THE IDENTIFICATION OF MAIN GREENHOUSE GAS EMISSION SOURCES AND THE POTENTIAL MITIGATION OPTIONS IN LUANDA

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Introduction of the Article

Tropical and underdeveloped regions are always suffering from climate change that is directly brought by greenhouse gas emissions without enough mitigation capacity. As a tropical and developing city, Luanda is typical enough to represent a wide range of regions with similar features when facing climate change and reducing greenhouse gas emissions by mitigation. Nonetheless, an introduction of Luanda in terms of demographic, economic, and environment as the basic context is necessary to be given first. Then, an identification of the main sources of greenhouse gas emission in Luanda will be expanded to decide which parts need more concern when mitigating the overall greenhouse gas emissions in Luanda. Furthermore, four mitigation options that can help reduce the greenhouse gas emissions in Luanda from the main sources will be given. Finally, a comprehensive conclusion and thought on a broader picture and a connection with the adaptation that is suggested to occur in Luanda will be discussed.

Introduction of the Study Area

Demographic Study of Luanda

Luanda is the capital of Angola, which is also the hugest city in Angola (Luanda Province 2020). By 2014, 6542944 people live within the 2418-square-kilometer area in Luanda, which means that the local population density has reached 2705.93 people per square kilometer (Knoema 2020). In conclusion, the population in Luanda is extremely dense and still increasing.

Economic and Social Study of Luanda

The local economy and public resources in Luanda are in scarcity, but Luanda is still the industrial centre of Angola. First, because Luanda depends much on the oil and diamond trade since 2002. As a result, Luanda is facing tough inequality after the closure of the route from London to Luanda, which used to bring enormous oil and diamond trades. The dilemma has led to a series of effects that worsen the economy in Luanda (The Guardian 2019 as cited by Ding Li in Assignment 1). In addition, Luanda is interrupted by serious governmental corruption, which directly made most wealth gathered by the elite and the power class and thus, no adequate social resources for reduction of local inequity until the new president came into power (The Guardian 2019 as cited by Ding Li in Assignment 1). Nevertheless, Luanda is still the industrial centre of Angola, whose industries involve beverages, automotive products, and cement (The Editors of Encyclopaedia Britannica 2019). Just as the star-marked objects in Fig. 1. demonstrate, the density of the industries in Luanda is absolutely high. Generally speaking, the local economy in Luanda is depressing because of the dependence on British Airways that can bring trades, the social resources are poor because of the governmental corruption, but the industries in Luanda are relatively dense.

Environmental Study of Luanda

Luanda a tropical city surrounded by the Atlantic Ocean with extremely abundant biodiversity. (see Fig. 1.) (Ferreira-Baptista, L. and Eduardo De Miguel 2005).

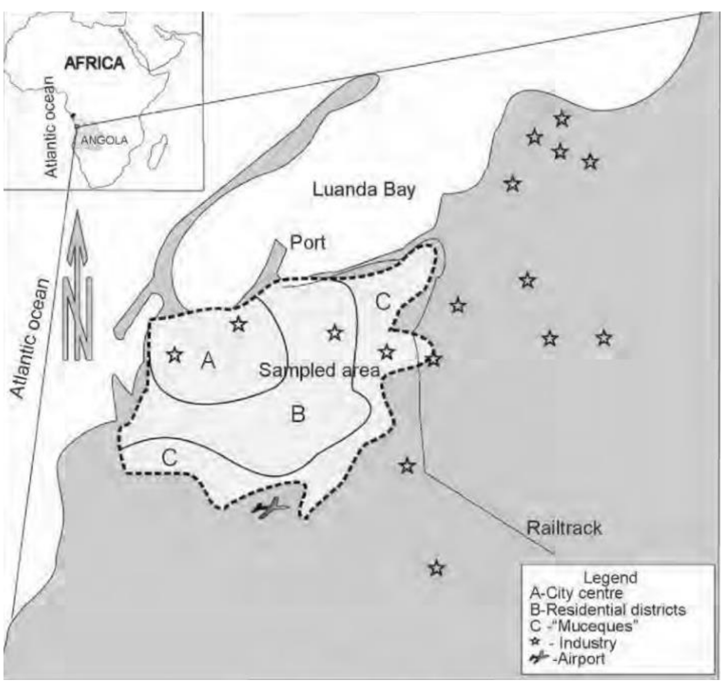

Fig. 1. Abstract map of Luanda. Created by Ferreira-Baptista, L. and Eduardo De Miguel. From "Geochemistry and risk assessment of street dust in Luanda, Angola: A tropical urban environment."

Spatially, Luanda is a coastal city near the Atlantic Ocean, and most of Luanda is surrounded by the ocean. From the perspective of climatology, Luanda has a tropical climate with a temperature of 26 Celsius degrees, and precipitation of 350-400 millimeters each year (see more in Fig. 2.) (Ding Li 2020).

Climate data for Luanda (1961–1990, extremes 1879–present) [hide]

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Record high °C (°F)	33.9 (93.0)	34.1 (93.4)	37.2 (99.0)	36.1 (97.0)	36.1 (97.0)	35.0 (95.0)	28.9 (84.0)	28.3 (82.9)	31.0 (87.8)	31.2 (88.2)	36.1 (97.0)	33.6 (92.5)	37.2 (99.0)
Average high °C (°F)	29.5 (85.1)	30.5 (86.9)	30.7 (87.3)	30.2 (86.4)	28.8 (83.8)	25.7 (78.3)	23.9 (75.0)	24.0 (75.2)	25.4 (77.7)	26.8 (80.2)	28.4 (83.1)	28.6 (83.5)	27.7 (81.9)
Daily mean °C (°F)	26.7 (80.1)	28.5 (83.3)	28.6 (83.5)	28.2 (82.8)	27.0 (80.6)	23.9 (75.0)	22.1 (71.8)	22.1 (71.8)	23.5 (74.3)	25.2 (77.4)	26.7 (80.1)	26.9 (80.4)	25.8 (78.4)
Average low °C (°F)	23.9 (75.0)	24.7 (76.5)	24.6 (76.3)	24.3 (75.7)	23.3 (73.9)	20.3 (68.5)	18.7 (65.7)	18.8 (65.8)	20.2 (68.4)	22.0 (71.6)	23.3 (73.9)	23.5 (74.3)	22.3 (72.1)
Record low °C (°F)	18.0 (64.4)	16.1 (61.0)	20.0 (68.0)	17.8 (64.0)	17.8 (64.0)	12.8 (55.0)	11.0 (51.8)	12.2 (54.0)	15.0 (59.0)	17.8 (64.0)	17.2 (63.0)	17.8 (64.0)	11.0 (51.8)
Average precipitation mm (inches)	30 (1.2)	36 (1.4)	114 (4.5)	136 (5.4)	16 (0.6)	0 (0)	0 (0)	1 (0.0)	2 (0.1)	7 (0.3)	32 (1.3)	31 (1.2)	405 (15.9)
Average precipitation days (≥ 0.1 mm)	4	5	9	11	2	0	0	1	3	5	8	5	53
Average relative humidity (%)	80	78	80	83	83	82	83	85	84	81	82	81	82
Mean monthly sunshine hours	217.0	203.4	207.7	192.0	229.4	207.0	167.4	148.8	150.0	167.4	186.0	201.5	2,277.6
Mean daily sunshine hours	7.0	7.2	6.7	6.4	7.4	6.9	5.4	4.8	5.0	5.4	6.2	6.5	6.2

Source #1: Deutscher Wetterdienst[26]

Source #2: Meteo Climat (record highs and lows)[27]

Fig. 2. Climate Data for Luanda. Created by Wikimedia Foundation by citing Deutscher Wetterdienst (2019) and Meteo Climat (2016). From "Luanda."

In the perspective of biodiversity, Luanda has remarkable richness in biodiversity according to the book Biodiversity of Angola: Science & Conservation: A Modern Synthesis (Huntley, et al. 2019 p. 543 as cited by Ding Li in Assignment 1). Therefore, Luanda is a coastal city surrounded by the Atlantic Ocean with extremely rich biodiversity in the Ocean, and Luanda has a tropical climate, which makes the region warm and rainy.

Major Sources of Greenhouse Gas Emission in Luanda

The main sources of greenhouse gas emission in Luanda are fugitive emission from the energy sector, biomass burning from the land-use change and forestry sector, the burning activities in the agriculture sector, and the waste management (see Fig. 1). (USAID 2019).

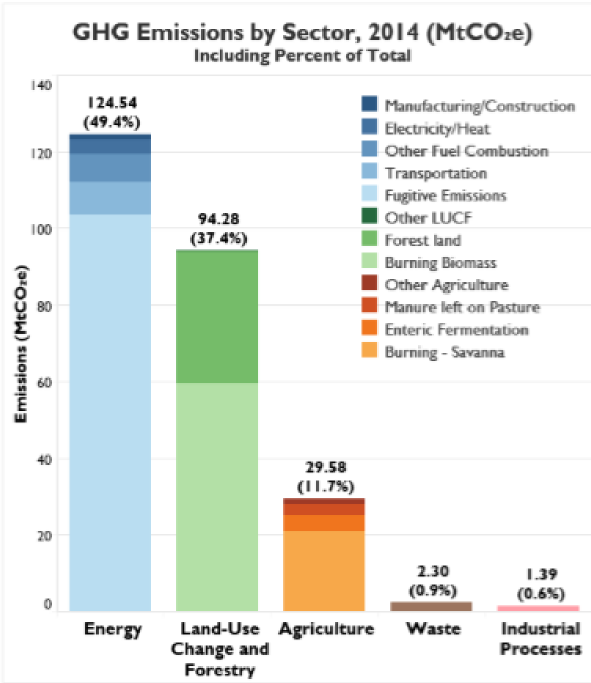

Fig. 2. Greenhouse Gas Emissions by Sector in 2014 in Luanda. Created by USAID. From "Greenhouse Gas Emissions in Angola."

Just as Fig. 2. demonstrates: The energy sector contributes 124.54 McCO2e greenhouse gas emission, which includes manufacturing, electricity, fuel combustion, transportation, and fugitive emissions. However, the fugitive emissions take up almost 80% of share in the energy sector, which is not surprising since high density of industrial factories exist within Luanda (see Fig. 1.) (The Editors of Encyclopaedia Britannica 2019) and those factories are exactly the main sources of the fugitive emissions (Envirotech Online 2015). Thus, the fugitive emission part is regarded as one main source of greenhouse gas emission in Luanda; The land-use change and forestry sector is the second ranked sector, which contributes 94.28 McCO2e greenhouse gas emission in

Luanda, because change in the biosphere has been recognized as a reason for greenhouse gas emission occurrence, which can perfectly explain why the land-use change and forestry sector contributes so much to the overall greenhouse gas emission (Tanabe 2003). In addition, the biomass burning activities make up the hugest component in the land-use change and forestry sector, perhaps because as a tropical city, Luanda undertakes a higher risk to suffer from biomass burning emissions basically due to the high temperature (Crutzen 1990). And although biomass has always been regarded as a kind of renewable energy (Klass et al. 1994), unintended biomass burning that is not controlled by people for getting energy is totally a burden as an extreme and meaningless greenhouse gas emission. Therefore, biomass burning is another main source of greenhouse gas emission in Luanda; In the agriculture sector, 29.58 McCO2e greenhouse gas is emitted. According to an article written by Laris, a reasonable hypothesis is that the burning activities are from an essential local convention that is widespread in Africa caused by the overreaction to the wildfire, with which local people burn the savanna in agricultural land in dry seasons periodically in order to divide the landscape so that later fires are not likely to damage local nature resources (2002). And the burning activities contribute the most part of emission in the agriculture sector, which is therefore supposed to be the third main source of greenhouse gas emission in Luanda; The waste sector also has 2.30 McCO2e emission, and should be considered to be the last and the least main source of greenhouse gas emission in Luanda. Also, Maria, Góis, and Leitão argue that within the waste sector in Luanda, the direct landfill emissions are the main contributors among other problems, so more concern should be concentrated on the direct landfill emissions reduction in Luanda (2019). Comprehensively speaking, four greenhouse gas emission sources in Luanda are the fugitive emission from the energy sector, the biomass burning from the land-use change and forestry sector, the burning activities in the agriculture sector, and the direct landfill emissions in the waste sector.

Mitigation Options for the Main Greenhouse Gas Emission Sources in Luanda

Mitigation Option for the Fugitive Emission

The fugitive emission can be reduced by developing and implementing strict and effective fugitive emissions management plans in all of the local factories in Luanda. According to the article "What Are Fugitive Emissions?", the author suggests that fugitive emissions refer to the unpredictable accidents in which some vapour or gases are emitted from damaged or fault pressurized devices, which usually occur in storage tanks or wastewater treatment facilities in factories (2015). Therefore, a fugitive emissions management plan is recommended to be developed in order to lessen the overall fugitive emissions in Luanda (BC Oil & Gas Commission 2019). To be more specific, a fugitive emissions management plan includes: giving sufficient political support as well as budget to maintain the plan, developing and maintaining an appropriate regulation of the plan through adequate supervision and intervention, introducing more effective and economic methods to test and screen the occurrence of any fugitive emissions, adding more individual reports about the use condition of devices in the factories to accelerate the process in which any fugitive emissions is recognized to occur, reinforcing the frequency of fugitive gas leaking detection in the factories, and utilizing a more effective and frequent method to confirm the effectiveness of device repair (BC Oil & Gas Commission 2019). Generally speaking, the fugitive emissions in Luanda is expected to be reduced by developing and implementing an effective and strict revolution that includes external social and governmental cooperation, schedule developer and supervisor team, fugitive emissions supervisor team, field operator team, and maintenance team in the local factories.

Mitigation Option for the Biomass Burning Emissions in the Land-use and Forestry Sector

A mitigation option for the biomass burning emissions may be developing near-vegetation livestock grazing. Due to the high possibility of nature-caused biomass burning for tropical cities specifically in the land-use and forestry sector (Crutzen 1990), more concern may be focused on how to reduce the nature-caused biomass burning. According to Evans and some other researchers, livestock grazing can effectively clear the amount of fine fuel load and other fuel sources because the cattle is expected to eat and digest the dead and total fuel loads without affecting the live or wet fuel loads that are unlikely to be burned (2015). Therefore, more stock farming industry is recommended to be introduced in the rural areas and those well vegetated regions. In summary, Luanda can develop or introduce more cattle farming industry to the local rural areas and vegetated regions, so that the cattle can decrease the fuel sources without breaking the local ecosystem, and as a result, biomass burning occurrence and emissions are likely to decrease in both the land-use and forestry sector.

Mitigation Option for the Savanna Burning Emissions in the Agriculture Sector

The savanna burning emissions is expected to be mitigated by replacing the nongovernmental savanna burning activities with a more scientific, localized, and official method. Unlike the biomass burning that is discussed before, the burning emissions in the agriculture sector are mainly caused by the overemphasis on wildfire from people rather than nature factors (Laris 2002) that is proposed under the "Major Sources of Greenhouse Gas Emission in Luanda" component of the article. Therefore, a more reasonable mitigation option is suggested to be establishing specific regulations to limit the unscientific nonofficial savanna burning activities, and make the activity under the government's control. According to an article published by the Clean Energy Regulator Crest in 2018, the savanna burning management should be scientifically modeled, calculated, and analyzed by the professional tool using professional and localized data, so that the frequency can reach a rational level in which the wildfire can be limited to the lowest level by burning minimum but appropriate amount of savanna, and thus, fewer greenhouse gas emissions will be generated as the wildfire prevention is finished. Therefore, any nonofficial savanna burning activities should be prohibited, and instead, a professional expert team regulated by the local government is suggested to decide the time, method, and the location of the savanna burning with the localized data and the scientific analysis under the government's supervision. In conclusion, the savanna burning emissions can be reduced by establishing the regulation and professional export team to officialize the savanna burning activities with scientific analysis and localized data.

Mitigation Option for the Direct Landfill Emissions

Introducing a breathing bio-cover system to each of the main landfill sites in Luanda can help reduce the greenhouse gas emissions from the local landfill activities. First, a hypothesis about where the landfill emissions in Luanda derive from is that the landfill emissions are supposed to be methane and carbon dioxide generated by the process in which anaerobic bacteria break down the biodegradable carbon compounds in the local landfill sites in Luanda (Lombardi 2006). Thus, to solve the methane emissions in the landfill sites in Luanda, a breathing bio-cover system is suggested to introduce in the largest several landfill sites in Luanda (Lu et al. 2011). According to Lu and some other researchers, a breathing bio-cover system is expected to increase the methane oxidation capacity by offering acceleration of the oxygen supply within landfill site, which can hugely lessen the overall methane emission in the landfill site (Lu et al. 2011). Furthermore, the methane oxidation rate can reach one hundred percent when the passive air venting system within the breathing bio-cover system makes the gas flow within the landfill site between 1028 g m^{-3} d^{-1} and 1285 g m^{-3} d^{-1}. In conclusion, each of the main landfill sites in Luanda is recommended to implement a breathing bio-cover system whose passive air venting system is set between 1028 g m^{-3} d^{-1} and 1285 g m^{-3} d^{-1}, so that the strengthened methane oxidation rate can make more methane oxidized rather than emitted.

Conclusion and Thoughts on a Broader Picture

Since lots of regions in the world are tropical, coastal, lack of social resources, economy, but have dense population and industries as Luanda, many difficulties that those regions may meet when mitigating greenhouse gas emissions are not unique. For those regions, the lack of social resources and economy can make some mitigation options which involve high-cost revolution difficult to be executed, which means some of the mitigation options proposed in the article that include introducing a breathing bio-cover system to each of the main landfill sites to mitigate landfill emissions, developing cattle farming industry to reduce biomass burning emissions, and offering enough governmental budget for the suggested fugitive emissions management plan in order to mitigate fugitive emissions unlikely to be well supported in those regions although the suggestions have already been selected as relatively cheap mitigation options. Also, the governmental corruption which may occur in those regions is also a negative factor which may terribly affect the execution of some political mitigation options, such as the establishment and supervision of the fugitive emissions management plan for mitigating fugitive emissions, or the performance of the law to prohibit all of non-official savanna burning activities. Additionally, those tropical coastal regions with rich ocean biodiversity are more likely to suffer much from ocean acidification that can make huge damage to the local ecosystem, which is regarded as one of the impacts brought by greenhouse gas emissions apart from climate change (Manzello 2010). Furthermore, the dense population and industries make those regions have huger possibility to emit more greenhouse gas than other places (Jones 2014 &Kajaste 2016). Therefore, the tropical coastal regions with abundant ocean biodiversity, poor social resources and economy, and a huge amount of population and industry is expected to have extremely low mitigation capacity and worse impact from greenhouse gas emissions.

Synergies or Trade-offs between Mitigation and Adaptation

For the tropical, coastal, densely populous, and underdeveloped regions as Luanda, adaptation should be more crucial than mitigation, but the mitigation that has co-benefits to adaptation is still recommended. According to Baer and some other researchers' articles, underdeveloped regions are thought to be less responsible for the greenhouse gas emissions (2000), basically because for climate change impacts, basic needs for surviving are always having priority and more hurry to be dealt with. Therefore, more adaptation policies, such as water safety plans proposed in the previous assignment to adapt to water pollution caused by climate change, should be paid more attention by the local government than fugitive emissions management plan that is used to mitigate fugitive emissions during a long term. Also, the governmental setback regulation which is recommended to prevent the sea turtles from extinction due to climate change should also be considered before the governmental regulation of prohibiting any non-official savanna burning that is for reducing greenhouse gas emissions. However, although perhaps none of my adaptation and mitigation options have obvious synergies, some adaptation options and mitigation options that have synergies should be encouraged. For instance, Luanda is suffering from heavy ocean acidification that is caused by greenhouse gas emissions that is absorbed by the ocean, which even worsens the ocean biodiversity in Luanda due to climate change. Therefore, reducing greenhouse emissions can not only mitigate climate change but also help the ocean biodiversity adapt to climate change impact, which is efficient and worthy doing. In conclusion, the tropical, coastal, densely populous, and underdeveloped regions with high vulnerability to climate change should pay more attention to the adaptation to climate change rather than mitigation due to the little responsibility to global greenhouse gas emissions and the priority for the basic need for surviving, whereas some mitigation options that are helpful to some climate change impacts, the mitigation is still encouraged because of the efficiency of solving several problems simultaneously.

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