POLYTECH® TOURS
Département Aménagement et Environnement
Ecole d'ingénieurs polytechnique de l'université de Tours
UNIVERSITÉ FRANÇOIS - RABELAIS TOURS

CITERES
UMR 6173
Cités, Territoires, Environnement et Sociétés
Equipe IPA-PE
Ingénierie du Projet d'Aménagement, Paysage, Environnement

Projet de Fin d'Etudes

Organic carbon accumulation in mangroves of Xuan Thuy National Park, Northern Vietnam.

L'accumulation de carbone organique dans les mangroves du Parc National de Xuan Thuy, Nord du Vietnam.

2016-2017
S9

GAYRAL Julia

Directeur de recherche
GRELLIER Séraphine

Organic carbon accumulation in mangroves of Xuan Thuy National Park, Northern Vietnam.

L’accumulation de carbone organique dans les mangroves du Parc National de Xuan Thuy, Nord du Vietnam.

Directeur de recherche :
Grellier Séraphine

Auteur :
Gayral Julia

Année 2016

AVERTISSEMENT

Cette recherche a fait appel à des lectures, enquêtes et interviews. Tout emprunt à des contenus d'interviews, des écrits autres que strictement personnel, toute reproduction et citation, font systématiquement l'objet d'un référencement.

L'auteur (les auteurs) de cette recherche a (ont) signé une attestation sur l'honneur de non plagiat.

FORMATION PAR LA RECHERCHE ET PROJET DE FIN D'ETUDES

EN GENIE DE L'AMENAGEMENT

La formation au génie de l'aménagement, assurée par le département aménagement de l'Ecole Polytechnique de l'Université de Tours, associe dans le champ de l'urbanisme et de l'aménagement, l'acquisition de connaissances fondamentales, l'acquisition de techniques et de savoir faire, la formation à la pratique professionnelle et la formation par la recherche. Cette dernière ne vise pas à former les seuls futurs élèves désireux de prolonger leur formation par les études doctorales, mais tout en ouvrant à cette voie, elle vise tout d'abord à favoriser la capacité des futurs ingénieurs à :

- Accroître leurs compétences en matière de pratique professionnelle par la mobilisation de connaissances et de techniques, dont les fondements et contenus ont été explorés le plus finement possible afin d'en assurer une bonne maîtrise intellectuelle et pratique,
- Accroître la capacité des ingénieurs en génie de l'aménagement à innover tant en matière de méthodes que d'outils, mobilisables pour affronter et résoudre les problèmes complexes posés par l'organisation et la gestion des espaces.

La formation par la recherche inclut un exercice individuel de recherche, le projet de fin d'études (P.F.E.), situé en dernière année de formation des élèves ingénieurs. Cet exercice correspond à un stage d'une durée minimum de trois mois, en laboratoire de recherche, principalement au sein de l'équipe Ingénierie du Projet d'Aménagement, Paysage et Environnement de l'UMR 6173 CITERES à laquelle appartiennent les enseignants-chercheurs du département aménagement.

Le travail de recherche, dont l'objectif de base est d'acquérir une compétence méthodologique en matière de recherche, doit répondre à l'un des deux grands objectifs :

- Développer toute ou partie d'une méthode ou d'un outil nouveau permettant le traitement innovant d'un problème d'aménagement
- Approfondir les connaissances de base pour mieux affronter une question complexe en matière d'aménagement.

Afin de valoriser ce travail de recherche nous avons décidé de mettre en ligne sur la base du Système Universitaire de Documentation (SUDOC), les mémoires à partir de la mention bien.

REMERCIEMENTS

Je tiens à remercier toutes les personnes qui ont contribué au succès de mon projet de fin d'étude et qui m'ont aidé lors de la rédaction de cet article.

Tout d'abord, j'adresse mes remerciements à ma directrice de recherche, **Mm Grellier Séraphine de l'Ecole Polytech Tours Aménagement et Environnement** qui m'a beaucoup aidé tout au long de ma démarche de projet. Son écoute et ses conseils m'ont permis de cibler les points importants à développer.

Enfin, je tiens à remercier toutes les personnes qui m'ont conseillée lors de la rédaction de ce rapport de stage : **Adrien Jacotot** thésard qui travail sur l'impact des diverses concentrations de CO_2 et des temps d'immersion par l'eau de mer sur la croissance des plantes dans les mangroves, Nouvelle Calédonie et ma famille.

SOMMAIRE

Introduction

Mangroves constitute an ecosystem that is found in tropical and subtropical areas and more precisely in transition zones between the land and the coast. The term mangrove refers to both the plants and their habitat.

Mangroves provide several ecosystem services. Within the context of the fight against greenhouse gas emissions, they represent an important carbon reservoir in a small area compared to other forests in the world (Spalding et al. 2010). "The average value of carbon storage per hectare is much higher in mangroves than in other forests. In mangroves, it would appear that this process is more intensive. "(Kauffman 2011). To a study relesed in Indonesia “Ecosystem carbon stocks of sampled mangrove forests ranged from 437 Mg C/ha to 2186 Mg C/ha. The overall mean ecosystem carbon stock across the three study sites was 993.3 Mg C/ha. This carbon storage is exceptionally high compared with upland tropical forests which typically store between 150 and 500 Mg C/ha. » (Murdiyarso et al. 2009). This study also found that the entire ecosystem contributes to the carbon storage. Indeed, they found that the soil could stock 85% to 98% of the total carbon of the ecosystem.

The world has lost around 3.6 million hectares (ha) of mangroves between 1980 and 2005, which represent a loss of 20% of the total area of mangroves (FAO 2008). The total area of mangroves has decdeclined from 18.8 million hectares in 1980 to 15.2 million hectares in 2005. Southeast Asia, includes a third of the world's mangroves and has recorded the largest mangrove desappearance since 1980, with more than 1.9 million hectares destroyed, mainly due to changing land use. In the 1990s Vietnam, Malaysia and Madagascar suffered increased clearing and moved into the top five countries with major area losses in the 1990s and 2000-2005. (FAO 2008). More specifically, Vietnam saw its mangrove forests reduced to 155,290 hectares in 2007, which represent a reduction of 50% compared to 1980 (Sherman 2009).

Victims in recent decades of alarming deforestation, the authorities pay now a special attention to these mangroves. The example of Xuan Thuy National Park in the Red River Delta clearly illustrates the dynamics of the Vietnamese mangrove (Roche 2015).

The purpose of the study is to calculate the average carbon stock in the Xuan Thuy National Park mangroves in order to determine how would mangroves contribute to the carbon storage.

Materials and methods

Study area

The study site was set in Xuan Thuy National Park, Nam Dinh province (20° 14’ 21.75’ ‘N, 106° 31’ 12.59’ ‘E), located in the Red River Delta, Northern Vietnam about 150km from Ha Noi (Cf. Figure 1).

Figure 1. Xuan Thuy National Park location, Northern Vietnam. Source : google map data

More specifically, the study was carried out in the replanted mangrove part of the national park. This ecosystem is about 3000 ha (Thao 2014). The mangrove was replanted between 1998 and 2000. The main species of the replanted mangrove is *Kandelia candel*. Two other species, *Sonneratia caseolaris* and *Rhizophora stylosa,* are also represented but because of their low resistance there is almost none left and they are present in lower density (Thao 2014). *Kandelia candel* will thus be the main specie studied in this study.

Vietnam has a subtropical climate with two distinct seasons: the dry season and the rainy season (May to October). The annual average temperature is 24.3°C. In summer temperatures can drop to 40.3°C while in winter they can go down to 6.8°C. The average humidity is around 48%. Annual precipitation average is 2102 mm, the lowest precipitation average is in December: 9 mm with around 9 days of rainy days and the highest average in August with 421 mm of precipitations and 19 days of rain (climate-data.org 2015). Annual average evaporation is from 1,000 to 1,200 mm. In the rainy season from Mayy to October, the weather is significantly affected by ocean nearby current and the wind direction (MONRE 2012). Xuan thuy follows a diurnal monsoon system. Mangroves forest has 23 hours of tidal which ranges from minimum of 0.0 m to maximum of 4.3 m; average level is from 1,5 m to 1,8 m (Thao 2014).

Soil properties had been studied in the research site: the replanted mangroves forest (Thao 2014). The bulk density was 0.99 ± 0.65 g/cm^3, the soil humidity was 125.97 ± 13.15%, the TOC concentration was 1.76% to 2.68%. And finally the grain size was : 0.02% of coarse sand (0.2 – 2 mm), 40.31% of fine sand (0.02 – 0.2 mm), 38.68% of silt (0.002 – 0.02 mm) and 20.99% of clay (<0.002 mm) (Thao 2014).

Sample collection

Above ground sampling

In April 2014, selection of the sampling site, a 15 years old replanted mangrove area (Cf. Figure1). To investigate the characteristics of the vegetation in the sampling site, three square plots of 10 *10 m were set up in the mangroves forest along a catena from the river to the mangrove. The distance between each plot was about 20 m. For estimating the above ground biomass for each plot, the number of trees, species, number of stems, stems circumference at breast height (CBH at 1.3 m) and the height of the main stem of each tree were recorded. To avoid a massive tree cutting, a selection of representative was made as follows (Cf. Table 1): trees were classified according to their number of stems. Then the total of trees in the different plots for each class was made in order to determine the representativeness of each class compared to the total number of trees. In response to these results, a number of of tree to sample and a mean circumference was determined for each class.

In July 2014, 11 trees representative of the different classes according to the characteristics presented in Table.1 were identified. For each of these 11 trees, the circumference at breast height (DBH at 1.3 m) and the height of the main stem were measured as in April. Each tree was cut by

Table 1. Characteristics of trees to be sampled in Xuan Thuy National Park in July 2014.

Classes of trees (number of stems)	Number of trees in Plot 1 (previous results*)	Number of trees in Plot 2 (previous results*)	Number of trees in Plot 3 (previous results*)	Number of trees in Total (previous results*)	% of tree for each class	Number of tree to sample	Mean circumference, DBH (cm) (sum of all stems)
1	23	23	41	87	28	3	13
2	37	44	48	129	42	4	22
3	37	16	16	69	22	2	31.5
4	5	8	4	17	5.5	1	42
5	3	1	0	4	1.3	1	52

*correspond to the April *in situ* sample collection.

separating the following parts: main stem (base of stem : before stem separates in several secondary stems), secondary stems (above main stem, up to the top), branches, leaves and fruits if there were any. Each part was weighed on the field in order to obtain the wet weight. To have the dry weight, 5kg of main stem, 5kg of secondary stems, 3 kg of branches and 1 kg of leaves were bringing back to a laboratory in Ha Noi, dried in an oven for 48h at 60°C and then weighed again. The total dry weight of the different parts was estimated by the dry/wet weight ratios. In order to obtain the TOC (total organic carbon), 500g of each dry part was sent in a closed plastic bag (one bag for each part) in the laboratory.

Soil sampling

In December 2014, to characterize the biogeochemical properties of the sediment, triplicate cores of 50 cm depth were collected. Sediment samples and porewaters were collected every 5cm along the 50 cm cores.

Samples for TOC and IC (inorganic carbon) were stored in closed plastic bags and freeze before analyze. TOC and IC were determined using a Shimadzu Solid Sample Module (SSM-5000A) combined with a TOC analyzer. Samples for IC were previously acidified by phosphoric acid and burn at 200 °C in the Shimadzu. TOC was deduced from the measure of Total Carbon, burning soil at 900°C in the Shimadzu:

TOC = Total Carbon – Inorganic Carbon

Roots sampling

Roots were separated from sediment just after sampling by sieving at 1 mm and washed. They were dried in the oven at 60°C for 48h before being weighted to obtain dry root biomass and TOC.

Data processing

The purpose of the study is to evaluate the TOC (total organic carbon) stored in the ecosystem. It involved several steps.

Above ground biomasse estimation

First, we estimated the above ground biomass thanks to allometric models. To define the best allometric models, we based this first processing on the 11 most representatives trees (*K. candel)* selected in July 2014 (Cf. Table2). The allometric models for biomass estimation were developed from the relationship between morphological parameters measured on trees (diameter at breast height, calculated from the CBH) and tree biomass. DBH and height are commonly used variables in allometric models to estimate the above ground biomass of mangrove species (DelVecchia et al. 2014). For each part of the tree, various graphs were built : the y-axis corresponding to the weight and the x-axes corresponding to different variables (DBH, DBH^2, DBH*H, DBH^2*H and H). Allometric regression equation were done from those graphs (Cf. Table3).

Table 2. Characteristics of trees for allometric models.

Tree No	DBH (cm)	Height (m)	Dry weight Stem1 (primary stem) (g)	Dry weight Stem2 (secondary stem) (g)	Dry weight Branches (g)	Dry weight Leaves (g)	Total dry weight (g)
1	4.77	4.4	670,6	2257,9	714,2	423,1	4065,8
2	4.14	4.6	836,6	2339,8	730,8	350,9	4258,1
3	4.62	4.35	716,4	3252,3	559,2	443,1	4971,1
4	6.37	4.1	725,2	2983,2	692,1	326,8	4727,3
5	8.91	4.3	1922,2	5358,1	1458,9	1050,7	9789,9
6	8.91	4.3	1675,3	5096,9	1901,8	1082,8	9756,8
7	8.59	4.3	1498,4	5420,5	1785,6	705,8	9410,3
8	11.46	4.3	2197,4	8754,7	2239,6	1473,8	14665,5
9	11.62	4.5	1898,1	7257,3	2605,0	1247,2	13007,6
10	13.53	4.8	2169,0	9487,9	2018,1	1044,7	14719,7
11	16.07	5	2461,7	8863,9	2137,2	1062,7	14525,5

Table 3. Allometric relations of different parts of trees with different variables.

VARIABLES	STEM_1	STEM_2	BRANCHES	LEAVES	TOTAL
DBH*W	$y = 151,45x^{1,0451}$ **$R^2 = 0,88$**	$y = 464,31x^{1,1206}$ **$R^2 = 0,93$**	$y = 122,3x^{1,1372}$ $R^2 = 0,83$	$y = 81,781x^{1,0445}$ $R^2 = 0,75$	$y = 826,01x^{1,1021}$ **$R^2 = 0,93$**
LOG10 (DBH) *LOG10 (W)	$y = 3,2332x^{0,2923}$ $R^2 = 0,87$	$y = 3,7963x^{0,2649}$ $R^2 = 0,92$	$y = 3,234x^{0,3241}$ **$R^2 = 0,85$**	$y = 2,9649x^{0,3248}$ **$R^2 = 0,76$**	$y = 4,0287x^{0,246}$ $R^2 = 0,92$
DBH²*W	$y = 151,45x^{0,5225}$ $R^2 = 0,88$	$y = 464,31x^{0,5603}$ $R^2 = 0,93$	$y = 122,3x^{0,5686}$ $R^2 = 0,83$	$y = 81,781x^{0,5223}$ $R^2 = 0,75$	$y = 826,01x^{0,551}$ $R^2 = 0,92$
DBH*H*W	$y = 0,4415x^{0,98}$ $R^2 = 0,87$	$y = 0,9083x^{1,048}$ $R^2 = 0,92$	$y = 0,2342x^{1,0549}$ $R^2 = 0,81$	$y = 0,2747x^{0,9626}$ $R^2 = 0,72$	$y = 1,8246x^{1,0285}$ $R^2 = 0,91$
DBH²*H*W	$y = 7,34x^{0,5071}$ $R^2 = 0,88$	$y = 18,22x^{0,543}$ $R^2 = 0,92$	$y = 4,6844x^{0,5488}$ $R^2 = 0,82$	$y = 4,1579x^{0,5024}$ $R^2 = 0,74$	$y = 34,406x^{0,5335}$ $R^2 = 0,92$
H*W	$y = 6E\text{-}08x^{3,914}$ $R^2 = 0,19$	$y = 1E\text{-}07x^{3,9911}$ $R^2 = 0,18$	$y = 1E\text{-}06x^{3,4223}$ $R^2 = 0,12$	$y = 6E\text{-}05x^{2,6765}$ $R^2 = 0,08$	$y = 9E\text{-}07x^{3,7614}$ $R^2 = 0,17$

Note: y denoted for respective part dry weight (W) and x denoted for different variables concerning to diameter and height (DBH, DBH^2, DBH*H, DBH^2*H and H).

After choosing the best allometric relationship for each part, the corresponding equation was applied to the whole data set of the 3 plots (a total of 402 trees) in order to estimate the biomass of each part.

Above ground TOC estimation

Once the biomass was obtained, the organic carbon concentration was taken to be the product of the weight (Mg/ha) and the percentage TOC value.

Soil TOC estimation

Second, the organic carbon concentration of sediments was taken to be the product of individual sample bulk density and the percentage TOC value.

Roots TOC estimation

Finally, the organic carbon concentration of roots was taken to be the product of individual sample root bulk density and the percentage TOC value.

Results and discussion

Above ground biomasse

The most representative allometric relationships for plant component are represented in Figure 2, and the corresponding regression equations are in Table 4. For principal stem (stem1), secondary stem (stem2) and total above ground weight, the coefficient of determination was the highest between DBH and W and exceeded 0.88. Those allometric relationships between diameter and the biomass are generally less robust for smaller plant components (branches and leaves) than for stem or total biomass because they are more easily broken off by

Table 4. Regression equations corresponding to allometric relationships in Figure 2.

Plant components	Regression aquations	R^2 value
Stem1	W stem1= 151,45*(DBH)^{1,0451}	$R^2 = 0,88$
Stem2	W stem2= 464,31*(DBH)^{1,1206}	$R^2 = 0,93$
Branches	W branches = 10^(3,234*Log10(DBH)^{0,3241})	$R^2 = 0,85$
Leaves	W leaves = 10^(2,9649*Log10(DBH)^{0,3248})	$R^2 = 0,76$
Total above ground	W total above ground = 826,01*(DBH)^{1,1021}	$R^2 = 0,93$

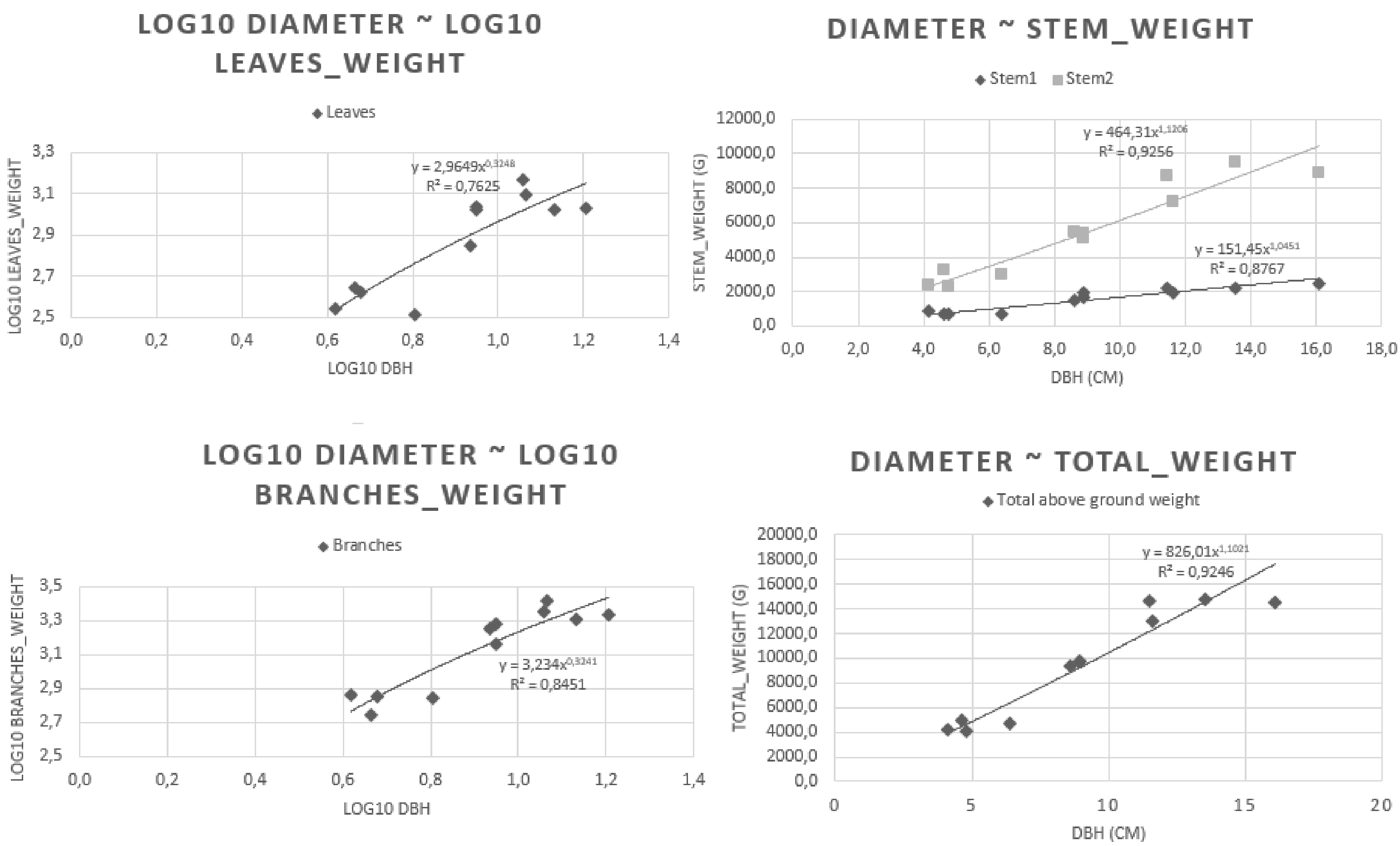

Figure 2. Allometric relationships of each plant component.

strong winds (Cuc 2007). This is reflected in Table 3 where R^2 are less than 0.83 for branches and leaves with DBH*W relationship. In order to increase those values, log10(DBH) and log10 (W) were used. The coefficient of determination increased from 0.83 to 0.85 for branches and from 0.75 to 0.76 for leaves.

In Table 5, there is the average weight for each part of trees in a 100m^2 area. Those were calculated from the previous regression equations. The secondary stem represents more than 50% of the total above biomass. Then the primary stem and branches contribute in approximately the same proportions in the total biomass followed by the leaves.

Table 5. Weight of each plant component in the 3 plot (study area).

	Total Weight (Kg)				
Plot	**Stem1**	**Stem2**	**Branches**	**Leaves**	**Total**
1	463,21	1710,12	468,02	248,78	2890,13
2	369,49	1361,64	373,80	199,07	2304,00
3	394,01	1455,11	398,11	211,53	2458,76
Average	**408,90**	**1508,96**	**413,31**	**219,79**	**2550,96**

Above ground TOC stock

The Table 6 shows the stock of carbon for each component of trees for 1 hectare. Here, just over 50% of the carbon is stored on secondary stems, a bit less than 40% is stored in primary stems and branches and the remaining carbon is stored in leaves. This coincident between weight and carbon stock proportion can be explained the TOC values. In fact, we can notice in Table 7 that the variation of the TOC percentage changes little from one component to an other. The leaves present the lowest TOC (43.2%) which is only 1% less than the highest TOC value for branches (44.2%). Hence, we can say that the capacity for carbon storage is the approximately the same for all plant components.

Table 6. Carbon stock of each plant component in the 3 plot (study area).

	Stem1	Stem2	Branches	Leaves	Total above stock
Plot	Stock ($kg.ha^{-1}$)	Stock ($kg.ha^{-1}$)	Stock ($kg.ha^{-1}$)	Stock ($kg.ha^{-1}$)	Stock ($kg.ha^{-1}$)
1	20103,31	74732,24	20780,09	10747,30	126362,94
2	16035,87	59503,67	16596,72	8599,82	100736,08
3	17100,03	63588,31	17676,08	9138,10	107502,52
Average (Mg.ha-1)	17,75	65,94	18,35	9,50	**111,53**

Table 7. TOC % of each plant component.

PART	TOC (%)
STEM1	43,4
STEM2	43,7
BRANCHES	44,2
LEAVES	43,2

Table 8. Carbon stock in the soil in the 3 plot (study area).

		Plot 1			Plot 2			Plot 3		
Depth (cm)	moy_depth	TOC %	ρ (g/cm^3)	Carbon ($Mg.ha^{-1}$)	TOC %	ρ (g/cm^3)	Carbon ($Mg.ha^{-1}$)	TOC %	ρ (g/cm^3)	Carbon ($Mg.ha^{-1}$)
0-5	2,5	1,66	0,7	5,81	1,53	0,65	4,97	1,67	0,67	5,59
5-10	7,5	1,56	0,77	6,01	1,43	0,78	5,58	1,56	0,75	5,85
10-15	12,5	1,99	0,86	8,56	2,46	0,79	9,72	1,93	0,81	7,82
15-20	17,5	1,90	0,75	7,13	2,55	0,84	10,71	2,19	0,8	8,76
20-25	22,5	1,86	0,77	7,16	2,58	0,76	9,80	1,81	0,74	6,70
25-30	27,5	1,49	0,86	6,41	2,15	0,76	8,17	2,04	0,83	8,47
30-35	32,5	1,10	0,87	4,79	1,53	0,84	6,43	1,99	0,83	8,26
35-40	37,5	1,20	0,83	4,98	1,36	0,81	5,51	1,68	0,77	6,47
40-45	42,5	0,83	0,77	3,20	1,07	0,85	4,55	1,51	0,92	6,95
45-50	47,5	0,89	0,83	3,69	1,03	0,78	4,02	1,10	0,99	5,45
			Total_cor1	57,72		Total_cor2	69,45		Total_cor3	70,30

Average organic CS 65,82 $Mg.ha^{-1}$

Standard deviation 7,03

Soil TOC stock

The average of OC (organic carbon) stored in soil is 65.82 Mg/ha. The Table 8 shows how the TOC varies with soil depth.

Roots TOC stock

The Table 9 presents the carbon stock in roots. As for the above ground parts, the TOC percentage is constant so the variation of the TOC value will depend on the roots biomass.

Table 9. Carbon stock in roots in the 3 plot (study area).

	TOC %	Carbon stock (Mg/ha)	Carbon stock average (Mg/ha)
Alive dry roots	32	Plot1: 0.61 Plot2: 1.78 Plot3: 0.84	1.08
Dead dry roots	38	Plot1: 0.26 Plot2: 0.11 Plot3: 0.14	0.17
Total roots			1.25

Comparison between the various components

The Figure 3 is a summary of key values based on the analysis set forth above. These carbon stock values were used to create Figure 4 which represents the proportion role of each element (principal stem, secondary stems, branches, leaves, roots and soil) in carbon storage. As mentioned earlier, for the above ground elements, secondary stems are the most significant component in terms of carbon storage followed by branches and principal stem and then leaves. In a more global vision, we can see that the total above ground components (the plant without roots) stock more than 60% of the total carbon stock. This can be explained by the fact that the carbon is directly absorbed by plants. The soil is the second element of storage and represents 37% of carbon stock. Roots are not significant in the carbon storage in this study and represent only 1% of the carbon storage. This is due to the fact that the roots sampling does not include the principal roots. Only thin roots have been taken into account. The TOC of the area (Total above ground carbon + roots TOC + soil TOC) is 178.6 Mg/ha but could have been more important if the principal roots were included.

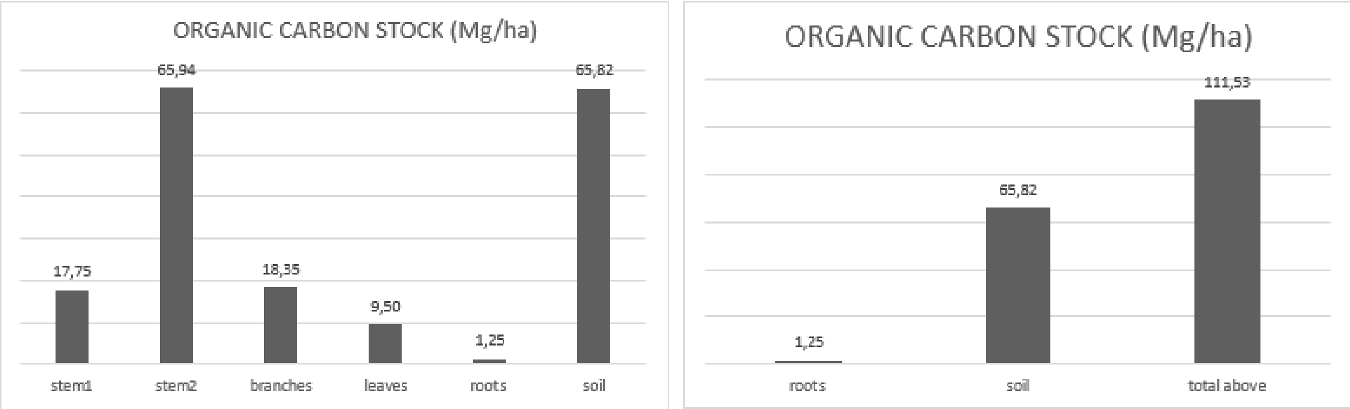

Figure 3. Organic carbon stock (total above = stem1 (principal stem) + stem2 (secondary stem) + branches + leaves)

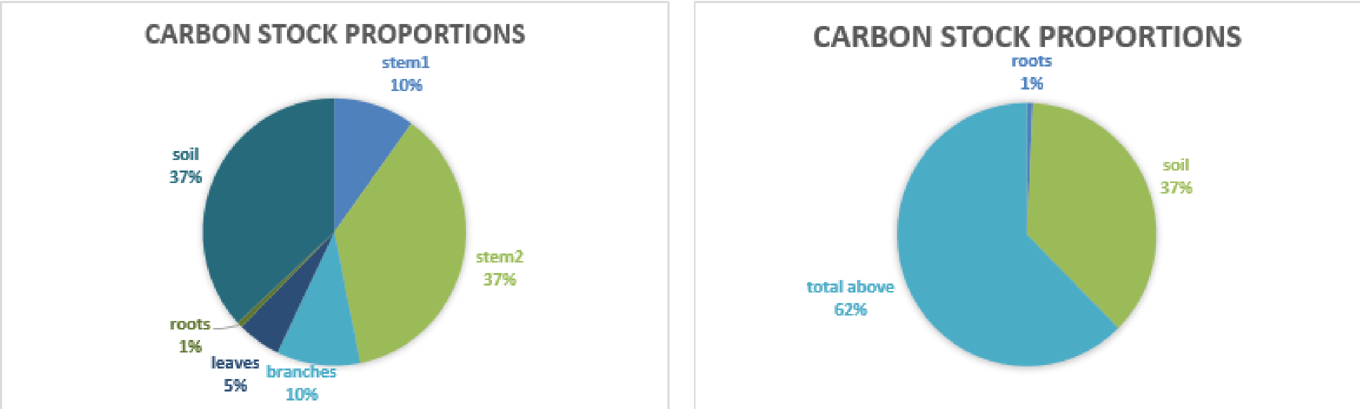

Figure 4. Organic Carbon stock proportions (total above = stem1 (principal stem) + stem2 (secondary stem) + branches + leaves)

Comparison to other studies

A study has been done in the mangroves of Sian Ka'an biosphere Reserve (SKBR) (Adame et al. 2013). They measured whole-ecosystem carbon stocks of different natural coastal mangroves in the Yucatan Peninsula, Mexico. The objective was to determine and compare ecosystem carbon stocks of different vegetation types. The Table 10 shows a summary of this study's values in which we are interested.

Table 10. Sammury of Adame's study values.

	TALL MANGROVES	MEDIUM MANGROVES	DWARF MANGROVES
HEIGHT	Up to 14m	Around 5m	Don't reach 1.5m
DIAMETER	8cm or more	Around 4cm	Around 1.5cm
ABOVE GROUND BIOMASSE	176.2 ± 47.4 Mg/ha	/	3.0 ± 0.4 Mg/ha
SOIL CARBON STOCK	508 Mg/ha	577 ± 496 Mg/ha	426 ± 286 Mg/ha
GLOBAL CARBON STOCK (TREE + SOIL)	987 ± 338 Mg/ha	623 ± 41 Mg/ha	381 ± 52 Mg/ha

The caracteristics of our vegetation correspond better to the carcteristics of tall mangroves in the Adame's study. For this reason, we will compared them together. If we compared the global carbon stock we can notice a big difference. It goes from 178.6 Mg/ha for our replanted mangroves to 987 ± 338 Mg/ha for natural mangroves.

We can see that the value of the above ground carbon stock in our replanted mangroves (111.53 Mg/ha) is included in tall mangroves above ground carbon stock values (176.2 ± 47.4 Mg/ha). So this does not explaine the difference of carbon stock in our two types of mangroves.

Looking at the soil carbon stock, the replanted mangroves present a vary low value (65.82 Mg/ha) compared to natural mangroves (508 Mg/ha). This could be explained by the fact that our study is only looking at the first 50 cm below the ground contrary to the Adame's study which is looking below a depth of 100 cm. Considering that the soil may stock 59% to 97% of the carbon in some mangrove ecosystems (Kauffman 2014), the lack of data under 50 cm in depth in our study may explaines this difference.

In 2012, Chen conducted a study on replanted mangroves, in the intertidal zones of Shenzhen Bay, Guangdong Province, China. The study aimed to estimate the growth, carbon accumulation in biomass and carbon sequestration in sediments of two species, in both mixed (50% S. caseolaris; 50% S. apetala) and monoculture plantations. It showed that in mixed plantion the carbon storage in biomasse is lower than in monoculture but, the accumulation in sediment was higher in the mixed plantation. Hence, the relative advantage of the mixed plantation was in sequestering more carbon in sediment. We can compared our plantation to a monoculture of *Kandelia candel* because the other species are present in a very low density. Hence, this monoculture can also explain our lower value of carbon stocks in the soil compared to natural mangroves regarding to the Chen's study.

Conclusion

Replanted mangroves of Xuan Thuy Nation Park present a good carbon stock in above ground biomass, but in order to evaluate the real carbon average in soil, more research could be done under 100cm in depth. As a genaral remak, replanted mangroves present solid carbon storage capacities. The most inportant element of carbon stock in mangrove is the soil and we saw that mixed plantations increase the amount of carbon stocks in sediments. In this way, to enhance the carbon storage capacities of the ecosystem, mixed plantation could be a good option for mangrove restoration. This issue can be expanded thanks to more research around the most efficient species combinations.

References

Adame M.F., Kauffman J.B., Media I., Gamboa J.N., Torres O., Caamal J.P., Reza M., Herrera-Silveira J.A., 2013. *Carbon Stocks of Tropical Coastal Wetlands within the Karstic Landscape of the Maxican Caribbean.* PLoS ONE 8(2): e56569. doi:10.1371/journal.pone.0056569

Chen L., Zeng X., Tam N.F.Y., Lu W., Luo Z., Du X., Wang J., 2012. *Comparing carbon sequestration and stand structure of monoculture and mixed mangrove plantations of Sonneratia caseolaris and S. apetala in Southern China.*

Cuc N.T.K., Ninomiya I., 2007. *Allometric Relation for Young Kandelia candel (L.) Blanco Plantaion in Northen Vietnam*. Journal of Biological Science 7 (3): 539-543.

DelVecchia A.G, Bruno J.F, Benninger L., Alperin M., Banerjee O., De Dios Morales J., 2014. *Organic carbon inventories in natural and restored Ecuadorian mangrove forests.* PeerJ. 2014; 2: e388.

FAO, 2007. *Mangrove guidebook for Southeast Asia.*

FAO, 2008. *Les mangroves du monde 1980-2005.*

Fromard F., Kiet L. K., 2002. *Les mangroves du Vietnam du Sud : histoire récente, dynamique actuelle et perspectives Bois et Forêts des tropiques.* N° 273 (3), Dossier Vietnam du Sud/Mangrove.

Fu W., Wu Y., 2011. *Estimation of aboveground biomass of different mangrove trees based on canopy diameter and tree height.* Procedia Environmental Sciences 10 (2011) 2189 – 2194

Füssel H.M., 2010. *Review and quantitative analysis of indices of climate change exposure, adaptive capacity, sensitivity and impacts*.

Hossain M. S., 2009. *Coastal Community Resilience Assessment : Using Analytical Hierarchy Process*, and, *Climate Change Resilience.* Mangrove Ecosystem.Prdi, Dhaka, Bangladesh.

Hossain M., Raqibul Hasan Siddique M., Bose A., S., Hasan Limon S., Chowdhury Md. R.K., Saha S., 2012. *Allometry, above-ground biomass and nutrient distribution in Ceriops decandra (Griffith) Ding Hou dominated forest types of the undarbans mangrove forest, Bangladesh.* Wetlands Ecol Manage (2012) 20:539–548

Hossain M., Saha C., Rubaiot Abdullah S.M., Saha S., Raqibul Hasan Siddique M, 2015. *Allometric biomass, nutrient and carbon stock models for*

Kandelia candel of the Sundarbans, Bangladesh. Trees (2016) 30:709–717

Kauffman J.B., Donato D.C., 2012. *Protocols for the measurement, monitoring and reporting of structure,biomass and carbon stocks in mangrove forests*. Working Paper 86. CIFOR, Bogor, Indonesia.

Kauffman J.B., Heider C., Cole T.G., Dwire K.A., Donato D.C., 2011. *Ecosystem carbon stocks of micronesian mangrove forests.* Wetlands. 31: 343-352.

Kauffman J.B., Hernadez Trejo H., Del Carmen Jesus Gracias M., Heider C., Contreras Sanchez W.M., 2014. *Estimation des stocks de carbone dans les mangroves de la région de Pantanos de Centla au Mexique.*

Marchand C., Lallier-Verge E., Baltzer F., 2001. *The composition of sedimentary organic matter in relation to the dynamic features of a mangrove-fringed coast in French Guiana.* Estuarine, Coastal and Shelf Science 56 (2003) 119–130

Murdiyarsi D., Donato D., Kauffman J.B., Kurnianto S., Stidham M., Knninen M., 2009. *Carbon storage in mangrove and peatland ecosystems. A premilinary account from plots in Indonesia.*

Nguyen Thi Kim Cuc, Ikuo Ninomiya, 2007. *Allometric Relations for Young Kandelia candle, Blanco plantation on Northem Vietnam*. Journal of Biological Sciences 7 (3) : 539-543.

Pham Thi Thu Thao, 2014. *Effect of cut mangrove forest on soil properties and CO2 fluxes at the soil-air interface.* Bachelor Thesis, Hanoi.

Roche Y., Van Cu P., 2015. *Les mangroves face aux changements climatiques. Le cas du Vietnam, à la fois typique et particulier.* Journal électronique VertigO : N° 23.

Sherman K., Aquarone M.C., Adams S., 2009. *Sustaining the World's Large Marine Ecosystems.Gland.* IUCN. 142p, Switzerland.

Spalding, M., Kainuma M., Collins L., 2010. *World Atlas of Mangroves*. Earthscan, London.
Tang A., 2012. *Vietnam's mangroves trees threatened by rising tide of deforestation*. The Guardian (24 avril 2012).

Thi Ha H., Duarteb C.M., Nguyen H.T., Terrados J., Borum J., 2003. *Growth and population dynamics during early stages of the mangrove Kandelia candel in Halong Bay, North Viet Nam.* Estuarine, Coastal and Shelf Science 58 (2003) 435–444

Xuan Thuy National Park, Vietnam, 2007. *The Regional Training Course on Sustainable Use and Management of Coastal Wetlands*. Mahidol University, Thailand.

CITERES

UMR 6173
Cités, Territoires, Environnement et Sociétés

Equipe IPA-PE
Ingénierie du Projet d'Aménagement, Paysage, Environnement

POLYTECH TOURS
Département Aménagement et Environnement

35 allée Ferdinand de Lesseps
BP 30553
37205 TOURS cedex 3

Directeur de recherche :
Grellier Séraphine

Gayral Julia
Projet de Fin d'Etudes
DA5
2016-2017

Organic carbon accumulation in mangroves of Xuan Thuy National Park, Northern Vietnam. (L'accumulation de carbone organique dans les mangroves du Parc National de Xuan Thuy, Nord du Vietnam.)

Résumé :

Dans le cadre de la lutte contre les émissions de gaz à effet de serre, la mangrove représente un important puits de carbone, de petite taille (étendue) comparativement aux autres forêts du monde, mais extrêmement efficace par unité de surface (Spalding et al., 2010). Victimes ces dernières décennies d'une alarmante déforestation, les mangroves font maintenant l'objet d'une attention particulière de la part des autorités.

Il est ici question du traitement et de l'analyse des données récoltées *in situ* (Xuan Thuy National Park) autour de la thématique du stockage du carbone dans des mangroves replantées. Il s'agit dans un premier temps d'évaluer la biomasse végétale de l'espèce Kandelia Candel grâce à l'utilisation d'équations allométriques. Dans un second temps il est question d'évaluer le carbone stocké dans les diffréntes parties de cet écosystème à partir des masses, masses volumiques, densités et TOC.

Le TOC total de notre zone d'étude (végétation, racines et sol) est de 178.6 Mg/ha. Dans notre écosysteme la végatation (parties hors sol) stocke à elle seule plus de 60% du carbone, le sol contient 37% du carbone et les racines environ 1%.

Après comparaison des résultats obtenus avec d'autre études réalisées nous pouvons dire que les mangroves replantées ont une capacité de stockage du carbone similaire à des mangroves naturelles. Des études portées sur l'opimisation du stockage du carbone par les mangroves en fonction des espèces de plantes présentes sur un même site pourront être une piste intéressante à explorer afin d'améliorer la restauration de ces écosystèmes.

Mots Clés : mangroves, Xuan Thuy National Park (Nord Vietnam), équations allométriques, stockage carbone.