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STUDY OF NATURAL DISASTERS AND OF THEIR IMPACT ON THE ENVIRONMENTAL CONDITION RWENZORI MOUNTAIN REGION

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Abstract

Rwenzori Mountain is located in western part of Uganda and has richness in biodiversity which include many natural habitats of endangered species and unusual flora. On the mountains grows 278 species of woody plants, 81 % are endemic to East Africa. Natural hazards are becoming frequent along the slopes and contribute to the decline in biodiversity. In order to ensure environmental safety, the places of natural disasters, their causes and frequency should be set. This study is conducted for hazard registration and assessment the state of the environment along the Rwenzori slopes in districts of Kabarole, Kasese and Bundibugyo within a period of February 2017 to March 2018. Geo-observers used smart phones to record the coordinates where disasters occurred and they filled of close and open questionnaire with aid of KoBo application. Quantum GIS software was used for analyzing and managing received geospatial information, as well as its visualization. SPSS software (version 16.0) was used to generate descriptive statistics in frequency of disaster occurrence. Kasese slopes experienced 177 landslides, 29 windstorms 21 flash floods, 13 hailstorms, 1 earthquake, 6 lightening incidences and 14 occurrences of drought. While Kabarole slopes the least occurrences of disasters experienced. The most frequent of the disasters on the slopes of Rwenzori were landslides – 214 incidents, then windstorms – 51 incidents and flash floods – 36 incidents. Research shows that planting trees and shrubs can prevent or reduce the effects of several types of natural disasters. For develop natural protection technology and reduce the effects of natural disasters in the future is necessary to study potential of *Ficus*, *Albizia julibrissin*, *Markhamia lutea* and their characteristics such as growth rate and density of the root system and of the crowns, water absorption ability of the root system, mechanical strength and elasticity of tree (for that to resist the storm wind), etc.

Keywords: landslides; droughts; flash flood; hazard registration; environmental safety; volcano.

1. Problem statement and analysis of the recent researches and publications.

Rwenzori Mountain is located in western part of Uganda and it is a global heritage and Ramsar site because of its richness in biodiversity which include many natural habitats of endangered species and unusual flora [1]. On the mountains grows 278 species of woody plants, 81 % are endemic to East Africa. In additional to its biodiversity richness, Rwenzori Mountain is watershed to most of the water resources such as lakes Edward and George [2].

Rwenzori Mountains plays a significant in the economy of the country with several activities taking place such as tourism, agriculture and mining. Rwenzori mountain area is one of the most disaster prone areas in Uganda due to its mountainous nature of the landscape, climate and human activities such as farming, road construction, mining, deforestation among others that contribute to various forms of hazards within the mountain area [3]. Some destruction of property, massive land degradation and loss of lives has been reported to have occurred [4]. Nevertheless, natural hazards are becoming frequent along the slopes.

Natural hazards lead to the decline in biodiversity of area when habitats are destroyed. For instance drought drying the grass and water source hence shortage of food and water for wild and domestic animals. Sometimes strong animals move long distances in search for those necessities. Some weak animals end up dying in the process. In plant community changes due to disasters, leaving bear soil hence prone to soil (according to [5], that 41 to 60 percent of species can be lost due to disaster occurrence so this calls for disaster management).

The cause of these natural disasters is human activity. So, for example, flash floods were caused by diverging the river course/path (river Nyamwamba) to build hospital infrastructure during heavy rain season. However the river recovered its natural path and this contributed to the flood.

Landslides are triggered by loosening soil by cultivation and road construction along the slopes. With this in states of earthquake created lines of weakness to enable landslides to occur [6].

Earthquakes are naturally occurring (tectonic movements). Windstorms, hailstorms, droughts, lightening are highly associated with climate change which was human induced [7] by destroying natural vegetations, wetland degradation. These contribute to environmental degradation reduce the effectiveness of the capacity of ecosystem to mitigate natural disasters.

That is why natural disasters are an increasingly serious problem [7, 8]. Moreover, the situation is complicated by the fact that extreme weather gets a boost from climate change [7, 8].

Therefore, the aftermath of natural disasters must be mitigated and their quantity should be reduced. This means that in order to ensure environmental safety, the places of natural disasters, their causes and frequency should be set.

This study is conducted for hazard registration and assessment the state of the environment along the Rwenzori slopes in districts of Kabarole, Kasese and Bundibugyo within a period of February 2017 to March 2018.

2. Statement of the problem and its solution.

2.1. Materials and method.

Mountain Rwenzori is block mountain (non-volcanic) and one of the highest mountains in Africa, located in a rift transfer zone within the Northern Western Branch of East African Rift System in western Uganda (figure 1). The Rwenzori span the equator along the border between Uganda and the Democratic Republic of Congo, between Lakes Edward and Albert in the western arm of the East African Rift System. Have a total area of 3000 km^2 and a maximum elevation of 5,109 m a.s.l. The study was conducted in the slopes of Rwenzori in districts of Kasese, Kabarole and Bundibugyo where 20 disaster prone parishes were selected.

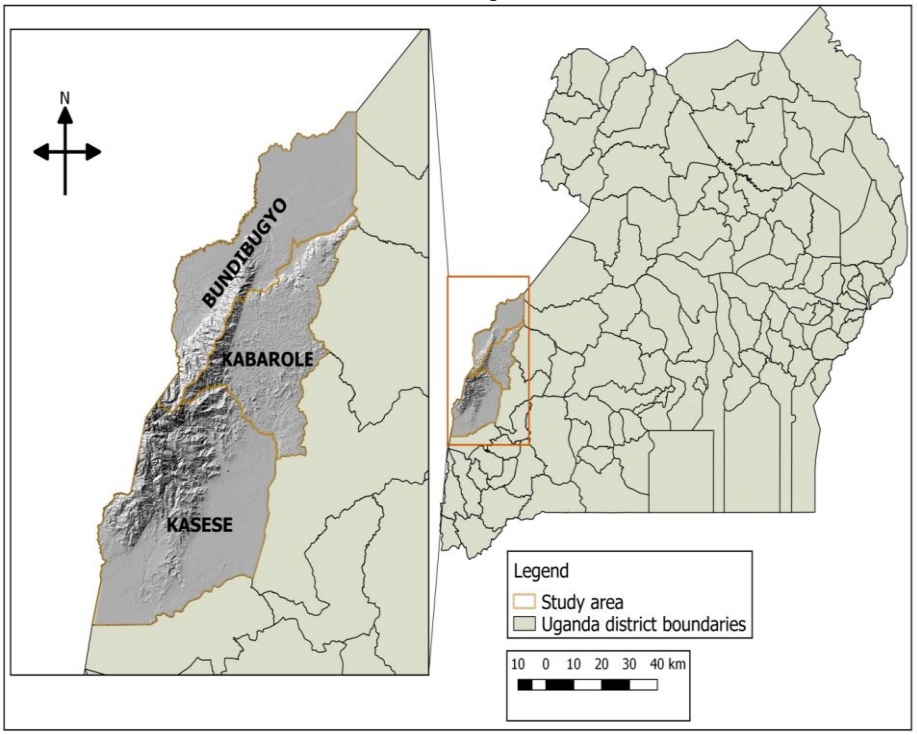

Figure 1 – Geographical area of the Rwenzori Mountains in Uganda, admin Boundary from [9] and Elevation from NASA SRTM

Research design. When the disaster was detected by an observer, then it was photographed and then downloaded to the software. Geo-observers in selected parishes in Kabarole, Kasese and Bundibugyo, used smart phones to record the coordinates where disasters occurred in and filled close and open end questionnaire with aid of KoBo application. After filling the questionnaire, the information was electronically uploaded for disaster coordination office in Mountains of the Moon University to access to do data analysis.

Rainfall data collection. Ten rainfall stations were established along the slopes of Mount Rwenzori and each station with automatic rain gauge as tipping bucket. Tipping bucket rain gauge operates as: rain drops fall into bucket then flow into spoon like structures called tippers. The accumulation in tippers is recorded to USB by sensors. The 10 rainfall stations were located: Buhesi, and Kabonero in Kabarole distict, Kasitu, Bundibugyo town council, Bukonzo and Bubandi in Bundibugyo district, Mubuku, Bugoye, Kilembe and Mahango in Kasese district.

Data analysis and interpretation. Quantum GIS software was used for analyzing and managing received geospatial information, as well as its visualization. SPSS software (version 16.0) was used to generate descriptive statistics in frequency of disaster occurrence. For rainfall data was always downloaded from the USB using software of Easy log every 3 months. The total amount of rainfall in a month was obtained by adding amount from all station in that month.

2.2. Results.

2.2.1. Spatial-temporal distribution of the hazards in the Rwenzori mountain area. A spatial distribution of different natural hazards in the Rwenzori Mountain area was generated by Quantum Geographic Information System (figure 2). Slopes in Kasese district were mostly affected by landslides, flash floods, windstorms, drought, lightening pest and diseases (table 1). While slopes in Kabarole district were least affected by natural hazards, Bundibugyo slopes were more affected (figure 2).

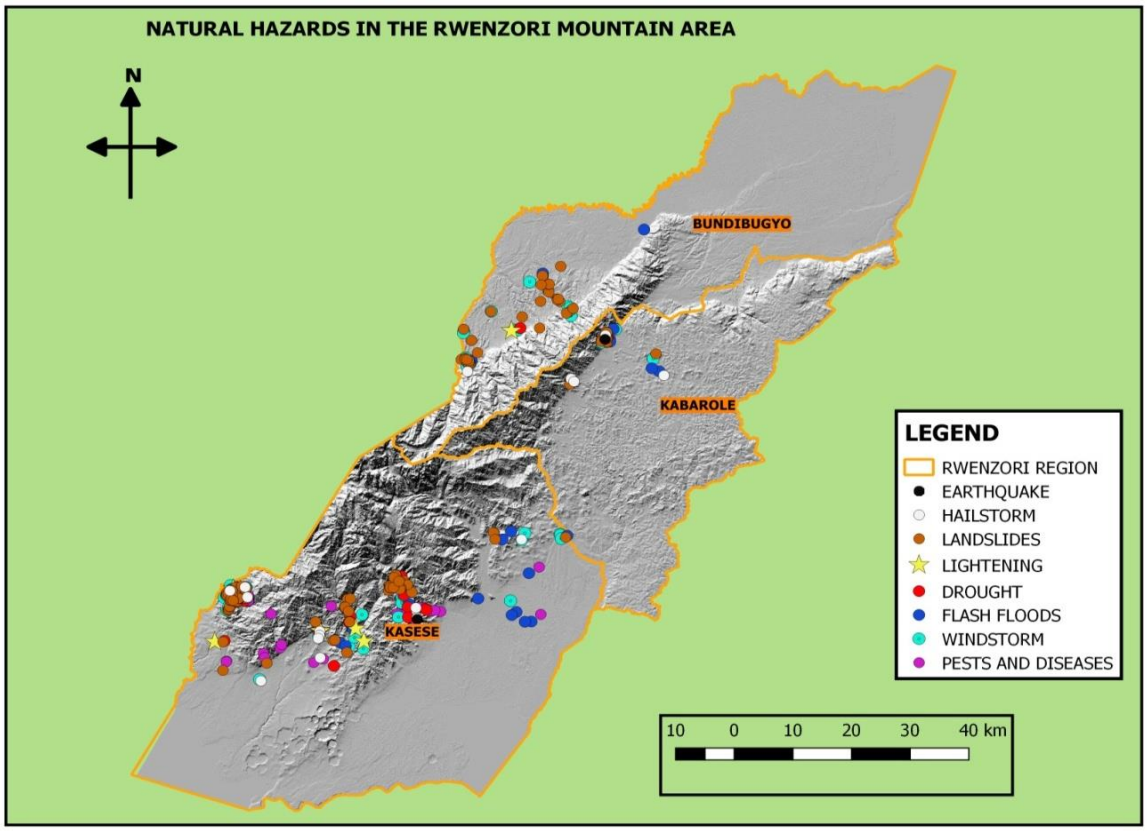

Figure 2 – Map of Natural hazards distribution in the slopes of Rwenzori Mountain in February 2017 to May 2018 aided by use of UBOS, 2014; NASA SRTM

Table 1 – Frequencies of various natural hazards in Kasese, Kabarole and Bundibugyo slopes

District in Rwenzori slopes	Natural hazards and their frequencies in slopes						
	Landslides	Windstorm	Hailstorms	Earth-quakes	Drought	Flash floods	Lethal Lightening
Kasese	177	29	13	1	14	21	6
Kabarole	22	16	4	1	0	8	1
Bundibugyo	42	6	1	0	1	7	0
Total	241	51	18	2	15	36	7

2.2.2. Disaster frequencies along Rwenzori Kasese, Kabarole and Bundibugyo slopes and effects of natural hazards. Landslides were the most rampant disaster in the Rwenzori slopes with 214 frequencies followed by windstorms with 51 Frequencies then flash floods with 36 frequencies and the least frequent disaster was earthquake with 2 frequencies (figure 3).

Kasese slopes experienced high occurrences of disasters i.e. 177 slides, 29 windstorms 21 flash floods, 13 hailstorms, 1 earthquakes , 6 lightening incidences and 14 occurrences of drought (see table 1). While Kabarole slopes experienced the least occurrences of disasters with 22 landslides, 16 windstorms, 4 hail-storms, 1 earthquake, 8 flash floods, 1 lightening incidence and 0 occurrence of drought (see table 1).

Most destructive hazard was the landslide cracking 234 permanent houses, damaging 19 temporary houses, 95 plantations of food and 180 coffee plantations (table 2). Then by hailstorms 18 houses, 50 plantations of food crops and 18 coffee plantations was destroyed. The least destructive hazard was earthquake with no damage.

2.3. Discussion.

2.3.1. The most frequent natural disasters and analysis of the possibility of reducing their quantity. The most frequent danger is landslides: 177 frequencies in Kasese slopes, 42 frequencies in Bundibugyo slopes and 22 frequencies in Kabarole slopes with high damage of 528 properties (see table 1). This can be attributed to the interaction of natural factors such as prolonged heavy rainfall, steep gradients with human activities i.e. continuous cultivation, deforestation, poor construction designs [4]. The spots of landslides include Kitholhu with 110 landslides, followed by Kilembe with 42 land-slides, then 20 landslides in Bukuku, 20 landslides in Ndugutu and least landslides in Kyarumba 13. Though tree planting has been implemented along the slopes of Rwenzori by quantity of NGOs but local communities were not involved in the implementation [4]. Therefore little maintenance was given to trees so they experienced poor growth to prevent landslides.

The maximum effectiveness of reducing quantity of landslides will be achieved if the population moves from dangerous areas and in these areas introduce a dense planting of trees.

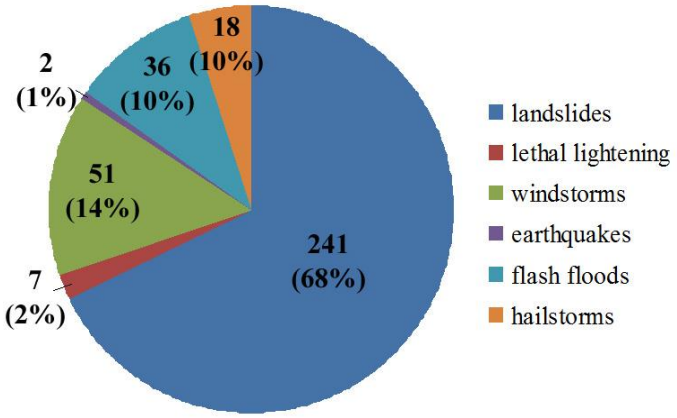

Figure 3 – Frequencies (occurrences) of natural hazards in slopes of Rwenzori Mountain February 2017 to March 2018

Table 2 – Destructive effect of natural hazards along slopes of Rwenzori Mountain

Nature of disaster	Property damaged	Extent of damage	Quantitative property damage
Landslides	Temporary houses	Completely damaged	19 houses
	Permanent houses	Cracked	234 houses
	Food crops	Completely damaged	95 plantations
	Coffee	Partially damaged	180 plantations
Windstorms	Temporary house	Completely damaged	11 houses
	Temporary house	Partial damaged	21 houses
	Food crops	Completely damaged	37 plantations.
	Coffee	Partially damaged	6 plantations
Flash floods	Temporary houses	Partially damaged	12 houses
	Permanent houses	Partially damaged	5 houses
	Permanent bridges	Partially Destroyed	2 bridges
Hailstorms	House roof	Removed	18 roofs
	Food crops	Partially damaged	50 plantations
	Coffee	Partially damaged	18 plantations
Drought	Food crops	Completely damaged	14 plantations
	Food crops	Partially damaged	15 plantations
	Coffee	Partially damaged	4 plantations
Earthquake	–	–	No damage

However, properly maintenance care must be given for trees, until they are strong enough to have strong roots restrain landslides. To restrain landslides can be recommended tree species with strongest roots. At the same time, commercial interest to these trees should be low [10]. Since tree species of high commercial value such as eucalyptus, pines after certain period will be cut down for timber or firewood so at end, the purpose is not fulfilled. Consequently, most appropriate to plant *Ficus*, *Albizia julibrissin*, *Markhamia lutea*, which do not used for firewood or building and it is of low commercial as compared to pine trees.

2.3.2. Discussing the causes and solving problems of flash floods, drought and storms. There is high disaster occurrence during the months of heavy rainfall i.e. May and October with high occurrence of flash floods, landslides, storms (figure 4) because these disasters are related to precipitation. As evidenced by low disaster occurrence in dry seasons in months of January, June and July. According to Tweheyo, 2017 (unpublished data) Rwenzori slopes received lowest amount of rainfall of 203 mm in January 2016 and highest amount in May of 1422.6 mm and 1440.4 mm in October 2016. Though rainfall patterns normally behave differently in different year, Tweheyo 2017 reported of lowest amount of 188 mm in January 2015 and highest amount in September 2015 of 2110.6 mm (table 3).

Flash floods were more frequent in Kasese slopes because of several flooding spots along Rivers Nyamwamba and Mubuku as earlier reported in paper [3, 11]. For the case of river Nyamwamba flooding is attributed to diversion of the river course in the past to create space for infrastructure construction in Kilembe [12]. So river regain back its natural course of flow during the heavy rains.

Forest fires is another factor contributing to flooding where by destroys the vegetation that absorb water hence [3] so there is need to construct flood defense structures such as levees and reservoirs to prevent damage [13].

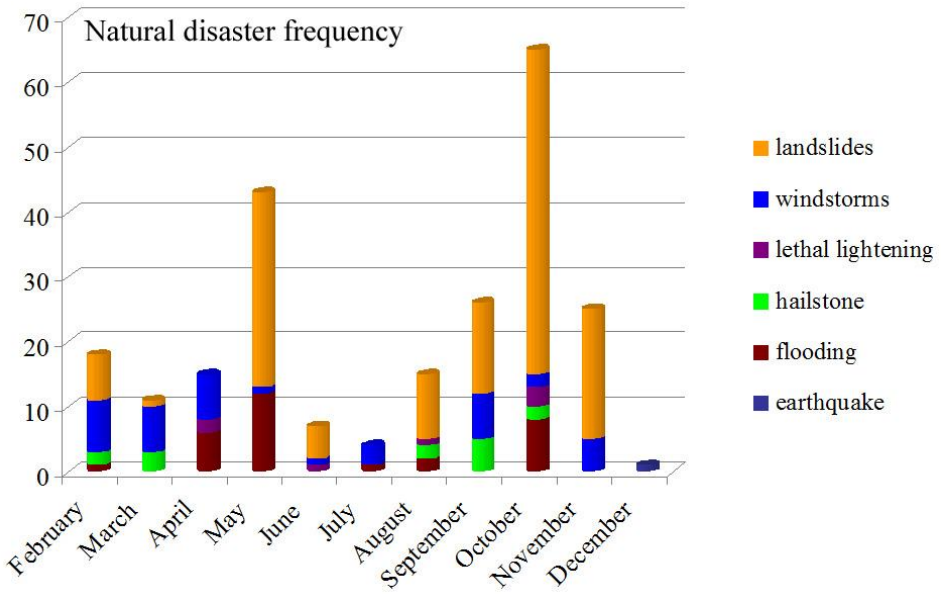

Figure 4 – Disaster occurrence during 2017

Table 3 – Rainfall distribution along the slopes in years of 2015 and 2016 adopted from Tweheyo 2017 (unpublished data)

Total rainfall (mm)	Jan	Feb	Mar	April	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
in 2015	188	405	952	1407.6	1359.6	1255.4	989.3	496.5	2110.6	1737.6	1546.4	575.8
in 2016	203.8	588	703.6	2409.4	1422.6	777.6	700.6	984	1305.4	1440.4	1368.4	307.2

Kasese experiences higher temperatures than Kabarole and Bundibugyo slopes due to effect of equator [14] and being located in lee ward side of the mountain so this contributes the severity of droughts.

Drought is very severe in the area in the months of January, June and July [15] so people can establish reserves to collect rain water during the rain peak season. This would address the drought associated problems for farmers.

Storms were not under influence of anthropogenic factors [16] only solution is to prevent destructive effects of winds to reduce the wind intensity by promoting tree planting [17, 18] since trees decline wind force.

Conclusion and recommendations.

1. Landslides, flash floods and windstorms management problems in Rwenzori region should be given top priority to solve them. These disasters were the most frequent and caused a lot of damage of infrastructures and loss of lives in the region as reported in this study and other studies in paper [3, 4, 11].

2. Earthquakes were less frequent throughout 2017 – 2018, but basing on the history, their destructive effects can greatly exceed the scale of the effects of landslides and windstorms. Severe earthquakes occurred in 1966 and 1994, causing a lot deaths and destruction [19]. This is a natural phenomenon that people are not able to control. However, people are able to reduce the negative impact of secondary hazards that arise from earthquakes, such as landslides and others.

3. Research shows that carrying out forestry activities such as planting trees and shrubs can prevent or reduce the effects of several types of natural disasters, because:

– the dense root system is capable of holding landslides and absorb a significant amount of water in the rainy season, and, consequently, reduce the likelihood of strong flooding;

– the crown delays the wind and reduces its intensity, which prevents the occurrence of windstorms.

4. Based on the foregoing, a promising scientific direction is the study for different plant species of its potential and characteristics, such as:

– growth rate and density of the root system, as well as growth rate and density of the crowns of a certain type of tree species;

– water absorption ability of the root system;

– mechanical strength and elasticity of tree species (for that to resist the storm wind), etc.

These studies will provide an opportunity to develop natural protection technology and mitigate the effects of natural disasters in the future.

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Conflicts of interest.

None of the authors have any potential conflicts of interest associated with this present study.

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ВИВЧЕННЯ СТИХІЙНИХ ЛИХ ТА ЇХНЬОГО ВПЛИВУ НА СТАН НАВКОЛИШНЬОГО СЕРЕДОВИЩА ГІРСЬКОГО РЕГІОНУ РУВЕНЗОРІ

Гора Рувензорі розташована в західній частині Уганди і володіє багатим біорізноманіттям, має безліч природних місць мешкання зникаючих видів і незвичайної флори. На горах росте 278 видів деревних рослин, з яких 81 % ендемічних для Східної Африки. Природні небезпеки стають все більш частими уздовж схилів і сприяють скороченню біорізноманіття. З метою забезпечення екологічної безпеки необхідним є визначення місць стихійних лих, причин їх виникнення й частоти. Це дослідження має на меті реєстрацію небезпек і оцінювання стану навколишнього середовища уздовж схилів Рувензорі в районах Кабароле, Касесе й Бундібугіо в період з лютого 2017 року по березень 2018 року. Географічні спостерігачі використовували смартфони для запису координат, де відбулися лиха, і заповнювали закриту і відкриту анкету за допомогою додатку КоБо. Програмне забезпечення Quantum GIS використовували для аналізу одержаної геопросторової інформації, управління нею, а також для її візуалізації. Програмне забезпечення SPSS (версія 16.0) використовували для генерації описової статистики частоти виникнення стихійних лих. Схили Касесе піддалися 177 зсувам, 29 ураганам, 21 повеням, 13 випадкам випадання граду, 1 землетрусу, 6 ударам блискавки й 14 випадкам посухи. У той час як схили Кабароле піддалися меншій кількості стихійних лих. Найбільш частими з лих на схилах Рувензорі були зсуви – 214 випадків, потім бурі – 51 випадок й повені – 36 випадків. Дослідження показує, що насадження дерев й чагарників може запобігти або зменшити наслідки декількох видів стихійних лих. Для розробки природних захисних технологій й зменшення наслідків стихійних лих в майбутньому необхідним є вивчення потенціалу *Ficus, Albizia julibrissin, Markhamia lutea* та їхніх характеристик, таких як швидкість росту й щільність кореневої системи і крони, водовбирна здатність кореневої системи, механічна міцність і еластичність дерева (з метою протистояти штормовому вітру) тощо.

Ключові слова: зсуви; посухи; раптова повінь; реєстрація небезпеки; екологічна безпека; вулкан.

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ИЗУЧЕНИЕ СТИХИЙНЫХ БЕДСТВИЙ И ИХ ВЛИЯНИЯ НА СОСТОЯНИЕ ОКРУЖАЮЩЕЙ СРЕДЫ ГОРНОГО РЕГИОНА РУВЕНЗОРИ

Гора Рувензори расположена в западной части Уганды и обладает богатым биоразнообразием, имеет множество естественных мест обитания исчезающих видов и необычной флоры. На горах произрастает 278 видов древесных растений, из которых 81 % эндемичных для Восточной Африки. Природные опасности становятся все более частыми вдоль склонов и способствуют сокращению биоразнообразия. В целях обеспечения экологической безопасности необходимо определить места стихийных бедствий, причины их возникновения и частоту. Это исследование проводится с целью регистрации опасностей и оценки состояния окружающей среды вдоль склонов Рувензори в районах Кабароле, Касесе и Бундибугио в период с февраля 2017 года по март 2018 года. Географические наблюдатели использовали смартфоны для записи координат, где произошли бедствия, и заполняли закрытую и открытую анкету через приложение КоБо. Программное обеспечение Quantum GIS использовали для анализа полученной геопространственной информации и управления ею, а также для ее визуализации. Программное обеспечение SPSS (версия 16.0) использовали для генерации описательной статистики частоты возникновения стихийных бедствий. Склоны Касесе подверглись 177 оползням, 29 ураганам, 21 наводнению, 13 случаям выпадения града, 1 землетрясению, 6 ударам молнии и 14 случаям засухи. В то время как склоны Кабароле подверглись меньшему количеству стихийных бедствий. Наиболее частыми из бедствий на склонах Рувензори были оползни – 214 случаев, затем бури – 51 случай и наводнения – 36 случаев. Исследования показывают, что насаждение деревьев и кустарников может предотвратить или уменьшить последствия нескольких видов стихийных бедствий. Для разработки естественных защитных технологий и уменьшения последствий стихийных бедствий в будущем необходимо изучить потенциал *Ficus*, *Albizia julibrissin*, *Markhamia lutea* и их характеристики, такие как скорость роста и плотность корневой системы и кроны, водопоглощающая способность корневой системы, механическая прочность и эластичность дерева (с целью противостоять штормовому ветру) и т. д.

Ключевые слова: оползни; засухи; внезапное наводнение; регистрация опасности; экологическая безопасность; вулкан.