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Application of Nature-Based Solutions for Flood Risks Reduction in Five Urban Sub-Catchments in Rwanda

1. BACKGROUND

Over the last decade Rwanda has been experiencing recurrent destructive flooding especially in urban area mainly due to an increase in rainfall intensity combined with rapid urbanization. The increase in rainfall intensity is being triggered by increased temperatures whereby the mean temperature for Rwanda has risen between 1.4°C and 2.56°C during the period from 1971 to 2016 in some parts of Rwanda (South-West and Eastern Regions) and rain variability is predicted to increase further by 5% to 10% in the future (GoR, 2018, Third National Communication Report to the United Nations Framework Convention on Climate Change).

Changes in temperature and precipitation and their distributions are the key drivers of climate and weather-related disasters that negatively affect Rwandans and the overall economy. During 2020 only, 232 people have been killed with floods and landslides, 7,769 houses destroyed, 4, 437 ha of crops damaged and 103 bridges destroyed (Annual Disaster Effects Report, GoR,2020).

Within the framework of building the resilience to climate change, the Global Green Growth Institute(GGGI)-Rwanda Program in partnership with the Rwanda Environment Management Authority (REMA) in its capacity as the National Designated Authority (NDA) for Green Climate Fund (GCF) in Rwanda has formulated a National Adaptation Readiness Project proposal to GCF aiming at building flood resilience capacities in Rwanda in line with the governmental policies, strategies and priorities, and enhance Rwanda's capacity to respond to climate change in high risk zones by implementing an adaptation plan for integrated flood and landslide management in urban areas. The project outputs include:

a. Capacity and coordination strengthened;
b. Appropriate technical studies identified and prioritized, climate finance strategies and project pipeline strengthened;
c. Adaptation knowledge management, information sharing, and communications strengthened;
d. Mechanisms for reporting, monitoring and review of adaptation and resilience planning progress developed.

Within the framework of this project, five urban sub-catchments within the capital city, Kigali, and secondary cities (Huye and Rusizi) as well as a peri-urban area of Kamonyi district, have been selected for detailed assessment of flood risks and mitigation measures in order to inform a funding proposal to the Green Climate Fund. The below map illustrates the location of the selected sub-catchments in Rwanda.

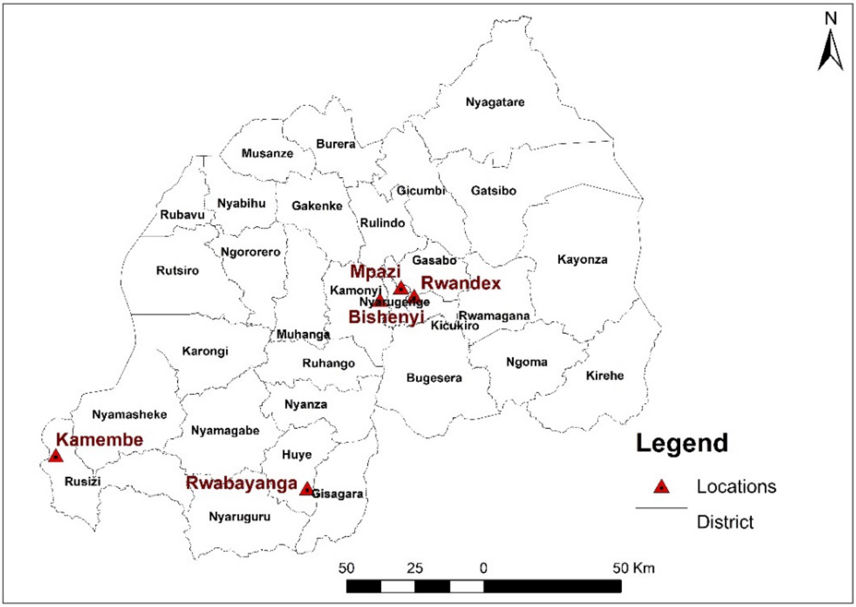


Figure1: *Map showing the location of the selected sub-catchments*

2. METHODOLOGY

The analysis of flood risks in the five urban sub-catchments namely Rwandex-Magerwa and Mpazi (City of Kigali), Bishenyi (Kamonyi district), Rwabayanga (Huye district) and Kamembe-Gihundwe(Rusizi district) focused on flood extent delineation and water depths assessment for rainfall with specific return periods from 5 years to 100 years. HEC-HMS and HEC RAS software have been used respectively for hydrological and hydraulic modelling and the below figure describes the methodology that was applied.

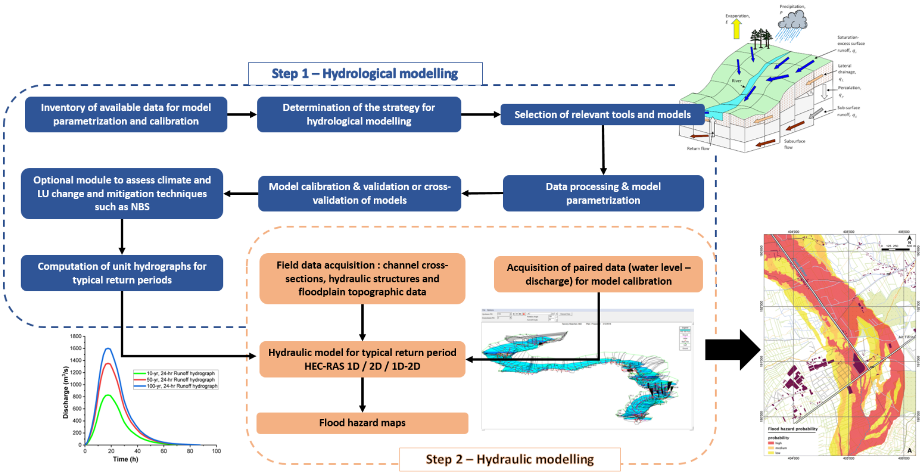


Figure2: *Applied methodology for flood risks assessment*

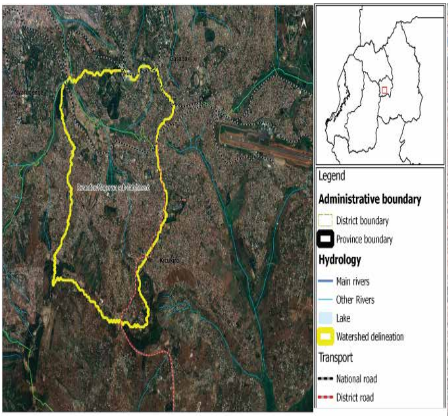
Appropriate nature-based solutions have been simulated in both the hydrological models (upstream NBS) and hydraulic models (downstream NBS) to compute their impacts in reducing flood risks. The most commonly used definition of Nature-Based Solutions is from the International Union for Conservation of Nature (IUCN) which defines NBS as “actions to protect, sustainably manage, and restore natural or modified ecosystems that address societal challenges effectively and adaptively, simultaneously providing human well being and biodiversity benefits”. If well implemented, Nature-Based Solutions present multiple benefits such as resilience and avoided losses; economic gains and long-term growth; and essential social and environmental services (Smart, Sustainable and Resilient Cities: the power of NBS, UNEP, 2020).

There is a wide range of applicable nature-based solutions in an urban set-up and the applied ones under this study include permeable pavements, urban trees, green roofs and rainwater harvesting at household level while the applied downstream nature-based solutions include detention basins and grassed swales.

3. FINDINGS

3.1 Rwandex-Magerwa sub-catchment

Rwandex-Magerwa sub-catchment is located to the centre-south of Kigali City and it forms part of the larger Nyabugogo catchment and has an area of about 10 km². The land use of the sub-catchment is predominantly residential with a combination of planned and unplanned settlements (Figure 3). The results from the flood model for a 100-year return period has shown that 3.37 ha are prone to flooding excluding the wetland zone (Figure 4)



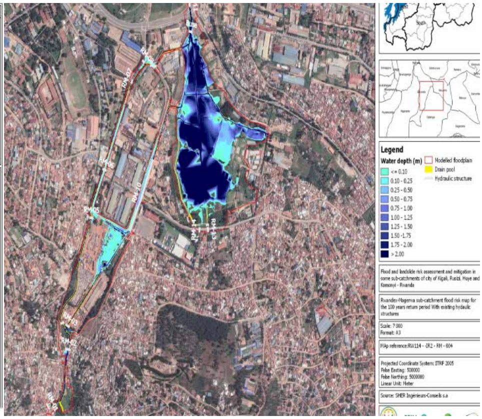


Figure3: Rwandex-Magerwa sub-catchment location map(left)

Figure 4: Flood hazard map for a 100-year return period(right)

With the application of nature-based solutions at both household level and localized downstream NBS as illustrated under figure 5 below, the flood prone area under a 100-year return period has been significantly reduced as illustrated under figure 6&7 below.

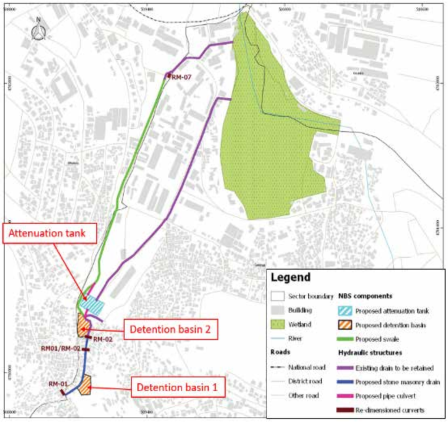


Figure 5: Map showing the location of the proposed downstream NBS

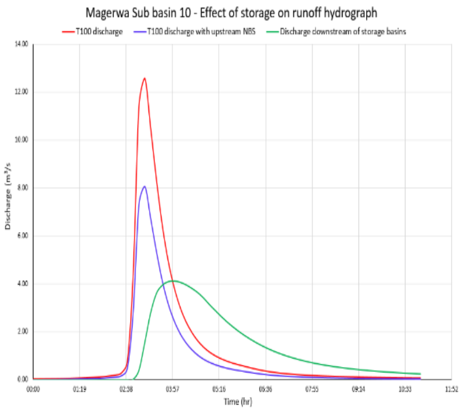


Figure6: Effect of NBS on T100 run off hydrograph

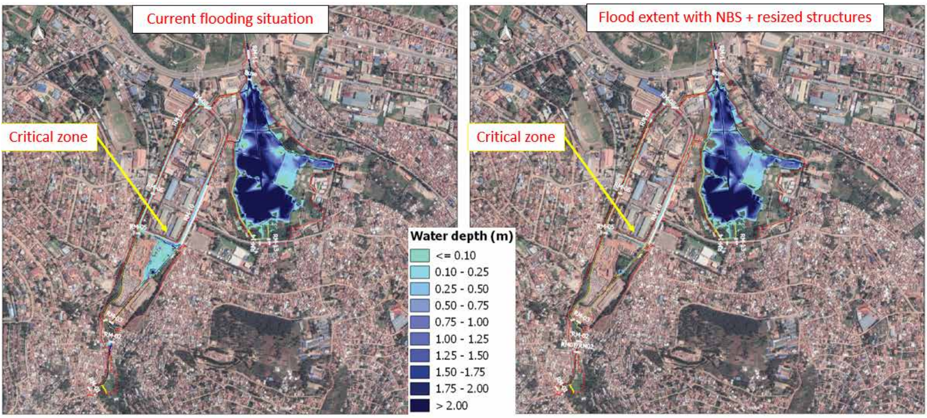


Figure7: Comparison of flood extents between the current situation and after application of NBS + resized structures (T100) in Rwandex-Magerwa sub-catchment

As illustrated under figure 7 above, the wetland remains a flood prone area since this should be its natural function. The main focus under this study was to protect other upstream flooded areas under settlements.

3.2 Bishenyi sub-catchment

The Bishenyi sub-catchment is located in Kamonyi District, Southern province, with an area of about 43 km^2. The land use within the sub-catchment is predominately agriculture with a rapidly urbanizing upstream area (Figure 8). The results from the flood model for a 100-year return period has shown that 38.63 ha are prone to flooding (Figure 9).

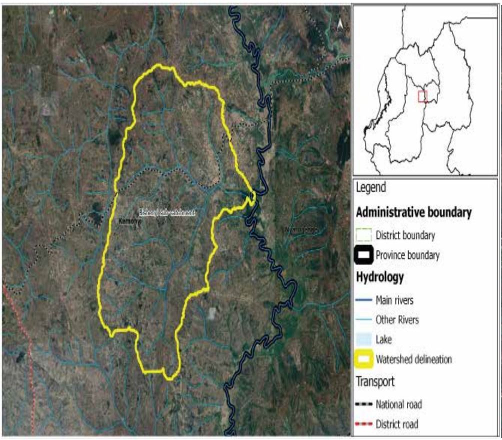


Figure8: Bishenyi sub-catchment location map

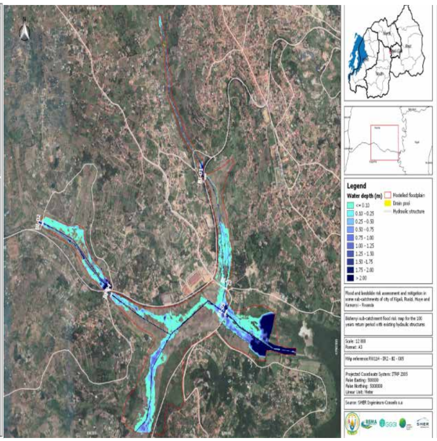


Figure 9: Flood hazard map for a 100-year return period

With the application of nature-based solutions at both household level and localized downstream NBS as illustrated under figure 10 below, the flood prone area under a 100-year return period has been significantly reduced as illustrated under figure 11&12 below.

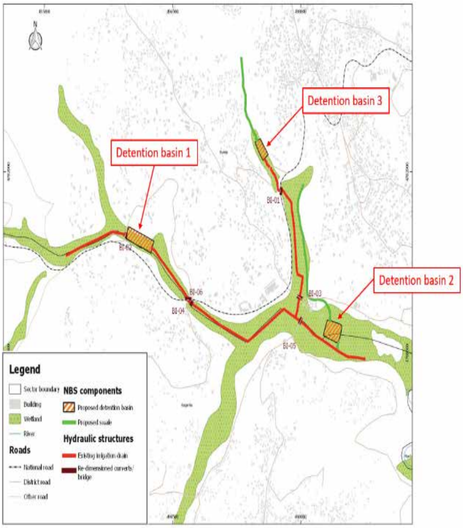


Figure 10: Map showing the location of the proposed downstream NBS

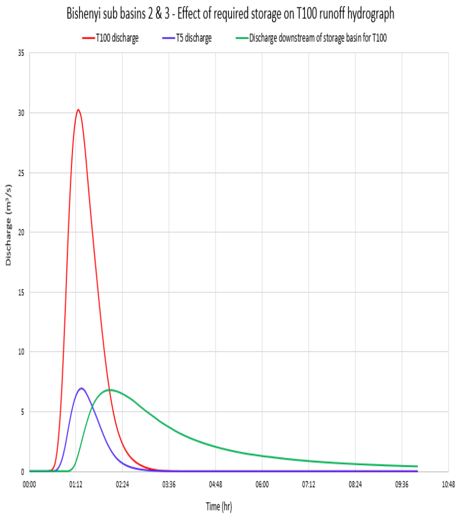


Figure11: Effect of NBS on T100 run off hydrograph

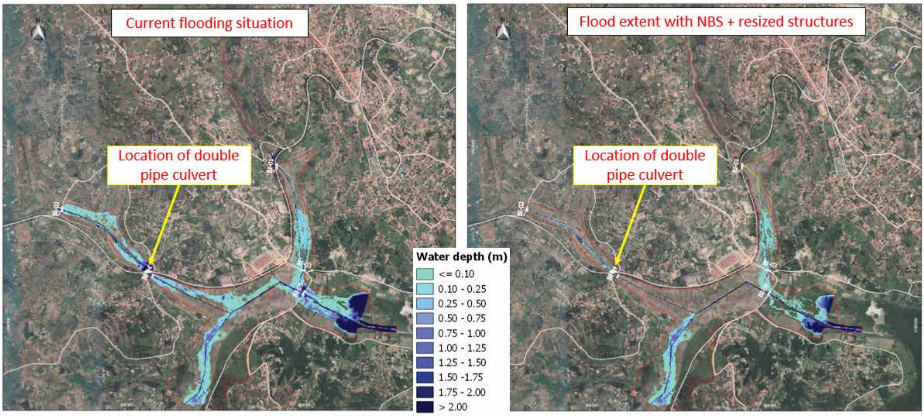


Figure12: Comparison of flood extents between the current situation and after application of NBS + resized structures (T100) in Bishenyi

For Bishenyi sub-catchment, the main important function of the implementation of NBS and resizing of hydraulic structures is the reduction effect on flood depth. Figure 12 above shows that there is no flooding at the structures at the main road. However, the flooded area is reduced by 22 % at T100. Whilst the reported 22 % may not seem not as significant, it is emphasized that this refers to absolute reduction to zero flooding, and a big portion of the remaining 78 % is small depths of water, which the model nonetheless identifies as flooding given its binary nature of assessment. To achieve a higher value of absolute reduction to zero flooding would require a redesign of existing irrigation channels.

3.3. Rwabayanga sub-catchment

Rwabayanga sub-catchment is located in Huye District in the Southern Province with an area of 8 km2. The eastern and northern sides of the sub-catchment are urbanised, part of Huye City, whilst the western and southern sides are predominantly rural and agricultural areas (Figure 13). The results from the flood model for a 100-year return period has shown that 26.36 ha are prone to flooding (Figure 14).

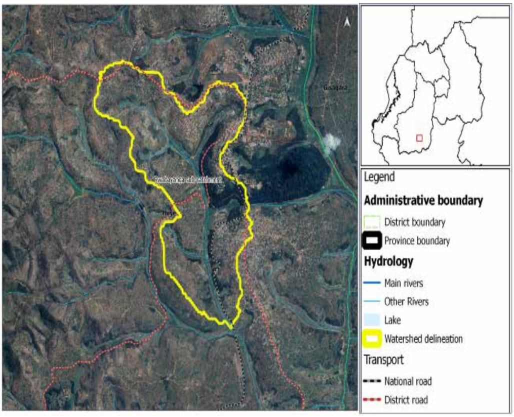


Figure13: Rwabayanga sub-catchment location map

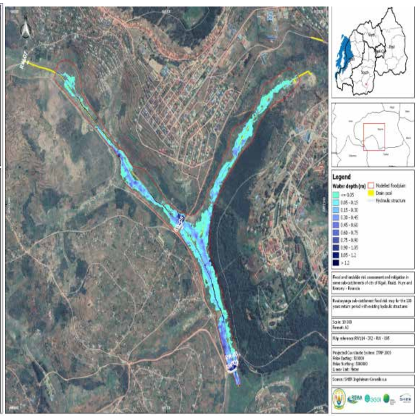


Figure 14: Flood hazard map for a 100-year return period

With the application of nature-based solutions at both household level and localized downstream NBS as illustrated under figure 15 below, the flood prone area under a 100-year return period has been significantly reduced as illustrated under figure 16 & 17 below.

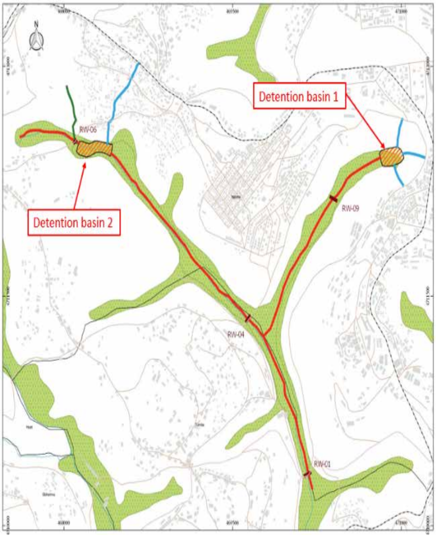


Figure 15: Map showing the location of the proposed downstream NBS

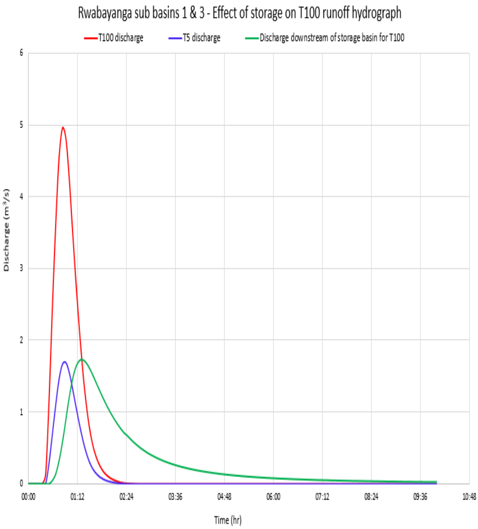


Figure16: Effect of NBS on T100 run off hydrograph

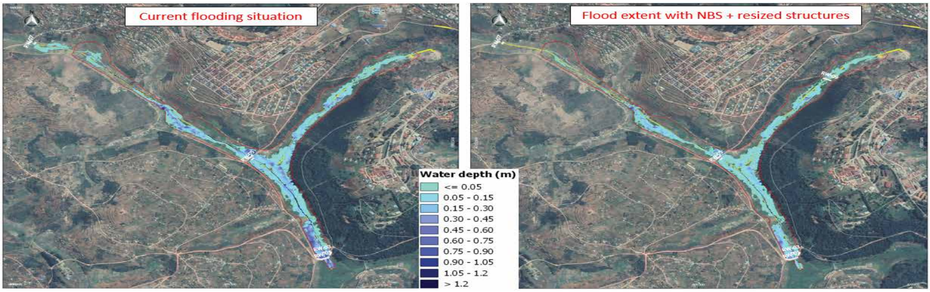


Figure17: Comparison of flood extents between the current situation and after application of NBS + resized structures (T100) in Rwabayanga sub-catchment

As illustrated under figure 17, Rwabayanga sub-catchment follows a pattern similar to that of Bishenyi whereby reduction to absolute zero flooding will depend on the redesign of the irrigation channels. The net reduction of the flooded area is insignificant (1%) whereas the reduction of flood depth is 16 %. Results present a strong case to review the existing irrigation system in Rwabayanga. The channels need to be redesigned to convey flow downstream of the proposed detention basins without overflowing.

3.4 Mpazi sub-catchment

Mpazi sub-catchment has an approximated area of 8.45 sq.km, located in the City of Kigali, in the Nyarugenge District. The main Mpazi channel is a tributary of the Nyabugogo River. The sub-catchment is characterized by a very complex topography with abrupted changes in slopes over short distances (Figure 18). The land use/land cover of the sub-catchment is characterized by a high rate of urbanization, mostly poor and unplanned settlements forming a slum as illustrated under figure 19 (Rwanda YWP, 2021).

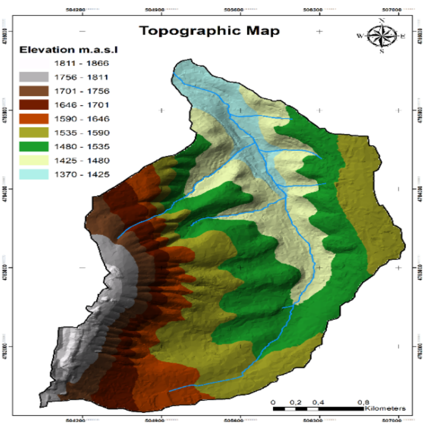


Figure18: Topography of Mpazi sub-catchment

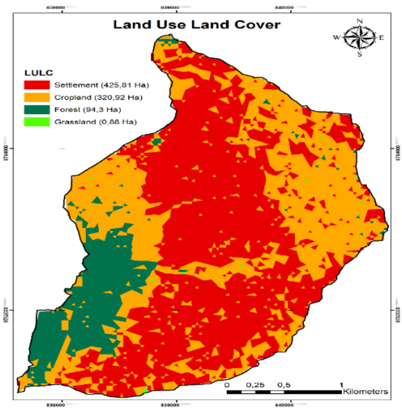


Figure19: Land use in Mpazi sub-catchment

Both the topography and land use in the sub-catchment are key drivers of recurrent destructive flooding occurring in the downstream part of the sub-catchment.

The results from a flood model for a 100-year return period shows a large area along the main river channel and its tributaries which are prone to flooding as illustrated under figure 20 (Rwanda YWP, 2021).

Figure 20: Flood hazard map in the downstream part of Mpazi sub-catchment

Within the framework of mitigating recurrent destructive flooding affecting mostly the downstream of the sub-catchment, the City of Kigali is upgrading two bridges at two National roads and the river channel section in between as illustrated under figure 21.

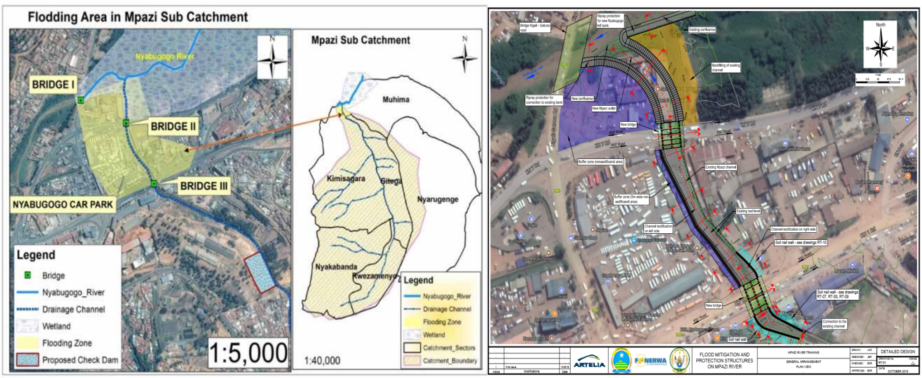


Figure21: Illustration of two bridges and a river channel section being upgraded

However, considering that the upgrading of the two bridges and the in between river channel section needs upstream measures to reduce the run off and therefore sustain the downstream investments, the Rwanda Young Water Professional Organization (Rwanda YWP) has conducted a study with the aim of identifying appropriate nature-based solutions to reduce flood risks within the sub-catchment. The defined measures include reforestation and conservative agriculture in the upstream part of the sub-catchment and green spaces as well as permeable paving in the urbanized areas. The below map illustrates the location of the proposed nature-based solutions (Rwanda YWP, 2021).

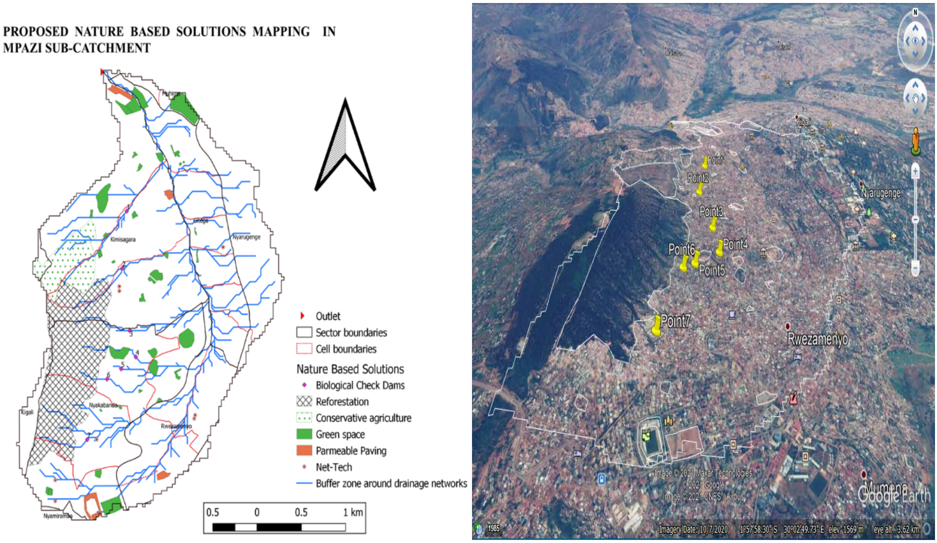


Figure 22: Proposed NBS in Mpazi sub-catchment

The main limitation for the implementation of nature-based solutions is the lack of space to due to the predominance of very dense informal settlements within the sub-catchment. Therefore, the most sustainable solution would be to start first with the upgrading of the area, which fortunately has already started.

3.5 Kamembe-Gihundwe sub-catchments

The selected study areas in Kamembe and Gihundwe sectors of Rusizi district are scattered micro-catchments which needed urgent interventions to address localized flooding.

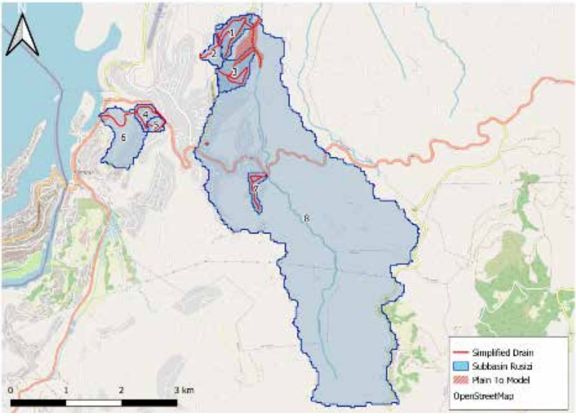


Figure 23: Location of the selected micro-catchments in Rusizi town

For most of the selected sites, the proposed interventions are the re-design or new design of drainage systems with some sections to be covered by grassed swales where the slope is gentle (less than 6%). Other measures include the applicable nature-based solutions at household level such as urban trees, permeable pavement, green roofs and rainwater harvesting. The only proposed detention basin to manage the peak run off is located at Mont Cyangugu.

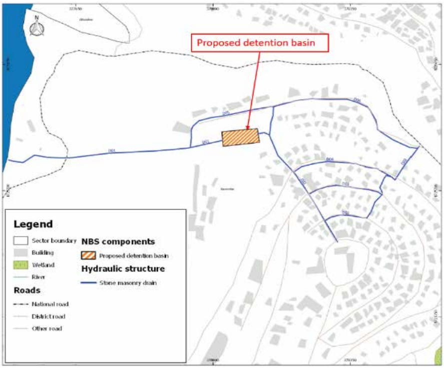


Figure 24: Proposed detention basin at Mont Cyangugu, Rusizi

Considering that the proposed location of the detention basin is on steep slope, the detention basin should be built with an impermeable geotextile lining to prevent all infiltration. This is important given that the basin will be located a hill and infiltration could cause water saturation in the soil, potentially leading to gullies or landslides.

4. CONCLUSION

The study findings have shown that the application of nature-based solutions at household level namely urban trees, permeable pavements, green roofs and rainwater harvesting in any of the sub-catchment can reduce the peak run off by about 40%. This reduction factor is achieved using an assumption that the proportion of households adopting the above-mentioned nature-based solutions is 50 % except for green roofs which was assumed to be 5 % considering its complexity. This is an indication that the reduction of the peak run off and ultimately the flood risks can be considerably reduced with a higher rate of adoption by households.

Therefore, it is recommended that the run off reduction guidelines in an urban set-up, developed alongside this study, be consulted and applied during the planning stage of the built environment like roads and all categories of buildings. It is worth mentioning that the excess run off after the application of nature-based solutions at household level can still be managed using localized nature-based solutions mainly in the downstream areas like detention basins, grassed swales, etc and the flood risks can be fully managed.

The success of nature-based solutions will strongly depend on the technical capacity of both regulators and practitioners, hence the need for a capacity building program on the application of nature-based solutions.

To learn more about our work, please contact us.

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