



Impact of gold panning on biomass of Benoue and Bouba - Ndjidda National Park in the Mayo-Rey Division

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Abstract

A study was conducted in Benoue and Bouba-Ndjidda National Park (5 gold panning sites per national park) from 13th September 2016 to 7th January 2018. Its objective was to evaluate the effects of the pressure exerted by gold panning on biomass in the protected areas of the Mayo-Rey Division. Floristic inventories were carried out in 12 plots of 20 x 20 m² in each site, ie 6 plots in the gold panning area and 6 other plots in the non-panning area. The diversity of the species in the gold mining area is influenced by the effects of the gold mining practice which is at the origin of a total destruction of the vegetal cover. The deleterious effects of gold panning on vegetation are evidenced by the rapid change in L-shaped vegetation structure as a function of heights and DBHs. It appears that the diversity index of Shannon and Pielou are more remarkable in the witnesses of the sites studied. They are of the order of ISH = 42.31 bits, ie 21.38 bits in the control sites of the Benoue National Park and 20.92 bits in the control sites of the Bouba-Ndjidda National Park. A total of 517 498.06 t/ha of total biomass is obtained from all the inventories carried out, ie 97 293.15 t/ha in the gold panning part and 208 588.31 t/ha in the non-gold panning part of the Benoue National Park; ie 85 921,83 t/ha in the gold panning part and 125 694,76 t/ha in the non-panning part of the Bouba-Ndjidda National Park.

Keywords: Impact, gold panning, protected area, biomass, Mayo-Rey Division, North-Cameroon.

I. Introduction

Natural ecosystems around the world are under all kinds of pressures that cause them to degrade. Degradation of forest ecosystems is one of the most important causes of biodiversity reduction in the world (Oszwald, 2005; N'da *et al.*, 2008). In the northern region, particularly in Mayo-Rey, the problem of human pressure due to the increase in the practice of gold panning through the population explosion around protected areas, the destruction of plant cover, the degradation of forest ecosystems, ecosystem fragmentation and the boom in activity itself remain the main threat to protected areas in the minds of public opinion recently (Oumar, 2016; Sylvain *et al.*, 2018). However, gold panning is only one of the anthropogenic activities that take place illegally in and around protected areas in the Department of Mayo-Rey. The renewed importance and the lack of knowledge of its effects on vegetation justify the present research work.

The practice of gold panning within protected areas is a major conservation concern for national parks in the northern region. In addition to agriculture and livestock, gold panning appears to be an activity accentuating land degradation in this region Sylvain *et al.* (2018). Overexploitation of land is considered the main cause of degradation of vegetation cover and loss of biodiversity Diallo *et al.* (2011); Mama *et al.* (2013). The practice of gold panning has developed considerably in recent times in the northern region, including in protected areas. It has grown throughout the region with high concentrations of populations, the number of which can reach 100 to 200 individuals on the same site. This obviously puts pressure on the environment. This pressure on the environment is manifested by the destruction of vegetation (Bakhoum, 2013).

Several research works have been carried out by Tsakem (2006) on the contribution to development, Ndamè (2007) on the difficult development of protected areas, Koagne (2009) on the evaluation of the ecological monitoring system and the dynamics of anthropogenic

activities, Vounserbo (2010) on the inventory of the corridors of peripheral hunting zones 1 and 4, Saleh (2012) on the co-management of biosphere reserves, Sylvain *et al.* (2018) on the mapping of gold mining sites. However, no work has been carried out on the impact of gold panning on biomass in the gold panning sites. The present work aims to fill this void. Its general objective is to assess the harmful effects of the pressure exerted by gold panning on biomass in the protected areas of the Department of Mayo-Rey. Specifically, it involves: i) estimating the above-ground and below-ground woody biomass, ii) evaluating the total woody biomass, iii) estimating the stock and carbon credit of vegetation and iv) calculating CO₂ emissions.

II. Methodology

1- Presentation of the study area

The research was carried out between 2016 and 2018 in the Benoue and Bouba-Ndjidda National Park (5 gold mining sites per national park). These are the Douala, Fimbé1, Million, Lit-Benoue 1, Lit-Benoue 2 sites in the Benoue National Park and the Mayo-Tokor, Sinassi-Frontier, Taoubawa, Mayo-Bidjou, Gaibalein sites in the National Park of Bouba-Ndjidda (Figure 1). These study sites are located in the administrative district of the North Cameroon region (Figure 1). Indeed, this region was created by the Presidential Decree of August 23, 1983 following the splitting of the Far North into three Regions (Adamaoua, North and Far North). Covering an area of 6,798 km², the region extends between the 8th and 10th degree of North latitude and the 12th and 16th degree of East longitude (DRFFN, 2013). It is bounded to the North by the Far North Region, to the South by the Adamaoua Region, to the East by Chad and the Central African Republic, and to the West by Nigeria.

The relief of the northern region is dominated by plains and highlands. The plains are cultivation areas par excellence, like the great peneplain from 200 m to 300 m in altitude. The highlands stand on both sides of the plains. The study area is

subject to a Sudano-Sahelian type climate characterized by a long dry season that lasts 8 to 9 months with an average precipitation of 850 mm and an average annual temperature is 28° C and the amplitude 7° (RADER, 2011). The hydrological regime of the main rivers of the Benoue Basin is characterized by high flows, brutal annual floods, very prolonged low flows and a seasonal flow locally called Mayo or seasonal rivers Mendjemo (1998).

The vegetation of this zone is made up of species very characteristic of the Sudanese zone and of species normally associated with the north of the Guinean zone. Eight different types of plant formation have been defined by Letouzey (1968), Bosch (1976): the wooded savannah with *Terminalia laxiflora* which extends over the entire extent of the park; the clear forest with *Isoberlinia doka*; the clear forest with *Monotes kerstingii*; the open forest with *Isoberlinia doka*, *Monotes kerstingii* and *Anogeissus leiocarpus*; the shrub savannah with *Combretum glutinosum*; the

savanna with *Isoberlinia doka*, *Burkea africana*, *Terminalia macroptera*, *Azelia africana* and *Lophira lanceolata*; the gallery forest with *Anogeissus leiocarpus*; mountain vegetation is quite diverse in terms of trees and shrubs.

Agriculture is the main production activity in the area and is practiced by all social strata (Boum *et al.*, 2009). The population of this zone is made up of Faly and Kangou, the Fulani who are indigenous Essimi (2010) and the Toupouri, the Massa, the Moundang, the guigar, the guiziga, Mofou, the Sarah and the Kotoko who are the populations who came mostly from the Far North, in search of fertile land and water. Likewise, we note the presence of populations from neighboring countries.

The Northern Region is geographically located between the 7th and 10th meridian, 12th and 16th parallel. Its area, which is approximately 66,333 km², represents 14.2% of the Cameroonian territory.

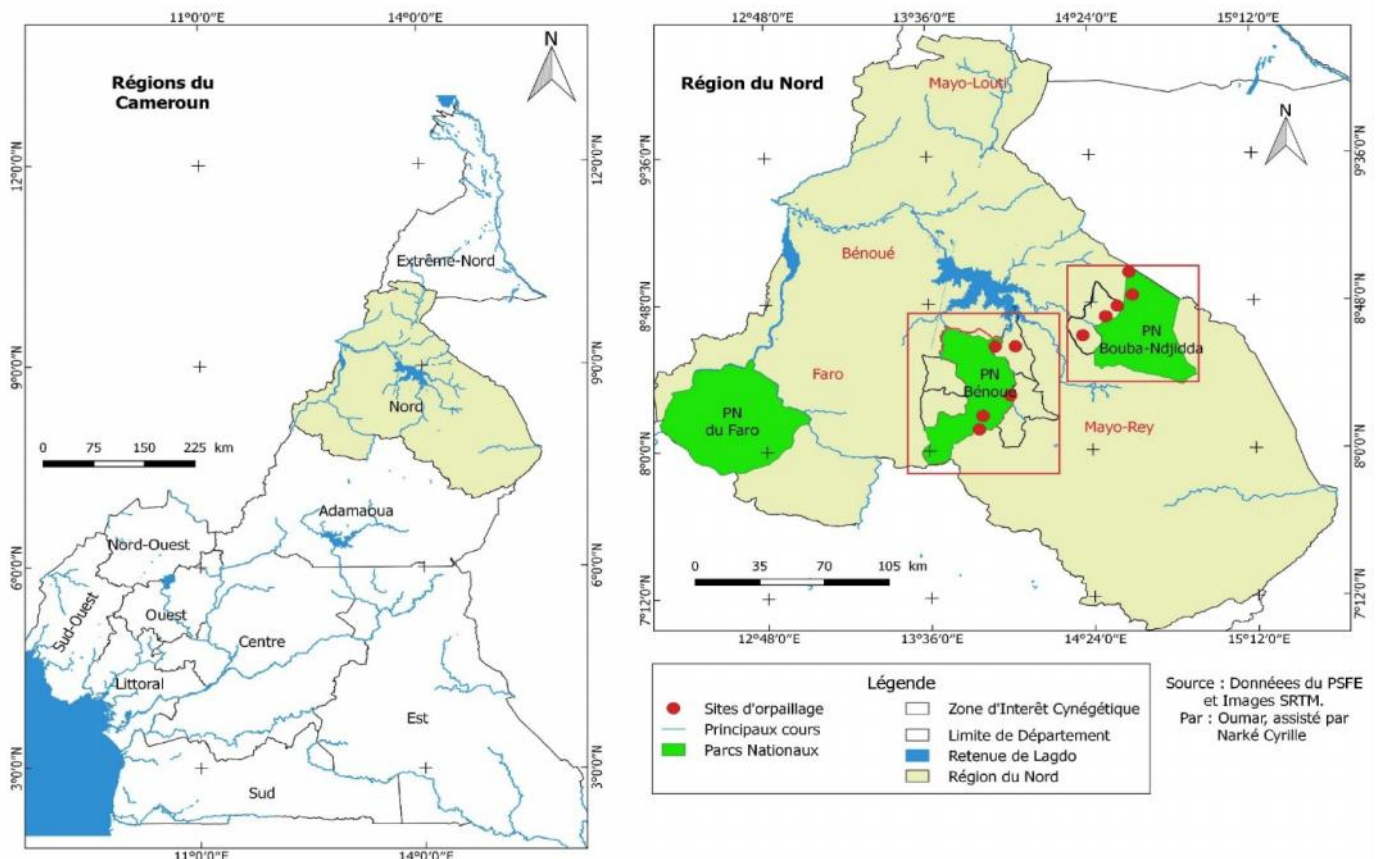


Figure 1 : Location map of the study area

2- Estimation of above-ground biomass

Tree biomass was estimated indirectly using an allometric model taking into account tree parameters such as DBH and height. Among the equations used to estimate this biomass, that of Segura *et al.*(2006) was retained because it was developed in climatic conditions where the average rainfall varies from 1500 to 4000 mm, including that of Adamaoua (1200-2000 mm) and the coefficient of determination between the biomass of trees was selected because it was developed in the climatic conditions in which the average rainfall varies from 1500 to 4000 mm, including that of Adamaoua (1200-2000 mm) and the coefficient of determination between tree biomass and their two parameters (DBH) is highly significant ($R^2 = 0.987$). It is given by the following formula:

$$Ba = \exp(-3,114 + 0,9719 \ln(D2H))$$

where Ba is the above-ground biomass of the tree in kg, DBH is the diameter at breast height in meters and H is the height of the tree in meters.

3- Estimation of underground biomass

The biomass of the root system was estimated using the relationship developed by Cairns *et al.* (1997).

$$Br = \exp(-1,0587 + 0,8836 \times \ln(Ba))$$

with Br = root biomass, ln = natural logarithm and Ba = aboveground biomass.

4- Estimation of total woody biomass

The total biomass is the sum of the above-ground and below-ground biomass (FAO., 1997).

$$Bt = Ba + Br$$

with Bt = total biomass, Br = root biomass and Ba = aboveground biomass

5- Estimation of carbon stock and credit

The carbon stock assessment is obtained from the biomass calculated according to the following equation (Ibrahima & Abib, 2008):

$$CE = B \times FC$$

with CE = carbon stored in the total biomass (t C / ha), B = total biomass (tC / ha) and FC = Carbon Fraction (%). HR = 50%. As for the evaluation of carbon credit, the method of Saïdou *et al.* (2012) was adopted. According to this method, the carbon credit is obtained by multiplying the carbon stock by 95 dollars.

6- Calculation of CO₂ emissions for a deforested area

The amount of carbon dioxide (CO₂) emitted into the atmosphere if the trees inventoried in the sample plot were cut down and burned completely is calculated as follows:

$$CO_2 = AGBP \times \left(\frac{PMCO_2}{PMC} \right)$$

where AGBP is the total above-ground biomass of the sample site;

PMCO₂ is the molecular weight of carbon dioxide (44) and PMC is the molecular weight of carbon (12).

III. Results and Discussion

1- Aerial phytomass of woody plants in gold mining sites depending on the parks

The phytomass of the ligneous plants vary according to the parks and according to the type of zone (Table 1). A total of 475,456,211 t/ha of aerial phytomass is obtained from all the inventories carried out and distributed as follows: 89,091,736 t/ha in the gold washing areas, 192,395,341 t/ha in the non-gold mining areas of the Benoue National Park (BNP) and 78,581,472 t/ha in the gold mining areas, 115,387,662 t/ha in the non-gold panning areas of the Bouba-Ndjidda National Park (BNNP). The aerial phytomass of woody plants in Benoue National Park (281,487.077 t/ha) are greater than that of Bouba-Ndjidda (193,969.134 t/ha).

Table 1 : Aerial phytomass of woody plants in gold panning sites

Species	BNP		BNNP		Total		Total (t/ha)
	gold panning areas(t/ha)	non-gold panning areas (t/ha)	gold panning areas(t/ha)	non-gold panning areas(t/ha)	Total of gold panning areas (t/ha)	Total of non-gold panning areas (t/ha)	
<i>Acacia ataxacantha</i>	0,048	0,045	0,210	0,227	0,258	0,272	0,530
<i>Acacia dudgeoni</i>	0,057	0,044	0,359	0,183	0,416	0,227	0,643
<i>Acacia hockii</i>	0,025	0,035	0,172	0,295	0,197	0,33	0,527
<i>Acacia polyacantha</i>	0,023	0,054	0,237	0,388	0,26	0,442	0,703
<i>Acacia polyacantha var c</i>	0,086	0,273	0,121	0,195	0,207	0,468	0,676
<i>Acacia senegalensis</i>	0,136	0,156	0,329	0,123	0,465	0,279	0,745
<i>Acacia sieberiana</i>	0,122	0,150	0,116	0,193	0,238	0,343	0,580
<i>Adenodouchos paniculatum</i>	0,003	0,050	0,005	0,090	0,008	0,14	0,148
<i>Adenolobus paniculatum</i>	0,101	0,114	0,103	0,126	0,204	0,24	0,444
<i>Adenolobus rufescens</i>	0,070	0,117	0,073	0,214	0,143	0,331	0,474
<i>Azalia africana</i>	0,538	0,693	0,096	0,186	0,634	0,879	1,512
<i>Albizia zygia</i>	0,063	0,095	0,009	0,205	0,072	0,3	0,372
<i>Allophyllus africanus</i>	0,053	0,097	0,134	0,105	0,187	0,202	0,389
<i>Annona senegalensis</i>	0,027	0,013	0,037	0,061	0,064	0,074	0,138
<i>Anogeissus leiocarpus</i>	0,149	0,206	0,187	0,164	0,336	0,37	0,706
<i>Antidesma venosum</i>	0,029	0,087	0,111	0,125	0,14	0,212	0,353
<i>Berlinia grandiflora</i>	0,021	0,071	0,028	0,055	0,049	0,126	0,174
<i>Bombax costatum</i>	0,924	1,369	0,026	0,140	0,95	1,509	2,459
<i>Borassus sp</i>	0,448	0,568	0,067	0,219	0,515	0,787	1,302
<i>Boswellia dalzielii</i>	0,087	0,097	0,114	0,074	0,201	0,171	0,371
<i>Boswellia papylifera</i>	0,054	0,290	0,130	0,120	0,184	0,41	0,594
<i>Bridellia ferruginea</i>	0,009	0,013	0,037	0,029	0,046	0,042	0,087
<i>Bridellia scleroclaria</i>	0,008	0,013	0,018	0,066	0,026	0,079	0,104
<i>Burkia africana</i>	0,187	0,275	0,022	0,147	0,209	0,422	0,631
<i>Cassia sieberiana</i>	0,078	0,234	0,143	0,129	0,221	0,363	0,584

<i>Clerodendrum capitatum</i>	0,044	0,050	0,033	-	0,077	0,05	0,127
<i>Combretum collinum</i>	0,275	0,300	0,170	0,189	0,445	0,489	0,934
<i>Combretum glutinosum</i>	0,234	0,247	0,060	0,079	0,294	0,326	0,620
<i>Combretum molle</i>	0,114	0,180	0,057	0,045	0,171	0,225	0,396
<i>Combretum nigricans</i>	0,210	0,277	0,090	0,178	0,3	0,455	0,755
<i>Combretum paniculatum</i>	0,029	0,139	0,035	0,114	0,064	0,253	0,316
<i>Cussonia arborea</i>	0,009	0,040	0,007	0,053	0,016	0,093	0,109
<i>Crossopteryx febrifuga</i>	0,181	0,044	0,044	-	0,225	0,044	0,270
<i>Daniellia oliveri</i>	0,706	2,426	0,509	0,252	1,215	2,678	3,892
<i>Desmodium vitelinum</i>	0,075	0,219	0,085	0,194	0,16	0,413	0,574
<i>Detarium microcarpum</i>	0,116	0,142	0,123	0,134	0,239	0,276	0,514
<i>Dichrostachys cinerea</i>	0,044	0,069	0,037	0,105	0,081	0,174	0,256
<i>Diospyros mespiliformis</i>	0,120	0,295	0,139	0,254	0,259	0,549	0,808
<i>Entada africana</i>	0,031	0,134	0,050	0,084	0,081	0,218	0,299
<i>Erythrina senegalensis</i>	0,012	0,044	0,026	-	0,038	0,044	0,083
<i>Ficus capensis</i>	0,338	0,407	0,064	0,090	0,402	0,497	0,898
<i>Ficus cordata</i>	0,317	0,936	0,051	0,079	0,368	1,015	1,383
<i>Ficus glaucescens</i>	0,188	0,044	0,044	-	0,232	0,044	0,277
<i>Ficus platyphylla</i>	0,495	0,851	0,037	0,081	0,532	0,932	1,463
<i>Ficus sycomorus</i>	0,455	0,836	0,077	0,101	0,532	0,937	1,469
<i>Ficus thonningii</i>	0,670	1,395	0,158	0,181	0,828	1,576	2,403
<i>Forea racheliana</i>	0,009	0,014	0,038	0,047	0,047	0,061	0,109
<i>Gardenia aqualla</i>	0,001	0,004	0,067	0,064	0,068	0,068	0,137
<i>Grewia bicolor</i>	0,022	0,106	0,047	0,049	0,069	0,155	0,223
<i>Grewia flavescens</i>	0,020	0,085	0,039	0,044	0,059	0,129	0,188
<i>Haematostaphis barbari</i>	0,027	0,044	0,044	-	0,071	0,044	0,116
<i>Harungana madagascaiensis</i>	0,326	0,697	0,142	0,147	0,468	0,844	1,312
<i>Hymenocardia acida</i>	0,078	0,395	0,151	0,205	0,229	0,6	0,830
<i>Isoberlinia doka</i>	1,210	1,897	0,202	0,266	1,412	2,163	3,574
<i>Isoberlinia tomentosa</i>	0,044	3,116	0,361	0,335	0,405	3,451	3,856
<i>khaya senegalensis</i>	2,002	4,676	0,614	0,379	2,616	5,055	7,672

<i>Kigelia africana</i>	0,016	0,044	0,044	-	0,06	0,044	0,105
<i>Klosklospermum plancini</i>	0,071	0,220	0,150	0,034	0,221	0,254	0,474
<i>Lannea fruticosa</i>	0,035	0,146	0,051	0,152	0,086	0,298	0,384
<i>Lannea humilis</i>	0,031	0,101	0,058	0,067	0,089	0,168	0,257
<i>Lannea kerstingi</i>	0,044	0,040	0,030	0,050	0,074	0,09	0,164
<i>Lannea shimperi</i>	0,005	0,044	0,044	-	0,049	0,044	0,094
<i>Lippia adoensis</i>	0,044	0,198	0,047	0,157	0,091	0,355	0,446
<i>Lonchocarpus laxiflorus</i>	0,037	0,241	0,045	0,202	0,082	0,443	0,525
<i>Lophira lanceolata</i>	0,017	0,069	0,020	0,076	0,037	0,145	0,181
<i>Malacantha alnifolia</i>	0,044	0,100	0,089	0,168	0,133	0,268	0,401
<i>Maytenus senegalensis</i>	0,105	0,073	0,137	0,083	0,242	0,156	0,398
<i>Mitragyna inermis</i>	0,055	0,095	0,055	0,120	0,11	0,215	0,325
<i>Monotes kerstingii</i>	0,512	0,586	0,210	0,274	0,722	0,86	1,582
<i>Nauclea latifolia</i>	0,063	0,020	0,053	0,024	0,116	0,044	0,160
<i>Ochna rhizomatosa</i>	0,058	0,137	0,099	0,135	0,157	0,272	0,429
<i>Ochna ovata</i>	0,021	0,031	0,027	0,025	0,048	0,056	0,105
<i>Ochna schweinfurthiana</i>	0,044	0,196	0,017	0,186	0,061	0,382	0,444
<i>Opilia amenthacea</i>	0,061	0,107	0,107	0,061	0,168	0,168	0,334
<i>Ozoroa insignis</i>	0,015	0,032	0,118	0,016	0,133	0,048	0,180
<i>Parinari curatellifolia</i>	0,044	0,111	0,027	0,120	0,071	0,231	0,302
<i>Parkia biglobosa</i>	0,036	0,161	0,051	0,151	0,087	0,312	0,398
<i>Pavetta crassipes</i>	0,044	0,064	0,075	0,055	0,119	0,119	0,239
<i>Pericopsis laxiflora</i>	0,105	0,250	0,119	0,269	0,224	0,519	0,743
<i>Phyllanthus welwitschianus</i>	0,044	0,069	0,082	0,079	0,126	0,148	0,274
<i>Piliostigma thonningii</i>	0,027	0,082	0,033	0,066	0,06	0,148	0,207
<i>Prosopis africana</i>	0,044	0,139	0,053	0,179	0,097	0,318	0,415
<i>Protea occidentalis</i>	0,036	0,065	0,056	0,056	0,092	0,121	0,212
<i>Pseudocedrela kotschy</i>	0,409	0,751	0,159	0,356	0,568	1,107	1,674
<i>Psorospermum febrifugum</i>	0,229	0,402	0,270	0,324	0,499	0,726	1,225
<i>Psorospermum senegalensis</i>	0,281	0,210	0,236	0,231	0,517	0,441	0,958
<i>Pterocarpus erinaceus</i>	0,338	0,995	0,046	0,164	0,384	1,159	1,542

<i>Pterocarpus lucens</i>	0,132	0,753	0,200	0,413	0,332	1,166	1,498
<i>Securidaca longepedunculata</i>	0,057	0,098	0,069	0,106	0,126	0,204	0,330
<i>Securinega virosa</i>	0,065	0,084	0,120	0,098	0,185	0,182	0,367
<i>Sterculia setigera</i>	0,049	0,044	0,044	-	0,093	0,044	0,138
<i>Stereopermim khunthianum</i>	0,007	0,063	0,013	0,099	0,02	0,162	0,181
<i>Steganotaenia araliacea</i>	0,044	0,049	0,036	0,167	0,08	0,216	0,297
<i>Strychnos innocua</i>	0,021	0,057	0,033	-	0,054	0,057	0,111
<i>Strychnos spinosa</i>	0,044	0,078	0,007	0,103	0,051	0,181	0,233
<i>Swartzia madagascariensis</i>	0,072	0,090	0,082	0,080	0,154	0,17	0,324
<i>Syzygium guineense var. g.</i>	1,140	0,563	0,236	0,511	1,376	1,074	2,450
<i>Syzygium guineense var. m.</i>	0,413	0,544	0,207	0,133	0,62	0,677	1,296
<i>Tamarindus indica</i>	0,161	1,897	0,193	0,396	0,354	2,293	2,646
<i>Terminalia laxiflora</i>	1,706	1,249	0,195	0,189	1,901	1,438	3,338
<i>Terminalia avicennioides</i>	1,352	1,535	0,105	0,131	1,457	1,666	3,123
<i>Terminalia glaucescens</i>	1,348	1,960	0,169	0,361	1,517	2,321	3,838
<i>Terminalia macroptera</i>	1,552	1,866	0,173	0,250	1,725	2,116	3,840
<i>Trichilia emetica</i>	0,009	0,053	0,010	0,058	0,019	0,111	0,130
<i>Uapaka togoensis</i>	0,044	0,267	0,074	0,129	0,118	0,396	0,514
<i>Uvaria chamae</i>	0,014	0,059	0,021	0,056	0,035	0,115	0,149
<i>Vitellaria paradoxa</i>	0,242	0,357	0,015	0,237	0,257	0,594	0,851
<i>Vitex doniana</i>	0,060	0,077	0,082	0,083	0,142	0,16	0,301
<i>Vitex simplicifolia</i>	0,108	0,067	0,097	0,074	0,205	0,141	0,347
<i>Ximenia americana</i>	0,068	0,146	0,085	0,142	0,153	0,288	0,441
<i>Ziziphus abiscenia</i>	0,103	0,150	0,157	0,157	0,26	0,307	0,566
<i>Ziziphus mucronata</i>	0,135	0,101	0,194	0,112	0,329	0,213	0,542
<i>Zyzyphus mauritiana</i>	0,096	0,130	0,142	0,115	0,238	0,245	0,483
Total	89 091,736	192 395,341	78 581,472	115 387,662	167673,208	307783,003	475 6,211

The aerial phytomass of sites not exploited by gold miners within protected areas are the higher than those of the operated sites. Considering the level of species, phytomass are higher in *Khaya senegalensis*, *Daniellia oliveri*, *Isoberlinia tomentosa*, *Terminalia macroptera*, *Terminalia glauscescens* and *Isoberlinia doka*. This high value is believed to be due to the absence of signs of deforestation such as excessive logging, uprooting of large trees and pruning in this area. However, the exploited zone of protected areas has the lowest phytomass value in *Gardenia aqualla* (0.001 t/ha), *Adenodouchos paniculatum* (0.003 t/ha), *Lannea shimperi* (0.005 t/ha). This low phytomass shows that the pressure of artisanal gold panning is very significant on the vegetation of the department of Mayo-Rey and is felt much more in protected areas. Therefore, this mining activity has a high influence on the production of aerial phytomass. The significant amount of phytomass observed in woody plants is explained by the fact that the environment is favorable for their development and therefore these species have large trunks. The total phytomass of 2 types of exploited sites (167,673.208 t/ha) is almost twice as low as that of non-exploited sites (307,783.003 t/ha). This difference can be explained by the exploitation of gold.

2- Root phytomass of woody plants in parks gold panning sites

Table 2 gives the different values of the root phytomass according to the parks and according to the type of site. A total of 42,041.852 t/ha of root phytomass is obtained from all the inventories carried out, i.e. 8,201.415 t/ha in the gold mining areas and 16,192.978 t/ha in the non-gold panning areas of the Benoue National Park (BNP); 7,340,359 t/ha in the gold panning areas and 10,307,099 t/ha in the non-gold panning areas of Bouba-Ndjidda National Park (BNNP). The root phytomass of non-gold panning areas (26,500 t/ha) within protected areas is higher than that of gold panning areas (155 41,774 t/ha). Considering the species, *Khaya senegalensis* (2.369 t/ha or 0.866 t/ha in the exploited sites and 1.503 t/ha

in the non-exploited sites) and *Isoberlinia tomentosa* (1.242 t/ha or 0.163 t/ha in the exploited sites and 1.079 t/ha in non-exploited sites) have the highest root phytomass value of around 1.356 t/ha, 0.947 t/ha and 0.611 t/ha, respectively. This high value is said to be due to the absence of signs of deforestation such as excessive logging, uprooting of large trees and pruning in this area. Nevertheless, the exploited zone of protected areas has the lowest phytomass value of around 0.001 t/ha for *Gardenia aqualla*, 0.002 t/ha for *Adenodouchos paniculatum*, 0.003 t/ha for *Lannea shimperi*. This low phytomass measurement still shows that the pressure of artisanal gold panning is very significant on the vegetation of the Mayo-Rey division and is felt much more in protected areas. Therefore, this mining activity has a high influence on the production of root phytomass.

3- Total phytomass of ligneous plants in the parks gold panning sites

The phytomass obtained for ligneous plants varies from one species to another and is higher in the non-gold panning zone than the zone already exploited or in exploitation (Table 3). A total of 517,498.06 t/ha of total biomass is obtained from all the inventories carried out, i.e. 97,293.15 t/ha in the gold panning part and 208,588.32 t/ha in the non-gold panning part of the Benoue National Park (BNP); 85,921.83 t/ha in the gold panning part and 125,694.761 t/ha in the non-gold panning part of Bouba-Ndjidda National Park (BNNP). Phytomass from areas not exploited by gold miners in protected areas have the highest average phytomass of around 10.04 t/ha in the species *khaya senegalensis*, i.e. 2.64 t/ha in the gold panning part and 6.03 t/ha in the non-gold panning part of Benoue National Park (BNP); 0.84 t/ha in the gold mining part and 125 0.527 t/ha in the non-gold panning part of Bouba-Ndjidda National Park (BNNP). This high value is thought to be due to the size of the trunk of the species. This low measurement of phytomass shows that the pressure of artisanal gold panning is very significant on the vegetation of the department of Mayo-Rey and is felt much more in unprotected areas.

Table 2: Root phytomass of woody plants in gold panning sites (t/ha)

Species	BNP		BNNP		Total		Total(t/ha)
	gold panning areas (t/ha)	non-gold panning areas (t/ha)	gold panning areas (t/ha)	non-gold panning areas (t/ha)	Total of gold panning areas (t/ha)	Total of non-gold panning areas (t/ha)	
<i>Acacia ataxacantha</i>	0,024	0,022	0,087	0,094	0,111	0,116	0,227
<i>Acacia dudgeoni</i>	0,028	0,022	0,140	0,077	0,168	0,099	0,267
<i>Acacia hockii</i>	0,013	0,018	0,073	0,118	0,086	0,136	0,222
<i>Acacia polyacantha</i>	0,013	0,026	0,097	0,150	0,11	0,176	0,286
<i>Acacia polyacantha var c.</i>	0,040	0,110	0,054	0,082	0,094	0,192	0,286
<i>Acacia senegalensis</i>	0,060	0,067	0,130	0,055	0,19	0,122	0,311
<i>Acacia sieberiana</i>	0,054	0,065	0,052	0,081	0,106	0,146	0,251
<i>Adenodouchos paniculatum</i>	0,002	0,025	0,003	0,041	0,005	0,066	0,071
<i>Adenolobus paniculatum</i>	0,046	0,051	0,046	0,056	0,092	0,107	0,199
<i>Adenolobus rufescens</i>	0,033	0,052	0,034	0,089	0,067	0,141	0,209
<i>Azelia africana</i>	0,200	0,251	0,044	0,078	0,244	0,329	0,573
<i>Albizia zygia</i>	0,030	0,043	0,005	0,085	0,035	0,128	0,164
<i>Allophyllus africanus</i>	0,026	0,044	0,059	0,047	0,085	0,091	0,176
<i>Annona senegalensis</i>	0,014	0,007	0,019	0,029	0,033	0,036	0,070
<i>Anogeissus leiocarpus</i>	0,065	0,086	0,079	0,070	0,144	0,156	0,300
<i>Antidesma venosum</i>	0,015	0,040	0,050	0,055	0,065	0,095	0,161
<i>Berlinia grandiflora</i>	0,012	0,033	0,015	0,027	0,027	0,06	0,086
<i>Bombax costatum</i>	0,323	0,458	0,014	0,061	0,337	0,519	0,856
<i>Borassus sp</i>	0,171	0,210	0,032	0,091	0,203	0,301	0,504
<i>Boswellia dalzielii</i>	0,040	0,044	0,051	0,035	0,091	0,079	0,170
<i>Boswellia papyrifera</i>	0,026	0,116	0,057	0,053	0,083	0,169	0,253
<i>Bridellia ferruginea</i>	0,005	0,007	0,019	0,015	0,024	0,022	0,046
<i>Bridellia scleroclaria</i>	0,005	0,007	0,010	0,031	0,015	0,038	0,053
<i>Burkia africana</i>	0,079	0,111	0,012	0,064	0,091	0,175	0,266
<i>Cassia sieberiana</i>	0,037	0,096	0,062	0,057	0,099	0,153	0,252

<i>Clerodendrum capitatum</i>	0,022	0,024	0,017	0,347	0,039	0,371	0,411
<i>Combretum collinum</i>	0,111	0,120	0,073	0,080	0,184	0,2	0,383
<i>Combretum glutinosum</i>	0,096	0,101	0,029	0,037	0,125	0,138	0,263
<i>Combretum molle</i>	0,051	0,076	0,028	0,022	0,079	0,098	0,177
<i>Combretum nigricans</i>	0,087	0,112	0,041	0,075	0,128	0,187	0,316
<i>Combretum paniculatum</i>	0,015	0,061	0,018	0,051	0,033	0,112	0,144
<i>Cussonia arborea</i>	0,005	0,020	0,004	0,026	0,009	0,046	0,056
<i>Crossopteryx febrifuga</i>	0,077	0,022	0,022	0,347	0,099	0,369	0,468
<i>Daniellia oliveri</i>	0,255	0,759	0,191	0,103	0,446	0,862	1,307
<i>Desmodium vitelinum</i>	0,035	0,091	0,039	0,081	0,074	0,172	0,247
<i>Detarium microcarpum</i>	0,052	0,062	0,054	0,059	0,106	0,121	0,226
<i>Dichrostachys cinerea</i>	0,022	0,033	0,019	0,047	0,041	0,08	0,121
<i>Diospyros mespiliformis</i>	0,053	0,118	0,061	0,103	0,114	0,221	0,335
<i>Entada africana</i>	0,016	0,059	0,025	0,039	0,041	0,098	0,138
<i>Erythrina senegalensis</i>	0,007	0,022	0,014	0,347	0,021	0,369	0,390
<i>Ficus capensis</i>	0,133	0,157	0,030	0,041	0,163	0,198	0,361
<i>Ficus cordata</i>	0,126	0,327	0,025	0,037	0,151	0,364	0,515
<i>Ficus glaucescens</i>	0,079	0,022	0,022	0,347	0,101	0,369	0,470
<i>Ficus platyphylla</i>	0,186	0,301	0,019	0,038	0,205	0,339	0,543
<i>Ficus sycomorus</i>	0,173	0,296	0,036	0,046	0,209	0,342	0,551
<i>Ficus thonningii</i>	0,243	0,466	0,068	0,076	0,311	0,542	0,853
<i>Forea ratchetiana</i>	0,006	0,008	0,019	0,023	0,025	0,031	0,056
<i>Gardenia aqualla</i>	0,001	0,003	0,032	0,031	0,033	0,034	0,066
<i>Grewia bicolor</i>	0,012	0,048	0,023	0,024	0,035	0,072	0,107
<i>Grewia flavenscens</i>	0,011	0,039	0,020	0,022	0,031	0,061	0,092
<i>Haematostaphis barbari</i>	0,014	0,022	0,022	0,347	0,036	0,369	0,406
<i>Harungana madagascariensis</i>	0,129	0,252	0,062	0,064	0,191	0,316	0,507
<i>Hymenocardia acida</i>	0,037	0,153	0,065	0,086	0,102	0,239	0,340
<i>Isoberlinia doka</i>	0,411	0,611	0,084	0,108	0,495	0,719	1,213
<i>Isoberlinia tomentosa</i>	0,022	0,947	0,141	0,132	0,163	1,079	1,242
<i>khaya senegalensis</i>	0,641	1,356	0,225	0,147	0,866	1,503	2,369
<i>Kigelia africana</i>	0,009	0,022	0,022	0,347	0,031	0,369	0,400
<i>Klorklospermum plancini</i>	0,033	0,091	0,065	0,017	0,098	0,108	0,207

<i>Lannea fruticosa</i>	0,018	0,063	0,025	0,066	0,043	0,129	0,172
<i>Lannea humilis</i>	0,016	0,046	0,028	0,032	0,044	0,078	0,122
<i>Lannea kerstingi</i>	0,022	0,020	0,016	0,025	0,038	0,045	0,082
<i>Lannea shimperi</i>	0,003	0,022	0,022	0,347	0,025	0,369	0,395
<i>Lippia adoensis</i>	0,022	0,083	0,023	0,067	0,045	0,15	0,196
<i>Lonchocarpus laxiflorus</i>	0,019	0,099	0,022	0,084	0,041	0,183	0,224
<i>Lophira lanceolata</i>	0,009	0,033	0,011	0,035	0,02	0,068	0,088
<i>Malacantha alnifolia</i>	0,022	0,045	0,041	0,072	0,063	0,117	0,180
<i>Maytenus senegalensis</i>	0,047	0,034	0,060	0,038	0,107	0,072	0,180
<i>Mitragyna inermis</i>	0,027	0,043	0,027	0,053	0,054	0,096	0,150
<i>Monotes kerstingii</i>	0,192	0,216	0,088	0,110	0,28	0,326	0,606
<i>Nauclea latifolia</i>	0,030	0,011	0,026	0,013	0,056	0,024	0,080
<i>Ochna rhizomatosa</i>	0,028	0,060	0,045	0,059	0,073	0,119	0,192
<i>Ochna ovata</i>	0,012	0,016	0,014	0,013	0,026	0,029	0,056
<i>Ochna schweinfurthiana</i>	0,022	0,082	0,010	0,079	0,032	0,161	0,193
<i>Opilia amenthacea</i>	0,029	0,048	0,048	0,029	0,077	0,077	0,154
<i>Ozoroa insignis</i>	0,008	0,016	0,053	0,009	0,061	0,025	0,086
<i>Parinari curatellifolia</i>	0,022	0,050	0,014	0,053	0,036	0,103	0,139
<i>Parkia biglobosa</i>	0,018	0,069	0,025	0,065	0,043	0,134	0,177
<i>Pavetta crassipes</i>	0,022	0,031	0,035	0,027	0,057	0,058	0,115
<i>Pericopsis laxiflora</i>	0,047	0,102	0,053	0,109	0,1	0,211	0,311
<i>Phyllantus welwitschianus</i>	0,022	0,033	0,038	0,037	0,06	0,07	0,129
<i>Piliostigma thonningii</i>	0,014	0,038	0,017	0,031	0,031	0,069	0,100
<i>Prosopis africana</i>	0,022	0,061	0,026	0,076	0,048	0,137	0,184
<i>Protea occidentalis</i>	0,018	0,031	0,027	0,027	0,045	0,058	0,104
<i>Pseudocedrela kotschy</i>	0,157	0,269	0,068	0,139	0,225	0,408	0,634
<i>Psorospermum febrifugum</i>	0,094	0,155	0,109	0,128	0,203	0,283	0,487
<i>Psorospermum senegalensis</i>	0,113	0,087	0,097	0,095	0,21	0,182	0,392
<i>Pterocarpus erinaceus</i>	0,133	0,345	0,023	0,070	0,156	0,415	0,571
<i>Pterocarpus lucens</i>	0,058	0,270	0,084	0,159	0,142	0,429	0,571
<i>Securidaca longepedunculata</i>	0,028	0,045	0,033	0,048	0,061	0,093	0,153
<i>Securinega virosa</i>	0,031	0,039	0,053	0,044	0,084	0,083	0,168

<i>Sterculia setigera</i>	0,024	0,022	0,022	0,347	0,046	0,369	0,415
<i>Stereopermim khunthianum</i>	0,004	0,030	0,007	0,045	0,011	0,075	0,086
<i>Steganotaenia araliacea</i>	0,022	0,024	0,018	0,071	0,04	0,095	0,136
<i>Strychnos innocua</i>	0,011	0,028	0,017	0,347	0,028	0,375	0,403
<i>Strychnos spinosa</i>	0,022	0,036	0,004	0,047	0,026	0,083	0,110
<i>Swartzia madagascariensis</i>	0,034	0,041	0,038	0,037	0,072	0,078	0,151
<i>Syzygium guineense var.g</i>	0,390	0,209	0,097	0,192	0,487	0,401	0,887
<i>Syzygium guineense var.m</i>	0,159	0,203	0,086	0,058	0,245	0,261	0,506
<i>Tamarindus indica</i>	0,069	0,611	0,081	0,153	0,15	0,764	0,914
<i>Terminalia laxiflora</i>	0,556	0,422	0,082	0,080	0,638	0,502	1,140
<i>Terminalia avicennioides</i>	0,453	0,507	0,047	0,058	0,5	0,565	1,064
<i>Terminalia glaucescens</i>	0,452	0,629	0,072	0,141	0,524	0,77	1,293
<i>Terminalia macroptera</i>	0,512	0,602	0,073	0,102	0,585	0,704	1,289
<i>Trichilia emetica</i>	0,005	0,026	0,006	0,028	0,011	0,054	0,065
<i>Uapaka togoensis</i>	0,022	0,108	0,035	0,057	0,057	0,165	0,222
<i>Uvaria chamae</i>	0,008	0,028	0,011	0,027	0,019	0,055	0,075
<i>Vitellaria paradoxa</i>	0,099	0,140	0,008	0,097	0,107	0,237	0,344
<i>Vitex doniana</i>	0,029	0,036	0,038	0,038	0,067	0,074	0,141
<i>Vitex simplicifolia</i>	0,049	0,032	0,044	0,035	0,093	0,067	0,159
<i>Ximenia americana</i>	0,032	0,063	0,039	0,062	0,071	0,125	0,197
<i>Ziziphus abiscenia</i>	0,046	0,065	0,067	0,068	0,113	0,133	0,246
<i>Ziziphus mucronata</i>	0,059	0,046	0,082	0,050	0,141	0,096	0,237
<i>Zyzyphus mauritiana</i>	0,044	0,057	0,062	0,051	0,106	0,108	0,214
Total	8 01,415	16 192,978	7 40,359	10 307,099	15541,774	26500,077	4241,852

Table 3: Total woody biomass in gold panning sites

Species	BNP		BNNP		Total		Total(t/ha)
	gold panning areas (t/ha)	non-gold panning areas (t/ha)	gold panning areas (t/ha)	non-gold panning areas (t/ha)	Total of gold panning areas (t/ha)	Total of non-gold panning areas (t/ha)	
<i>Acacia ataxacantha</i>	0,071	0,067	0,297	0,321	0,368	0,388	0,757
<i>Acacia dudgeoni</i>	0,085	0,067	0,499	0,260	0,584	0,327	0,910
<i>Acacia hockii</i>	0,039	0,053	0,246	0,412	0,285	0,465	0,749
<i>Acacia polyacantha</i>	0,036	0,080	0,334	0,539	0,37	0,619	0,989
<i>Aciacia polyacantha var c.</i>	0,126	0,383	0,174	0,277	0,3	0,66	0,961
<i>Acacia senegalensis</i>	0,196	0,223	0,459	0,178	0,655	0,401	1,056
<i>Acacia sieberiana</i>	0,176	0,215	0,167	0,273	0,343	0,488	0,832
<i>Adenodouchos paniculatum</i>	0,006	0,075	0,008	0,131	0,014	0,206	0,220
<i>Adenolobus paniculatum</i>	0,147	0,165	0,149	0,182	0,296	0,347	0,643
<i>Adenolobus rufescens</i>	0,103	0,169	0,107	0,303	0,21	0,472	0,683
<i>Azelia africana</i>	0,738	0,944	0,139	0,264	0,877	1,208	2,085
<i>Albizia zygia</i>	0,094	0,138	0,014	0,290	0,108	0,428	0,536
<i>Allophyllus africanus</i>	0,079	0,141	0,193	0,152	0,272	0,293	0,565
<i>Annona senegalensis</i>	0,042	0,020	0,055	0,091	0,097	0,111	0,208
<i>Anogeissus leiocarpus</i>	0,214	0,291	0,266	0,235	0,48	0,526	1,006
<i>Antidesma venosum</i>	0,045	0,127	0,161	0,181	0,206	0,308	0,514
<i>Berlinia grandiflora</i>	0,033	0,104	0,042	0,081	0,075	0,185	0,261
<i>Bombax costatum</i>	1,247	1,827	0,040	0,200	1,287	2,027	3,315
<i>Borassus sp</i>	0,619	0,778	0,099	0,310	0,718	1,088	1,806
<i>Boswellia dalzielii</i>	0,127	0,141	0,165	0,108	0,292	0,249	0,541
<i>Boswellia papylifera</i>	0,080	0,406	0,188	0,173	0,268	0,579	0,846
<i>Bridellia ferruginea</i>	0,014	0,020	0,055	0,044	0,069	0,064	0,133
<i>Bridellia scleroclaria</i>	0,013	0,020	0,028	0,097	0,041	0,117	0,158
<i>Burkia africana</i>	0,266	0,385	0,034	0,211	0,3	0,596	0,897
<i>Cassia sieberiana</i>	0,115	0,330	0,205	0,185	0,32	0,515	0,836
<i>Clerodendrum capitatum</i>	0,067	0,074	0,050	0,347	0,117	0,421	0,538
<i>Combretum collinum</i>	0,386	0,420	0,243	0,268	0,629	0,688	1,317
<i>Combretum glutinosum</i>	0,331	0,347	0,088	0,116	0,419	0,463	0,883

<i>Combretum molle</i>	0,165	0,256	0,085	0,067	0,25	0,323	0,573
<i>Combretum nigricans</i>	0,297	0,389	0,132	0,253	0,429	0,642	1,071
<i>Combretum paniculatum</i>	0,044	0,200	0,053	0,164	0,097	0,364	0,460
<i>Cussonia arborea</i>	0,014	0,060	0,011	0,080	0,025	0,14	0,165
<i>Crossopteryx febrifuga</i>	0,258	0,067	0,067	0,347	0,325	0,414	0,738
<i>Daniellia oliveri</i>	0,961	3,184	0,699	0,355	1,66	3,539	5,199
<i>Desmodium vitelinum</i>	0,111	0,309	0,125	0,275	0,236	0,584	0,820
<i>Detarium microcarpum</i>	0,167	0,203	0,177	0,192	0,344	0,395	0,740
<i>Dichrostachys cinerea</i>	0,067	0,102	0,057	0,152	0,124	0,254	0,377
<i>Diospyros mespiliformis</i>	0,173	0,413	0,200	0,358	0,373	0,771	1,144
<i>Entada africana</i>	0,047	0,193	0,075	0,122	0,122	0,315	0,437
<i>Erythrina senegalensis</i>	0,020	0,067	0,040	0,347	0,06	0,414	0,473
<i>Ficus capensis</i>	0,471	0,564	0,094	0,131	0,565	0,695	1,259
<i>Ficus cordata</i>	0,443	1,263	0,076	0,116	0,519	1,379	1,898
<i>Ficus glaucescens</i>	0,267	0,067	0,067	0,347	0,334	0,414	0,747
<i>Ficus platyphylla</i>	0,682	1,151	0,055	0,118	0,737	1,269	2,007
<i>Ficus sycomorus</i>	0,628	1,132	0,113	0,147	0,741	1,279	2,019
<i>Ficus thonningii</i>	0,913	1,861	0,226	0,257	1,139	2,118	3,256
<i>Forea ratchetiana</i>	0,015	0,022	0,058	0,071	0,073	0,093	0,165
<i>Gardenia aqualla</i>	0,002	0,006	0,099	0,095	0,101	0,101	0,203
<i>Grewia bicolor</i>	0,033	0,153	0,070	0,073	0,103	0,226	0,330
<i>Grewia flavenscens</i>	0,031	0,124	0,058	0,067	0,089	0,191	0,281
<i>Haematostaphis barbari</i>	0,042	0,067	0,067	0,347	0,109	0,414	0,522
<i>Harungana madagascaiensis</i>	0,455	0,949	0,204	0,210	0,659	1,159	1,819
<i>Hymenocardia acida</i>	0,115	0,548	0,216	0,291	0,331	0,839	1,171
<i>Isoberlinia doka</i>	1,621	2,508	0,286	0,373	1,907	2,881	4,788
<i>Isoberlinia tomentosa</i>	0,067	4,063	0,501	0,467	0,568	4,53	5,098
<i>khaya senegalensis</i>	2,643	6,032	0,839	0,527	3,482	6,559	10,041
<i>Kigelia africana</i>	0,025	0,067	0,067	0,347	0,092	0,414	0,505
<i>Klosklospermum plancini</i>	0,104	0,311	0,215	0,051	0,319	0,362	0,681
<i>Lannea fruticosa</i>	0,053	0,210	0,076	0,217	0,129	0,427	0,556
<i>Lannea humilis</i>	0,047	0,146	0,087	0,099	0,134	0,245	0,379
<i>Lannea kerstingi</i>	0,067	0,060	0,045	0,074	0,112	0,134	0,246
<i>Lannea shimperi</i>	0,009	0,067	0,067	0,347	0,076	0,414	0,489

<i>Lippia adoensis</i>	0,067	0,281	0,070	0,224	0,137	0,505	0,642
<i>Lonchocarpus laxiflorus</i>	0,056	0,340	0,067	0,286	0,123	0,626	0,749
<i>Lophira lanceolata</i>	0,026	0,102	0,031	0,111	0,057	0,213	0,270
<i>Malacantha alnifolia</i>	0,067	0,145	0,130	0,240	0,197	0,385	0,581
<i>Maytenus senegalensis</i>	0,152	0,108	0,197	0,121	0,349	0,229	0,577
<i>Mitragyna inermis</i>	0,081	0,138	0,082	0,174	0,163	0,312	0,475
<i>Monotes kerstingii</i>	0,704	0,802	0,298	0,384	1,002	1,186	2,188
<i>Nauclea latifolia</i>	0,093	0,031	0,079	0,036	0,172	0,067	0,240
<i>Ochna rhizomatosa</i>	0,086	0,197	0,144	0,194	0,23	0,391	0,621
<i>Ochna ovata</i>	0,033	0,048	0,041	0,038	0,074	0,086	0,160
<i>Ochna schweinfurthiana</i>	0,067	0,278	0,027	0,265	0,094	0,543	0,637
<i>Opilia amenthacea</i>	0,090	0,154	0,154	0,090	0,244	0,244	0,488
<i>Ozoroa insignis</i>	0,023	0,048	0,171	0,024	0,194	0,072	0,266
<i>Parinari curatellifolia</i>	0,067	0,160	0,041	0,174	0,108	0,334	0,441
<i>Parkia biglobosa</i>	0,054	0,230	0,076	0,216	0,13	0,446	0,576
<i>Pavetta crassipes</i>	0,067	0,094	0,111	0,082	0,178	0,176	0,353
<i>Pericopsis laxiflora</i>	0,153	0,352	0,172	0,377	0,325	0,729	1,054
<i>Phyllanthus welwitschianus</i>	0,067	0,101	0,120	0,116	0,187	0,217	0,403
<i>Piliostigma thonningii</i>	0,041	0,119	0,050	0,097	0,091	0,216	0,308
<i>Prosopis africana</i>	0,066	0,200	0,078	0,255	0,144	0,455	0,600
<i>Protea occidentalis</i>	0,054	0,096	0,083	0,083	0,137	0,179	0,316
<i>Pseudocedrela kotschy</i>	0,566	1,021	0,227	0,495	0,793	1,516	2,308
<i>Psorospermum febrifugum</i>	0,324	0,557	0,379	0,452	0,703	1,009	1,712
<i>Psorospermum senegalensis</i>	0,394	0,298	0,333	0,326	0,727	0,624	1,351
<i>Pterocarpus erinaceus</i>	0,470	1,340	0,069	0,234	0,539	1,574	2,113
<i>Pterocarpus lucens</i>	0,190	1,023	0,284	0,572	0,474	1,595	2,069
<i>Securidaca longepedunculata</i>	0,084	0,143	0,102	0,154	0,186	0,297	0,483
<i>Securinega virosa</i>	0,097	0,123	0,173	0,142	0,27	0,265	0,535
<i>Sterculia setigera</i>	0,073	0,067	0,067	0,347	0,14	0,414	0,553
<i>Stereopermim khunthianum</i>	0,011	0,093	0,020	0,144	0,031	0,237	0,267
<i>Steganotaenia araliacea</i>	0,067	0,073	0,055	0,238	0,122	0,311	0,433
<i>Strychnos innocua</i>	0,032	0,084	0,050	0,347	0,082	0,431	0,513
<i>Strychnos spinosa</i>	0,067	0,115	0,012	0,150	0,079	0,265	0,343
<i>Swartzia madagascariensis</i>	0,106	0,132	0,120	0,117	0,226	0,249	0,475

<i>Syzygium guineense</i> var. <i>g.</i>	1,530	0,772	0,332	0,703	1,862	1,475	3,337
<i>Syzygium guineense</i> var. <i>m.</i>	0,571	0,746	0,293	0,191	0,864	0,937	1,802
<i>Tamarindus indica</i>	0,230	2,507	0,274	0,549	0,504	3,056	3,560
<i>Terminalia laxiflora</i>	2,262	1,671	0,276	0,269	2,538	1,94	4,478
<i>Terminalia avicennioides</i>	1,805	2,041	0,152	0,189	1,957	2,23	4,188
<i>Terminalia glaucescens</i>	1,799	2,589	0,241	0,502	2,04	3,091	5,131
<i>Terminalia macroptera</i>	2,063	2,468	0,246	0,352	2,309	2,82	5,129
<i>Trichilia emetica</i>	0,014	0,078	0,016	0,086	0,03	0,164	0,195
<i>Uapaka togoensis</i>	0,067	0,375	0,109	0,185	0,176	0,56	0,736
<i>Uvaria chamae</i>	0,021	0,087	0,032	0,083	0,053	0,17	0,224
<i>Vitellaria paradoxa</i>	0,341	0,497	0,023	0,334	0,364	0,831	1,195
<i>Vitex doniana</i>	0,088	0,112	0,120	0,121	0,208	0,233	0,442
<i>Vitex simplicifolia</i>	0,157	0,099	0,141	0,109	0,298	0,208	0,506
<i>Ximenia americana</i>	0,100	0,209	0,124	0,204	0,224	0,413	0,637
<i>Ziziphus abiscenia</i>	0,149	0,215	0,224	0,224	0,373	0,439	0,812
<i>Ziziphus mucronata</i>	0,194	0,147	0,276	0,162	0,47	0,309	0,779
<i>Zyzyphus mauritiana</i>	0,140	0,187	0,204	0,166	0,344	0,353	0,697
Total	97 293,151	208 88,319	85 921,831	125694,761	183214,982	334283,08	517498,063

4- Carbon stock of ligneous plants in gold panning sites

Table 4 presents the capacity of the flora studied to reverse the trend of climate change from their stored carbons. The carbon production expressed in tC/ha/year is proportional to the quantity of phytomass produced in the different types of plant formation. Table 4 shows a higher carbon stock in the non-gold panning zone than in the gold panning zone. A total of 258,749,031 t/ha of stored carbon is obtained from all the inventories carried out, i.e. 48,646,576 t/ha in the gold panning part and 104,294,160 t/ha in the non-gold panning part of the Benoue National Park (BNP); i.e. 42,960.915 t/ha in the gold mining part and 62,847.381 t/ha in the non-gold panning part of Bouba-Ndjidda National Park (BNNP). In addition, the carbon stocks of species such as *khaya senegalensis* (5,020 t/ha), *Daniellia oliveri* (2,600 t/ha), *Terminalia glaucescens* (2,566 t/ha), *Terminalia macroptera* (2,565 t/ha), *Isobertia tomentosa* (2,549 t/ha), *Terminalia laxiflora* (2,239 t/ha), *Terminalia avicennioides* (2,094 t/ha), *Isobertia doka* (2,394 t/ha) are the highest in the gold mining sites of the Benoue and Bouba-Ndjidda National Parks. The conversion of savannahs into completely bare soil by the practice of gold panning leads to a drastic reduction in plant phytomasses and consequently in the carbon stored in the plants that composed them. Considering the results obtained by comparing carbon stocks in the exploited area and the unexploited zone, we have to remember that the capacity of species to reverse the effects of climate change is important if the vegetation is not destroyed. However, the vegetation in the exploited areas contributes to the reduction of the effects due to climate change but in a weak way.

5- Quantity of carbon dioxide (CO₂) emitted by the ligneous plants in the gold panning sites

The carbon sequestered in different types of land use depends on biomass and necromass. When

vegetation is cut and burned for agricultural purposes, the carbon that was sequestered in this vegetation is released and affects climate change. The amount of carbon dioxide (CO₂) that would be emitted into the atmosphere if the inventoried trees were completely destroyed varies according to the parks and zones (Table 5). This quantity of carbon dioxide (CO₂) that would be emitted into the atmosphere if the inventoried woody plants were completely destroyed is of the order of 1,743,339.44 tCO₂/ha, i.e. 326,669.70 tCO₂/ha in the gold panning sector and 705,449.58 tCO₂/ha in the non-gold panning part of Benoue National Park (BNP); i.e. 288,132.06 tCO₂/ha in the gold panning part and 423,088.09 tCO₂/ha in the non-gold panning part of the Bouba-Ndjidda National Park (BNNP). The practice of gold panning contributes to climate change when plots are converted and trees are felled. The emission of CO₂ (carbon dioxide) varies according to the type of zone (exploited and not exploited) and according to the different families of woody plants. The quantity of CO₂ emitted varies according to the volume of the diameter of the trunk and the number of individuals per hectare. The practice of gold panning through the blow of wood, the uprooting of trees has a strong impact on vegetation and therefore on the amount of carbon dioxide (CO₂) emitted by plants. Forests are important in the global carbon cycle because they store large amounts of carbon in vegetation and soil. They exchange carbon with the atmosphere through photosynthesis and respiration. They are the sources of atmospheric carbon when they are disturbed by anthropogenic actions. The development of a method for the rapid sequestration of CO₂ in the biosphere could significantly lower atmospheric CO₂ over the next 50 years pending the advent of more advanced and more permanent technology.

Table 4: Carbon stored (tC/ha)

Species	BNP		BNNP		Total of gold panningareas (tC/ha)	Total of non-gold panningareas (tC/ha)	Total (tC/ha)
	gold panningareas (Ct/ha)	non-gold panningareas (Ct/ha)	gold panningareas (Ct/ha)	non-gold panningareas (tC/ha)			
<i>Acacia ataxacantha</i>	0,036	0,034	0,149	0,161	0,185	0,195	0,378
<i>Acacia dudgeoni</i>	0,042	0,033	0,249	0,130	0,291	0,163	0,455
<i>Acacia hockii</i>	0,019	0,026	0,123	0,206	0,142	0,232	0,375
<i>Acacia polyacantha</i>	0,018	0,040	0,167	0,269	0,185	0,309	0,495
<i>Aciacia polyacantha var c</i>	0,063	0,192	0,087	0,139	0,15	0,331	0,481
<i>Acacia senegalensis</i>	0,098	0,111	0,230	0,089	0,328	0,2	0,528
<i>Acacia sieberiana</i>	0,088	0,107	0,084	0,137	0,172	0,244	0,416
<i>Adenodouchos paniculatum</i>	0,003	0,037	0,004	0,065	0,007	0,102	0,110
<i>Adenolobus paniculatum</i>	0,073	0,082	0,075	0,091	0,148	0,173	0,322
<i>Adenolobus rufenscens</i>	0,052	0,084	0,054	0,152	0,106	0,236	0,341
<i>Azelia africana</i>	0,369	0,472	0,070	0,132	0,439	0,604	1,042
<i>Albizia zygia</i>	0,047	0,069	0,007	0,145	0,054	0,214	0,268
<i>Allophyllus africanus</i>	0,039	0,070	0,096	0,076	0,135	0,146	0,282
<i>Annona senegalensis</i>	0,021	0,010	0,028	0,045	0,049	0,055	0,104
<i>Anogeissus leiocarpus</i>	0,107	0,146	0,133	0,117	0,24	0,263	0,503
<i>Antidesma venosum</i>	0,022	0,064	0,081	0,090	0,103	0,154	0,257
<i>Berlinia grandiflora</i>	0,017	0,052	0,021	0,041	0,038	0,093	0,130
<i>Bombax costatum</i>	0,624	0,914	0,020	0,100	0,644	1,014	1,658
<i>Borassus sp</i>	0,309	0,389	0,050	0,155	0,359	0,544	0,903
<i>Boswellia dalzielii</i>	0,063	0,070	0,082	0,054	0,145	0,124	0,270
<i>Boswellia papylifera</i>	0,040	0,203	0,094	0,086	0,134	0,289	0,423
<i>Bridellia ferruginea</i>	0,007	0,010	0,028	0,022	0,035	0,032	0,067
<i>Bridellia scleroclaria</i>	0,006	0,010	0,014	0,049	0,02	0,059	0,079
<i>Burkia africana</i>	0,133	0,193	0,017	0,106	0,15	0,299	0,448
<i>Cassia sieberiana</i>	0,058	0,165	0,103	0,093	0,161	0,258	0,418
<i>Clerodendrum capitatum</i>	0,033	0,037	0,025	0,173	0,058	0,21	0,269

<i>Combretum collinum</i>	0,193	0,210	0,122	0,134	0,315	0,344	0,659
<i>Combretum glutinosum</i>	0,165	0,174	0,044	0,058	0,209	0,232	0,441
<i>Combretum molle</i>	0,082	0,128	0,042	0,034	0,124	0,162	0,287
<i>Combretum nigricans</i>	0,149	0,194	0,066	0,126	0,215	0,32	0,535
<i>Combretum paniculatum</i>	0,022	0,100	0,026	0,082	0,048	0,182	0,230
<i>Cussonia arborea</i>	0,007	0,030	0,005	0,040	0,012	0,07	0,082
<i>Crossopteryx febrifuga</i>	0,129	0,033	0,033	0,173	0,162	0,206	0,369
<i>Daniellia oliveri</i>	0,480	1,592	0,350	0,177	0,83	1,769	2,600
<i>Desmodium vitelinum</i>	0,055	0,155	0,062	0,138	0,117	0,293	0,410
<i>Detarium microcarpum</i>	0,084	0,102	0,089	0,096	0,173	0,198	0,370
<i>Dichrostachys cinerea</i>	0,033	0,051	0,028	0,076	0,061	0,127	0,188
<i>Diospyros mespiliformis</i>	0,087	0,206	0,100	0,179	0,187	0,385	0,572
<i>Entada africana</i>	0,024	0,097	0,037	0,061	0,061	0,158	0,219
<i>Erytrina senegalensis</i>	0,010	0,033	0,020	0,173	0,03	0,206	0,236
<i>Ficus capensis</i>	0,235	0,282	0,047	0,065	0,282	0,347	0,630
<i>Ficus cordata</i>	0,222	0,632	0,038	0,058	0,26	0,69	0,949
<i>Ficus glaucescens</i>	0,133	0,033	0,033	0,173	0,166	0,206	0,373
<i>Ficus platyphylla</i>	0,341	0,576	0,028	0,059	0,369	0,635	1,003
<i>Ficus sycomorus</i>	0,314	0,566	0,056	0,074	0,37	0,64	1,010
<i>Ficus thonningii</i>	0,457	0,930	0,113	0,128	0,57	1,058	1,628
<i>Forea ratchetiana</i>	0,007	0,011	0,029	0,035	0,036	0,046	0,083
<i>Gardenia aqualla</i>	0,001	0,003	0,050	0,048	0,051	0,051	0,101
<i>Grewia bicolor</i>	0,017	0,077	0,035	0,037	0,052	0,114	0,165
<i>Grewia flavescens</i>	0,016	0,062	0,029	0,033	0,045	0,095	0,140
<i>Haematostaphis barbari</i>	0,021	0,033	0,033	0,173	0,054	0,206	0,261
<i>Harungana madagascaiensis</i>	0,228	0,475	0,102	0,105	0,33	0,58	0,909
<i>Hymenocardia acida</i>	0,057	0,274	0,108	0,145	0,165	0,419	0,585
<i>Isobertia doka</i>	0,810	1,254	0,143	0,187	0,953	1,441	2,394
<i>Isobertia tomentosa</i>	0,033	2,032	0,251	0,233	0,284	2,265	2,549
<i>khaya senegalensis</i>	1,322	3,016	0,420	0,263	1,742	3,279	5,020
<i>Kigelia africana</i>	0,013	0,033	0,033	0,173	0,046	0,206	0,253
<i>Klosklospermum plancini</i>	0,052	0,155	0,107	0,026	0,159	0,181	0,341
<i>Lannea fruticosa</i>	0,026	0,105	0,038	0,109	0,064	0,214	0,278

<i>Lannea humilis</i>	0,023	0,073	0,043	0,049	0,066	0,122	0,189
<i>Lannea kerstingii</i>	0,033	0,030	0,023	0,037	0,056	0,067	0,123
<i>Lannea shimperii</i>	0,004	0,033	0,033	0,173	0,037	0,206	0,244
<i>Lippia adoensis</i>	0,033	0,141	0,035	0,112	0,068	0,253	0,321
<i>Lonchocarpus laxiflorus</i>	0,028	0,170	0,033	0,143	0,061	0,313	0,375
<i>Lophira lanceolata</i>	0,013	0,051	0,015	0,055	0,028	0,106	0,135
<i>Malacantha alnifolia</i>	0,033	0,073	0,065	0,120	0,098	0,193	0,291
<i>Maytenus senegalensis</i>	0,076	0,054	0,098	0,060	0,174	0,114	0,289
<i>Mitragyna inermis</i>	0,041	0,069	0,041	0,087	0,082	0,156	0,237
<i>Monotes kerstingii</i>	0,352	0,401	0,149	0,192	0,501	0,593	1,094
<i>Nauclea latifolia</i>	0,047	0,015	0,040	0,018	0,087	0,033	0,120
<i>Ochna rhizomatosa</i>	0,043	0,099	0,072	0,097	0,115	0,196	0,311
<i>Ochna ovata</i>	0,017	0,024	0,021	0,019	0,038	0,043	0,080
<i>Ochna schweinfurthiana</i>	0,033	0,139	0,013	0,133	0,046	0,272	0,318
<i>Opilia amenthacea</i>	0,045	0,077	0,077	0,045	0,122	0,122	0,244
<i>Ozoroa insignis</i>	0,012	0,024	0,085	0,012	0,097	0,036	0,133
<i>Parinari curatellifolia</i>	0,033	0,080	0,020	0,087	0,053	0,167	0,221
<i>Parkia biglobosa</i>	0,027	0,115	0,038	0,108	0,065	0,223	0,288
<i>Pavetta crassipes</i>	0,033	0,047	0,055	0,041	0,088	0,088	0,177
<i>Pericopsis laxiflora</i>	0,076	0,176	0,086	0,189	0,162	0,365	0,527
<i>Phyllanthus welwitschianus</i>	0,033	0,051	0,060	0,058	0,093	0,109	0,202
<i>Piliostigma thonningii</i>	0,020	0,060	0,025	0,049	0,045	0,109	0,154
<i>Prosopis africana</i>	0,033	0,100	0,039	0,128	0,072	0,228	0,300
<i>Protea occidentalis</i>	0,027	0,048	0,042	0,041	0,069	0,089	0,158
<i>Pseudocedrela kotschy</i>	0,283	0,510	0,113	0,248	0,396	0,758	1,154
<i>Psorospermum febrifugum</i>	0,162	0,279	0,189	0,226	0,351	0,505	0,856
<i>Psorospermum senegalensis</i>	0,197	0,149	0,167	0,163	0,364	0,312	0,675
<i>Pterocarpus erinaceus</i>	0,235	0,670	0,035	0,117	0,27	0,787	1,057
<i>Pterocarpus lucens</i>	0,095	0,511	0,142	0,286	0,237	0,797	1,034
<i>Securidaca longepedunculata</i>	0,042	0,071	0,051	0,077	0,093	0,148	0,241
<i>Securinega virosa</i>	0,048	0,062	0,086	0,071	0,134	0,133	0,267
<i>Sterculia setigera</i>	0,036	0,033	0,033	0,173	0,069	0,206	0,276

<i>Stereopermim khunthianum</i>	0,006	0,046	0,010	0,072	0,016	0,118	0,134
<i>Steganotaenia araliacea</i>	0,033	0,037	0,027	0,119	0,06	0,156	0,216
<i>Strychnos innocua</i>	0,016	0,042	0,025	0,173	0,041	0,215	0,257
<i>Strychnos spinosa</i>	0,033	0,057	0,006	0,075	0,039	0,132	0,171
<i>Swartzia madagascariensis</i>	0,053	0,066	0,060	0,058	0,113	0,124	0,237
<i>Syzygium guineense var.g.</i>	0,765	0,386	0,166	0,351	0,931	0,737	1,668
<i>Syzygium guineense var.m.</i>	0,286	0,373	0,147	0,096	0,433	0,469	0,901
<i>Tamarindus indica</i>	0,115	1,254	0,137	0,275	0,252	1,529	1,780
<i>Terminalia laxiflora</i>	1,131	0,836	0,138	0,135	1,269	0,971	2,239
<i>Terminalia avicennioides</i>	0,902	1,021	0,076	0,094	0,978	1,115	2,094
<i>Terminalia glaucescens</i>	0,900	1,295	0,120	0,251	1,02	1,546	2,566
<i>Terminalia macroptera</i>	1,032	1,234	0,123	0,176	1,155	1,41	2,565
<i>Trichilia emetica</i>	0,007	0,039	0,008	0,043	0,015	0,082	0,097
<i>Uapaka togoensis</i>	0,033	0,188	0,054	0,093	0,087	0,281	0,368
<i>Uvaria chamae</i>	0,011	0,044	0,016	0,041	0,027	0,085	0,112
<i>Vitellaria paradoxa</i>	0,170	0,248	0,012	0,167	0,182	0,415	0,598
<i>Vitex doniana</i>	0,044	0,056	0,060	0,061	0,104	0,117	0,221
<i>Vitex simplicifolia</i>	0,079	0,049	0,071	0,055	0,15	0,104	0,253
<i>Ximenia americana</i>	0,050	0,105	0,062	0,102	0,112	0,207	0,319
<i>Ziziphus abiscenia</i>	0,075	0,107	0,112	0,112	0,187	0,219	0,406
<i>Ziziphus mucronata</i>	0,097	0,073	0,138	0,081	0,235	0,154	0,389
<i>Zyzyphus mauritiana</i>	0,070	0,094	0,102	0,083	0,172	0,177	0,349
Total	48 646,576	104 294,160	42 960,915	62 847,381	91607,491	167141,541	258 749,031

Table 5: Quantity of carbon dioxide (CO₂) emitted by the ligneous plants in the sites

Species	PNB		PNBN		Total		Total global (tCO ₂ /ha)
	gold panningareas (tCO ₂ /ha)	non-gold panningareas (tCO ₂ /ha)	gold panningareas (tCO ₂ /ha)	non-gold panningareas (tCO ₂ /ha)	Total of gold panningareas (tCO ₂ /ha)	Total of non-gold panningareas (tCO ₂ /ha)	
<i>Acacia ataxacantha</i>	0,174	0,165	0,770	0,834	0,945	0,998	1,943
<i>Acacia dudgeoni</i>	0,209	0,163	1,315	0,670	1,524	0,833	2,357
<i>Acacia hockii</i>	0,092	0,128	0,632	1,080	0,724	1,208	1,932
<i>Acacia polyacantha</i>	0,086	0,198	0,869	1,424	0,955	1,621	2,577
<i>Aciacia polyacantha var c</i>	0,317	1,002	0,442	0,716	0,759	1,718	2,477
<i>Acacia senegalensis</i>	0,500	0,571	1,208	0,452	1,708	1,023	2,731
<i>Acacia sieberiana</i>	0,447	0,549	0,424	0,706	0,872	1,255	2,127
<i>Adenodouchos paniculatum</i>	0,013	0,184	0,018	0,329	0,031	0,513	0,543
<i>Adenolobus paniculatum</i>	0,371	0,417	0,377	0,464	0,748	0,881	1,628
<i>Adenolobus rufescens</i>	0,258	0,428	0,267	0,786	0,525	1,215	1,739
<i>Afzelia africana</i>	1,971	2,541	0,350	0,680	2,321	3,221	5,543
<i>Albizia zygia</i>	0,232	0,347	0,033	0,751	0,265	1,098	1,362
<i>Allophyllus africanus</i>	0,194	0,355	0,491	0,385	0,685	0,740	1,425
<i>Annona senegalensis</i>	0,101	0,047	0,134	0,225	0,235	0,272	0,507
<i>Anogeissus leiocarpus</i>	0,547	0,754	0,685	0,603	1,232	1,357	2,589
<i>Antidesma venosum</i>	0,108	0,320	0,409	0,460	0,516	0,779	1,296
<i>Berlinia grandiflora</i>	0,078	0,260	0,102	0,200	0,180	0,459	0,640
<i>Bombax costatum</i>	3,387	5,021	0,097	0,512	3,484	5,533	9,016
<i>Borassus sp</i>	1,643	2,082	0,246	0,804	1,889	2,886	4,775
<i>Boswellia dalzielii</i>	0,318	0,355	0,417	0,271	0,735	0,626	1,361
<i>Boswellia papylifera</i>	0,197	1,062	0,478	0,439	0,676	1,501	2,177
<i>Bridellia ferruginea</i>	0,033	0,046	0,134	0,105	0,167	0,152	0,319
<i>Bridellia scleroclaria</i>	0,029	0,046	0,065	0,242	0,095	0,287	0,382
<i>Burkia africana</i>	0,686	1,007	0,082	0,540	0,768	1,547	2,315

<i>Cassia sieberiana</i>	0,288	0,859	0,524	0,472	0,812	1,331	2,142
<i>Clerodendrum capitatum</i>	0,163	0,182	0,121	-	0,284	0,182	0,466
<i>Combretum collinum</i>	1,008	1,100	0,625	0,692	1,633	1,793	3,426
<i>Combretum glutinosum</i>	0,860	0,904	0,218	0,291	1,078	1,195	2,273
<i>Combretum molle</i>	0,417	0,660	0,210	0,165	0,627	0,825	1,452
<i>Combretum nigricans</i>	0,770	1,016	0,331	0,651	1,100	1,668	2,768
<i>Combretum paniculatum</i>	0,105	0,510	0,128	0,417	0,233	0,926	1,159
<i>Cussonia arborea</i>	0,032	0,147	0,024	0,196	0,057	0,343	0,400
<i>Crossopteryx febrifuga</i>	0,665	0,163	0,163	-	0,827	0,163	0,990
<i>Daniellia oliveri</i>	2,588	8,894	1,865	0,924	4,452	9,818	14,270
<i>Desmodium vitelinum</i>	0,277	0,802	0,312	0,711	0,589	1,514	2,103
<i>Detarium microcarpum</i>	0,424	0,520	0,450	0,490	0,874	1,009	1,884
<i>Dichrostachys cinerea</i>	0,163	0,253	0,137	0,384	0,300	0,637	0,938
<i>Diospyros mespiliformis</i>	0,440	1,082	0,510	0,932	0,950	2,014	2,964
<i>Entada africana</i>	0,113	0,493	0,183	0,306	0,297	0,799	1,096
<i>Erythrina senegalensis</i>	0,046	0,163	0,095	-	0,141	0,163	0,304
<i>Ficus capensis</i>	1,239	1,493	0,233	0,328	1,472	1,821	3,293
<i>Ficus cordata</i>	1,164	3,432	0,187	0,290	1,350	3,721	5,072
<i>Ficus glaucescens</i>	0,688	0,163	0,163	-	0,851	0,163	1,014
<i>Ficus platyphylla</i>	1,816	3,119	0,134	0,297	1,950	3,416	5,366
<i>Ficus sycomorus</i>	1,669	3,064	0,281	0,371	1,950	3,435	5,385
<i>Ficus thonningii</i>	2,456	5,115	0,579	0,662	3,034	5,777	8,811
<i>Forea ratchetiana</i>	0,034	0,051	0,140	0,173	0,175	0,224	0,399
<i>Gardenia aqualla</i>	0,005	0,014	0,246	0,236	0,251	0,251	0,501
<i>Grewia bicolor</i>	0,079	0,388	0,171	0,179	0,251	0,567	0,818
<i>Grewia flavenscens</i>	0,074	0,312	0,142	0,163	0,216	0,475	0,691
<i>Haematostaphis barbari</i>	0,100	0,163	0,163	-	0,263	0,163	0,426
<i>Harungana madagascariensis</i>	1,197	2,556	0,521	0,538	1,718	3,094	4,812
<i>Hymenocardia acida</i>	0,287	1,450	0,554	0,753	0,841	2,203	3,044
<i>Isoberlinia doka</i>	4,437	6,956	0,739	0,974	5,176	7,929	13,106
<i>Isoberlinia tomentosa</i>	0,163	11,426	1,322	1,227	1,485	12,654	14,139

<i>khaya senegalensis</i>	7,342	17,146	2,251	1,391	9,593	18,537	28,130
<i>Kigelia africana</i>	0,060	0,163	0,163	-	0,222	0,163	0,385
<i>Klosklospermum plancini</i>	0,260	0,806	0,549	0,124	0,809	0,931	1,740
<i>Lannea fruticosa</i>	0,127	0,536	0,187	0,556	0,315	1,093	1,407
<i>Lannea humilis</i>	0,112	0,369	0,214	0,246	0,327	0,616	0,942
<i>Lannea kerstingi</i>	0,163	0,145	0,109	0,183	0,272	0,328	0,600
<i>Lannea shimperi</i>	0,019	0,163	0,163	-	0,182	0,163	0,345
<i>Lippia adoensis</i>	0,163	0,727	0,172	0,575	0,335	1,302	1,637
<i>Lonchocarpus laxiflorus</i>	0,137	0,885	0,164	0,739	0,301	1,624	1,925
<i>Lophira lanceolata</i>	0,061	0,254	0,073	0,277	0,134	0,531	0,665
<i>Malacantha alnifolia</i>	0,163	0,366	0,326	0,616	0,489	0,982	1,471
<i>Maytenus senegalensis</i>	0,384	0,269	0,502	0,303	0,886	0,571	1,458
<i>Mitragyna inermis</i>	0,200	0,348	0,202	0,441	0,402	0,789	1,191
<i>Monotes kerstingii</i>	1,877	2,148	0,771	1,004	2,649	3,152	5,801
<i>Nauclea latifolia</i>	0,231	0,073	0,195	0,087	0,426	0,160	0,586
<i>Ochna rhizomatosa</i>	0,212	0,503	0,363	0,496	0,575	0,999	1,573
<i>Ochna ovata</i>	0,079	0,115	0,099	0,092	0,178	0,207	0,384
<i>Ochna schweinfurthiana</i>	0,163	0,718	0,064	0,684	0,226	1,402	1,628
<i>Opilia amenthacea</i>	0,222	0,391	0,391	0,222	0,612	0,612	1,225
<i>Ozoroa insignis</i>	0,054	0,116	0,434	0,057	0,488	0,173	0,661
<i>Parinari curatellifolia</i>	0,163	0,406	0,098	0,441	0,261	0,846	1,107
<i>Parkia biglobosa</i>	0,131	0,590	0,186	0,553	0,317	1,143	1,460
<i>Pavetta crassipes</i>	0,163	0,234	0,276	0,202	0,439	0,436	0,875
<i>Pericopsis laxiflora</i>	0,386	0,916	0,436	0,985	0,822	1,902	2,724
<i>Phyllanthus welwitschianus</i>	0,163	0,252	0,300	0,290	0,463	0,541	1,004
<i>Piliostigma thonningii</i>	0,098	0,299	0,121	0,242	0,219	0,541	0,760
<i>Prosopis africana</i>	0,161	0,511	0,193	0,658	0,354	1,169	1,522
<i>Protea occidentalis</i>	0,132	0,237	0,206	0,204	0,338	0,441	0,779
<i>Pseudocedrela kotschyi</i>	1,498	2,755	0,581	1,305	2,079	4,060	6,139
<i>Psorospermum febrifugum</i>	0,841	1,475	0,990	1,187	1,831	2,661	4,492
<i>Psorospermum senegalensis</i>	1,030	0,771	0,867	0,846	1,897	1,617	3,514
<i>Pterocarpus erinaceus</i>	1,238	3,647	0,169	0,601	1,407	4,248	5,655

<i>Pterocarpus lucens</i>	0,484	2,761	0,734	1,516	1,217	4,277	5,494
<i>Securidaca longepedunculata</i>	0,208	0,359	0,254	0,389	0,462	0,748	1,210
<i>Securinega virosa</i>	0,240	0,309	0,439	0,358	0,679	0,667	1,346
<i>Sterculia setigera</i>	0,179	0,163	0,163	-	0,342	0,163	0,504
<i>Stereopermim khunthianum</i>	0,025	0,229	0,047	0,362	0,072	0,591	0,663
<i>Steganothaenia araliacea</i>	0,163	0,180	0,133	0,611	0,296	0,792	1,087
<i>Strychnos innocua</i>	0,076	0,209	0,121	-	0,197	0,209	0,405
<i>Strychnos spinosa</i>	0,163	0,286	0,026	0,379	0,189	0,666	0,855
<i>Swartzia madagascariensis</i>	0,265	0,331	0,300	0,292	0,565	0,623	1,188
<i>Syzygium guineense var. g.</i>	4,180	2,064	0,864	1,875	5,044	3,938	8,983
<i>Syzygium guineense var. m.</i>	1,513	1,994	0,759	0,487	2,272	2,481	4,753
<i>Tamarindus indica</i>	0,589	6,955	0,707	1,453	1,296	8,407	9,704
<i>Terminalia laxiflora</i>	6,254	4,580	0,714	0,694	6,967	5,274	12,241
<i>Terminalia avicennioides</i>	4,957	5,628	0,385	0,481	5,343	6,109	11,451
<i>Terminalia glaucescens</i>	4,942	7,188	0,618	1,324	5,560	8,512	14,072
<i>Terminalia macroptera</i>	5,690	6,841	0,633	0,916	6,324	7,757	14,081
<i>Trichilia emetica</i>	0,033	0,193	0,038	0,212	0,071	0,405	0,476
<i>Uapaka togoensis</i>	0,163	0,980	0,271	0,472	0,434	1,452	1,886
<i>Uvaria chamae</i>	0,050	0,216	0,077	0,205	0,127	0,421	0,548
<i>Vitellaria paradoxa</i>	0,887	1,309	0,054	0,870	0,941	2,179	3,120
<i>Vitex doniana</i>	0,218	0,281	0,300	0,304	0,519	0,585	1,103
<i>Vitex simplicifolia</i>	0,398	0,245	0,356	0,272	0,753	0,517	1,271
<i>Ximenia americana</i>	0,248	0,535	0,311	0,521	0,559	1,056	1,616
<i>Ziziphus abiscenia</i>	0,376	0,549	0,574	0,575	0,951	1,124	2,075
<i>Ziziphus mucronata</i>	0,495	0,370	0,713	0,410	1,208	0,780	1,988
<i>Zyzyphus mauritiana</i>	0,353	0,476	0,522	0,421	0,875	0,897	1,772
Total	326 669,700	705 449,583	288 132,063	423 088,095	614 801,762	1 128 537,678	1 743 339,440

6- Carbon credit or carbon market in gold panning sites

The amount of CO₂ released into the atmosphere if the woody species inventoried have not been destroyed can be capitalized on in the form of carbon credit or carbon market. It is from the stored carbon that the carbon credit was deducted. Therefore, a total monetary value of US \$ 24,581,157.978 is obtained from all plant inventories in the study area, i.e. US \$ 4,621,424,676 in the gold panning part and US \$ 9,907,945,167 in the no gold washing in the Benoue National Park (BNP); or US \$ 4,081,286.972 in the gold panning part and US \$ 5,970,501,163 in the non-gold panning part of Bouba-Ndjidda National Park (BNNP). This mining activity has a strong impact on the vegetation and consequently on the production of phytomass. This carbon credit is a means of improving the living conditions of the population through the financial resources allocated to them under the United Nations Framework Convention on Climate Change (UNFCCC). The amount of carbon stock sequestered by trees confirms the important role of woody plants in carbon sequestration. Raising public awareness of carbon credit would encourage farmers to conserve their plant cover. These ideas point in the same direction on the solution contained in REDD+ which offers individuals, communities, local governments and national rewards for the conservation of their forests. In this last aspect, the Kyoto protocol and the carbon market play an innovative role. Indeed, carbon sequestration and

its exchange represent an extremely interesting potential for this locality by allowing the influx of financial and vital resources for the local populations. Perceived as a means of attracting credit financing, REDD+ is a mechanism for conserving biodiversity-rich tropical forests and generating a new stream of income in these regions for poor people living in rural areas Carmenza *et al.* (2010).

Conclusion

The present work consisted in evaluating the impact of the effects of the pressure exerted by the practice of gold panning on the biomass of woody plants in the protected areas of the department of Mayo-Rey. The floristic inventories carried out in the study area led to the constitution of a floristic list of 113 species which are divided into 65 genera and 35 families and an average density equal to 2302 individuals/ha. A total of 258,749.03 t/ha of stored carbon is obtained from the inventories, i.e. 48,646.57 t/ha in the gold panning part and 104,294.16 t/ha in the non-gold panning part of Benoue National Park (BNP); 42,960.91 t/ha in the gold mining part and 62,847.38 t/ha in the non-gold panning part of Bouba-Ndjidda National Park (BNNP). The carbon stock is higher in the control zone than in the exploited zone. Gold panning therefore contributes to climate change when plots are converted and woody plants are cut down.

Table 6: Carbon credit for woody plants (CC) (\$) in gold panning sites

Espèces	PNB		PNBN		Total		Total (\$)
	gold panning areas	non-gold panning areas	gold panning areas	non-gold panning areas	Total of gold panning areas	Total of non-gold panning areas	
<i>Acacia ataxacantha</i>	3,375	3,196	14,131	15,252	17,506	18,448	35,954
<i>Acacia dudgeoni</i>	4,026	3,162	23,694	12,348	27,72	15,51	43,230
<i>Acacia hockii</i>	1,831	2,503	11,668	19,584	13,499	22,087	35,587
<i>Acacia polyacantha</i>	1,713	3,810	15,878	25,587	17,591	29,397	46,988
<i>Aciacia polyacantha var c</i>	6,002	18,214	8,274	13,166	14,276	31,38	45,656
<i>Acacia senegalensis</i>	9,312	10,582	21,824	8,444	31,136	19,026	50,161
<i>Acacia sieberiana</i>	8,366	10,197	7,945	12,989	16,311	23,186	39,497
<i>Adenodouchos paniculatum</i>	0,277	3,554	0,383	6,213	0,66	9,767	10,428
<i>Adenolobus paniculatum</i>	6,976	7,818	7,090	8,659	14,066	16,477	30,543
<i>Adenolobus rufescens</i>	4,916	8,023	5,090	14,411	10,006	22,434	32,439
<i>Azzeria africana</i>	35,055	44,833	6,607	12,535	41,662	57,368	99,030
<i>Albizia zygia</i>	4,443	6,541	0,676	13,788	5,119	20,329	25,448
<i>Allophyllus africanus</i>	3,735	6,696	9,157	7,229	12,892	13,925	26,817
<i>Annona senegalensis</i>	1,994	0,955	2,624	4,314	4,618	5,269	9,887
<i>Anogeissus leiocarpus</i>	10,162	13,843	12,613	11,153	22,775	24,996	47,771
<i>Antidesma venosum</i>	2,126	6,052	7,664	8,584	9,79	14,636	24,426
<i>Berlinia grandiflora</i>	1,568	4,951	2,015	3,849	3,583	8,8	12,383
<i>Bombax costatum</i>	59,238	86,803	1,915	9,518	61,153	96,321	157,473
<i>Borassus sp</i>	29,386	36,968	4,703	14,722	34,089	51,69	85,779
<i>Boswellia dalzielii</i>	6,014	6,696	7,818	5,151	13,832	11,847	25,679
<i>Boswellia papyrifera</i>	3,803	19,279	8,918	8,205	12,721	27,484	40,205
<i>Bridellia ferruginea</i>	0,686	0,949	2,619	2,080	3,305	3,029	6,334

<i>Bridellia scleroclaria</i>	0,613	0,939	1,319	4,619	1,932	5,558	7,489
<i>Burkia africana</i>	12,632	18,308	1,638	10,025	14,27	28,333	42,603
<i>Cassia sieberiana</i>	5,468	15,695	9,740	8,803	15,208	24,498	39,706
<i>Clerodendrum capitatum</i>	3,162	3,517	2,380	16,478	5,542	19,995	25,537
<i>Combretum collinum</i>	18,328	19,943	11,543	12,748	29,871	32,691	62,561
<i>Combretum glutinosum</i>	15,708	16,495	4,192	5,530	19,9	22,025	41,924
<i>Combretum molle</i>	7,818	12,179	4,029	3,193	11,847	15,372	27,219
<i>Combretum nigricans</i>	14,118	18,469	6,250	12,015	20,368	30,484	50,852
<i>Combretum paniculatum</i>	2,069	9,484	2,511	7,809	4,58	17,293	21,873
<i>Cussonia arborea</i>	0,673	2,871	0,512	3,780	1,185	6,651	7,836
<i>Crossopteryx febrifuga</i>	12,253	3,162	3,162	16,478	15,415	19,64	35,055
<i>Daniellia oliveri</i>	45,630	151,263	33,223	16,847	78,853	168,11	246,963
<i>Desmodium vitelinum</i>	5,266	14,700	5,915	13,083	11,181	27,783	38,965
<i>Detarium microcarpum</i>	7,945	9,663	8,410	9,128	16,355	18,791	35,146
<i>Dichrostachys cinerea</i>	3,162	4,837	2,684	7,220	5,846	12,057	17,903
<i>Diospyros mespiliformis</i>	8,225	19,617	9,498	16,984	17,723	36,601	54,324
<i>Entada africana</i>	2,234	9,184	3,542	5,805	5,776	14,989	20,765
<i>Erythrina senegalensis</i>	0,932	3,162	1,888	16,478	2,82	19,64	22,459
<i>Ficus capensis</i>	22,361	26,788	4,462	6,209	26,823	32,997	59,821
<i>Ficus cordata</i>	21,055	59,998	3,604	5,500	24,659	65,498	90,157
<i>Ficus glaucescens</i>	12,675	3,162	3,162	16,478	15,837	19,64	35,477
<i>Ficus platyphylla</i>	32,376	54,695	2,621	5,628	34,997	60,323	95,319
<i>Ficus sycomorus</i>	29,844	53,747	5,344	6,989	35,188	60,736	95,924
<i>Ficus thonningii</i>	43,375	88,377	10,723	12,205	54,098	100,582	154,680
<i>Forea ratchetiana</i>	0,712	1,040	2,742	3,353	3,454	4,393	7,846
<i>Gardenia aqualla</i>	0,103	0,303	4,704	4,526	4,807	4,829	9,636

<i>Grewia bicolor</i>	1,582	7,289	3,319	3,469	4,901	10,758	15,660
<i>Grewia flavenscens</i>	1,482	5,913	2,770	3,159	4,252	9,072	13,324
<i>Haematostaphis barbari</i>	1,987	3,162	3,162	16,478	5,149	19,64	24,788
<i>Harungana madagascariensis</i>	21,633	45,096	9,682	9,990	31,315	55,086	86,402
<i>Hymenocardia acida</i>	5,456	26,046	10,283	13,815	15,739	39,861	55,601
<i>Isoberlinia doka</i>	76,982	119,119	13,583	17,724	90,565	136,843	227,408
<i>Isoberlinia tomentosa khaya senegalensis</i>	3,162	193,012	23,814	22,163	26,976	215,175	242,151
<i>Kigelia africana</i>	125,547	286,508	39,866	25,018	165,413	311,526	476,939
<i>Klosklospermum plancini</i>	1,203	3,162	3,162	16,478	4,365	19,64	24,005
<i>Lannea fruticosa</i>	4,951	14,768	10,197	2,437	15,148	17,205	32,354
<i>Lannea humilis</i>	2,497	9,961	3,619	10,320	6,116	20,281	26,396
<i>Lannea kerstingi</i>	2,213	6,955	4,118	4,702	6,331	11,657	17,988
<i>Lannea shimperi</i>	3,162	2,829	2,155	3,538	5,317	6,367	11,684
<i>Lippia adoensis</i>	0,411	3,162	3,162	16,478	3,573	19,64	23,212
<i>Lonchocarpus laxiflorus</i>	3,162	13,371	3,333	10,646	6,495	24,017	30,512
<i>Lophira lanceolata</i>	2,680	16,162	3,180	13,574	5,86	29,736	35,596
<i>Malacantha alnifolia</i>	1,222	4,849	1,469	5,272	2,691	10,121	12,812
<i>Maytenus senegalensis</i>	3,162	6,893	6,165	11,392	9,327	18,285	27,612
<i>Mitragyna inermis</i>	7,224	5,114	9,350	5,741	16,574	10,855	27,430
<i>Monotes kerstingii</i>	3,854	6,566	3,894	8,249	7,748	14,815	22,562
<i>Nauclea latifolia</i>	33,442	38,104	14,151	18,250	47,593	56,354	103,947
<i>Ochna rhizomatosa</i>	4,426	1,465	3,762	1,723	8,188	3,188	11,376
<i>Ochna ovata</i>	4,072	9,370	6,831	9,231	10,903	18,601	29,505
<i>Ochna schweinfurthiana</i>	1,574	2,264	1,957	1,821	3,531	4,085	7,616
<i>Opilia amenthacea</i>	3,162	13,204	1,282	12,592	4,444	25,796	30,241
	4,256	7,338	7,338	4,256	11,594	11,594	23,189

<i>Ozoroa insignis</i>	1,100	2,273	8,119	1,153	9,219	3,426	12,646
<i>Parinari curatellifolia</i>	3,162	7,611	1,935	8,244	5,097	15,855	20,952
<i>Parkia biglobosa</i>	2,566	10,917	3,591	10,267	6,157	21,184	27,340
<i>Pavetta crassipes</i>	3,162	4,481	5,258	3,890	8,42	8,371	16,790
<i>Pericopsis laxiflora</i>	7,260	16,712	8,156	17,927	15,416	34,639	50,055
<i>Phyllanthus welwitschianus</i>	3,162	4,805	5,688	5,504	8,85	10,309	19,159
<i>Piliostigma thonningii</i>	1,936	5,676	2,372	4,630	4,308	10,306	14,614
<i>Prosopis africana</i>	3,125	9,505	3,717	12,131	6,842	21,636	28,477
<i>Protea occidentalis</i>	2,586	4,538	3,961	3,926	6,547	8,464	15,010
<i>Pseudocedrela kotschy</i>	26,879	48,483	10,767	23,522	37,646	72,005	109,651
<i>Psorospermum febrifugum</i>	15,386	26,471	17,998	21,453	33,384	47,924	81,309
<i>Psorospermum senegalensis</i>	18,714	14,144	15,831	15,466	34,545	29,61	64,156
<i>Pterocarpus erinaceus</i>	22,348	63,643	3,278	11,122	25,626	74,765	100,390
<i>Pterocarpus lucens</i>	9,017	48,588	13,479	27,188	22,496	75,776	98,272
<i>Securidaca longepedunculata</i>	4,008	6,770	4,845	7,304	8,853	14,074	22,926
<i>Securinega virosa</i>	4,591	5,853	8,212	6,751	12,803	12,604	25,406
<i>Sterculia setigera</i>	3,457	3,162	3,162	16,478	6,619	19,64	26,259
<i>Stereopermim khunthianum</i>	0,527	4,397	0,952	6,819	1,479	11,216	12,695
<i>Steganotaenia araliacea</i>	3,162	3,486	2,599	11,302	5,761	14,788	20,549
<i>Strychnos innocua</i>	1,515	4,010	2,381	16,478	3,896	20,488	24,383
<i>Strychnos spinosa</i>	3,162	5,442	0,549	7,136	3,711	12,578	16,289
<i>Swartzia madagascariensis</i>	5,045	6,262	5,698	5,545	10,743	11,807	22,550
<i>Syzygium guineense</i> var. g.	72,658	36,651	15,785	33,392	88,443	70,043	158,486

<i>Syzygium guineense</i> <i>var. m.</i>	27,142	35,456	13,925	9,080	41,067	44,536	85,603
<i>Tamarindus indica</i>	10,905	119,102	13,015	26,089	23,92	145,191	169,111
<i>Terminalia laxiflora</i>	107,423	79,384	13,123	12,782	120,546	92,166	212,711
<i>Terminalia</i> <i>avicennioides</i>	85,731	96,970	7,242	8,965	92,973	105,935	198,907
<i>Terminalia</i> <i>glaucescens</i>	85,473	122,988	11,429	23,843	96,902	146,831	243,733
<i>Terminalia</i> <i>macroptera</i>	98,016	117,220	11,691	16,702	109,707	133,922	243,628
<i>Trichilia emetica</i>	0,686	3,715	0,783	4,075	1,469	7,79	9,259
<i>Uapaka togoensis</i>	3,162	17,825	5,164	8,806	8,326	26,631	34,958
<i>Uvaria chamae</i>	1,019	4,150	1,536	3,942	2,555	8,092	10,647
<i>Vitellaria paradoxa</i>	16,193	23,596	1,095	15,885	17,288	39,481	56,769
<i>Vitex doniana</i>	4,192	5,335	5,698	5,764	9,89	11,099	20,990
<i>Vitex simplicifolia</i>	7,463	4,688	6,703	5,182	14,166	9,87	24,036
<i>Ximenia americana</i>	4,740	9,943	5,893	9,693	10,633	19,636	30,269
<i>Ziziphus abiscenia</i>	7,082	10,189	10,642	10,660	17,724	20,849	38,574
<i>Ziziphus mucronata</i>	9,213	6,965	13,114	7,693	22,327	14,658	36,985
<i>Zyzyphus mauritiana</i>	6,659	8,883	9,698	7,885	16,357	16,768	33,124
Total	4 621 424,676	9 907 945,167	4 081 286,972	5 970 501,163	8702711,648	15878446,33	24 581 157,978

Conflict of interest statement

Authors declare that they have no conflict of interest

Acknowledgment

The authors would like sincerely to thank the administrative, traditional authorities and local population of the Mayo-Rey Division and personals of the park to have actively contributed to the achievement of this research.

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Quick Response Code	
DOI: 10.22192/ijarbs.2022.09.08.005	

How to cite this article:

Oumar Mahamat Oumar, Tchobsala, Megueni Clautilde, Sali Bourou, Pa Ai Vivien. (2022). Impact of gold panning on biomass of Benoue and Bouba -Ndjidda National Park in the Mayo-Rey Division. Int. J. Adv. Res. Biol. Sci. 9(8): 38-72.

DOI: <http://dx.doi.org/10.22192/ijarbs.2022.09.08.005>