Waseda-Bridgestone Initiative for Development of Global Environment

W-BRIDGE Model

Reforestation Model of Degraded Land for benefits to local people in Lombok Island, Indonesia

(English version report)

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Takao Kawaguchi[1], Eiichiro Nakama[2], Yasuo Osumi[2], Sri Tejowulan[3], Baderun Zainal[4], Hartina[5], A. Ngaloken Gintings[6] and Yasushi Morikawa[1]

[1] Graduate School of Human Sciences, Waseda University, [2] Japan International Forestry Promotion and Cooperation Center, [3] Mataram University, [4] Former Head of Forestry Service in West Nusa Tenggara Province, [5] Head of Forestry Service in West Nusa Tenggara Province, [6] Former Senior Researcher in Forest Research and Development Agency in Indonesia

Introduction

The project focused on benefits to local people through the rehabilitation activities on degraded land with severe drought. The project evaluated the CO_2 sequestration by planting trees, benefits to local people, and removal of soil nutrients by harvesting on various models of plantation.

Project site

This study was carried out at southeast of Labuhan Pandan Village, Samberia County ,East Lombok Prefecture, Nusa Tengara State of Indonesia and people are concerned about severe drought of this area in dry season from May to November. The annual rainfall there is around 1,000mm (Table 1).

Labuhan Village: The area is 3,897ha; Population is 8,402 in 2007; Population density is 2.2/ha which is relatively low comparing with the mean density of Lombok Island (Table 2).

HDI (Human Development Index) of West Nusa Tengara State is 30th in 30 States of Indonesia (BPS-Statistics Indonesia, 2004) and an annual income of the Village is 1,212,000Rp per capita (JIFPRO, 2007). Recently income slightly increases to 1,525,000Rp per capita. However, the amount is still low because the poverty line is 1,570,000Rp per capita in West Nusa Tengara State.

The project site is grassland with scattered trees of *Zizyphus jujube,* and it is under the threat of human-caused fire which is possibly started from the neighboring agriculture and pasture lands in dry season. Previously unsuccessful plantation in this area might be caused by frequent fire and severe drought.

Design of the Project

The project site is state-owned land as production forest, and there are no any problems with local people on the land utilization. The 1.2ha plot of W-BRIDGE model (Fig.3) was set in rainy season from December, 2008 to January, 2009. Seedlings were planted with the selection and application of tree species as follows:

1. Plantation of long-term timber trees
   . *Swietenia macrophlla*: 100trees/ha
   .*Gmelina arborea*: 80trees/ha

2. Plantation of oil-production trees
   .*Jatropha curcas*: 2,050trees/ha

3. Plantation of fuel and fodder trees
   .*Sesbania grandiflora*: 720trees/ha

4. Plantation of fire protection trees at the fire-mantle of the project boundary
   .*Spondias pinatta*
   .*Gliricidia sepium*

The plantation was set along the east to west direction. As shown in Fig.2 and 3. The space between *S.macrophylla* and *G.arborea* rows was 10m. *J.curcas* trees were planted at 2m intervals. *S.macrophylla* trees were planted at 5m intervals. Both of *S.grandiflora* and *G.arborea* trees were planted at 1m intervals.

Methods

1. Jatropha curcas

Growth measurements of *J.curcas* which was planted in 2007 at 1×1m^2 area was carried out near the project site on Aug.13th, Dec.16th of 2008 and Feb.10th , Aug.9th of 2009. The growth parameters were tree height, root collar diameter, and tree crown (length, breadth).

Seeds of *J.curcas* were collected from 20 trees in April and May 2009. Annual seeds yield of a tree was calculated by the mean one-month yield multiplied by 5 months. The reason of multiplying 5 is the productive period lasts 5 months in rainy season. Seeds yield on area basis was calculated by basal area of root collar per ha multiplied by the ratio of total yield and total basal area of root collar with 20 sample trees.

Sample trees of *J.curcas* with various sizes were dug up carefully, then cut off into above and below organs and finally weighed on Aug.10th, 2009. The soil attached to roots was also removed carefully. There were no leaves left because of dry season. About 500g was taken as a drying sample from each organ, then brought back to the laboratory of Mataram University and put into a oven at 90℃ for 2 weeks for estimating dry and fresh weight ratio.

The sample seeds were squeezed by manual squeezing instrument (San Seiki Co.Ltd) and measured the amount of oil. The carbon and nitrogen contents were measured by dry combustion method by vario MAX CN of Elementar Analysen Systeme GmbH (Elementar Co. Ltd) in Forestry and Forest Products Research Institute in Japan. Another element such as phosphorus and potassium was calculated with the ratio of mineral elements in *J.curcas* oil (Kumar and sharma, 2008, Openshaw, 2000) and the ratio of 4:2:1 of N, P, K.

There was no more information about mineral contents of other tree species, so we used some values from the literature (Yamada *et al.*, 2004).

2. Biomass

Biomass increments of *S. macrophylla* and *G. arborea* were predicted with general DBH growth curve with age (Morikawa 2007) in Fig.4 and *S.grandiglora* was predicted from the diameter date of 6-year-old trees (Jama *et al.*, 1989) and diameter-biomass relation (Morikawa, 2007) because the planting trees were small at this time.

3. Prediction

Carbon dioxide Sequestration for 30 years was predicted in *S.macrophylla*、*G.arborea*、*J.curca* and *S.grandiglora*. The amount of stem was predicted as fuel wood for *S.grandiglora* and *J.curca*. Predicted oil was accounted as alternative energy of kerosene oil from fossil fuel. Woods of *S. grandiglora* and *J.curcas* are used as fuel, so the wood was also accounted as alternative energy of kerosene. Generated heat of wood in *S.grandiflora* was estimated with the coefficient in IPCC. The oil from the seeds of *J.curcas* was calculated as follows.

$V_{oil} = W_h \times S \times Pc$ -------- (1)

$E_{Vj} = V_{oil} \times EV_0$ --------- (2)

$E_{CO2} = EV_J \times CEF_{fuel}$ --- (3)

where:

V_{oil}	Squeezed oil (kl/ha/30years)
Wh	Yield of seeds (t/ha/30years)
S	Efficiency of squeezed oil (kg/kg)
Pc	Volume/weight (l/kg)
E_{Vj}	Generated heat (GJ/ha/30years)
EV_o	Coefficient to generated heat (MJ/kg, Openshaw, 2000)
Eco_2	Released CO_2 from alternative oil ($kgCO_2$/MJ)
CEF_{fuel}	Efficiency of releasing from kerosene ($kgCO_2$/MJ)

4. Revenue

Stem volume of *S.macrophylla* and *G.arborea* was calculated (Morikawa, 2004, JIFPRO, 1996) from the biomass as mentioned above. Useful timber volume was calculated with 0.45, the coefficient of total stem volume (Forestry Service in West Nusa Tenggara Province) as follows.

$Va = B_{AGB} \times V_0$ -------- (4)

$V_T = Va \times 0.45$ --------- (5)

$I_{Rp} = V_T \times PL$ ---------- (6)

where:

Va	Stem volume (m^3/ha) B_{AGB}: Above ground biomass (t/ha)
P_V	Stem volume to above ground biomass (m^3/t)
V_T	Useful timber volume (m^3/ha)
I_{rp}	Revenue from the timber
PL	Price of timber (Rp/m^3)

The revenue of *J.curcas* was estimated from transaction cost of seeds and *S.grandiglora* was from transaction cost of single tree after 6 years from planting year. The wood of *J.curcas* did not account because there was no information about the stem in the fuel market.

5. Effect to soil

Exploitation of nutrients through harvesting was estimated based on woods of *G.arborea*, *S.grandiglora* and seeds of *J.curcas*. Input of nutrient was assumed that the nutrient elements are supplied from rain fall. The data of nutrient elements in tropical rain was from JIFPRO (1995) and the data of rain fall was collected near the project site (Table. 1). We do not consider the inputs of dust or ground water.

Results and Discussion

Mean annual diameter growth at root collar was 2.0cm/year for 2 years (Table 3, 4). The relationship between the diameter and tree height was with high correlation of R^2=0.71 in August, 2008. However, R^2 was decreased to 0.37 in August, 2009 (Fig.5). This might be caused by growth performance of ramification above the root collar. There were high allometric relation between diameter of root collar and biomass (Table 5, Fig.6, 7, 8).

Comparing to another species of planting tree, high water content of stem (Table 6, 7) is important to *J.curcus*, because they may endure severe dry season with it and avoid shedding of leaves. If *J.curcus* is planted in fire prevention belt, it will be effective to protect from wind and fire because of stems with relatively high water content.

The amount of squeezed oil was 314g and 252ml and then divided by the seed weight of 1,180g, which were respectively 0.29g/g and 0.23ml/g as the squeezing rate (Table. 8).

Carbon and nitrogen contents of seeds were 57 and 2.2%, respectively. With the ratio of N, P and K (4:2:1) (Kumar and Sharma, 2008. Openshaw, 2000), the amount of P and K in seed was predicted as 1.1 and 0.55% (Table. 9), respectively. Above ground biomass and yield of seeds of a tree was shown in Table.10. Yield of seeds was 0.48t/ha in 2-year-old *J.curcas*. It is said that the maximum yield of seeds is in about 5 years after planting, so we assume that the yield will be same level after five years (Table. 10). Predicted maximum yield was 0.9 trees one year. Total yield was 2.3 t/ha/year from 2,500 trees/ha. Integrated yield for 10 years was 6.8 kg/tree. The maximum was 5.3t/ha/year after 6 years in India and 2.5 to 3.5 t/ha/year in the hedge in Mali (Openshaw, 2000). Low productivity on this site will be caused by severe drought and poor soil.

Predicted diameter and biomass growth and nutrients contents of *S. macrophylla*, *G.arborea*, *S.grandiflora* were shown in Fig.9、10 and Table 11. Applying data of *A.mangium* in Indonesia and PNG (Yamada et al., 2004) to the species, N, P, K contents to 1t of biomass were 2.22, 0.19, 1.25kg, respectively.

Evaluation of W-BRIDGE model

We set the harvesting period at 6 years for *S.grandiflora*, 10 year for *J.curcas*, 20 years for *G. arborea*, and 30 years for *S. macrophylla*, respectively and annual growth was predicted with allometry (Morikawa,2007)(Table 12, Fig.11). Biomass had been obviously decreased since 6 to 10, and 20 years after plantation because of harvesting of *S. grandiglora*, *J.curcas* and *G.arborea*. Final biomass, *S. macrophylla*, was 85t/ha after 30 years.

Predicted sequestration of CO_2 after 30 years was eventually 231 tCO_2/ha (Fig.12) which included sequestration of 155 tCO_2/ha by planting trees and 75.8 tCO_2/ha was sequestrated as fuel woods of *S. grandiflora* and *J.curucas.*

Biomass of *S.grandiflora* and *J.curcas* was 18.8t/ha/6years and 17.9t/ha/10years, respectively. Seed production of *J.curucas* was 14 t/ha/10years (Table. 13, 14).

It is said that the volume of timber business in Nusa Tengara State in February 2009 was 2,000,000~2,500,000Rp/m^3 from *G.arborea*, about 6,000,000 Rp/m^3 from *S.macrophylla*, and 4,500~6,000Rp/tree from *S. grandiflora*, respectively (Table. 13, 15).

Prospective final revenue of the project was shown in Table.16 and Fig.13, 14. Short-term revenue in 10 years after planting was from seeds of *J.curcas* and fuel woods of *S.grandiflora*. After that, relatively high revenue appeared in timber of *G.arborea* in 20 years and *S.macrophylla* in 30 years, respectively. If the harvesting period is short such as a size of 10 to 15cm of DBH, the volume of timber business might be decreased to the range of 100,000 to 125,000. So we need to focus on the long-term revenue of timber products. Another important suggestion might be selecting and combining species with different growth performance such as fast (e.g. *G.arborea*) and slow growing species (e.g *S.macrophylla*). These selections will be sustainable for revenue to the local people.

Detail revenue in 10years was shown in Fig.14. Local people could get revenue of 1,300,000 Rp/ha (JIFPRO, personal information) as wages of planting for 5 years. If one worker engages in one ha, he could draw 260,000 Rp/ha/year. In addition, local people could get revenue of about 1,000,000Rp/ha/year from the seeds of *J.curcas* and woods of *S.grandiflora*, even if the price of them is low (Table. 16).There is income of about

1,500,000Rp/year/capta in this region. Local people could get around two third from the income of the project site. It might be motivation to attend planting project in degraded land.

Nutrient problem

Predicted nutrient input from rainfall was shown in Table. 17. Total input was 1.5-3.8kg/ha/30years for nitrogen and 0.4-1.5kg/ha/30years for phosphorous, respectively. Removal of these elements through harvesting was shown in Fig.16. There is obvious removal of phosphorous by harvesting seeds of *J.curucas* which was about ten times larger than another tree for30 years (Fig.15).It might not make sense to plant *J.curcas* in degraded land.

Social circumstances

The demand of fuel woods is increasing recently in Lombok Island and the dependence to fuel wood as energy resources is high: 86% family to total (Table. 18). The subsidy of kerosene is 2,500Rp/l in May, 2009 and they could buy the kerosene at 4,000Rp/l which initially cost 6,500Rp/l. However, families who use the kerosene might shift to fuel wood because the subsidy of kerosene will come to an end in 2010. In addition, the situation which will be almost the same as some companies might cause an obviously increasing cost of kerosene e.g. cigarette company in Lombok Island.

Comparison among the models

1. Reforestation models

a) W-BRIDGE model

Plantation of long-term timber trees

. *S.macrophylla* : 100trees /ha, harvesting in 30 years

. *G.arborea:* 80trees/ha, harvesting in 20 years

Plantation of oil-productive trees

. *J.curcas*: 2,050trees/ha, harvesting in 10 years

Plantation of fuel and fodder trees

. *S.grandiflora*: 720trees/ha, harvesting in 6 years

Plantation of fire protection trees at the fire-mantle of the project boundary

. *S.pinatta*

. *G.sepium*

b) Productive forest model

Plantation of long-term timber trees

Area: 5×5m

. *S.macrophylla*: 350 trees/ha, harvesting in 30 years

.*G. arborea*: 180 trees/ha, harvesting in 20 years

2. Plantation models

a) Coppice model

. *S.grandiflora*: 2×2m area and 2,500 trees/ha, harvesting in 6 years of 5 rotation

b) *J.curcas* plantation model

. J.curcas: 2×2m area and 2,500 trees/ha, harvesting in 3 rotation for 10 years.

Carbon dioxide sequestration among the models was shown in Fig.16. There was effective sequestration in reforestation models comparing to plantation models. When we consider the effect of fuel wood of *S. grandiflora* and seeds of *J.curcas* as alternative energy for oil, the coppice model was remarkably higher than *J.curcas* model (Fig.17). The reason might be dense intervals, high growth performance, short rotation, and total usage of harvesting of woods. On the other hand, *J.curcas* model is depending on the production of seeds which is the part of plant organs.

Obvious decrease of CO_2 sequestration in *G.arborea* after harvesting was depending on the following calculation. We did not account the timber as alternative energy for oil, because wood products including of timber are not recognized as carbon stock in the definition of Kyoto Protocol. If we consider the effect of timber, the amount was 80t CO_2/ha in W-BRIDGE model and 180t CO2/ha in productive forest model.

1. Revenue among the models

Difference of the revenue among the models in 30 years was shown in Table.19 and Fig17. Reforestation models were much higher than plantation models in average. In those estimations, we assume that the survival rate is 50% in *S.macrophylla* and *G.arborea*. Those woods and seeds are at a high price right now. In addition, the high revenue of 60,000Rp/m^3 at present in productive forest model might be because of *S. macrophylla*. So the merit of plantation models is people will get revenue in a short period and last for 10 years. However, there is still a problem about seeds of *J.curcas*. The revenue of it is unstable and small in total.

2. Internal Rate of Return

Internal rate of return among the models was shown in Table. 20. There was a relatively high internal rate of return in reforestation models. Comparing to the total revenue as mentioned above, increasing internal rate of revenue might be results of total revenue, investment, and time after plantation.

3. Removal of nutrient among models

The removal of nutrient elements was obviously higher in *J.curcas* model (Table. 21, 22, Fig.19) and even higher than agricultural crops in this district. Nitrogen elements will be added by rainfalls and plants with the function of nitrogen fixation. However, phosphorous will be only supplied from the weathering rocks with phosphorous component. We could focus on the *J.curcas* plantation by the viewpoint of filling up phosphorous deficiency in degraded land. Otherwise, the land will be more degraded when we continue the plantation without nutrient supply.

4. Evaluation of fuel woods and bio-oil

Generating energy and using coefficients were shown in Table.23. Generating energy from woods of *S.grandiflora* (4,553GJ/ha/30year) was much higher than oil of *J.curcas* (2,550GJ/ha/year). In addition, the woods will be directly used, but the oil will be available through harvesting, squeezing, and refining. It will be an increase of costs in oil production. If there is no problem in fire machine, the wood will be more effective than bio-oil. Another problem will be the productivity of seeds in *J.curcas*. The productivity of seeds is quite low. Instead, the removal of nutrients from the soil is high in degraded land as mentioned above. We suggest that if we utilize the degraded land as bio-energy resources, we could choose the fire wood species with fast grow performance. If we would like to produce the bio-oil effectively, we will select the land with high productivity which is also suitable for crops. Our conclusion is bio-oil species do not compete with crops in the tropics.

5. Introduction of W-BRIDGE model

W-BRIDGE model presents that local people could get revenue in short period after *J.curcas* and *S.grandiflora* are introduced. Another purpose to introduce *J.curcas* is protecting forest function from the wild fire as mentioned above. We would like to introduce the W-BRIDGE model to the national forest land with degraded area of 5,565 ha in Lombok Island.

There was no trade of *J.curcas* seeds in February, 2009 because of the stable supply of oil. The price of seeds was 1,500Rp/kg in December, 2008 and was decreased to 700Rp/kg. That is why seeds in fire belt of this project were not harvested. Local people will get the money of 20,000 Rp/day/capita from the construction works and be able to harvest the seeds by 10kg/day/capita. The price should be 2,000 Rp/kg which makes it profitable. The situation is unstable revenue and seeds productivity is depending on the climate condition and the productivity of the land was actually quite low as mentioned above.

Reforestation project will be requested to buy seeds with a reasonable price in short period until the end of reforestation, and the budget of the project need to include the cost of seeds. Such project will become a motivation in long-term reforestation for local people.

There is no revenue from the timber of *G. arborea* until their suitable harvesting year, so our project intercrops the fodder and fire wood trees with fast growing performance between the timber trees. The system will be helpful for getting revenue from the project site. After 20 years, the timber will be supplied, and the land will be a community forest with sylvicultural managing system. The scheme of the project was shown in Fig.20.

Figure 1　W-BRIDGE project site (Turi and Jatropha, Mar. 2010)

Table 1　Annual changes of monthly rainfall (mm) in Sambelia

Year	Month												Total
	1	2	3	4	5	6	7	8	9	10	11	12	
1999	963	307	180	113	0	0	2	15	0	0	37	138	1755
2000	493	179	145	107	62	0	0	0	23	88	225	385	1707
2001	371	90	214	98	25	0	0	0	0	13	121	50	982
2002	0	0	0	35	0	0	0	0	0	0	0	35	70
2003	194	360	126	129	0	0	0	0	0	0	38	135	982
2004	207	237	321	37	39	0	0	0	0	0	14	252	1107
2005	140	213	187	204	0	0	84	35	20	18	17	191	1109
2006	658	181	257	370	21	0	0	0	0	0	0	121	1608
2007	128	348	277	147	21	61	0	0	0	0	11	39	1032
Total	3155	1917	1710	1244	173	67	93	58	52	129	474	1358	10352
Average	350	213	190	138	19	7	10	6	5	13	51	150	1150

Source: Dinas Kehunantan (2008)

Table 2　Social information around the site and Indonesia

administrative district	Total Area (ha)	Pupulation (people)	Dencity (people/ha)
Labuan Pandan village *1	3,897	8,402	2.2
Sambelia sub-district *1	24,522	30,829	1.3
East Lombok district *1	160,600	1,067,673	6.7
Lombok district Island *2	473,900	2,837,642	6.0
West Nusa Tenggara province *3	1,970,900	4,286,000	2.2
Indonesia *3	186,036,000	216,382,000	1.7

*1 : BPS-NTB (2008), *2 : BPS-NTB（2004）, *3 : BPS（2006）

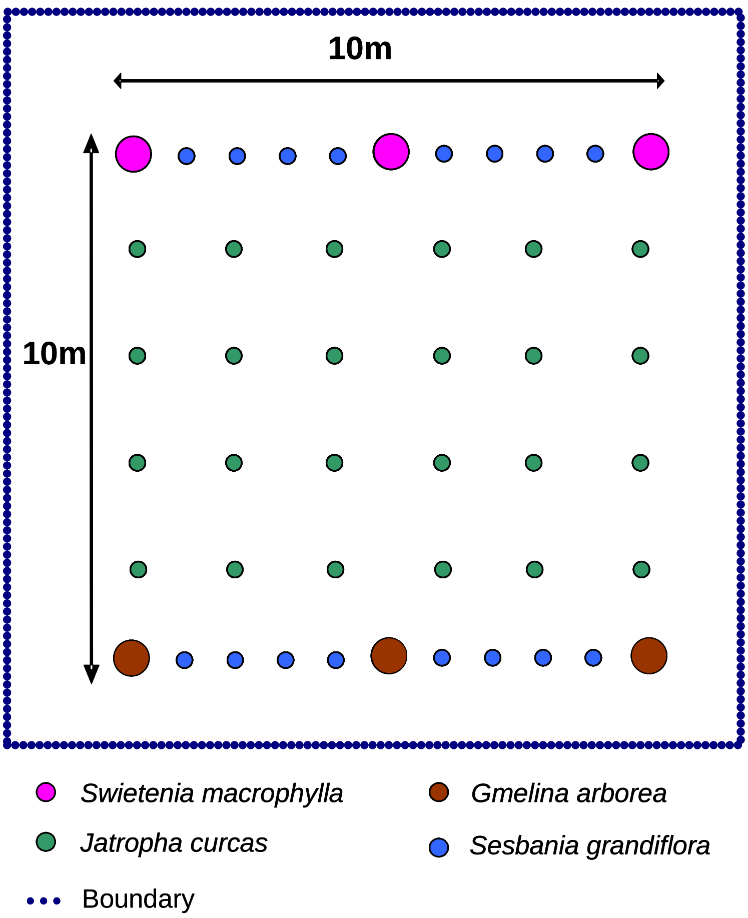

Figure 2　Design of plantation

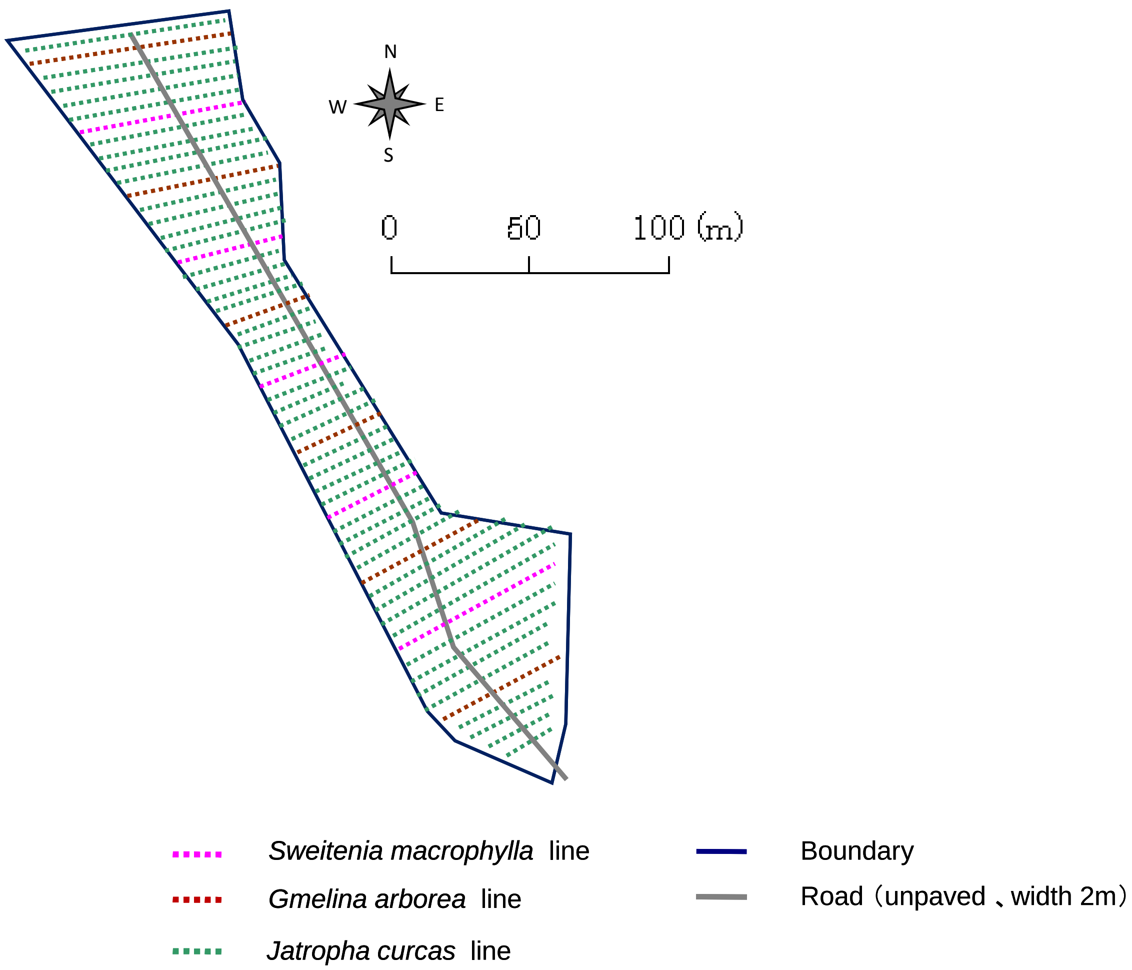

Figure 3　Plantation lines

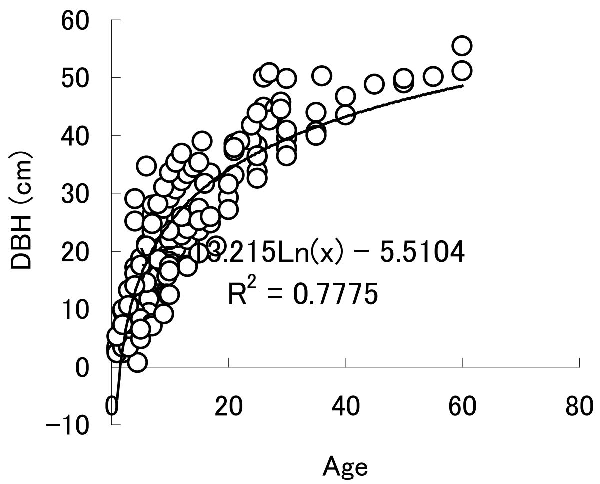

Figure 4　Age-DBH relations of various species of plantation in the tropics
(from the database of JIFPRO, 1996)

Table 3　Growth of *Jatropha*

Species	*Jatropha curcus*			
Date	Aug-08	Dec-08	Feb-09	Aug-09
Number of trees	80	63	63	63
Diameter(cm)				
Max	6.4	7	8.3	9.1
Min	2.2	3.2	4	4.1
Average	4.3	4.8	5.9	6.4
Height(cm)				
Max	165	197	206	215
Min	42	54	90	100
Average	111	135	160.0	170
Crown Width (cm)				
Max			168	125
Min			63	13.5
Average			105	59.3

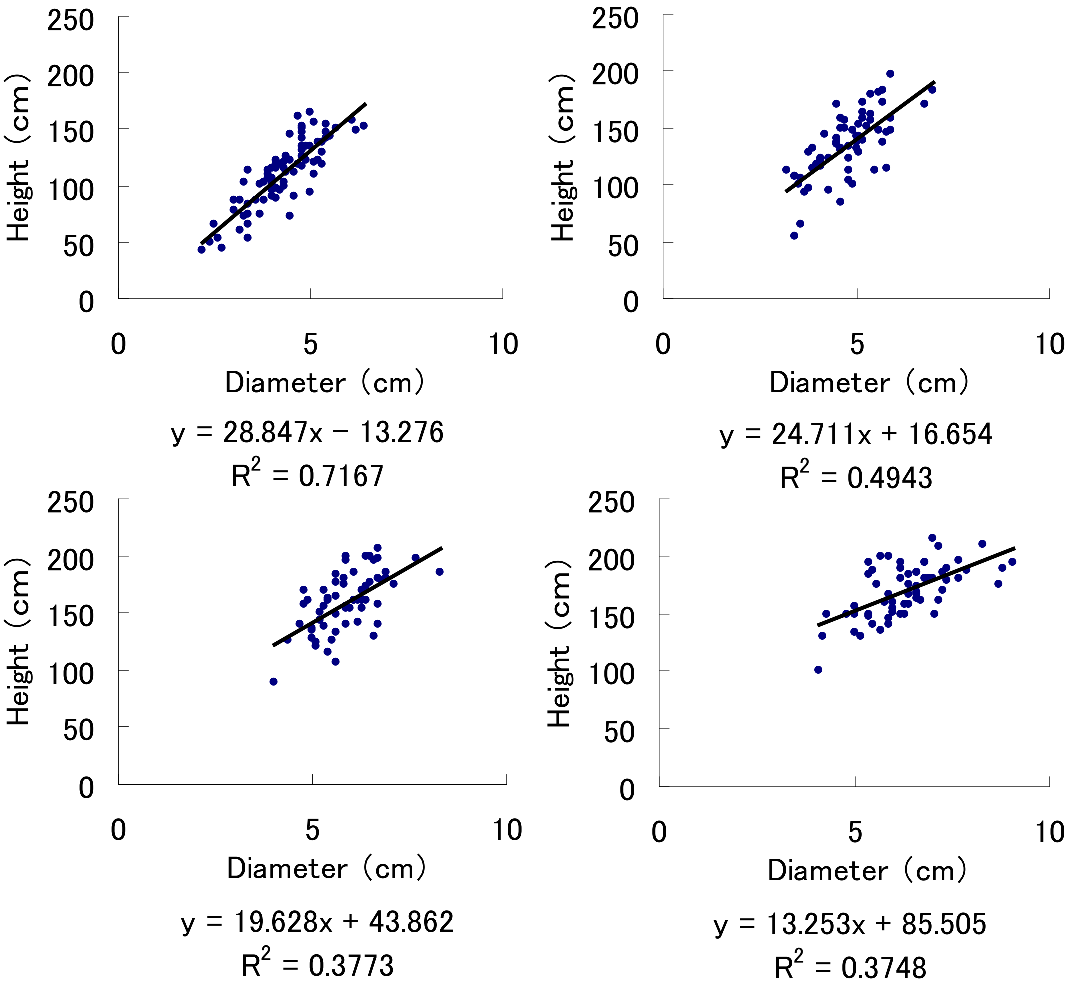

Figure 5　Diameter at root collar and height relations in *Jatropha*

Upper left; Aug.2008, Upper right; Dec. 2009, Lower left; Feb. 20096, Lower right; Aug.2009

Table 4　Annual growth of *Jatropha*

Amount of growth	Aug-08 to Aug-09
Diameter (cm/year)	2.04
Height (cm/year)	58.7

Table 5　Sample trees for estimating biomass of *Jatropha*

Species	*Jatropha curcus*					
Sample No,	1	2	3	4	5	6
Age(year)	2	2	2	2	2	2
Diameter(cm)	8.6	7.5	7.1	6.4	5.9	4.6
Height(cm)	290	195	200	175	144	113
Crown Width 1(cm)	93	80	65	55	40	40
Crown Width 2(cm)	69	55	80	55	30	30
Dry mass(kg)						
Above ground	2.20	0.85	0.95	1.00	0.42	0.18
Root	0.65	0.58	0.57	0.34	0.22	0.09
Total	2.85	1.44	1.52	1.34	0.64	0.27

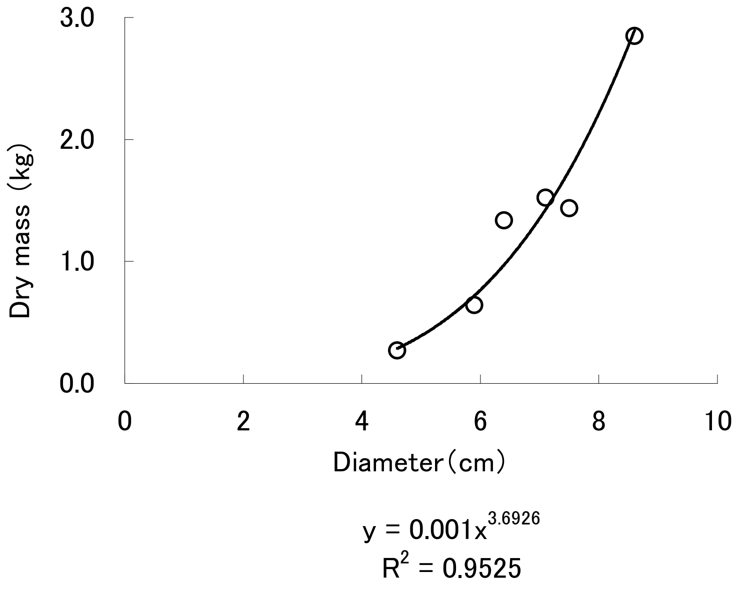

Figure 6　Allometric relations between diameter at root collar and total biomass of *Jatropha*

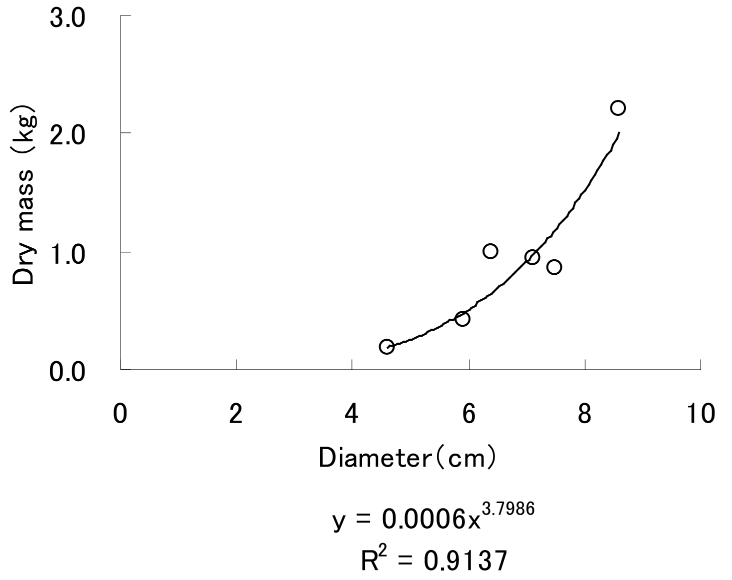

Figure 7 Allometric relations between diameter at root collar and above-ground biomass of *Jatropha*

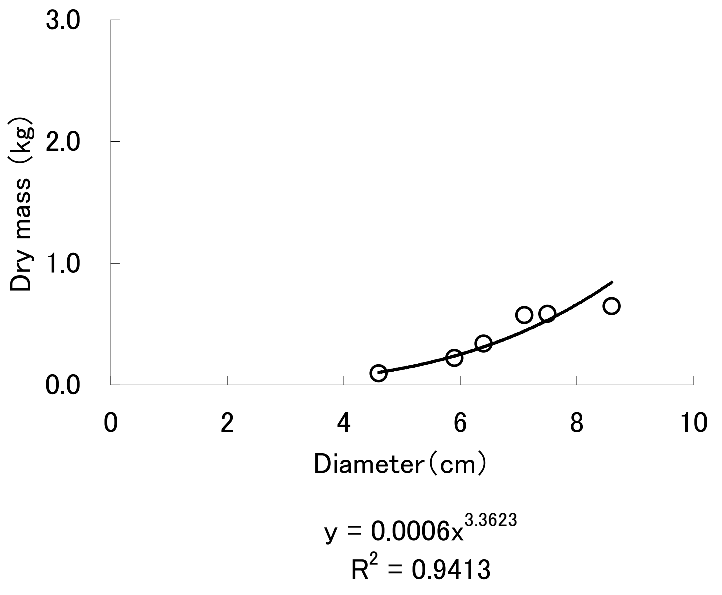

Figure 8 Allometric relations between diameter at root collar and root biomass of *Jatropha*

Table 6 Fresh and dry weight, and water content (Dry weight basis) of sample trees of *Jatropha*

	Fresh mass (g)	Dry mass (g)	Water content (g)	Water content (%)
Above grounc	502	127.1	374.9	295.0
Root	537	135.5	401.5	296.3
Total	1039	262.6	776.4	295.7

Table 7 Water content of various tree species in Sambelia

Species	*Gmelina arborea*	*Tectona grandis*	*Samanea samman*	*Azadirachta indica*
Water content (%)				
Above ground	122.0	112.6	73.3	78.9
Root	104.6	126.1	72.5	80.8
Total	117.0	116.6	73.1	79.5

Table 8 Squeezed oil of *Jatropha* seeds

	Sample(g)	Marc (g)	Oil		Oil / Sample	
			Weight (g)	Volume (ml)	Weight (g/g)	Volume (ml/g)
1	120	91.5	28.5	23	0.24	0.19
2	120	82.2	37.8	30	0.31	0.25
3	120	82.8	37.2	30	0.31	0.25
4	120	85.8	34.2	27	0.28	0.23
5	120	82.1	37.9	30	0.32	0.25
6	120	76.9	43.1	35	0.36	0.29
7	120	82.1	37.9	30	0.32	0.25
8	120	86.8	33.2	27	0.28	0.22
9	120	95.7	24.3	20	0.20	0.17
Total	1080	765.8	314.2	252	0.29	0.23

Table 9 Carbon and nitrogen contents of *Jatropha* seeds

	Weight(mg)	C (%)	N (%)
Sanmple 1			
Seed	293	57.2	2.2
Marc	240.3	51.3	2.8
Sample 2			
Seed	259.8	57.2	2.2
Marc	229.4	51.1	2.8

Table 10　Predicted above-ground biomass and seed yield of *Jatropha* with age

Age	Diameter (cm)	Basal area (cm^2)	Above graund biomass (kg)	Harvest (kg)
1	4.3	14.6	0.2	0.1
2	6.4	31.7	0.7	0.2
3	8.4	55.3	1.9	0.4
4	10.4	85.4	4.4	0.6
5	12.5	122.1	8.7	0.9
6	12.5	122.1	8.7	0.9
7	12.5	122.1	8.7	0.9
8	12.5	122.1	8.7	0.9
9	12.5	122.1	8.7	0.9
10	12.5	122.1	8.7	0.9
			Total	6.8

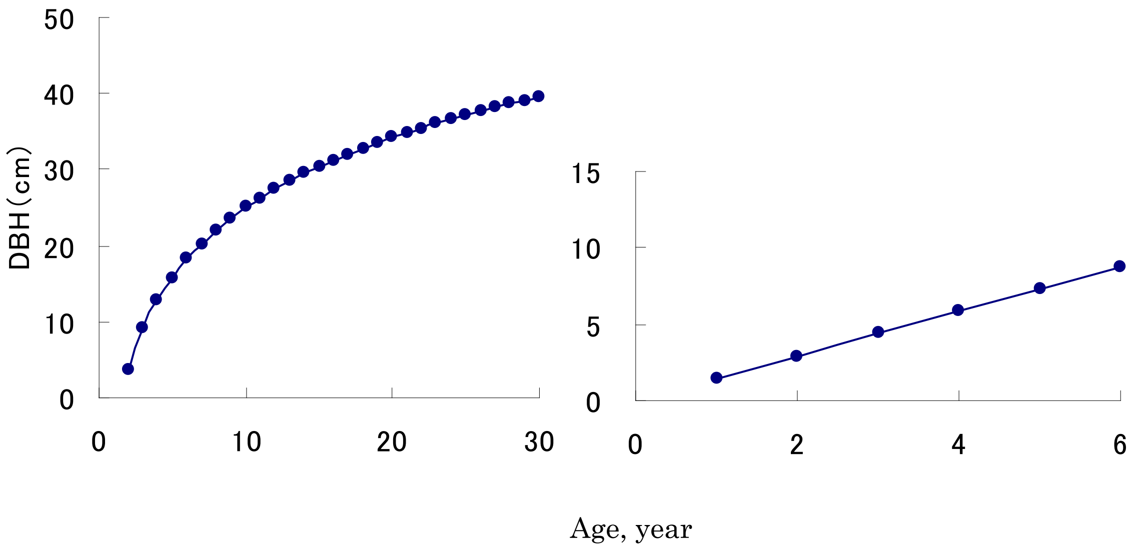

Figure 9　Predicted diameter growth of *Swietenia macrophylla* and *Gmelina arborea* (Left)、and *Sesbania grandiflora* (right)

Data from Jama et al. (1989)

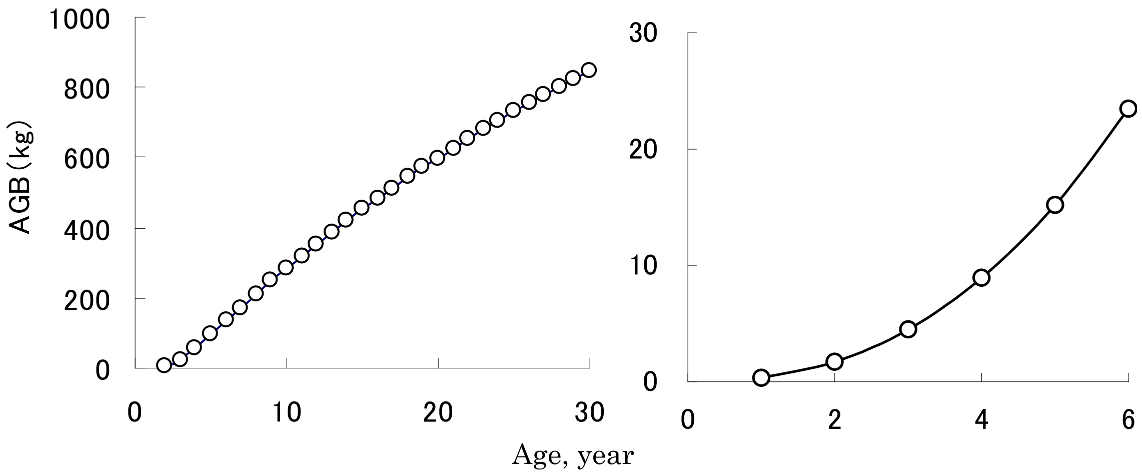

Figure 10　Predicted above-ground biomass of of *Swietenia macrophylla* and *Gmelina arborea* (Left)、and *Sesbania grandiflora* (right)

Using the allometry of Morikawa (2007) and data of Jama et al. (1989)

Table 11　Nutrient contents of *Acacia mangium*

Species	*Acacia mangium*			
Country	PNG	Indonesia	Indonesia	Average
N /Dry mass (kg/t)	2.52	2.39	1.76	2.22
P /Dry mass (kg/t)	0.13	0.05	0.37	0.19
K /Dry mass (kg/t)	1.48	1.76	0.51	1.25

Yamada et al. (2004)

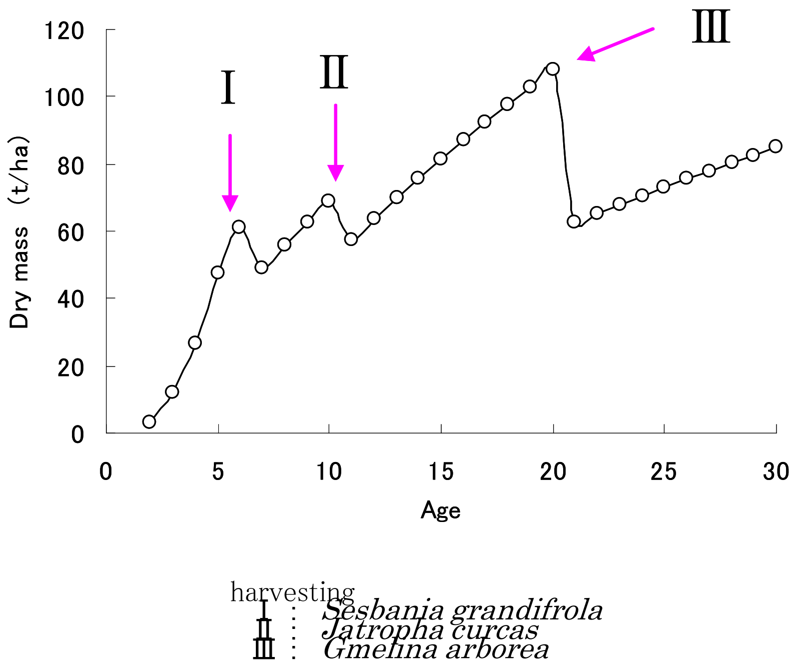

Figure 11 Predicted biomass change at the project site
From the allometry of Morikawa (2007) and data of Jama et al. (1989)

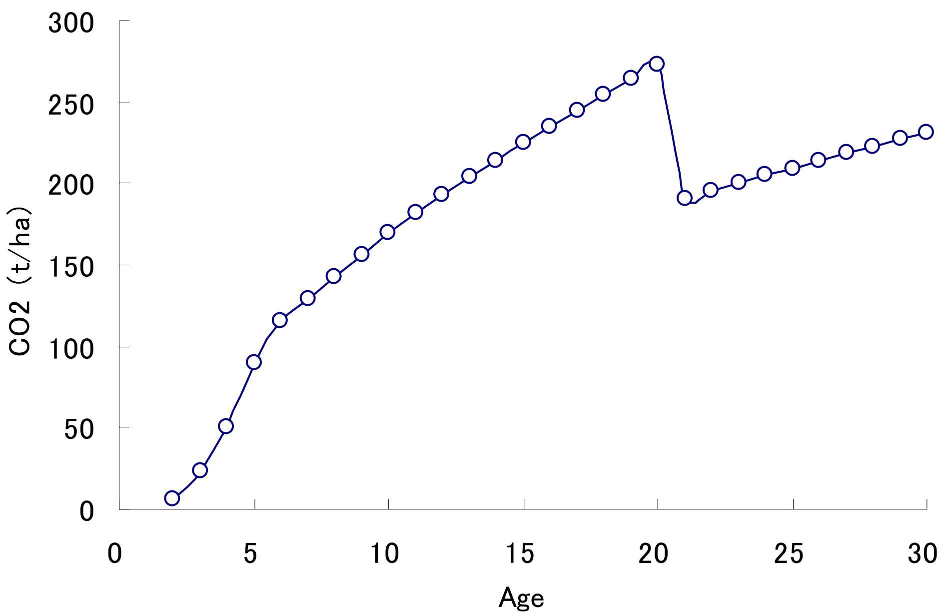

Figure 12 Predicted carbon sequestration at the project site

Table 12　Predicted timber production and revenue at the project site

Species	*Gmelina arborea*	*Swietenia macrophylla*
Age	20	30
Above ground biomass (t/ha) *1	47.9	84.8
Timber products（m^3/ha)	51.4*1,2	127.5*1,3
Revenue (mil Rp/ha)	102.9～128.6 *1,2	765*1,3

Calculating from Morikawa (2007), JIFPRO (1996), and Morikawa (2004)

Table 13　Predicted above-ground biomass and revenue of *Sesbania grandiflora*

Species	*Sesbania grandiflora*	
Number of Tree（tree/ha)	800	
Above ground biomass（t/ha/6yea	18.8	
Price (Rp/tree)	4500	6000
Revenue (mil Rp/ha/6year)	3.6	4.8

Calculating from Morikawa (2007)and Jamma et al. (1989)

Table 14　Predicted total revenue of *J. curcas* from the project site

Species	*Jatropha curcus*
Age	10
Above ground biomass (t/ha/year)	17.9
Harvest (t /ha/year)	1.86
Total Harvest (t /ha/10year)	14
Revenue from timber (mil Rp /ha)	—
Revenue from seed (mil Rp /ha/10year	7～21
Seed price：500　(Rp /kg)	7
Seed price：1000　(Rp /kg)	14
Seed price：1500　(Rp /kg)	21

Table 15 Transaction price of timber in Lombok Island (Feb. 2009)

Species	*Swietenia macrophylla*	*Gmelina arborea*	*Tectona grandis*
Timber price (mil Rp/ m3)	6	2～2.5	7～7.5

Species	*Samanea samman*	Azartica indica
Timber price (mil Rp/ m3)	5～6	3.5～4

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Table 16 Total revenue from the forest products for 30 years at the project site

Species	Total	*Gmelina arborea* *[1,2]	*Swietenia macrophylla* *[1,3]	*Jatropha curcas*	*Sesbania grandiflora* *[1,4]
Revenue (mil Rpp)					
1～10 year	10.6-25.8	0	0	7.0-21.0	3.6-4.8
11～20 year	102.9-128.6	102.9-128.6	0	0	0
21～30 year	765	0	765	0	0
Total	879-919	102.9-128.6	765	7.0-21.0	3.6-4.8
Average	29.3-30.6				

Calculating from Morikawa (2004, 2007), JIFPRO (1996), and Jama et al. (1989)

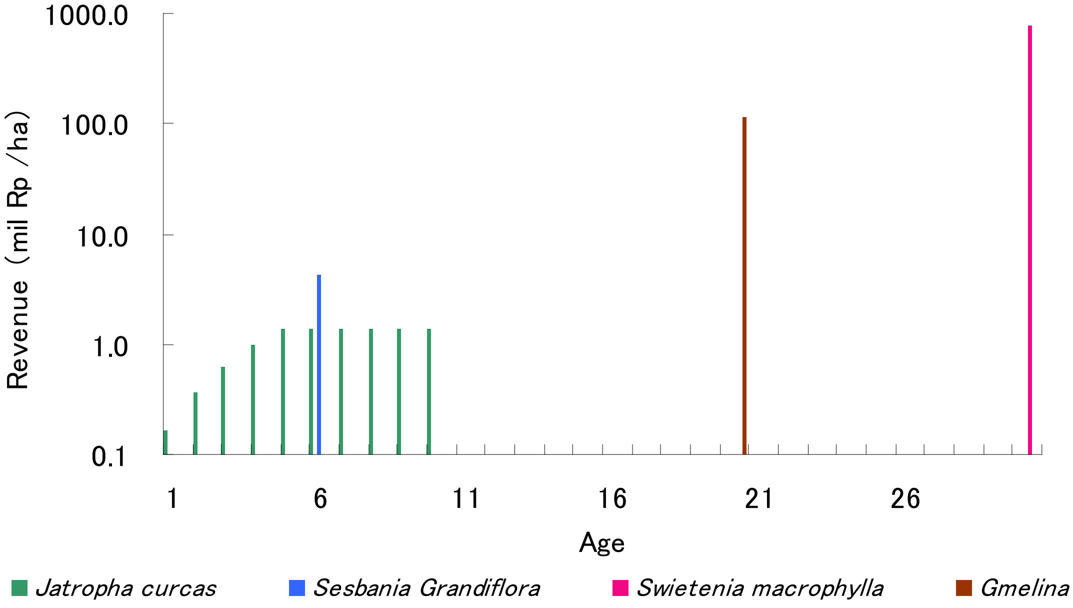

Figure 13 Yearly revenue from the forest products for 30 years at the project site
Calculating from Morikawa (2004), JIFPRO (1996), Jama et al. (1989), and Forest Service in Nusa Tengara

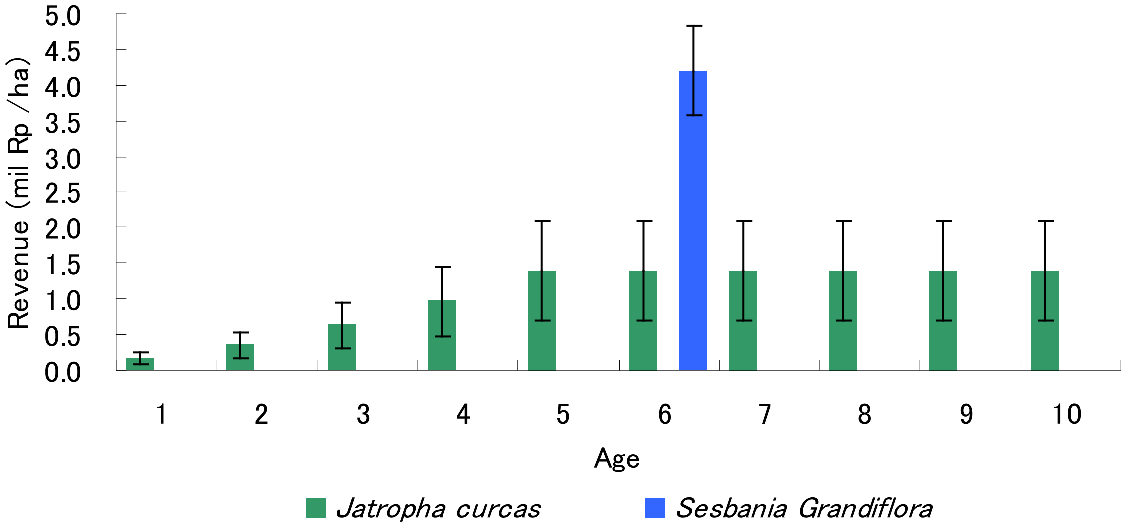

Figure 14 Revenue in short period from the forest products at the project site
Calculating from Morikawa (2004), Jama et al. (1989), and Forest Service in Nusa Tengara

Table 17 Input of nutrient elements from yearly rainfall (1,150mm)

Species of Nutrient	Nitrogen	Phosphorus
Supply from rainfall		
Unit requirement (mg /mm)	46 - 111	11.3 - 44.3
per year (g/year)	53 - 128	13 - 51
30years total (kg /30years)	1.5 - 3.8	0.4 - 1.5

DINAS Kehunanantan（2008）、JIFPRO（1995）

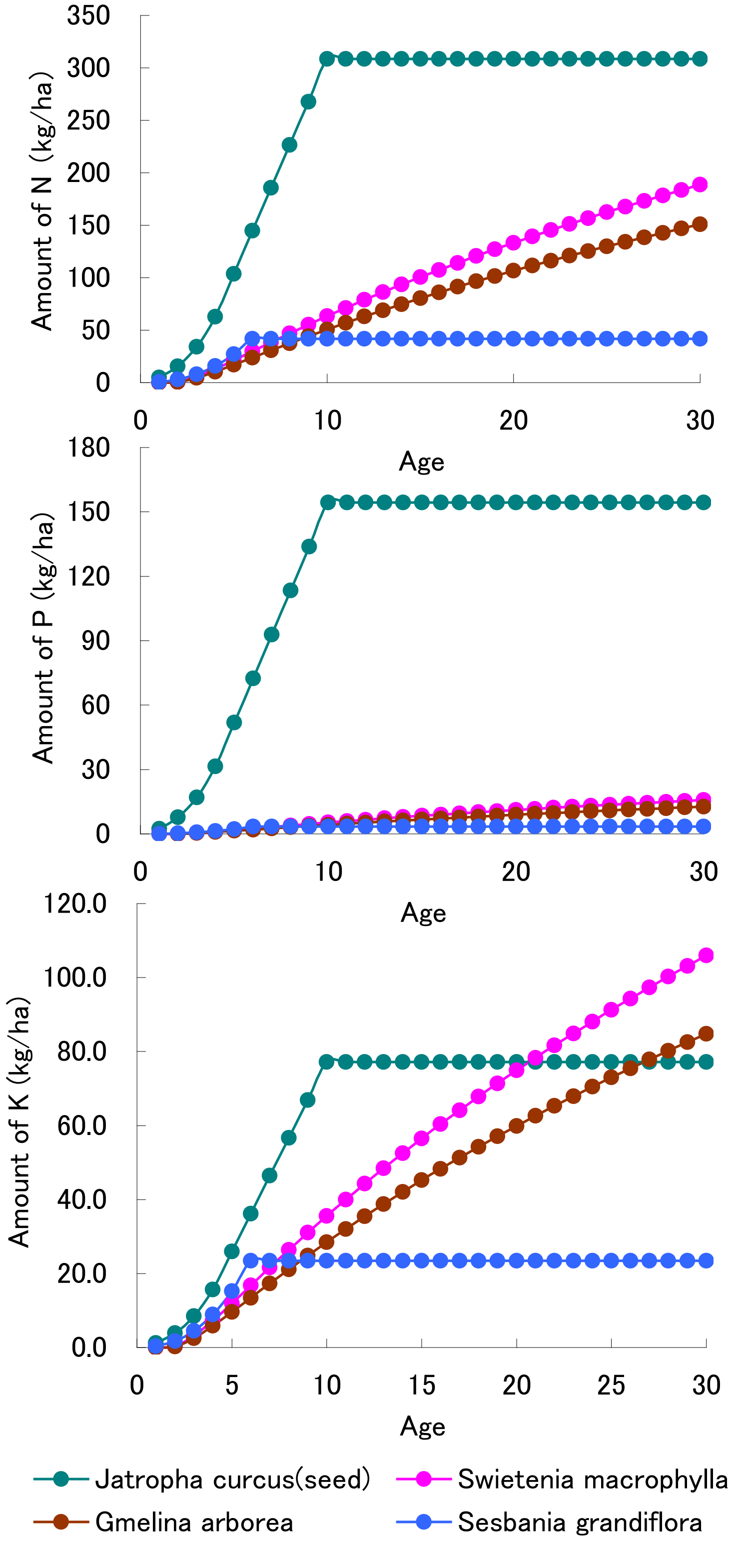

Figure 15 Predicted nutrient removal by harvesting of planting trees

Calculating from Yamada et al. (2004)、Morikawa(2007)、and Jamaet al. (1989)

Table 18　Main energy of families in Sambelia

No	Village	Number of family			% of Fuel wood
		use Fuel wood	use Kerosene	Total	
1	Sambelia	1300	505	1805	72
2	Belanting	1629	123	1752	93
3	Obel-Obel	954	168	1122	85
4	Sugien	1448	76	1524	95
5	Labuan Panda:	1958	319	2277	86
	Total	7289	1191	8480	86

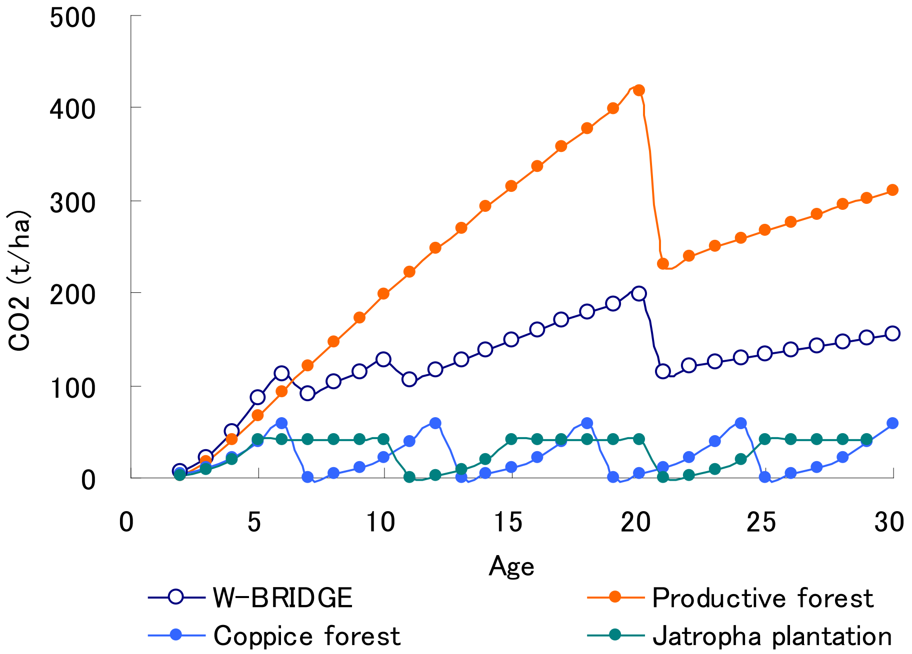

Figure 16　Predicted carbon sequestration in various plantation models

Calculating from Morikawa(2007) and Jamaet al. (1989)

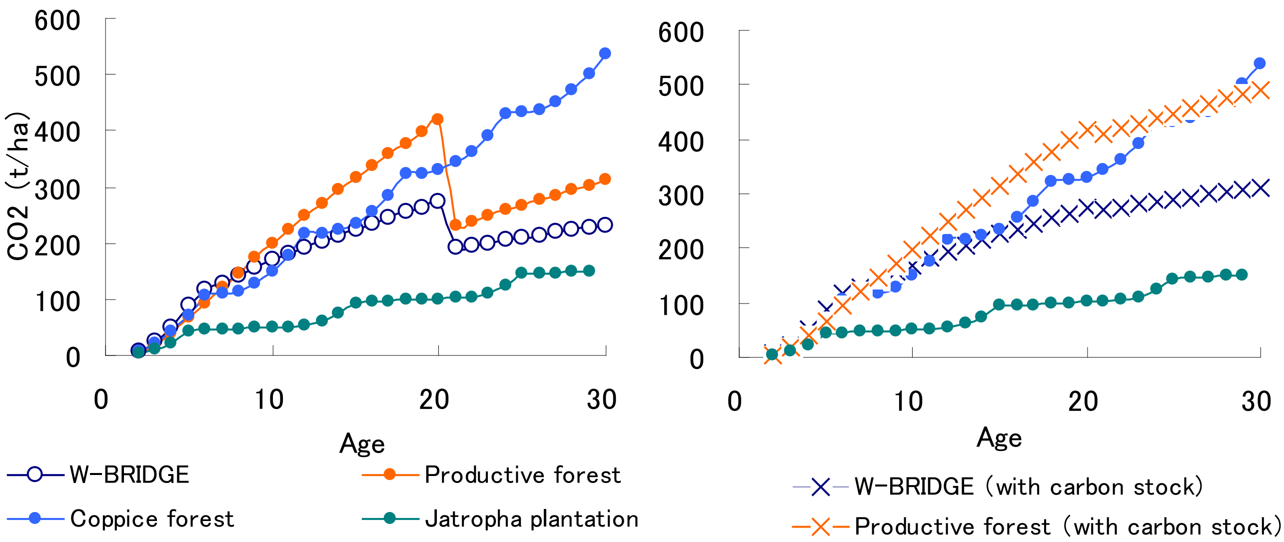

Figure 17 Predicted final cutback of CO_2 in various plantation models

Calculating from ＊Morikawa(2007)、Jamaet al. (1989)、Openshaw(2000)、and IPCC

Table 19 Revenue in each model

Land use	W-BRIDGE *[1,2,3]	Productive forest *[1,2,3]	Coppice forest *[1,4]	Jatropha plantation
Revenue(mil Rpp)				
1～10 year	10.6-25.8	0	11.3-15	8.6-25.7
11～20 year	103-129	232-290	22.6-30	8.6-25.7
21～30 year	765	1529	22.6-30	8.6-25.7
Total	878.6	1760-1819	56.5-75	25.7-77.0
Average (mil Rp /year)	29.3-30.7	58.7-60.6	1.9-2.5	0.9-2.6

Calculating from ＊1 : Morikawa (2007) ,＊2 : JIFPRO (1996) ,＊3 : morikawa (2004) ,and ＊4 : Jamaet al. (1989)

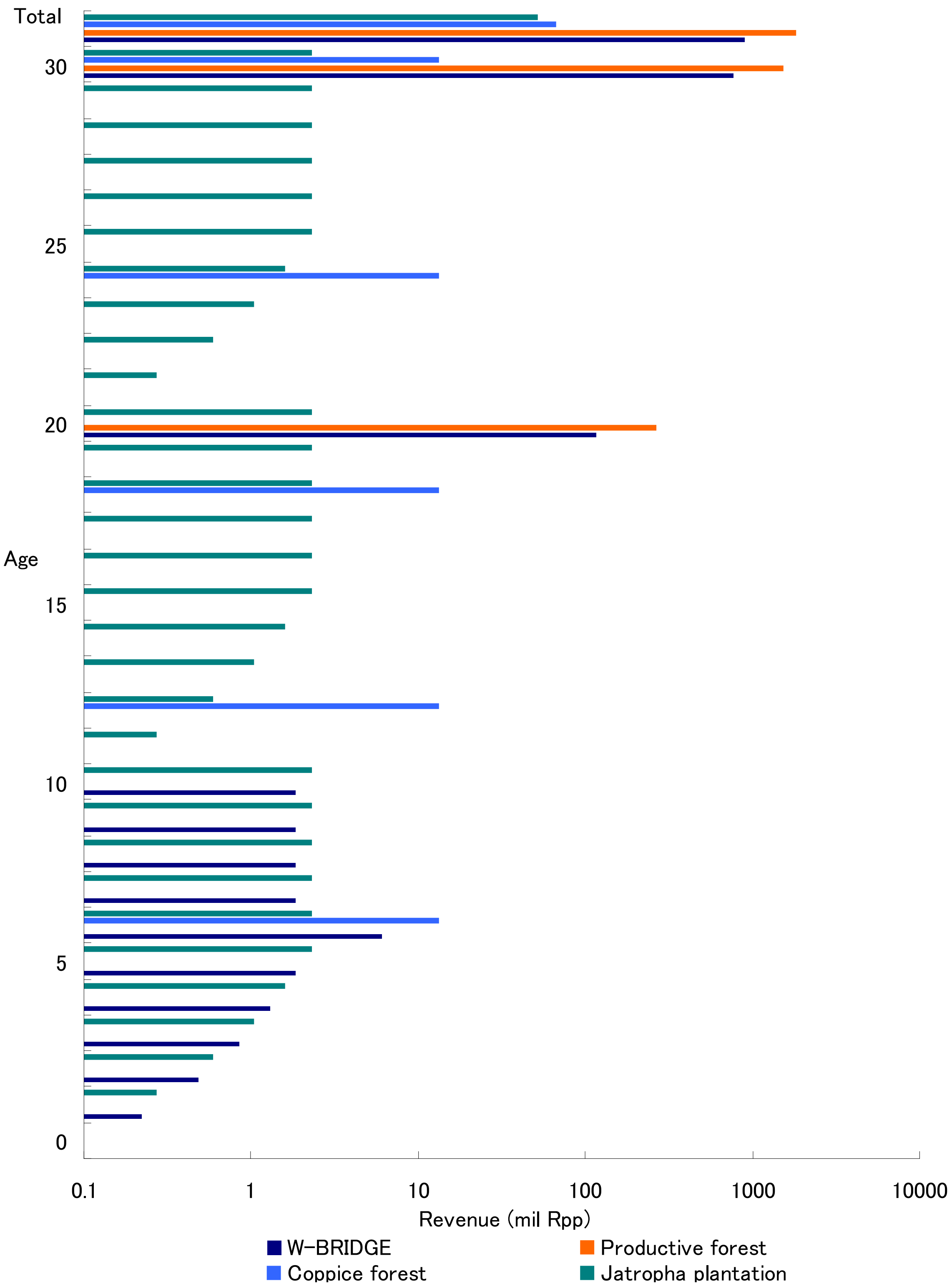

Figure 18　Predicted yearly revenue in various plantation models

Calculating from Morikawa(2004, 2007)、JIFPRO(1996)、Jamaet al. (1989)、and Forest Service in Nusa Tengara

Table 19　IRR in various plantation models

Land use	W-BRIDGE *1,2,3	Productive forest *1,2,3	Coppice forest *1,4	Jatropha plantation
Investment（mil Rp/ha）				
Seedling	1.45	1.45	2.5	1.25
Planting up keep	1.3	1.3	1.3	1.3
IRR（%）	29~50	28~29	20~26	22~54

Calculating from *1,3 : Morikawa（2004, 2007）,*2 : JIFPRO（1996）,and *4 : Jamaet al.（1989）

Table 20　Nutrient contents from Jatropha and agricultural crops

Species	*Jatropha curcas*	Corn	Soybeans	Rice
Productivety (t/ha)	1.7	5*1	0.7*1	9*1
Nurient content（%）				
N	2.2	1.38*2	5.78*2	1.03*2
P	1.1	0.27*2	0.48*2	0.09*2
K	0.55	0.29*2	0.18*2	0.09*2

Calculating from ＊1 : Ministry of Education, Japan （2005） and ＊2 : Barbier （1989）

Table 21 Nutrient removal from Jatropha and agricultural crops

Species	*Jatropha curcas*	Corn*	Soybeans*	Rice*
Nurient deprivation (kg/ha /year)				
N	38	69	40	93
P	19	14	3	8
K	9	15	13	8

Calculating from ＊ Ministry of Education, Japan（2005） and Barbier（1989）

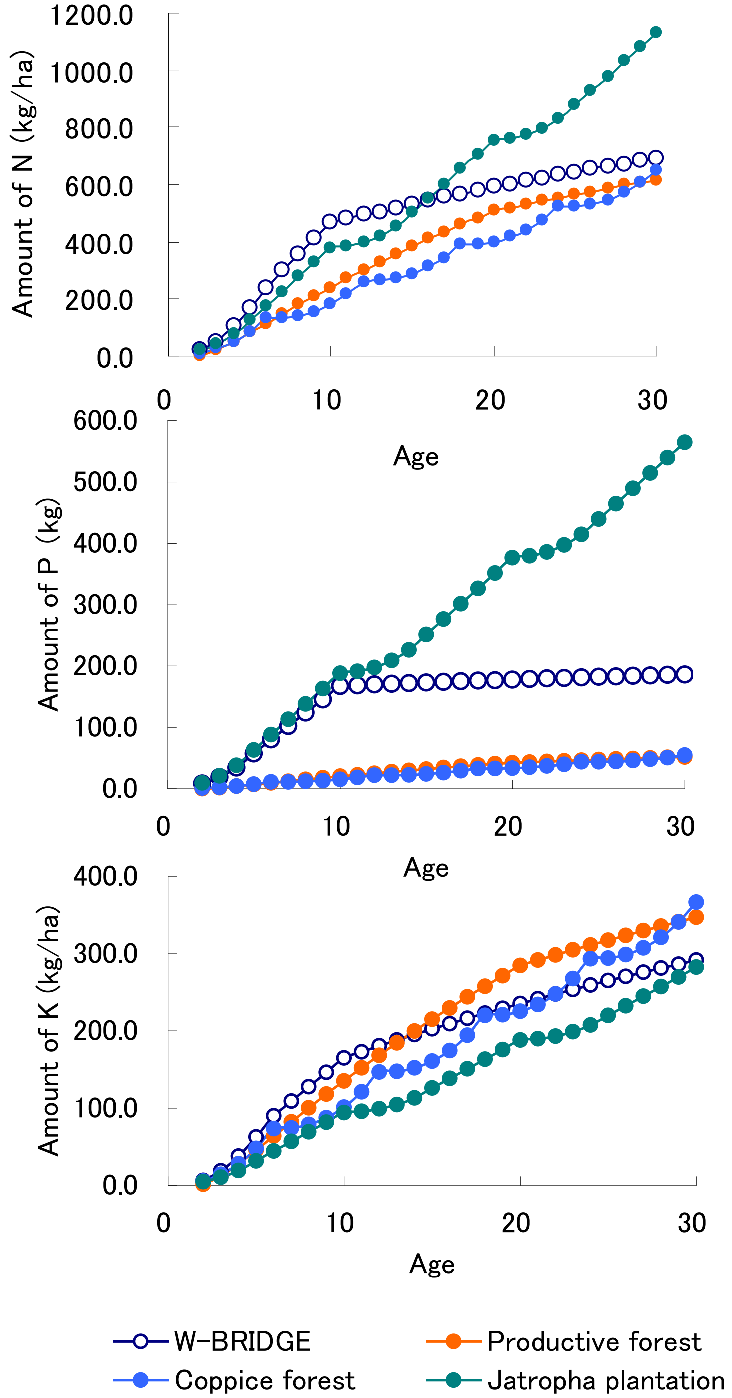

Figure 19 Predicted nutrient removal from the plantation modeks

Calculating from ＊Yamadaet al. (2004)、Morikawa(2007)、and Jamaet al. (1989)

Table 22　Energy value (Density:2,500 trees/ha)

Species	*Sesbania grandiflora*	*Jatropha curcas*		
Part	Above ground mass	Oil	Marc	Avove graound mass
Energy value (MJ/kg)	15.5 ＊1	40.7 *3	25.5 *3	15.5 *3
Harvest（t /ha /30year）	293 *2	14.9	36.4	65.4
Energy value (GJ /ha / 30year)	4553 *1,2	606*4	930*4	1014*4

Calculating from ＊1：IPCC, ＊2：Jama ら(1989)、Morikawa（2007），＊3：Openshaw (2000), and ＊4：Openshaw（2000）

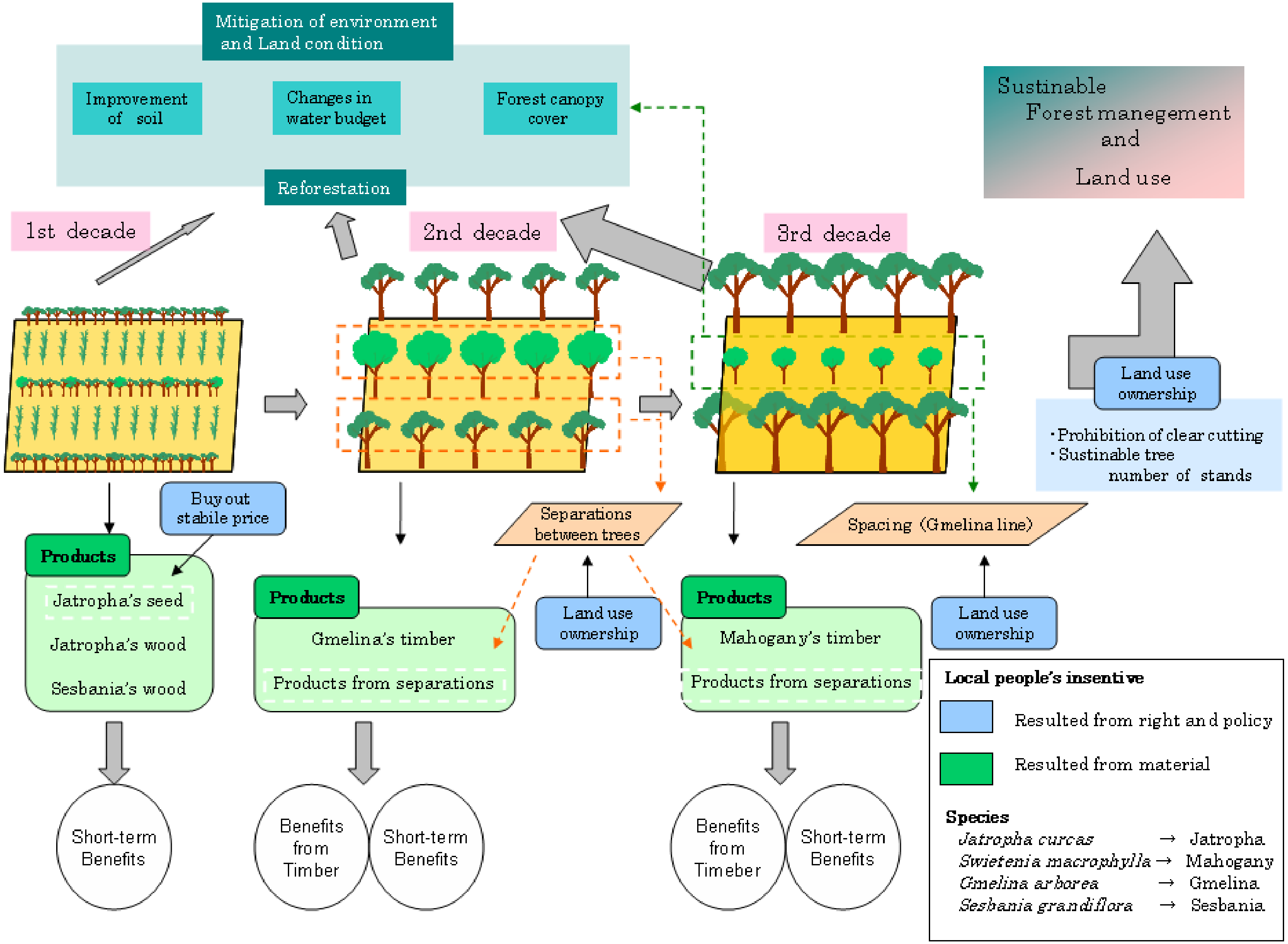

Figure 20 Image of W-BRIDGE Project

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