

Distribution of *Casuarina Equisetifolia* along the Southern Coast of Yogyakarta after Sixteen Years (1996-2012)

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Abstract—Distribution of *Casuarina equisetifolia* in Indonesia based on the examination of Bogoriense Herbarium specimen were Islands of Sumatera, Kalimantan, Sulawesi, Moluccas, Java, and Lesser Sunda. Recently *C. equisetifolia* had also been spreading with the aid of people into Parangtritis sand dune and 27 beaches in 21 coastal villages (65.5%) along the southern coast of Yogyakarta. Their locations and plantation patterns clarified by using exploring method and Google Earth reference images. Five plantation patterns were depicted i.e. oblique comb, *untu walang*, rows formation, individual, and rectangle. The first two constitute the early pattern, but not currently replicated. The largest numbers of rows formation and rectangle, which were established between fore-dune and landward in Bantul and Kulonprogo, proved associated with agricultural land. In individual, *C. equisetifolia* had been distributing in roadsides, yard of fishing villages, and tourism beaches as shady tree and greenery landscape.

Index Terms—*Casuarina equisetifolia*, distribution, southern coast of Yogyakarta, coastal forest, coastal village, use

I. INTRODUCTION

The Java Island, one of five major islands in Indonesia, has some forest types due to rainfall varied and climate types [1]. There are tropical rain forest, seasonal monsoon forest [2], mangrove forest [1], [3], and potentially a coastal forest [4]. In the southern part of Java Island, coastal zones stretch from West Java to East Java, through Central Java and Yogyakarta. The coasts, which border directly onto the Indian Ocean along more than 1400 km, become very important. They represent a habitat that is intermediate between the land, the fresh water and the sea [5], [6]. These zones have conservation

area [7], sandy agricultural land [8]–[10], and a significant contribution to regency's or province's income from mining, tourism, cultural beach and fish landing ports [11], [12]. However, poor families also reside and exploit these zones considering limited fertile agriculture land [4], [9]. In order to emphasize on agricultural development for income and food security, management of the coastal zones are always needed [13].

In October 1996, Universitas Gadjah Mada (UGM) introduced beach she-oak (*Casuarina equisetifolia*), a species of the genus *Casuarina*, in Samas Beach, Bantul Regency, Yogyakarta Province. The seeds of those *C. equisetifolia* were collected from Lombang Beach, Madura Island, East Java Province [10]. *Casuarina* is native to Southeast Asia, Australia, Polynesia, Micronesia, and Melanesia [15]. The distribution of *Casuarina* in the world is shown in Fig. 1. Ref. [16] informed that *C. equisetifolia* has two subspecies i.e. subsp. *equisetifolia* and subsp. *incana*. They are distinguished by the length of the leaf teeth (0.5–0.7 mm in subsp. *equisetifolia*; 0.7–1.0 mm in subsp. *incana*) and the dense pubescent immature phyllichnia (ridge of a branchlet article) in subsp. *incana*. The natural distributions of the two subspecies of *C. equisetifolia* are shown in Fig. 2.

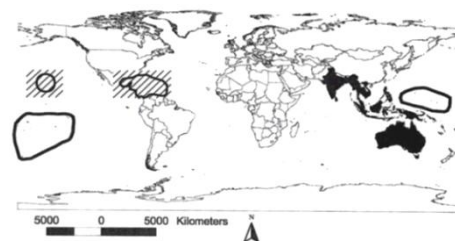


Figure 1. Distribution of *casuarinas*. Native ranges are shaded black or encircled with solid black lines. The stippled polygons show regions where *Casuarinas* have been introduced in North America, the Caribbean, the Bahamas, and Hawaii (map source: [14]).

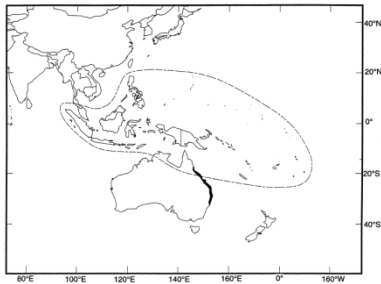


Figure 2. Natural distribution of *Casuarina equisetifolia*: subsp. *equisetifolia* (within broken line) and subsp. *incana* (black shading) (map source: [16]).

During the last decade, *C. equisetifolia* has been extensively spreading along the southern coast of Yogyakarta because of various beneficial factors [4, 10, 17–20] (Fig. 3). Habitat changing related to this species was interesting to investigate. The specific questions addressed included: 1. Were *C. equisetifolia* had growing in the conservation area e.g. Parangtritis sand dune? 2. What plantation pattern of *C. equisetifolia* more replicated by coastal inhabitant?

II. METHODS

A. Study Sites

Explorations were conducted along the southern coast of Yogyakarta those borders directly onto the Indian Ocean. It spreads across 32 coastal villages in 13 coastal districts and three regencies i.e. Kulonprogo, Bantul and Gunungkidul (Fig. 4, Table I). The population and other infrastructure performances along the southern coast of Yogyakarta can be seen in Fig. 5.

B. Materials

C. equisetifolia those shown in Fig. 6 were observed along the southern coast of Yogyakarta. During recording, information about subspecies was not considered. The taxonomy description of *C. equisetifolia* follows references [22]–[27].

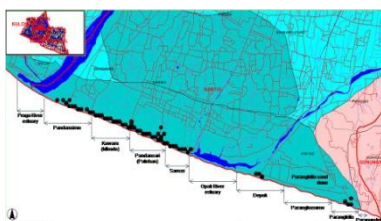


Figure 3. The 2009 distribution of *C. equisetifolia* along the southern coast of Bantul indicated by black dots. Index map of Yogyakarta Province in the upper left corner (map source: [4]).

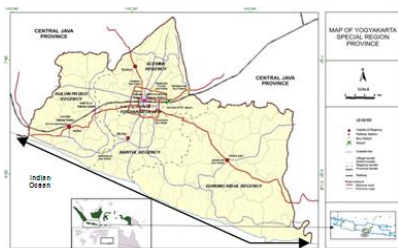


Figure 4. Study sites, which were along the southern coast of Yogyakarta, indicated by black arrow (map source: [21]).

TABLE I. COASTAL VILLAGES ALONG THE SOUTHERN COAST OF YOGYAKARTA

No	Regency	Name of district	Name of village
1	Kulonprogo	Temon	Jangkaran, Sindutan, Palihan, Glagah
2		Wates	Karangwuni
3		Panjatan	Garongan, Pleret, Bugel
4	Bantul	Galur	Karangsewu, Banaran
5		Srandakan	Poncosari
6		Sanden	Srigading, Gadingsari
7	Gunungkidul	Kretek	Parangtritis
8		Purwosari	Giripurwo, Girichayo, Girijati
9		Panggung	Girikarto, Giriwargo
10		Saptosari	Kanigoro, Krambil Sawit
11		Tanjungsari	Ngestirejo, Banjarejo, Kemadang
12		Tepus	Purwodadi, Tepus, Sidoharjo
13	Girisubo		Songbanyu, Pucung, Tileng, Jepitu, Balongan

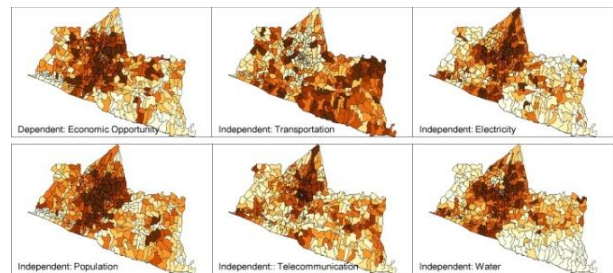


Figure 5. Spatial distribution of infrastructure performance in Yogyakarta Provinces. The dark colors represent higher values or better infrastructure performances. Name of regency and clearly border of village and regency see Fig. 4 (Map source: [21]).

C. Field Collection and Data Analysis

The locations of *C. equisetifolia* were mapped by using exploring method to investigate their presence or absent. This method looked at every side of the study sites to gain data [28]. All roadsides were traversed by vehicles or walking (especially within Parangtritis sand dune) to identify the locations of *C. equisetifolia*. It was possible to span the horizon from a vantage point to identify the general locations of adult tress and individual [14].

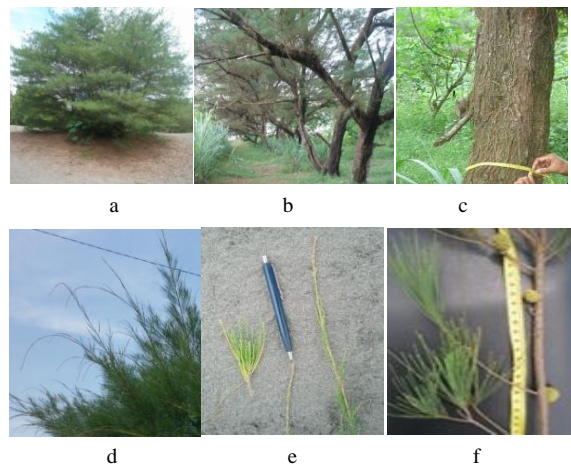


Figure 6. Morphology of *C. equisetifolia*: a. crown; b. stem; c. bark; d. foliage, like shrimp tails; e. branchlets; f. branch with cones (photographs taken by first author in February 2012, except a. photograph source: [17]).

In addition, *C. equisetifolia* along the southern coast of Yogyakarta were recorded. These locations were then compared with the distribution of *C. equisetifolia* in Indonesia based on the examination of herbarium specimens from herbaria of the National Herbarium Bogoriense (BO) [29]–[31]. Google Earth reference images also used to clarify distribution and plantation pattern of *C. equisetifolia* [32]–[36]. The collected data were then analyzed and explained descriptively.

III. RESULTS AND DISCUSSION

A. *C. equisetifolia* Distribution in Indonesia

The distribution of *C. equisetifolia* in Indonesia based on the examination of herbarium specimens from herbaria of BO is shown in Fig. 7. The detail data are as follows:

1) *Casuarina equisetifolia*

Distribution in Indonesia: Sumatera, Kalimantan, Sulawesi, Moluccas, Java, Lesser Sunda Islands.

Specimens: Lampung, *Verlaten/Ferlaten* Island (Sertung Island), Krakatau groups, 1906 (64052); North Sumatera, Serdang near Tjermin beach, 1928; Tapakuda Island in delta of Wampu and Batang Serangan river, 1934; Sibolangit Bali Garden; Siberut Island, North Siberut, Timiti district, Sikabalu, 1994 (BO 1866448); West Kalimantan, Sukadana, Sukadana village, 1953 (BO 1652722); East Kalimantan, Tarakan, Tidung, Amal village, 1953 (BO 1652719); Nunukan, Sebatik, Badjau river (BO 1398812); Flores, Manggarai, 197?; Flores, Manggarai, Cebe village, Batucie, 1988 (BO 1866458); Lombok, Mt. Rinjani, 1964; Lombok, Mt. Rinjani, 2003 (BO 1519039); Lombok, Mt. Rinjani, 2003 (1838767); Sultanat Bima, 1909 (BO 1652758); Sumbawa (BO 1652758); Sumba, Winkelo, 1932 (BO 1410332); Moluccas, Wetar, 1909 (BO 1652757), Selaru Island, Tanimbar Islands.

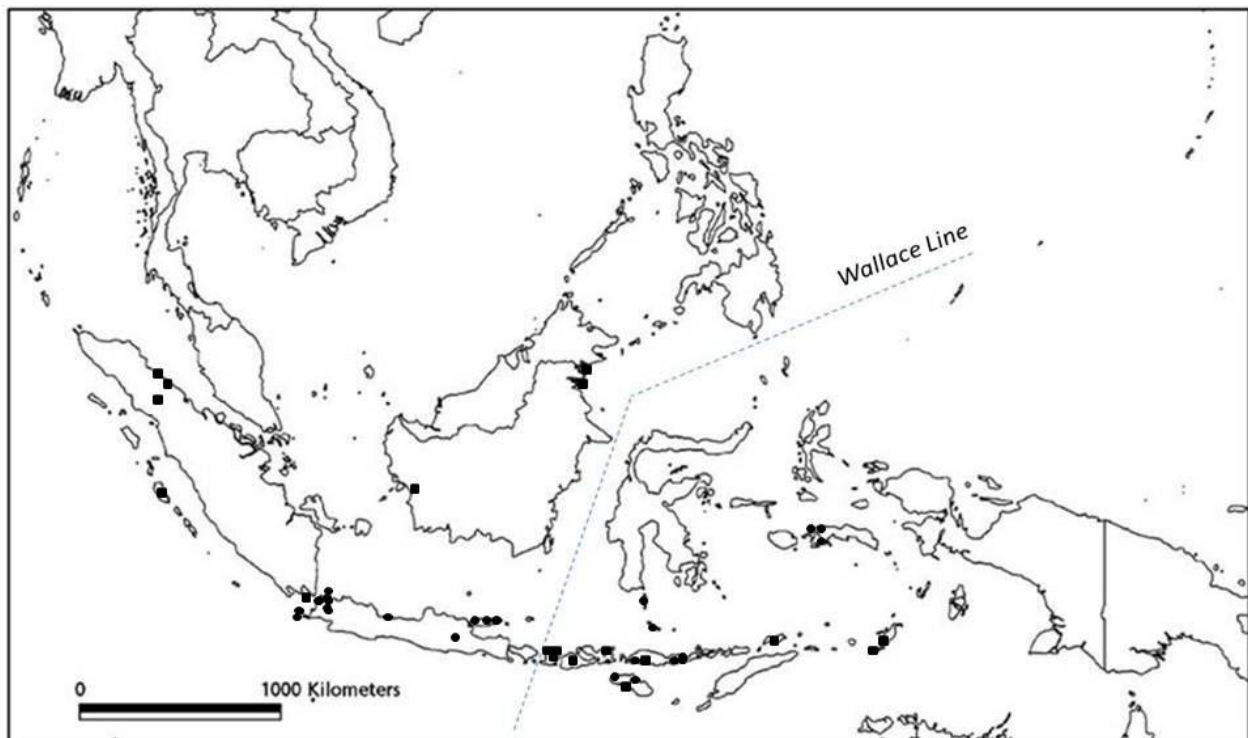


Figure 7. The distribution of *C. equisetifolia* (■) and *C. equisetifolia* subsp. *equisetifolia* (●) in Indonesia based on the examination of herbarium specimens from the National Herbarium Bogoriense (BO) in 2010.

2) *Casuarina equisetifolia* subsp. *equisetifolia*

Java, Batavia, Tanjung Priok, *Culta*, 1902, 1903, 1904; Cilincing, 1904, 1928; Pajoeng Island, 1906; Paniki Island, 1906; Bokor Island, 1920; 1922 (63894); West Java, Batu Tulis, 1894; Bogor, *Culta*, 1928 (BO 1410331); Central Java, Tegal, 1917 (BO 1398741); East Java, Madura Island, Bangil (?), 1913 (BO 1398742); Madura Island, Sapulu, 1915 (BO 1400332); Madura Island, *N.O. van Batang*, Batang Daja, *Duincamp/duinen*; Kediri, Gadoengan, 1922 (63892); Java ? , 1951 (63930); South Sulawesi, Selayar Island, 1904; Kalao Island; Panaitan Island, Legon Mandar/North Peninsula, West of Tg. Paraf, 1951 (BO 1652762); Flores, Ende,

1927; Flores, Ende, 1941 (BO 1660549), Ende, 1941; Manggarai, Lili Beach, 1972; Sumba, Waikalo, 1925 (1398811); Wurhelo (?), 1932 (BO 1660544); Ambon, Pombo Island, 1984; West Seram, Lobbi village, 1928 (BO 1660553); West Seram, Wae Selan, 1938.

B. *C. equisetifolia* Distribution and Plantation Pattern along the Southern Coast of Yogyakarta

The distributions of *C. equisetifolia* in Bantul Regency were studied in 2009 (Fig. 3). According to reference [4], in 2009, *C. equisetifolia* were absent in Parangtritis sand dune, Parangkusumo Beach, and two estuaries of Opak river and Progo river. Recently, *C. equisetifolia* were

widely established along the southern coast of Yogyakarta. They had been spreading into Parangtritis sand dune and 27 beaches in 21 coastal villages (65.5%) and 13 coastal districts (100%) with the aid of people (Table II). Bantul Regency had the most populated of *C. equisetifolia* (9 beaches and Parangtritis sand dune),

followed by Kulonprogo Regency (8 beaches), and Gunungkidul Regency (10 beaches). The many direct benefits gained attracted coastal inhabitant to conserve and to plant more *C. equisetifolia* sustainably [17].

TABLE II. PLANTATION PATTERN AND LOCATIONS WHERE *CEMARA UDANG*¹ DISTRIBUTED ALONG THE SOUTHERN COAST OF YOGYAKARTA AFTER SIXTEEN YEAR (1996-2012)

No	Name of beach or sand dune	Village	District	Regency	Plantation pattern ²				
					1	2	3	4	5
1	Cogot	Jangkaran	Temon	Kulonprogo	-	-	█	●	□
2	Glagah	Glagah			-	-	█	●	□
3	Karangwuni	Karangwuni	Wates		-	-	█	●	-
4	Garongan	Garongan	Panjatan		-	-	█	-	□
5	Pleret	Pleret			-	-	█	●	□
6	Bugel	Bugel			-	-	█	●	□
7	Karangsewu	Karangsewu	Galur		-	-	█	●	-
8	Trisik	Banaran			-	-	█	●	-
9	Pandansimo	Poncosari	Srandakan	Bantul	-	-	█	●	-
10	Baru				-	▲	█	●	-
11	Kuwaru				-	-	█	●	□
12	Patehan (Gua cemara)	Gadingsari	Sanden		-	-	█	●	□
13	Pandansari	-			-	█	●	□	
14	Samas	Srigading			⊥	-	█	●	□
15	Depok	Parangtritis	Kretek		-	-	█	●	□
16	Parangkusumo				-	-	█	●	□
17	Parangtritis sand dune			-	-	█	●	-	
18	Parangtritis			-	-	-	●	-	
19	Gesing	Girikarto	Purwosari	Gunungkidul	-	-	-	●	-
20	Ngrenehan	Kanigoro	Saptosari		-	-	-	●	-
21	Kukup	Kemadang	Tanjungsari		-	-	-	●	-
22	Sepanjang				-	-	-	●	-
23	Drini	Ngestirejo			-	-	-	●	-
24	Krakal				-	-	-	●	-
25	Sundak	Sidoharjo	Tepus		-	-	-	●	-
26	Indriyani	Tepus			-	-	-	●	-
27	Siung	Purwodadi		-	-	-	●	-	
28	Sadeng	Pucung and Songbanyu	Girisubo	-	-	-	●	-	
Total		21	13	3	1	1	17	27	11

¹ *cemara udang* is in Indonesian language instead of beach she-oak (*C. equisetifolia*). Some coastal inhabitants also mentioned *C. equisetifolia* in Java language as *cemoro laut* or *cemoro pantai* [17].

² plantation pattern of *C. equisetifolia*: 1. oblique comb (⊥), 2. *untu walang* (▲), 3. rows formation (█), 4. individuals (●), and 5. rectangle (□), whereas (-) was not found the same pattern within one column or no data.

Five plantation patterns of *C. equisetifolia* were recorded. Those are oblique comb, *untu walang*, rows formation, individual, and rectangle (Fig. 8). Oblique comb pattern, which was used in the first establishment in Samas Beach, Bantul Regency, is *C. equisetifolia* plantation that formed like a comb, which was not parallel to coastline. Their growths were expected better because had minimum collision side with coastal wind [10]. The second pattern is *untu walang* (Java language). It was like pair of inverted pyramids and represented the action of grasshopper teeth. This pattern was imaged by Google Earth in Baru Beach, Bantul Regency. Oblique comb and *untu walang* constitute the early trial plantation pattern, but not currently replicated by coastal inhabitant. It may be related to the limited space and form of agricultural land border.

The third pattern is rows formation, which illustrated in Fig. 8C as thick lines parallel to the coast. They were stand of *C. equisetifolia* in the form of lines. Whereas rectangle pattern constitutes a pattern that *C. equisetifolia* both homogeneity or together with other species formed a hedgerows. This pattern was also used for agricultural land boundaries. Rectangle pattern existed in 11 beaches, whereas rows formation applied in 17 beaches, mainly found in Bantul and Kulonprogo Regencies (Table II). They were strongly associated with agricultural land. Bantul and Kulonprogo Regencies were located surrounding Opak River and Progo River has a relatively flat topography. Thus agricultural land activities had been developed and became main economic resources. Rows formations of *C. equisetifolia*, which were established between fore-dune and landward be able to prevent agricultural land, fishing villages and embankment from wind erosion and salt spray [4], [10], [17], [20]. In the past time, coastal inhabitant had only used pioneer vegetation like *Pandanus sp.* to prepare cultivation in the sandy agricultural land, then *Acacia sp.* and *Gliricidia sepium* to make boundary land clearly and to shade crops [37].

In individual pattern, the most of *C. equisetifolia* were artificially pruned from middle to the lowest branch. This pattern associated with the need of shade, space, green landscape and protection (Fig. 9). The presences of *C. equisetifolia* in individuals were found almost continuously along the most southern roadsides that parallel with Indian Ocean, They also scattered in yard of



Figure 8. Plantation pattern of *C. equisetifolia* by using Google Earth reference images: A. oblique comb; B. *untu walang* (left) and rectangle (right); C. rows formation; D. individual.

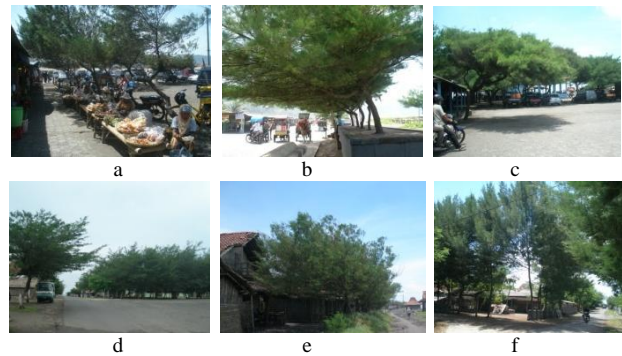


Figure 9. The use of *C. equisetifolia* in individuals as shady tree: a. in Depok Beach; b. in Parangtritis Beach; c. in the parking area of Depok Beach; d. along roadside to Samas Beach; e. in the fishing villages of Pandansimo Beach; f. in the village near the coast (photographs taken by first author in March 2012, except a. source: [17]).

fishing villages and 27 beaches. They apparently suitable for tourism area, trading area, parking area, roadside, rest area, and villages. Green coastal landscape with better infrastructure performance, such as more water, electricity, transportation, telecommunication and population prompted more tourism areas, trade areas and wide residential [21] such as in Parangkusumo Beach, Parangtritis Beach, Patehan Beach, and Baru Beach, Bantul Regency. The two latter demonstrated that rows formation of *C. equisetifolia* changed to in individuals due to tourism's needs (Fig. 10).

Generally, three regencies, 13 coastal districts, and 65.5% coastal villages along the southern coast of Yogyakarta, include Parangtritis sand dune had the distribution of *C. equisetifolia*. These results would enrich *C. equisetifolia* distribution in Indonesia (Fig. 7) and should encourage appropriate management strategy at costal zones [13], [38], [39]. The remaining coasts where located in Gunungkidul Regency (9 coastal villages) and Kulon-progo Regency (2 coastal villages) faced problems like steep topography, remote coasts, and minimum activities.

The 16 years establishment of *C. equisetifolia* that reached 65.5% of coastal villages with 27 coasts and Parangtritis sand dune seems to be relatively fast. People became the most important dispersing agent considering their needs, mainly to agriculture, tourism, and fishery. Support researches relating to the coastal site and silviculture were also greatly assist coastal inhabitant, government, and NGO in the wider plantation of *C. equisetifolia* [10], [12], [37].



Figure 10. a. Rows formation of *C. equisetifolia* were then artificially pruned from middle to the lowest branch in order to support tourism in Baru Beach; b. same case in Patehan Beach (Gua Cemara Beach), Bantul Regency (photographs taken by first author in February 2012).

Finally, we must also remain aware of ecosystem changing due to the spreading of *C. equisetifolia* [14]. Conservation and management of dune communities should consider the complex mosaic of coastal zones. Each element will respond differently to people alteration [29], [39].

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