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APPLICATION OF ENVIRONMENTAL MONITORING TOOLS FOR CLIMATE CHANGE MITIGATION IN RWANDA

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ABSTRACT

This study aims to assess the effectiveness of Environmental Impact Assessment (EIA) on climate change mitigation in Gasabo District of Rwanda. Structured questionnaire and interview were addressed to a sample of 155 respondents, including both individual residents and leaders from regulatory institutions related to or working on environment and climate change. Geographic Information System (GIS) and Microsoft Excel are used for data collection. The results revealed that 64% of respondents voted EIA application after project implementation, which implies that even long-term project consequences are not foreseen and mitigated as well. In addition, agriculture and cooking by burning biomass were found to be among the major causes of environmental degradation. These activities were perceived to cause soil, water, and air pollution (53%), followed by decreasing grassland and forestlands (34%) and rising respiratory diseases (13%). Climate scenario revealed decreasing annual maximum rainfall (from 120 to 58 mm) and raising temperature record (from 17 to 25oC) between 1990 and 2020. EIA in climate change mitigation is ranked as moderately effective which calls for efforts to strengthen EIA contribution to climate mitigation. Crosschecking the parameters assessed while conducting EIA and their connectivity with climate change mitigation is suggested. This study serves policy makers in formulating relevant climate change mitigation monitoring tools.

1. INTRODUCTION

Globally, climate change has emerged as one of the most pressing global challenges of the 21st century. The increase in greenhouse gas emissions (GHG), primarily from human activities such as burning fossil fuels, deforestation, and industrial processes, led to rising global temperatures, sea-level rise, extreme weather events, and other adverse impacts on ecosystems and societies worldwide (Akinsemolu and Olukoya, 2020; NISR, 2022; Pachauri et al., 2014).

In Rwandan context, the changing climate is also observed in different sectors and the largest affected are local communities relying on agriculture (Fraschini et al., 2022; Kigali, 2013). Increase on temperature of 1.4o C higher than the global average was recorded in 1970 heading to about 2.0oC in the years of 2030. It is predicted that changes on monthly minimum and maximum rainfall which shift from 1.5-2.7°C and 1.7-2.8°C, respectively (Ngarukiyimana et al., 2021).

In the City of Kigali, more efforts are under practice to minimize the impact of climate change. These include not limited to car free day (a mass sport organized every two weeks in the City of Kigali) (Subramanian et al., 2020), Environmental Impact Assessment (EIA) appliances to each new development activity, relocation of industrial zones to minimize each activity associated risks including emis-

sion of pollutants, water pollution and environmental degradation (Kigali, 2013; Mugisha, 2015). However, recent reports on air pollution highlight Gasabo District as the largely polluted area due mainly to high traffic jam and industrial activities (Nahayo et al., 2019; Subramanian et al., 2020).

Since climate change facts are under record, it is essential to assess the monitoring tools being applied and their effectiveness in strengthening climate change mitigation. Across several areas, various environmental monitoring tools, such as carbon pricing mechanisms, renewable energy policies, reforestation initiatives, EIA, polluter pay principle, and carbon capture technologies, have been implemented worldwide. While these tools have shown promise in mitigating climate change in the short term, their long-term sustainability remains uncertain (Amankwah, 2013; Di Battista et al., 2016; Mayembe et al., 2023).

The central problem lies in the need to assess the effectiveness of these environmental monitoring tools to mitigate climate change but also their capacity to endure and adapt over time while minimizing adverse effects (Gao, 2018; Mayembe et al., 2023). Addressing these questions is therefore vital to advance the understanding of the usefulness of these environmental monitoring tools for climate change mitigation. Moreover, as the Gasabo district is the most populous district in Kigali and houses both rural and urban areas, under its rapidly growing population in need of food and other development activities likely contributing to emission of GHG in the atmosphere (Henninger, 2009; Nahayo et al., 2019; Subramanian et al., 2020), it is deemed important to ensure that relevant environmental management policies are well addressed to minimize activities leading to global warming and climate change. Therefore, the above expresses the need to carry out scientific research on the effectiveness of existing environmental monitoring tools on climate change mitigation.

As such, this study aims to assess the impact of Environmental Monitoring Tools in strengthening climate change mitigation. The study focuses on EIA in Gasabo District, one of three districts in the City of Kigali of Rwanda, in the period ranging from 1990 to 2020. The main contributions of this study include evaluating EIA awareness and application procedures; analyzing climate change trends and its mitigation measures under implementation; and assessing the effectiveness of EIA application in building climate change mitigation. The findings of this study can serve as reference in understanding how existing environmental monitoring tools can contribute to climate change mitigation.

2. METHODS AND MATERIALS

2.1 Description of study area

Figure 1 shows the map of the study area. This research focused on Gasabo district, one of three districts of the City of Kigali, along with Kicukiro and Nyarugenge. The district of Gasabo is made of 15 Sectors namely Bumbogo, Gatsata, Jali, Gikomero, Gisozi, Jabana, Kinyinya, Ndera, Nduba, Rusororo, Rutunga, Kacyiru, Kimihurura, Kimironko and Remera. The district is localized in the North East of Kigali City Province and bordered by Kicukiro district (South), Nyarugenge (West), Rwamagana (East), and Rulindo and Gicumbi (North).

Gasabo district has a population of 879,505 representing 50.4% of the total population for Kigali City and 6.6% of the total national population (NISR, 2022). The district records an average temperature of 22oC and annual rain ranging between 900 and 1,500 mm (Manirakiza, 2014). It has the largest forest cover compared to the other districts and is well linked to large rural zone area. However, the natural flora has been largely depleted and is being replaced with artificial vegetation mainly of eucalyptus trees (Manirakiza, 2014; Mushimiyimana, 2021).

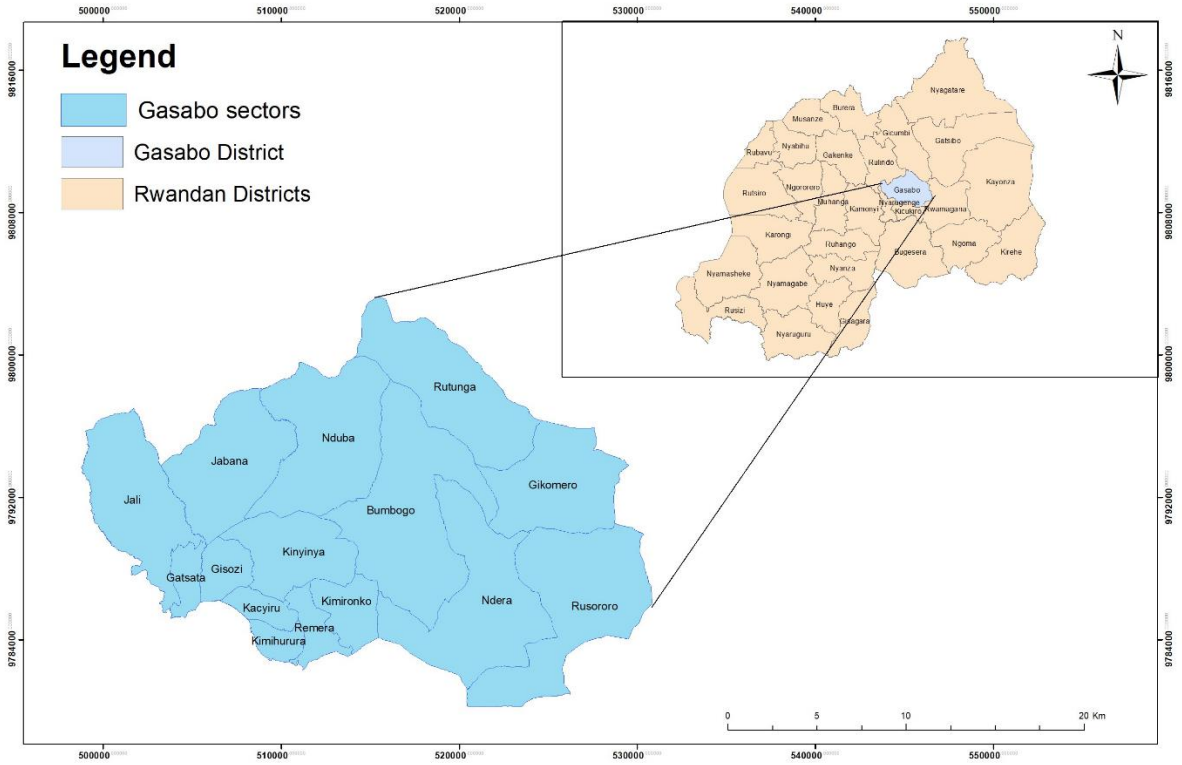

Figure 1: Map indicating the location of research area
Source: Authors, 2023

The district of Gasabo was chosen as study area mainly because it is the one housing Masoro industrial zone and the entire City's household wastes (Nduba Dumping sites). Moreover, the district is also the largely inhabited compared to its counterparts, Kicukiro and Nyarugenge districts, and houses some parts which are still rural areas. All these features are associated with different human activities (transportation, housing, fossil fuel consumption) which cause emissions of GHG into the atmosphere.

2.2 Data collection

During data collection, both qualitative and quantitative research techniques were applied. The qualitative research relied on the use of interview which generated primary data on the application of EIA from different respondents selected from several institutions. The study also applied quantitative research design since through secondary data mainly rainfall and temperature variation over the study area.

2.2.1 Primary data

For the primary data collection, the authors employed a structured interview to local readers from institutional regulatory bodies in charge of environmental inspection and climate change mitigation in Gasabo District such as: the Ministry of Environment (MoE); Rwanda Environment Management Authority (REMA); Rwanda Development Board (RDB); Directorate of Motor Vehicle Inspection Center; Rwanda Association of Professional Environmental Practitioners (RAPEP); and the Directorate of Environment and Natural Resources Management in Gasabo District.

To capture the local communities' perspectives on EIA protocol, a questionnaire survey was also administered to 10 residents per each sector of the district by using the cluster and random sampling techniques. Both sampling techniques facilitated to get the sample from the large population (all residents of the district), widely geographically dispersed and could not be all reached. More importantly, people working in and/or located to areas that likely contribute to climate change in the district were included in the sample. These locations are namely Nduba waste dumping site in Nduba sector and Prime Economic Zone in Ndera Sector.

The table 1 below shows the type and total number of selected respondents used in this study. A total number of 155 respondents were obtained, corresponding to 150 individual respondents from all 15 sectors of Gasabo district (i.e. 10 people in each sector) and 5 institutional respondents from regulatory bodies.

Table 1: Type and number of selected respondents

Individual respondents in Gasabo sectors		
1	Remera	10
2	Jali	10
3	Nduba	10
4	Gisozi	10
5	Kimironko	10
6	Ndera	10
7	Gikomero	10
8	Bumbogo	10
9	Jabana	10
10	Kinyinya	10
11	Rusororo	10
12	Rutunga	10
13	Kacyiru	10
14	Kimihurura	10
15	Jabana	10
Institutional respondents		
16	Rwanda Environment Management Authority	1
17	Rwanda Development Board	1
18	Automobile inspection Center	1
19	Rwanda Association of Professional Environmental Practitioners	1
20	Directorate of Environment and Natural Resources Management in Gasabo District	1
	Total	**155**

Source: Authors, 2023

The figure 2 shows the location of all respondents, both individual and institutional. As shown in the figure, the institutions where respondents were selected in this research are located in Remera, Kimihurura, Jabana, Kacyiru and Kimironko sectors. They are marked by shapes in different colors.

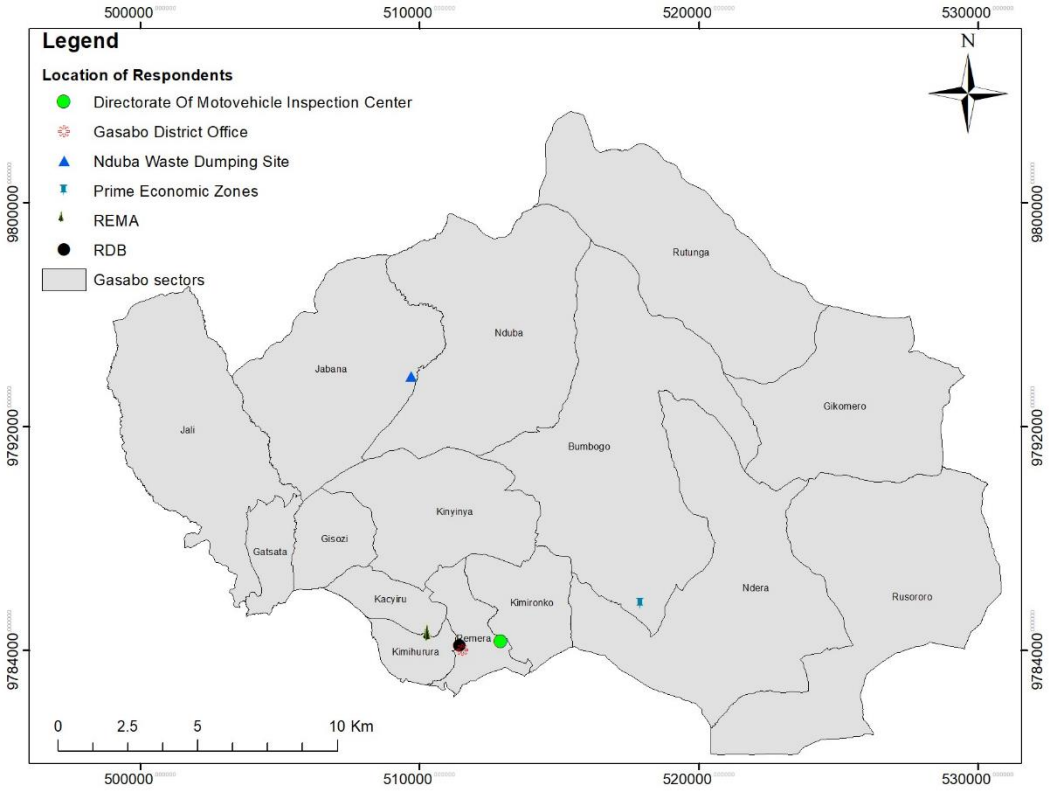

Figure 2: Location of individual (all sectors) and institutional (marked) respondents
Source: Authors, 2023

Both interviews and questionnaire survey were administered face to face and took place in the respondents respective living areas or

working offices. Prior to taking part in any research activities, the respondents were given an overview on climate change (rainfall and temperature) scenario recorded in Gasabo district in the period between 1990 – 2020, from which adaptation mechanisms should base on with reference to EIA application.
Therefore, the individual respondents were asked the questions related to topics such as human activities that impact on environment and impact extent; how environmental degradation led to the recorded climate change; awareness on EIA application in Gasabo District; local climate change adaptation mechanisms being applied. As for institutional respondents, the interview questions focused on aspects such as awareness on climate change over the study area; key activities/indicators monitored for EIA protocol; frequency of EIA, its results and of sharing/communication channels.
Furthermore, respondents were further asked to rank EIA effectiveness on climate change mitigation in Gasabo district, ranking them as very highly effective, highly effective, moderate/effective, and not effective. Each respondent then provided the explanation on their EIA ranking.

2.2.2 Secondary data

For the secondary data, the study utilized climate change data mainly annual mean rainfall and temperature ranging from 1990 to 2020. The employed daily rainfall data is collected from the Tropical Applications of Meteorology using Satellite (TAMSAT) data and ground-based observations (Tarnavsky et al., 2014).
Monthly average temperature related data recorded in the same period of study were collected from the Oak Ridge National Laboratory Distributed Active Archive Center (ORNL DAAC) for Biogeochemical Dynamics which is a NASA Earth Observing System Data and Information System (EOSDIS) data Center managed by the Earth Science Data and Information System (ESDIS) Project. The climate related data were mainly collected from the Spatial Data Access Tool (SDAT) of the ORNL DAAC's available at: https://webmap.ornl.gov/.

2.3 Data analysis

The recorded data were analyzed by using GIS and Microsoft Excel and were plotted into relevant tables and charts. Descriptive statistics was adopted to analyze awareness on EIA application by using a 4-point Likert scale (very highly aware, aware, moderately aware and not aware, coded 4 to 1, respectively) and perception of EIA effectiveness by using a 5-point Likert scale (very highly effectiveness, highly effective, moderately effective, not effective, not effective at all, coded 5 to 1, respectively). The analysis was focused on analyzing the frequency and percentage per each scaling level, and by evaluating the mean score using the table 2 as shown below. The mean score was calculated by the ratio between the sum of the total score and the total number of respondents.

Table 2: Levels of statistical mean score for EIA awareness and EIA effectiveness

	Mean score	Evaluation
EIA awareness	1.00 – 1.99	Low awareness
	2.00 – 2.99	Moderate awareness
	3.00 – 4.00	Strong awareness
EIA effectiveness	1.00 – 2.49	Not effective
	2.50 – 3.49	Moderately effective
	3.50 – 5.00	Highly effective

3. RESULTS

3.1 Awareness on EIA application

As illustrated in Table 3, there is a moderate awareness among residents about EIA protocol application (mean score of 2.45). However, more mobilization and community approach would advance the awareness and this in turn, leads to ensuring practice of EIA recommendations from the lowest level of the community which leads to reducing the risks being social, economic, and environmental related.

Table 3: Residents' EIA awareness

EIA awareness	Frequency	Numerical score	Total score	Mean score	Comment
Very highly aware	27	4	108	**2.45**	**Moderate awareness**
Aware	57	3	171		
Moderately aware	23	2	46		
Not aware	43	1	43		
Total	**150**				

Source: Researcher, 2023

All five (5) institutional interviewees from the visited institutions confirm that they are aware of EIA practices and its protocol illustrated in Figure 3.

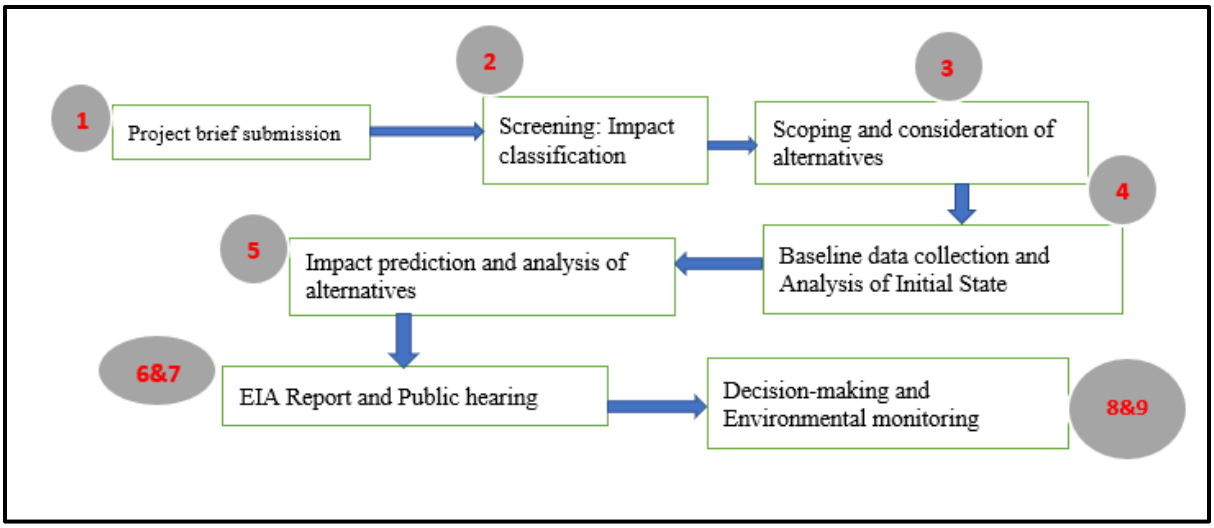

Figure 3: Summarized EIA Protocol
Source: Authors, 2023

The results in terms of EIA conduct frequency (Figure 4) reveal that EIA is conducted before and during the project implementation cycle as asserted by 100% of respondents. However, since the votes of EIA execution after project implementation are low (64%), it can be noted that even long-term consequences of the project are not foreseen and mitigated as well. Hence, if EIA is not considered after the project ends, there might be long term consequences not mitigated but leading to losses among people and environment.

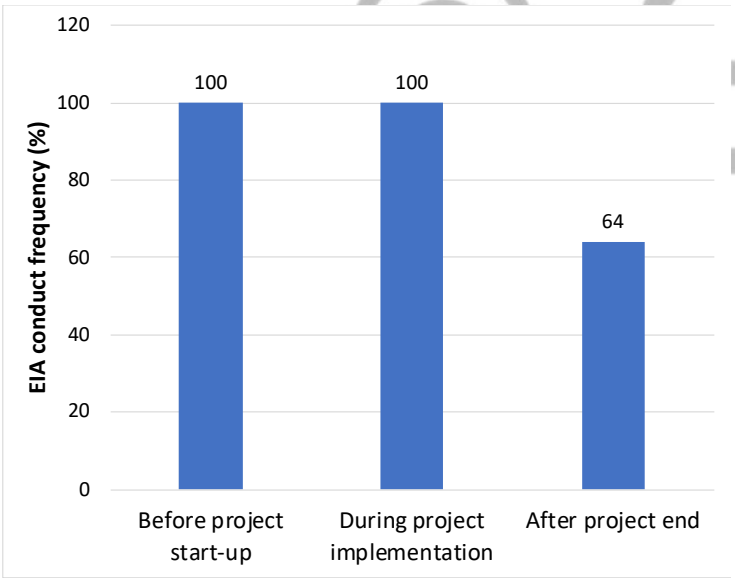

Figure 4: EIA Conduct Frequency
Source: Authors, 2023

3.2 Climate change and mitigation measures under implementation

3.2.1 Human activities' impact on environment

Participants were asked which human activities impact mostly the environment in the district. As shown in Table 4, agriculture and cooking by burning biomass were perceived as the major sources of pollutants that lead to environmental degradation, with 29% and 25% of responses, respectively, followed by transportation and industry (19%), while waste treatment (15%) and deforestation (13%) were perceived as the relatively least impactful sources of environmental degradation.

Table 4: Human activities that impact on environment in Gasabo District

Human activity	Frequency	Percentage
Agriculture biomass burning	43	29
Firewood for cooking	37	25
Transport and Industrial pollution	29	19
Waste treatment	22	15
Deforestation	19	13
Total	150	100

Source: Authors, 2023

Meanwhile, as shown in Figure 5, most of respondents (53%) believe that soil, water, and air pollution is the most direct result of human environmental degradation from the above human activities, followed by decrease of the area covered by grassland and forestlands (34%) along with respiratory diseases (13%).

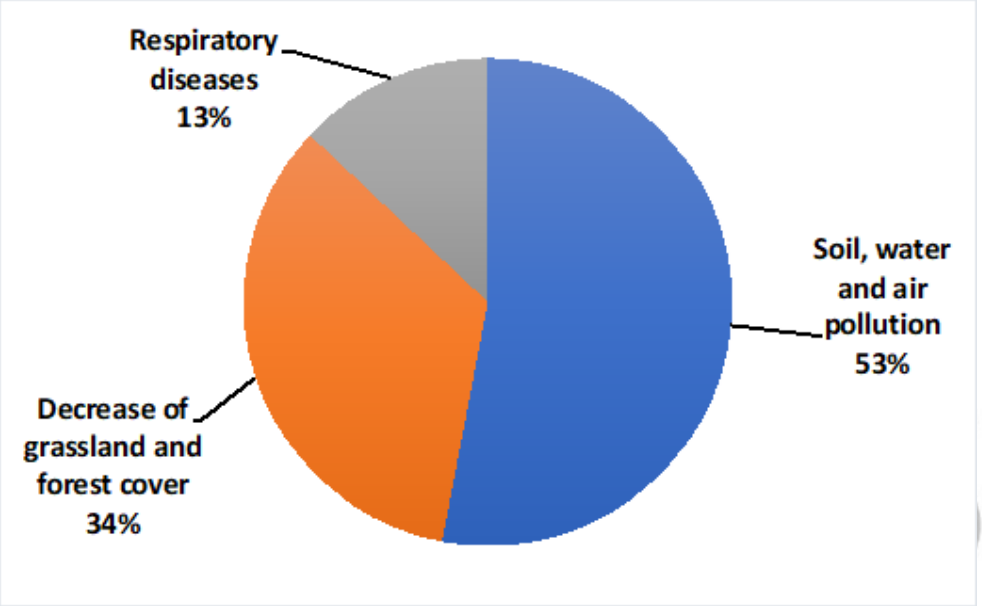

Figure 5: Results of environmental degradation from human activities in Gasabo district
Source: Authors, 2023

3.2.2 Climate change scenario in Gasabo district

Figure 6 shows the annual mean rainfall in Gasabo district covering the period from 1990 to 2020. It can be seen that the sectors of Kimuhura, Remera, Kimironko, Ndera, Kacyiru recorded relatively the highest annual mean rainfall of 120 mm in 1990 (figure 6a), and 97mm in 2000 (figure 6b), However, the lowest record of annual mean rainfall was registered by different sectors in the same time period: Rutunga sector in 1990 (116 mm), and Jali sector in 2000 (92mm). Meanwhile, as shown in figure 6c, a shift of rainfall distribution was noticed in 2010, whereby high rainfall (96 mm) was recorded in Rutunga, Gikomero and Rusororo and low rainfall (70mm) was recorded in Kimuhurura, Remera, Kimironko, Ndera, Kacyiru, Jabana and Jali. As for 2020 (figure 6d), the recorded rainfall was unevenly distributed within the sectors of Gasabo District, ranging between 50 – 58 mm, significantly lower than previous years considered in this study.

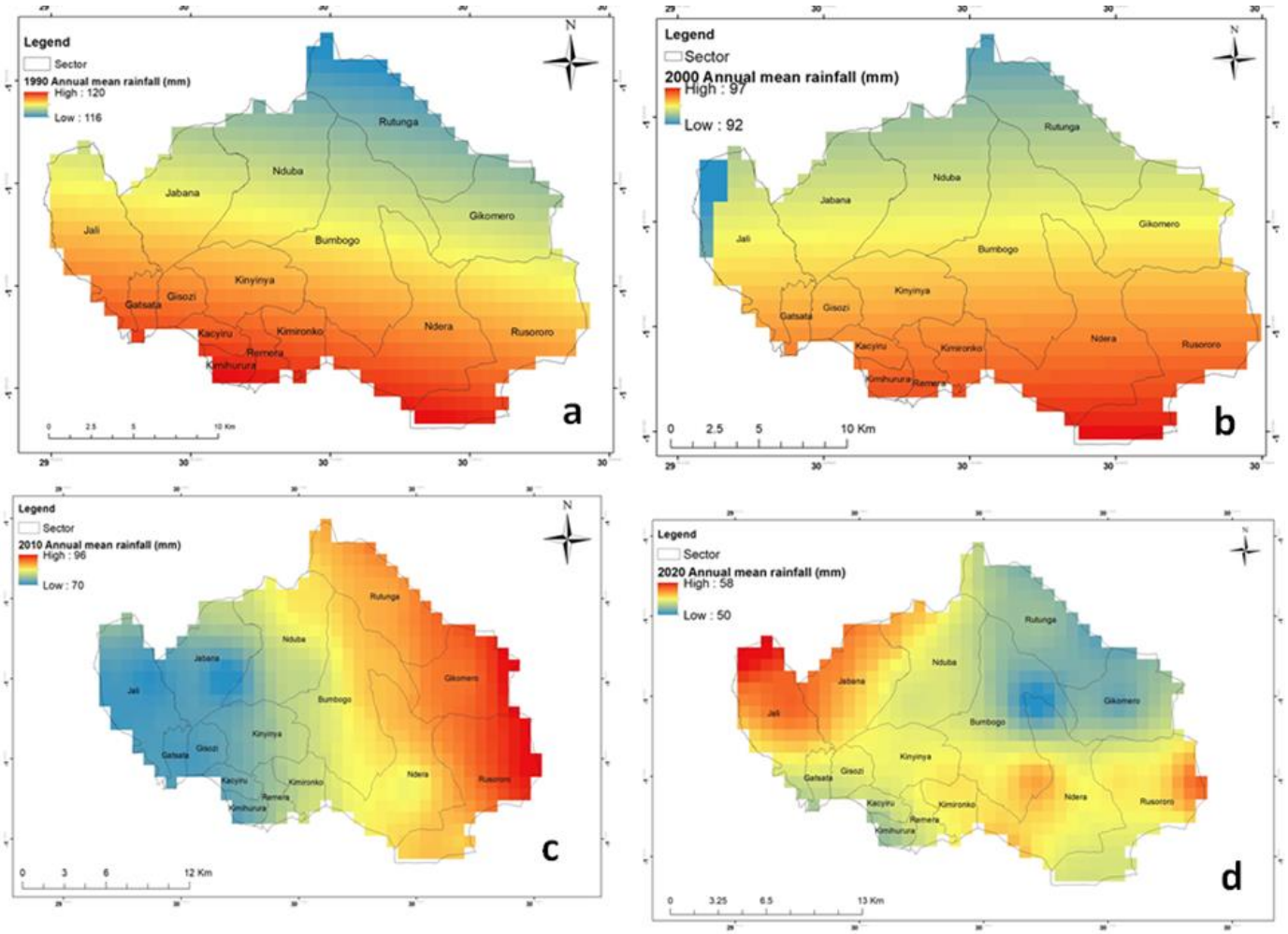

Figure 6: Annual mean rainfall (mm) in (a) 1990; (b) 2000; (c) 2010 and (d) 2020.
Source: Authors, 2023

Regarding temperature variation, the results in Figure 7 demonstrate that, in 1990 (figure 7a), high annual mean temperature of 17°C was mainly registered by all sectors except Jali, Jabana, Gisozi and Gatsata, which had the lowest record of 11°C. In the year 2000 (figure 7b), the recorded annual mean temperature ranged between 21 – 25 °C, clearly higher than in 1990. However, the annual mean temperature decreased again in the year 2010 to between 14 and 21 °C (figure 7c). Finally, as of the year 2020 (Figure 7d), there is growing trend of annual mean temperature from 20°C to 25 °C.

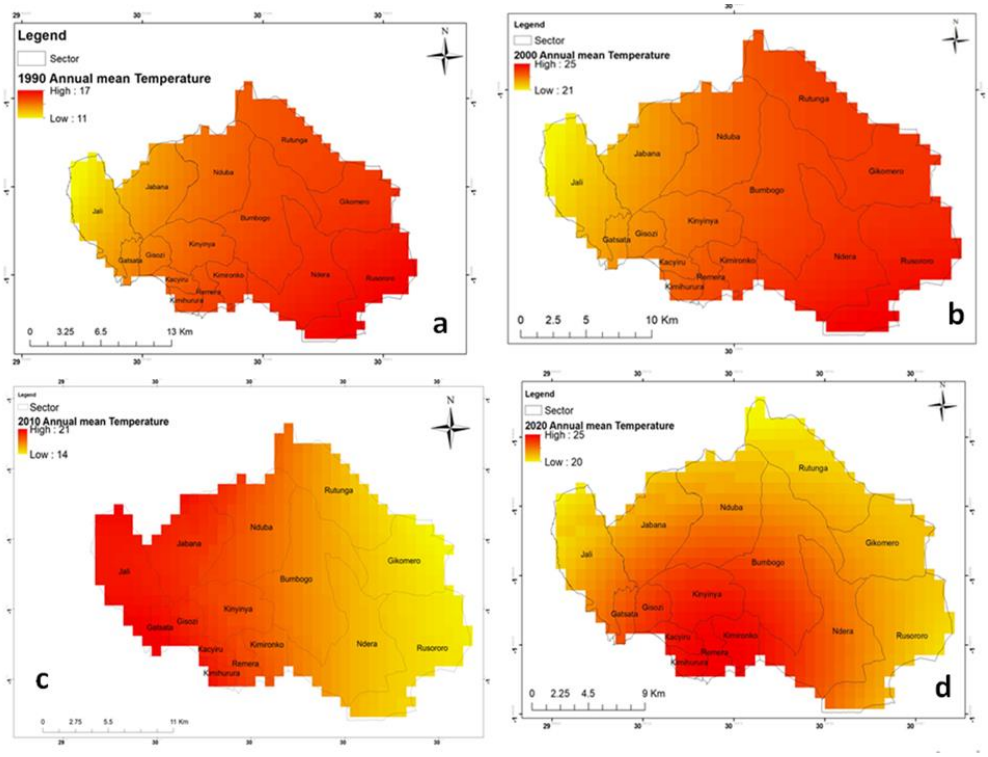

Figure 7: Annual mean Temperature (°C) in (a) 1990; (b) 2000; (c) 2010 and (d) 2020
Source: Authors, 2023

3.2.3 Climate change mitigation practices

The recorded rainfall and temperature in Gasabo district clearly certify the changes on the local climate within the region. As the respondents are aware of the causes and consequences of climate change, it is therefore essential to assess their locally applied climate change mitigation mechanisms and to evaluate their effectiveness towards reducing the associated consequences on environment as well as on livelihoods.

When asked the main activities undertaken to mitigate climate change (figure 8), most respondents (36%) highlighted the extension of forest cover and applying organic fertilizers instead of chemical fertilizers, followed by participating in the car free day and ensuring annual motor vehicle inspection (32%). Furthermore, other 22% of respondents believe that EIA should be conducted before any project starts to evaluate the likely environmental degradation that might results from the project activities and adaptation actions proposed by the project owner. Meanwhile, only 10% mentioned another activitiy converning the use of waste collection points.

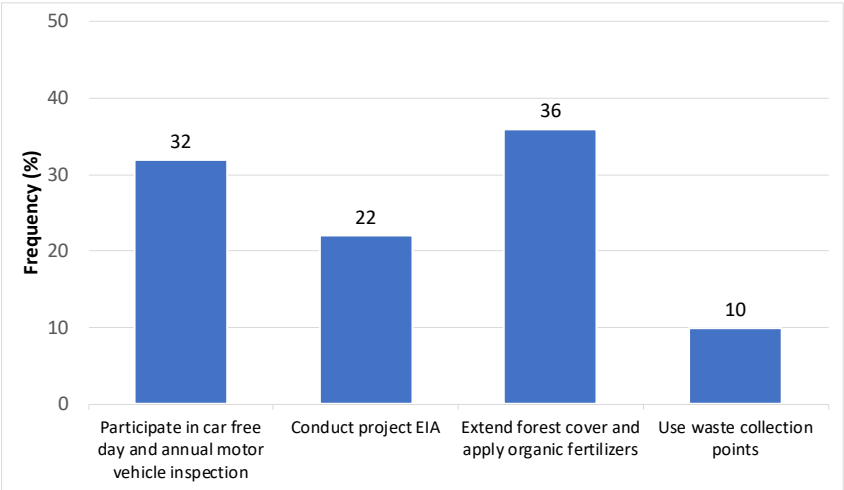

Figure 8: Local mitigation measures
Source: Authors, 2023

3.3 Effectiveness of EIA on Climate Change Mitigation

During the discussion with selected interviewees from the listed institutions (see Table 1 and Figure 2 for details), a step-by-step of the EIA protocol was explained by the respondents form institutions. As shown in Table 5, the evaluation of EIA protocol in Table 5 shows that step 5 (Impact prediction and analysis of alternatives) if not well addressed might lead to environmental consequences prediction can fail due to not considering the major ones and/or not understanding the sources. In addition, the 7th step (Public hearing) might lead to the case of wrong public involvement due to choosing the wrong audience such as that not possess full/right information about the project being introduced.

Table 5: Critics on EIA protocol regarding Climate Mitigation

No	Step	Comment regarding climate change
1	**Project brief submission**	The project title can partially indicate the targets but leads to climate change and not clearly indicating the mitigation policies.
2	**Screening: Impact classification**	If not well classified, the impact leads to environmental degradation and climate change.
3	**Scoping and consideration of alternatives**	Sorting out environmental impact to be considered during project execution. If not well listed, impact becomes larger.
4	**Baseline data collection and Analysis of Initial State**	Status of existing environment at a location before intervention of the proposed project. Some important data if not considered before, monitoring might be expensive with losses and/or not understand the indicators to consider
5	**Impact prediction and analysis of alternatives**	Environmental consequences prediction can fail due to not considering the major ones and/or not understanding the sources.
6	**EIA Report**	On with, with alternatives and without the project. One step can confuse decisions mainly both with and with alternatives.
7	**Public hearing**	Public involvement which sometimes can be done but targeting the wrong audience. Also, the public might not possess full/right information about the project being introduced.
8	**Decision-making**	Some mitigation measures cannot be well addressed to predicted consequences. As the future is uncertain the mitigation measures might not correspond to future scenario.
9	**Environmental monitoring**	As it takes place during and after project initiation, major climate drivers can be forgotten and/or not well monitored.

Source: Researcher, 2023

Furthermore, the results in Table 6 show a moderate effectiveness of EIA in terms of climate change mitigation in Gasabo District. This ranking bases on the calculated mean score of 2.76 suggesting that the respondents perceive the EIA as generally moderately effective.

Table 6: EIA effectiveness ranking

EIA effectiveness	Frequency	Numerical value	Total value	Mean	Comment
Very highly effective	20	5	100		
Highly effective,	24	4	96		
Moderately effective	23	3	69	2.76	Moderately effective
Not effective	67	2	134		
Not effective at all	16	1	16		
Total	**150**		**415**		

Source: Researcher, 2023

4. Discussion of Results

The results of this study indicate advanced awareness and knowledge of climate change causes and consequences among respondents. However, Figures 6 and 7 confirm the presence of climate change due to rainfall and temperature scenarios being recorded in Gasabo District. It is indeed becoming evident that temperature is increasing while rainfall record decreases. This agrees with recent studies which highlighted the changing climate in Rwanda (Fraschini et al., 2022; Taremwa et al., 2016; Umugwaneza et al., 2021) and other studies that pointed out that increasing of motorbikes in the City of Kigali are the main sources of air pollution leading to atmospheric warming (Henninger, 2009; Nahayo et al., 2019; Subramanian et al., 2020).

Moreover, the results in this study are consistent with recent research on community and climate change (NISR, 2022), that as long as both rainfall and temperature reveal changing patterns, local people are becoming more aware of the impact on their livelihood despite low mitigation and adaptation capabilities. Despite EIA progress so far made in Gasabo District, it can be mentioned that there is still much to do towards ensuring that the application of EIA contributes to climate change mitigation in the area. For exam-

ple, according to the results of our study in Figure 8, there are already the locally applied mitigation measures among which EIA is featured.

However, the results in Table 6, identified EIA as moderately effective in terms of climate change mitigation in Gasabo District. This implies that EIA should be applied in conjunction with other practices. If the tool is applied alone, mitigation cannot be assured unless other tools are applied jointly. On the one hand, it can be noted that in Gasabo District, EIA contributes to environmental management since each project indicates its likely environmental degradation actions and proposed relevant mitigation and adaptation actions. Nevertheless, on the other hand, its effectiveness is still relatively good to some reasons such as the fact that other mitigation practices being applied in Gasabo District are more effective than EIA.

CONCLUSION

This study used a questionnaire survey and interviews to assess the effectiveness of environmental monitoring tools towards climate change mitigation in Rwanda. A sample of 155 respondents was selected from both individual residents and local leaders from regulatory institutions operating in Gasabo in areas related to environmental management and climate change. The results revealed that the respondents are moderately aware of the negative impact of climate change towards their livelihood. Extension of forestland and applying organic fertilizers, as well as participating in mass sports and ensuring annual motor vehicle inspection were highlighted as the most important climate change mitigation practices. The results also revealed that there is still much to do as far as EIA effectiveness in building climate change mitigation. It is suggested to ensure that EIA takes place during all project cycles (before, during and after implementation). This would contribute to tracing possible emission resulting from each project phase and propose immediate actions. It is also imperative to crosscheck the parameters assessed while conducting EIA and their connectivity with climate change mitigation. This would lead to enhancing its application with reference to current climate scenarios. Further studies are encouraged to undertake single research to analyse each mitigation practice's contribution to climate change mitigation.

Acknowledgment

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