	304(27,31)	73(6,56)	434(38,99)
Temayang	587	135(23,00)	169(28,79)	39(6,64)	242(41,23)
Trucuk	1193	289(24,22)	370(31,01)	77(6,45)	452(37,89)

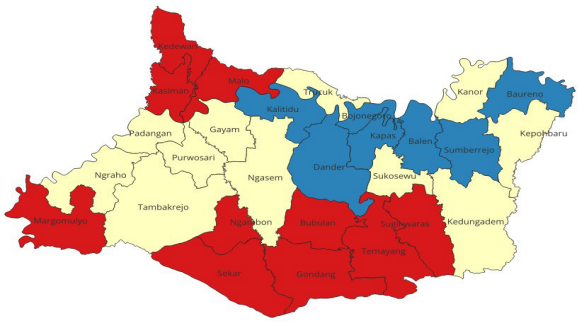

Figure 1: Geospatial distribution of Blood Donor (red color defines prodigious amounts of blood donor, blue color defines considerable amounts of blood donor, and yellow color define adequate amounts of blood donor.)

These findings indicate that blood type AB has the lowest distribution, while blood types A, B, and O show relatively more widespread presence across multiple areas. The variation in distribution suggests potential genetic, demographic, or environmental influences affecting blood group prevalence. The specific distribution of blood type shown in Figure 2.

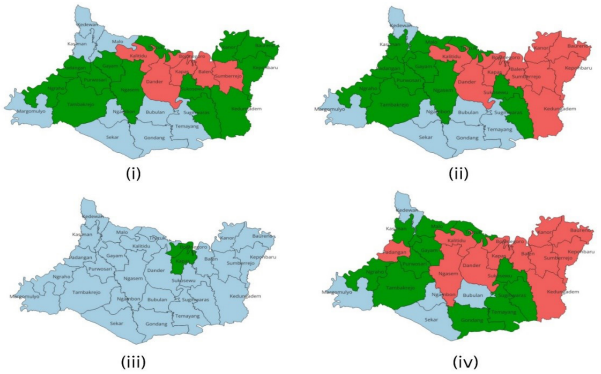

Figure 2: Allele frequency of blood type distribution (i) A, (ii) B, (iii) AB, and (iv) O (orange color defines prodigious amounts of blood donor, green color defines considerable amounts of blood donor, and blue color define adequate amounts of blood donor).

ABO frequency was not significantly different (P=0.40) between donor residency. As compare of blood donors, Bojonegoro had a significantly higher amounts of donor of all blood type, O (3,304), A (1,923), B (2,636) and AB (619), while Kedewan has a lower amounts of donor for

all blood type, O (48), A (31), B (53) and AB (13).

DISCUSSION

The blood supply chain is a complex system of collecting, processing, distribution and transfusion sites located globally. This supply management involves coordinating with facilities, laboratories, and blood center in various geographic areas. Effective emergency response not only knowledge of current blood stock but also provided information about availability, proximity, and accessibility of supplies in other location are needed (22,25).

Distribution of blood donor need to assess and monitoring routinely to maintain the existence and fulfil blood demand in Bojonegoro, Indonesia. As much hospital and neighbourhood regency supplied their transfusion need from Bojonegoro Blood Donation Unit, the strategy for recruits and maintain voluntary blood donor become the major issue. The data of voluntary blood donor supper around Bojonegoro areas and the distribution are unique according to demographic statue of the inhabitant and the accessibility from blood donation units.

The amounts of blood donor according to voluntary blood donation is shown in Figure 1 and there is no area with deficient amounts of donors for each blood group (Figure 2). While other three categories vary over the districts and its distribution expected depends on the area coverage from the blood donation center and people age meets inclusions criteria of donor selections(34). According to data provided, as much 8,517 out of 45,096 signed as voluntary blood donor in Bojonegoro district and followed by sumberrejo (3,148), Dander (3,126), and Kapas (2,742). These four districts easily accessed by the donor within a minute to Blood Donation Center (29). The total resident in each district doesn't correlate with donor involvement. Bojonegoro and Dander consist of people in productive ages and included the donor criteria, while Kedungadem and Baureno resident majority in late ages and excluded from donor criteria (29).

The distribution of blood donors shows Bojonegoro having the highest number of donors for all blood types, while Kedewan has the lowest. This discrepancy is largely attributed to geographic and infrastructural factors. Bojonegoro, being closer to the city center, has better accessibility to blood donation facilities, leading to higher donor participation. In contrast, Kedewan's remote location and difficult road access hinder blood donation activities, resulting in a lower number of donors.

This finding aligns with previous studies indicating that urban and semi-urban areas tend to have higher blood donation rates compared to rural areas. A study conducted in Nigeria reported that 89.7% of total blood donations came from urban and semi-urban regions, whereas only 10.3% originated from rural areas, primarily due to accessibility challenges (35). Similarly, research in Tanzania found that blood donation was more prevalent in urban settings, particularly among students in schools and universities, whereas rural participation remained low due to limited awareness and logistical barriers (35).

Further supporting this observation, a study in Ethiopia concluded that urban residents were 2.27 times more likely to donate blood voluntarily compared to rural inhabitants. The study emphasized that access to donation unit and awareness campaigns play a crucial role in influencing donor participation (36). The findings from Bojonegoro and Kedewan reinforce the importance of improving infrastructure and accessibility in remote areas to enhance blood donation participation and ensure an adequate blood supply.

Indonesia regulation about blood donation target must be above 2% of population and Bojonegoro regency reached 3.3% of population (34,37). Its confidently declare the amounts of blood is surpassed the requirement according to the blood stock regulation. Blood supply is not evenly sourced from all 28 districts. The distribution of blood components is directed to approximately 11 hospitals within Bojonegoro and to healthcare facilities outside the regency, particularly for rare blood types. The delivery of blood for transfusion across these hospitals involves varying travel durations, ranging from a few minutes to several hours. Therefore, mapping voluntary blood donors based on blood type diversity proves to be a highly effective strategy (15,34). Timely access blood products essential to treat a wide array of human illnesses where patients can suffer from life-threatening haemorrhage within minutes (38). In emergency condition such as accidents or specific treatment and surgeries, its need specific blood types can be particularly time consuming and challenging (39–41). It can be more serious if the rare blood type needed, such us O- and AB-.

By categorizing results and developing a versatile geospatial model, we were able to draw information from the data to generate each allele frequency map simultaneously in Figure 2. The distribution of blood donors by blood type indicates that blood group O has the highest number of donors (17,768 and 39.4%), while blood group AB has the lowest (3,040 and 6.7%). This trend aligns with the natural prevalence of blood groups in the general population, where blood group O is the most common, and blood group AB is the rarest (2). The higher number of donors with blood type O may also be influenced by its universal donor status for red blood cell transfusions, encouraging more individuals with this blood type to donate. Conversely, the limited number of AB donors may be due to the lower prevalence of this

blood type in the population (13,33).

Similar findings have been reported in previous studies. Research conducted in Nigeria found that blood group O constituted the largest proportion of donors (50.7%), whereas blood group AB had the lowest representation (4.6%) (42). A study in India also reported that 39.8% of blood donors were of blood group O, whereas only 6.6% had blood group AB (43). Additionally, a study in Ethiopia highlighted that blood group O donors were the most prevalent due to their high frequency in the population, while blood group AB remained the least donated due to its low occurrence (42). The consistency of these results across different regions emphasizes the need for targeted donor recruitment strategies, especially for rarer blood groups such as AB, to ensure an adequate and diverse blood supply (44).

The human blood type has been used as a genetic marker and can be imaged to provide geographic data to detect the availability of donor. The different blood types are grouped into many systems, and the major blood type grouping been used ABO and Rhesus system. All blood type referred to phenotypes or epitopes presence in the red blood cell surface (RBC) as a result of alleles of linked-genes. Allele frequency of blood type distribution among voluntary blood donor in Bojonegoro showed AB blood type has similar distribution in 26 districts listed as adequate while considerable and prodigious mentioned only one district each of AB blood type. These referred to the most population between whole district allocated in the center of business and government facilities (29). The findings of this study highlight a clear disparity in blood group distribution, with blood type AB having the lowest prevalence across the surveyed regions, while blood types A, B, and O are more evenly and widely distributed. This variation may reflect underlying genetic inheritance patterns, population structure, or socio-demographic dynamics in Bojonegoro. Similar patterns have been observed in previous studies conducted in various populations, where the frequency of blood group AB was consistently lower due to its genetic rarity and the inheritance mechanism from both A and B alleles (23, 29, 43). Recommendation to the regional blood services and donor recruitment programs adopt targeted strategies to encourage donation from rare blood group individuals, particularly AB, to ensure an adequate and diverse blood supply. This includes enhancing public awareness, especially in underrepresented and geographically isolated communities, and possibly integrating mobile blood donation units in rural or low-access regions like Kedewan.

The study applies a geospatial clustering analysis, allowing for a detailed visualization of blood donor distribution across multiple districts and understanding of regional disparities in blood donation. Comprehensive area coverage provides and offers a broad and representative view of the blood donation landscape in Bojonegoro, making the findings valuable for regional health planning. The study identifies and compares the distribution of specific blood types (A, B, AB, O), which is essential for ensuring a balanced blood supply according to demand. Otherwise, the findings are restricted to one geographic region and provides a cross-sectional snapshot rather than analysing changes over time, which would be beneficial for tracking long-term trends.

CONCLUSION

The study on the geospatial clustering pattern of blood type diversity among voluntary blood donors in Bojonegoro, Indonesia, reveals significant geographic variations in the distribution of blood types. The analysis all blood types only dominant in Bojonegoro district influenced by donor involvement, reflecting the underlying population genetics and demographic factors within the region. The prevalence of blood types follows a common trend, with blood group O being the most dominant (39.40%), followed by blood group B (31.02%), blood group A (22.56%), and blood group AB as the least prevalent (6.74%). Understanding these patterns is crucial for optimizing blood collection strategies and ensuring an adequate and equitable blood supply across Bojonegoro. By recognizing areas with specific blood type needs or surpluses, local blood banks can enhance their inventory management, target donor recruitment efforts more effectively, and improve overall transfusion services. Future efforts should focus on integrating this geospatial information into public health planning to address disparities in blood availability and meet the transfusion demands of all communities in Bojonegoro.

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