



A history of Floral diversity (pollen, spores and algal) during the latest Holocene in the Bandung basin based on palynological analysis in Cihideung, West Java, Indonesia

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Abstract

Floral diversity is a measure of number of type flora in an area, and reflects how vegetation develops in response to the environmental condition during a certain time interval. The present study aims to examine changes in the diversity of vegetation (pollen, spores and algae), evenness, and similarity in the Bandung Basin through a core of 240 cm depth using a ground drill, as well as the radiocarbon dating (940 ± 120 BP) of a clayey peat level, located at the bottom (172.5 - 52.5 cm depth) of study section. Twenty four samples were taken at 5 cm intervals down the surface of the sediment core. Changes were obtained by comparing the quantity of pollen, spores, algae, and the lithology of the deposits. Palynomorph data show that Shannon diversity index ranged from 2.14 to 2.80 for pollen and spores, and 0 to 1.64 for algae; Shannon evenness index ranged from 0.64 to 0.81 for pollen and spores, and 0 to 1.74 for algae; and Jaccard similarity index results ranged from 30% - 68%. Faunal diversity is moderate with a good level of balance, and an overall trend in the increase of diversity in the clayey peat level. These changes are influenced by the presence of the Lembang Fault.

Keywords: *Floral diversity, evenness, similarity, Palynology, Holocene, Bandung Basin, West Java*

1. Introduction

Indonesia islands are situated on the equator region of South East Asia with a tropical climate. These islands are generated by the subduction between Eurasian and Indian plates, and also the Australian continental crust which is moving towards Indonesia. These major tectonic events have influenced the atmospheric circulation patterns and the Indonesian climate (Hope et al. 2004). During the Holocene, Indonesia was dominated by tropical rain forest C3 plants with very high rainfall conditions (> 3,000 mm/year) and a stable climate after the Pleistocene Ice Age (Birks and Birks 1980, Stuijts et al. 1988, Kaars et al. 2001, Hartmann et al. 2013). Indonesia is considered to be a mega-biodiversity country because of its range and variety of flora and fauna (Butarbutar and Soemarmo 2013, Yuliani et al. 2018). One of the main components of the high diversity in Indonesia is the flora. Plants are one of the organisms that live on the surface of the earth and become part of an ecosystem with other organisms (Magurran 2005, Basna et al. 2017). Plants are very diverse, ranging from higher plants such as Gymnosperms and Angiosperms to low-level plants such as Bryophyta and Pteridophyta (Friis and Endress 1990, Roth and Lorscheitter 2013), and down to microscopic plants such as algae (Setoaji and Hermana 2013). A certain area containing a certain number of species of plants, is known as faunal diversity (Setiadi 2005, Tudjuka et al. 2014, Peggia 2014).

Java Island has a Holocene basin called the Bandung Basin of area 400 km², surrounded by volcanic terrains at 2,400 m, has an elevation of 665 m, a mean annual temperature of 23.7°C, and a mean annual rainfall of 1,700 mm (Kaars and Dam 1995 and 1997). During the Holocene, Bandung Basin vegetation was dominated by freshwater swamp which replaced the previous open swamp forest (Kaars and Dam 1997, Kaars and Bergh 2004). Lembang and the surrounding areas are located at an altitude of 1,312 to 2,084 m and are famous for their fertile soils which are overgrown with a variety of plants including higher plants, low-level plants, and algae (Charina 2016). Lembang area has a freshwater body area due to depression by the influence of fault known as sagpond. The sagpond in northern part of the Bandung Basin is lake that continues to change its water level into a swamp, even now the sagpond is completely dry (Hidayat 2010, Bachtiar and Syafriani 2012). Variety of plants produced pollen and spores which are preserved alongside the algae in the sediments. Pollen and spores can be used to identify the vegetation that grew around the basin during a particular interval time (Stuijts 1993). By the analysis of contents of pollen, spores, and algae in the sediment, types of vegetation and the environmental conditions occurring during the sedimentation can be established (Lavelle 1996, Edlund et al. 2004, Lelono 2007, Jurnaliah and Winantris 2015).

Sampling was carried out using a hand drill in Cihideung, West Bandung Regency, West Java, Indonesia (6° 49' 6.2" S, 107° 35' 31.2" E) (Fig 1). The lithological column includes three levels, from the oldest to the youngest (Fig 2): volcanic rocks; sagpond deposits; and resilient soils.

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The volcanic rocks were dated of Holocene age (Silitonga 1973). They formed by the eruption of Tangkuban Perahu volcano. This area once formed, the northern side of the Bandung Basin has rapidly experienced changes in environmental conditions, due to the activity of the Lembang Fault. This activity affects the elevation and the influx sediment in the study area (Hidayat 2010). These

environmental and climate changes affected also the vegetation and floral diversity around the Bandung Basin (Kneller 2009; Winantris et al. 2018). The aim of this research is to intend to characterize the changing patterns of taxa diversity, evenness, and similarity through the peat lithological levels (Fig 2), based on the palynological analysis of pollen, spores, and algae.

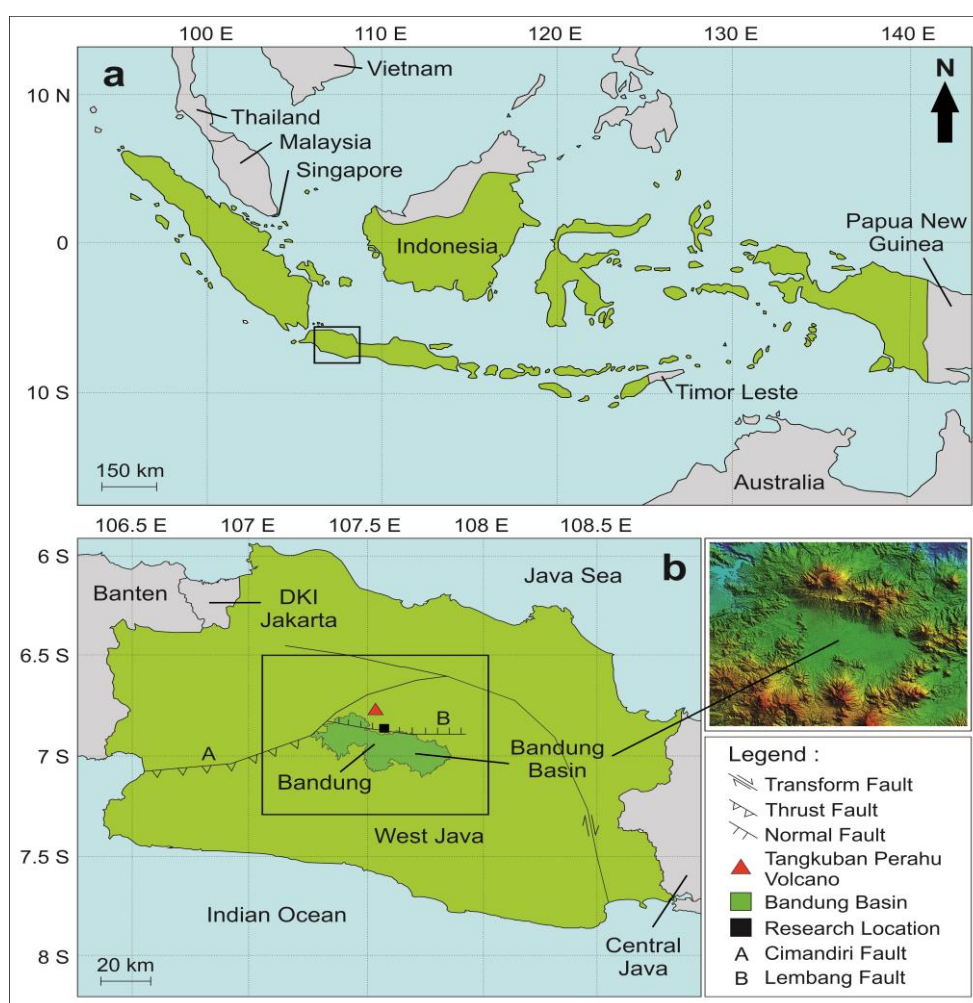


Fig 1. Location of the study area; a) on the map of Indonesia; b) on the map of West Java (Kaars & Dam 1995 and 1997; Bachtiar and Syafriani 2012).

2. Materials and Method

Sediment core were collected during fieldwork using a ground drill to a depth of 240 cm, with undisturbed soil sample type (sampling tube). So samples were not contaminated. For pollen analysis, 24 samples were obtained for the preparation, taken at 5 cm intervals from a depth of 172.5 - 52.5 cm. The collected samples were then processed using the acetolysis method to remove other materials. So pollen, spores, and algae can be collected. This method was done by immersing the sample with various chemicals (HF 40%, HCl 10%, KOH 10%, HNO₃ 10% and Alcohol 70%) and neutralizing it with distilled water. This method refers to Moore & Webb (1978) modified by Setijadi (2005), Setijadi

(2008), Setijadi and Suedi (2011). Identification and determination faunal taxa were carried out with a binocular transmission microscope Olympus CX-22 with a magnification of 400x and 1000x. Reference in identifying refers to several references such as APSA (2007), Bellinger and Sigee (2010).

The diversity of the floral and algal assemblages were statistically analysed using the Shannon diversity index (H'), which determines the distribution of taxa and the individual frequencies in each sample, that can be calculated using the following equation (Formula 1) (Krebs 1978, Barbour et al. 1987, Ludwig and Reynolds 1988, Winarni 2005, Magurran 2013, Ismaini et al. 2015):

$$H' = \sum_{i=1}^s (pi)(\ln pi) \dots (formula 1)$$

where:

pi : Proportion of individuals of one particular taxa (n) divided by the total number of individuals found (N).

H' : Shannon diversity index.

n : Individual number of one species.

N : Total number of all individuals.

Assemblage results were also analyzed using the Shannon evenness index (SEI), which assesses the distribution of plant taxa in each sample and can be calculated using the following equation (Formula 2) (Barbour et al. 1987; Winarni 2005):

$$E = \frac{H'}{H \max} \dots (formula 2)$$

where:

E : Evenness index.

H' : Shannon diversity index.

H max : Maximum Shannon diversity index.

To investigate the similarity or closeness between vegetation traces found in different lithological deposits (different sample depths), the Jaccard similarity index (S_j) is also used, and can be calculated using the following equation (Formula 3) (Real & Vargas 1996):

$$S_j = \frac{a}{a + b + c} \dots (formula 3)$$

where:

a : Number of taxa found in both sample A and B.

b : Number of taxa found in sample B, but not present in sample A.

c : Number of taxa found in sample A, but not present in sample B.

Once these indices were obtained for all samples, the results of the calculation were used to classify the diversity, evenness, and similarity index of the ecosystem. The Shannon diversity index results were classified into 3 parts (Table 1) (Barbour et al. 1987, Efendi et al. 2013, Krebs 1985, Barus 2002).

The Shannon evenness index results which are closer to 1 indicate that no single type of vegetation is dominant in the sample, while the index results which are further from 1 (and closer to 0) means the dominance of one type of vegetation. Whereas, if it is seen from the deposit samples, the value of evenness index with vast difference from one deposit to another, it means that the vegetation of the study area has changed significantly. Conversely, when this index is relatively balanced, each sample has the same vegetation content during the formation (Setiadi 2005; Santosa et al. 2008).

Table 1. Shannon diversity index (H') classification (Barbour et al. 1987, Efendi et al. 2013, Krebs 1985 in Barus 2002).

Shannon diversity index	Interpretation
H' < 2.302	- Low diversity - Unstable ecosystem
2.302 < H' < 6.907	- Medium diversity - Fairly balanced ecosystem - Moderate ecological pressure
H' > 6.907	- High diversity - Unstable ecosystem

For the Jaccard similarity index, the range of possible values is from 0-100%, where the greater number, the closer diversity that exists between 2 samples, or the more likely it is that both samples represent the same vegetation distribution at the time of deposition. Conversely, when the similarity index is smaller, the more different vegetation types which are represented in the 2 samples during deposition (Setiadi 2005, Santosa et al. 2008).

Finally, the age of the sediment was identified using radiocarbon dating from Geology Laboratories (Geological Survey Center, Indonesia), Gas Proportional Counting method, and Oxcal 2-sigma at the bottom of the sagpond deposit level, consists of clayey peat level located at 172.5 cm depth.

3. Results and findings

3.1. Lithology and palynomorph content

The lithology of the sediment core consists of 3 levels (Fig 2). The deepest (240 - 172.5 cm depth) is composed of tuff, with a silt-clay peat variation lying on the level above (172.5 - 25 cm depth). The uppermost level (0 - 25 cm depth) is composed mainly of sand.

The results show that pollen, spores, and algae existing in the study sediment core vary from sample to sample. Key identified groups of pollen are Areaceae, Araceae, and Graminae, while commonly spores are from the Polypodiaceae group. Common algae taxa are genera *Pinnularia* and *Euglena* (Fig 3). At least 4,800 individuals from 37 families of pollen along with spores and algae were identified. In general, the development of pollen, spore, and algae content shows consistent variations, with younger samples containing more all pollen and spores taxa except algae which shows less influence from water (Fig 4). Palynomorph assemblages can be used to investigate the diversity in the Bandung Basin and its changes during the latest Holocene.

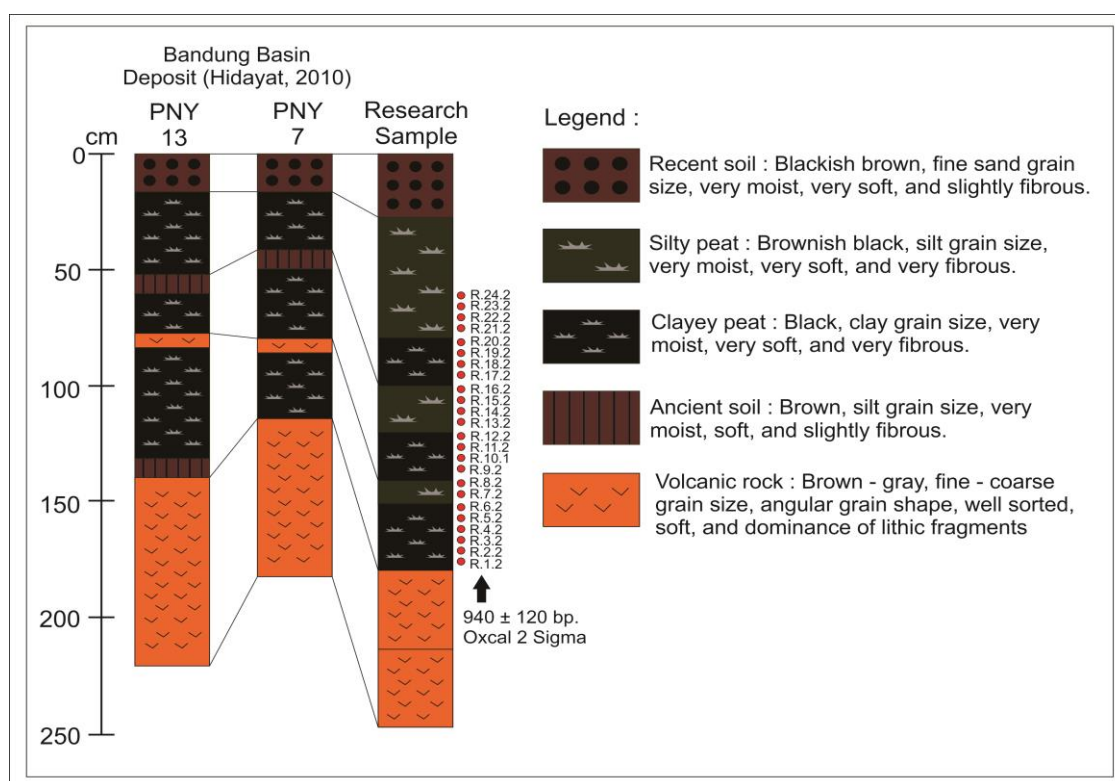


Fig 2. Lithology of study core (to the right), and location of sample correlated to the cores PNY7 and PNY13 from Hidayat (2010).

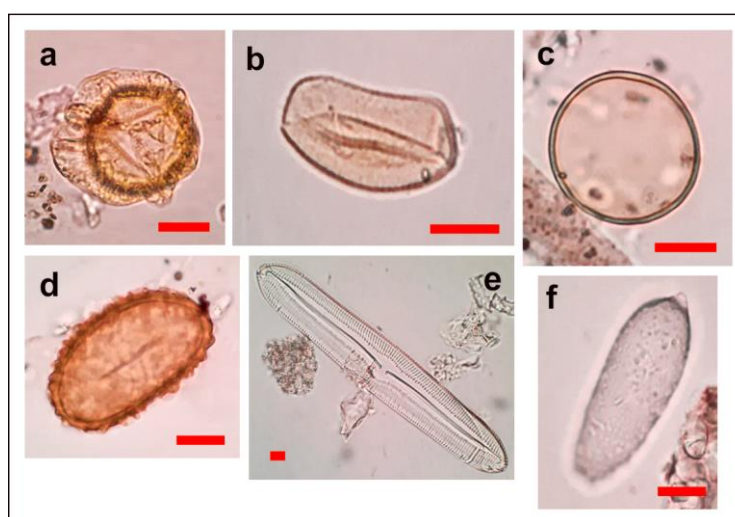


Fig 3 . Dominant palynomorph in study core, a-c. pollen, a. Podocarpaceae, b. Araceae, c. Graminae; d. spores (Polypodiaceae); e-f. algae, e. *Pinnularia*, f. *Euglena*. Scale bar = 10 μ m

3. 2. Diversity, evenness, and similarity index

Shannon diversity index results vary through time, although the changes that occurred are not high. Shannon diversity index results ranged from 2.14 to 2.80 for pollen and spores, and 0 to 1.64 for algae, while the Shannon evenness index results vary from 0.69 to 0.81 for pollen and spores, and 0 to 0.74 for algae (Table 2). The Jaccard similarity index results show some

differences, with results ranging from 30% in samples R 15.2 with R 22.2, to 68% in samples R 11.2 with R 12.2. These results reflect that vegetation traces represented in each sample was not always the same through time, and show changes in line with the respective environmental conditions (Table 3). Radiocarbon dating of the oldest sample (peat deposits) is 940 ± 120 years old.

Table 2. Shannon diversity index (H') and Shannon evenness index from the study area.

Sample Code	H' Pollen	H' Algae	Total H'	h'max Pollen	h'max Algae	Pollen Evenness (E)	Algae Evenness (E)
R 1.2	2.15	0.69	2.84	3.09	1.95	0.69	0.35
R 2.2	2.80	0.74	3.54	3.47	1.61	0.81	0.46
R 3.2	2.48	0.82	3.31	3.09	1.61	0.80	0.51
R 4.2	2.51	1.03	3.54	3.09	1.39	0.81	0.74
R 5.2	2.31	0.84	3.15	2.89	1.39	0.80	0.61
R 6.2	2.42	1.02	3.45	2.77	1.39	0.87	0.74
R 7.2	2.58	0.32	2.89	3.26	1.10	0.79	0.29
R 8.2	2.43	1.09	3.52	3.26	1.39	0.75	0.79
R 9.2	2.27	1.19	3.46	2.89	1.39	0.79	0.86
R 10.1	2.64	0.67	3.30	3.30	0.69	0.80	0.96
R 11.2	2.35	0.90	3.25	3.04	1.10	0.77	0.82
R 12.2	2.19	0.86	3.05	2.71	1.39	0.81	0.62
R 13.2	2.25	1.04	3.29	3.22	1.10	0.70	0.95
R 14.2	2.28	1.21	3.49	3.18	1.39	0.72	0.88
R 15.2	2.15	0.00	2.15	2.83	0.00	0.76	-
R 16.2	2.14	1.29	3.43	2.94	1.39	0.73	0.93
R 17.2	2.36	0.55	2.90	3.04	0.69	0.77	0.79
R 18.2	2.29	0.89	3.18	3.00	1.61	0.76	0.55
R 19.2	2.15	0.96	3.10	2.94	1.10	0.73	0.87
R 20.2	2.31	0.55	2.86	2.89	1.61	0.80	0.34
R 21.2	2.56	1.06	3.62	3.22	1.39	0.79	0.77
R 22.2	2.67	1.64	4.31	3.43	1.79	0.78	0.92
R 23.2	2.38	1.37	3.75	3.18	1.95	0.75	0.70
R 24.2	2.54	0.90	3.44	3.09	1.39	0.82	0.65
Average	2.38	0.90	3.28	3.08	1.32	0.78	0.70

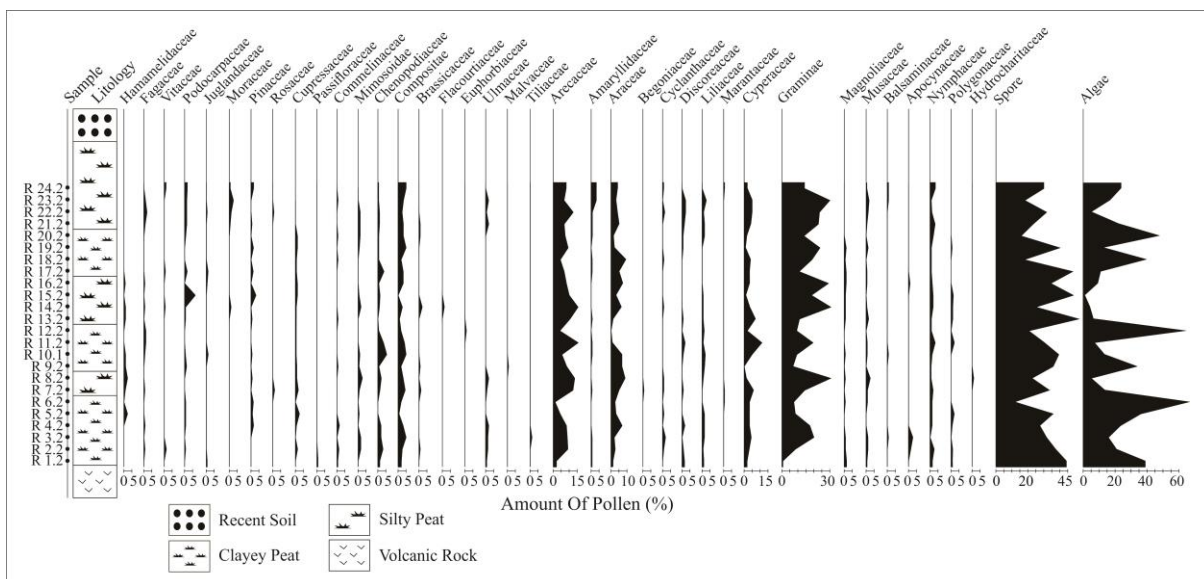


Fig 4. Stratigraphic plot of pollen, spore, and algal assemblages from the study area.

4. Discussion

Lithology of the study core (Fig 2) correlates with cores from Hidayat (2010) shows that the oldest deposits (172.5 - 240 cm), composed of tuff, is related to the volcanic eruption of Tangkuban Perahu volcano. Above it (25 - 172.5 cm), rests a layer of silt-clay peat which was correlated with sagpond deposits, and the uppermost layer (0 - 25 cm), composed of sand is correlated with recent soil level described by Silitonga (1973) and Hidayat (2010).

4.1. Diversity and evenness index

Data obtained showed that Lembang Basin and the surrounding area have pollen and spore diversity within the range of medium to low diversity, with no significant changes through time (Table 2). This medium diversity results from sufficiently productive conditions which support a fairly balanced ecosystem with moderate ecological pressure, based on the Shannon diversity index. Data also indicate that pollen and spore taxa evenness in the study area is quite balanced with little change in the depth samples and with values close to 1. This means that the vegetation types were relatively consistent within the each sample, and also having a fairly balanced evenness.

Data from pollen assemblages show the highest diversity in the deeper sample R 2.2. These diversity reflect significant plant development after the volcanic eruption, while the uppermost sample R 16.2 has the lowest diversity that may be caused by the development of a lake swamp, as show the high diversity of algae in this sample. On the other hand, the Shannon evenness index resultings for pollen taxa does not show significant changes through the section. There are only slight increases in younger samples.

According to the Shannon diversity index, algal diversity is classified as low. Based on this classification, the ecosystems in the study area can be considered unstable with low productivity, due to high ecological pressure. Shannon evenness index results of algal taxa shows significant change values in the Lembang area. This results from changes in the algal assemblage living in the study area. Furthermore, low Shannon evenness index values indicate that individual algal taxa were dominant in certain samples. The algal assemblage in the oldest sample (R.1.2) is dominated by the genus *Euglena*, whereas the youngest sample (R.24.2) is dominated by the genus *Pinnularia*. The latter is more commonly dominant in algal assemblages. Dominance of these algal genera explains the tendency of Shannon evenness index results from the study area to have values close to 0.

The algal assemblage in the younger deposit shows higher values of both diversity and evenness, but in the deeper sample such as R 15.2, diversity and evenness of algal taxa have a value of 0. No algae have been found in this sample. This indicating that the swampy area was shrank from this time, allowing angiosperms to become more developed. Moreover, possible that other factors

such as active faults also have caused changes in diversity and evenness, preventing algae from growing at this time (Hidayat 2010).

Diversity diagram of pollen, spores, and algae show slight changes through time. Assuming that palynomorph assemblages was aligned with changes in the sedimentation. Diversity becomes higher when the texture of grain size decreases and the sediment becomes fine-grained. Conversely, there are significant decreases in diversity when the grain size becomes coarser. This relationship also applies to the Shannon evenness index results for pollen and spores assemblages (Fig 5). This shows that changes in the diversity are influenced by changes in the grain size. Grain sizes can vary in line with a changing environment resulting from various factors including higher or lower elevations of the geological structure caused by the activity of the Lembang Fault.

Lembang and surrounding area are known for their active tectonic, and still current structure of this area is influenced by the active Lembang Fault (Marjiyono et al. 2008; Rasmid 2014). The movement of this fault has also influenced climate and vegetation growing in this area, causing changes of the ecosystem. So, diversity and evenness of the vegetation try to regain balance. According to Hidayat (2010), the sedimentation in the study area is always changing due to the permanent activity of the Lembang Fault. This environmental change is shown by the occurrence of progradation, starts from the lowest peat clay which become sand at the top of the core showing coarsening upward.

Based on radiocarbon dating, the peat deposits start form 940 ± 120 years ago, after a huge eruption of Tangkuban Perahu volcano around 3,500 years and a minor eruption around 1,000 years (Cottrell 2015, Jimawan and Pratama 2017), which gave rise to the basal volcanic and volcanoclastic level of the study section. After this volcanic eruption, and from 1,000 years ago up to the current, geodynamic of Bandung Basin was dominated by tectonic activity of the Lembang Fault which controlled the sedimentation and the peat deposits. There is still evidence for the existence of this sagpond. It can be seen from the presence of local ponds and the presence of peat in several locations in the study area (Ameridyani and Sagala 2011, Yulianto 2011).

Furthermore, current environmental conditions of the study area show high levels of floral and faunal diversities, supported by the diverse vegetation with a good level of evenness (Subahar and Yuliana 2010, Clarisa and Kasmara 2016). Therefore, the Lembang area has experienced a slight change in the condition of the vegetation over a long time period, since the formation of the ancient lake of Bandung around 940 ± 120 years, palynomorph changes interested especially diversity and evenness of pollen, spores, and algae.

4.2. Similarity index

The Jaccard similarity index shows the relationship between samples at different depths (Table 3).

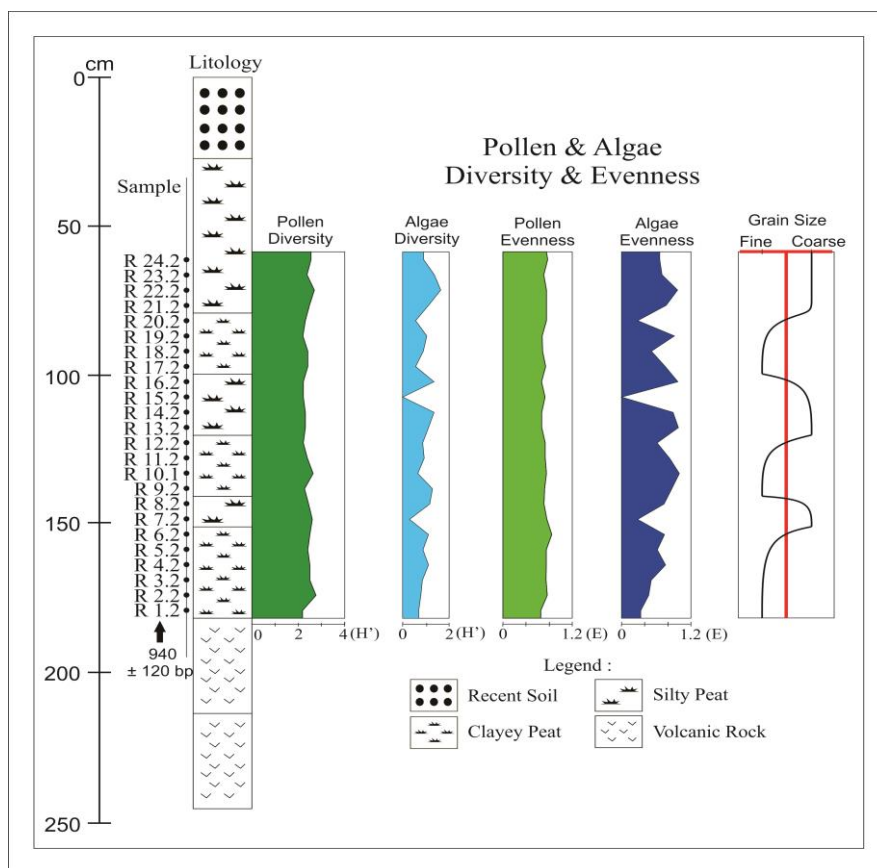


Fig 5. Shannon diversity index (H') and Shannon evenness index (E) results at each sample depth.

Samples that have a close similarity or a high similarity index value are those which are relatively close in depth through the core. For instance, a comparison between sample R 1.2 with R 2.2 produces a similarity index that reaches 57%, while samples which are more distant in the core, such as R 1.2 with R 24.2, have a lower similarity value (37%). This is a result of the environmental changes, so the pollen, spores and algae content in samples are very different, when the sample depth is different during the formation of these deposits (Sokal & Sneath 1963; Febritasari et. al. 2016). Overall, it can be summarized that more the samples are close in the core, more their similarity indices are higher, which indicates that there are significant changes in the content of the pollen, spores, and algae from oldest (deepest) samples to younger (shallowest) samples.

From the overall results of the Shannon diversity and evenness indices, a linear trend can be used to understand the overall changes occurring in pollen, spores, and algal assemblages. Diagram a-e of Fig 6, show that pollen diversity and evenness have very little increased through time, but algal diversity and evenness have well increased. In total, from the start of the peat deposits, there is an increasing trend in overall diversity with $y = 0.0098x + 3.16$ and $R^2 = 0.03$, continued changes in the

palynomorph assemblage caused by variations of environmental conditions, resulting, partially, from the activity of the Lembang Fault.

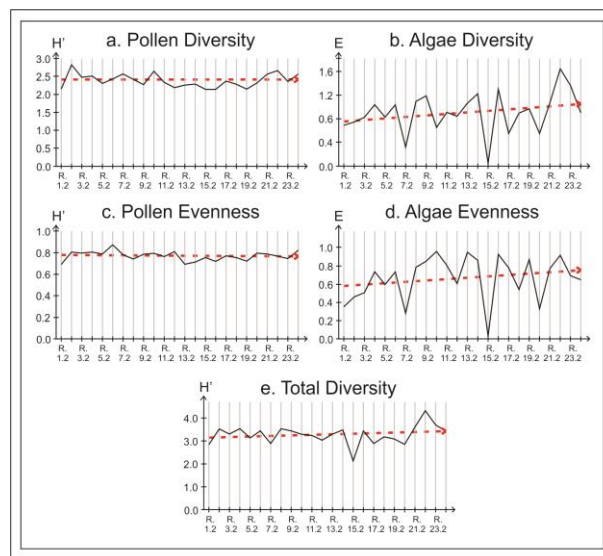


Fig 6. a-e. Diversity and evenness index pollen, spores, and algae results from the study area.

Table 3. Jaccard similarity index from the study area.

Sampel Code	Sampel Code																							
	R 1.2	R 2.2	R 3.2	R 4.2	R 5.2	R 6.2	R 7.2	R 8.2	R 9.2	R 10.1	R 11.2	R 12.2	R 13.2	R 14.2	R 15.2	R 16.2	R 17.2	R 18.2	R 19.2	R 20.2	R 21.2	R 22.2	R 23.2	R 24.2
R 1.2	100%	57%	50%	53%	42%	40%	41%	44%	38%	45%	49%	33%	49%	39%	36%	41%	44%	42%	46%	43%	49%	45%	39%	37%
R 2.2		100%	56%	62%	48%	36%	55%	56%	44%	55%	53%	40%	59%	55%	45%	40%	55%	51%	46%	50%	53%	60%	45%	43%
R 3.2			100%	43%	50%	42%	46%	54%	40%	42%	43%	35%	41%	45%	38%	47%	43%	48%	44%	43%	47%	45%	38%	47%
R 4.2				100%	64%	46%	45%	57%	55%	52%	69%	61%	63%	50%	52%	44%	47%	46%	60%	53%	59%	45%	50%	44%
R 5.2					100%	55%	46%	62%	63%	48%	50%	46%	56%	60%	62%	45%	45%	42%	57%	48%	46%	38%	29%	43%
R 6.2						100%	40%	51%	40%	48%	43%	41%	50%	45%	46%	48%	54%	40%	55%	38%	48%	35%	34%	58%
R 7.2							100%	55%	50%	56%	53%	37%	41%	50%	35%	53%	44%	46%	50%	43%	49%	53%	39%	41%
R 8.2								100%	51%	59%	55%	48%	52%	52%	45%	54%	47%	48%	62%	39%	51%	53%	38%	47%
R 9.2									100%	50%	50%	46%	47%	54%	48%	50%	41%	48%	51%	60%	41%	34%	32%	33%
R 10.1										100%	62%	45%	61%	54%	56%	57%	67%	50%	57%	50%	53%	53%	46%	44%
R 11.2											100%	68%	63%	54%	46%	58%	53%	54%	68%	55%	53%	50%	50%	44%
R 12.2												100%	45%	46%	42%	55%	45%	53%	52%	50%	41%	37%	44%	40%
R 13.2													100%	51%	51%	50%	64%	54%	61%	50%	48%	42%	47%	42%
R 14.2														100%	52%	54%	50%	43%	56%	54%	54%	45%	40%	45%
R 15.2															100%	41%	57%	42%	60%	46%	38%	30%	34%	33%
R 16.2																100%	58%	58%	60%	43%	36%	39%	38%	41%
R 17.2																	100%	60%	55%	43%	41%	43%	38%	47%
R 18.2																		100%	52%	54%	35%	41%	40%	46%
R 19.2																			100%	50%	50%	40%	36%	45%
R 20.2																				100%	61%	43%	50%	46%
R 21.2																					100%	61%	57%	60%
R 22.2																						100%	53%	44%
R 23.2																							100%	50%
R 24.2																								100%

5. Conclusion

Shannon diversity and evenness index results from the Holocene deposits of Lembang area and its surroundings are classified as moderate and quite stable. Results suggest an increase in the diversity and a more evenly distributed vegetation and algal community from the oldest to the youngest deposits. The Jaccard similarity index results show greater differences in the content of pollen, spores, and algae in the study areas, also from the oldest to the youngest deposits. Changes in the diversity and evenness are very high in the sample R 15.2, that probably related to the activity of the Lembang Fault. This is also shown by the grain size progradation that occurs from the basal clay peat to the sand at the top of the core.

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