Preliminary assessment of ironwood (*Eusideroxylon zwageri* Teijsm. & Binnend.) stand on the KPPN Bulian of the District VIII of PT. Wirakarya Sakti, Jambi as seed source candidate

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**Abstract.** Ironwood (*Eusideroxylon zwageri*) is one of Indonesia's most economically valuable timber tree species and was listed as Vulnerable in 1998 by the IUCN. To support conservation activities and establish *E. zwageri*’s plantation, good quality planting stocks should be collected from specific seed sources. Currently, there is only one ironwood seed source in Sumatra that has been registered. This study aimed to assess the potential for an ironwood stand on the KPPN Bulian of the District VIII of PT. Wirakarya Sakti is to be proposed as a seed source. The assessment was conducted on July 2020 by a 100% inventory of ironwood trees in the area of 43 ha. Every individual tree and copy of ironwood was measured for its stem diameter and tree height and observed for its health, flowers, fruits, and seedlings in the ground. In total, 1,029 individual trees, copies and seedlings were recorded. Among them, 116 trees were found to have young fruits and seedlings emergence in the forest floor. Generally, the ironwood stand is sound and meets the criteria to be registered as an identified seed stand of ironwood.

1. Introduction
Ironwood (*Eusideroxylon zwageri* Teijsm. & Binnend.) (Lauraceae) was one of the most economically valuable timber tree species in Indonesia [1]. *E. zwageri* grows naturally in lowland primary forests at an altitude of up to 400 m asl [2, 3], 625 m asl [4], or even up to 800 m asl [5]. It distributes naturally in southern and eastern part of Sumatra, Bangka, Belitung, Borneo (including Serawak, Sabah and Brunei Darussalam), and the Sulu and Pelawan Islands (The Philippines) [1, 4].

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The international community widely knows ironwood as "Borneo Ironwood" or ironwood from Borneo. In Indonesia, this species is also known locally by the community under several different names. In Jambi and South Sumatra, people recognize this species by local names: bulian, bulian rambai, and onglen. Meanwhile, the people of Borneo call it belian, tabulin, telian, ulin, and tulian [3]. Ironwood is often used as a pillar in the ground, beams, floors, furniture, carvings, and home decorations. In addition, ironwood is also often used for shingle roofs, maritime buildings, house frames, boards, bearings, floodgates, road cladding beams, fences, printing beams, stakes, car body, construction and shipping ornaments, electric poles, and food chopsticks [3]. Due to the nature of the robust and durable wood and its various uses, ironwood has become a lucrative trading commodity in the past for local, regional and export markets. Consequently, logging took place on a large scale, leading to a drastic decline in the population [4].

Population reduction of this species has been noted since 1955, mainly due to over-exploitation, shifting cultivation, forest fires and illegal logging [6, 7]. E. zwageri has been listed as vulnerable A1cd+2cd ver 2.3 by The IUCN Red List since 1998 [7]. It means that E. zwageri is not critically endangered but facing a high risk of extinction in the wild in the medium-term future [8]. Conservation (both in-situ and ex-situ) efforts and promotion of plantation of E. zwageri are necessary to keep the sustainability of the species. Enrichment planting and commercial planting of ironwood using good quality planting stocks need to be done immediately. Good quality seeds for plantation could be collected from determined seed sources consisted of adequate mother trees. To date, in Sumatera Island, only one ironwood seed source has been registered, namely the Identified Seed Stand of Mambang Customary Forest at Musi Rawas Regency, South Sumatra Province (Certificate Number 38/V/BPTH.Sum-3/SSB/2006). The development of additional ironwood seed sources on Sumatra Island, especially in Jambi Province, is critical to ensure the availability of ironwood seeds for planting in Jambi Province in the future. This study aims to assess the potential for an ironwood stand on the KPPN Bulian of the District VIII of PT. Wirakarya Sakti Jambi (PT. WKS) to be proposed as a seed source.

2. Assessment methods

2.1. Location

The assessment was located at the protected area (KPPN) Bulian of District VIII of PT. WKS, Tebo Regency, Jambi Province. This protected area covers 43 Ha, encompassing about 0.1% of the WKS' protected areas. The KPPN Bulian is located at S°26'57" E 102°47'19" to S1°27'00" E 102°47'51" in Kunangan, Tebo Ilir, Tebo Regency, Jambi Province (Figure 1). It is a lowland forest ecosystem naturally dominated by E. zwageri with flat to undulating topography between 70 to 90 m asl. There is a tributary of the Rengas River, whose water flows throughout the year in this area. The existence of this river causes the humidity of the forest area to be maintained, which is very necessary for ironwood growth.
2.2. Equipment
The equipment needed to carry out the inventory is composed of a Geographic Positioning System (GPS) receiver and extra batteries, the Thematic map (working map of KPPN Bulian Jl. 810), diameter tape, hagameter/Vertex, 50-meter rope, machete, data collection forms, and stationery.

2.3. Data collection in the field
Data are collected for entire trees in the KPPN area through measurements and observations. All trees and wildings (>150 cm of total height) found within the area are measured, observed and recorded on a field form. Tree diameter is measured at 1.3 m above the ground (diameter at breast height or DBH), with the support of a diameter tape. Tree height measurement is carried out using hagameter/Vertex. The geographical position of every single tree was recorded in a GPS. Every measured tree was then observed for its health (occurrence of pest and disease attacks), flowers, fruits and the presence of seeds and or seedlings underneath by direct observation and gathering information from the stand manager.

Accessibility of the stand was evaluated by observing an existing road to the stand. Stand quality was determined by evaluating the phenotype (diameter and height) of the measured trees. Security of the stand was measured by observing the incidence of encroachment, illegal logging, selective logging, livestock disturbance, and fires. Finally, stands health was evaluated by direct observation of pest and disease attack levels on existing trees.

2.4. Assessment process
Assessment can be divided into assessment on a tree as individual and assessment on stand candidate (site). An assessment of tree quality and tree health of an individual tree is necessary to determine the eligibility of the tree to be a mother tree. The assessment on a stand is needed to quantify the eligibility of the stand as a seed source candidate, including the accessibility, some mother trees available on the site, stand quality, stand productivity (flowering and fruiting capability), security of the stand, stand health and clear origin.

Figure 1. Working map of the KPPN Bulian of the District VIII of PT. WKS.
The potential tree's cluster assessment was done by subjectively grouping trees in the map based on their coordinates. In contrast, assessment of the stand whether or not it is feasible to be proposed as a seed source of ironwood is carried out descriptively based on the results of measurements and observations of the parameter required in the Seed Source Standard Guideline (Directorate General of Land Rehabilitation and Social Forestry Decree No: P05/V-SET/2010), namely accessibility, number of mother trees (and size of seed source), stand (phenotypic) quality, flowering and fruiting, security, health, the origin of trees, and isolation.

3. Results and Discussion
Referring to the Regulation of the Minister of Forestry No. P.01/Menhut-II/2009 (P.72/Menhut-II/2009) that has been revised to P.3/Menhk/Setjen/Kum.1/1/2020 on the Seed Source Standard Guideline by the Directorate General of Land Rehabilitation and Social Forestry (Decree No: P05/V-SET/2010), seed sources can be obtained in two ways. Those are: (1) designating an existing stand (either a natural forest or a plantation forest)-that was initially established not for seed production but for other uses, for example, timber production, protection forest, and so on- to be converted as a seed source, or (2) establishing a seed source by planting a new stand which intentionally developed to produce seeds [9].

The KPPN Bulian of the District VIII of PT. WKS is a natural stand that was not originally intended as a seed source of ironwood. Therefore, before being determined as a seed source, this stand needs to be assessed based on the following criteria:

3.1. Accessibility
According to the Directorate General of Land Rehabilitation and Social Forestry Decree No: P05/V-SET/2010, the location of the seed source must be easy to reach so that it is easy to maintain and collect the fruit and speed up transportation time. Seed sources that have good accessibility will also guarantee the physical-physiological quality of the seeds. The stand should be easy to visit in any season, preferably near a road. Managing, supervising, and inspecting the seed source will be challenging if the stand accessibility is not good. In addition, collecting the seeds will be more difficult [9]. The KPPN Bulian is located just next to the logging road, namely Jalan 810 of PT. WKS District VIII. Therefore it is easily accessible with 4-wheel vehicles in any season. The location is about 5 km from District VIII's basecamp (office) (Figure 2).

**Figure 2.** Jalan 810 of PT. WKS District VIII to the KPPN Bulian.
3.2. Number of mother trees (and size of seed source)

In total, 1029 trees and copies were recorded during the assessment. The distribution of the number of individuals for each tree growth phase is presented in Figure 3. The average stem diameter of the mature trees is 32.2 cm, while the average tree height is 19.4 m. When the stand is designated as a seed source, collecting seeds from every tree in the stand should be avoided. The seeds must be collected from mother trees that are not close together because, in natural forests, there is often a family structure where adjacent trees usually come from the same mother tree leading to a narrow genetic variability [9]. Therefore, it is imperative to have at least 25 family groups in the seed source [9]. Based on the map of the distribution of ironwood trees at the KPPN Bulian (Figure 3), there are at least 50 tree clusters. However, field observations are needed to ascertain the actual conditions in the field before this stand is proposed to be designated as an identified seed stand.

In this assessment, a comprehensive vegetation inventory was not carried out, so the dominance of the ironwood in this area was unknown. However, based on the report on the vegetation inventory at the KPPN Bulian in 2012 [10] and 2018 [11], ironwood is the dominant species in this forest area which is indicated by the highest Importance Value Index of the species in all phases of growth, namely seedlings, saplings, poles and trees.

The dominance of ironwood trees in this area is 91.25%, causing other tree species to be unable to spread and develop properly, leading to low species diversity at tree level in this area, with a Shannon-Wiener Diversity index of 2.4 [10], 2.9 [11]. This is consistent with the results of other studies that the species diversity in tropical rainforest ecosystems dominated by ironwood is generally low compared to forests dominated by Dipterocarpaceae [12, 13]. However, even with low vegetation diversity, there was an evenness in the number of individual species at all growth phases, as indicated by a high evenness index. This indicates a balance between the number of individuals and the number of species found to make the ecosystem more stable [11].

Ironwood in this forest stand is associated with 35 other tree species, such as kacang-kacang (Strombosia javanica), meranti putih (Shorea sp.), medang kuning (Litsea sp.), meranti merah (Shorea sp.), mahang (Macaranga maingayi), meranti rambah (Shorea sp.), arang-arang (Trenstromia sp.), kedondong (Spodias pinnata), kasai (Pometia sp.), tampui (Baccaurea crassifolia), rambutan hutan (Nephelium sp.) and kelat (Eugenia sp.) [10]. Although ironwood is very dominant in the forest stand, the distribution of individual trees is limited. It might be caused by the limited ability of the seeds to disperse due to the size and weight of the fruits and seeds. Ironwood fruits and seeds can only disperse barochory (depending on gravity and slope), so the ironwood will grow in certain clusters [13]. Figure 3 shows the distribution of ironwood trees in the KPPN Bulian, which is not evenly distributed throughout the KPPN area but only clustered in certain areas of about 15 ha. Therefore, a seed source should be determined in the area dominated by ironwood trees only.
Figure 3. Distribution of ironwood trees at the KPPN Bulian.

3.3. Stand (phenotypic) quality

Stand quality is a fundamental criterion in selecting stands as a seed source. Stands of better quality (above average) to compare with other stands will ensure that the seeds produced are also good quality. Therefore, designated seed sources from natural stands should be selected from stands that have not undergone good quality trees being logged and only leave low-quality trees [9]. The KPPN Bulian of the District VIII of PT. WKS is a log-over area of the former HPH concession of PT. Loka Rahayu, so that the concessionaire logs over the existing ironwood stand in the past. As a result, large-diameter trees have been felled, leaving trees with relatively small diameters. The largest remaining tree has a DBH of 85 cm and a height of 30 m (Figure 4a). However, the nature of the ironwood tree, which can produce coppice, a regeneration from the cut stump of the harvested trees, eliminates the concern that the stand quality is below average because trees with good quality have been felled. The coppices have now grown and can produce fruit (Figure 4b) which is an excellent genetic inheritance from the mother tree that has been felled. In general, the ironwood stand at the KPPN is in reasonably good condition, where 40% of mature trees have stem diameters and tree height greater than the population average.

Figure 4. (a) A mother tree candidate of ironwood, and (b) coppice of ironwood.
Vegetation populations usually distribute the number of individuals based on age or growth stage that is typical in a particular area. Sometimes age classes (growth stages), especially young individuals, are absent or present only in small numbers. This indicates that there will be a population reduction in the future. Conversely, if the seeds and individual trees are in large quantities, the population will be stable or even increase [18]. The number of ironwood individuals in the KPPN Bulian for each growth phase is presented in Figure 5.

![Figure 5. Distribution of the number of individuals for each tree growth phase of ironwood in the KPPN Bulian.](image)

3.4. Flowering and fruiting
During the assessment, 101 trees and 15 poles were found to have immature fruits, or seeds and seedlings emergence in the forest floor (Figure 6), which is distributed throughout the stand area. A total of 59 trees were found to bear at least 25 fruits. Therefore, it is estimated that at least 1,475 seeds will be produced from the stand. It indicates that there is no regeneration issue in the stand. However, there is no information on the flowering and fruiting season for ironwood trees in this area. Further observations of the ironwood’s flowering phenology in this stand are required to obtain more accurate data about the precise flowering and fruiting times of ironwood and potential seed production of the stand.

It should be noted that the stands that will be designated as seed sources have already flowered and produced seed. Therefore, flowering and fruiting on the tree should be examined or observed. Observation of fruit can also be done by looking for fallen fruit and seeds and looking for saplings that grow on the forest floor. When data on flowering and fruiting was not available, it is not recommended to be designated as a seed source. In addition, a seed source should not be designated when the stands are young and have not yet begun to flower and bear fruit [9].
Ironwood bears fruit for 2-3 years or even every year, especially in July-August (Sumatra) and October-November (Kalimantan) [1, 3]. Large fruits are oval with 5-10 cm and 10-20 cm in diameter. Each fruit consists of a single seed with a rind thickness of 9.5 to 1 cm. The color of the fruit is green when it is immature and becomes a little dusky after ripe; the rind and flesh of the fruit will separate from the seed by rotting within 2-3 months after the fruit falls on the ground. Ivory white seed protected by a 1-2 mm thick hard shell [1]. Another study reported that ironwood in southern Sumatra bears fruit every year or every few years. Ironwood bears fruit in February-April (Serumpit Mountain Protection Forest - East Belitung), August (Mambang Customary Forest-South Sumatra), November (Durian Luncuk II Nature Reserve and Senami Forest Park-Jambi) [14]. However, this information needs to be updated because climate change has shifted the phenological patterns of many plant species [15, 16].

3.5. Security
The existence of the ironwood stand in the KPPN Bulian is still well preserved and protected. No illegal logging, encroachment for agriculture and other uses, fire disturbance, disturbance of livestock and wildlife, which can damage stands and disrupt seed production, have been recorded to occur in the stand. However, because the stand's location is relatively far from the camp, it is possible that illegal logging by the surrounding community can occur at any time in the future if the company does not properly manage it. In addition, a minor threat to the sustainability of the ironwood stands are animals that consume ironwood seeds, such as hedgehog (Hystrix javanica) and wild boar (Sus scrofa) [3, 17]. In the future, when the stand is designated as a seed source of ironwood, people's access to the stand must be restricted. The collection of ripe fruits needs to be done immediately and adequately before being eaten by animals.

3.6. Health
The stand designated as a seed source should be sound, i.e., free or less pest and disease attacks [9]. Ironwood trees at the KPPN Bulian are in good condition, where no severe pests and diseases are found,
which attacked seedlings, saplings, poles and trees in the stand. This suggests that the sustainability of this stand can be persistent in the future provided there are no natural conditions or human intervention to prevent the natural regeneration of the trees.

3.7. The origin of trees
The origin of the trees that make up a stand that will be designated as a seed source is critical because it can determine the quality of the stand. The certainty of the origin of the trees that make up the seed source affects the genetic quality of the seeds produced from the seed source, and concerns about genetic mixing between populations can be minimized. For example, ironwood trees at KPPN Bulian grow naturally, and no enrichment planting has been recorded in the area. Therefore natural regeneration origin is assured so that the genetic purity of the species is beyond doubt.

3.8. Isolation
The isolation path around the seed source is needed to avoid pollen contamination from outside the stands to pollinate mother trees at the seed source, which can reduce the genetic quality of the seeds produced. However, not all seed sources are required to have an isolation path. Based on the Seed Source Standard Guideline by the Directorate General of Land Rehabilitation and Social Forestry, no isolation path is required for seed sources classified as Identified Seed Stand and Selected Seed Stand [9]. The fact that a eucalyptus plantation surrounds the ironwood stand in the KPPN eliminates concerns about the cross-pollination of ironwood trees from other trees outside the seed source. Thus, the genetic purity of the seeds produced from the seed source will be maintained.

4. Conclusion
The KPPN Bulian of the District VIII of PT. WKS meets the requirements to be registered as an Identification Seed Stand of ironwood because it fulfills the eight criteria for designating seed sources stipulated by the Directorate General of Land Rehabilitation and Social Forestry (No: P05/V-SET/2010), namely: the stand is easily accessible, the stand has an adequate number of mother trees candidate (>50 family groups of trees), stand quality is good, the trees can regenerate, the stand is relatively safe from human and animal disturbances, the trees are in good condition and healthy, the trees grow from natural regeneration, and the stand is isolated from other ironwood stands.

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**Author's contribution**

All authors contributed equally to this work as the main contributor.