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# Contribution of Building Codes in Disaster Risk Reduction in Rwanda

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## Abstract

In Rwanda, the City of Kigali records frequent flooding, heavy rains and windstorms which affect people's livelihoods, particularly those located in disaster prone areas. This study assessed the contribution of building codes in reducing community disaster exposure in Kicukiro district of Rwanda. The employed secondary data on disasters losses were provided by the Ministry in Charge of Emergency Management (MINEMA) and building codes from Kigali Master Plan. The Microsoft Excel compared losses before (2013-2014) and after (2015-2020) building codes initiation. The Geographic Information System (GIS) spatially distributed recent disaster losses (2013-2020) and their prediction (2020-2050) within Kicukiro district. The results indicated that between 2013 and 2014, 8 cases of fire, 4 cases of heavy rains and 2 cases of windstorms were registered by Nyarugunga and Kicukiro sectors. After initiating building codes, the number increased to 12 cases of fire, 27 cases of heavy rains, 11 cases of windstorms and 2 cases of flood and landslide. The Kigarama, Gikondo and Kicukiro sectors were the largely affected among others. The prediction highlighted high number of cases in Kigarama, Kicukiro and Gikondo sectors, and safe areas where people could settle in are Niboye, Kagarama and Gahanga sectors. Finally, as heavy rains caused many losses; enforcing rain harvest mechanisms can minimize losses. Therefore, policy makers in charge of the execution of building codes should consider each sector and plan to relocate people from high risk sectors to safe ones.

## Keywords

Building Codes, Community, Disaster Exposure, Disaster Risk, Kicukiro District

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## 1. Introduction

The process of rural-urban migration in the developing world over recent decades has taken place largely in the absence of effective building or land use regulation [1]. Without regulatory guidance, urban development has extended to hazardous sites and resulted in the construction of unsafe, vulnerable settlements. Which has vastly expanded global disaster risk [2, 3]. The failure of regulatory policy and implementation in low- and middle-income countries is mainly attached to poverty which leads to urban migration and a limiting factor in the development of municipal services and regulatory capacity [4].

Buildings today are likely to dictate city and town development and consumption patterns for the next 20 to 30 years. The way we design, build and maintain our buildings will influence the sustainability of a city and the health and safety of its inhabitants for decades to come [5, 6]. Disaster resilience, energy efficiency and prevention of diseases are all issues that are influenced by building codes [7, 8]. In most parts of the world where disaster affect people's livelihoods, lack of resilient building has been identified among the driving factors.

In Rwanda, recent disasters caused significant losses and damages among the vulnerable people. In Kigali city, for example, the residents located in flood prone areas have been

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subject to risk of flood and those with poor buildings [9]. In Kigali city, approximately 5,000 ha of built up areas are prone to disaster. This has led to significant losses between 2000 and 2019 where 27 people were affected (died/injured), houses collapsed and hectares of croplands were damaged. The Gasabo and Kicukiro districts of Kigali city are the largely affected by disasters compared to Nyarugenge district [10, 11].

The city of Kigali is expanding and this requires safe place where people can settle and install their business/livelihood activities. However, its location, in the middle of mountains expose its residents to more hazards, which attracted the city planners' attention to relocate those located in prone areas in order to minimize their exposure [12]. In order to ensure safety communities, building codes are initiated at local levels to minimize disaster exposure among people. The process involves settling new living areas from prone zones [11].

This raises the need to understanding the types of disasters under record in this area and their drivers, the initiated building codes, how far they are executed and their role in minimizing people's exposure to disasters in Kigali city. However, apart from the studies carried out in Kigali considering disasters, on the best of the researcher' knowledge, there is no current study conducted to assess the impact of building codes in minimizing people's exposure to disasters. Therefore, the researcher recognized the above facts and then chose to conduct a study on the potentiality of building codes in reducing community exposure to disasters with focus on Kicukiro district of the City of Kigali.

## 2. Materials and Methods

### 2.1. Description of Study Area

This study was conducted in Kicukiro district; one of three districts (Kicukiro, Gasabo and Nyarugenge) of Kigali, the capital city of Rwanda. The district of Kicukiro seizes an area of 166.7 $Km^2$. And as shown in Figure 1, the district shares borders with Gasabo district in its north, Bugesera district and Rwamagana districts of the eastern province are located in the east and southern parts of Kicukiro district. And in its west, there is Nyarugenge district of Kigali city.

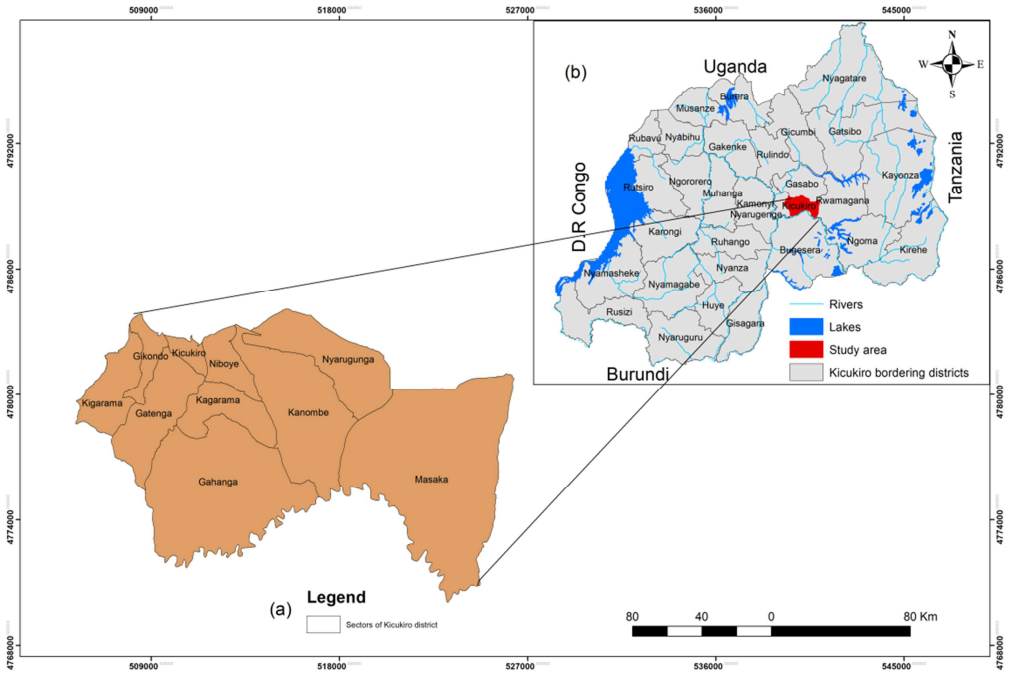


**Figure 1.** Map indicating the (a) sectors of study area and (b) district bordering with Kicukiro district.

The district of Kicukiro is composed by ten (10) sectors (Niboye, Kagarama, Kicukiro, Gatenga, Kigarama, Gikondo, Kanombe, Masaka, Nyarugunga and Gahanga) and 41 cells. The forth Integrated Household Living Conditions Survey (EICV 4) of the National Institute of Statistics of Rwanda reported that Kicukiro district is populated by 350,621 population and its total households are 93,729 [13].

The city of Kigali is becoming more exposed to disasters mainly flooding, landslide and heavy rains, and the community located in prone areas are largely affected. Both Gasabo and Kicukiro district are the main parts of the city largely affected by disasters [10]. In addition, as recently reported [14, 15], in Kicukiro district, storm water runoff has created a natural earth channel which is continuously increasing in width due to storm water which carries soil particles of the channel and the channels undergo side slope failure and excessive increase of depth due to scouring. This exposes the community to associated losses mainly during heavy rainfall.

### 2.2. Materials

During the conduct of a study, one can adopt a quantitative research methodology which allows to analyze numbers and statistics datasets, while the qualitative research methodology enables the researcher to analyze facts, words and/or meanings [16, 17]. For this study, quantitative approach helped to indicate the number of disasters recorded and associated losses and their location. The qualitative approach was then applied to analyze relevant literature on disaster exposure and building codes.

The study mainly used secondary data the types of disasters recorded in Kicukiro district, the resulted losses like killed/injured people, damaged cropland, destroyed houses, bridges and roads. Also, secondary data on shapefiles of sectors of Kicukiro district facilitated the authors to make maps of disaster record across the district. The authors mapped and compared disaster losses before (2013-2014) and after (2015-2020) building codes initiation. The employed data were collected from the Ministry in Charge of Emergency Management (MINEMA) and building codes from Kigali Master Plan.

### 2.3. Methods

For this study, to analyze the building code implementation in Kicukiro district, the types of building codes initiated and sectors in which they are implemented were presented in Tables and/or Figures by using the Microsoft word and Excel. Spatial distribution of disaster occurrence and its effect on people's livelihoods in Kicukiro district was performed by using the IDW (Interpolation) and Extraction by Mask techniques in the Spatial Analysts Tools of the Geographic Information System (GIS). Finally, Microsoft Excel predicted disaster exposure based on recorded events (2015-2020) after building codes initiation. Thereafter, ArcGIS software helped to spatially distribute the predicted disaster occurrence within the next 30 years (2020 - 2050).

## 3. Results and Discussion

### 3.1. Building Codes Implementation in Kicukiro District

The results in Table 1 showed that Kagarama, Gikondo, Gatenga, Kigarama, Kanombe and Nyurugunga sectors are mainly reserved for agricultural activities and low density residential densification zone to Medium density residential improvement zone. The sectors of Kicukiro and Niboye are for high density residential zone, city commercial and agricultural zone. Gahanga and Masaka sectors are mainly for the industrial, health and religious facilities and medium density residential (Table 1).

**Table 1.** Initiated building codes in sectors of Kicukiro district.

| Sector | Building codes | Meaning |
|---|---|---|
| Kagarama | A1 and R1A | Agricultural and low density residential densification zone |
| Gikondo, Gatenga and Kigarama | R2 | Medium density residential improvement zone |
| Kanombe and Nyurugunga | A1, C1 | Agricultural and mixed use zone |
| | From R1A to R2 | Low density residential densification zone to Medium density residential improvement zone |
| | From R3 to R1A | Medium density residential, expansion zone to Low density residential densification zone |
| | From R1A to R2 | Low density residential densification zone to Medium density residential improvement zone |
| Kicukiro and Niboye | From R4 to C3 | High density residential zone to City commercial zone |
| | From R1A to R4 | Low density residential densification zone to High density residential zone |
| | A1 | Agricultural zone |
| Gahanga | From R1A to R3 | Low density residential densification zone to Medium density residential, expansion zone |
| | Increased I1, I2 and C3 | Light industrial zone, General industrial zone and City commercial zone |
| | PF2 and PF3 | Health and Religious facilities |
| Masaka | From I2 to R3 | General industrial zone to Medium density residential, expansion zone |
| | C3 | City commercial zone |
| | PF5, PF2 and PF1 | Cemetery, Health and Religious facilities |

Source: City of Kigali, 2020

### 3.2. Disaster Occurrence and Its Effect on People'S Livelihood in Kicukiro District

The results presented in this section were related to the recorded disasters before (2013-2014) and after (2015-2020) the implementation of building codes in Kicukiro district.

#### 3.2.1. Recorded Disasters Before Building Codes Initiation in Kicukiro District

The results in Figure 2 showed that Nyarugunga and Kigarama sectors were largely affected by fire where 8 and 7 cases were recorded, respectively. Regarding heavy rains, Kicukiro sector was the largely hit by heavy rains with 4 cases. Gikondo, Kigarama and Niboye sectors only registered one case, respectively, between 2013 and 2014 (Figure 2). Similarly, the results in Figure 2 indicated that Kicukiro, Masaka and Niboye sectors recorded one case of windstorms each one, respectively. The same Figure 2 showed that Nyarugunga sector was the largely affected by windstorms with 2 cases between 2013 and 2014.

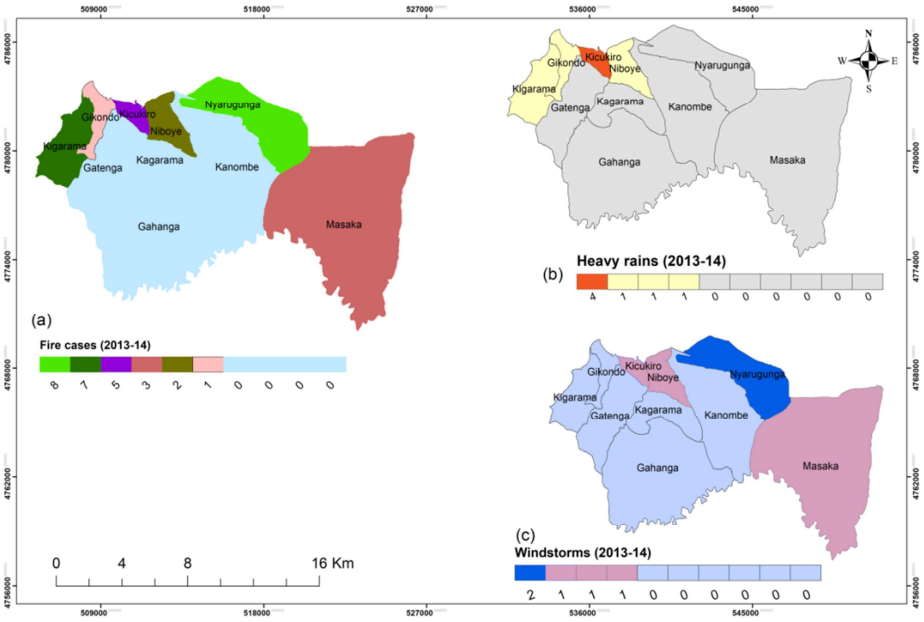


**Figure 2.** Types of disasters recorded namely: (a) fire, (b) heavy rains and (c) windstorms before execution of building codes in Kicukiro district.

### 3.2.2. Recorded Disasters After Building Codes in Kicukiro District

The authors presented disasters which ranged between 2015 and 2020 and were namely fire, heavy rains, flood and landslide and windstorms (Figure 3).

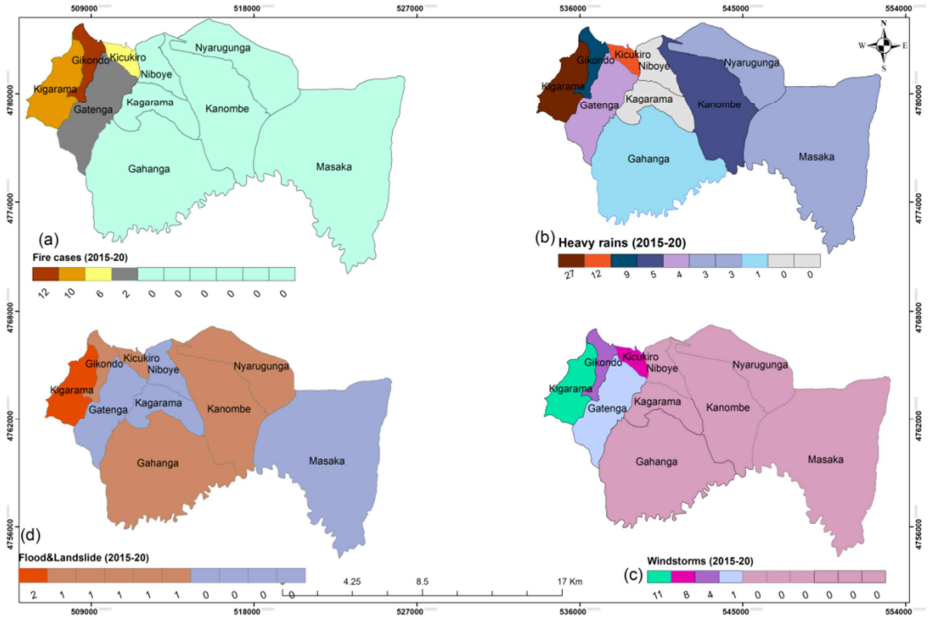


**Figure 3.** Recorded disasters namely: (a) fire, (b) heavy rains, (c) windstorms and (d) flood and landslide after initiating building codes in Kicukiro district.

The results in Figure 3 indicated that Gikondo and Kigarama sectors registered increased number of fire cases (10 for each sector, respectively). The same Figure 3 revealed that Kigarama sectors recorded 27 cases of heavy rains followed by Kicukiro and Gikondo sectors with 12 and 9 cases, respectively. Regarding the windstorms (Figure 3), Kigarama was the largely affected by 11 cases whereas high number of flood and landslide cases were only two (2) in the same sector of Kigarama.

Furthermore, with regard to the comparison of disaster losses before and after implementing building codes, it can be noted that the number of disaster losses among residents in Kicukiro district increased after 2015 (Table 2).

**Table 2.** Recorded disaster losses before and after implementing building codes.

| Disaster losses before initiating building codes (2013-2014) | | | | | | |
|---|---|---|---|---|---|---|
| | **Dead** | **Injured** | **Affected houses /fences/items** | **Affected Roads/bridges** | **Damaged cropland** | **Affected Garages, industries/boutiques/stores** |
| Fire | | | 19 | | | 11 |
| Heavy rains | | 3 | 26 | | | 4 |
| Windstorms | | 3 | 13 | | | |
| Total | 0 | 6 | 58 | 0 | 0 | 15 |
| Disaster losses after initiating building codes (2015-2020) | | | | | | |
| Fire | | 3 | 30 | | | 12 |
| Heavy rains | 6 | 11 | 151 | 1 | | |
| Windstorms | | | 30 | | | |
| Flood/Landslide | 3 | 2 | 13 | 3 | 2 | |
| Total | 9 | 15 | 224 | 4 | 2 | 12 |

Source:[18, 19].

Based on the result in Table 2, 58 cases of affected houses/fences and items were registered. However, since 2015, the number increased considerably and reached 224. In addition, the number of disasters increased after 2014, there has been record of flood and landslides which caused 9 deaths and 15 injuries (Table 2). This expresses that people's exposure to disaster increased regardless the implemented building codes and that people likely settled in areas which were not reserved for building. Also, some sectors (Figures 2 and 3) which have recorded these disasters are largely exposed compared to the remaining sectors which can be named as safe place.

## 3.3. Contribution of Building Codes in Reduction of Disaster Exposure

Based on the fact that disaster losses kept on increasing (Figure 3), it can be noted that the initiated building codes did not contribute to reducing the disaster exposure in Kicukiro district. This can results from the fact that the number of fire cases, flood and landslide, heavy rains and windstorms comparatively increased than that of before initiating building codes (Figure 2).

In addition, one can mention that building codes were not implemented as planned either by the fact that the residents did not respect it or the local leaders did not enforce, monitor and evaluate the implementation process. For example, Kigarama sector recorded high number of all disaster which took place between 2015 and 2020 while the sector was reserved from medium density residential improvement zone (Table 1). Thus, people continued settling in the sector which likely led to the recorded losses as proved by high number of destroyed houses/fences. In addition, Gikondo and Kicukiro sectors whose building codes were medium density residential improvement zone, agricultural and commercial zones were turned into high residential zones and thus leading to high number of losses (Figure 3).

## 3.4. Prediction of Disaster Losses Across Kicukiro District

To predict occurrence of disaster and their losses in this area, the authors used the total cases of recorded disaster losses after initiating building codes (Figure 4) in sectors of Kicukiro district.

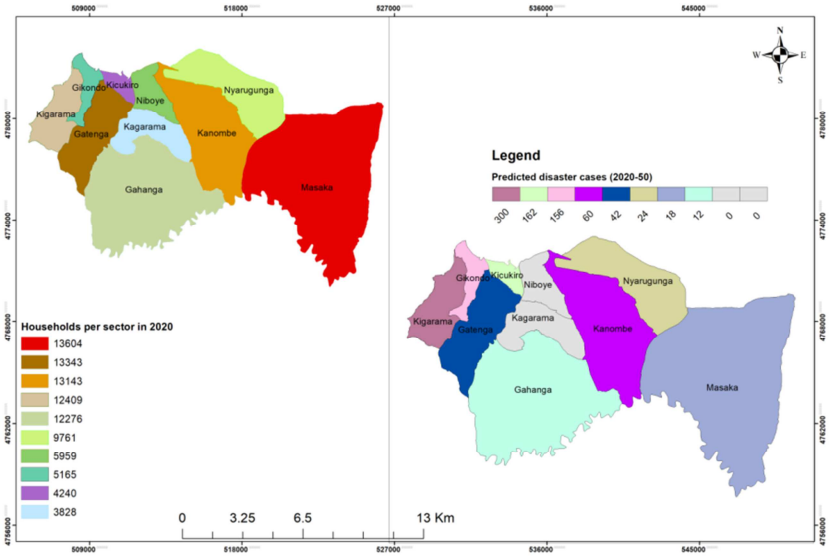


**Figure 4.** Predicted community disaster exposure between 2020 and 2050 in Kicukiro district.

The results in Figure 4 showed that from 2020 to 2050, 300 cases of disasters (fire, heavy rains, windstorms, flood and/or landslide) will be recorded in Kigarama sector which is the fifth among the largely populated sectors with 12,409 households (Figure 4). This sector (Kigarama) is followed by Kicukiro and Gikondo sectors which will be record 162 and 156 cases of disaster losses (Figure 4) despite their low number of households among others (Figure 4). The same results in Figure 4 illustrated that Niboye, Kagarama and Gahanga sectors are safe place where people should settle in the next 30 years (2020-2050). This can result from the fact that among these sectors, there will be no more than 10 cases of disaster in the predicted period (Figure 4).

**Table 3.** Predicted cases of disaster losses from 2020 to 2050.

| | Death | Injuries | Houses/fences | Roads/bridges | Cropland | Garages, industries /boutiques/stores |
|---|---|---|---|---|---|---|
| Total losses (2015-2020) | 9 | 15 | 224 | 4 | 2 | 12 |
| Average annual loss | 1.8 | 3 | 44.8 | 0.8 | 0.4 | 2.4 |
| Predicted loss | 54 | 90 | 1344 | 24 | 12 | 72 |

The results in Table 3 showed that the losses which will be recorded from the above disaster cases between 2020 and 2050 will increase accordingly. There will be 90 injuries and 54 deaths while 1,344 houses/fences, items will be damaged. It can be mentioned that these losses will be at large extent, registered by sectors which are predicted to record high number of disaster cases as shown in Figure 4.

### 3.5. Discussion

In Kigali city, it has been reported that flood is the major hazard being recorded with other cases of windstorms, heavy rains and fire outbreak [15]. This was recognized and the City of Kigali implemented a Kigali City Master Plan and initiated the Building Codes which state the areas which are not highly exposed to disaster, types of building materials to be used to ensure resilience and regulation in setting up building [14]. Nevertheless, losses are still recorded in Kigali city and the changing climate accelerates the record [20].

The authors recognized the above facts and chose to conduct this study whose results in Figure 2 (a, b and c) indicated that between 2013 and 2014, 8 cases of fire, 4 cases of heavy rains and 2 cases of windstorms were registered by Nyarugunga and Kicukiro sectors. However, as shown in Figure 3 (a, b, c and d), disasters increased after 2014, there were 12 cases of fire, heavy rains (27), windstorms (11) and 2 for flood and landslide in Kigarama, Gikondo and Kicukiro sectors. The results of this study agree with recent report on disaster in Kigali city [21, 22] which indicated that during rainfall, people in Gikondo sector are affected due to the fact that most of them are located in/close to marshland which are flooded during rainfall.

In addition, as recently reported [10], Kicukiro is among districts largely affected by disasters in Kigali city due to the fact that people locate (settle) and locate their economic activities in disaster prone areas. Similarly, in Kicukiro district, for sectors which recorded high number of disaster cases (Figures 2 and 3) and losses (Table 2), it can be mentioned that settling in disaster prone areas was the main reason. Despite the fact that Kigali city made a Master Plan [23] in order to relocate people from high risk zones to safe areas, the number of disaster losses are recording gradual rise in number (Table 2).

Furthermore, the prediction in Figure 4 revealed that Kigarama, Kicukiro and Gikondo sectors will record high number of cases. However, Niboye, Kagarama and Gahanga sectors are safe and could be the safe areas to settle in. These sectors (Niboye, Kagarama and Niboye) are not highly populated (Figure 4) compared to Kigarama, Gikondo and Kicukiro which will register high number of disaster cases in the next thirty one years (2020-2050).

## 4. Conclusion

This study assessed the contribution of building codes in reducing disaster exposure in Kicukiro district of Rwanda. The analysis was for before (2013-2014) and after (2015-2020) building code initiation. The Microsoft Excel and Geographic Information System (GIS) were the main tools of data analysis. The results showed that between 2013 and 2020, fire, heavy rains, windstorms and flood and landslide were the major hazards recorded in Kicukiro district. However, after the initiation of building codes (after 2015), record on disaster occurrence and associated losses increased as well. This expresses that regardless the initiated policies on building, people have kept on settling their buildings in disaster prone areas. In addition, the prediction of disaster occurrence and losses indicated that Kigarama, Kicukiro and Gikondo sectors will be prone to disasters in Kicukiro district. The Niboye, Kagarama and Gahanga sectors are safe compared to others and it would be good to relocate people from high risk sector to face places.

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