Trials on Some of Charcoal Production Methods for Carbon Sequestration in Indonesia

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SUMMARY

In Indonesia large amount of wood residues is not effectively utilized to cause carbon emission, water pollution and environmental degradations. Carbonizing these residues is one of the way to solve this problem. The charcoal production can be also recognize as one of the most promising carbon sequestration methods. Upon the situation the study has been conducted at West Java and West Kalimantan for the purpose to compare several types of charcoal kilns in the term of carbonization efficiency (carbon yield) and cost efficiency and then to estimate potential carbon sequaestration for three different material (wood residues from secondary forest, plantation and sawmill). The most highest efficiency of charcoal production method which can minimize carbon emission was Yoshimura kiln (37.85%). The lowest cost was observe at "earth pit kiln" (US $29/t-Carbon) especially operated at sawmill. The experiment also showed potentiality of charcoal produced in the field as carbon sequestration material.

Charcoal Production Methods

Phot 1. Earth pit kiln

Phot 2. Sawdust moud kiln

Phot 3. Drum kiln

Phot 4. Modified earth pit kiln (Brick floor)

Phot 5. Permanent kiln which made by brick (design by Yoshimura)

Phot 6. Sawdust flat kiln (design by Sugai)

Methodology

(Charcoal yield)

$$\text{Charcoal yield (\%)} = \frac{\text{Weight of charcoal (kg)}}{\text{Oven dry weight of wood material (kg)}} \times 100 = \frac{C}{A} \times \frac{100}{100 - \text{Moisture content (\%)}}$$

(Fixed carbon content)

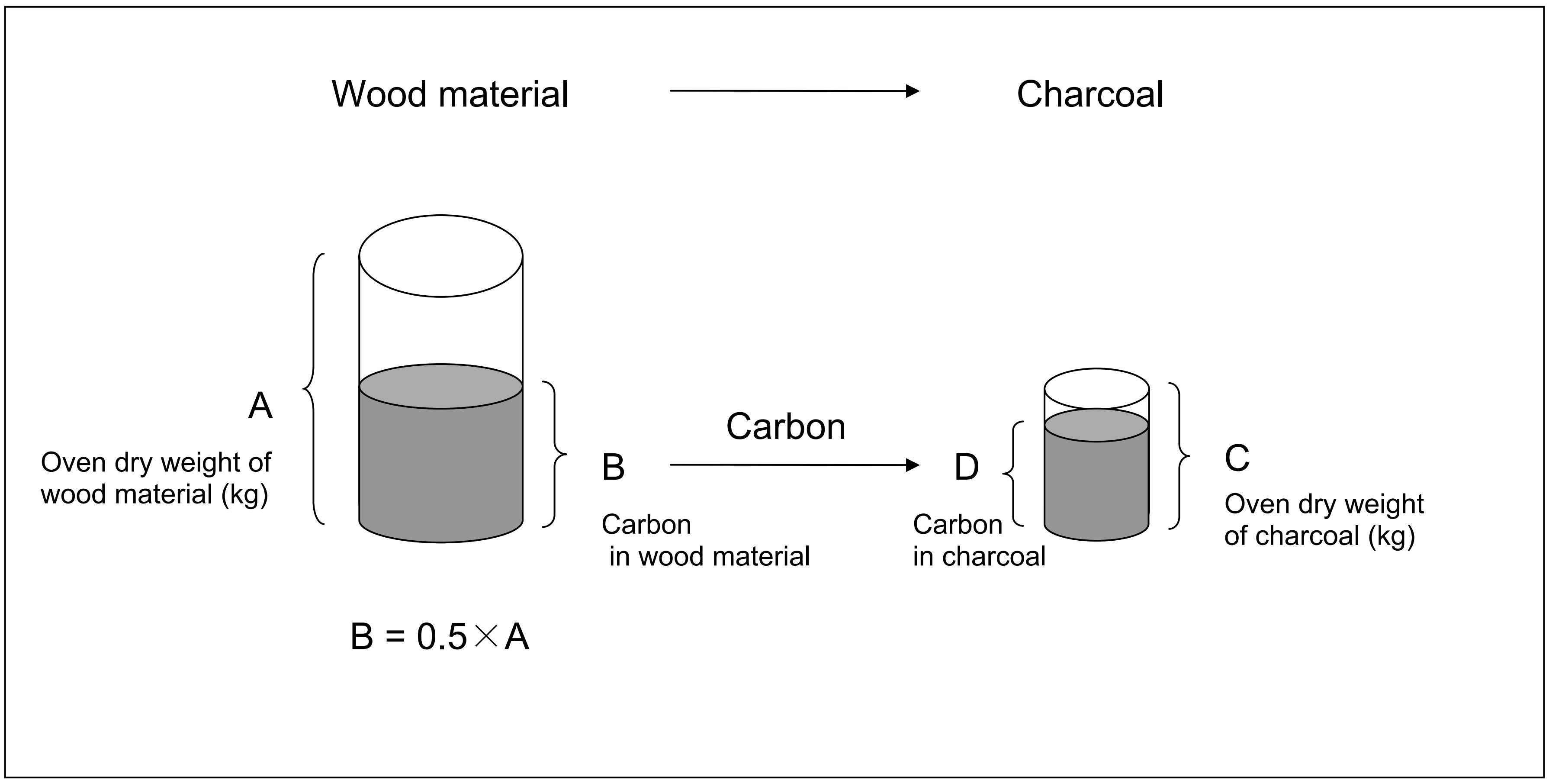
$$\text{Fixed carbon content (\%)} = 100 - \text{Ash content} - \text{Volatile matter content} = \frac{D}{C}$$

(Carbon yield)

$$\text{Carbon yield (\%)} = \frac{\text{Weight of charcoal (kg)}}{0.5 \times \text{Oven dry weight of wood material (kg)}} \times \frac{\text{Fixed carbon content (\%)}}{100} \times \frac{100 - \text{Moisture content (\%)}}{100} \times 100$$

$$= \frac{D}{B}$$

Figure 1. Carbon in wood material and pure carbon in charcoal



LOCATION

Figure 2. Map of Indonesia

Figure 3.
Location of field trial sites in West Java

- Maribaya
- Ngasuh
- Cianten

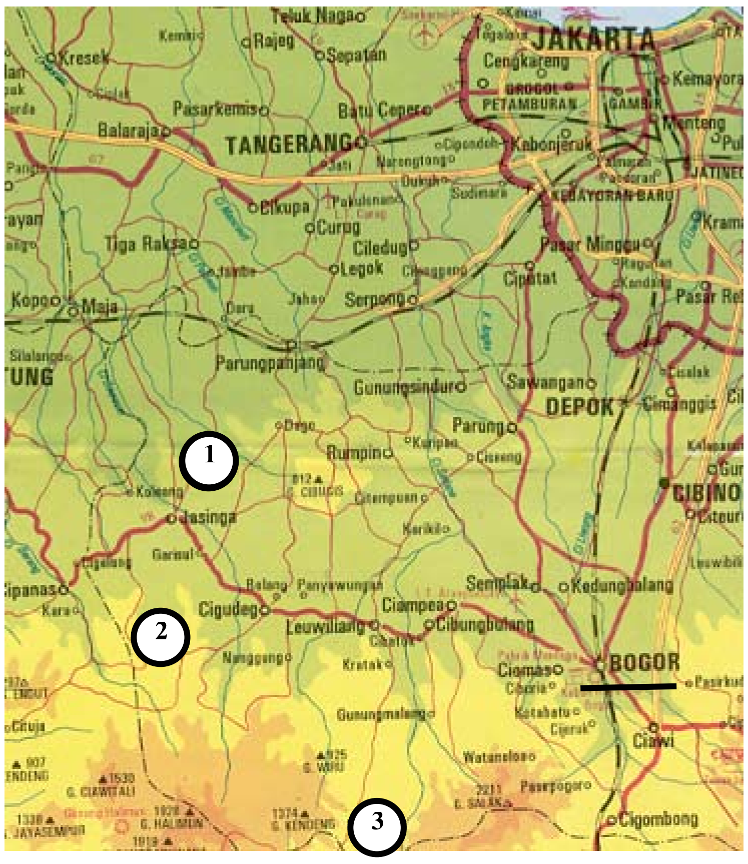


Figure 4.
Location of Toho experimental site in West Kalimantan

Table 1. Potentiality of carbon sequestration

Sites of study

Site	item	description
Maribaya	Vegetation type:	Shrub and secondary forest
	DBH	maximum 8 cm
	Species	Schima sp, Fagraea sp., etc..
	wood density	522 kg/m ^{3}
	land utilization	slash and burn for rice production
	charcoal production	earth pit kiln prevailed
	others	small- size branches and twigs dominant
Ngasuh	Vegetation type	Shrub and secondary forest
	DBH	maximum 43 cm (mostly under 20 cm)
	Species	Maesopsis sp.,Bellucia sp., Schima sp., etc..
	wood density	390 kg/m ^{3}
	land utilization	devasted forest (formerly plantation)
	charcoal production	earth pit kiln prevailed and existence of skilled labor
	others	large- size wood not for charcoal, but other uses
Cianten	Vegetation type	Shrub and secondary forest
	DBH	maximum 38 cm (mostly under 20 cm)
	Species	Macaranga sp., Maesopsis p., etc.
	wood density	415 kg/m ^{3}
	land utilization	devasted forest
	charcoal production	not common
	others	large- size wood not for charcoal, but other uses

Photo 7.
Shrubs in Maribaya, West Java

(in the year of 2001)

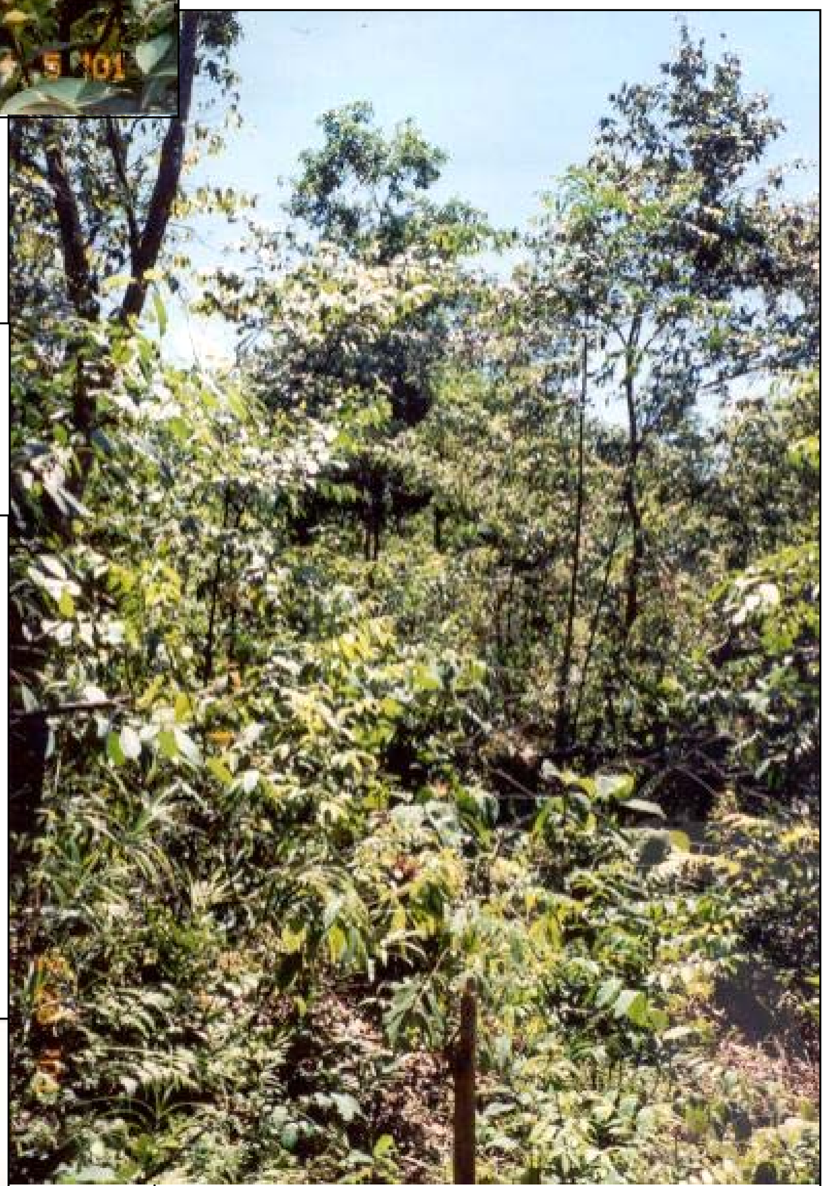


Photo 8.
Secondary forest in Ngasuh, West Java

(in the year of 2001)

Photo 9.
Secondary forest in Cianten, West Java

(in the year of 2001)

RESULTS

1. Carbonization efficiency

Table 2. Comparison of charcoal efficiency among charcoal production methods

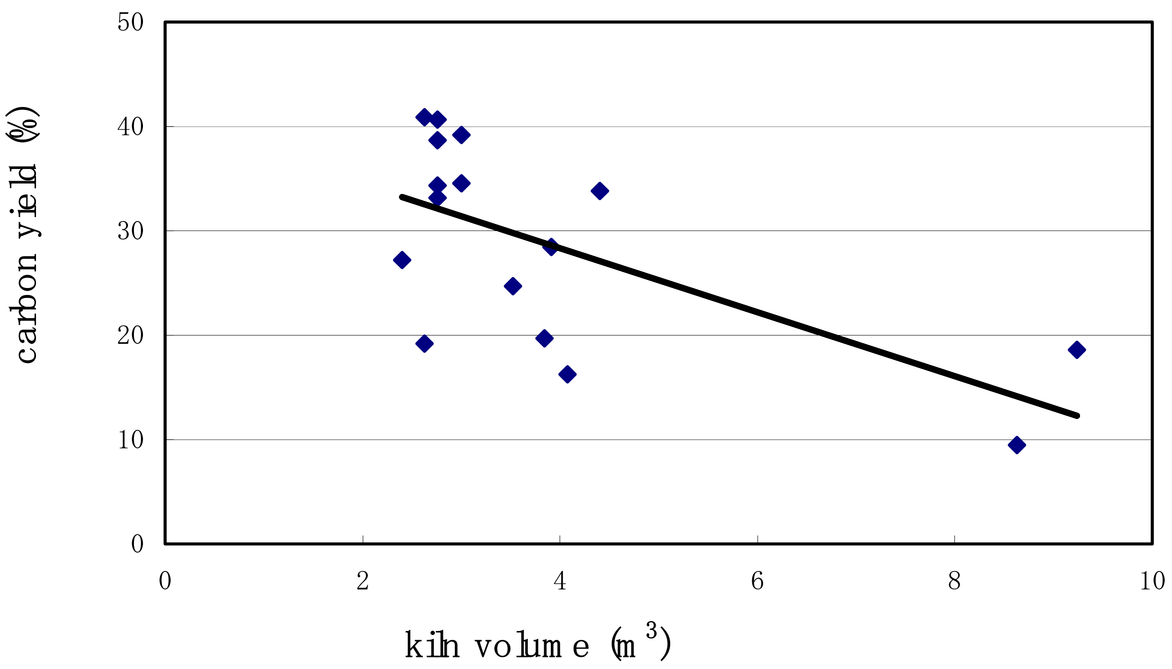
Type of kiln	size of kiln (m3)	no. of samples (kilns)	moisture content (%)	ash content (%)	volatile matter (%)	fixed carbon content (%)	charcoal yield (%)	carbon yield (%)	carbonization time (days)	materials used	location
Earth pit kiln	2.4-9.2	12	4.73	2.36	17.61	80.03	20.45	31.09	5～10	wood from secondary forest	Jasinga
Modified earth pit kiln(brick floor)	2.8-8.6	7	8.19	1.84	16.46	81.69	14.7	21.64	4～5	wood from secondary forest	Jasinga
Modified earth pit kiln(GIS)	3.6,4.2	2	7.83	3.94	11.12	84.95	6.93	10.72	n.a	wood from secondary forest	Jasinga (Marbaya,Ngasuh)
Sawdust mound kiln	10	1	4.33	2	19.02	78.98	15.71	23.66	13	wood from secondary forest	Ngasuh
Single drum kiln	0.2	47	5.82	2.67	11.07	86.27	20.7	33.63	1	wood from secondary forest	Jasinga (Ngasuh, Cianten)
Yoshimura kiln	5	2	4.4	1.8	17.43	80.77	26.4	37.85	10	wood from plantation (A. mangium, Rubber)	Toho,W.Kali
Flat kiln	11	2	3.16	5.22	22.29	72.49	16.66	23.39	2～3	sawdust (Paratheanthes, Maesopsis,etc.)	Bogor

Table 3. Relationship between the size of kiln and carbon yield

kiln volume(m3)	carbon yield	type of kiln
9.24	18.62	earth pit kiln
3.91	28.47	earth pit kiln
3.52	24.69	earth pit kiln
4.4	33.85	earth pit kiln
2.76	40.68	earth pit kiln
3	39.21	earth pit kiln
2.63	40.85	earth pit kiln
3	34.53	earth pit kiln
2.4	27.2	earth pit kiln
3.84	19.68	modified kiln
2.76	34.33	modified kiln
2.76	33.13	modified kiln
2.76	38.67	modified kiln
4.08	16.23	modified kiln
8.63	9.47	modified kiln
2.63	19.22	modified kiln

source: all data obtained by the Project activities

Figure 5. Relation ship between kiln volume and carbon yield



2. Cost efficiency

Table 4. Summary of cost efficiency

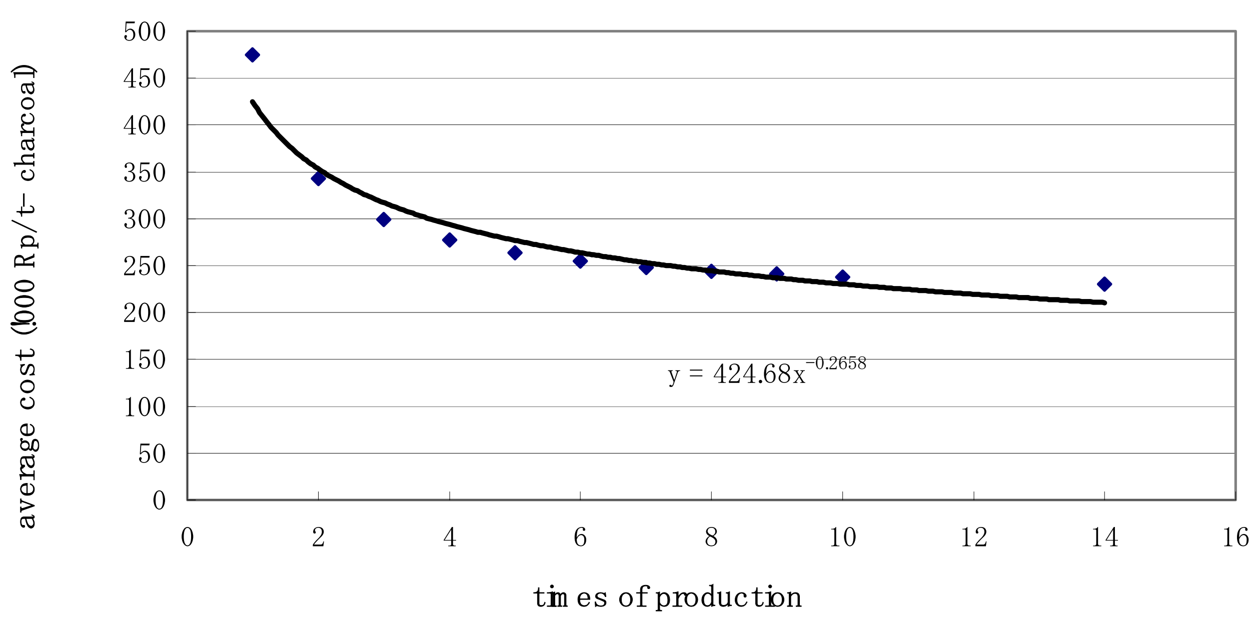
Type of kiln	Average cost (US$/ton)		Asssumption of cost calculation
	per charcoal	per carbon	
Earth pit kiln	26.8	35.5	Kiln volume : 4.0 m3, Material used: available in the field Weight of produced charcoal: 284 Kg/kiln (estimation from the relashionship between kiln volume and weight of produced charcoal) No. of workers: One worker, No. of kilns handled at the same time : two kilns, Cost of materials and transportation: free, Wage of labor: Rp 15,000/ day, Working schedule : as follows
Single drum kiln (Air inlet at the bottom)	61.0	76.4	Kiln volume : 0.2 m3, Material used: available in the field Weight of produced charcoal: 7.88 Kg/kiln (estimated from the field data in Ngasuh and Cianten), No. of workers: One worker, No. of kilns handled at the same time : five (5) kilns, times to be used: : 100 times, Cost of materials and transportation: free, Wage of labor: Rp 15,000/ day, Production cost of single drum kiln: Rp 109,000/kiln
Yoshimura kiln	292.0	378.0	Kiln volume : 5 m3, Material used: wood (acacia) Weight of produced charcoal: 385 Kg/kiln (gained from the trials in Toho), No. of workers: depending on kind of work (table below), No. of kilns handled at the same time : two (2) kilns, times to be used: : 10 times, Cost of materials and transportation: free, Wage of labor: Rp 25,000/ day, Production cost of kiln: Rp 5,650,000/kiln (5m3)
Flat kiln	181.0	261.0	Kiln volume : 11 m3, Material used: sawdust Weight of produced charcoal: 255 Kg/kiln (gained from the trial in Bogor), No. of workers: two (2) workers, No. of kilns handled at the same time : one (1) kiln, times to be used: : 20 times, Cost of materials and transportation: free, Wage of labor: Rp 15,000/ day, Production cost of kiln : Rp 6,146,500/kiln

Table 5. Calculation of cost per charcoal and carbon by Earth pit kiln (under the assumption above)

Charcoal production	days	Accumulated amount			Average cost (1000Rp/ton)	
		Total cost (1000Rp)	Charcoal (Kg)	Carbon (Kg)	per charcoal	per carbon
1st	9	135	284	213	475	631
2nd	13	195	568	427	343	456
3rd	17	255	852	641	299	397
4th	21	315	1136	855	277	368
5th	25	375	1420	1069	264	350
6th	29	435	1704	1283	255	339
7th	33	495	1988	1497	248	331
8th	37	555	2272	1711	244	324
9th	41	615	2556	1925	241	319
10th	45	675	2840	2139	238	316
11th						
12th						
13th						
14th	61	915	3976	2995	230	306
					US$26.8	US$35.5

Note: Pure carbon content in charcoal is 75.32 %, which was estimated from the earth pit kiln data in Maribaya and Ngasuh, 1US$=8600Rp (April 2004)

Figure 6. Relation ship between times of production and average cost



3. Potentiality of carbon sequestration

Table 6. Calculation of amount of carbon stored in charcoal

Site	Wood material (t/ha) A	Amount of charcoal produced (t/ha) B	Charcoal yield (%) C	Amount of carbon stored in charcoal (t/ha) D	carbon sequestered in charcoal (%) E	estimated stand age (years)
Maribaya	5.24	0.6	11.45	0.48	18.32	1
Ngasuh	36.62	2.22	6.06	1.77	9.67	7
Cianten	25.28	1.91	7.56	1.53	12.10	4～5

Note 1. Carbon content in wood is 50 % of wood weight

2. carbon content in charcoal is 80 % of charcoal from the data of earth pit kiln

3. Earth pit kiln is used for carbonization

4. C=B/A ×100, D= B×0.8, E=D/(A/2) ×100

5. Stand age was estimated from the equation ($y= 10.122X^{0.7113}$) between stand age and aboveground biomass obtained by Mr. Kojima et.al (1997), Morikawa (2001) and the project (2

Table 7. Summary of Potentiality of carbon sequestration

Type of kiln	Location	Charcoal efficiency	Cost efficiency	Potentiality for carbon sequestration
Earth pit kiln	field	middle	high	high
Modified earth pit kiln	field	low	high	low
single drum kiln	field	middle	middle	low
Yoshimura kiln	factory	high	low	low
Flat kiln	factory	low	low	low

CONCLUSION

1. It is shown that the most promising charcoal production for carbon sequestration projects in West Java is “Earth pit kiln” with relatively small size, because of high level of carbon yield and low production cost.

2. It is also shown that the younger stand age for charcoal production is, the larger carbon yield is.

3. Permanent kiln can achieve higher carbon yield, but the cost is too high for carbon sequestration projects.

4. However it is essential that further study on charcoal production for the utilization of charcoal as carbon sequestration material will be continued.