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A MULTI-AGENT ESTIMATION OF THE QUANTITY OF CARBON DIOXIDE (CO_2) IN THE CITY OF NIAMEY

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ABSTRACT
This article proposes a multi-agent paradigm for estimating the quantity of CO_2 in the city of Niamey. Only the main sources of emissions and absorptions have been considered in the investigations. The figures used are obtained from the available official data and projections in the future. All emitters and absorbers have been modeled as agents. A series of predictive and counterbalance simulations have been realized. The possibilities of counterbalance by fixing or dosing the sources of emissions and absorptions were studied and analyzed. The results of the simulations are graphically represented and thoroughly discussed.

KEYWORDS: Modeling, Multi-agent simulator, Greenhouse gas, Carbon dioxide.

1. INTRODUCTION
The global mobilization to mitigate the greenhouse effect remains a major challenge for humanity. In the management of CO_2, as the first gas responsible for the greenhouse effect, analyzing the most polluting areas becomes an important strategy. In the absence of a global and temporal assessment of anthropogenic emissions and CO_2 absorptions by the biomass, the need to assess the most polluting areas is a good alternative. Estimated at more than half of the world's population in 2011, the city's population is expected to reach nearly 67% by 2050 [1]. By this galloping urbanization phenomenon, big cities have become areas of high CO_2 emissions due to the perpetual demands for energy, transport, households, socio-economic activities, incineration or outdoor burning of waste, etc. To better understand and circumscribe complex problems such as CO_2 pollution over time, multi-agent systems are important tools to use. Using a multi-agent simulator, this work estimates the quantity of CO_2 in the city of Niamey.

2. BRIEF OVERVIEW OF THE CLIMATIC CHARACTERISTICS OF NIAMEY
Capital of Niger, Niamey is located in the south-western part of the country between the latitudes 13° 35' and 13° 24' South and the longitude 2 ° 15' East. Its administrative limits extend to approximately 297.46 km^2 of urbanized area [2]. It is the largest city in the country and has more than one third ($\frac{1}{3}$) of the national urban population with 1, 203, 766 inhabitants in 2017 [3]. Crossed by the river Niger at a North West - South East direction, Niamey has a sahelosudanese climate characterized by a short rainy season (June to September) and a long dry season (October to May). The city has five (5) municipal districts and covers an urban area of fifty-eight (58) administrative districts.

3. MULTI-AGENT MODELING OF THE MAIN SOURCES OF CO_2 EMISSIONS
The most important sources of emissions are households, mobile engines, stationary engines, air flights and solid waste. Only ordinary households were considered because of the availability of their statistics and the types of fuels used [4-7]. These households mainly use natural gas, charcoal and wood [8-9]. Further investigations have showed that the proportions of ordinary households according to the cooking method used are 8.9% for natural gas, 12.5% for charcoal, 74.2% for wood, 3% for those who do not prepare and 1.4% for others [4; 6]. However, there are no statistics on the evolution of households since the general population census of 2012 [8]. Therefore, to calculate the numbers of households for the years after 2012, the average annual growth rate (4.6%) of households from 2001 to 2012 was used. There are also no available statistics on the distribution of households according to the quantity of fuel consumed. To overcome these shortcomings, default

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assignments were made to the parameters for all households based on our observations and expert judgements. Table 1 shows the households in Niamey from 2013 to 2020.

Table 1. Households of Niamey from 2013 to 2020

2013	2014	2015	2016	2017	2018	2019	2020
166 998	174 680	182 715	191 120	199 912	209 108	218 726	228 788

Emissions from mobile engines come from private cars, vans, trucks, tractors/trailers/semi-trailers, coaches and 3 and 2-wheels vehicles as described in Table 2. The data on the average daily consumption capacity of engines are not available. However, under real operating conditions, the machines are distributed according to their categories and daily consumption capacity. In the absence of these illustrative statistics on the consumption and the fuels used by the engines, an allocation in sub-groups has been proposed in order to better represent their real operations.

Table 2. Mobile engines of Niamey from 2013 to 2017

	2013	2014	2015	2016	2017
4-wheels vehicles	**147 328**	**168 641**	**186 148**	**201 826**	**219 676**
Private cars	115 129	131 692	145 672	157 939	171 900
Vans	14 890	16 770	18 386	19 935	21 697
Trucks	3 594	4 354	5 072	5 500	5 986
Tractors / Trailers / Semi-trailers	8 699	10 061	10 707	11 610	12 635
Coaches	5 016	5 764	6 311	6 842	7 447
3 and 2-wheels vehicles	**61 094**	**71 652**	**81 783**	**92 422**	**102 047**

CO_2 emissions from stationary engines are generated by fuel combustion during socio-economic activities such as energy production and the transformation of petroleum products to produce electricity. In Niamey, the main stationary emitters are owned by NIGELEC (National Electrical Power Authority) and some independent self-producers of electricity. NIGELEC's engines operate most often during the hot weather, a time of numerous disruptions in electricity supply from Nigeria. The independent self-producers of electricity are understood to be all entities with an electricity generation set [10]. They are individuals who use their generators as relays in the event of a blackout from NIGELEC or sometimes for their own needs. The statistics on self-producers are not available, which makes their estimates difficult. In our models, emissions from self-producers are not considered. Each engine has been modeled as a temporary agent and the average consumption is that of NIGELEC, namely 250g / kWh [10]. The following table illustrates the selected stationary engines.

Table 3. Stationary engines of Niamey

Agent name	Modeled entity	Average consumption/day	Occurrences
CentralGoudelGroupPC4	Goudel central PC4	1262,195122	1
GroupMTUMTU 1	MTU MTU 1generator	238,4146341	1
GroupMTUMTU6	MTU MTU 6 generator	84,14634146	1
GroupMTUMTU7	MTU MTU 7 generator	84,14634146	1
GroupAggreko16QSK	aggreko 16 QSK generator	1311,280488	1
CentralNYIITAG2	NYII TAG2 central	841,4634146	1
GroupAggrekoNYII4QSK	Aggreko NYII 4QSK generators	1255,182927	1
CentralGorouBanda	Gorou Banda central	14024,39024	1
GroupSommetUA19	sommet UA 19 generators	2243,902439	1

For air transport, the totality of domestic flights is provided by Niger Airlines with its two Fokkers F50/F60. For international flights, with the absence of data on various flights and the presence of major airlines such as Air France, Ethiopian Airlines, etc., it was difficult to determine with accuracy all the types of aircrafts used. By default, the most representative types of aircrafts of all the companies present in Niamey were selected: Airbus 319, Airbus 320, Airbus 321, Boeing 737-100/200, Boeing 737-300/400/500 and Boeing 737- 600. In our analysis of departures and arrivals, we considered an average daily traffic consisting of 47% take-off and 53% landing [11]. The daily air flights figures computed from Table 4 are given in Table 5.

Table 4. Commercial traffic at Diori Hamani International Airport [12]

Years		2013	2014	2015	2016	2017
	Traffic					
Commercial movements (Number)	International	4 423	4 936	5 361	6 247	6 633
	Local	2 660	2 456	2 012	2 817	1 782
	Total	**7 083**	**7 392**	**7 373**	**9 064**	**8 415**

Table 5.Estimated numbers of landings and take-offs per day from 2013 to 2017

Traffic			Average number of flights / day				
Commercial movements (Number)	International	Year	**2013**	**2014**	**2015**	**2016**	**2017**
		Total	4 423	4 936	5 361	6 247	6 633
		Average/day	12	14	15	17	18
		Take-offs/day	6	7	7	8	9
		Landings/day	6	7	8	9	10
	Local	Total	2 660	2 456	2 012	2 817	1 782
		Average/day	7	7	6	8	5
		Take-offs/day	3	3	3	4	2
		Landings/day	4	4	3	4	3

For the years after 2017, the average growth rate from 2015 to 2017 was considered. The following table shows the flight agents modeling the landings and take-offs estimated according to the numbers and types of aircrafts for the year 2013.

Table 6.Air flight agents for the year 2013

Reference	Type	Fuel	Consumption	Occurrences
LandingsF50-2013	F50	Kerosene	342	2
LandingsF60-2013	F60	Kerosene	360	2
LandingsA319-2013	A319	Kerosene	328,5	1
LandingsA320-2013	A320	Kerosene	346,5	1
LandingsA321-2013	A321	Kerosene	432	1
LandingsB737-100-200-2013	B737/100/200	Kerosene	391,5	1
LandingsB737-300-400-500	B737/300/400/500	Kerosene	351	1
LandingsB737-600-2013	B737-600	Kerosene	324	1
TakeoffsF50-2013	F50	Kerosene	418	2
TakeoffsF60-2013	F60	Kerosene	418	1
TakeoffsA319-2013	A319	Kerosene	401,5	1
TakeoffsA320-2013	A320	Kerosene	423,5	1
TakeoffsA321-2013	A321	Kerosene	528	1
TakeoffsB737-100-200-2013	B737/100/200	Kerosene	478,5	1
TakeoffsB737-300-400-500-2013	B737/300/400/500	Kerosene	429	1
TakeoffsB737-600-2013	B737-600	Kerosene	396	1

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Through their incineration or burning, wastes also constitute a source of CO_2 emissions. They are processed in two different ways say, by the population itself and by town halls. The population manages waste by burning it in concessions or on the streets. The town halls manage the waste through pre-collection, transit or regrouping, collection, transport, dumping and valorization [13]. Moreover, the production of solid waste in urban areas in Niger is estimated at an average rate of 0.62 kg/day/inhabitant [10]. To simulate these emissions, five solid waste agents were created representing the five municipalities of Niamey. The population of the five municipalities from 2013 to 2017 are given in table 7. The rate of growth of the population for the years after 2017 is the average of the rates of growth from 2015 to 2017. Table 8 describes some of the basic parameters of the agents used.

Table 7.Evolution of the population by municipal district [12]

	2013	**2014**	**2015**	**2016**	**2017**
Niamey	1 051 605	1 088 557	1 126 257	1 164 680	1 206 766
Municipality I	215 084	222 641	230 352	238 211	246 205
Municipality II	252 851	261 735	270 800	280 039	289 437
Municipality III	167 109	172 981	178 972	185 078	191 289
Municipality IV	281 102	290 979	301 057	311 328	321 775
Municipality V	135 460	140 220	145 076	150 026	155 060

Table 8. Some parameters of solid waste agents from 2013 to 2017

Agent name	Population	Fraction which burns its waste	Waste / inhabitant / day (kg)	Burnt fraction /Total volume	Rate (in %)	Occurrence
2013MunI	215084	0,5	0,62	0,5	0	1
2013MunII	252 851	0,5	0,62	0,5	0	1
2013MunIII	167 109	0,5	0,62	0,5	0	1
2013MunIV	281 102	0,5	0,62	0,5	0	1
2013MunV	135 460	0,5	0,62	0,5	0	1
2014MunI	222 641	0,5	0,62	0,5	0	1
2014MunII	261 735	0,5	0,62	0,5	0	1
2014MunIII	172 981	0,5	0,62	0,5	0	1
2014MunIV	290 979	0,5	0,62	0,5	0	1
2014MunV	140 220	0,5	0,62	0,5	0	1
2015MunI	230 352	0,5	0,62	0,5	0	1
2015MunII	270 800	0,5	0,62	0,5	0	1
2015MunIII	178 972	0,5	0,62	0,5	0	1
2015MunIV	301 057	0,5	0,62	0,5	0	1
2015MunV	145 076	0,5	0,62	0,5	0	1
2016MunI	238 211	0,5	0,62	0,5	0	1
2016MunII	280 039	0,5	0,62	0,5	0	1
2016MunIII	185 078	0,5	0,62	0,5	0	1
2016MunIV	311 328	0,5	0,62	0,5	0	1
2016MunV	150 026	0,5	0,62	0,5	0	1
2017MunI	246 205	0,5	0,62	0,5	3,51	1
2017MunII	289 437	0,5	0,62	0,5	3,51	1
2017MunIII	191 289	0,5	0,62	0,5	3,51	1
2017MunIV	321 775	0,5	0,62	0,5	3,51	1
2017MunV	155 060	0,5	0,62	0,5	3,51	1

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Niamey city does not have modern liquid waste incineration facilities. So, the assessment of CO_2 emissions from liquid waste cannot be considered. The liquid waste produced is most often buried or completely spilled out.

4. MULTI-AGENT MODELING OF THE MAIN CO_2 ABSORBERS

CO_2 absorptions were evaluated with the minimum approach on the basis of trees only by considering that the variations between the gains and losses of carbon stock of shrubs and grasses are null. The trees are mainly composed of hyphaenethaebaïca, borassusaethiopum, acacia albida, acacia balinates, combretum (gluttinosum, micranthun, nigricans, aculeatum), prosopusafricana, eucalyptus camaldulensis, terminaliamentalüü and azadirachtaindica [12]. Several scientific studies have shown that azadirachtaindica is the most dominant species in Niamey [14]. According to the National Environment Council for Sustainable Development (CNEDD) [10], investigations on the carbon sequestration of urban trees remain inexistant in Niger [10]. In addition, the collected literature did not provide any information, neither on the carbon capture of trees in urban areas in Niger, nor on the role of urban trees in mitigating climate change in the Sahel region [14]. For the city of Niamey, only one study on the carbon sequestration of azadirachtaindicas exists and was carried out by Soulé et al. [14]. In order to determine the rate of growth per tree and per species, we have considered that the average age of trees is 30 years. Furthermore, to determine the number by species (except azadirachtaindica), the minimum method applied by CNEDD [10] was used. It consists of estimating the number of urban trees using the number of households in the simulated city and taking into account the trees in the green spaces for which data are available. This method uses three (3) trees per household in urban centers and Table 9 provides a summary of the most dominant species in Niamey determined from the analysis of the collected literature [10; 12; 15].

Table 9.Growth rate and numbers of the most dominant species in Niamey

Tree species	Growth rate (kg C/year/tree)	Estimated number
Hyphaenethaebaïca	4.66	35 939
Acacia nilotica	14	35 939
Combretumgluttinosum	14	35 939
Combretummicranthun	6.66	35 939
Piliostigmareticulatum	4.66	35 939
Borassusaethiopum	27,85	35 939
Acacia balanites	27,85	35 939
Eucalyptus camaldulensis	27,85	35 939
Terminalia mentalüü	27,85	35 939
Combretumnigricans	27,85	35 939
Combretumaculeatum	27,85	35 939
Mangiferaindica	27,85	35 939
Prosopisafricana	27,84	35 939
Azadirachtaindica	16	1 427 808
Faidherbiaalbida	27,85	35 939

Table 10 describes the basic parameters of the absorbers for the year 2013. For the years after 2013, the estimates have been made on the basis of the annual growth rate of 4.6% which represents the annual growth of households.

Table 10.Basic parameters of absorbers in 2013

Reference	Species	Type	Occurrence	Growth rate
Hyphaene_thaebaïca	Tree	Hyphaenethaebaïca	35 939	4,6
Acacia_nilotica	Tree	Acacia nilotica	35 939	4,6
Combretum_gluttinosum,	Tree	Combretumgluttinosum,	35 939	4,6
Combretum_micranthun	Tree	Combretummicranthun	35 939	4,6
Piliostigma_reticulatum	Tree	Piliostigmareticulatum	35 939	4,6

Borassus_aethiopum	Tree	Borassusaethiopum	35 939	4,6
Acacia_balanites	Tree	Acacia balanites	35 939	4,6
Eucalyptus_camaldulensis	Tree	Eucalyptus camaldulensis	35 939	4,6
Terminalia_mentalüü	Tree	Terminalia mentalüü	35 939	4,6
Combretum_nigricans	Tree	Combretumnigricans	35 939	4,6
Combretum_aculeatum	Tree	Combretumaculeatum	35 939	4,6
Prosopis_africana	Tree	Prosopisafricana	35 939	4,6
Mangifera_indica	Tree	Mangiferaindica	35 939	4,6
Faidherbia_albida	Tree	Faidherbiaalbida	35 939	4,6
Azadirachta_indica	Tree	Azadirachtaindica	1 427 808	-

5. RESULTS AND DISCUSSION

The possible CO_2 emissions and absorptions of Niamey are simulated over the period from 01/01/2013 to 31/12/2020 with an initial quantity estimated at 100 Gg. The multi-agent platform of Dan Djari and Naroua [16-18] was used for the computations.

Figure 1 illustrates two forecast series with and without varying operating times for temporary agents. The curves represent the sum of the emissions from which are removed the absorptions due to trees. We observe that:

- The average values alone are not enough because they will limit the global changes to simple linear values (Forecast # 1), which is far from reflecting the reality;
- Assuming that for each category, agents are born and die over time (Forecast # 2) then, we get closer to reality because we take into account the possibility of agents to operate or stop at any time. This shows that the operating times of the emission and absorption sources have a great influence on the evolution of CO_2.

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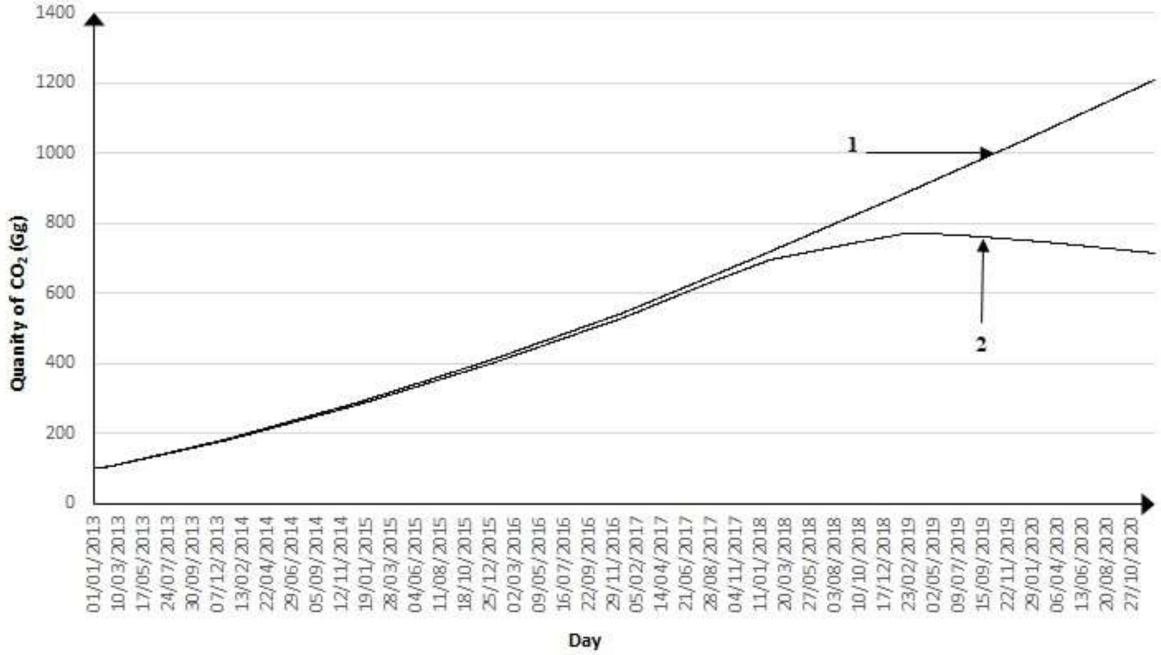


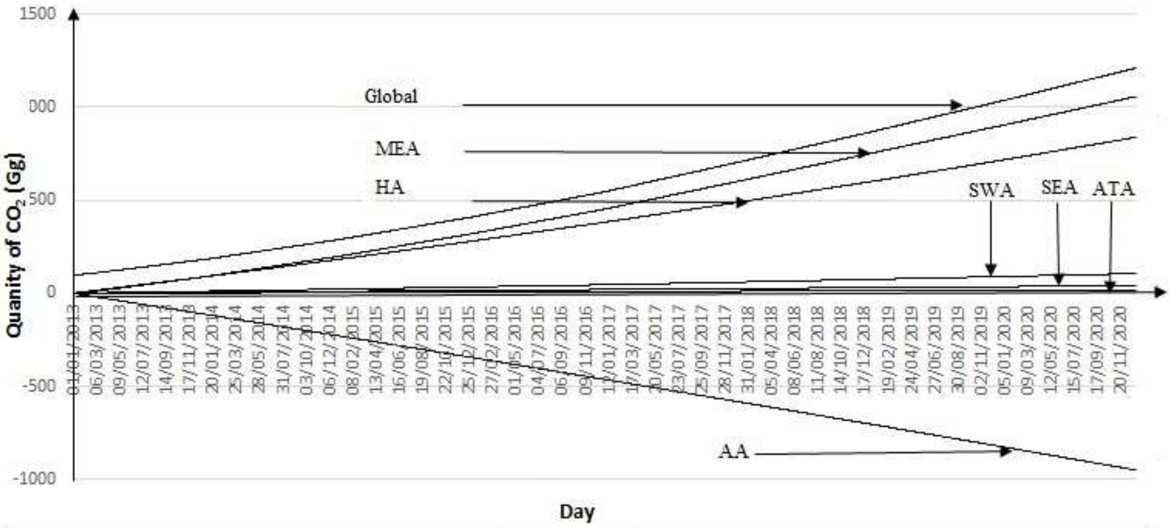
		Number or growth rate by year							
Forecast	Agents	2013	2014	2015	2016	2017	2018	2019	2020
1	MEA	208422	240293	267931	294248	321723	8,63%	8,63%	8,63%
	SEA	9	9	9	9	9	9	9	9
	ATA	19	21	21	24	25	11,34%	11,34%	11,34%
	HA	166630	4,6%	4,6%	4,6%	4,6%	4,6%	4,6%	4,6%
	SWA*	5	5	5	5	5	5	4,6%	4,6%
	AA **	1930954	4,6%	4,6%	4,6%	4,6%	4,6%	4,6%	4,6%
2	Variation of agents operating times								

* The growth rate concerns the number of the population of Niamey
** The growth rate concerns all the trees except Azadirachta indica

Figure 1. Forecast series with and without variations in operating times

From Figure 2, we observe the basic simulation for all agents. The global curve is the sum of emissions minus the absorption due to trees. From the results obtained, we observe that:

- Despite the individual pollution capacity of planes, the pollution due to air transport (represented by ATA) remains insignificant due to the limited number of landings and take-offs;
- The large numbers of stationary engines (SEA), mobile engines (MEA), households (HA) and wastes (SWA) make their polluting contributions important.



		Number or growth rate by year							
Forecast	Agents	2013	2014	2015	2016	2017	2018	2019	2020
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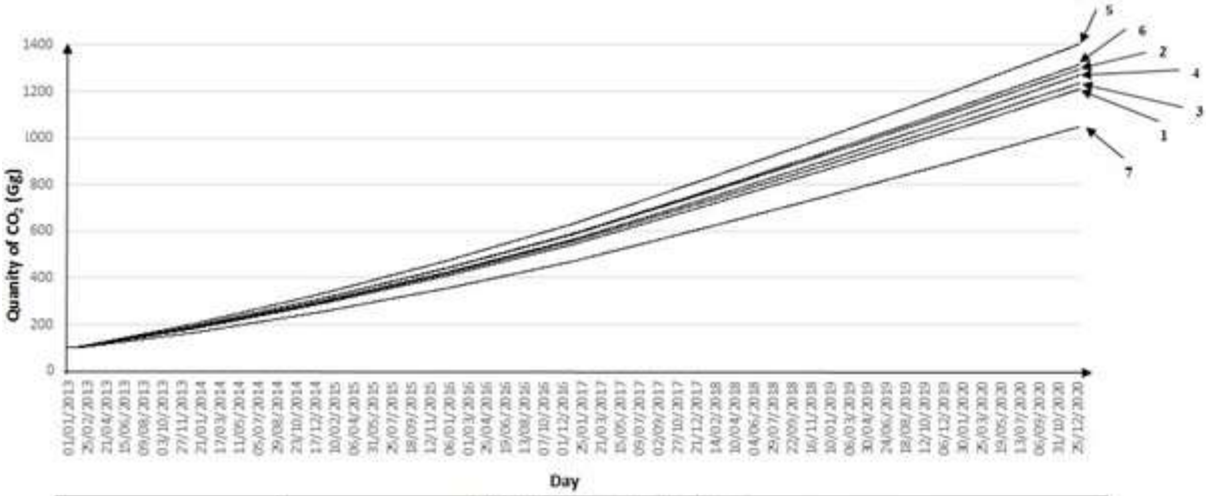
	SEA	9	9	9	9	9	9	9	9
	ATA	19	21	21	24	25	11,34%	11,34%	11,34%
	HA	166630	4,6%	4,6%	4,6%	4,6%	4,6%	4,6%	4,6%
	SWA *	5	5	5	5	5	5	4,6%	4,6%
	AA **	1930954	4,6%	4,6%	4,6%	4,6%	4,6%	4,6%	4,6%

* The growth rate concerns the number of the population of Niamey
** The growth rate concerns all the trees except Azadirachta indica

Figure 2. Basic simulation for all agents

Figure 3 illustrates the results obtained as a function of the increase in the number of temporary agents by category. Only the average values of emissions and absorptions were considered. We observe that:

- The global quantity of gas emissions is proportional to the quantity of emitting agents by category;
- The global amount of gas emissions depends on the nature of the emitting agents;
- An increase in the number of absorbers greatly decreases the quantity of gas. However, the absorption remains limited compared to emissions. Indeed, we have limited the absorbers to trees which are the main consumers of CO_2.



		Number or growth rate by year							
Forecast	Agents	2013	2014	2015	2016	2017	2018	2019	2020
1	MEA	208422	240293	267931	294248	321723	8,63%	8,63%	8,63%
	SEA	9	9	9	9	9	9	9	9
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	HA	166630	4,6%	4,6%	4,6%	4,6%	4,6%	4,6%	4,6%
	SWA*	5	5	5	5	5	5	4,6%	4,6%
	AA**	1930954	4,6%	4,6%	4,6%	4,6%	4,6%	4,6%	4,6%
2	MEA	308422	340293	367931	394248	421723	8,63%	8,63%	8,63%
3	SEA	19	19	19	19	19	19	19	19
4	ATA	79	81	81	84	85	11,34%	11,34%	11,34%
5	HA	366 630	4,6%	4,6%	4,6%	4,6%	4,6%	4,6%	4,6%
6	SWA*	15	15	15	15	15	15	1,6%	1,6%
7	AA**	2932954	4,6%	4,6%	4,6%	4,6%	4,6%	4,6%	4,6%

* The growth rate concerns the number of the population of Niamey
** The growth rate concerns all the trees except Azadirachta indica

Figure 3.Forecasts with increase of the number of temporary agents according to their types without variation in operating times

To study the impact of varying parameters, daily CO_2 emissions and absorptions were considered. The analysis of the impact of the agent parameters was carried out on the basis of the elements which determine the type of combustion. The results from these modifications and simulations are presented in Figure 4 and we observe that:

- The number of agents determines the global quantity of CO_2 generated;
- The parameters of emitters and absorbers have different impacts on the total quantity of gas;
- With mobile engines, stationary engines and households, the type of fuel used has a considerable influence on the global quantity of CO_2 released;
- For the same consumption, the release of CO_2 is greater for diesel than for gasoline with mobile and stationary engines and this is in agreement with the results of Helmers et al. [19].
- For mobile engines, non-combustive emissions have little influence on the global quantity;
- For air transport, the fuel used does not have a significant impact on CO_2 emissions;
- The fraction of the population that burns waste, the quantity of waste produced per inhabitant and the rate of incineration or open air burning per inhabitant significantly impact the global quantity of CO_2;
- The absorption varies according to the species of trees and it contributes to the reduction of the quantity of CO_2 but, its influence remains weak compared to the global emissions. This result agrees with several works as for example Lerman et al. [20] and Privitera et al. [21].

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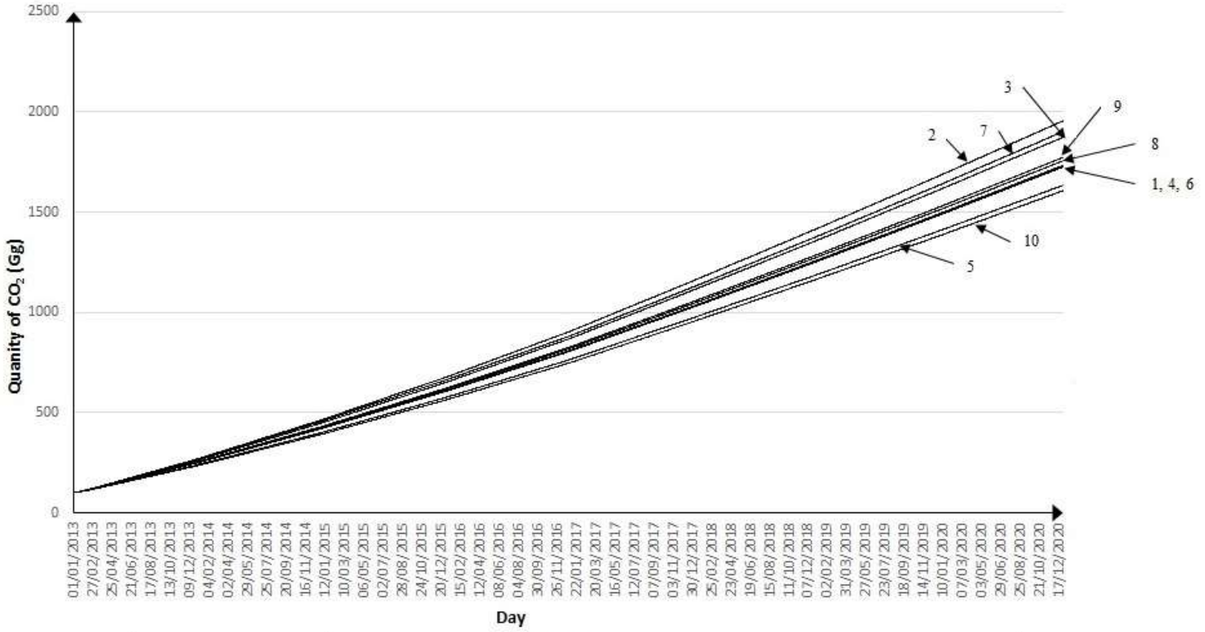

Forecast	Agents	Number or growth rate by year							
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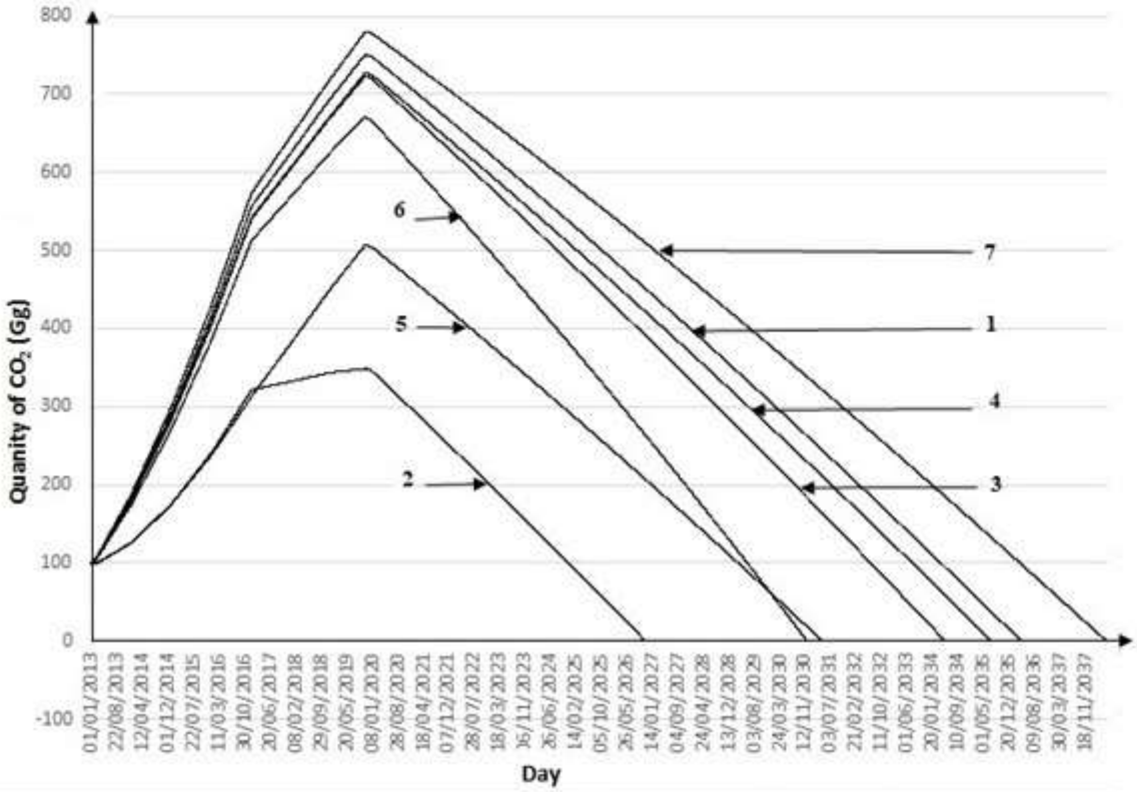
	HA	166630	4,6%	4,6%	4,6%	4,6%	4,6%	4,6%	4,6%
	SWA*	5	4,6%	4,6%	4,6%	4,6%	4,6%	4,6%	4,6%
	AA**	1930954	4,6%	4,6%	4,6%	4,6%	4,6%	4,6%	4,6%
		Same value settings / Agent type							
	MEA	Fuel = essence, Activity = 0.00000000025							
	SEA	Fuel = gasoline							
	HA	Fuel = wood							
	ATA	Fuel = kerosene							
	SWA	Fraction of the population burning their waste = 0.3; Waste / inhabitant / day = 0.62 Fraction of the volume of waste burned / Total volume = 0.7							
	AA	Tree species = Hyphaene thaebaïca							
Changing parameters									
Forecast	Agents	Parameter changed			Old value		New value		
2	MEA	Fuel			Gasoline		Diesel fuel		
3	MEA	Activity			0.0000000025		0.0000000075		
4	SEA	Fuel			Gasoline		Diesel fuel		
5	HA	Fuel			Wood		Natural gas		
6	ATA	Fuel			Kerosene		Aviation gasoline		
7	SWA	Fraction of the population burning their waste			0,3		0,8		
8	SWA	Waste / inhabitant / day = 0.62			0,62		0,8		
9	SWA	Fraction of the volume of waste burned / Total volume = 0.7			0,7		0,9		
10	AA	Tree species			Hyphaene thaebaïca		Combretum micranthun		

Figure 4. Forecasts with changing parameters of agents

Figure 5 illustrates the search for counterbalance by fixing the sources of emissions and absorptions with variation in the operating times of the agents. Although the final configuration is a function of several parameters such as the number of agents of each type, the duration of operation of the emitting agents, the lifetime of the absorbing agents, the interval of time, we observe that:

- The counterbalance search time decreases with a decrease in the number of emitting agents;
- A decrease in the massive combustion of fossil fuels (coal, oil, natural gas) leads to a decrease in the quantity of CO_2, which is in agreement with Van and Jean [22];
- A decrease in the number of absorbers significantly increases the counterbalance time. This proves the need for planting trees, creating and maintaining green spaces. This is in agreement with Jürgen and Oliver [23] on the strategies of global climate policy and Neya et al. [24];

- The mitigation of CO_2 greenhouse effect must include measures to reduce, absorb and sequestrate emissions in accordance with Peters et al. [25].



		Number or growth rate by year							
Fixation	**Agents**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**
1	MEA	208422	240293	267 931	294248	321723	8,63%	8,63%	8,63%
	SEA	9	9	9	9	9	9	9	9
	ATA	19	21	21	24	25	11,34%	11,34%	11,34%
	HA	166 630	4,6%	4,6%	4,6%	4,6%	4,6%	4,6%	4,6%
	SWA*	5	4,6%	4,6%	4,6%	4,6%	4,6%	4,6%	4,6%
	AA**	1930954	4,6%	4,6%	4,6%	4,6%	4,6%	4,6%	4,6%
	Variation of agents operating time								
2	MEA	78 423	110 294	137 932	164 249	191 724	8,63%	8,63%	8,63%
3	SEA	6	6	6	6	6	6	6	6
4	ATA	9	11	11	14	15	11,34%	11,34%	11,34%
5	HA	66 630	4,6%	4,6%	4,6%	4,6%	4,6%	4,6%	4,6%
6	SWA*	2	4,6%	4,6%	4,6%	4,6%	4,6%	4,6%	4,6%
7	AA**	1859076	4,6%	4,6%	4,6%	4,6%	4,6%	4,6%	4,6%

* The growth rate concerns the number of the population of Niamey
** The growth rate concerns all the trees except Azadirachta indica

Figure 5.Counterbalance by fixing the sources

Figure 6 illustrates the search for counterbalance by dosing the sources of emissions and absorptions with varying operating times. We observe that:

- An increase in the periodical number of agents to inject decreases the time for counterbalance search;
- An increase in the dosing period increases the counterbalance time;
- A decrease in the tolerance value significantly reduces the counterbalance time;
-

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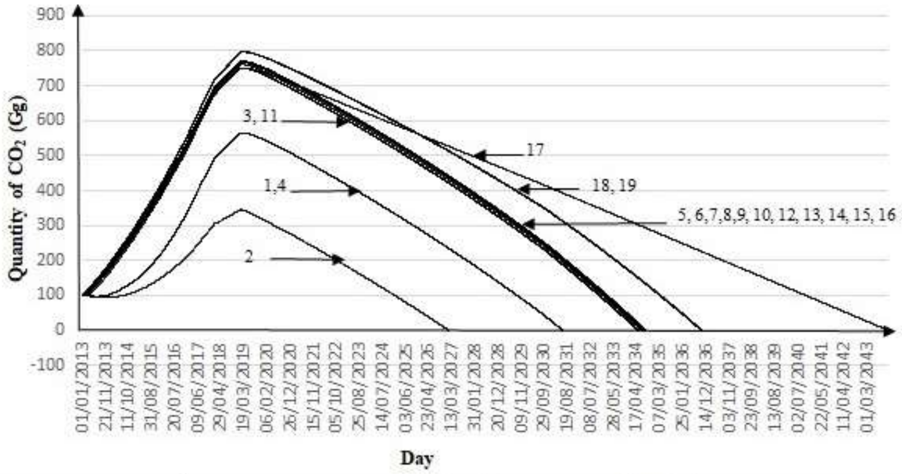
- Dosing the sources of absorption gives a longer counterbalance time. Thus, efforts to create and multiply absorbers are necessary to mitigate CO_2 emissions. This is in line with several scientific works such as Privitera et al. [21] and Kombate et al. [27];
- The dosage of emission sources is the best strategy for obtaining a rapid counterbalance in an urban environment.



		Number or growth rate by year							
Dosage	**Agents**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**
1	MEA	208422	240293	267931	294248	321723	8,63%	8,63%	8,63%
	SEA	9	9	9	9	9	9	9	9
	ATA	19	21	21	24	25	11,34%	11,34%	11,34%
	HA	166630	4,6%	4,6%	4,6%	4,6%	4,6%	4,6%	4,6%
	SWA*	5	4,6%	4,6%	4,6%	4,6%	4,6%	4,6%	4,6%
	AA**	1930954	4,6%	4,6%	4,6%	4,6%	4,6%	4,6%	4,6%
	Variation of agents operating time								
	Parameter				**Parameter value**				
	Dosing period				50				
	Number of agents				10				
	Tolerance				0.0001				

Dosage	Agents to dose	Changed parameter	Changed parameter value
2	MEA	Dosing period	100
3	MEA	Number of agents	100
4	MEA	Tolerance	0.01
5	SEA	Dosing period	100
6	SEA	Number of agents	100
7	SEA	Tolerance	0.01
8	ATA	Dosing period	100
9	ATA	Number of agents	100
10	ATA	Tolerance	0.01
11	HA	Dosing period	100
12	HA	Number of agents	100
13	HA	Tolerance	0.01
14	SWA	Dosing period	100
15	SWA	Number of agents	100
16	SWA	Tolerance	0.01
17	AA	Dosing period	100
18	AA	Number of agents	100
19	AA	Tolerance	0.01

Figure 6.Counterbalance by dosing the sources

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6. CONCLUSION

Using a multi-agent simulator, an investigation was carried out on the quantity of CO_2 in the city of Niamey. The main sources of emissions (mobile engines, stationary engines, air flights, households and solid wastes) and absorptions (trees) have been estimated and modeled. Both predictive and counterbalance (by fixing and dosing the sources) simulations were performed. From the results obtained, it was concluded that multi-agent systems can greatly contribute to the mitigation of greenhouse effect.

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