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Uncontrolled urbanization and expected unclogging of Congolese cities: Case of Bukavu city, Eastern DR Congo

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ABSTRACT

This study was conducted to contribute to improvement and sustainable development of Congolese cities, particularly Bukavu city. GIS and Remote Sensing technics were used to estimate the built-up suitable areas in Bukavu taking into account the slopes, rivers, exclusion zones, protected zones, lakes, roads, identified landslides areas, erosion and flooding. These exclusion areas were subtracted from the total city area to determine the suitable areas. 2030 and 2050 population projections were made based on 2016 estimations. The results obtained show that only 68.6% (~29.7 km^2) are suitable for built-up. Based on 2016 estimation, the population will double by 2030 and triple by 2050. While the areas that can be developed for settlements can accommodate only ~186 000 people, the surplus will be relocated in two selected satellite cities, namely Nyatende and Miti-Murhesa centres, having ~38 and ~125 km^2 of suitable areas, respectively. Both vertical and horizontal development with an average plot size of 350 m^2 would reduce the negative impacts and ensure a sustainable city environment. To maintain the sustainability of Bukavu and its former name of "green city", both horizontal and mixed extensions will be considered while the two selected zones have to be well planned for new satellites cities and new Bukavu city development.

1. Introduction

Historically, cities have been centers of economic development, cultural transformation, and social emancipation of societies (Tieleman, 2015). According to the 1943 Athens Charter, people should live adequately., The city must fulfill four fundamental functions: living; offering city dwellers decent housing, jobs; providing facilities, circulation; offering sufficient infrastructure, recreation; and cultivating body and mind (Tieleman, 2015).

The population growth forecast for the next 50 years will have important consequences for all cities, especially those with a population of about two million. Developed countries will have to double their urban

Abbreviations: AEE, Agence Européenne pour l'Environnement; ASTERDEM, Advanced Spaceborne Thermal Emission and Reflection Radiometer; DEM, Digital Elevation Model; CES, Coefficient d'Emprise au Sol; CIAM, Congrès International d'Architecture Moderne; COS, Coefficient d'occupation du sol; DPS, Division Provinciale de la Santé; DSCRP, Document de la Stratégie de croissance et de réduction de la pauvreté; FAO, Food and Agriculture Organization; GIS-RS, Geographic Information System and Remote Sensing; HEQ, High Environment Quality; INS, Institut National de Statistique; IPS, Inspection Provinciale de la Santé; NGO, Non Government Organization; ONU, Organisation des Nations Unies; PNUD, Programme de Nations-Unies pour le Développement; DRC, Democratic Republic of the Congo; ROI, Region of Interest; SNSA, Service National des Statistiques Agricoles; USGS, United States of Geological Survey.

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space by 2050 to accommodate the expected population while developing countries will have to increase urban space by more than 300% (UN-Habitat, 2013).

Cities are growing and the reasons for their growth can be measurable, linked to undeniable demographic and social factors (Desgrandchamps et al., 2008). The majority of the world's population or inhabitants currently live in urban areas (Collin, 1976).

Alternatives to be considered include, horizontal and/or vertical development but also the development of new satellite cities. Thus, the policy of creating new cities-satellite cities allows restructuring and strengthening the national and regional urban framework. It aims at reducing pressure exerted on the big cities. These cities should preferably be "sustainable" and "green" in their design. According to UN-Habitat (2016), the need for sustainable cities is particularly urgent since cities produce 70% of global carbon emissions. UN-Habitat (2016) thus proposes a three-pronged approach towards sustainable cities, based on "comprehensive and effective urban legislation", "good urban planning" and "good urban design", as well as "adequate financing" of projects. These three principles can be levers for transforming cities and human settlements into centers offering greater environmental, economic, and social sustainability. The approach will be almost the same for the horizontal extension with the only difference that here it will be a question of creating new housing estates which will also have to take into account the technical standards recommended worldwide to safeguard the environment. Thus, the concept of "eco-neighborhoods" is constantly developing (Bonard and Matthey, 2010). However, these concepts remain less advanced in Africa and much more so in developing countries.

Bukavu city, the big city in the South Kivu province in the eastern Democratic Republic of Congo (DRC). It is experiencing strong population growth, especially accentuated during the first years of independence because of uncontrolled rural exodus. Urban immigration is more important as the average density of Bukavu hinterland is the highest in the country (DR Congo) (DSCRP, 2010).

The environment has been threatened, the migrants (rural exodus) are looking for land in the surrounding area and especially the shores of the lake and very steep slopes land of the city. On the other hand, the physical and topographical conditions of the city limit important developments and thus reduce the areas that can be developed in the city. Gullies and landslides are becoming more and more frequent in the city and deformation are observed in all areas of the city (Buzera et al., 2017). Other environmental issues such as flooding, land surface temperature, biodiversity loss, local warning, ecosystem degradation and habitat losses can be mentioned among others. This has led to the building of areas that are not suitable for construction, such as river banks, lakes, and even roads with important consequences on the environment. Indeed, the majority of species found in the littoral and on the shallows (between 40 and 60 m along the edges) are already suffering pollution effects causing significant drop in fishing production (INS, 2015). *Tilapia* and *Limnothrissa* (the most consumed) production on Kivu lake Bukavian coasts went from 841 to 965 tonnes from 1986 to 1997; and dropped to 723 tonnes in 2002 and 423 tonnes in 2015 (INS, 2015) In the city, the visible consequences include anarchic construction and a relatively high sanitation degradation rate.

Given the current situation of Bukavu city and because of the above described situation which has led to poor city development control, it is urgent to carry out a thorough reflection on the implementation, development and creation of new satellite cities; and at the same time, establish a strategy for the development, strengthening, and restructuring the existing with the potential to accommodate a large number of people. Despite this lack of regulation in the urban planning sector, we note that DR Congo has continued to urbanize in anarchy and at accelerated pace (Sambieni, 2019). It seems important that a development plan for people living in slums (areas with a high birth rate) be established

Planning for increased urban space remains a key aspect of most cities around the world. Indeed, due to lack of planning, many cities will be unable to cope with unavoidable major problems, including population growth, climate change, resource depletion, environmental degradation, and limited budgets.

The overall objective of this study was to contribute to the improvement of urbanization of the eastern DRC cities, especially of Bukavu, in South Kivu province. Specifically, this research determines the available suitable and non-suitable areas in Bukavu city based on known urban requirements as well as urban densification by taking into account the number of people that will have to occupy the city by 2030 and 2050 considering the four city functions. Environmental protection and globally established technical standards should be considered, as well as the areas of the ideal urbanization terrain slopes in the perspective of horizontal, vertical and mixed projections. The study, finally evaluates the perception of the population as well as their ability to move to the next proposed satellite cities.

2. Materials and methods

2.1. Study area

2.1.1. Location

Bukavu is located in South Kivu province, eastern DR Congo (**Fig. 1**). The total area of the city is ~43.3 km^2 divided into three municipalities: Kadutu (~6.68 km^2), Ibanda (~13.38 km^2), and Bagira (~23.26 km^2). The Bagira municipality is composed of four districts: Cahi, Lumumba, Nyakavogo, and Kasha (the largest with ~19.4 km^2). Ibanda has only three districts, including Ndendere, Nyalukemba, and Panzi, with ~4.3, 4.7, and 4.4 km^2, respectively. Considered as commercial municipality, Kadutu is composed of seven districts: Cimpunda, Kajangu, Kasali, Mosala, Nkafu, Nyakaliba, and Nyamugo. These are small districts (not reaching 1 km^2 except for the last two with ~2.2 and ~1.5 km^2, respectively (DCRP, 2010).

The Ibanda municipality alone is densely populated as evidenced by the large number of houses that have been built in the last two decades (Karume et al., 2017). Alone, it has 69 elementary schools, 124 secondary schools, and 22 kindergartens. Located on the shores of Lake Kivu, which offers a panoramic view, Bukavu has a port that allows trade between Goma city in North Kivu and Idjwi island. The satellites cities selected in this study are located in the vicinity of Bukavu: Miti-Murhesa in the north while Nyantende and Nyangezi are located in the south.

2.1.2. Climate, soil, and vegetation

The city of Bukavu benefits from a humid tropical climate moderated by the elevation. It is of Aw3 type according to the Köppen-Geiger classification (Kajibwami, 2015; Buzera *et al.,* 2017). The analysis of available meteorological data from recent years (**Supplementary data**) shows that the average annual rainfall is ~1500 mm. Two seasons characterize the area: a short dry season that lasts 3 months from June to September a rainy season that lasts 9 months. The dry season presents high temperatures and a scarcity of rains. During this period, swampy areas are cultivated to cover the needs of vegetables in the city.

The city of Bukavu presents a marked relief (more than ~700m of difference in altitude). It is located in the west zone of the eastern African rift. It is a seismically "active" region; numerous fractures can also be observed in the region, one of which even crosses the town. The area is highly favorable for landslides. Indeed, Bukavu is strongly affected by landslides (Moeyersons et al., 2004; Delveau et al., 2017). Buzera et al. (2017); deformations all over the city impact water and electricity distribution. Bukavu is also dominated by steep slopes and mountainous relief. The soil consists of regoliths, deep Nitisols, and Ferralsols, and clayey soils. Alternating layers of more or less altered basalt accentuate the landslides and erosions that shape its form.

The vegetation cover in and around Bukavu is contrasted; it is characterized by a strong anthropization that constantly favors the erosion process of the soils resulting in the appearance of large gullies often on the slopes. Apart from a few isolated trees located in the city, green spaces are rare (Moeyersons et al., 2004).

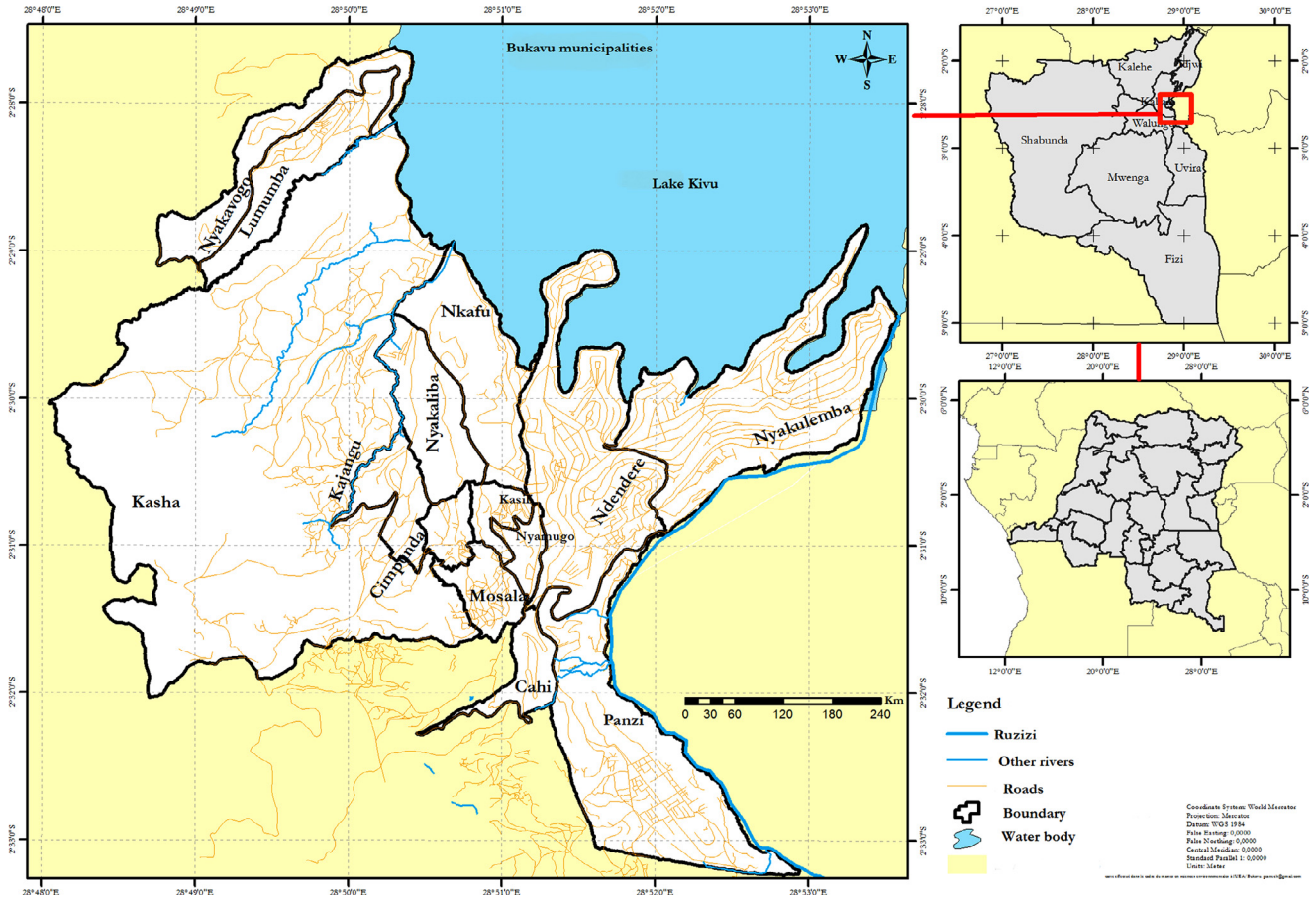

Fig. 1. Bukavu city and its minicupalities and districts, the city is located in South-Kivu province, eastern DR Congo.

2.1.3. Socio-economic situation of Bukavu city

There is a population's diversity in Bukavu city. All the ethnic groups of South Kivu province, if not of the country, can be found in Bukavu. However, the majority are Bashi and Rega. Apart from foreigners, ten ethnic groups live in the city: the Bashi from neighbor territories (Walungu and Kabare), Rega (Mwenga, Shabunda, and Fizi), Havu from Idjwi and Kalehe. In addition Bavira, Bembe, Nyindu, and Batwa can be found in Bukavu. There are also foreigners, often from neighboring countries (Rwanda and Burundi) (DSCRP, 2010).

An increase in groups and numbers of people has been mentioned over the last decades; it is characterized by the destruction of basic socio-economic infrastructure (statehouses, roads, bridges, engineering structures, factories, etc.) and by the destruction of the town's infrastructure. This phenomenon has resulted in a decline in the production, market, and movement of people and their goods (DSCRP, 2010). Moreover, population's low level of income can be noticed (Vwima, 2014). This mass poverty (especially in suburbs where people no longer have access to the production factors) also results in an economy oriented towards neighboring countries where economic operators have the facility to import. From a demographic point of view, the province has more women (52%) than men; the age group of less than 18 years being more represented than other groups (56.1%).

2.2. Methods

2.2.1. Determination of suitable area for dwelling and settlement installation in Bukavu

2.2.1.1. Topographic features of Bukavu city and segmentation of the city into suitable and unsuitable zones. The combination of GIS and Remote Sensing (RS) was used to determine the suitable area for settlement installation. Suitable area was determined based on the slope (in %); an ASTERDEM of 30 m of spatial resolution was used. ArcGIS 10.7 software helped to first extract the city area on the Digital Elevation Model (DEM) downloaded from the USGS website; and secondly to calculate and classify the slopes based on building requirements (slope<2%: not suitable as subjected to flood and inundations, slope between 2-15%: suitable and slope>15%: not suitable as subjected to soil erosion as mentioned in the environmental law of DR Congo). The digital elevation model was first filled using the "Fill" analysis tool and slope classes were obtained after running slope analysis and reclassified in the same software. The suitable slope areas (between 2-15%) were saved after conversion into a polygon. Bukavu roads, rivers, and lakeshores were clipped from existing DRC shapefiles and buffer zones from each one were determined. According to the country regulation on urbanization, 5 – 8 m, 100 m, and 50 m of buffer zones have to be applied for roads, rivers, and lakes, respectively. Buffer zones area were calculated and subtracted from the suitable zone of 2 - 15% slope area to obtain the final settlement and dwelling suitable area. Data used, maps of buffer zones, and the methodological design workflow is presented in the **Supplementary material**.

2.2.2. Subdivision of Bukavu city according to different land-use types and population repartition based on the GeoEye and Sentinel 2A satellite images

GeoEye satellite image was used to assess the land use and land cover (LULC), and the population distribution in Bukavu city (2016 image); and Sentinel 2A (of 2020), respectively. The Sentinel-2A was obtained from USGS website (https://earthexplorer.usgs.gov/), while the GeoEye was purchased and ordered on http://www.trigis.de/. The procedure

used was developed by Karume et al., (2017). For 2016, ten classes were obtained due to the very high resolution of the image used while in 2020, only four classes were considered after classification. The city was then divided into high, medium, and low density zones, and water bodies. Supervised classification was performed using ENVI Tools 5.3 version; while the post-classification based on classes separability was executed in the same software. The overall precision and Kappa index were also calculated after classification.

2.2.3. Population projection in Bukavu and its surrounding selected area in 2030 and 2050

Population exponential projection formula was used to quantify the population of the city in 2030 and 2050. $\mathbf{P_t = P_0\ (1+r)^t}$ was used; with $\mathbf{P_t}$= projected population, $\mathbf{P_0}$= initial population (based on the 2016 estimation of 686 854 people, the growth rate **r**= 0,031 (Direction Provinciale de la Santé, 2013), **t**= time between 2016 and the projected years (14 years for 2030 and 34 years for 2050, respectively).

2.2.4. Perception of the population on the extension of Bukavu town to the selected sites (Miti-Murhesa and Nyantende) and the households' readiness to be relocated to the satellite cities in Katana and Nyangezi

To assess the population's perception of the city's extension and readiness to be relocated to the satellite cities, surveys were conducted in Bukavu and in the selected zones to accomodate satellite cities. The population living in Bukavu city was surveyed and questioned whether they are ready to move to the selected sites for both the city extensions and satellite cities. Households were randomly selected from the total Bukavu population. Two selections criteria were considered, those including the recently established in the city and often living in the unsuitable areas for construction and the one living in the selected zones for expansion. These area included Kabwakasire (in Kadutu), Mulambula (in Kasha and Bagira), and Mulungulungu (in Panzi-Ibanda and, Luziba in the Ibanda municipalities). Those who have lived in the city for a long time (since the 70s) were selected in the "old districts" (Cimpunda and Mosala in Kadutu commune), Burhiba, and quarter A, B, C, and D in Bagira as well as Nyawera and Nguba in Ibanda municipality.

Regarding the introduction of the newly displaced population and the construction of the satellite cities in Miti-Murhesa and Nyantende as well as Nyangezi and Katana, people living in these areas were surveyed. Given the financial means and the time available, a total of 10 people in each site, (~150 people in total) were randomly selected for the survey. The survey consisted of a direct interview followed by a survey questionnaire composed of both closed and open questions. These questions focused on socio-economic information's (age, origin, and marital status, number of persons per household (HH), main activity, and study level); while the main questions on perceptions were formulated (are they ready to move/to leave Bukavu for the newly selected sites? If yes which sites? If not why? On the other hand, for those living in the selected sites (new cites and satellites cities), if they are ready to receive urbanization; if yes/no, what is the reasons for that.

3. Tools, data treatments, and analysis

Spatial analyses were performed using ArcGIS 10.7 Esri software while image classification and class separability assessment were performed using ENVI tools 5.3 version. Attribute tables were extracted from raster images using the "Extract by the table" to perform statistical analysis with Microsoft Excel 2016. The database from the survey was analyzed using the Rstudio software and R 3.4.3 version. This software also allowed us to make graphs and tables. The logistic regression was performed to assess the dependency and/or influence of socio-economic factors on the willingness for relocation to the selected satellite sites. A significant effect was assessed at the 0.05 probability threshold.

4. Results

4.1. Suitable and unsuitable zones for urban dwelling and settlements development in Bukavu town

The table extracted from the slopes map has allowed reclassifying slopes into three classes according to urban planning requirements. Results from Fig. 2 present these classes on the map. It shows that ~68.6% (~29.7 km^2) of the city is suitable for dwelling and settlement installation regarding its slope (2-15%) and therefore, suitable for urbanization implementation. On the other hand, ~1.85% (or ~0.8 km^2) of the total city's area are subjected to flooding hazards given their slope (<2%); while the remaining areas have steep slopes (>15%), thus are more susceptible to erosion and landslides. **Supplementary data** presented photos of the inundation and destruction of houses built in these areas. Comsidering slope classes, roads, rivers, and lakes buffer zones as well as deformation areas (by landslides), the suitable and not suitable areas in Bukavu town are ~21.7 km^2 (~49.3%) and ~21.9 km^2 (~50.7%), respectively.

These areas are not equally distributed among municipalities. For example, ~12.62 km^2 of the total surface area is found in Bagira compared to ~10.64 km^2 that can't be developed for dwelling and settlements. With nearly ~13.4 km^2, Ibanda has only a 6.26 km^2 suitable area. Finally, in Kadutu only ~2.45 km^2 are suitable out of the 6.7 km^2 of the municipality (Fig. 2 and Fig 3). In terms of percentages, it was noticed that ~36.6% of Kadutu municipality are suitable, ~46.7% and ~54.4% for Ibanda and Bagira, respectively. From the total suitable areas in Bukavu, more than half (~59.2%) are found in Bagira municipality, ~29.3% in Ibanda, and ~11.5% in Kadutu. These results indicate that for future planning, only Bagira municipality still has important places for dwelling and settlement establishment (Fig. 3).

4.2. Land use and land cover (LULC) in Bukavu in 2016 and 2020 and division of Bukavu surface based on population distribution

Fig. 5 represents the subdivision of Bukavu city according to different occupations types and actual population distribution (by density) based on Geoeye (2016) and Sentinel 2 (2020) image classifications.

The obtained results (Fig. 5**a**) dividBukavu (in 2016) into ten LULC varying from high density zones to open spaces and water bodies. The agricultural, open space, and woodland were found in peripheral zones (Panzi, Kasha, Nyakavogo, and Lumumba); these zones also had a low population density compared to Ndendere (south side) in Ibanda. Mosala, and Nyamungo in Kadutu were high densely populate. Nyalukemba and the South of Ndendere were medium to low densely populated. However, these areas had a great amount of commercial zone that went through PE Lumumba Road Avenue; the other commercial part was located in Nyamugo (with Kadutu market). Over the entire city area (~43.3 km^2), nearly a quarter (24.4%) was classified as medium density zones (~10.7 km^2), while 18.7% (~8.1 km^2) and 12.6% (~5.46 km^2) were classified as low and high-density zones, respectively. The agricultural and wooded zones were located in the western part of the city and represented ~19.2% and ~7.3% (or ~8.4 and ~3.2 km^2), respectively; these areas were mostly called agrarian-urban zones.

The same trend was observed for no suitable areas. Fig. 4, which shows the two zones in the Bukavu city by the municipality, shows that the suitable zones vary not only from one municipality to another but also from one to another. Supplementary 1 shows that some quarters are almost found in the non-suitable zones. This is the case, for example, in Kadutu municipalities such as Nyamugo, Nyakaliba, and Kasali with only 0.19, 0.16, and 0.15 km^2 of appropriate areas, respectively. The districts with a large suitable surface that can be developed for planning are Kasha (10.4 km^2), Nyalukemba (2.53 km^2), Panzi (1.91 km^2), and Ndendere (1.83 km^2), respectively. Others have moderately large surfaces, such as Nyakavogo (0.95 km^2), Lumumba (0.85 km^2), Cimpunda

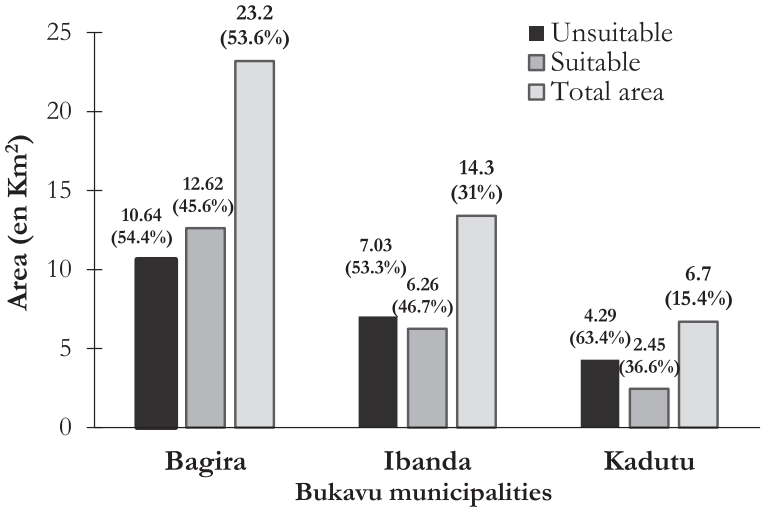

Fig. 2. Suitable and unsuitable area in the three municipalities of Bukavu town in South-Kivu province, eastern DR Congo (value in parenthesis are % of suitable and unsuitable area by the total of each municipality).

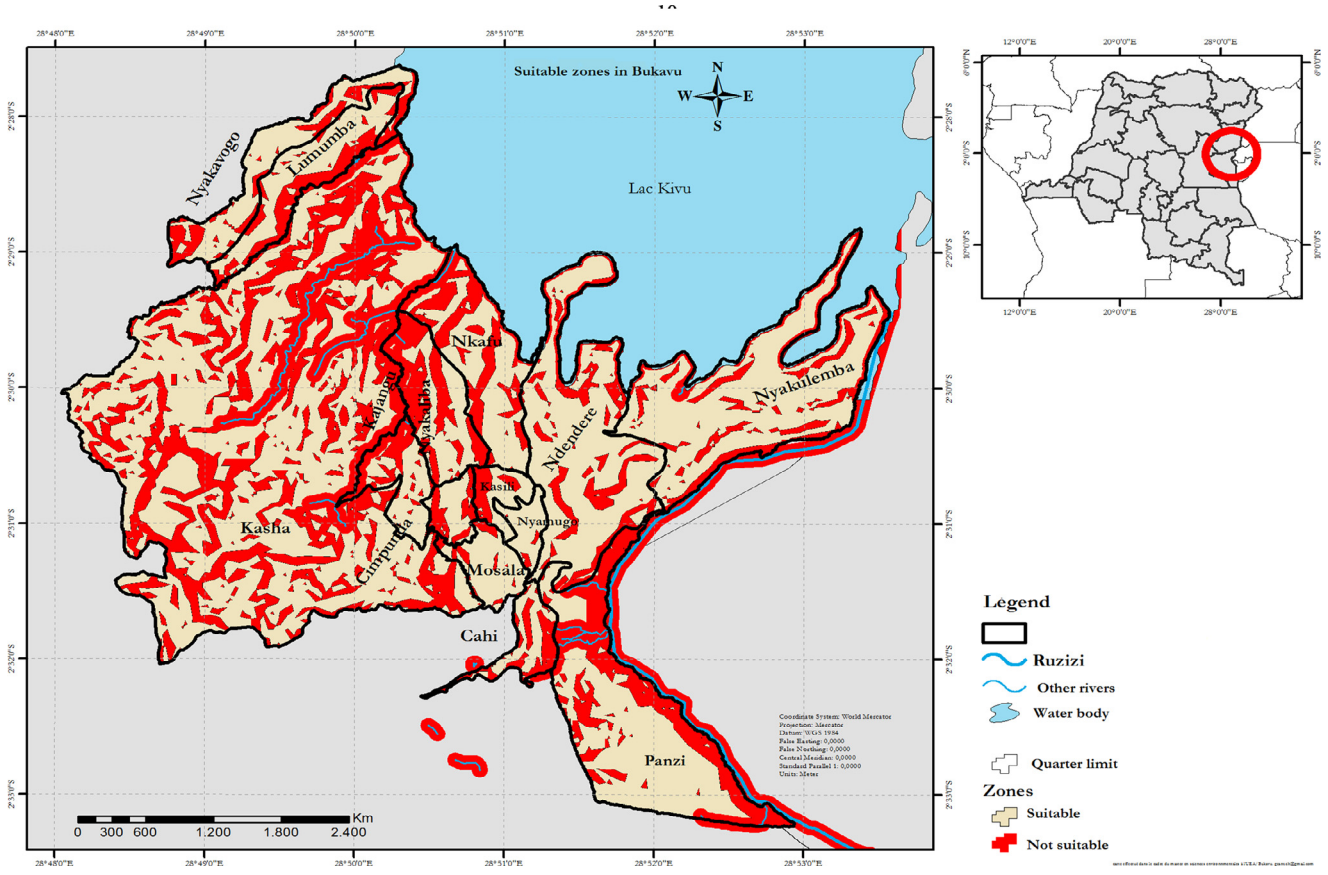

Fig. 3. Suitable zones for settlements and dwelling in Bukavu city, South Kivu province, eastern DR Congo.

(0.64 km^2), Mosale (0.69 km^2), and Nkafu (0.54 km^2). The districts of Kadutu are those with the least suitable areas.

4.2.1. Land use and cover in Bukavu cities and on satellite images classification

The classification of the GeoEye satellite image (for 2016) and Sentinel 2 (for 2020), shows that agricultural and wood areas were only found in the outlying districts (Panzi, Kasha, Nyakavogo, and Lumumba). These quarters are also those with low population density compared to Ndendere (southern part), Mosale, Nyamugo which are densely populated. Nyalukemba and the southern part of Ndendere are moderate to lightly populated. These areas also had most of the commercial zones along the roads and in the Nyamugo quarter (Kadutu, the city's big one market). One finding is that quarter such as Kasha with more suitable areas (10.4 km^2) are less densely populated and still has significant woodland,

For 2020, Sentinel 2A image analysis results in Fig. 5**b** show four zones. Due to the image resolution, it was difficult to separate these classes into more other specific classes as in Fig. 5**a**. However, the post-classification analysis performed showed a precision of ~92.8%, i.e. a Kappa index of ~0.896. Table 1 shows the separability of the obtained classes (4). Based on separability class analysis; and from Table 1 ob-

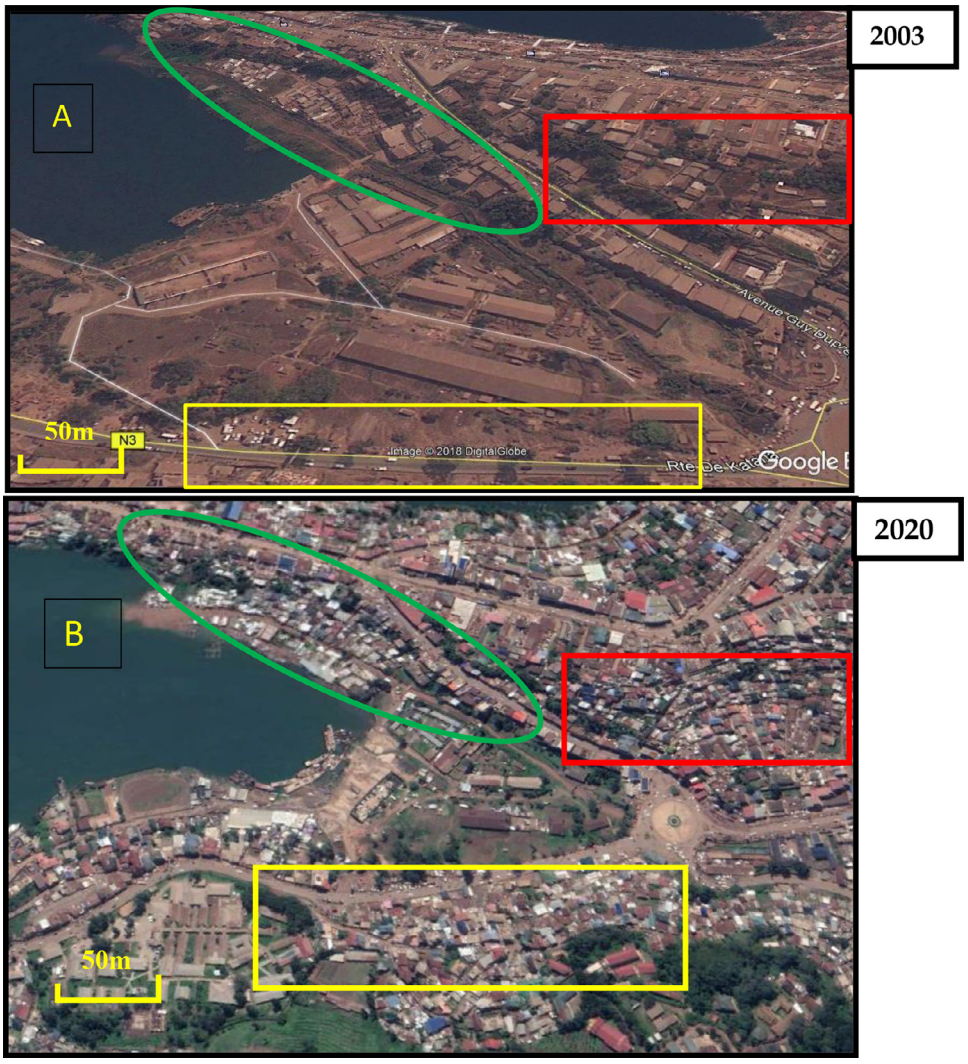

Fig. 4. Evolution of construction in SNCC bay in Bukavu between 2003 (A) and 2020 (B).

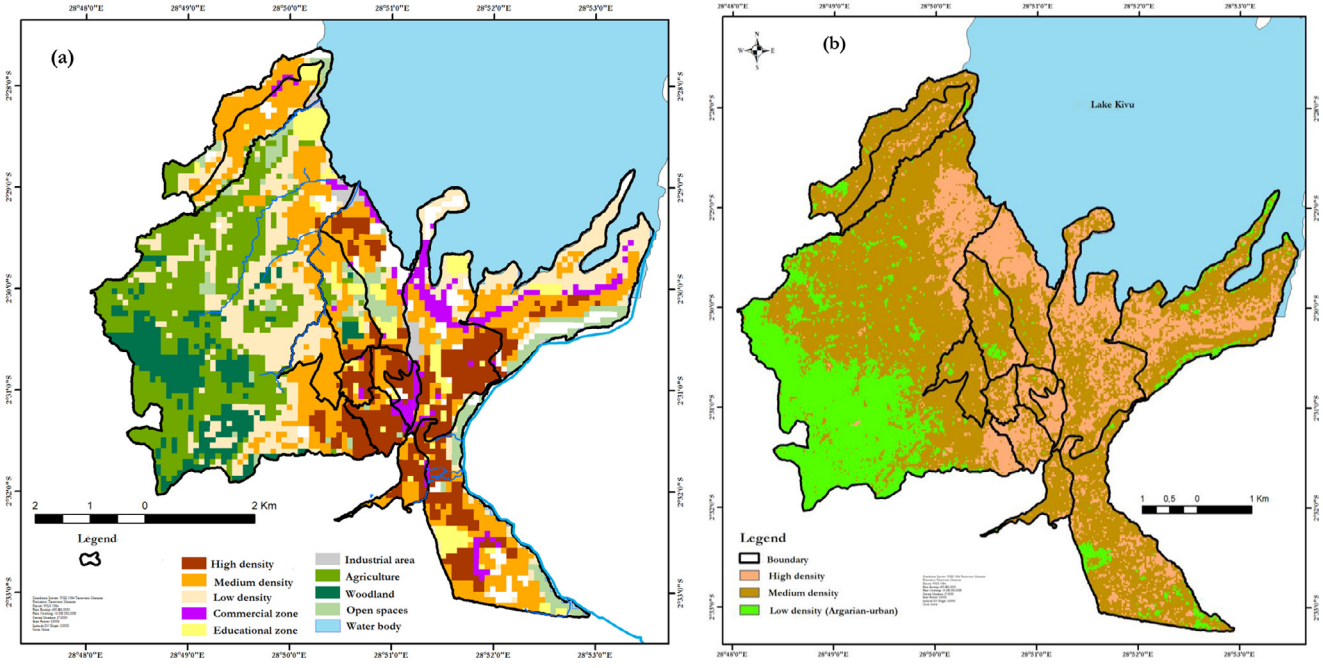

Fig. 5. Subdivision of Bukavu town according to different land use and land cover and actual population distribution after land use and cover analysis using GeoEye image (a) and density classes based on Sentinel 2 image classification of 2020 (b).

Table 1
Separability analysis density classes ~~found~~ in Bukavu town in 2020.

Classes	High density	Medium-density	Low density	Waterbody	Separability index
High density	4483				**1.9652**
Medium-density	(2173/4483)	(2173/2173)			**1.7608**
Low density	(3530/4483)	(2173/3530)	(3530/3530)		**1.5851**
Waterbody	(913/4483)	(913/2173)	(913/3530)	(913/913)	**2.000**

tained, it can be seen that low separability was observed for the "low populated" (1.58) and "moderately populated" (1.76) zones compared to the "densely populated area" (1.96) or areas covered with water body (lake and rivers). Fig. 4 obtained from google earth shows the settlement development in Bukavu from 2003 to 2020. It shows building development around SNCC bay without urbanization requirements consideration. Such images help to well point out the location of each density class.

Fig. 5**b** divided Bukavu into three zones based on density; the medium density area was dominant (~58.8%) and located in Ndendere, Panzi, and Lumumba, and Nyakavogo. Also, other zones (Cahi, Mosala, Nyamugu, and Cimpunda) had the same characteristics. Nyalukemba, Nyakaliba, and Nkafu were divided into medium to high densities. The low-density areas (~24.6%) were found in Kasha municipalities and a little bit in Panzi. These low-density areas were locally called “urban-rural” zones as they still had some open spaces, some farm gardens, and woodland (tree plantation area). They also border rural areas such as Nyantende (for Panzi), Kabare, and Walungu territories (for Kasha).

4.3. Population projection for 2030 and 2050 in Bukavu and surrounding areas based on the 2016 population estimation

The estimation made indicates 686854 people in 2016. Based on these estimations, the projection in 2030 (14 years) and 2050 (34 years) indicate ~1386238 and ~2552766 people for the two years, respectively. On the other hand, in 2030, the two selected satellites cities of Miti-Murhesa and Nyantende, will have an estimated population of ~870781 people (~124397 HH) and 689795 people (~98542 HH), respectively, with an average of 7 persons per HH. In 2050, the two areas will have 1603548 (~229078 households) and 1270263 (181466 households), respectively. The results show that with ~21.7 km^2 of suitable areas, Bukavu town will only be able to accomodate ~260400 people. The surplus of ~500,854 should be relocated into the other selected sites.

4.4. Unclogging scenarios for Bukavu town in South-Kivu, eastern DR Congo

4.4.1. Suitable zones in Miti-Murhesa and Nyantende as satellite cities and Nyangezi and Katana for new cities as Bukavu city extension

Fig. 6 (**a** and **b**) presents the suitable areas obtained in the selected zones for Bukavu unclogging based on terrain slope in new cities and satellites cities selected for Bukavu extension. Nyantende and Miti-Murhesa were selected as satellite cities while Nyangezi and Katana were selected as new cities.

Based on slope classes, buffer zones from rivers, roads, and Lake Kivu, and national park (specifically the Kahuzi-Biega National Park: PNKB), we obtained suitable areas for dwelling and settlements presented in Fig. 7. Five slope classes were generated as indicated on Fig. 6; including, flooding susceptible zones (slope < ~2%) which covers more than a quarter of the area (~30.7%) in Miti-Murhesa and Nyantende (~28.6%). Suitable for settlement and dwelling development zones, i.e. with a slope between 2 and 15%; these areas were mostly located in Nyantende (~57.5%) than in Miti-Murhesa (~47.5%). On the other hand, areas with slopes <2% dominated the two zones selected as satellites cities; with ~40% in Nyangezi and ~33.9% in Katana. Suitable zones (2 to 15% of terrain slope) represent~49.2% and ~48.1% of these areas, respectively. This corresponds to ~38 km^2 in Nyantende, ~154 km^2, ~125, and ~100 km^2, respectively in Katana, Miti-Murhesa, and Nyangezi (Fig. 7).

4.4.2. Urbanization scenarios of Bukavu town

a) Horizontal extension

Extension of Bukavu town in the two-axis implies determination of space required for equipment and settlements in 2016, 2030, and 2050 and based on population growth obtained for each selected year. The surface requirements based on horizontal extension are presented in Table 2 while Table 3 presents the vertical extension requirements.

a) Vertical expansion
b) Towards the northern axis of the Bukavu town (Miti-Murhesa and Katana)

A surplus of ~500854 people was found in Bukavu; this value was split into two groups: half (~250427) will be relocated in the northern axis and on which will be added 246071 people that already live in the area according to DPS statistics. This bring a total of ~496498 people in the northern axis. That figure is used to deduce the space required for ideal urbanization in 2016, 2030, and 2050 (**Supplementary data** in tableau presenting the mixed development:horizontal and vertical combined urbanization framework).

It appears that in 2016 14.90 km^2 was needed, while the surface area of Miti-Murhesa that was suitable for urbanization represented ~125 km^2, hence a surplus of ~110.1 km^2 is noticable. In 2030, the required space will be ~22.84 km^2 with the population growth, the surplus of 102.16 km^2, and in 2050, it will be required ~42.06 km^2, and surplus of ~83.94 km^2 will remain in the selected zone of Miti-Murhesa. From these results and even the one on mixed extension (**Supplementary data**), it appears that there will still be enough space to accommodate a large population in Miti-Murhesa taking into account all the three extension types (Horizontal, vertical and mixed).

In 2030, the total space occupied by settlements should be 47.57 km^{2,} and for equipment 31.71 km^2 in Miti-Murhesa. While, in Nyantende, 60.44 km^2 will be needed. In 2050, Miti-Murhesa zone should be 146.02 km^2 and 111.31 km^2 covering 60% and 40% for housing and equipment, respectively for Nyantende. Tables 2 and 3 present the horizontal and vertical types requirements, respectively.

a) Towards the southern axis of Bukavu city (Nyantende and Nyangezi)

The approach was the same as the one adopted for the northern axis; the added population (250427 coming from Bukavu) with the 128033 that already live in the area gives a total of 378460. Proceeding the same way as above, it was found that in 2016, ~11.35 km^2 was needed, whereas the Nyantende area had only 38 km^2 of suitable area. Hence, a surplus of ~26.65 km^2 will still be needed in the area. In 2030, it will be ~17.41 km^2, which gives a surplus of ~20.59 km^2 compared to 38 km^2. In 2050, it will be 32.06 km^2, only a surplus of 5.94 km^2 will be available in the future in the zone.

a) Population and surface requirements

426454 people will have to be relocated from the city to restore the Bukavu town’s urban planning standards. Thus, the surplus will be placed in new cities to reduce waste of space, considering the mechanisms of horizontal, vertical, or mixed extension. Referring to **supplementary data**, the number of households in different zones was deduced

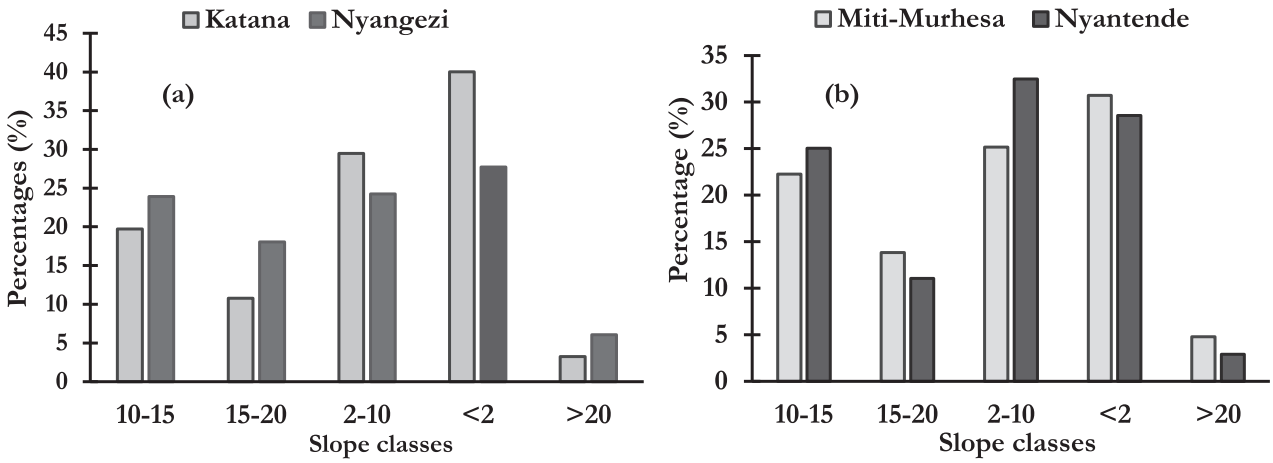

Fig. 6. Slope classes in the new cities (Katana and Nyangezi) (a), and satellites cities (Miti-Murhesa and Nyantende) (b); these areas were selected for Bukavu town extension (Slope classes were obtained after projection and reclassification of the DEM raster analysis of the "terrain slope analysis" in ArcGIS 10.7 version).

Table 2
Space required for equipment and settlement in selected sites.

Years	Modalities	Percentage	Bukavu (Km^2)	Miti (Km^2)	Nyantende (Km^2)	Nyangezi(Km^2)	Katana(Km^2)
2016	***Settlements***	60%	34.34	14.90	11.35	17.18	21.03
	Equipement	40%	22.89	9.93	7.57	11.45	14.02
	Total required	100%	57.23	24.83	18.92	28.63	35.05
2030	***Settlements***	60%	52.66	22.84	43,54	34,49	32.25
	Equipement	40%	35.11	15.23	29,07	22,99	21.50
	Total required	100%	87.77	38.07	72,57	57,48	53.75
2050	***Settlements***	60%	96.97	42.06	80,18	63,51	59.38
	Equipment	40%	64.65	28.04	53,45	42,34	39.59
	Total required	100%	161.62	70.1	133,63	105,85	98.97

Table 3
Required space for equipment and settlements in the selected site.

Years	Modalities	Percentage	Bukavu (Km^2)	Miti(Km^2)	Nyantende(Km^2)	Nyangezi(Km^2)	Katana(Km^2)
2016	***Settlements***	60%	20,60	17,04	13,5	10,90	12,62
	Equipement	40%	13,73	11,36	9	07,27	8,41
	Total required	100%	34,33	28,4	22,5	18,17	21,03
2030	***Settlements***	60%	31,60	26,13	20,7	16,73	19,35
	Equipement	40%	21,07	17,42	13,8	11,15	12,90
	Total required	100%	52,67	43,55	34,5	27,88	32,25
2050	***Settlements***	60%	58,19	48,11	38,11	30,80	35,63
	Equipment	40%	38,79	32,07	25,41	20,53	23,75
	Total required	100%	96,98	80,18	63,52	51,33	59,38

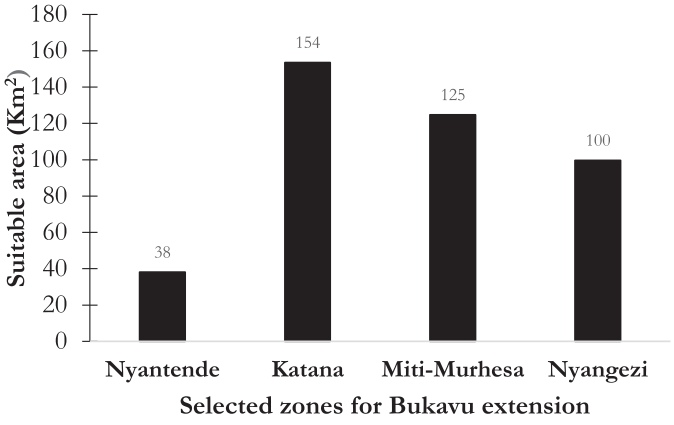

Fig. 7. Suitable areas for Bukavu town extension in four selected zones–Two (Nyantende and Miti-Murhesa as satellites cities and Katana and Nyangezi as New cities).

(knowing that the average size of a household is 7 people). The number of households also increased significantly depending on the zones and the two future projected years. In fact, in 2016, the number of households in the city of Bukavu was estimated to be 98122 while Nyangezi and Katana had ~51941 and ~60091. The probably household projection that will be visible in 2030 and 2050 are 150448 and 277052 households in Bukavu, respectively. If we take into account the prevention of any eventuality that might arise from the tragic population explosion, we have increased the calculated area by 25%. Thus, in 2030, Bukavu should need 109.71 km^2 exceeding by far the available suitable area of the town. In Nyangezi, it will be 34.84 km^2 in which 23.22 km^2 will be allocated to equipment; while in Katana it will be ~26.87 km^2 distributed according to the order of 60% and 40%, for dwelling and settlement, and equipment, respectively. In 2050, Bukavu and Nyangezi will need ~202.02 and ~106.94 km^2, respectively, and ~49.49 km^2 in Katana. These areas should be distributed in the order of 60% and 40% between dwelling and settlement, and equipment, respectively.

The results on the space requirements for dwelling and settlements in selected zones according to the vertical extension are presented in Ta-

Table 4
Socioeconomic characteristics of survey households in Bukavu city and selected zones.

		Selected zones					Bukavu municipalities			
Parameters	**Modalities**	**Katana**	**Miti**	**Nyangezi**	**Nyantende**	**Mean±Sd**	**Bagira**	**Ibanda**	**Kadutu**	**Mean ±Sd**
Age	***(years)***	29.0±8.0	33.3±11.2	44.6±14.4	42.7±8.6	**36.3±12.7**	49.3±9.1	43.03±13.8	46.2±15.0	**45±13.9**
Household		10.4±0.5	7.9±2.6	7.6±1.8	7.7±2.3	**8.4±2.2**	6.7±1.7	7.3±1.7	7.2±2.9	**7.2±2.9**
Sex	***Female***	40.0	40.0	30.0	20.0	**32.50**	20.0	42.5	31.0	**35.4**
	Male	60.0	60.0	70.0	80.0	**67.50**	80.0	57.5	69.0	**64.6**
Marital status	***Single***	17.6	11.1	5.3	0.0	**8.1**	0.0	6.7	13.3	**8.4**
	Married	82.4	88.9	94.7	100.0	**91.9**	100.0	93.3	60.0	**81.3**
	Divorced	-	-	-	-	**-**	0.0	0.0	26.7	**10.3**
Monthly Revenue ($)	***<100***	40.0	40.0	25.0	42.9	**36.7**	42.9	8.2	61.5	**25.3**
	100-200	40.0	40.0	75.0	57.1	**53.3**	57.1	33.0	25.6	**33.3**
	200-300	20.0	20.0	0.0	0.0	**10.0**	0.0	27.8	0.0	**18.0**
	300-400	-	-	-	-	**-**	0.0	20.6	0.0	**13.3**
	> 500	-	-	-	-	**-**	0.0	10.3	12.8	**10.0**
Educational Levels	***Illiterate***	0.0	0.0	0.0	0.0	**0.0**	0.0	0.0	0.0	**0.0**
	Primary	0.0	7.7	16.7	16.7	**9.8**	28.6	8.0	7.1	**9.7**
	Secondary	100.0	92.3	83.3	83.3	**90.2**	71.4	48.0	17.9	**38.6**
	University						0.0	44.0	75.0	**51.7**
Profession	***Public officer***	0.0	0.0	0.0	9.5	**1.5**	0.0	10.0	16.7	**11.3**
	Trader	10.5	9.5	25.0	47.6	**19.6**	20.0	22.5	33.3	**23.8**
	Other	23.7	7.1	28.1	42.9	**22.6**	60.0	52.5	26.7	**46.3**
	Agriculture	65.8	83.3	46.9	0.0	**56.4**	20.0	12.5	3.3	**10.0**
	Student/teacher						0.0	2.5	20.0	**8.8**

bles **3** and **Supplementary data** showed the vertical extension. Based on such extension, it appears that in 2016 a need of ~20.61 km^2 in Bukavu while only ~21.70 km^2 were available. In 2030, that area will rise to ~31.60 km^2 (deficit of ~9.9 km^2), and ~58.19 km^2 (deficit of ~36.39 km^2) in 2050. From this, it appears that even in the option of mixed extension there will be a part of the households that will always be moved from the town to satellites cities and new cities. In 2030 households occupying ~9.9 km^2; and ~36.49 km^2 in 2050 will be relocated from the town to ensure sustainable urban planning.

Results for mixed (combined vertical and horizontal extension) found in **Supplementary data**, it appears that in adopting mixed extension, in 2016, ~10.91, ~16.73, and 30.8 km^2 will be needed in 2030 and 2050, respectively. From these results, it emerges that even in the mixed extension option, there will be population delocalization while important spaces to accommodate such a large population are still found in Nyangezi and Katana, taking into account the mixed extension. For example, in Katana, within the framework of mixed extension (horizontal and vertical combined), it appears that in 2016, ~12.62 km^2 will be needed while the suitable area represented ~154 km^2 (hence a surplus of 141.38 km^2). In 2030, it will be ~19.35 km^2, which will be taken on the ~154 km^2 of suitable area in the zone. In 2050, the surface need will be ~35.63 km^2, which means that a surplus of ~118.37 km^2 will still be observed in Katana (with ~154 km^2 of suitable area). If we take into account any eventuality that might arise from the tragic population explosion in the great lake region, an increased area of ~25% is needed. In 2030, in Bukavu we will need ~26.34 km^2 which largely exceeds the available suitable surface in the town; in Nyangezi, Katana it will be ~20.91 and 40.3 km^2, respectively. These figures will be increased in 2050 up to ~48.49 km^2 (in Bukavu), ~64.16, and ~74.22 km^2 in Nyangezi and Katana, respectively (and this only if 60% and 40% of the area is dedicated to settlements and dwelling, and equipment, respectively). Table 4 indicates the socioeconomic characteristics of the surveyed households in the selected zones.

4.5. Perceptions of the population and ability to move to the proposed new cities

4.5.1. Socio-economic factors on affordability option to be relocated to the selected sites based on socioeconomic characteristics of households

a) Socioeconomic characteristics

The socioeconomic characteristics of surveyed households in the study area are presented in table 4. The socio-economic characteristics were obtained from the household (HH) heads selected and surveyed in the selected areas. Table 4 shows that the average age of people in the new satellite cities and new cities was 36.3±12.7 years, with an average of 8.4±2.2 persons per household; while in Bukavu, 7.2±2.9 persons per HH were found, with an average of 45±13.9 year's age-old of the HH head. The majority were men (~67.5%). These HH heads were generally married (~91.9%) and more than half (~53.3%) had a monthly income of between $100 and $200 per month, which is different from those in Bukavu, where nearly a quarter (~23.3%) already have a monthly income of over $300. In all the selected zones, no HH head had confirmed having a monthly income of more than $500, which reflects the economic level of people living in the selected zones; compared to Bukavu, where ~10% of respondents HH had a monthly income of more than $500 per month and ~13.3% between 300 and $400. The majority of respondents in the selected areas had secondary education levels (~90.2%) compared to those in Bukavu who had university education levels. In the selected areas, more than half had agriculture as their main profession or activity.

Table 4 shows also that the average age's old of people in the areas selected for the construction of the new satellite towns was 36.3±12.7 years, with an average of 8.4±2.2 people per HH; while in Bukavu, a value of 7.2±2.9 persons per HH was found, with the head of household averaging 45±13.9 year's age-old. The majority were men (~67.5%). These HH heads were generally married (~91.9%) and more than half (~53.3%) had an income of between 100 and 200$ per month; which was different from those in Bukavu where nearly a quarter (~23.3%) had a monthly income of over 300$. In all the selected zones, no HH head confirmed having an income >500$, which gave an idea on the economic level of people living in the selected zones; compared to Bukavu, where nearly 10% of respondents had monthly income >500$ and ~13.3% between 300 and 400$. The majority (~90.2%) of respondents in the selected areas had secondary education levels compared to those in Bukavu who had university education levels (~51.7%).

In the selected areas, more than half had agriculture as the main activity. In contrast to the population surveyed in Bukavu, which ~46.3% had other activities, or were goods traders (~23.8%), only ~10% are farmers, and they often live far from the town center, such as in Mulungulugnu, Kabwakasire or near Bagira.

In contrast to the population surveyed in Bukavu, where nearly 46.3% of the population is engaged in other activities, or the trade of goods (23.8%), only 10% are farmers, and they often live far from the city, as in Mulungulugnu, Kabwakasire or Bagira. This table thus shows a

Table 5
Socioeconomic factors affecting the affordability of relocation to the selected locations (from Bukavu to selected site for new cities and satellites cities.

Variables	*Coefficients*	*Error-typ*	*Test-z*	*Prob*
Constant	1,8434	0,4793	13,331	*0,000****
Household (HH) head profession	-4,0030	0,0604	-0,342	*0,068ns*
Monthly income of the HH head	125,76	26,1295	4,236	*0,987ns*
Land owner	0,0006	0,0301	2,9	*0,040**
Municipalities	-0,0133	0,1549	-16,081	*0,0235**
HH head origin	-2,029	0,0372	2,646	*0,587ns*
Educational level	-1,067	0,0733	42,45	*0,450ns*
HH Head age	23,275	3,0302	1,866	*0,0036****
Sex	-0,0337	0,0444	19,675	*0,393ns*
Nber of persons per HH	5,567	0,1044	9,497	*0,583ns*
Marital status	-0,2025	0,1268	23,31	*0,032***
Occupations	0,0393	0,0677	3,331	*0,038***

R^2=72.34
LR χ2 (12) = 213.0
*Prob > χ2 = 0.000****
Log likelihood = -20.153
Pseudo R2 = 0.733
AIC = 58.305
AUC = 0.984
n=150

disparity that can be observed between households in the areas selected for the new satellite towns and the "mother" town of Bukavu, both from an education and economic point of view.

Taking into account the origin of people found in the survey selected sites in Bukavu as well as in the selected zones for extension, it follows that in Bukavu, the majority of HH came from two border territories (namely Kabare: 30% and Walungu: 23%). Other portions came from Kalehe (~12%), Kaziba chiefdom (~6%), and other DRC provinces such as Goma (3%), Maniema (1%), Uvira (7%), and Katanga towards Moba (3%) (**Supplementary data**).

In the selected zones for extension, although the HH majority came from Kabare (~18%) and Walungu (~39%), other communities or households came to settle in the area from neighboring territories; only ~5% had returned from Bukavu town to the selected satellite areas.

a) Acceptability of relocation to the selected zones

According to the question addressed to Bukavu town population on whether they were ready to move to more or less stable and urbanized places such as Nyantende, Miti-Murhesa, or in Nyangezi, Kamanyola and Katana; similarly, whether householders in the selected areas are willing to accept urbanization in the area and thus accept the integration of the new population that would move to the sites, results show that the willingness or approval of the relocation of the population to the satellite cities varied significantly (Chi^2=12.75, *p<0.001*) according to the expectations of each HH. That decision depends on the HH socioeconomic characteristics and differed between HH area (municipality) of residence (*p=0.023*). Having a plot of land to live in Bukavu significantly explains the model (p=0.040). Two other factors influence the approval of a possible relocation; these are marital status (p=0.032) and the age of the head of household.

Data from **supplementary materials** show that more than half of the population from Ibanda municipality; (~55.8%) of its population seem to be in favor of relocation to the satellite city, while ~43.2% do not agree at all. The same trend was observed in Kadutu, where that vision is equally shared between those who are able and those who are not. The population of these two municipalities already felt that they belong to the city and it was difficult to leave. Some also kept confirming that they were born and raised in Bukavu and felt rather like home and therefore mentioned their difficulties to leave the town. Others had seen the Bukavu town deterioration, however, they agreed to leave for "reasonable" new satellite cities to preserve Bukavu from its complete degradation.

Other socioeconomic factors were obtained from the logistic regression made as mentioned in Table **5**.

Factors such as the age of the household's head significantly influenced the choice to move to the new satellite city. The constant was that it was generally older who willingly accepted to move rather than the younger. Indeed, young people assumed that the new cities will always depend on Bukavu town, especially in terms of entertainment (gym or fitness rooms, stadiums, sports facilities, cinemas, market, etc.), elements that appeared to not favor moving in the satellite cities.

Another aspect was sustainability in terms of electricity and water access. Although these elements were taken into account in any creation of new satellite cities, the realities of the country mean that these types of doubts sometimes persist. Another aspect was related to the young people's connotation, who assumed that any young person who does not live in the three municipalities of Bukavu was locally called "villagers", or "peasants". Sometimes even other connotations or terms such as "he rebuke", "Honoka", "Mukuya Kuya" and so many other terms classified as "depreciating" made young people find it difficult to agree to move to the new cities or satellite cities. Finally, another break linked to youth was linked to poverty that reigns in the surrounding cities of Bukavu town. Young people often left their villages and territories to search better life in Bukavu town. Once arrived, they often don't want to return and prefer to stay and settle by buying plots of land in unsuitable areas for settlements or dwelling; while the old ones prefer to move to live peacefully, without disturbance, which they are supposed to find in the new satellite cities compared to Bukavu where all the streets everywhere had become markets, churches, dancing clubs thus accentuating noise pollution in the city.

Another factor influencing the choice was the marital status of the respondent. Married people were more willing to relocate than single people who generally preferred the Bukavu town mood. However, it was noticed that although the terms new cities were introduced, these areas will always have a sense rather of the village, countryside, rural and be engraved in the minds of youth.

Households living in selected zones present a reluctance to development in their area. According to the question of whether or not they were ready to receive urbanization and thus a new population in their area. It arise that almost all the people living in the selected areas were ready to welcome urbanization in their environment. Only a very small

proportion of population (especially in Katana (20%) and Nyantende (10%) were reluctant to accept urbanization in their area. In contrast, in Miti-Murhesa (100%) and Nyangezi (100%) were entirely ready to welcome the development of new satellite cities.

5. Discussion

5.1. Suitable areas in Bukavu town are insignificant

The results obtained confirmed that in Bukavu town few suitable areas can be used for settlement and dwelling. These areas were estimated to be ~21.7 km^2 (~49.3%). These areas being reduced by several factors such as steep slopes, high occurrence of soil deformation zones, and buffer zones of rivers, roads, and lakes, respectively. Unfortunately, apart from the urbanization requirement non-respect, unregulated buildings in all the municipalities are observed in Bukavu (Muhaya, 2020). Plots are being split up into small plots that do not meet the main urban planning criteria. These practices are against the law given the fact the assignment of the parcel must be done with the approval of the responsible authority. In fact, in section IV and its Article 8 it is stated that the place of construction must have the possible options of connection to existing water pipes, but above all with a topographic situation provided that the slope of the land does not exceed 5% (CAB/MIN.URB-HAB/2005).

Urgent measures are needed to re-establish a development that meets the universally recognized standards for the protection of the environment. Among the prospects of its decongestion or the improvement of the habitat, this study propose three tracks of solution: the vertical or horizontal extension of the city, the creation of new cities, and satellite cities. Thus, in the light of the results obtained, we find that both vertical and horizontal extensions would be appropriate for the Bukavu city to ensure its decongestion and subsequently the creation of new satellite cities in northern and southern extremities of Bukavu, more precisely in Nyangezi and Katana.

It is therefore obvious that Bukavu had a low propensity for suitable areas. Indeed, the area is located in the Albertine Rift, and along the Mitumba chain, an area characterized by strong volcanic activity (Gevers, 1940; Michellier et al., 2020), mountains, and hills with steep slopes (Trefois et al., 2007; Ndyanabo et al., 2011). Also with the presence of lakes and rivers (Wafula et al., 2007), protected reserves (national park, respectively) (Kasereka, 2003) minimize these areas. Indeed, these areas are therefore subjected to enough buffer zones that will have to be put in place to protect these ecosystems. However, the question related to the applicability of the law for such protection remains. That was the case, for example, of anarchic constructions along the riversides, roads, and on the lake shores. Another aspect is related to the physical conductions of the region with strong incidences of landslides (Moeyersons et al., 2004; Nobile et al., 2018) erosion of all types (but much more urban gullies reported everywhere else (Trefois et al., 2007). All these elements keep reducing the suitable areas.

Such cases are not only applicable to Bukavu, this is also observed in Uvira and Goma towns and other eastern DRC cities, respectively. Thus, important contributions have to be made regarding the application of the law. In addition to these cases, the armed conflicts in the territories neighboring these cities (Büscher, 2018; Pech et al., 2018). It seems that the conditions and scenario of development would be difficult to consider; the extension of the cities in the new cities or satellite cities has been adopted in this study and appeared to be one of the ways out of these cities (and typical case here of Bukavu). The results obtained planned ~72.57 km^2 and ~57.48 km^2 of suitable area required in Miti-Murhesa and Nyantende, respectively by 2030; these areas will increase to 133.63 km^2 and 105.85 km^2 for Miti-Murhesa and Nyantende in 2050, respectively. Taking into account the terrain slope, these sites have however suitable areas (slope of 2-15%) of 38 and 125 km^2 for Nyantende and Miti-Murhesa (and the two others: 154 and 100 km^2). Thus, to ensure the expansion of the town these areas are adequate to accommodate the Bukavu population to ensure and recover its former reputation of "green city" in a sustainable manner. It is therefore not surprising that the city has a low proportion of developable areas.

5.2. Population projection and population allocation needs in selected zones

The results of the population projections showed that Bukavu, Nyangezi, and Katana will have approximately ~ 1386238, 740516, and 824961 people in 2030, respectively, which will increase up to 2552766 in 2050 (in Bukavu). Unfortunately, that population growth does not follow the urbanization rate. According to World Bank (2018), the eastern region of DRC (North and South Kivu suffers from civil war effect and display a relatively low urbanization rate (~17%); excerpt Goma town which recorded an annual growth rate higher than 10% since 1984 with the urban population rate higher than 60%. Poverty is becoming an urban phenomenon. 75% of the urban population lives in precarious zones, 15% higher than the average proportion in sub-Saharan Africa (Banque Mondiale, 2018). Moreover, the author emphasized that shelters, local infrastructure, and other capital investments are lacking in these areas. As in other African cities, the high population density is not supported by infrastructure or economic activity. As a result, Congolese cities and eastern towns especially have little infrastructure that enables people to work and live healthy, and for businesses to access inputs, customers, and reliable sources of water and electricity (Banque Mondiale, 2018; Muhaya, 2020). The non-control of the population movements whose causes are, however measurable; related to the rural exodus and the lack of an adequate management policy of the dwelling in particular and space in general.

Bukavu (as other eastern DRC cities) belongs to the African Great Lakes region, which is known for its high birth rate and therefore a very high density among the most populated areas of the African continent (Nkoko et al., 2011; Satterthwaite, 2017; Büscher, 2018). It is therefore clear that this high population growth coupled with poor legal practices, and population migration due to armed conflict lead to poor planning of urbanization.

5.3. Problem with vertical extension

From the obtained results, it appears that either horizontal, vertical or mixed extension, all allow to unclog Bukavu city. However, given the physical conditions of the area, it is not preferable to adopt the vertical extension although it reduces significantly the land cover. Indeed, with the position of the city, and the entire eastern part of the country in volcanic zones, the tectonic movements frequently observed would not allow such extension. On the other hand, it would favor the increase of buildings and settlements destruction due to frequent earthquakes (Nobile et al., 2018). Another aspect would be the difference in planning between the vertical structures types in the new cities and satellites cities which will be different from the reality of the area, without forgetting that these extensions are proposed far from the town; thus, rather social problems could appear. This could be difficult to implement, especially since some socioeconomic factors have determined the choice to relocate and resettle the population in these areas.

Therefore, the approach would only be effective if the intervention becomes rather integrated and where the social sciences have an almost non-negligible place. Especially in the Bushi (population tribe living around Bukavu) context where man has no rightful place in society unless he has land, and a house.

This is the case, for example, in the city of Nairobi, Dakar, and Johanesnourg with their problems of rent in the satellite cities and their slums (Talukdar et al., 2010).

Other authors interpret this as the consequences of the big entrepreneurs, the capitalists considered here as "the developers" who have and continue to build small houses and even entire small towns to fix the workers on the spot and monitor their way of life. Some traces of this

history remain, such as the cities of Kolwezi, Kamituga, etc. Others take this as the French history of 1955 and 1970 where the satellite or new cities were popular rental housing, called "HLM" (or dwellings with low rent), which were built in an industrial way on the outskirts of the cities, taking over agricultural land. This also seems to be in our sense that the selected areas provide a non-negligible share of goods and services, and especially market garden products to the city and other nearby cities (Murard and Merklen, 2018)

However, whether they were destroying neighborhoods and displacing people or incentive-based, all government or humanitarian attempts failed. This seems quite obvious in our case as well. One of the most important elements would be to forget about a rather integral approach without taking into account the perceptions of the population.

It is possible to observe a disparity between the people coming from the cities who seem to have a rather higher level than the high standings of the areas (Fourcaut, 1996). Especially in the case of Bukavu and even other cities, the precarious housing areas are far from housing of the poorest urban population of the city. Another question that arises is related to the accessibility to educational and medical institutions, etc. It has been noted that the university institutions, for example, which some people consider "serious", are all located in Bukavu city. This implies that accessibility in the new towns, satellite towns, should be well studied to allow exchanges and links with Bukavu city until they are completely autonomous.

The population of both Bukavu and the selected zones are ready to leave and to welcome the surplus population, respectively, once the areas intend for possible relocation are developed. However, certain socio-economic factors influence these choices, notably the age of the head of household. Older people were willing to relocate to find a quiet place where life is good, compared to younger people who found the approach prohibitive. The civil status also affects this issue. In Bukavu, the speculative rise in housing prices, the clientelism, and corruption of landlords and lessors have kept a large proportion of the middle class from accessing healthy housing. The average salary of a young person or congolese household (which is far less than $300 per month) does not allow him or her to live in cities (where the average minimum housing is $150 to $200 per month in Bukavu). Paying rent outside of the slums, which, due to the economic crisis and continued high rural migration, young people and those without decent salaries are therefore moving into these areas; this would also explain their strong expansion in Bukavu. Migrants in search of salaried work from the surrounding areas, young non-salaried graduates who want to leave their father's home, and Bukavian households below the income threshold are therefore attracted to these areas for two reasons: first, the rents are affordable, and the exchanges between neighbors and sometimes the mutual support between neighbors are remarkable. On the other hand, however, they are the places with the highest rates of urban crime and insecurity, which makes the "ethnic" groupings that occur there reassuring.

6. Conclusion

This work contributes to the improvement of urban planning of DR Congo Towns in general and Bukavu Town specifically, in South Kivu province. The study deals with urbanization problem and proposes at the same time some perspectives of unclogging.

Bukavu has only 21.7 km^2 suitable areas for building; these areas are unevenly distributed across the town and neighborhoods; a larger portion remains available only in Bagira. Based on the estimates made, the city will only have to remain with 260400 inhabitants with an average of 7 persons per HH and a recommended plot size of 350 m^2.

By 2030 the population will double and almost triple by 2050 leading to a population of 1386238 and 2552766, respectively. Such population will require the development of new satellite cities in Nyantende and Miti-Murhesa, which have 38 and 125 km^2 of suitable area, respectively. The surplus will be taken to Nyangezi (100 km^2) and Katana (154 km^2) as new cities.

Both horizontal and mixed extension designs are recommended for future development. From these results, it is suggested that the population surplus (643700 inhabitants) be divided equally between the two selected zones. The majority of people will be poor by then, followed by medium class. The high standing class will be sparsely distributed in these areas.

The results will help decision-making in both current and future developments of Bukavu Town as well as the proposed satellite cities taking into account the environment.

Ethics approval and consent to participate

Not applicable.

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Availability of data and materials

The authors want to declare that they can submit the data at whatever time based on your request. The data used for the current study are available from the corresponding author on reasonable request.

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The authors declare that they have no competing interests.

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