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Inventory and Mapping of Aren (*Arenga pinnata* Merr.) Plus Tree in Tanggamus District, Lampung, Indonesia

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ABSTRACT

A plus tree is a tree that exhibits superior phenotypic expression compared to other trees in the vicinity and, therefore, has potential for plant breeding. The study aimed to inventory and map the aren plus in Air Abang Village, Ulu Belu Sub-district, Tanggamus Regency, Lampung. Sampling was drawn by the census method, where the entire producing and tapped aren population were taken as samples. Identification for sap productivity was conducted through interviews with the farmers to determine plus trees candidates. The direct observation was carried out to determine plus tree by measuring 11 criteria of aren plus (tree health, tree age, stem circumference, number of fronds, fronds shape, leaf colour, leaf length, number of male mayangs, number of female mayangs, sap production, and sugar content). A tree was categorized as a plus if it met all those criteria. Seven out of 60 producing aren were identified as aren plus tree. This finding indicates that the village has actual land suitability for aren cultivation. The research has identified that Air Abang has the genetic potential to be a superior aren broodstock, which is significant for planting material and plant breeding. The mapping results show that the distribution of aren plus in Air Abang is relatively random. The aren plus is predominantly found in sites with low levels of competition, where the planting distance is long enough so that the tip of the aren fronds does not intersect with the crowns of other trees.

1. INTRODUCTION

Sugar palm, known as aren (*Arenga pinnata* Merr.), is a member of the Arecaceae family and possesses potential as a food crop, medicinal raw material, and for use in industries such as bioenergy, biofuel, and nano cellulose [1-3]. The primary valuable product of aren is sugar juice (sap), which contains 91.1% water, 0.28% ash content, 0.41% protein, 0% fat, 8.21% carbohydrate, and 0.67% sugar [4]. Aren fibre is rich in cellulose, which boasts high tensile strength and durability [5]. Young aren seeds (*kolang-kaling*) are abundant in galactomannan, an antioxidant, flavonoids, alkaloids, and quinones, which have been proven efficient in treating osteoarthritis [6, 7]. Due to its high economic potential, aren has gained popularity amongst farmers and is widely cultivated [8]. However, traditional methods dominate most of the palm cultivation in Indonesia and have not yielded significant improvements in farmers' welfare.

The cultivation of aren in Indonesia is hindered by the dearth of high-quality plant material. Over 90% of the aren grown and produced in Indonesia are naturally regenerated plants, which usually possess poor genetic quality and productivity [9]. The shortage of superior planting material is commonly recognized as a significant hurdle in executing agroforestry innovations [10]. Therefore, providing superior varieties obtained from carefully selected parent trees is critical to enhancing crop yield. Boosting crop productivity guarantees food security and uplifts people's well-being. Genetically superior seeds significantly impact the growth quality of forest stands with noteworthy economic value [11]. Improvement in the genetic and physical traits of the planting material can enhance yields by up to 40% and result in significant increments in production [10].

In forestry, the initial crucial stage to create superior quality plant material involves plus tree selection. The selection of a plus tree establishes a crucial foundation for a successful program that would eventually deliver superior genetic resources for breeding. A plus tree is a plant that displays phenotypic superiority over the neighbouring average tree concerning various desirable traits [11]. Plus tree selection is an essential component of intensive silviculture techniques. Specifically, it involves the utilization of superior seedlings derived from selected plus trees [12]. Identifying plus trees is also crucial to preserve and accelerate the potential of genetic resources, enabling their transformation into viable business commodities [13]. Plus tree selection has been acknowledged by geneticists as a straightforward and primary approach in the development of progressive tree improvement programs [11].

Morphological features can provide valuable insights into the superiority of a species. Using morphological characters is a highly recommended approach to generate invaluable information on species diversity, as they are very cost-effective, time-saving, and potentially reveal fundamental information [14]. An efficient selection program requires fundamental knowledge of the correlation between plant anatomical traits [15]. Selective breeding of superior genotypes found in natural forests can yield a 10-15% genetic gain in the first generation. Such gains can be achieved by collecting and growing seeds from these plants [16].

Aren is a crop with great potential. However, it has not received enough attention from the scientific and business communities. The use of aren has a long history, but its products have been slow to attain status as agribusiness commodities due to their reliance on naturally occurring plants in their habitat [13]. Research on aren breeding is also limited. Some reported research findings related to aren breeding include an inventory and mapping of aren potential [17], an analysis of the morphological characteristics of aren and the sugar content of sap [18], an examination of phenotypic diversity in aren [19], genetic diversity of aren based on SSR markers [20], an exploration of aren biodiversity [21], and characterization of the stems and fronds of aren [22]. At present, research into the genetic improvement of the aren remains limited. Therefore, to preserve and accelerate the potential of genetic resources to be transformed into a viable agribusiness commodity, the identification and mapping of aren plus is a crucial initial step. Aren plus trees exhibit superior phenotypes, resistance to pests and diseases, high sap productivity, and high sugar content.

Aren is classified as 'plus' if they meet 11 specific criteria: they must be healthy, at least eight years old, have a trunk diameter of over 100 cm, have drooping and lush fronds, have at least 12 fronds, have dark green and shiny leaves, have fronds that are at least 5m long, have at least three male mayangs, have at least five female mayangs, produce at least 15 liters of sap per day, and have a sugar content of over 12% (Ministry of Agriculture, 2015; Tenda, 2010). Artika et al. [23] have reported on studies concerning identifying and mapping aren plus in the Integrated Conservation Education Forest Area of Wan Abdul Rachman Botanical Forest Park. The study identified 16 plants categorized as aren plus. However, because it is a conservation area and not a significant center for aren cultivation in Lampung Province, the prospects for aren development are unfavorable.

Tanggamus Regency is widely regarded as the preeminent palm sugar-producing area within Lampung Province, particularly in the Ulu Belu sub-district, where aren thrives naturally. The palm sugar of Ulubelu is revered as being amongst the most outstanding and desirable among consumers. It is noteworthy, however, that no reports have been published regarding Aren's cultivation or genetic improvement in the area. Based on the initial investigation findings, at least nine aren have a daily sap production of over 15 liters, with one yielding more than 25 liters per day. This initial finding regarding high productivity aren needs verification to determine whether these trees meet the criteria as plus trees, which are essential for planting material and genetically for plant breeding. The study's objectives were (1) to identify the presence of aren plus trees, and (2) to map aren plus trees in Air Abang village, Ulu Belu sub-district, Tanggamus Regency, Lampung Province.

2. MATERIALS AND METHODS

2.1 Site of study

The study was undertaken between August and October 2022 in Air Abang Village, Ulu Belu Sub-district, Tanggamus Regency, Lampung Province (Figure 1). The choice of Air Abang Village was due to its position as the hub of the palm sugar home industry in Ulubelu. The location has a high concentration of cultivated and tapped aren. Therefore, measuring all parameters for categorising aren quantitatively and qualitatively is possible. Air Abang is situated at an altitude of 720 meters above sea level. The topography is mainly flat to slightly steep (with a slope of 0-25%). The soil type typically exhibits a sandy clay texture. The temperature ranges from 20-25.6°C, with air humidity levels between 78-82% and light intensity between 701-887 FC. Ulubelu, being a mountainous area, receives high levels of rainfall, reaching approximately 1,750-3,000 mm annually.

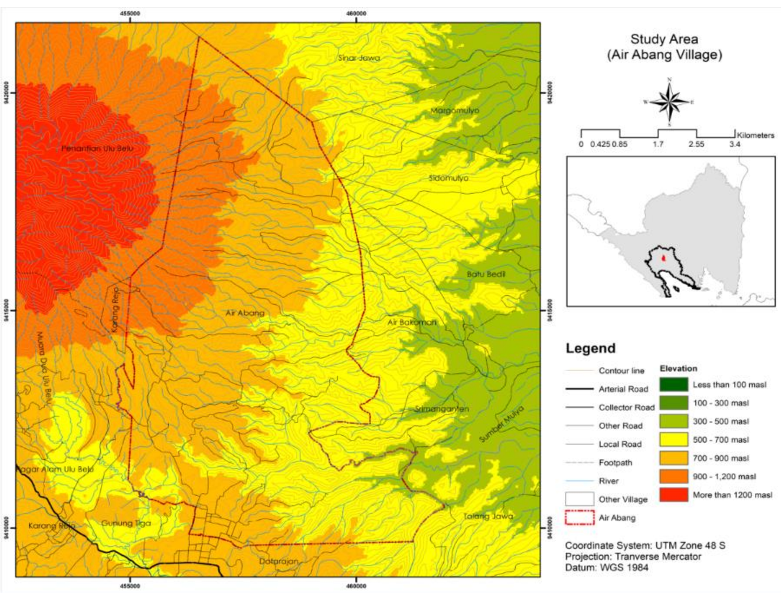

Figure 1. Site of study: Air Abang Village is situated in the Ulubelu sub-district of Tangamus District, Lampung Province, Indonesia

2.2 Data and sampling

The collected primary data comprised the identification parameters of aren plus its corresponding coordinate position data used for cartography. The Ministry of Agriculture of Indonesia [24] and Tenda [21] identified parameters that are indicative of aren plus, such as sap production, plant age, health status (presence or absence of pest attack), leaf colour and gloss, trunk circumference, frond bend (downward or straight), number of fronds, frond length, and quantity of male and female bunch. The study utilized administrative maps of the Air Abang Village area (1:40,000 scale) obtained from the Indonesia Geospatial Portal in 2020 as secondary data. The census method was employed for sampling, with all tapped aren serving as the samples. The census method was selected due to its ability to identify all the aren plus present in the study area, which was necessary for accurate mapping. However, the sample population was limited to palm trees managed and tapped by farmers, as not all palm trees that have entered productive age and potentially fulfill all the criteria of plus trees are managed and tapped by the community. This approach overcomes the shortcomings of the census method, which requires significant resources and time. Preparation of aren trees before taping requires labor and takes about four weeks.

2.3 Data collection and plant classification

The identification of plus trees begins with the data collection of candidates. Candidate plus trees were recorded through interviews with all palm tappers (farmers) to determine the productivity of the plants they tapped. Plants that produced 15 liters of sap or more were categorized as candidate plus trees. All plus tree candidates were then observed and measured for all parameters. An aren was categorized as a plus tree if it meets all of the following criteria (Ministry of Agriculture 2015; Tenda 2010): (1) the plant is free from pests and diseases, (2) the age of the plant is above eight years, (3) the trunk circumference measured at the height of one meter from the ground ≥100 cm, (4) the fronds are drooping and lush, (5) The number of fronds is at least 12, (6) the colour of the leaves dark green and shiny, (7) the length of the frond ≥ 5m, (8) The number of male mayangs is at least 3, (9) The number of female mayangs is ≥ 5, (10) sap production ≥ 15 liters per day, and (11) sugar contain within the sap is above 12%. Pest infestation is detected through visual observation of the stem, fronds, flowers, leaves, and fruit. Signs of infestation include tissue damage, discoloration, abnormal growth, and traces of pests. The disease is indicated by spots or lesions on plant tissue, fungal formations, and plant discharge. Sap tapped from the mayang stalk, collected in a container, and harvested twice daily, at 6.00 am and 5.00 pm. Plant productivity was assessed by measuring the volume of sap using a measuring cup, while sugar content was determined using a refractometer.

2.4 Mapping

The coordinates of all aren plus were recorded using GPS. The appearance of the plants was then photographed to be used as complementary data for the distribution map of aren plus. The coordinate data of each plant logged in the GPS unit was transferred to a computer and converted to a dBase file (DBF) using Garmin MapSource software. The dbf file was then inputted into the ArcGIS 10.3 software to view the distribution of the aren plus trees.

The coordinate map of the aren plus was then overlaid with the boundary map, Indonesia digital topographic map (scale 1:50k *Peta Rupa Bumi Indonesia*/RBI), digital elevation model (ALOS Global Digital Surface Model "ALOS World 3D - 30m") that was processed into slope and elevation classes of Air Abang Village. Furthermore, the layout was carried out by entering map attributes (from RBI) and transferring the Universal Transverse Marcator (UTM) grid system according to scale.

3. RESULT AND DISCUSSION

3.1 Aren plus trees and site factors

Sixty aren are currently managed and producing sap in Air Abang. Nine of these plants produce more than 15 liters of sap per day, with some producing as much as 25.6 liters per day. The finding indicates that the Air Abang Village possesses the potential for superior genetics of aren and is a suitable habitat for cultivating the commodity. The production of crops is significantly influenced by site suitability [25]. Air Abang Village holds promise for the development of sustainable aren production with proper cultivation management.

Site status analysis is a typical method of gauging the appropriateness of cultivating certain species under specific ecological conditions. A sound comprehension of species variability and the interplay between species and site status is imperative for developing sustainable management practices in forestry [26]. Climatic and environmental factors heavily influence tree growth and establishment, including light regime, air temperature, water availability, wind, soil characteristics, altitude, aspect, and slope [27]. It is essential to consider these factors to ensure successful tree growth and establishment in forestry management. Site status describes a multifaceted phenomenon from varying topographical, edaphic, and climatic factors [28].

According to the area's topography, Air Abang is 720 meters above sea level, within the optimal altitude range for growing aren. The ideal range for aren growth is between 500-800 metres [29]. Harahap [30] reported that sap production at altitudes between 400 and 800 m above sea level was 15.04 liters per tree per day, which is nearly twice as high as the production at altitudes lower than 400 m above sea level (7.56 liters/tree/day) or altitude higher than 800 m above sea level (8.54 liters/tree/day). Widarawati [31] found a significant correlation between altitude and various plant growth factors, including soil moisture content, proline content, leaf surface temperature, leaf temperature, leaf cell H_2O, leaf relative humidity, intercellular carbon, leaf cell CO_2, transpiration rate, volume, pH, and sap quality (sucrose content, moisture content, protein content, and sap yield). Altitude was identified as an essential physiographic factor that affects plant growth and productivity. Plant functional traits vary significantly with altitude. Differences in altitude cause variations in critical environmental factors such as air temperature, atmospheric pressure, rainfall, wind speed, extreme weather events, and global warming levels [32]. Altitude positively correlates with light intensity, where higher altitudes experience higher light intensities [33]. Decreased CO_2 concentration and increased light intensity at higher altitudes will increase stomatal density [34].

The Air Abang Village topography is predominantly flat to slightly steep (slope of 0--25%). The slope of the land is well-suited for aren cultivation since the plant flourishes on land within this 0-25% slope range [35]. Slope significantly affects soil water availability. Siringoringo et al. [36] reported that soil water content is higher when measured by gravimetric and volumetric methods on slopes of 0-30% compared to slopes >30%. Steep slopes exhibit lower moisture content due to surface runoff or faster water movement than flat or slightly steeper slopes [37]. Furthermore, Puturuhu et al. [35] reported that natural aren more abundant on land with slopes exceeding 7%. It is presumable because the drainage in the slope category is excellent, yet it supplies water to deep soil layers, which the roots of the aren can access by delving 6-8 metres deep.

Based on edaphic factors, the Air Abang typically exhibits sandy clay soil texture, which is the most conducive soil for growing and producing aren. According to Effendi [38], aren thrive in sloping land with sandy clay-textured soil. Additionally, aren will grow well in loose soil, volcanic soil on mountain slopes, and sandy clay soil along river banks [39]. The sandy clay soil in Air Abang is classified as volcanic due to several active volcanoes in the region, namely Rindingan, Kurupan, Kabawok, Sula, and Kukusan. The soil in the area is classified as well-drained, with a significant underwater presence. According to Lempang [40], soil that is permeable or able to drain excess water, such as loose soil, volcanic soil on mountain slopes, and sandy soil around river banks, is ideal for aren growth.

The Ulubelu region experiences temperatures ranging from 20-25.6℃, with air humidity levels between 78-82% and light intensity between 701-887 FC. Being a mountainous area, Ulubelu receives high levels of rainfall, reaching approximately 1,750--3,000 mm annually [41]. According to climatic factors, the Air Abang is ideal for aren cultivation. On the other hand, it requires an area with an average ambient temperature of 25℃ [40] or an annual temperature range of 19--27℃ [42]. Aren thrives in regions with rainfall ranging between 1,200-3,500 mm per year (Ministry of Agriculture of Indonesia, 2013). The optimum air humidity required for aren growth lies within 81-96.4% [35].

3.2 Aren plus classification

Of the 60 sugar palms tapped by farmers in Air Abang, nine potential trees were identified as superior because their sap production was ≥ 15 liters per day. From the observations and parameter measurements conducted, seven of the potential trees were classified as aren plus according to 11 predetermined criteria (Table 1). Aren plus trees exhibit superior phenotypic expression compared to other trees in the vicinity (Figure 2). The finding above suggests that the Air Abang region boasts the potential to produce exceptional genetic resources for the cultivation and breeding of aren, obtained from the growth of wild plants. The abundant availability of wild genes provides a promising opportunity for utilizing them as plant material and breeding them [11].

Table 1. Identification results of aren plus plants in Air Abang Village, Ulu Belu sub-district, Tanggamus Regency, Lampung

Code	Trees Status			Fronds				Number of Bunches		Sap Prod. (Liter)	Sugar Content (g/l)	Sugar Prod. (Grams/ Tree/Day)
	Health	Age (years)	Trunk girth (cm)	form	Total	Leaf colour	Length (m)	Male	Female			
AA16	Pest and disease-free	9	189	curved	12	Deep glossy green	5.0	3	6	15.15	199.67	3,025.00
AA21	Pest and disease-free	9	180	curved	14	Deep glossy green	5.3	3	6	15.68	201.92	3,166.10
AA25	Pest and disease-free	9	178	curved	13	Deep glossy green	5.2	3	6	15.45	199.03	3,075.01
AA32	Pest and disease-free	9	192	curved	20	Deep glossy green	5.5	3	7	25.26	198.41	5,011.84
AA50	Pest and disease-free	11	205	curved	12	Deep glossy green	5.0	3	6	15.02	196.70	2,954.43
AA53	Pest and disease-free	10	190	curved	13	Deep glossy green	5.2	3	6	15.34	205.88	3,158.20
AA56	Pest and disease-free	10	200	curved	12	Deep glossy green	5.2	3	6	15.71	199.04	3,126.92

Table 1 illustrates a significant positive correlation between the number and length of fronds and sap productivity. Aren with more significant frond number and length tend to yield higher sugar output. The finding aligns with Nirawati et al. [18] report, which indicates a strong relationship between sugar production and frond number and length. Ibrahim et al. [43] found a positive correlation between frond length and stem circumference with sugar productivity of aren. Leaves are essential organs for photosynthesis, producing required carbohydrates for aren's growth and development. They absorb and convert light energy through photosynthesis and play an essential role in the assimilation process, particularly in plant parts that use assimilation. Sucrose is the most common compound involved in this process [44].

The number and length of fronds are critical parameters for measuring the leaf area index (LAI) of aren. The LAI value indicates leafiness, which reflects the plant's photosynthetic capacity. Higher leafiness values suggest enhanced light interception and increased photosynthetic ability. Moreover, the higher the LAI value, the greater the light captured by the plant canopy, leading to a reduction in light intensity escaping into the shade. In line with the report of Nirawati et al. [18], light intensity under the shade of aren showed a negative correlation with Brix content. Noor and Harun [45] state that in the Arecaceae family, the Leaf Area Index (LAI) is determined by the frond density, the average area of each frond, and the plant density. Gromikora et al.'s [46] study demonstrated the impact of leaf area index (LAI) on plant productivity. The study found that oil palm plants aged under eight produced more fresh fruit bunches when the number of fronds left was between 57-64, compared to 49-56.

Air Abang village has seven aren plus, each with an average of 6,143 female bunches. The number of fruits from each bunch ranges from 5-8 thousand, each containing three seeds [47]. Therefore, the village has the potential to produce 119,786 superior aren seeds. Based on a germination rate of 82.2% [8], the total number of aren seedlings produced will be 98,464. The quantity is adequate to plant roughly 345 hectares of land in a mono-crop arrangement, with a 6m × 6m plant spacing.

Figure 2. The figure of plants that fulfill the 11 criteria as aren plus tree in Air Abang Village

3.3 Aren plus map

The distribution of aren plus in Air Abang Village is entirely random and devoid of any discernible pattern or natural conditions. Coordinate points of aren plus are presented in Table 2.

Table 2. Coordinate point of aren plus in Air Abang

Code	Coordinate Point	
	Latitude	Longitude
AA16	104°36.897'	05°20.199'
AA21	104°36.816'	05°20.244'
AA25	104°36.812'	05°20.265'
AA32	104°36.810'	05°20.230'
AA50	104°37.150'	05°19.868'
AA53	104°36.911'	05°20.108'
AA56	104°36.914'	05°20.127'

The random distribution of aren plus is mainly because the aren within the area are grown naturally with the assistance of common palm civets (*Paradoxurus hermaphroditus* Pallas) through the endozoocory mechanism. Civets are potential seed dispersers of aren due to their resistance against calcium oxalate, a compound in aren fruit that naturally protects plants against pests. Calcium oxalate is an irritant compound that causes a burning and itching sensation in most organisms [8]. According to Subrata and Syahudin [48], aren seeds are present in civet feces with a frequency of 0.07. Civets have been observed to swallow seeds up to 20.3 mm wide and 28.6 mm long [49], with most ingested seeds remaining intact and showing good germination [48]. Seeds discovered in civet feces have a more significant germination percentage than seeds extracted directly from fresh fruits [50]. This phenomenon occurs due to the mechanical, microbial, and enzymatic activities in civet digestion, which influence the germination of aren seeds [8]. The ability of civet digestion is supported by a broad home range of 79 ha (males) and 29 ha (females), thus making civets exceptional seed dispersers [49].

Civets are highly effective at dispersing large seeds due to their ability to swallow them. According to Nakashima and Sukor [49], the seed retention time of a civet is an average of 2.6 hours, which is significantly longer than long-tailed macaques (75 seconds) and pig-tailed macaques (156 seconds). In addition, they traveled several hundred meters during their digestion time, resulting in an average seed dispersal distance of 216 m. The civet's ability to disperse seeds makes it a crucial species in the recovery of degraded habitats. Additionally, civets tolerate anthropogenic disturbance, which enhances their ability to disperse seeds and overcome habitat fragmentation, a barrier to ecosystem recovery [49]. Although the International Union for Conservation of Nature (IUCN) still categorizes the species as 'least concern', civet populations are reportedly declining [51]. The existence of aren palm as a source of food and shelter for civets is expected to support their life and maintain the civet population. Similarly, the presence of civets can spread aren palm seeds, thereby maintaining the population and distribution of aren palm.

Civets are less shy toward human presence and can adapt well to anthropogenic habitats such as plantations, fragmented and degraded forests, human settlements, and even urban ecosystems [52]. The nature and ability of civets to disperse seeds, supported by human agricultural activities, have increased the spread of aren. Agricultural activities will significantly reduce canopy cover and create more open habitats. At the same time, civets generally prefer open habitats for defecation [49]. Seeds dispersed by civets on agricultural land will grow more easily because they get optimal soil, which is well prepared to support the growth of cultivated plants. Agriculture land that is clean of weeds and pest organisms provides better conditions for aren seeds to grow without excessive competition with other plants or disturbed by pests and diseases [53]. In this collaboration, humans have created the best conditions for aren seed germination, and civets have become seed carriers that benefit plants. In order to benefit the plant as a dispersal agent, the civet has directed the seeds to favourable microclimates, which can provide good biotic and abiotic conditions for germination, less competition and less mortality from seed predators and herbivores [53].

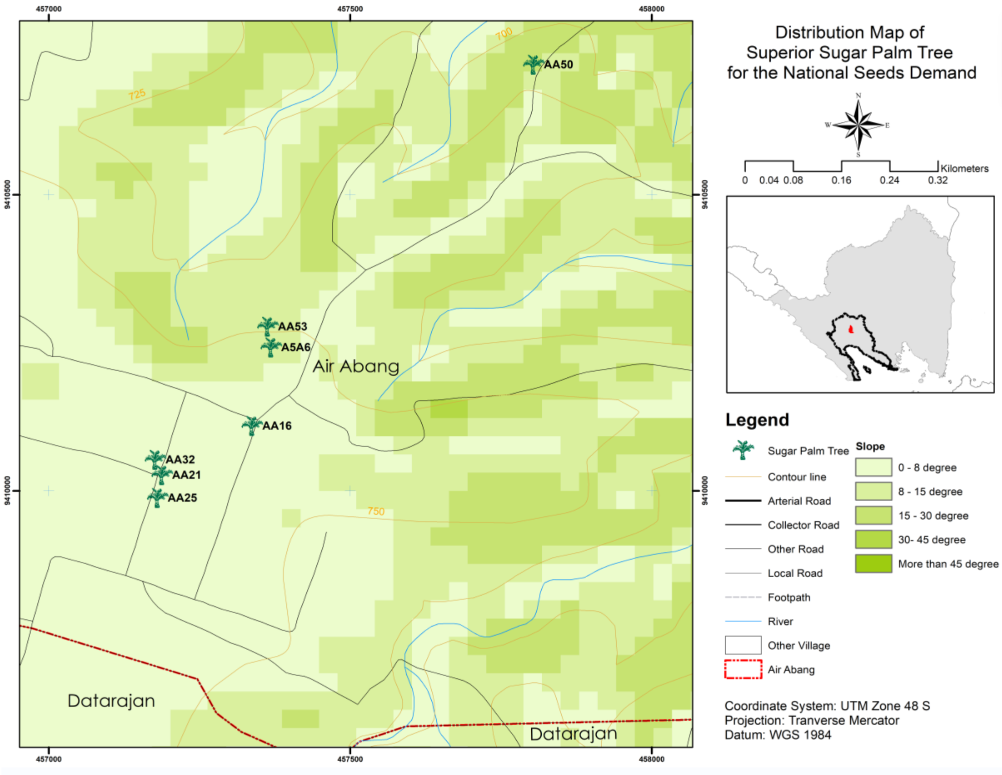

Figure 3. Map of aren plus distribution in Air Abang Village, Ulubelu sub-district, Tanggamus Regency

Based on Figure 3, it is apparent that the aren plus in Air Abang are located in a site with low competition. The distance is long enough to ensure that the tip of the palm frond does not intersect with the crowns of other trees, creating a suitable growing environment with less competition for plants. This finding suggests that planting distance is crucial in aren cultivation and provides opportunities for superior genetic expression. To date, there has been no scientific report about the optimal planting distance of aren for land productivity optimisation. The planting distance affects light use efficiency and competition for water and nutrients, ultimately influencing plant productivity [54]. The canopy structure and photosynthetic area largely determine light and carbon dioxide competition. Although root activity is a significant determinant of competition for water and nutrients, the distribution pattern and efficacy of water and nutrient absorption also play a crucial role [55].

4. CONCLUSION

Air Abang possesses valuable aren genetic resources for plant breeding and cultivation. Seven of the 60 producing aren trees are identified as aren plus trees based on 11 predetermined criteria. The presence of high-producing aren plus trees indicates that Air Abang has a suitable site factor for aren cultivation. Mapping results demonstrate that the distribution pattern of aren plus trees in Air Abang is random. It is because the aren trees in Air Abang grow naturally with the help of palm civet (*Paradoxurus hermaphroditus* Pallas) through the endozoocory mechanism. The random distribution of aren trees benefits genetic diversity and breeding, increasing genetic diversity and adaptability to environmental changes and reducing the risk of inbreeding. Generally, aren plus trees in Air Abang are located in areas with low competition and sufficient planting distance to prevent fronds from overlapping with other trees' crowns. These findings suggest that planting distance plays a crucial role in aren cultivation by reducing competition and supporting land productivity. The discovery of aren plus trees allows researchers to conduct genetic analysis studies to understand the heritability of desirable traits, explore vegetative propagation or cloning methods, and conduct adaptation tests to assess their performance in different environments. Practitioners can also follow up on these essential findings to collect seeds and establish seed orchards or seed stands. In order to maintain superior genetic resources that are important for agricultural and economic activities, it is crucial to conserve the existence of aren plus trees in Air Abang. Aren plus trees can serve as a source of planting material, which can increase the productivity of aren plantations. Additionally, seeds from plus trees can be used in aren nurseries, creating new business opportunities and increasing the income of the people of Air Abang.

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