Identification of suitable sites for translocation of endemic Podostemaceae threatened by dams in the Sanaga River (Cameroon)

DETAILED REPORT

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EXECUTIVE SUMMARY

This project, categorized under Wetlands was carried out in the Sanaga River in Cameroon where Podostemaceae, submerged freshwater plants, are threatened by the construction of dams. This report summarizes field activities and scientific findings to identify sustainable recipient river sites for the potential translocation of the Podostemaceae. The survey covered a period of five months. During this period, water samples of nine rivers in Cameroon (Sanaga, Afamba, Kelle, Nyong, Lep Riton, Dibang, Ngwei, Mbam, Eding) were collected. For each of the different stations, two water samples were collected for physico-chemical and biological analysis at the Hydrobiological laboratory of the University of Dschang. Temperature, altitude, and geographical coordinates of each station were recorded. Multivariate analysis of variance was done to compare the nitrate, phosphate, total dissolved solids, redox potential, conductivity and pH of the Afamba, Kelle, Nyong, Lep Riton, Dibang, Ngwei, Mbam and Eding rivers with those of the Sanaga River. Suitable Recipient Rivers were to be selected based on the relative similarity of their water with those of the Sanaga and their size. Based on their similarity, the results of this study revealed that there were no significance differences between waters of the Kelle and those of the Sanaga at Edea for the above mentioned parameters. No significant differences were observed between the Lep Riton and Sanaga at Nachtigal. Based on their size, the River Mbam was also selected. Hence, Lep Riton, Kelle and Mbam rivers were selected as potential sites for the translocation of Podostemaceae from the Sanaga River.

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List of Abbreviations

ALUCAM:	Aluminum du Cameroun
GPS:	Global Positioning System
pH:	Hydrogen potential
SAFACAM:	Société Africaine Forestière et Agricole du Cameroun
SOCAPALM:	Société Camerounaise de Palmerais
TDS:	Total Dissolved Solids

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1. Introduction

In Cameroon now, there is a serious issue of Podostemaceae conservation. In fact, proposed and ongoing projects of dam construction on the Sanaga River stand as a serious threat to their survival, as dams modify or destroy their habitat (Quiroz *et al*., 1997).

Podostemaceae are submerged Phanerogams. They are the most threatened freshwater plant family in Central Africa (Ghogue, 2011). The reason is that they live exclusively on rocks in waterfalls and rapids. Yet, with 10 genera and 37 species (now 39), Cameroon is the Eldorado for this family (Ghogue *et al*., 2010).

Generally, the *in situ* conservation of Podostemaceae is technically difficult and expensive in the process of dam construction. So, their possible translocation is the best alternative. However, they are very sensitive to the physico-chemical variations of the water (Ghogue *et al*., 2010). When transplanted, they will have more chance to regenerate if the physico-chemical characteristics of the recipient River are similar or close to that of the source river. These are the reasons why we decided to bring our contribution to this national conservation issue, and use our experience in Podostemaceae research; to develop some basis for Assisted Colonization of Podostemaceae in the country.

1.1. Objectives

1.1.1. General objectives

The overall objective of this project was to identify suitable sites for translocation of endemic Podostemaceae threatened by dams in the Sanaga River (Cameroon).

1.1.2. Specific objectives

More specifically the project aimed to:

1. Contribute to the successful conservation of the species of Podostemaceae threatened by dams in the Sanaga River in Cameroon;

2. Identify suitable sites for translocation of endemic Podostemaceae threatened by dams in the Sanaga River;

3. Contribute to the national effort for biodiversity conservation in Cameroon.

2. Location and Description of project Area

2.1. Geographic and administrative location

The Sanaga watershed, evaluated at 133.000 km^2, occupies the Central part of Cameroon in the forest-savannah contact zone and is located between latitudes N3°22' and N7°22', and longitudes E 9°45' and E 14°57' (Kpoumié *et al*., 2012). From its main sources on the Adamawa plateau to the mouth of the Atlantic Ocean, the Sanaga River flows through four regions of Cameroon namely: the Adamawa, East, Centre and Littoral regions. However, the Sanaga basin covert six regions of Cameroon which are Adamawa, East, Centre North West, West and Littoral (Waarde, 2007).

Human population density in the Sanaga basin is also varied. From the high plateau, the population density is more than 200 inhabitants to almost empty areas in the centre basin around Yoko passing through the agro-industrial area of Mbanjock (Sighomnou, 2004). Several ethnic groups are present in the Sanaga basin (Gbaya, Lara, Eton, Manguissa, Badjob, Mbang, Ndonga, Yabii etc.).

2.2. Climate

Flowing through the Adamawa, East, Centre and Littoral regions of Cameroon, the Sanaga River is found in different climatic zones. In the Adamawa plateau, the climate is a humid tropical climate with a dry season of 5 months and rainy season lasting 7 months. Annual rainfall is between 1500 and 2000 mm/yr. In the dry season there is virtually no rain and most of the region is burned by local grazers to stimulate growth of fresh grass for their cows. The average temperature is 21°C, daily maximum is 30°C throughout the year. According to Olivry (1986), 6 Cameroonian climatic units occur in the Sanaga basin. They include: the altitudinal tropical climate of the Adamawa, the tropical climate, the equatorial climate, the coastal equatorial climate, the coastal tropical climate and the mountainous tropical climate of the West.

Rainfall in the highlands is between 2000 and 4000 cm/yr, with one rainy season that lasts from April to September and a cool climate. The Highlands are a biodiversity hotspot and home to an exceptional range of endemic species of plants and animals. As the Sanaga river flows the Adamawa, through the centre and finally through the Littoral, the climate changes from humid tropical climate to coastal climate. Temperatures are high with abundant rainfall exceeding 4000cm/yr in the coastal area.

2.3. Topography

The Sanaga River rises 1000 m a.s.l at the Adamawa plateau, winds through a hilly landscape, passes through a forest-Savanna transition and then through a semi deciduous and evergreen tropical closed forest. The Mbam rises partly on the Adamawa plateau and partly on high volcanic peaks up to 3000 m a.s.l that forms the western boundary of the basin in the West region of Cameroun. From the Western region, the river flows through a constantly decreasing altitude to a very low altitude in the lower part of the Sanaga River at Edea and finally to the Atlantic Ocean.

2.4. Hydrography

With a total surface area of 133000 km^2, the Sanaga River is the largest and the most economically important river in Cameroon and covers a distance of 920 km from its source to the Gulf of Guinea. Its main source is found in the Adamawa plateau with main tributaries being the Lom in the south and the Djerem in the north**.** Three main divisions are distinguished in the river namely: the upper Sanaga dominated by the Djerem River in Adamawa; the middle Sanaga represented by the Mbam River which originates from the Western Highlands and joins the Sanaga some 80 km upstream from the mouth of the river; and the lower Sanaga which is the lower part after the Edea hydroelectric dam right to the Atlantic ocean**.** Several small rivers in the Sanaga basin are tributary to the Sanaga River.

Several waterfalls are observed in the Sanaga River with the most important ones exploited for hydroelectric dam construction such as the Nachtigal fall, Song Loulou and Edea falls. Rapids, conditioned mainly by the dominantly rocky river bed characterize the river, giving it a constantly varying flow rate. The average flow rate of the Sanaga river stands at 2072 m^3/sec (at Edea) with a minimum flow of 473 m^3 in March and a maximum from August to November of 5700 m^3 (Waarde, 2007).

2.5. Soils

In the forest savanna zone transition of the Adamaoua, soils are ferruginous with intrusions of ferralitic soils that cover the basaltic, granitic and sedimentary rocks. These soils have a fine structure, of high porosity (50 to 60%) with very high permeability of surface (under forest: 100 to 1000 mm/h) which decrease quickly in depth to reach 10 mm/h. The soils of the mountainous zones of the Sanaga basin are constituted of less evolved soils on the steep slopes; ferralitic soils more or less rich in clay in the closed depressions, ashy ferralitic

soils and andosols (Global water partnership, 2009). The river bed presents huge sand deposits with alternating layers of granite rocks.

2.6. Vegetation

The vegetation on the Adamawa plateau is equatorial rainforest and covers large tracts of the plateau. From the western highlands to Edea the Sanaga River flows through forest- Savannah transition, with a gallery forest covering most parts of the river basin. The area between Edea and Douala is part of the Cross-Sanaga-Bioko Coastal Forests ecoregion, comprising coastal forests and mangroves, with a very high animal biodiversity and a regional centre of endemism. Downstream from Edea, the Sanaga winds through extensive sand areas covered with swamp forests, an area very rich in birdlife and home to a sizeable population of West African Manatee. The river passes through the Douala-Edea reserve with several coastal beaches.

Fig. 1. Presentation of the Sanaga basin

2.7. Main economic activities in the Sanaga river basin

Several activities take place in the Sanaga basin. A majority of people in the Sanaga live by subsistent farming and fishing and are poor. These people need the river and its associated wetlands for domestic use, for fish, as source of fertilizer for their lands during floods, for sand extraction from the river bottom as building material (Waarde, 2007). The reservoirs are heavily over-fished, often by fishermen originating from other parts of the country and neighboring countries.

On the Sanaga River, hydroelectric developments are of two types notably: energy production works (the Edea hydroelectric dam, Song Loulou dam situated some 55 km upstream Edea) and dams to regulate the flow rate of water in the Sanaga River (the Mbakaou dam across the Djerem river, the Bamendjin dam on the Noun River, the Mapé on the Mapé River). Lom-Pangar and Nachtigal dams are under construction. These different constructions considerably affect the biodiversity and different natural habitats of species. Several economic activities take place in the Sanaga basin. These activities are in two main groups; one is practiced by industries and the other by individuals. Industrial activities are carried out by terminal industries and agro-industries, and the most known are: ALUCAM, SAFACAM, SOCAPALM etc. These enterprises discharge their untreated waste into the environment. This is a pollution risk to the phreatic nappe, water courses and tributaries of the Sanaga River (Global water partnership, 2009). Economic activities practiced by individuals include fishing, trading and the removal of sand. The removal of sand is widely spread in the middle and lower Sanaga, and this involves youths from many parts of Cameroon. It is practiced using boats and generates high amounts of revenues at the local and national levels.

In the soudano-sahelian zone, the traditional farming systems integrate more and more cash crops like maize and cotton with the advancement of cotton farming from the North. The cultivation of cotton consumes much inputs and space, and hence favours the rapid degradation of soils (Global water partnership, 2009). In the zone of high plateau of the Sanaga basin, we observe a land use value of 86 % exploited lands, household agricultural exploitations are of small scale (less than 2 ha) and intensive farming is practiced in two cycles. In higher zones, cattle's rearing is practiced with more or less intrusions of crop farming practices. The main problem of this zone is the progressive degradation of agro-sylvo-pastoral resources due to the high demographic density and production systems which

do not sufficiently make use of the synergy between agriculture and animal rearing (Global water partnership, 2009). All these activities probably affect the water quality.

3. Methodology

3.1. Material

The material used for the realization of this work was:

- 01 field vehicle
- 01 boat
- 02 paddles
- 01 pump
- 06 life jackets
- 06 security helmets
- 01 GPS
- 01 laptop
- 01 pair of binoculars
- 01 first aid box
- Field boots
- 3 bloc-notes
- Pencils
- 04 cutlasses
- Batteries for GPS and cameras
- 01 alpinism rope
- Pairs of field gloves
- 01 field magnifying glass
- 01 scrapping blade
- Plastic jars and plastic bags
- Conservation alcohol

- 01 multimeter mesuring kit

- 01 field thermometer (-40° - +40°C)

- Plastic bottles for collecting water samples

- Chemical reactants

- 01 pH-meter of mark SUNTEX TS-2

3.1. Field surveys

Globally, field surveys were carried out in two different directions: the northern trip to the Sanaga River at Nachtigal, the Afamba River at Obala and Mbam River at Bafia; and the western-littoral trip to the Kelle River at Boum Nyebel, the Nyong River South Eseka on Lolodorf Road, the Lep Riton, Dibang, Ngwei rivers on the Boum Nyebel-Douala highway, and finally the Rivers Sanaga and Eding at Edea. The recipient sites were recorded on a detailed map using the GIS tool and the Software is Arcview. Two water samples were collected in each site, at least 50 cl each sample, for physico-chemical analysis. The collections were repeated 5 times, one per month, three dry and two wet months. Water was directly collected from the stream. The collected materials were conserved with ice in a cooler. The other parameters collected for each site were temperature and altitude.

3.2. Data Analysis

The measured parameters were: temperature, pH, electric conductivity, total dissolved solids, orthophosphates (PO_4^{3-}) and Nitrates (NO^{3-}) . Temperature, electric conductivity, total dissolved solids and pH were taken directly from the field using a multimeter conductivity/TDS and a pH-meter, and later counterchecked in the lab. Later on, in the lab, the total NO^{3-} and PO_4^{3-} were obtained using a spectrophotometer DR/2000. All data recorded were entered in excel software for analysis. The analysis of variance (ANOVA) was done with R software to examine whether the other rivers studied had similar characteristics to those of the Sanaga River.

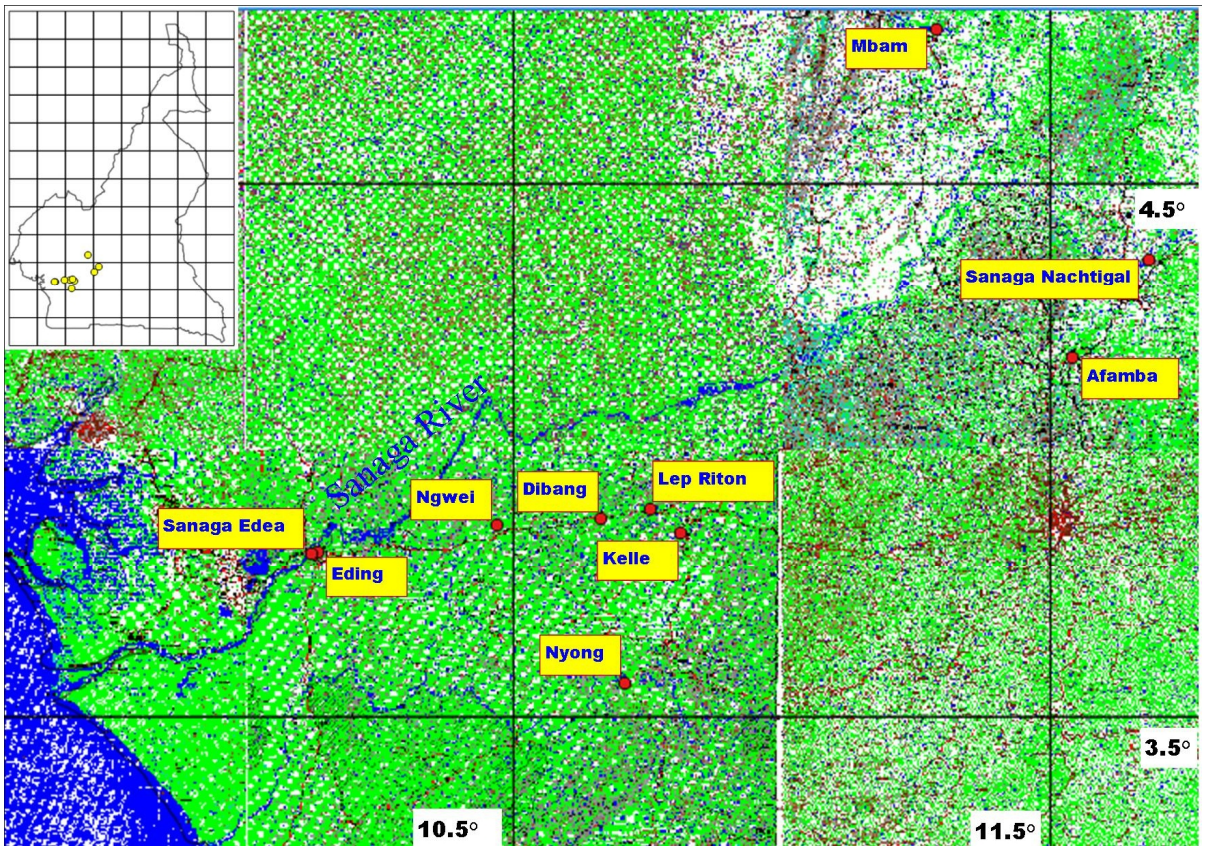

Fig. 2. Samples collecting sites

4. RESULTS AND DISCUSSION

4.1. GPS Location of each station

Table I: Location of each station

Collecting sites	*Latitude*	*Longitude*	*Elevation*
Afamba	4.17191667	11.5399722	505
Dibang	3.87294444	10.6618056	232
Eding	3.81072222	10.137	42
Kelle	3.84683333	10.8119444	222
Lep Riton	3.88922222	10.7561667	194
Mbam	4.78838889	11.2886389	471
Ngwei	3.85958333	10.4688611	148
Nyong	3.56244444	10.7074167	150
Sanaga Edea	3.80730556	10.1251111	34
Sanaga Nachtigal	4.35905556	11.684	534

4.2. Contribution to the successful conservation of the species of Podostemaceae threatened by dams in the Sanaga River in Cameroon

4.2.1. Nitrates and Phosphates

The highest nitrate content were obtained in the Sanaga at Natchigal (1.11mg/l), the Mbam (0.98 mg/l) and the Kelle (0.93 mg/l) rivers; followed by the Afamba, the Eding and the Dibang with respectively (0.61; 0.51 and 0.39mg/l). The highest content of phosphate were obtained for the Nyong River (2.49 mg/l) and Kelle (2.41 mg/l); followed by the Afamba (2.09 mg/l); the Sanaga at Edea (2.07 mg/l) and the Mbam River (1.96 mg/l) (Fig. 3).

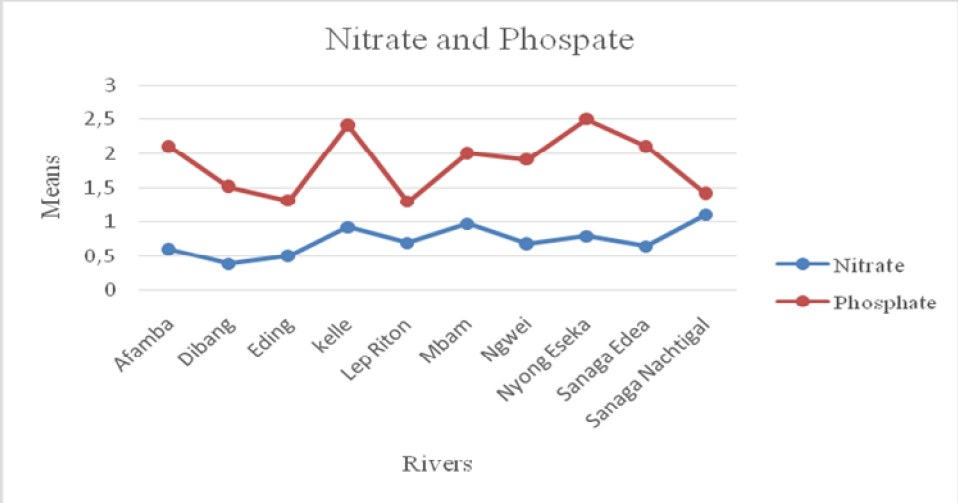

Fig. 3. Nitrates and phosphates in different rivers prospected

4.2.2. Conductivity and Total Disolved Solids

The electric conductivity of water permits a direct evaluation of the total mineralization of water. It is expressed in µS.cm-1. The waters of the different rivers prospected had values of conductivity oscillating between 24.27 and 40.17µS.cm-1. The Mbam and Afamba rivers showed the highest conductivity values (40.17 and 39.54 µS.cm-1) respectively. The lowest conductivity values were those of the Dibang and Nyong rivers (26.74 and 24.27 µS.cm-1). With regards to Total Dissolved Solids (TDS), the highest amounts of dissolved solids were obtained for the Mbam and the Afamba rivers respectively 21.23 and 20.80 mg/l. The lowest values of TDS were 14.10 and 12.88 mg/l for the Dibang and Nyong rivers (Fig. 4).

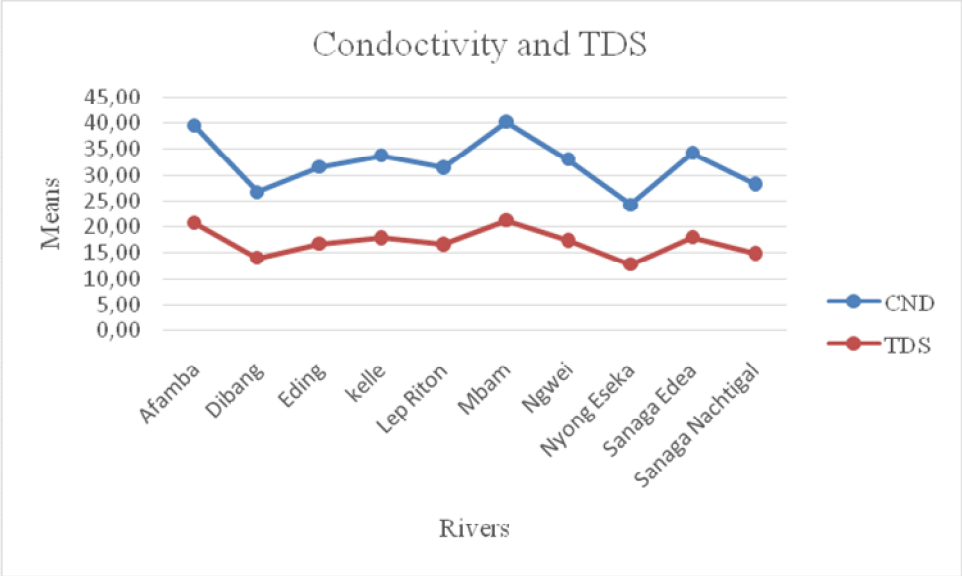

Fig.4. Conductivity and TDS

4.2.3. Hydrogen potential of rivers

For the 10 prospected stations, the values of pH varied between 7.08 and 6.40. Only the Mbam had the highest pH value of 7.08, corresponding to a neutral pH. The Dibang and Nyong rivers exhibited the weakest pH values of 6.40 and 6.42, corresponding to an acidic pH (Table II).

Table II: pH in different river

Rivers	*Ph*
Dibang	6,40
Nyong	6,42
Lep Riton	6,48
Kelle	6,59
Afamba	6,72
Ngwei	6,74
Sanaga at Nachtigal	6,79
Eding	6,85
Sanaga at Edea	6,89
Mbam	7,08

4.2.4. Redox potential

Low redox potentials were observed in the rivers Mbam (-29.20 mV), Sanaga at Edea (-10.50 mV), Eding (- 7.33 mV), Sanaga at Nachtigal (- 7.20 mV), Ngwei (- 6.40 mV), Afamba (-0.90 mV) and Kelle (- 0.30 mV). These figures show that water from the above rivers carry a high amount of minerals and will have a tendency to lose electrons. In the rivers Nyong south Eseka, Dibang and Lep Riton, the redox potentials had positive values (16.80 mV, 12.20 mV and 6.10 mV) and the water will tend to gain electrons (Fig. 5).

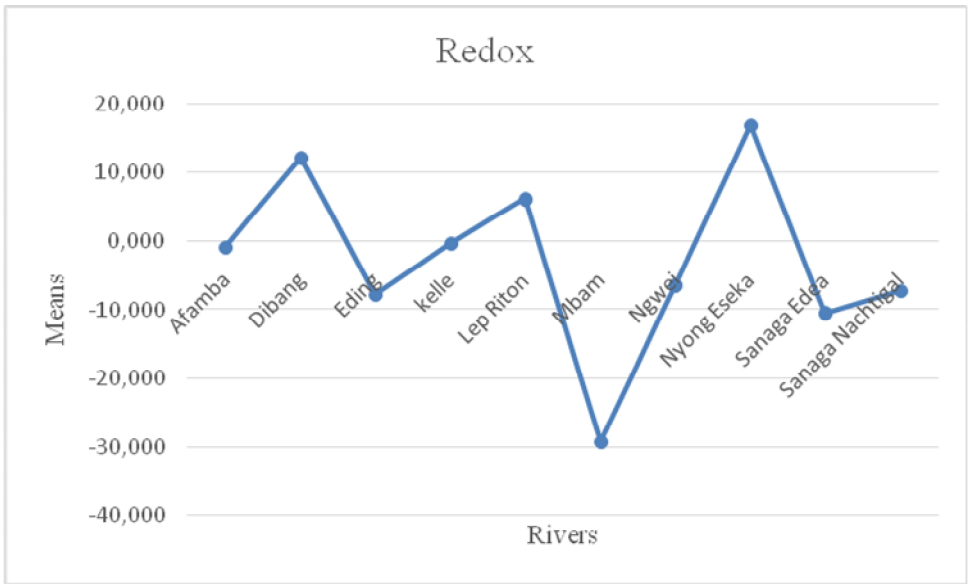

Fig. 5. Redox potential

4.3. Identification of suitable sites for translocation of endemic Podostemaceae threatened by dams in the Sanaga River

4.3.1. Based on water similarity

In order to identify potential receptor sites for Podostemaceae, a multivariate analysis of variance (ANOVA) at 0.5% of the different physico-chemical parameters was carried out to determine rivers having parameters similar to those of the Sanaga at Nachtigal and Edea.

4.3.1.1. Nitrate

The ANOVA for nitrate contents of the ten sites revealed that there were no significances differences in the nitrate content of rivers (Table: III).

Table III: Nitrate content of rivers

Rivers	*1st set*	*2nd set*	*3rd set*	*4th set*	*5thset*	*Mean*	*Anova*
Afamba	0.20	0.30	0.20	0.25	2.10	(0.61 ± 0.83)	"a"
Dibang	0.15	0.45	0.15	0.00	1.20	(0.39 ± 0.48)	"a"
Eding	0.00	0.00	0.30	0.05	2.20	(0.51 ± 0.95)	"a"
Kelle	0.35	1.50	0.20	0.20	2.40	(0.93 ± 0.99)	"a"
Lep Riton	0.50	0.00	0.00	0.00	3.00	(0.70 ± 1.30)	"a"
Mbam	0.00	1.50	0.50	0.40	2.50	(0.98 ± 1.01)	"a"
Ngwei	0.50	0.50	0.15	1.10	1.20	(0.69 ± 0.44)	"a"
Nyong Eseka	0.10	0.85	0.50	0.35	2.20	(0.80 ± 0.83)	"a"
Sanaga Edea	0.00	0.15	1.10	0.70	1.30	(0.65 ± 0.57)	"a"
Sanaga Nachtigal	0.85	2.00	0.15	0.45	2.10	(1.11 ± 0.89)	"a"

4.3.1.2. Phosphate

The analysis of variance at 0.5% risk level showed no significance differences in the phosphate content of water samples for the Afamba, Kelle and the Sanaga at Edea. Similarly, no significant differences were observed for the phosphate content of the Eding and Lep Riton rivers compared to the Sanaga River at Nachtigal (Table: IV).

Table IV: Phosphate in different river

Rivers	*1st set*	*2nd set*	*3rd set*	*4th set*	*5th set*	*Means*	*Aanova*
Afamba	2.20	1.90	2.20	2.37	1.80	(2.09 ± 0.23)	"de"
Dibang	1.50	1.45	1.70	1.35	1.60	(1.52 ± 0.14)	"abc"
Eding	1.23	1.50	1.09	1.18	1.53	(1.31 ± 0.20)	"a"
Kelle	2.00	2.90	2.10	2.13	2.90	(2.41 ± 0.45)	"de"
lep riton	1.17	1.20	1.34	1.17	1.47	(1.27 ± 0.13)	"a"
Mbam	2.00	1.50	2.50	2.00	1.80	(1.96 ± 0.36)	"cd"
Ngwei	1.95	1.85	2.00	2.00	1.75	(1.91 ± 0.11)	"bd"

Nyong Eseka	2.37	2.47	2.37	2.27	2.97	(2.49 ± 0.28)	"e"
Sanaga Edea	2.23	1.90	2.20	2.20	1.83	(2.07 ± 0.19)	"de"
Sanaga Nachtigal	1.38	1.28	1.48	1.38	1.58	(1.42 ± 0.11)	"ab"

4.3.1.3. Conductivity

Analysis of variance at 0.5 % revealed that the conductivity values of Eding River is close to that of the Kelle, Lep Riton, Ngwei, Sanaga at Edea and Sanaga River at Nachtigal whereas that of the Afamba is closer to that of the Mbam River and the conductivity of Dibang was closer to that of Nyong at Eseka (Table: V).

Table V: Conductivity in different river

Rivers	***1st set***	***2nd set***	***3rd set***	***4th set***	***5th set***	***Means***	***Anova***
Afamba	39.80	36.30	34.605	30.70	56.30	(39.54 ± 9.92)	"b"
Dibang	26.75	23.20	24.80	27.35	31.60	(26.74 ± 3.17)	"a"
Eding	37.45	30.30	25.75	29.60	34.60	(31.54 ± 4.56)	"ab"
Kelle	39.70	31.05	32.95	35.65	29.60	(33.79 ± 4.00)	"ab"
Lep Riton	28.60	26.60	29.35	34.85	37.80	(31.44 ± 4.69)	"ab"
Mbam	49.95	42.10	41.05	35.35	32.40	(40.17 ± 6.78)	"b"
Ngwei	33.95	28.40	30.40	34.15	38.40	(33.06 ± 3.85)	"ab"
Nyong Eseka	27.00	18.80	18.80	19.25	37.50	(24.27 ± 8.18)	"a"
Sanaga Edea	40.70	31.15	31.80	33.65	34.10	(34.28 ± 3.79)	"ab"
Sanaga Nachtigal	32.25	25.20	26.65	28.50	28.80	(28.28 ± 2.66)	"ab"

4.3.1.4. Total Dissolved Solids

ANONA for the total dissolved solids revealed distinct variation between rivers. Significant difference test at 0.5% risk confirmed similarity between the Dibang, and Nyong at Eseka; and between the Eding, Kelle, Lep Riton, Ngwei, Sanaga at Edea and Sanaga at Nachtigal (Table: VI).

Table VI: Total Dissolved Solid in different river

Rivers	***1st set***	***2nd set***	***3rd set***	***4th set***	***5th set***	***Mean***	***Anova***
Afamba	21.2	19.30	18.40	15.10	30.00	(20.80 ± 5.60)	"b"
Dibang	13.8	12.35	13.20	14.55	16.60	(14.10 ± 1.61)	"a"
Eding	19.75	16.05	13.75	15.70	18.40	(16.73 ± 2.36)	"ab"
Kelle	20.95	16.50	17.50	18.95	15.70	(17.92 ± 2.08)	"ab"
Lep Riton	15.2	14.15	15.60	18.50	20.10	(16.71 ± 2.49)	"ab"
Mbam	26.5	21.99	21.80	18.75	17.10	(21.23 ± 3.60)	"b"
Ngwei	17.75	15.05	16.10	18.15	20.30	(17.47 ± 2.02)	"ab"

Nyong Eseka	14.25	10.00	10.00	10.25	19.90	(12.88 ± 4.32)	"a"
Sanaga Edea	21.5	16.35	16.95	17.90	17.90	(18.12 ± 2.00)	"ab"
Sanaga Nachtigal	17.15	13.35	14.15	15.15	15.10	(14.98 ± 1.42)	"ab"

4.3.1.5. Hydrogen potential

The pH values of Dibang, Lep Riton, Nyong River at Eseka were sensibly equal. On the other hand, pH values of Afamba, Eding, Kelle, Ngwei, Sanaga at Edea and Sanaga at Nachtigal were close (Table: VII).

Table VII: pH in different river of Dibang

Rivers	***1st set***	***2nd set***	***3rd set***	***4th set***	***5th set***	***Means***	***Anova***
Afamba	6,36	6,685	6,825	6,89	6,85	(6.72 ± 0.22)	"ab"
Dibang	6,125	6,41	6,515	6,47	6,47	(6.40 ± 0.16)	"a"
Eding	6,81	7,015	6,95	6,7	6,78	(6.85 ± 0.13)	"ab"
Kelle	6,385	6,695	6,845	6,67	6,34	(6.59 ± 0.22)	"ab"
Lep Riton	5,885	6,51	6,735	6,585	6,67	(6.48 ± 0.34)	"a"
Mbam	6,82	6,94	7,615	7,165	6,88	(7.08 ± 0.32)	"b"
Ngwei	6,455	6,79	6,985	6,745	6,72	(6.74 ± 0.19)	"ab"
Nyong Eseka	6,14	6,32	6,34	6,53	6,78	(6.42 ± 0.24)	"a"
Sanaga Edea	6,42	6,955	7,365	6,625	7,06	(6.89 ± 0.37)	"ab"
Sanaga Nachtigal	6,53	6,8	6,93	6,88	6,79	(6.79 ± 0.15)	"ab"

4.3.1.6. Redox potential

At 0.5% threshold, there exist no significance difference in the redox potential of Afamba, Eding, Kelle, Ngwei Rivers and the redox potentials of the Sanaga at Edea and Nachtigal (Table VIII).

Table VIII: Redox potential in different rivers

Rivers	***1st set***	***2nd set***	***3rd set***	***4th set***	***5th set***	***Means***	***Anova***
Afamba	0,00	11,00	-6,00	16.5	-2,00	(-0.90 ± 7.30)	"ab"
Dibang	0,00	19,00	10,00	16.5	15.5	(12.20 ± 7.57)	"b"
Eding	0,00	-21,00	-11,00	3.00	-10,00	(-7.80 ± 9.58)	"ab"
Kelle	0,00	4,00	-4,00	3.5	-5,00	(-0.30 ± 4.15)	"ab"
Lep Riton	0,00	13,00	4,00	10,00	3.5	(6.10 ± 5.27)	"b"
Mbam	0,00	-12,00	-59,00	-24,00	-51,00	(-29.20 ± 25.19)	"a"
Ngwei	0,00	-2,00	-15,00	0,00	-15,00	(-6.40 ± 7.89)	"ab"
Nyong Eseka	0,00	25,00	20,00	14.5	24.5	(16.80 ± 10.30)	"b"
Sanaga Edea	0,00	-10,00	-42,00	34.5	-35,00	(-10.50 ± 3.53)	"ab"
Sanaga Nachtigal	0,00	-1,00	-16,00	-7.5	-11.5	(-7.20 ± 6.82)	"ab"

4.3.1.7. Anova comparism of all six physico-chemical parameters for the rivers

The combination of all six physico-chemical parameters was used to compare the nine rivers studied (Table IX). The characteristics of all the rivers are judged for similarity to the Sanaga River at Edea and the Sanaga River at Nachtigal. A high level of similarity was observed between the Kelle and the Sanaga at Edea. Similarity was also observed between Lep Riton and the Sanaga River at Edea.

Table IX: Anova comparism of all six physico-chemical parameters

Rives	***Nitrate***	***Phosphate***	***CND***	***TDS***	***pH***	***Redox***
Afamba	"a"	"de"	"b"	"b"	"ab"	"ab"
Dibang	"a"	"abc"	"a"	"a"	"a"	"b"
Eding	"a"	"a"	"ab"	"ab"	"ab"	"ab"
Kelle	"a"	"de"	"ab"	"ab"	"ab"	"ab"
Lep Riton	"a"	"a"	"ab"	"ab"	"a"	"b"
Mbam	"a"	"cd"	"b"	"b"	"b"	"a"
Ngwei	"a"	"bd"	"ab"	"ab"	"ab"	"ab"
Nyong Eseka	"a"	"e"	"a"	"a"	"a"	"b"
Sanaga Edea	"a"	"de"	"ab"	"ab"	"ab"	"ab"
Sanaga Nachtigal	"a"	"ab"	"ab"	"ab"	"ab"	"ab"

4.3.2. Based on the size of the recipient river

The Mbam is the biggest tributary of the Sanaga River (Fig. 6). Both the Mbam and the Sanaga share the same biogeographical environment on hundreds of kilometers. Despite their chemical dissimilarity, it is possible that both rivers could more or less contain the same species, or could be host each from the other.

Fig. 6. The Mbam and the Sanaga Rivers

4.4. Contribution to the national effort for biodiversity conservation in Cameroon

It consisted of carrying out direct observations on the possibility to conserve Podostemaceae species on site. Comparative studies of physico-chemical characteristics of the Sanaga River, its tributaries and other water courses in its environs permitted us to propose conservation measures.

5. DISCUSSION

All the parameters analyzed in this project could individually influence the presence of Podostemaceae in the milieu. They are the nitrates, Total Dissolved Solid (TDS), pH, conductivity and phosphates. Other least concerned parameters are temperature and altitude. Eight rivers were compared to the Sanaga River at Edea and Nacthtigal where the threatened species occur. These rivers are the Afamba, Mbam, Kelle, Nyong, Lep Riton, Dibang, Ngwei and Eding. Statistically, the physico-chemical characteristics of the Kelle and Lep Riton, showed that they are closest to the Sanaga at Nachtigal and Edea. They are therefore the most suitable sites for potential translocation of endemic Podostemaceae from the above threatened sites. Even though the Mbam River does not present similar physico-chemical characteristics to those of the Sanaga at Nachtigal, it can still be a potential translocation site taking into account the parameter "tributary or not to the Sanaga River" and its size since it is the main tributary of the Sanaga River at Nachtigal and relatively large. However, the Mbam and Afamba rivers had the highest amounts of total dissolved solids. The dissimilarity observed

between the Afamba, Dibang, Eding, Ngwei and Nyong rivers and the Sanaga River could be explained by the numerous anthropic activities in the rivers and their surroundings which could have modified the chemical composition of the rivers.

6. CONCLUSION AND RECOMMENDATION

The main objectives of this project were to contribute to the successful conservation of Podostemaceae species threatened by dams in the Sanaga River, to identify suitable sites for their translocation and contribute to the national efforts for the conservation of biodiversity in Cameroon. Our results show that the pH values of the studied rivers fluctuate slightly from acidic to neutral (Mbam). Their redox potentials often pass from reducer to oxidant values. Electric conductivities which depend on the amounts of total dissolved solids were very low for the rivers. Comparison of the various physico-chemical parameters did not show any significant differences between waters of the Kelle River and the Sanaga River at Edea. Similar results were obtained for Lep Riton River and the Sanaga River at Edea. The Mbam River, being the largest tributary to the Sanaga River could also serve for the translocation of threatened podostemaceae in the Sanaga River. Hence, the Kelle and Lep Riton and the rapids of the Mbam rivers are the most suitable sites for the translocation of Podostemaceae in the Sanaga at Edea and Sanaga at Nachtigal.

CONSTRAINTS

Many of our team members are University teachers. They live in Dschang, more than 300 km away from Yaoundé where other members live. Their busy schedule stood sometime as a brake for our fieldwork organisation and sometime affected our deadlines, especially during the result's analysis. As a solution to this, we had to discuss with them and the available team members could collect sample for them in the field. We also faced some technical difficulty, due to the breakdown of our old car. The fieldtrip of the month concerned by this was carried forward to the next month. We purchased a field thermometer but received it late, so we could not measure the temperature during the two first fieldtrips. But at least we could repeat the measurements four times in 4 months, enough to have an idea of the temperature's variation.

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ANNEX

Annex 1. Project pictures

a) Road security

b) Meeting with dam authorities at Edea

c) Visiting dam at Edea

d) Data collecting

e) Data collecting

f) Data collecting

g) Water samples

h) Data collecting at the Kelle River

i) Afamba River under human activities

j) Data collecting in the Afamba River

k) Podostemaceae on the Nyong River

l) Data collecting in the Afamba River

Annex 2: Report of different field trips

Project Update: October 2014

Last week I have been able to do the first mission in the frame of my project. This first mission was delayed because some project members were involved in the university academic year. With those available, we have finally been able to collect water specimens for analysis in 9 different rivers tributary or not of the Sanaga River: Rivers Sanaga at Nachtigal, Afamba at Obala, Mbam at Bafia, Kele at Boum-nyebel, Nyong at Eseka, Lep Riton, Dibang, Ngwei on the Yaoundé-Douala highway and Eding & Sanaga at Edea. The specimens are currently analysed in the laboratory of Hydrobiology of the faculty of Sciences of University of Dschang. In fact we are aiming at identifying the suitable sites for translocation of endemic Podostemaceae threatened by dams in the Sanaga River (Cameroon). Therefore, this operation will be repeated at least within the next five months, including dry and rainy season's months for comparative analysis. I join to this e-mail some fresh illustration photos from the recent fieldwork. One more time, thank you for all. I will let you informed progressively. All the best and bye for now.

Project Update: November 2014

From 26-27th November 2014, we carried out the second fieldtrip for our project. As for last October, we collected water specimens for analysis in nine different river tributaries of the Sanaga river: Rivers Sanaga at Nachtigal, Afamba at Obala, Mbam at Bafia, Kelle at Boum-Nyebel, Nyong at Eseka, Lep Riton at Mahole, Dibang, Ngwei on the Yaoundé-Douala highway and Eding and Sanaga at Edea. The specimens are currently being analysed in the laboratory of Hydrobiology of the Faculty of Sciences of University of Dschang. We will repeat this operation within the next four months.

We also met with the authorities of the dam at Edea and took an appointment for a join fieldwork next month. We want to familiarise the environment team of the dam in case there is any with the plants threatened by dam at Edea.

Left: Bridge on Kelle River. Middle: Collection Nyong River

Left: Note taking at Nyong River. Right: Water collecting Mbam River

Project Update: December 2014

The December 2014 campaign included two different field trips in two different directions: the northern trip to the Sanaga River at Nachtigal, the Afamba River at Obala and Mbam River at Bafia; and the western-littoral trip to the Kelle River at Boum Nyebel, the Nyong River South Eseka on Lolodorf Road, the Lep Riton, Dibang, Ngwei rivers on the Boum Nyebel-Douala highway, and finally the Rivers Sanaga and Eding at Edea. For each of the 10 different stations, two water samples are collected for physico-chemical and biological analysis at the hydrobiological lab at university of Dschang. For this trip, we have been able to take the temperature for the first time since when this project started because of the difficulty to purchase a field thermometer. Then, for each site, the parameters collected at the field are the temperature, the altitude, and the geographical coordinates.

The analysis of the water sample is carried on immediately after the field work since October 2014 and it's the same case for the December 2014 campaign.

In November 2014, we met with the authority of the dam at Edea. In December 2014, it was possible to meet with the Director of the dam himself as well as the responsible of environment. The director was a nice man, open minded, but strategically hard to understand the responsibility of the dam in a biodiversity damage caused outside the fence of the dam. I explained how the dam threated the freshwater species and he promised that they will do their best to keep the water flow in a more or less natural rhythm. A team was sent to show us the dam installations and by the meantime we discussed about the issue related to biodiversity conservation.

The December 2014 campaign involved five persons (two men and three women), myself and four students at PhD level, but also active members of my organisation. Apart of myself, it involved none of the participants of the previous expeditions.

Almost all the 10 stations host Podostemaceae. They involve some waterfalls that we have not yet surveyed before. Now that the dry season is here and that the water level is low in all these stations, I am planning to take the opportunity of the January 2015 campaign to do some botanical collection.

Project Update: January 2015

From 25th-27th January 2015, we have been able to carry out our fieldtrip. This campaign was the second of the dry season. For technical reasons, at the opposite of the previous months, we have started this one by the littoral direction, that's the trip involving the sample collection in the Rivers Nyong, Kelle, Lep Riton, Dibang, Ngwei, Eding and Sanaga at Edéa. As previously, two water samples were collected in each site, at least 50 cl each sample, to allow physico-chemical and biological analysis at the hydro-

biological laboratory of the University of Dschang. This trip covered about 334 km in total. This time, the water level was low enough and could allow us to do a quick inventory of the presence or not of Podostemaceae in the site and to identify them.

We continued the trip by the northern direction, to cover the rivers Afamba, Mbam and Sanaga at Nachtigal. As previously, two water samples were collected at each site and the Podostemaceae were surveyed. The good news is that all the 11 sites contain Podostemaceae, but none of them host those threatened by dams on the Sanaga River. In this direction, the total distance covered was 370 km.