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Baseline and Stand Structural Attributes Changes in Arid Woodland Vegetation

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Abstract: For evaluating sequestrated carbon amount by planted trees, baseline carbon stock change must be estimated. Since present land use type is natural vegetation, baseline carbon stock change is equivalent to stand biomass change. Repeated tree census in 15 sites inside the research area have been carried out about ten years, and then stand biomass and stand structural attribute changes were observed. Stand growth of Acacia forest and woodland, dominant vegetation type in the research area, varied from -0.57 to 5.98 Mg ha^{-1} $year^{-1}$, excluding artificial disturbance, and its average was 0.14 Mg ha^{-1} $year^{-1}$, equivalent to 0.068 Mg-carbon ha^{-1} $year^{-1}$. Thus, afforestation method which overcomes this baseline stand growth must be adopted for the future afforestation designing.

Keywords: Basal area, Biomass, Canopy cover, Leaf area index, Stand growth

1. Introduction

As one of the counter measures for global warming, arid land afforestation experiment has been proposed and implemented in an arid land of Western Australia (Yamada, 2004; Kojima *et al*., 2006). The experimental area, Sturt Meadows, locates 600 km from Perth, the provincial capital of Western Australia, and its coordinate is 120˚58'E, 28˚40'S. From UNFCCC (2006), sequestrated carbon amount by afforestation must be calculated from carbon stock changes in 5 types of carbon pools. This 5 carbon pools consist of above-ground biomass, below-ground biomass, litter, dead wood and soil organic carbon. Among 5 carbon pools, we focused on above-ground biomass, below-ground biomass in this study.

For accounting carbon amount for emission credit, in addition to evaluating the significant changes in carbon pools inside afforestation boundary, baseline and leakage must be considered (UNFCCC, 2006). Since main industries in this arid area are mining and extensive grazing, leakage was considered as nearly zero. There spreads vast unused land. On the other hand, present land use type in this research area is Acacia forest and woodlands (National Land and Water Resources Audit, 2002), so baseline is stand growth of this natural vegetation. Thus, stand growth in the representative sites in the research area were observed in this research.

2. Materials and Methods

15 representative natural vegetation sites were set for baseline monitoring in the research area, where mean annual rainfall is around 200 mm $year^{-1}$ and no obvious dry-season exists. As the major vegetation type is Acacia forests and woodlands in this research area, 9 sites were set where *Acacia aneura* was dominant tree species. 4 sites were set where *Eucalyptus camaldulensis* was dominant tree species. 2 sites were set where halophyte or salinity tolerant shrub distributed.

Repeated tree censuses have been carried out inside these 15 sites from June 1999 to August 2007. Most of the sites were monitored three times. Measured values were, tree species, tree height, girth at breast height (1.3 m) and canopy width. From these measurement data, stand biomass, stand growth canopy cover (CC), stand basal area (SBA), leaf area index (LAI) were calculated. Stand biomass was calculated using allometric equations which were described as power function ($Y=aX^b$). The coefficiants are shown on **Table 1**. As allometric equations were made only for dominant tree species, other tree species biomass were calculated from generalized allometric equations which were made by mixing 5 tree

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Table 1. Allometric equations.

Species	Dependent variable Y (kg)	Independent variable X	(unit)	Coefficient a	b	R square	n
Acacia aneura	*Ws + Wb*	DBH^2	(m^2)	5255.4	1.084	0.992	15
	Wl	DBH^2	(m^2)	77.6	0.676	0.914	15
	Ws + Wb	*Cpa*	(m^2)	1.44	1.442	0.962	11
	Wl	*Cpa*	(m^2)	0.53	0.847	0.982	15
	Wr	*Wabove*	(kg)	0.40	1	N/A	2
Eucalyptus camaldulensis	*Ws + Wb*	DBH^2	(m^2)	6212.9	1.188	0.990	11
	Wl	DBH^2	(m^2)	189.2	0.812	0.991	10
	Ws + Wb	*Cpa*	(m^2)	0.59	1.734	0.961	10
	Wl	*Cpa*	(m^2)	0.35	1.153	0.948	10
	Wr	*Wabove*	(kg)	0.72	1	N/A	3
Melaleuca sheathiana	*Ws + Wb*	*Cpa*	(m^2)	0.13	2.221	0.918	4
	Wl	*Cpa*	(m^2)	0.03	1.931	0.897	4
	Wr	*Wabove*	(kg)	0.40	1	N/A	2
other species	*Ws + Wb*	*Cpa*	(m^2)	1.38	1.211	0.959	11
	Wl	*Cpa*	(m^2)	0.22	0.900	0.903	10
	Wr	*Wabove*	(kg)	0.27	1	N/A	9

species data (*Acacia ramlosa*, *A. tetragonophylla*, *Eremophila forestii*, *Eremophila macmillaniana*, *Lawrencia squamata*). Stand growth was calculated as mean annual increment (MAI) which is simple arithmetic average of stand biomass change per year. CC, SBA and LAI were calculated from following formulas:

$$CC = \frac{\sum Cpa}{Plot} \quad \cdots(1) \qquad SBA = \sum \frac{\pi (DBH)^2}{4} \times \frac{Plot}{10000} \quad \cdots(2) \qquad LAI = \frac{\sum Wl}{LMA} \times \frac{Plot}{10000} \quad \cdots(3)$$

where *Cpa* [m^2] was crown projection area: *Plot* [m^2] was site area: *DBH* [m] was diameter at breast height: *Wl* [kg] was leaf biomass and *LMA* [kg m^2] was leaf mass per unit area. CC in this research was just a cumulative value of crown projection area, which is approximated as ellipse, inside the monitoring site, thus this value became over 1.0. SBA was the normalized value per 1 hectare. The LMA of *E. camaldulensis* was 169.5g m^2 (n=170, *SE*=3.3), and that of *A. aneura* was 327.9 g m^2 (n=75, *SE*=7.9) reported in Yamada (2004). For convenience, The LMAs of the other species were set as the same value of *A. aneura* because of insufficient data and similarity of leaf thickness.

3. Results and Discussion

From repeated tree censuses, species compositions in each site were obtained. Excluding site 10, dominance of *Acacia anuera* was 94.4% (*SD*=8.5) among Acacia woodland sites. Site 10 was mixture of *A. aneura* (57.1%), *A. coolgardiendsis* (18.3%) and *Eucalyptus kingsmilli* (17.4%). Dominance of *Eucalyptus camaldulensis* was 95.4% (*SD*=8.8) among Eucalypts sites. Since species compositions in each site were judged from basal area dominance, thus trees less than 2 m were neglected, and dominant species of site 3 and site 6 were judged from appearance ratio. Species compositions in each site have been relatively stable, because not so many trees appeared or died. Precisely, small trees (less than 1 m) and herbaceous species varied a lot. Observed tree species in Acacia and Eucalypts forests and woodlands were listed as follows, excluding above mentioned species. *Acacia burkittii*, *Acacia craspedocarpa*, *Acacia ramulosa*, *Acacia tetragonophylla*, *Atriplex rhagodioides*, *Canthium lineare*, *Cassia artemisioides*, *Cassia chatelainiana*, *Cassia desolata*, *Cassia nemophila*, *Cratystylus subspinescens*, *Eremophila forrestii*, *Eremophila fraseri*, *Eremophila georgei*, *Eremophila glabra*, *Eremophila granitica*, *Eremophyla longifolia*, *Eremophila maculata*, *Grevillea berryana*, *Hakea suberea*, *Maireana convexa*, *Pimelea microcephala*, *Ptilotus divaricatus*, *Rhagodia drummondii*, *Rhagodia eremaea* and *Scaveola spinescens*.

Table 2 shows the summary of stand biomass change and basic site information. Mean annual increment of Acacia forests and woodlands (*Acacia aneura*) varied from -0.57 to 5.98 Mg ha^{-1} $year^{-1}$, excluding artificial disturbance. Before third census of Site 2, not so many but not negligible number of trees were cut down by some Aboriginal activity. Therefore we considered the tree loss inside site 2 as artificial disturbance, and then mean annual increment of site 2 between 2nd and 3rd census was excluded from following consideration. Baseline data of this Acacia forests and woodlands were considered as arithmetic average of mean annual increment, thus baseline was calculated as 0.81 Mg ha^{-1} $year^{-1}$ (*SD*=

Table 2. Stand biomass change summary and site information.

Dominant Species	Site name	Stand biomass [Mg ha^{-1}] 1st census			2nd census			3rd census			Mean annual increment [Mg ha^{-1} year^{-1}]		Coordinate		Plot area [ha]	Census date		
		Stem & Branch	Leaf	Root	Stem & Branch	Leaf	Root	Stem & Branch	Leaf	Root	Between 1st and 2nd	Between 2nd and 3rd	Longitude	Latitude		1st	2nd	3rd
Acacia aneura	Site 2	66.6	6.0	29.1	81.0	7.2	35.4	71.2	6.2	31.1	5.98	-3.32	120°57:36"	28°30'24"	0.13	1997 Nov.	2001 Jul.	2006 Feb.
	Site 4	40.8	3.3	17.4	40.9	3.3	17.4	39.2	3.2	16.7	0.04	-0.57	121°05:51"	28°45'43"	0.08	1997 Nov.	2001 Jul.	2006 Feb.
	Site 5	20.9	1.3	8.5	21.2	1.4	8.6	21.0	1.4	8.6	0.16	-0.07	121°04:19"	28°47'05"	0.10	1998 Apr.	2001 Jul.	2006 Feb.
	Site 7	49.8	4.8	20.7	58.9	5.3	24.8	65.4	5.7	27.3	3.71	2.06	121°01:56"	28°52'09"	0.04	1997 Nov.	2001 Jul.	2006 Feb.
	Site 8	12.0	1.4	4.9	12.2	1.3	4.8	13.2	1.3	5.1	0.02	0.28	120°51:23"	28°52'20"	0.40	1999 Jun.	2002 Dec.	2007 Aug.
	Site 9	3.0	0.4	1.2	3.0	0.4	1.2	3.2	0.4	1.3	-0.01	0.08	121°06:25"	28°43'32"	0.40	1999 Jun.	2002 Nov	2007 Aug.
	Site 10	10.1	1.4	5.4	9.6	1.3	4.8	13.4	1.3	5.2	-0.31	0.84	120°49:58"	28°38'00"	0.40	1999 Jun.	2002 Nov	2007 Aug.
	Site 11	4.9	0.6	1.8	5.0	0.6	1.8	5.7	0.6	2.0	0.00	0.22	120°52:28"	28°33'09"	0.04	1999 Nov.	2002 Dec.	2007 Aug.
	Site 12	8.6	0.9	3.8	9.3	1.0	4.1	12.6	1.2	5.5	0.32	1.02	120°53:39"	28°29'59"	0.40	1999 Nov.	2002 Dec.	2007 Aug.
Eucalyptus camaleudlensis	Site 1	69.2	4.4	49.0	68.8	4.4	49.1	49.0	3.2	33.4	-0.07	-7.99	120°57'15"	28°31'24"	0.40	1997 Nov.	2001 Jul.	2006 Mar.
	Site 1C	55.0	3.9	40.8	56.5	4.1	42.0		N/A		0.67	N/A	120°57'27"	28°31'13"	0.25	2002 Jul.	2006 Sep.	N/A
	Site LP	16.9	1.7	13.2	19.3	2.0	14.8		N/A		1.08	N/A	120°57'41"	28°31'02"	0.25	2003 Aug.	2007 Aug.	N/A
	Site 14	53.2	5.6	42.3	65.5	6.2	51.4		N/A		6.39	N/A	120°57'35"	28°31'07"	0.25	2004 Mar.	2007 Aug.	N/A
Lawrencia squamata	Site 3	1.1	0.2	0.4	1.2	0.3	0.4		N/A		0.07	N/A	120°51'01"	28°41'50"	0.04	1997 Nov.	2001 Jul.	N/A
Melaleuca sheathiana	Site 6	32.3	2.3	13.9	34.3	2.4	14.8		N/A		0.80	N/A	121°02'26"	28°50'41"	0.80	1997 Nov.	2001 Jul.	N/A

Table 3. Stand structural attributes change summary.

Dominant Species	Site number	Canopy cover (CC)			ΔCC [year^{-1}]		Stand basal area (SBA) [m^2 ha^{-1}]			ΔSBA [m^2 ha^{-1} year^{-1}]		Leaf area index (LAI) [m^2 m^{-2}]			ΔLAI [m^2 m^{-2} year^{-1}]	
		1st	2nd	3rd	Between 1st and 2nd	Between 2nd and 3rd	1st	2nd	3rd	Between 1st and 2nd	Between 2nd and 3rd	1st	2nd	3rd	Between 1st and 2nd	Between 2nd and 3rd
Acacia aneura	Site 2	0.96	1.02	1.11	0.01	0.02	14.81	18.36	15.80	0.97	-0.56	1.82	2.19	1.88	0.10	-0.07
	Site 4	0.70	0.65	0.74	-0.01	0.02	7.76	8.31	7.37	0.15	-0.20	0.99	1.01	0.99	0.00	0.00
	Site 5	0.31	0.34	0.42	0.01	0.02	4.91	5.09	4.78	0.05	-0.07	0.40	0.42	0.41	0.01	0.00
	Site 7	1.07	1.12	1.44	0.01	0.07	11.39	13.05	13.65	0.45	0.13	1.46	1.61	1.74	0.04	0.03
	Site 8	0.32	0.35	0.41	0.01	0.01	1.82	1.78	1.96	-0.01	0.04	0.42	0.38	0.40	-0.01	0.00
	Site 9	0.10	0.10	0.10	0.00	0.00	0.44	0.40	0.53	-0.01	0.03	0.11	0.11	0.12	0.00	0.00
	Site 10	0.24	0.32	0.36	0.02	0.01	3.38	2.38	3.24	-0.29	0.18	0.42	0.40	0.38	-0.01	0.00
	Site 11	0.20	0.21	0.25	0.00	0.01	0.52	0.47	0.48	-0.01	0.00	0.18	0.18	0.20	0.00	0.00
	Site 12	0.15	0.17	0.23	0.01	0.01	1.69	1.80	2.65	0.03	0.18	0.28	0.30	0.36	0.01	0.01
Eucalyptus camaleudlensis	Site 1	0.92	0.93	0.72	0.00	-0.05	13.84	13.59	10.16	-0.07	-0.75	2.45	2.48	1.77	0.01	-0.15
	Site 1C	0.73	0.85	N/A	0.03	N/A	9.70	10.38	N/A	0.16	N/A	2.21	2.34	N/A	0.03	N/A
	Site LP	0.21	0.37	N/A	0.04	N/A	3.57	4.18	N/A	0.15	N/A	0.97	1.14	N/A	0.04	N/A
	Site 14	0.99	1.26	N/A	0.08	N/A	12.61	14.00	N/A	0.40	N/A	3.29	3.68	N/A	0.11	N/A
Lawrencia squamata	Site 3	0.10	0.11	N/A	0.00	N/A	N/A	N/A	N/A	N/A	N/A	0.07	0.08	N/A	0.00	N/A
Melaleuca sheathiana	Site 6	0.21	0.22	N/A	0.00	N/A	0.29	0.31	N/A	0.01	N/A	0.69	0.72	N/A	0.01	N/A

1.67). But as shown in *SD* value, the difference was relatively large. From Suganuma *et al*. (2006), average stand biomass in this research area was calculated as 7.57 Mg ha^{-1}, relatively small, so Site 2, 4 and 7 was considered to be not representative sites for baseline calculation. Excluding these high stand biomass sites, the average of mean annual increment, baseline, was 0.14 Mg ha^{-1} year^{-1} (*SD*=0.41). Since carbon conversion factor from biomass to carbon was reported as 0.477 (Yamada *et al*., 1999), baseline carbon accumulation by Acacia forests and woodlands was 0.068 Mg ha^{-1} year^{-1}, which is quite small value. Therefore, most of the research area, where Acacia forests and woodlands distributed, was considered as afforestation candidate.

From Table 2, mean annual increment data of Eucalypts forests and woodlands were also obtained, and their values were also varied. Judging from these data, mean annual increment value appeared to vary site by site. Particularly in site 1, mean annual increment has large minus value. The reason of this minus value was derived from dying many trees. Originally, site 1 was mature forest, thus mean annual increment value was considered as small or 0, but such massive death was unexpected. In consequence, since baseline values varied from large minus to large plus, Eucalypts forests and woodlands should be excluded from afforestation candidate in present situation.

Table 3 reports stand structural attributes changes in each site. Though mean annual increment value varies a lot, canopy cover (CC) did not change so much. On the other hand, stand basal area (SBA) and leaf area index (LAI) changed and had same tendency compared to mean annual increment (**Fig. 1**). This reason was considered that stand biomass, SBA and LAI were calculated based on girth at breast height, and thus these values had high correlations, originally. In other words, mean annual increment of this research area will be obtained from monitoring SBA change or LAI change. SBA can be monitored using laser lider, and LAI can be monitored using satellite imagery, generally. Though baseline value was obtained as simple value in this research, satellite image analysis or laser lider analysis will be expected to provide baseline distribution in future analysis. Either ways, afforestation method which overcomes observed baseline must be adopted for the future afforestation designing.

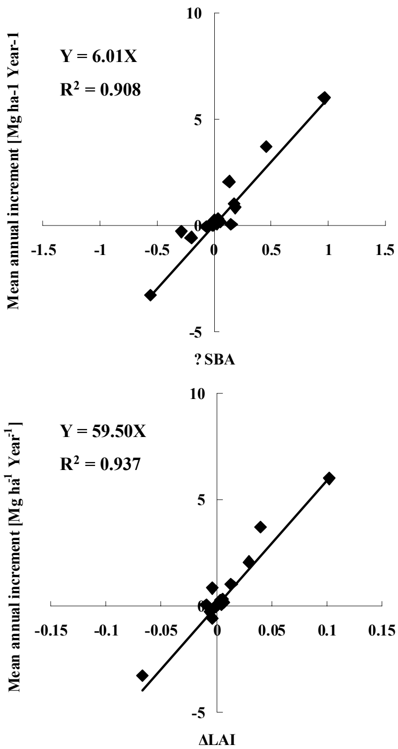

Fig. 1. Relationship between mean annual increment and stand basal area or leaf area index in Acacia forests and woodlands.

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References

Kojima T., Hamano H., Abe Y., Tanouchi H., Egashira Y., Saito M., Law J, Takahashi N., Yamada K. (2006): Basic Data of Research Project on Large Scale Afforestation of Arid Land for Carbon Fixation near Leonora in Western Australia. *J. of Arid Land Studies*, **16**(3): 167-174.

National land and water resources audit (2002): *Australia's native vegetation – A summary of the national land and water resources audit's Australian native vegetation assessment 2001*. Commonwealth of Australia, Canberra, 27p.

Suganuma H., Abe Y., Taniguchi M., Yamada K. (2006): Evaluation of the stand biomass estimation method by digitized aerial photographs in an arid area of Western Australia. *J. Jpn. Soc. Photogramm. Remote Sens*. **45**(3): 12-23.

UNFCCC (2006): *Guideline for completing CDM-AR-PDD and CDM-AR-NM. -Clean development mechanism guidelines for completing the project design document for A/R (CDM-AR-PDD), the proposed new methodology for A/R: Baseline and monitoring (CDM-AR-NM) version 4-* United Nation Framework Convention on Climate Change, 53p

Yamada K., Kojima T., Abe Y., Williams A., Law J. (1999): Carbon sequestration in an arid environment near Leonora, Western Australia. *J. Arid Land Studies*, **9**: 143-151.

Yamada, K., 2004. Establishment of carbon fixation system by afforestation of arid land. *In*: Japan Science and Technology Agency eds., *Final Report of Heisei 10th Adoption Project- Resource Circulation and Energy Minimized System Engineering-*. CREST, JST, Tokyo, 355-455.