REPUBLIC OF RWANDA

Ministry of Environment

Erosion Control Mapping Report

February 2020

NISR NATIONAL INSTITUTE OF STATISTICS OF RWANDA

IUCN

Kingdom of the Netherlands

Bundesministerium für Umwelt, Naturschutz, Bau und Reaktorsicherheit

Acknowledgements

The mapping of erosion control status in Rwanda is a result of collaborative efforts between the Government of Rwanda through the Ministry of Environment/Rwanda Water and Forestry Authority and its partners especially the Kingdom of the Netherlands. The Ministry of Environment thank all the partners who contributed to this work including the International Union for Conservation of Nature (IUCN) and the National Institute of Statistics of Rwanda (NISR).

Executive Summary

1. Background to Erosion Control mapping

Soil erosion is the most serious environmental problem in many catchments areas in Rwanda. The main factors affecting the amount of soil eroded include land use and vegetation cover, topography, soil and climate. In order to describe the areas with high soil erosion risks and to develop adequate erosion prevention measures for Rwanda, National erosion risk map were be generated and finalised in July 2018 based on the methodology named "Catchment Restoration Opportunity Mapping (CROM)" a spatial model developed by ESRI Rwanda Ltd. in coordination with Water for growth Rwanda (W4GR) and the Ministry of Environment through Rwanda Water and Forestry Authority (RWFA). The CROM model identified six erosion risk classes: (1) No risk, (2) Low risk, (3) Moderate risk, (4) high risk zones, (5) very high risk and (6) the extremely high risk zones of erosion.

The erosion risk map shows only the potential risk of erosion in different areas, however this map does not neither show areas already protected against erosion nor indicate the location of erosion features as proof of risk. This makes it hard to know the progress made to fight against erosion and achieved results. Moreover, the plan for the future interventions becomes difficult because the erosion risk map shows only the potential risks while districts need to know where exactly the problem still and what is appropriate measures to implement taking into account different land use. Hence, to make this erosion risk map more useful to the multi-scale planning and the decision making process for sustainable management of land and water resources, it was deemed significant to take this erosion risk map further to more interpreted erosion control map using most recent World View images available at National Institute of Statistics of Rwanda (NSIR). Using World View images with resolution of 30 cm to 50 cm and applying visual image interpretation techniques and onscreen digitizing, high risk areas already affected by erosion features (gullies, landslides, rill erosion etc.) were therefore identified, erosion control measures in place and unprotected areas were also visualized and recommendations on the best erosion control practices were also formulated. This study first covered the 20 districts in Rwanda from West, North and South Province (which this report is for the 20 NWS province) and later will be extended to cover Eastern province and Kigali city districts.

In order to serve its purpose of sustainable land and water resources management, the erosion control mapping produces 5 thematic maps: 1) erosion risk distribution, 2) erosion features currently in place, 3) Land use and vegetation cover in high erosion risk areas, 4) existing erosion control techniques and 5) Recommended erosion control practices in the view of unprotected land locate at high erosion risk. These thematic data will be important during the process of erosion control planning, land use planning, allocating land based on suitability, delineating place for protective forests, Agriculture, settlements etc. The data provided in this report will serve as benchmark for better monitoring of erosion control progress in Rwanda, Bonn Challenge and the Sustainable Development Goals (SDGs 2030) specifically Goal 13 for mitigating climate change impacts and Goal 15 related to 1) protection and restoration of terrestrial ecosystems; 2) halting and reversing land degradation and 3) promoting sustainable land management. The erosion control mapping outputs will finally serve as an entry point to planning for integrated watershed management in Rwanda.

2. Erosion risk and existence of erosion features in high erosion risk areas

The results of the erosion control mapping shows that of the 20 districts of NWS Provinces, Land under high risk of erosion is about 465,263 hectares (33.2% of the total NWS provinces land which is estimated to 1,402,446 hectares) of which 69,767 hectares (5% of the total risk areas) are at extremely high risk, 167,551 hectares are at very high risk (11.9% of the total NWS very high risk) and 227,944 hectares are at high risk (16.3% of the total risk identified). Muhanga District is the worst risk district affected with a total of 40,514 hectares i.e. 63% of its land at high erosion risk. Ngororero district is ranked the second high erosion risk district with 41,450 hectares under risk (61% of the district land) while the third is Rutsiro district with 35,110 hectares prone to erosion estimated to 53% of the district land. Other districts such as Gakenke, Burera, Karongi, Rulindo

and Nyamagabe districts need also considerable attention as the risk accounts more than 40% of the district land.
The observed erosion features in risk areas has shown that about 55,759 hectares are affected by Gullies, and rill erosion (55,494 hectares) estimated to 8% all together, however, we could not observe erosion features on about 352,509 hectares (25.1% of the NWS Province land at risk). This should not be understood that there is not erosion happening is such land but rather the time of acquisition and scale could not allow to trace small erosion features. An in-depth analysis up to sector level and characterization of each high risk areas in terms of land use and related management, existing control techniques and erosion control recommendations for unprotected land are also reported.

3. Land Use and Vegetation Cover (LUVC) in area at erosion risk

It is shown that land in the high-risk areas is mostly used for agriculture with seasonal crops (61.3% of the high-risk areas identified). This exposes land to splash erosion and further detachment as land is not permanently covered. In fact, the crop management and cover factor (C) is very high for seasonal crops with conventional (regular) tillage. Forests with high canopy density occupy only 117,388 hectares (8.4%) while Seasonal crops occupy 284,874 hectares (20.3% of the total NWS Province land) and built-up areas occupy 19,951 (1.4% of the total NWS Province land). Others like Banana, Coffee, Mining and Quarry sites, and Tea occupy less than 1% each. This means that land will continue to be eroded if no serious measures are taken in agricultural lands. Mining areas in high-risk zones account for 0.2% of the total province land. Built-up area accelerates water velocity, runoff and flow accumulation which creates severe gullies downstream. In such areas storm-water management facilities, as well as the rainwater harvesting infrastructure, should be established to collect storm-water from houses in agglomerated zones which are also mapped.

4. Existing efforts in controlling erosion in Northern, Western and Southern Provinces

In the NWS provinces, it was observed that the erosion control techniques i.e. proportion of land at high risk which are today protected against erosion for each district is very low. Of 465,263 hectares of land at risk in the NWS province, only 17,233 hectares are protected by contour bank terraces (commonly known as progressive terraces (3.7 % of the NWS province at risk) while forest protect about 118,837 hectares at risk (25.5 % of the NWS province at risk). Other 18,498 hectares by other practices like progressive terraces, contour banks etc. About 310,695 hectares are not protected yet which is about 66.7% of the NWS province land at risk.

5. Recommended erosion control practices

The recommended erosion control practices are required in unprotected areas or where the existing erosion control techniques are judged inadequate with regard to the type of risks found and existing land use. The contour bank terraces are recommended in high-risk agricultural lands and contour banks in the forested area without ditches. Bench terraces are recommended in areas at high to extremely high risk where there has been started the bench terracing but which did not complete the entire area which is suitable for that recommendation. Grassed waterways are recommended for existing terraces which was made without waterways or with but no grasses which can cause severe gullies and destruction of bench terraces created. No-till agriculture is recommended for perennial crops on the extremely high-risk area while Storm-water management facilities (SWMF) or water harvesting infrastructure is recommended in built-up areas. No-recommendation is provided on areas with existing erosion control measures which are adequate in reference to the total land protected. Contour banks are recommended for existing forest without ditches. Bamboos are recommended to close gullies or for riverside buffers. Forests are recommended in extremely high-risk areas.

In the view of this concept, contour banks terraces are required on 198,101 hectares, which is about 14.1% of the total NWS provinces land, while afforestation and reforestation are required on 13,965 hectares (10% of

the total NWS Province land), Hedgerows are required on 29,178 hectares (2.1% of the total NWS Province land) and agroforestry are required on 30,257 hectares (2.2% of the NWS Province land). Bamboo planting is required on 4,846 hectares affected by gullies and riverside buffers. No-tillage agriculture is required on 15,469 hectares for perennial crops. Storm-water management facilitation or water harvesting infrastructure is required on 17,834 hectares (1.3 % of the total NWS province land).

Because soil erosion itself is a symptom of poor land management, erosion control measures alone will remain insufficient to improve the management of land and water resources given the current agricultural land uses and related management. There should be a switch of emphasis to focus on the promotion of a high quality integrated soil management system rather than stand-alone erosion control measures in agricultural land. High quality soil management could be achieved through an integrated conservation agriculture approach that provides profitable agricultural yields, while minimising environmental damage. Rainwater harvesting in settlements and storm-water infrastructure in urban areas also has the potential to address accelerated erosion and other problems resulting from rainfall run-off.

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1. Introduction

1.1. Problem statement

While soil erosion in Rwanda is a longstanding problem, it has become nowadays more severe. Erosion studies indicated extreme gravity of the soil erosion problem facing Rwanda, with 47 percent and 34 percent of the country experiencing soil erosion rates of between 50 and 100 tonnes per hectare per annum, respectively[1].

Soil erosion processes involve more complex interactions between land use, climate and soil properties than previously assumed in historic interventions. Studies of the dynamics of soil erosion using sequential aerial photographs and Remote sensing techniques in combination with analyses of land use, settlement patterns, and climatic variables have indicated that alternating stages of increased and decreased land degradation can occur. Deforestation and vegetation clearance for inappropriate land use have resulted in significant localised soil erosion in Rwanda. But the extent of this effect was not mapped yet. In severely deforested areas, heavy rains compounded with the area's steep topography have washed great amounts of productive topsoil and caused serious flooding in many places in Rwanda. The lack of contour banks to retain water in agricultural land coupled with permanent bare soil, facilitated splash and accelerated runoff which in turn depletes soil fertility and its lowers productivity. Unsustainable settlements without storm-water management facilities and waterways in built-up have contributed to heavy runoff and flooding downstream in many places including Kigali city. It is important to recognise that unsustainable human activities and insufficient knowledge in land use and management are a significant factor amplifying people's vulnerabilities to disasters. Climate change as an emerging threat can exacerbate already existing environmental degradation and thus contribute to increased disaster vulnerability.

Soil erosion results in a significant decline in soil fertility, which is the primary cause of low agricultural productivity in Rwanda. Heavily degraded soils are incapable of supporting large plant biomass because of low or depleted soil nutrients and soil organic matter. Moreover, soil erosion has important downstream impacts. High sediment loads reduce the size of river channels and water-holding capacities of lakes, choke water harvesting and storage systems, and exacerbate flooding. In addition, erosion is a major cause of progressive eutrophication in many of the country's lakes, promoting the proliferation of algal blooms and water hyacinth, which reduce the amount of dissolved oxygen in the water.

Erosion risk map of Rwanda was produced in June 2018 using the Catchment Restoration Opportunity Mapping (CROM) – a GIS-based Decision Support tool. CROM model was developed based on the Universal Soil Loss Equation (USLE model) originally introduced by Wischimeier and Smith in 1978. The USLE model counts five input parameters derivable from Rainfall (R), Soils (K), Topography/ Relief (LS), Land cover and crop management (C), and conservation practices (P), each having a multiplier effect as follow:

$A=R \times K \times LS \times C \times P$

Where A is the average annual loss (T/Ha); R is the rainfall-runoff erosivity factor; K is the soil erodibility factor; LS is the slop length (L) and steepness (S) factor; C is the cover and management factor; P is the land management and conservation practices factor.

[1] United Nations Environment Programme (2011). Rwanda: From Post-Conflict to Environmentally Sustainable Development, ISBN: 978-92-807-3040-1, UNEP Nairobi, Kenya. 379p.

Combining these factors in the GIS model builder, CROM model identified six erosion risk classes: (1) No erosion risk, (2) Low erosion risk, (3) Moderate erosion risk, (4) high erosion risk, (5) very high erosion risk and (6) the extremely high erosion risk.

However, the 2018 CROM output did not capture where erosion controls measures have been put in place so that currently the risk is no longer a challenge. This is because land use and related management was not available thus vegetation cover factor was not accurately used during CROM modelling process. Remotely sensed high-resolution data and high-quality World View images have increasingly become available for Rwanda through a memorandum of understanding between the National Institute of Statistics of Rwanda (NSIR) and Digital Globe (a US based film). Although visual image interpretation requires large manpower and is time demanding, (especially when dealing with small-scale land use systems) several studies have shown that it produces accurate data in mapping landscape interventions towards sustainable land management.

The present erosion control mapping of 2020, therefore, provides the state of soil erosion in Rwanda in terms of land under erosion risk, erosion features currently in high risk areas, land use and vegetation cover in risk areas, presence or absence of erosion control measures, type and appropriateness, and recommended intervention where erosion control practices are currently missing.

1.2. Objective of the erosion control mapping

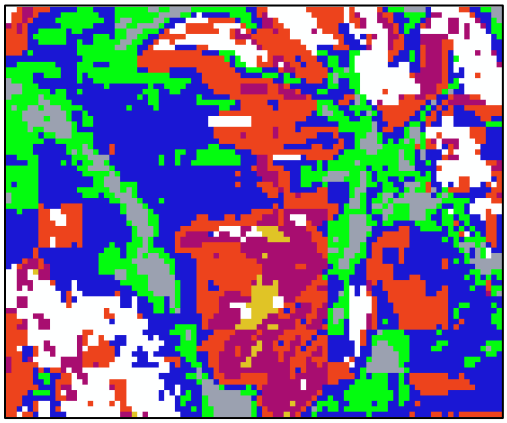
The ultimate objective of this erosion control mapping was to produce thematic maps on areas that have proved to be high erosion risk areas according to CROM model. For soil erosion control mapping of 20 districts of NWS Provinces, three erosion risk categories were prioritized: (1) high risk, (2) very high risk and (3) extremely high risk of erosion. Within these erosion risk categories, it is decided that the areas already covered by soil erosion control measures have to be demarcated using World View images (30cm X 30cm resolution), delineate the boundary of areas of high risk erosion without protection and proposed appropriate measures to mitigate the risk. To define the areas with no risk to soil erosion, observation on land use/cover type is important; and need to be considered: area covered by forests, pasture and prairies, perennial crops (tea, coffee and banana) and seasonal crops with erosion control measures (Terraces and agroforestry) as well as area occupied by settlements (built-up areas) have different level of risk.

2. Methodology

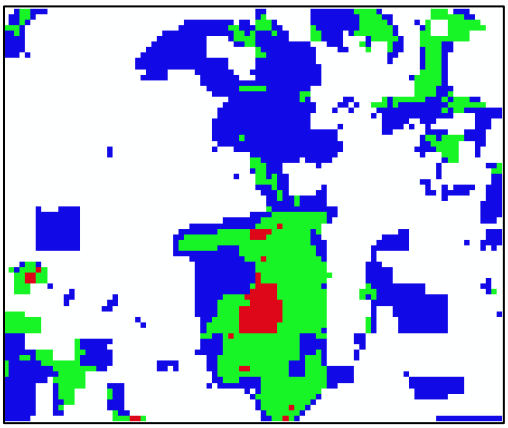
2.1 Identification of areas of high risk of erosion from CROM dataset

In this assignment of Erosion Mapping, we used data extracted from CROM (Catchment Restoration Opportunity Mapping). The CROM database has six classes: No risk, Low risk, Moderate risk, high risk zones, very high risk and the extremely high risk zones of erosion. The attention was paid to the three last categories: high risk zones, very high risk zones and extremely high risk zones in the twenty Districts of Northern Province, Southern Province and Western Province.

After extracting the concerned erosion classes from erosion risk raster from CROM, we realized that the output had to be smoothed .In fact the original dataset has been automatically generated using cartographic modelling techniques, and therefore there were a lot of zones characterized by a salt-and-pepper effect. Below is an example of original (a) and cleaned data (b).



(a) Original CROM output data



(b) Cleaned CROM output using boundary clean tool of ArcGIS spatial analyst

In order to produce such detailed map of erosion control practices easy to be implemented by different levels of planning (national, districts and sector levels), the erosion risk raster map (30 cm X 30cm) were cleaned up and filtered using 3x3 majority filter and boundary clean Geoprocessing tool available in ArcGIS/ArcMap (ESRI software). During the smoothing processes, the original risk categories as modelled by CROM were kept. The smoothing processes just allowed the merge of the neighboring cells (at least three neighbor pixels) in order to produce a map, after conversion to vector map that is easy to manipulate and produce statistics needed for implementation at different scales.

2.2 Creation of template geodatabase

This is a fundamental starting point step which consists of creating template geodatabase that will hold all polygons digitized and their respective attributes. In this empty geodatabase, fields' attributes along with

their respective domains were created. Using domains helps ensure data integrity by limiting the choice of values for a particular field, i.e. that attributes are captured without any typos errors of hand-writing. The attributes fields created to contain the information described in the section. Using the vector map of erosion risk, a geodatabase were created to contain the (1) three risk categories identified by CROM-DSS model, (2) the erosions features currently in place observable on the WV images, (3) existing land use/land cover, (4) observed erosion control practices and (4) proposed erosion control interventions for risk categories currently without erosion control measures or where the existing measures were judged inadequate and need for revision as briefly described in the table below. The geodatabase has two important roles: 1) to standardize the erosion and land management practices mainly recommended for Rwanda in the database, 2) to minimize errors which could be produced in the database by 10 GIS technicians while entering information manually.

Major thematic fields created in the erosion control geodatabase

Erosion risk class (identified by CROM)	**Erosion features in place (observed on the image)**	**Land Cover class (in high risk areas)**	**Erosion control practices currently in place**	**Recommended erosion control practices (choose one appropriate for each erosion category)**
1. High risk 2. Very high risk 3. Extremely high risk	1. Gullies 2. Landslide 3. Rill erosion 4. Severe gullies 5. None	1. Banana 2. Build-up area 3. Coffee 4. Degraded forest 5. Dense forest 6. Mining concession 7. Pasture or prairie grass 8. Seasonal crops 9. Tea 10. Water body 11. None/bare soil	1. Bamboo plantation 2. Bench terraces 3. Contour bank terraces 4. Forest 5. Grassed waterways 6. Hedgerows trees or shrubs 7. None	1. Afforestation 2. Agroforestry 3. Bamboo to close gullies 4. Bench terraces 5. Contour bank 6. Contour bank terraces 7. Grassed waterways 8. Hedgerows 9. No till 10. Perennial crops 11. Reforestation 12. Riverside bamboo 13. Storm water management facilities 14. Waterways infrastructure 15. None

The recommended erosion control practices are required in unprotected areas or where the existing erosion control techniques are judged inadequate with regard to the type of risks found and existing land use. The contour bank terraces are recommended in high risk agricultural lands and contour banks in the forested area without ditches. Bench terraces are recommended in areas at high to extremely high risk where there has been started the bench terracing but which did not complete the entire area which is suitable for that recommendation. Grassed waterways are recommended for existing terraces which was made without waterways or with but no grasses which can cause severe gullies and destruction of bench terraces created. No-till agriculture is recommended is recommended for perennial crops on extremely high risk area while Storm water management facilities (SWMF) or water harvesting infrastructure is recommended in built-up areas. No-recommendation is provided on areas with existing erosion control measures which are adequate

in reference to the total land protected. Contour banks are recommended for existing forest without ditches. Bamboos are recommended to close gullies or for riverside buffers. Forests are recommended in extremely high risk areas.

2.3 Training of the GIS technicians

The training of 10 GIS technicians was meant to help them acquire a common understanding of the following features on World View images:

- Categories of erosion risk
- Erosion feature types
- Land Use /Land Cover types
- Erosion control techniques
- Types of measures applied to mitigate erosion risks

2.4 Editing areas of high to extreme erosion risk

This method consists of correcting polygons geometries, completing polygons and adding attributes in the polygons attributes table. Very high resolution World View images (30-50 pixel size) of recent years (2018-2019) were used as basemap to check and using on-screen digitising techniques delineate different erosion risk features, land use and vegetation cover, erosion control techniques in place and recommendations of erosion control practices based on land uses.

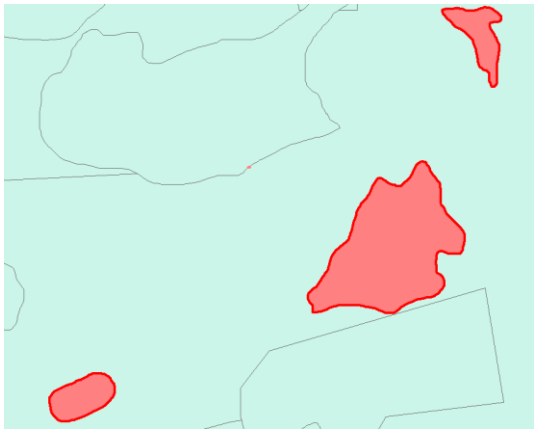
The 10 GIS technicians were organized in two team working in respectively day and night shift. Each computer had a connection to Digital Globe online images. Their tasks were to identify and interpreting the erosion feature types, the erosion control techniques in place, the land cover types and proposing adequate measures for mitigating the identified erosion risk. Technicians had to clean or edit polygons geometry if they find that the feature is not well demarcated. This consisted of either reshaping the polygon or completing it by adding a missing part of the identified erosion feature. Below is an illustration of the editing method showing the polygons shapes before (a) and after (b) the editing process.

(a)Before editing **(b) After editing**

2.5 Data cleaning process and validation

In this step, we applied topology rules to clean and validate the digitized forest cover polygons using the following:

Topology rules to identify polygons geometry errors: gaps, overlap and minimum cluster tolerance were the main topology rules applied to clean and validate the polygons. The **"Must not have Gaps"** rule is a way to find to find possible omissions within a polygon or between adjacent polygons. The **"Must not overlap"** rule is applied to detect areas where two or more polygons are overlapping each other. The polygons can share edges or vertices. This rule checks where there is an area that belongs to two or more polygons and marks this are as an error. Below is an example of overlapping polygons.



The **"Must not have gap"** rule requires that there are no voids within a single polygon or between adjacent polygons. All polygons must form a continuous surface. An error will always exist on the perimeter of the surface. Applying this rules helped us to locate and identify polygons which overlap each other or small areas of gaps which must be filled.

Cleaning topological errors and data validation: The implementation of topological rules consisted of checking and fixing the detected areas which are not complying with the rules specified above. During validation, the technician decides between merging the overlapping area with only one polygon, creating new polygon, completing the polygons or either ignoring the error (in case of an error marked at the perimeter of isolated polygon). Each time a topological error check is applied to validate the final output.

2.6 Geoprocessing process

After data cleaning, the resulting feature class is then geoprocessed using the following methods to produce disaggregated polygons:

- Disaggregation of the above geoprocessed data according to the administrative level of the country, down to the sector level for further cartographic layouts preparation.
- Export the features attributes into Excel for further statistical analysis and production of tables and graphs to be included in the report.

- Production of following thematic maps per Province and per District: erosion risk categories, erosion feature types, Land cover types, Erosion control techniques and recommended practices for mitigating erosion risks.

2.7 Limitations

- **Cloud cover hindered mapping existing erosion control techniques**, especially in mountainous areas of Western, Northern and Southern Provinces. In this case, technicians had to look for older uncloudy images. This causes a problem of temporal uncertainty. In fact some geographic features may not appear in old image, while they have been created in recent years. To overcome this problem of temporal accuracy, we had to look at the Google Earth to check if it had the best and more recent image. This process of going back and forth on Digital Globe images and Google Earth impacted negatively on the daily pace of erosion mapping.

- **Connection to Digital Globe services and unpredictable image updates**: Many times, the GIS team encountered a problem of connecting to Digital Globe online services which were disconnected for hours and even for some days. Moreover, on some locations, we have observed updated images while the area was already checked using old images. These areas had to be revisited and mapped to reflect the current situation. This also impacted negatively on the daily productivity of the mapping technicians.

3. Results

In the results section, we present in details the output of the applied methodology to map and geoprocess the erosion control thematic maps using very recent World View images of 2019. We discuss on the figures related to erosion risks, present erosion feature types, land use and vegetation cover for the land at erosion risk, erosion control practices already in place in risk areas, as well as recommended erosion control measures to mitigate erosion where identified erosion risk without erosion control measures currently in place.

3.1 Erosion Control status in Northern Province

Table 1 presents the situation of erosion risk in Northern Province of Rwanda. Land at high risk of soil erosion is about 104,005 hectares (33% of the total province land). The results show that Gakenke is the highest risk area with 34,702 hectares (i.e. 49% of the district land) followed by Rulindo District with 22,926 hectares (40% of the district land) and Burera with 23,030 hectares i.e. 39% of its land under high risk of erosion. Musanze and Gicumbi are the least susceptible to erosion with 17% of the land at risk in Gicumbi and 18% of land at risk in Musanze. The contribution of forests in protecting fragile land of Northern Province is evident, particularly small woodlots and alley tree planting in bass plain of Volcanoes catchment area in Musanze (36% of district land) and high forest plantations in Gicumbi District (28% of district land).

Table 1: Erosion risk per district in Northern Province

District	Erosion risk				District Land	Percentage
	Extremely high	High	Very high	Grand Total (Ha)		
GAKENKE	5,612	16,012	13,078	34,702	70,325	49%
RULINDO	2,294	12,104	8,528	22,926	56,699	40%
BURERA	3,210	11,414	8,406	23,030	58,856	39%
MUSANZE	1,161	4,468	3,423	9,052	50,717	18%
GICUMBI	600	9,978	3,717	14,295	82,721	17%
Grand Total	**12,877**	**53,976**	**37,152**	**104,005**	**319,318**	**33%**

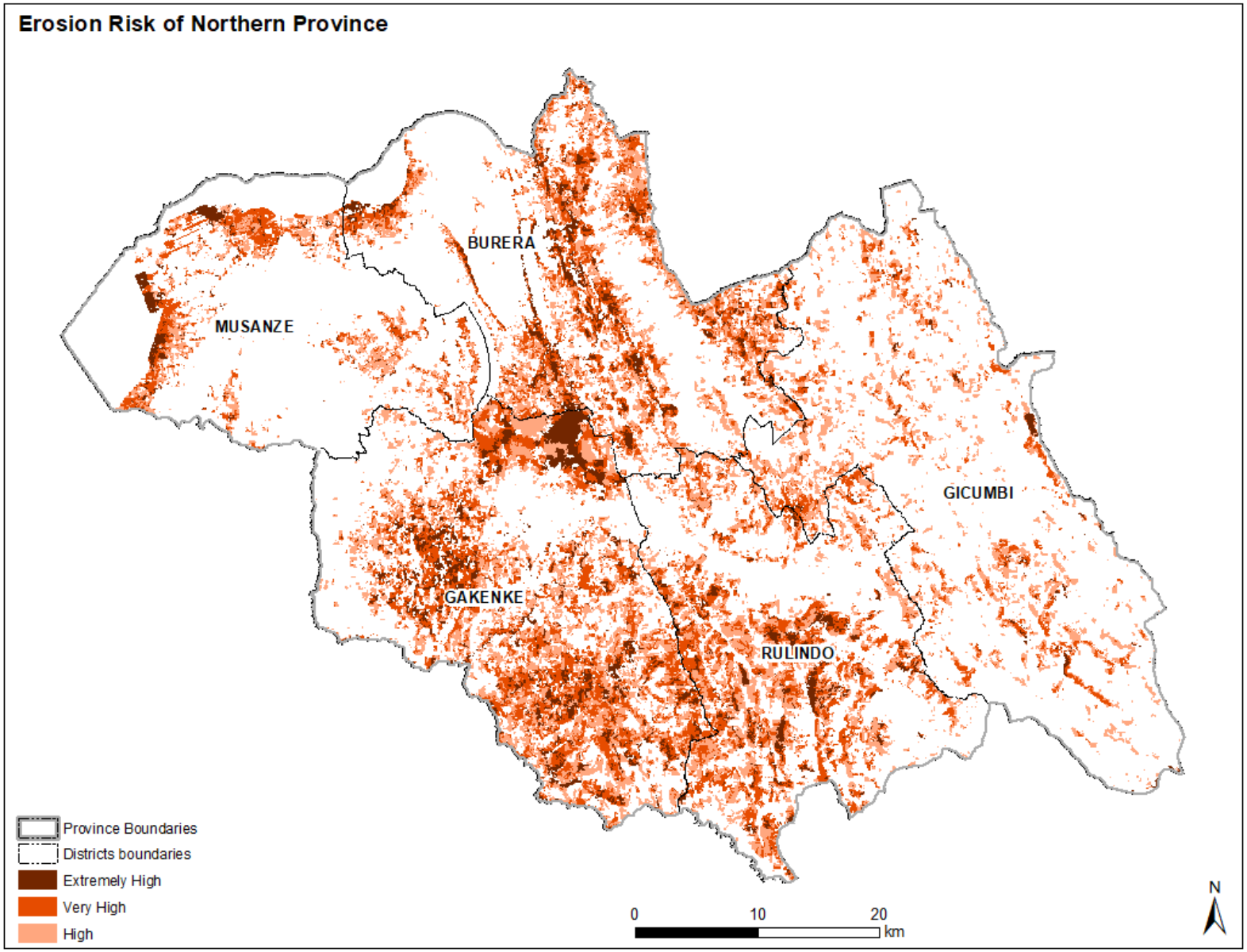


Figure 1: Erosion risk in Northern Province

3.1.1. Erosion Control status in Burera District

Erosion risk in Burera is summarised in Table 2 and presented in figure 2. Erosion risk in Burera District is estimated to 39% (Table 2), about 23,029 hectares are under high to extremely high erosion risk of which 1,182 hectares are located in Rugendabari sector (65% of sector land), 1,562 hectares are located in Rusarabuge sector (59% of sector land), 3,326 hectares are located in Butaro (57% of the sector), 2,073 hectares are found in Cyeru sector and 1,373 hectares are located in Bungwe sector, about 53% of the sector land. The least erosion risk sectors are Cyanika with 4,147 hectares (10% of the sector land), Kagogo with 2,229 hectares (11%), Rugarama with 2,642 hectares (12%) and Kinoni with 2,522 hectares, only 13% of the total sector land.

Table 2: Erosion risk per sector in Burera District

Sector Name	Erosion risk				Sector land (ha)	Percentage (%)
	Extremely high	High	Very high	Grand Total (Ha)		
RUGENGABARI	92	640	450	1,182	1,817	65%
RUSARABUGE	363	622	577	1,562	2,633	59%
BUTARO	346	1,727	1,253	3,326	5,876	57%
CYERU	519	708	845	2,073	3,779	55%
BUNGWE	119	827	427	1,373	2,575	53%
KIVUYE	140	944	736	1,819	3,737	49%
KINYABABA	264	1,091	723	2,078	4,504	46%
RWERERE	377	909	879	2,165	4,847	45%
NEMBA	193	844	558	1,595	3,769	42%
GITOVU	206	484	417	1,107	2,672	41%
GATEBE	157	796	448	1,401	3,870	36%
GAHUNGA	199	380	381	959	2,893	33%
RUHUNDE	85	770	268	1,122	4,344	26%
KINONI	66	132	131	329	2,522	13%
RUGARAMA	49	140	117	306	2,642	12%
KAGOGO	10	163	65	238	2,229	11%
CYANIKA	27	236	132	394	4,147	10%
Grand Total	**3,210**	**11,414**	**8,406**	**23,029**	**58,856**	**39%**

Land areas affected by soil erosion features as detected on World View images of 2019 are summarized in Table 3 and the map of erosion features are presented in Figure 3. The results show that Butaro sector is the worst affected by gullies and severe gullies on areas estimated to 1,173 hectares, followed by Kivuye sector on 484 hectares, kinyababa sector on 426 hectares, and Rugendabari on 203 hectares. Although Cyanika seems to be least sector at erosion risk however, it shows that 37% of its land at risk has already severe gullies which confirm the presence of erosion in the sector. Moreover, it appears that Rusarabuge, Rwerere, Cyeru, Bungwe sectors which were revealed by CROM model that more than half of the sector lands are at risk, there was less area affected already by erosion features. This should not read that CROM model could not perform well in these sectors, but rather due to the time of image acquisition, the erosion features could be observed or erosion control measures have been already taken and therefore runoffs have been prevented, thus erosion features could not be formed in this case. Further analysis will demonstrate that in Table 5 and 6.

Table 3: Erosion features types and areas affected in Burera District

Sector Name	Erosion feature types (Ha)				Total feature (Ha)	None (Ha)	Grand total (Ha)	% features
	Gullies	Landslide	Rill erosion	Severe gullies				
CYANIKA				147	147	247	394	37%
BUTARO	140	7	51	975	1,173	2,152	3,326	35%
KIVUYE	67	3	5	409	484	1,336	1,819	27%
RUGARAMA	22			59	81	225	306	26%
KINYABABA	127	6	32	261	426	1,652	2,078	20%
RUGENGABARI	201	1		1	203	979	1,182	17%
RUHUNDE	118	7		18	143	979	1,122	13%
NEMBA	90	8		95	193	1,402	1,595	12%
GAHUNGA	1		2	105	108	852	959	11%
GATEBE	44	1	37	62	144	1,256	1,401	10%
KINONI	26	1			27	302	329	8%
CYERU	17			150	166	1,906	2,073	8%
BUNGWE	14	0		84	98	1,275	1,373	7%
RWERERE	81	13		42	137	2,028	2,165	6%
RUSARABUGE	13	1		1	15	1,547	1,562	1%
KAGOGO					-	238	238	0%
GITOVU		0		2	3	1,104	1,107	0%
TOTAL	**963**	**48**	**127**	**2,411**	**3,548**	**19,481**	**23,029**	**15%**

In term of land use and management for areas at risk in Burera, the results of land cover mapping (Table 4 and Figure 4) show 16,134 hectares (70% of the total land at risk) are used for crop cultivation, 4,134 hectares (18% of the total land at risk) are covered by healthy forests and 2,042 hectares i.e. 9% are used for built-up and settlement.

Table 4: Land Use and Vegetation Cover (LUVC) of areas at risk in Burera District

Sector name	Banana	Build-up area	Degraded forest	Dense forest	Mining concession	Bare soil	Seasonal crops	Water body	Grand Total
BUNGWE	1	113	3	230	0		1,013	13	1,373
BUTARO		407	3	477	4	7	2,417	11	3,326
CYANIKA		39	5	103			247		394
CYERU	97	155	5	396	10	3	1,405	3	2,073
GAHUNGA		101	0	107			750	2	959
GATEBE		130	3	208			1060	0	1,401
GITOVU	99	34	13	259	0	3	698	1	1,107
KAGOGO	4	16	4	99	1	1	109	3	238
KINONI	7	21	0	99	1		197	3	329
KINYABABA	94	123	9	466		2	1,375	9	2,078
KIVUYE		211	7	303	5	5	1,280	8	1,819
NEMBA	18	144	2	290	2		1,093	46	1,595
RUGARAMA		28	1	94			183		306
RUGENGABARI	6	55	2	179	0		936	4	1,182
RUHUNDE		134	0	194	1		789	4	1,122
RUSARABUGE	4	100	3	265	153		1,023	14	1,562
RWERERE	0	230	3	365	2		1,560	4	2,165
Grand Total	**330**	**2,042**	**64**	**4,134**	**179**	**21**	**16,134**	**125**	**23,029**

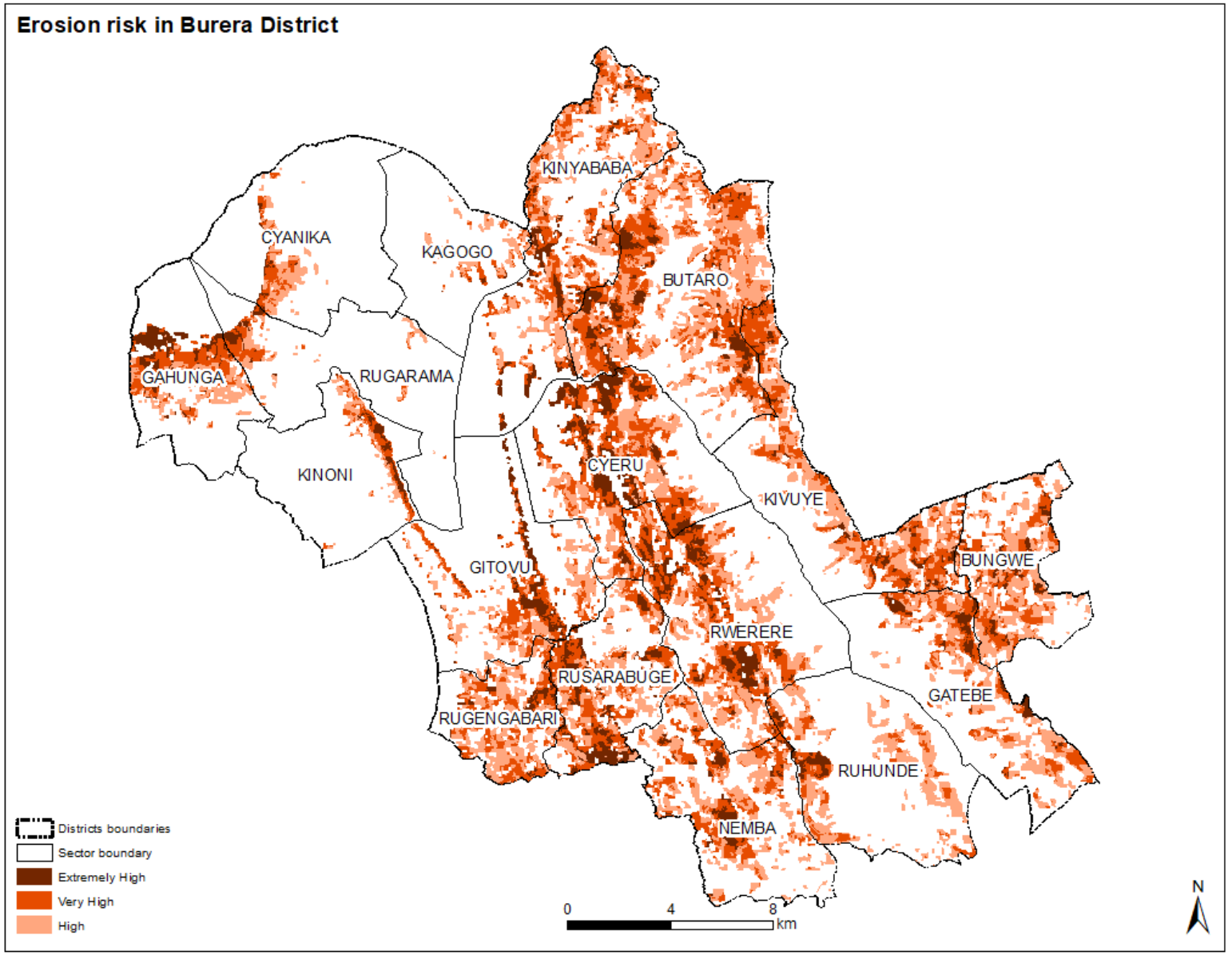


Figure 2: Erosion risk in Burera District

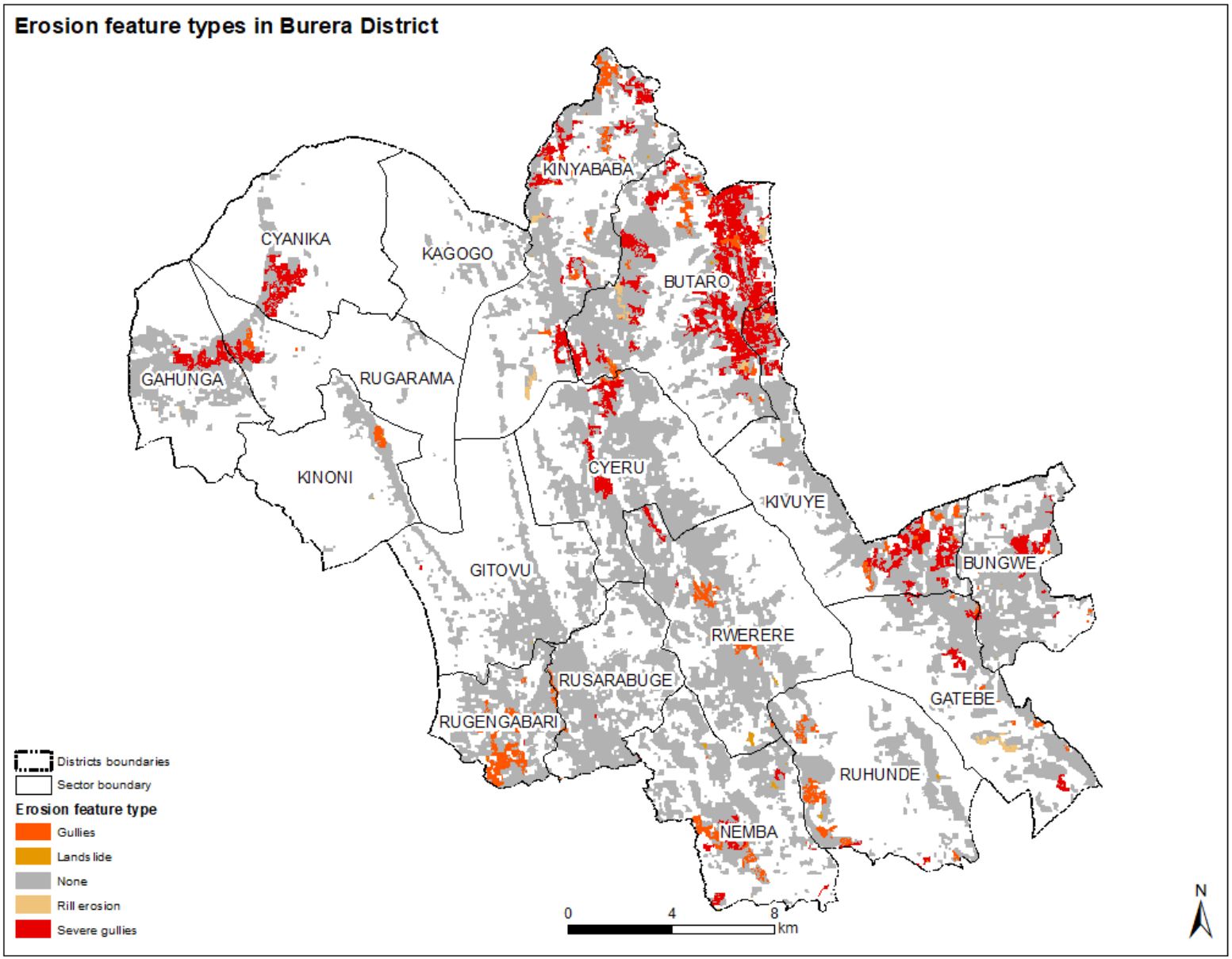


Figure 3: Erosion features detected in Burera District

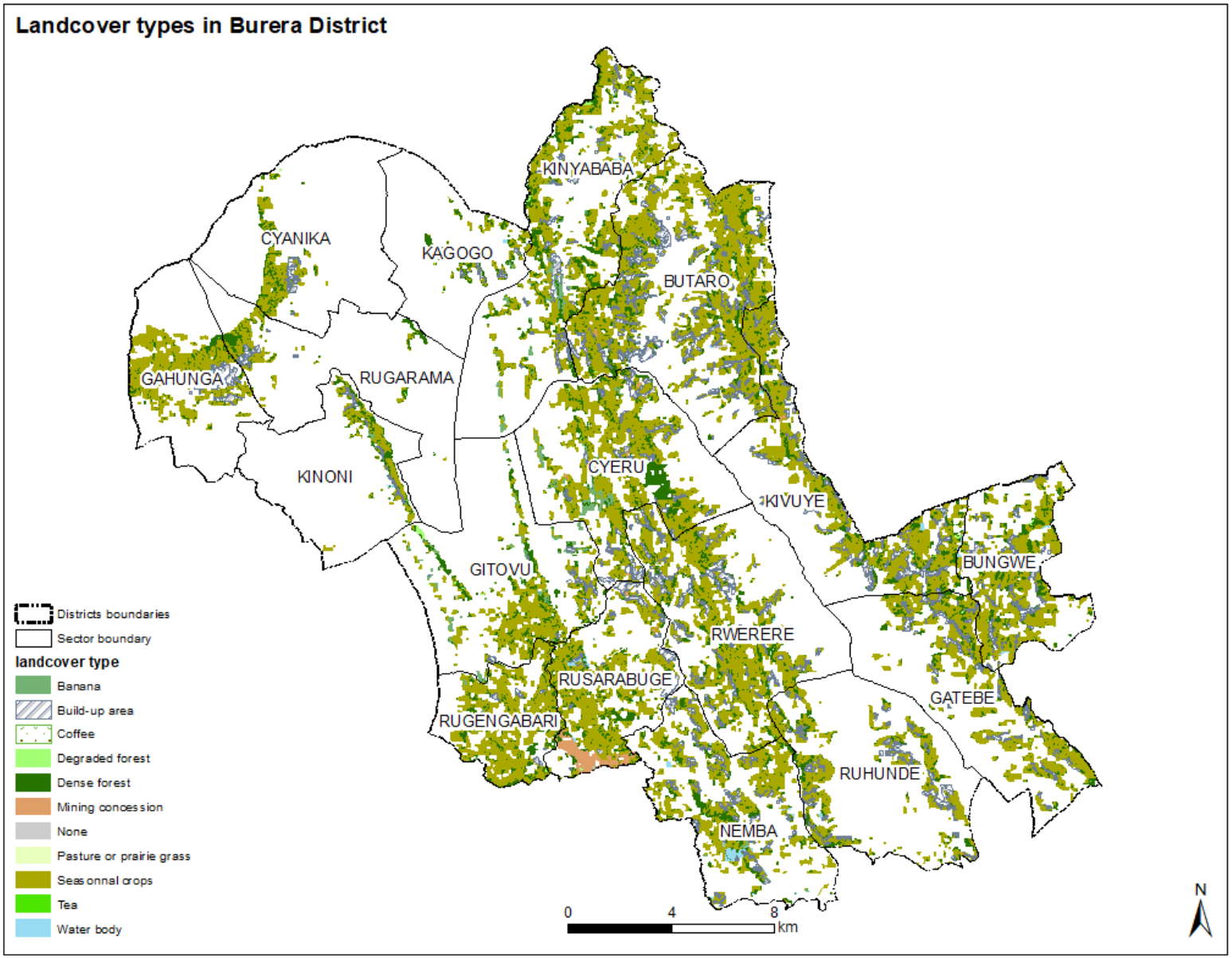


Figure 4: Land cover types in Burera District

About existing erosion control practices in Burera district, only 25% of land at risk is protected by forests (4,502 hectares), contour bank terraces or progressive terraces with ditches (699 hectares), and bench terraces (521 hectares). Although still low, the highest protected sectors are Kagogo with 43% of its land at risk protected, followed by Kivuye where 32% of the total land at risk is protected (651 hectares) and Kinoni with 32% of land protected. The least protected sectors are Gahunga with only 12% protected, Rusarabuge (only 18% protected), Ruhunde (19%) and Rugengabari (19% protected). The visual interpretation of World View images confirms earlier findings by CROM model that Rwerere, Cyeru, Bungwe and Rusarabuge sectors remain at very high risk of soil erosion since more than 80% of their respective land are not protected.

Table 5: Erosion control practices already in place in Burera District

Sector name	Erosion control techniques in place			Total protected (Ha)	Unprotected (Ha)	Grand Total (Ha)	% protected
	Contour bank terraces	Bench terraces	Forest				
KAGOGO	1		101	101	137	238	43%
KIVUYE	158	85	409	651	1,168	1,819	36%
KINONI	5		99	104	225	329	32%
RUGARAMA	0		93	93	213	306	31%
BUNGWE	122	40	251	412	960	1,373	30%
NEMBA	28	132	322	482	1,113	1,595	30%
CYANIKA	1		103	105	290	394	27%
CYERU	22	127	392	541	1,531	2,073	26%
RWERERE	87	71	407	564	1,600	2,165	26%
GATEBE	48	37	275	360	1,040	1,401	26%
GITOVU	10	12	268	289	817	1,107	26%
KINYABABA	26		474	500	1,578	2,078	24%
BUTARO	133	14	531	678	2,647	3,326	20%
RUGENGABARI	31		191	222	961	1,182	19%
RUHUNDE	8	0	210	217	905	1,122	19%
RUSARABUGE	18	3	266	287	1,275	1,562	18%
GAHUNGA	2		111	113	846	959	12%
Grand Total	**699**	**521**	**4,502**	**5,721**	**17,308**	**23,029**	**25%**

Erosion control practices in Burera district are recommended based on existing land uses, erosion control measures already in place, and predicted erosion risk by CROM model. Table 6 shows that contour bank terraces commonly known in Rwanda as progressive terraces are required for land about 10,531 hectares (49% of the total land at risk) used for seasonal crops. Bamboo plantation is required to rehabilitate 2,624 hectares affected by gullies (about 11% of the total land at risk), while storm water management facilities (SWMF) are recommended for built-up areas of about 2,009 hectares (9% of the total risk areas). Agroforestry is need in 1,655 hectares of agricultural land. Afforestation and reforestation (259 hectares) and bench terraces (170 hectares) are required on extremely high risk areas.

Table 6: Recommended erosion control practices in Burera District

Sector Name	Afforestation & Reforestation	Agroforestry	Bamboo to close gullies	Bench terraces	Contour bank terraces	Hedgerow trees/ shrubs	SWMF	None	Total
BUNGWE	7	38	76	6	717	141	110	256	1,373
BUTARO	7	99	891	16	1,341	79	404	474	3,326
CYANIKA	5	7	125		19	96	39	103	394
CYERU	10	327	91	1	845	64	137	416	2,073
GAHUNGA	-	135	105		490	16	101	112	959
GATEBE	14	46	95	-	821	44	126	237	1,401
GITOVU	13	127	1	2	541	12	34	266	1,107
KAGOGO	7	9	-		103	1	16	99	238
KINONI	3	38	-		155	5	27	99	329
KINYABABA	9	106	326	-	938	10	122	472	2,078
KIVUYE	10	59	433	14	598	147	192	309	1,819
NEMBA	4	33	143	92	711	37	145	304	1,595
RUGARAMA	1	18	68		36	62	28	94	306
RUGENGABARI	2	58	5		846	31	55	179	1,182
RUHUNDE	3	54	136		597	6	134	192	1,122
RUSARABUGE	151	228	15	1	777	20	100	266	1,562
RWERERE	14	275	114	36	997	51	238	361	2,165
Grand Total	**259**	**1,655**	**2,624**	**170**	**10,531**	**820**	**2,009**	**4,238**	**23,029**
%	**1%**	**7%**	**11%**	**1%**	**46%**	**4%**	**9%**	**18%**	**100%**

Other interventions: **Grassed waterways** are recommended for 385Ha of existing terraces (see Table 5) which was made without waterways or with them but not grassed which can cause development of severe gullies and destruction of bench terraces created. No-till agriculture is recommended for 333Ha of perennial crops while Storm water management facilities **(SWMF)** are recommended in built-up areas (see table 4). None: means no-recommendation is provided because existing erosion control measures are adequate with reference made to the total land protected (see table 5). Contour banks are recommended for existing forests without ditches.

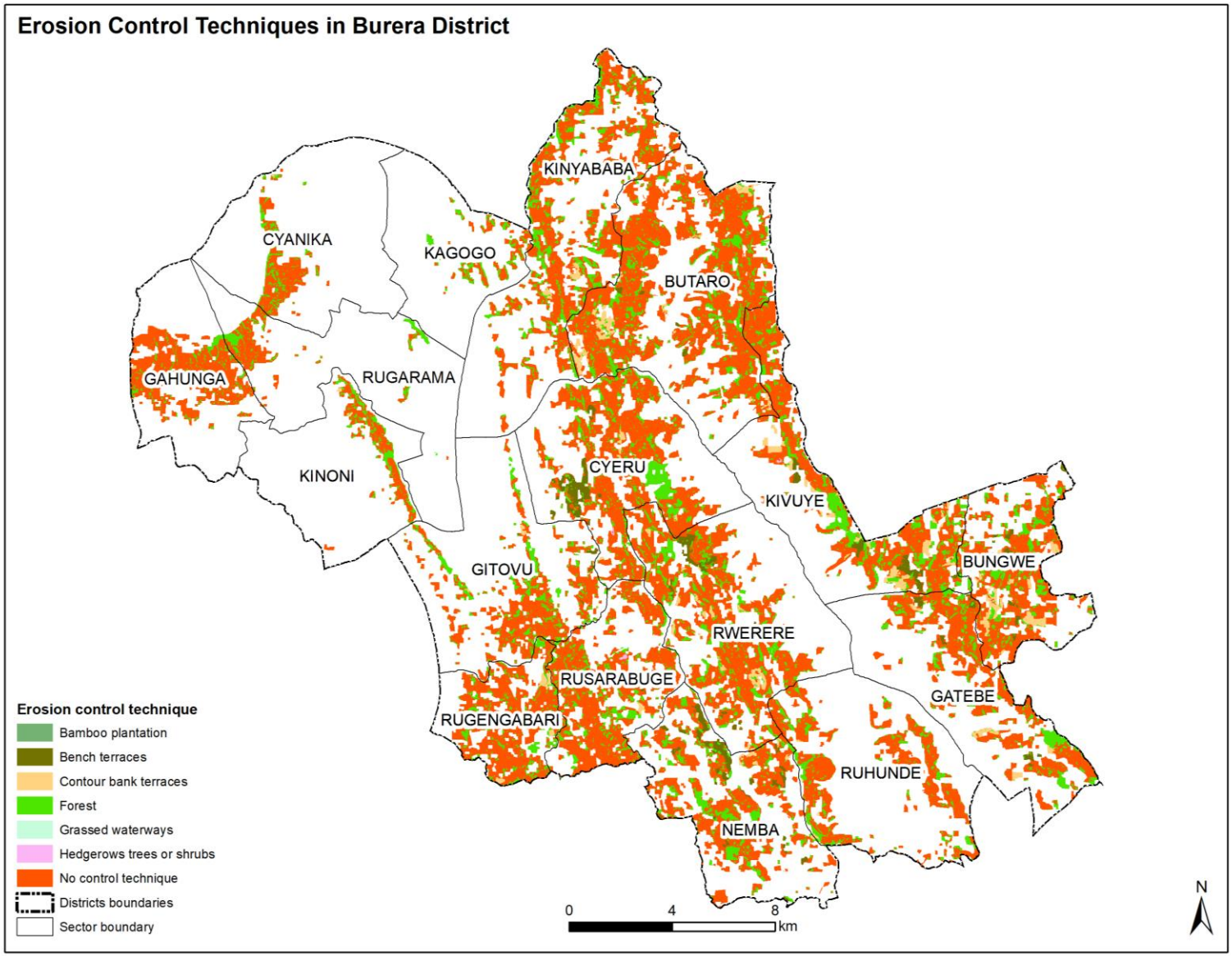


Figure 5: Erosion control techniques in place in Burera District

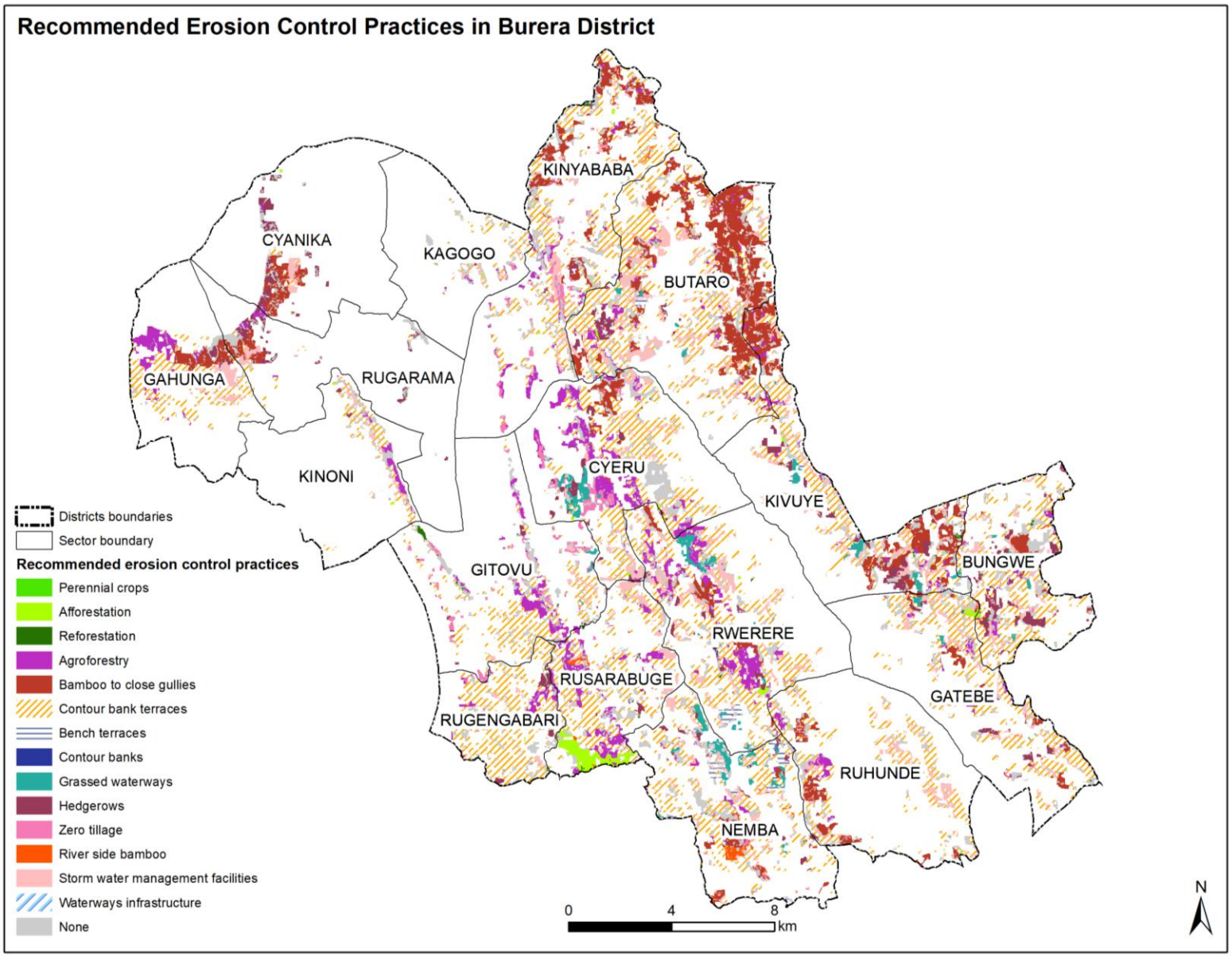


Figure 6: Recommended erosion control practices in Burera District

3.1.2. Erosion control status in Gakenke District

Erosion risk in Gakenke is summarised in Table 7 and presented in figure 7. Erosion risk in Gakenke District is estimated to 49% of the total district land; about 34,703 hectares are highly susceptible to erosion. In fact of 19 sectors of Gakenke, nine sectors have more than 50% of their land prone to erosion of which 2,987 hectares are located in Kamubuga sector (88% of sector land), 4,269 hectares are located in Coko sector (77% of sector land), 3,188 hectares are located in Ruli (68% of the sector land), 1,776 hectares are found in Janja sector (58% of the sector land), and 3,135 hectares are located in Muhondo sector, about 57% of the sector land. The least sectors are Rusasa with only 97 hectares (3% of the sector land) susceptible to erosion, Mugunga with 369 hectares (13%), Cyabingo with 357 hectares, about 15% of the total sector land.

Table 7: Erosion risk per sector in Gakenke District

Sector Name	Erosion risk				Sector Land (ha)	Percentage %
	Extremely high (Ha)	High (Ha)	Very high (Ha)	Grand Total (Ha)		
KAMUBUGA	1,175	1,097	715	2,987	3,392	88%
COKO	671	1,665	1,934	4,269	5,555	77%
RULI	420	1,553	1,214	3,188	4,666	68%
JANJA	408	531	837	1,776	3,053	58%
MUHONDO	398	1,595	1,142	3,135	5,494	57%
MINAZI	271	1,451	933	2,655	4,724	56%
RUSHASHI	284	1,193	751	2,228	4,014	55%
MUYONGWE	179	962	732	1,873	3,410	55%
KIVURUGA	121	708	745	1,574	3,121	50%
MATABA	202	840	570	1,613	3,316	49%
BUSENGO	313	802	690	1,805	3,821	47%
MUZO	499	640	999	2,138	4,662	46%
GASHENYI	197	955	661	1,812	4,177	43%
GAKENKE	216	904	540	1,660	4,116	40%
KARAMBO	160	171	302	632	2,187	29%
NEMBA	66	270	197	534	2,264	24%
CYABINGO	3	312	42	357	2,415	15%
MUGUNGA	29	284	56	369	2,913	13%
RUSASA	1	77	19	97	3,026	3%
Grand Total	**5,612**	**16,012**	**13,078**	**34,703**	**70,325**	**49%**

Land areas at risk which are already affected by soil erosion features in Gakenke District are summarized in Table 8 and the map of erosion features are presented in Figure 8. The results show that Kamubuga sector is the worst affected by gullies and severe gullies on areas estimated to 1,596 hectares, followed by Coko sector on 1,234 hectares, Minazi sector on 1,107 hectares, and Ruli sector on 952 hectares. The presence of gullies, landslides and severe gullies in Ruli, Coko and Minazi confirms the findings of CROM

model, however Janja, Busengo and Gakenke sectors which were revealed by CROM model that above 40% of the sector lands are at risk, there are among the least affected already by erosion features i.e. 8% for Janja, 12% for Busengo and 18% for Gakenke sector. This should not read that CROM model could not perform well in these sectors, but rather due to the time of image acquisition, the erosion features could be observed or erosion control measures have been already taken and therefore runoffs have been prevented, thus erosion features could not be formed in this case. Further analysis will demonstrate that in Table 9 and 10. The least sectors affected by gullies and landslides in Gakenke District are Mugunga with only 4 hectares, Rusasa with 6 hectares and Janja with 137 hectares.

Table 8: Erosion features types and areas affected in Gakenke District

Sector Name	Erosion feature types (Ha)						Grand Total (Ha)	% features
	Gullies	Landslide	Rill erosion	Severe gullies	Total features	None		
KAMUBUGA	715	50	4	826	1,596	1,391	2,987	53%
KARAMBO	311			3	314	318	632	50%
NEMBA	166		64		231	303	534	43%
MINAZI	789	6	61	251	1,107	1,548	2,655	42%
MUYONGWE	645			20	665	1,208	1,873	35%
MATABA	489	1		71	561	1,052	1,613	35%
RUSHASHI	623	2		147	771	1,456	2,228	35%
KIVURUGA	373	131		30	535	1,039	1,574	34%
GASHENYI	554			56	610	1,203	1,812	34%
RULI	819	1	9	124	952	2,235	3,188	30%
COKO	1,054	19		161	1,234	3,036	4,269	29%
MUHONDO	606	4		263	873	2,262	3,135	28%
MUZO	438	6		4	448	1,690	2,138	21%
CYABINGO	54	13			67	291	357	19%
GAKENKE	293	0		1	294	1,367	1,660	18%
BUSENGO	219				219	1,586	1,805	12%
JANJA	133	3		1	137	1,639	1,776	8%
RUSASA	6				6	91	97	6%
MUGUNGA	4			0	4	365	369	1%
Grand Total	**8,290**	**237**	**138**	**1,957**	**10,623**	**24,080**	**34,703**	**31%**

In term of land use and management for areas at risk in Gakenke, the results of land cover mapping (Table 9 and Figure 9) show 23,489 hectares (about 68% of the total land at risk) are used for crop cultivation, 8,354 hectares (24% of the total land at risk) are covered by healthy forests and 307 hectares i.e. 3% are used for built-up and settlement and 1,036 hectares (3% of total land at risk) are covered by banana.

Table 9: Land Use and Vegetation Cover (LUVC) of areas at risk in Gakenke District

Sector name	Banana	Build-up area	Coffee	Degraded forest	Dense forest	Mining concession	Seasonal crops	Water body	Grand Total
BUSENGO	19	3		5	272	0	1,503	4	1,805
COKO	33	28	110	94	1,328	3	2,632	40	4,269
CYABINGO	2	3		7	39		305	2	357
GAKENKE	97		45	69	390		1,053	6	1,660
GASHENYI	81	17	7	1	408	19	1,271	9	1,812
JANJA	84	1		3	336		1,353	1	1,776
KAMUBUGA	0	54		16	460	13	2,443	0	2,987
KARAMBO	20			1	102		510	0	632
KIVURUGA	15	8		14	183		1,353		1,574
MATABA	159	16	7	60	379		938	55	1,613
MINAZI	46	3	26	87	850	0	1,592	51	2,655
MUGUNGA	128	48		0	54	2	129	9	369
MUHONDO	98	23	79	63	884	57	1,886	46	3,135
MUYONGWE	42	4	10	21	429		1,365	2	1,873
MUZO	61	17	83	6	396		1,567	9	2,138
NEMBA	20	2		11	95		407		534
RULI	79	25	107	78	1,031	20	1,802	46	3,188
RUSASA	17	2		1	24		53		97
RUSHASHI	36	53	90	22	695		1,330	3	2,228
Grand Total	**1,036**	**307**	**564**	**555**	**8,354**	**115**	**23,489**	**283**	**34,703**

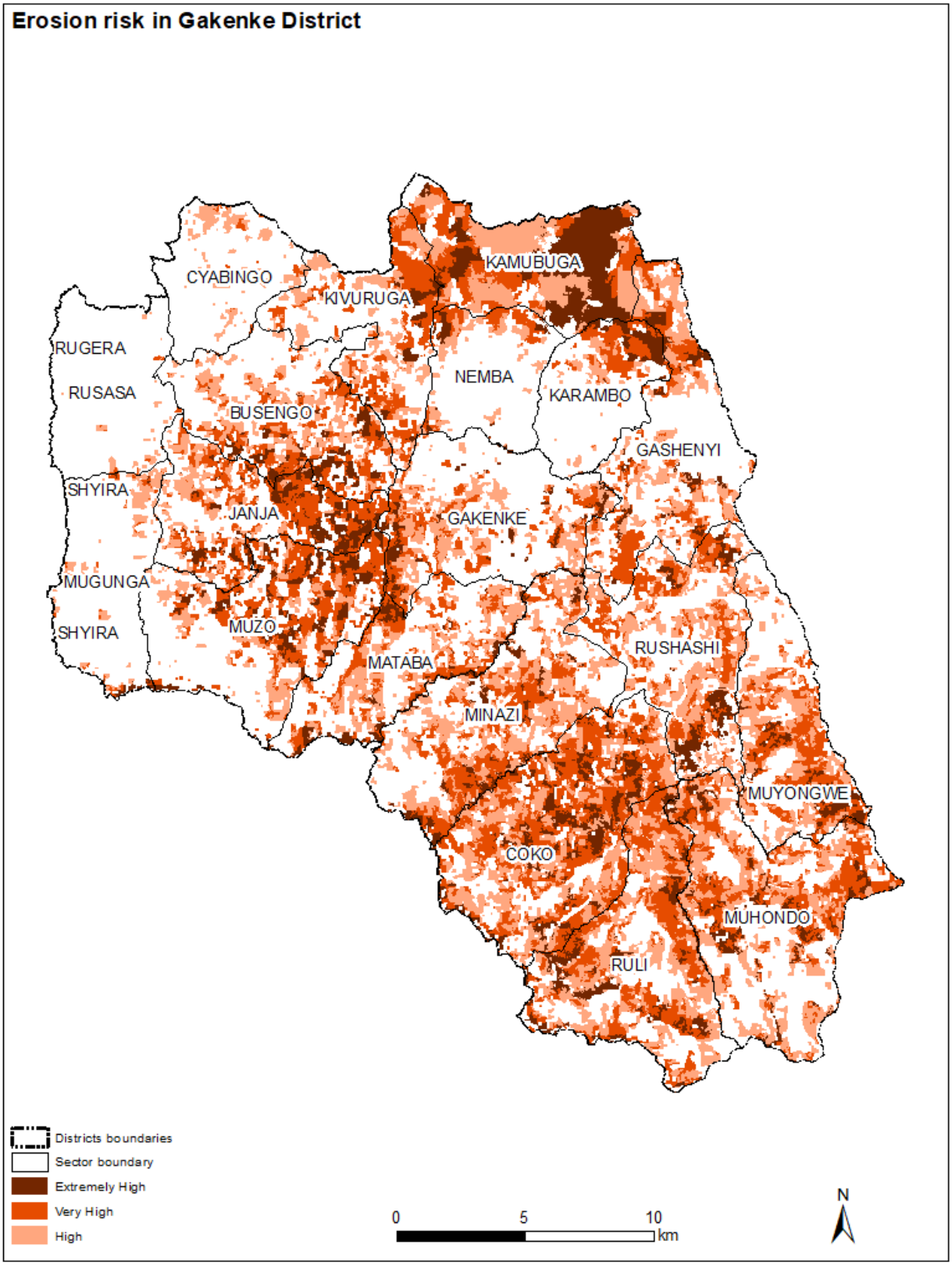


Figure 7: Erosion risk in Gakenke District

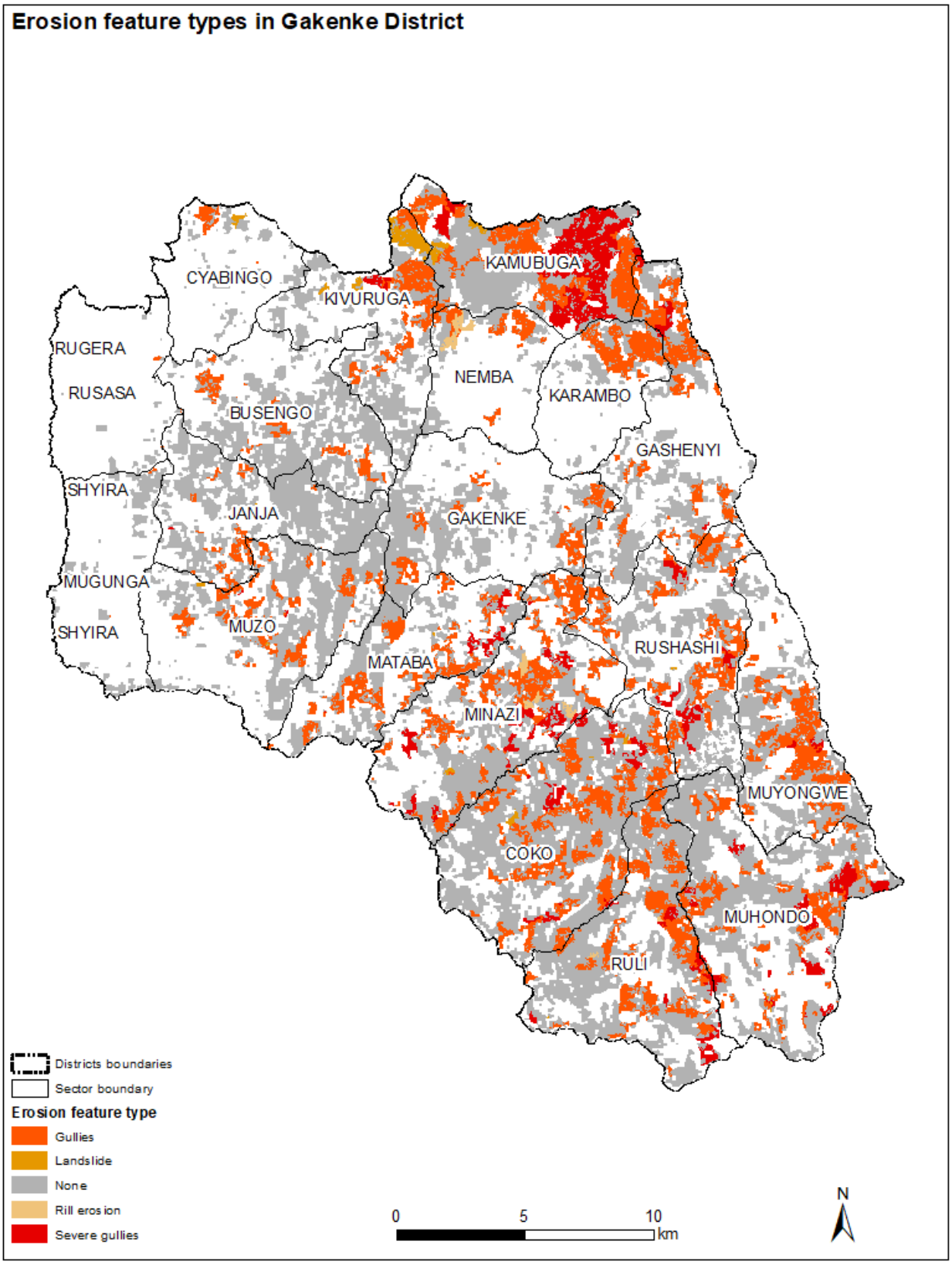


Figure 8: Erosion features detected in Gakenke District

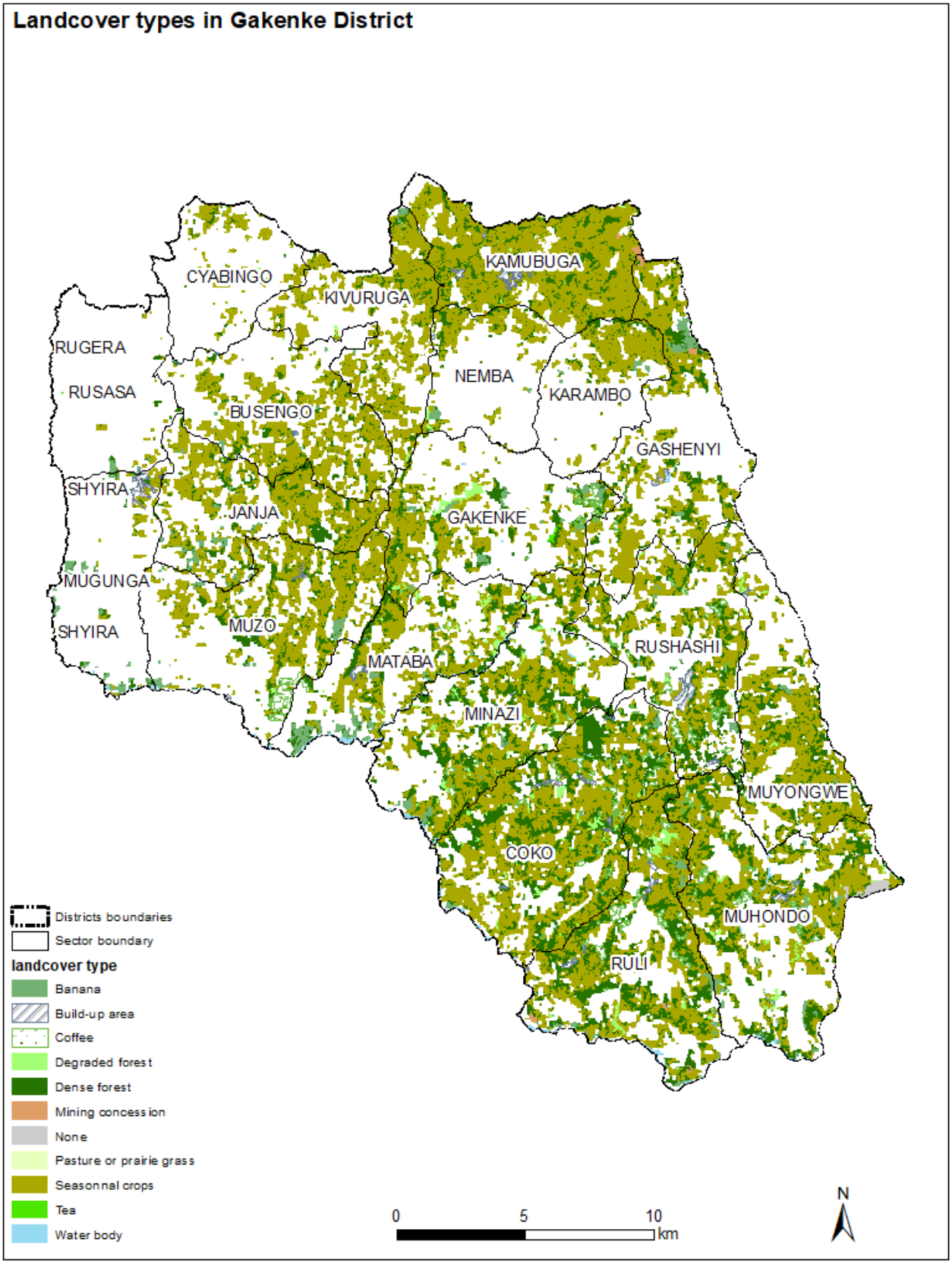


Figure 9: Land cover types in Gakenke District

About existing erosion control practices in Gakenke district, Table 10 indicates that only 33% of land at risk is protected by forests (8,785 hectares), contour bank terraces or progressive terraces with ditches (1,853 hectares), and bench terraces (641 hectares). Although still low, the highest protected sectors are Kivuruga with 45% of its land at risk protected, followed by Kamubuga where 42% of the total land at risk is protected (651 hectares) and Nemba with 39% of land protected. The least protected sectors are Cyabingo with only 14% protected, Busengo (only 23% protected), Muyongwe (24%) and Mataba (24% protected). The visual interpretation of World View images confirms earlier findings by CROM model that Cyabingo sector remains at very high risk of soil erosion since more than 80% of their respective land are not protected. It is the same case for Busengo, Muyongwe and Mataba sectors which also remain at very high risk of soil erosion since more than 70% of their respective land are not protected.

Table 10: Erosion control practices already in place in Gakenke District

Sector name	Erosion control techniques in place						Unprotected	Grand Total	% protected
	Bamboo plantation	Bench terraces	Contour bank terraces	Forests	Hedgerows trees or shrubs	Total protected			
KIVURUGA		46	457	202	0	704	870	1,574	45%
KAMUBUGA		56	618	593		1,267	1,720	2,987	42%
NEMBA		9	21	181		211	323	534	39%
MUGUNGA		5	87	50		141	228	369	38%
JANJA		227	89	339		655	1,121	1,776	37%
RUSHASHI		56	36	698		790	1,438	2,228	35%
MUHONDO	9	17	144	887	0	1,057	2,078	3,135	34%
COKO			25	1,359		1,384	2,885	4,269	32%
RULI	3			1,030		1,033	2,155	3,188	32%
MUZO		163	105	418	3	689	1,449	2,138	32%
MINAZI			3	850	2	855	1,800	2,655	32%
GASHENYI			97	464		560	1,252	1,812	31%
RUSASA			4	24		27	69	97	28%
KARAMBO			36	137		174	459	632	27%
GAKENKE		2	17	433		452	1,208	1,660	27%
MATABA		7	14	372		393	1,220	1,613	24%
MUYONGWE			13	429		442	1,431	1,873	24%

BUSENGO		53	81	280	10	424	1,381	1,805	23%
CYABINGO		0	9	41		49	308	357	14%
Grand Total	**12**	**641**	**1,853**	**8,785**	**16**	**11,308**	**23,395**	**34,703**	**33%**

Erosion control practices in Gakenke district are recommended based on existing land uses, erosion control measures already in place, and predicted erosion risk by CROM model. Table 11 shows that contour bank terraces commonly known in Rwanda as progressive terraces are required for land about 20,772 hectares (60% of the total land at risk) used for seasonal crops. Contour banks are required on 1,519 hectares of forest plantation currently without ditches. Hedgerows trees or shrubs are required to protect agricultural land. Grassed waterways are missing on 873 hectares of bench terraces while agroforestry or alley cropping is required on 206 hectares on steep slopes. Bamboo plantation is required to rehabilitate 455 hectares affected by gullies (about 11% of the total land at risk) and river buffers, while storm water management facilities (SWMF) are recommended for built-up areas of about 292 hectares (9% of the total risk areas). Agroforestry is needed on 206 hectares of agricultural land. Afforestation and reforestation are required on extremely high risk areas of about 648 hectares.

Table 11: Recommended erosion control practices in Gakenke District

Sector Name	Afforestation & Reforestation	Agroforestry (Ha)	Bamboos (Ha)	Contour bank/ditches (Ha)	Contour bank terraces (Ha)	Grassed waterways (Ha)	Hedgerows trees / shrubs (Ha)	SWMF (Ha)	None (Ha)	Total (Ha)
BUSENGO	7		2	14	1,356	53	81		292	1,805
COKO	98	2	40	144	2,603		25	28	1,284	4,269
CYABINGO	7		1		303	0	9	3	34	357
GAKENKE	70		11	111	1,006	2	17		428	1,660
GASHENYI	23		8	57	1,204	81	10	17	413	1,812
JANJA	3		1	86	1,068	227	56	1	336	1,776
KAMUBUGA	38	43	21		1,720	160	491	54	447	2,987
KARAMBO	1	105	133	18	259	15			101	632
KIVURUGA	16	29	7	2	824	130	344	8	168	1,574
MATABA	58		55	166	924	9	14	16	371	1,613
MINAZI	114		51	72	1,559		3	3	805	2,655
MUGUNGA	2		8	124	60	5	73	48	50	369
MUHONDO	62		65	196	1,779	10	79	23	853	3,135
MUYONGWE	21		2	51	1,352		13	4	397	1,873
MUZO	6	7	9	144	1,277	119	99	10	424	2,138
NEMBA	11		-	3	385	1	20	9	104	534
RULI	90	7	38	191	1,802	5		25	770	3,188
RUSASA	1		-	17	50		4	2	24	97
RUSHASHI	22	13	3	123	1,240	56	34	40	697	2,228
Grand Total	**648**	**206**	**455**	**1,519**	**20,772**	**873**	**1,370**	**292**	**7,996**	**34,703**
Percentage	**2%**	**1%**	**1%**	**4%**	**60%**	**3%**	**4%**	**1%**	**23%**	**100%**

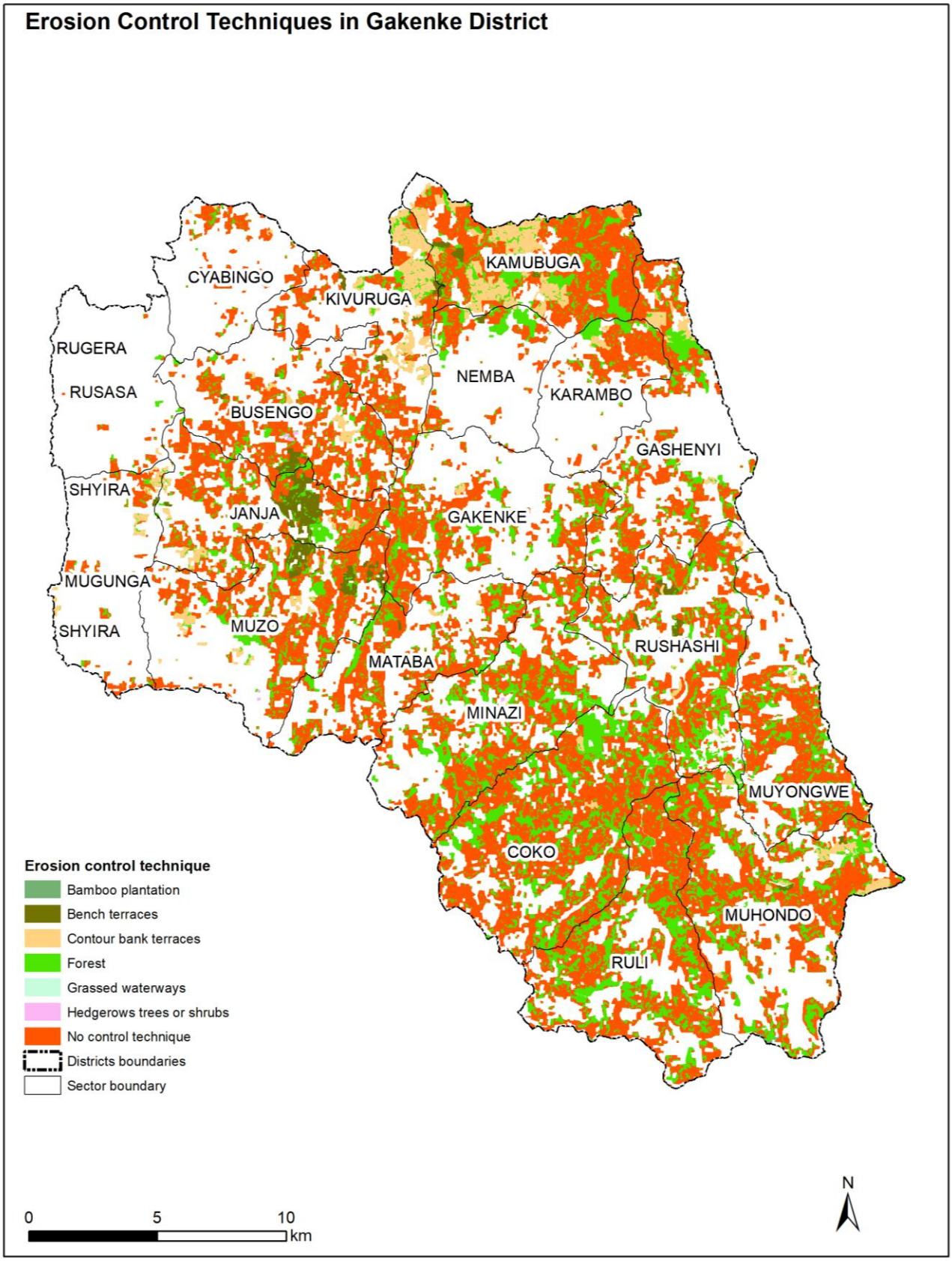


Figure 10: Erosion control techniques in place in Gakenke District

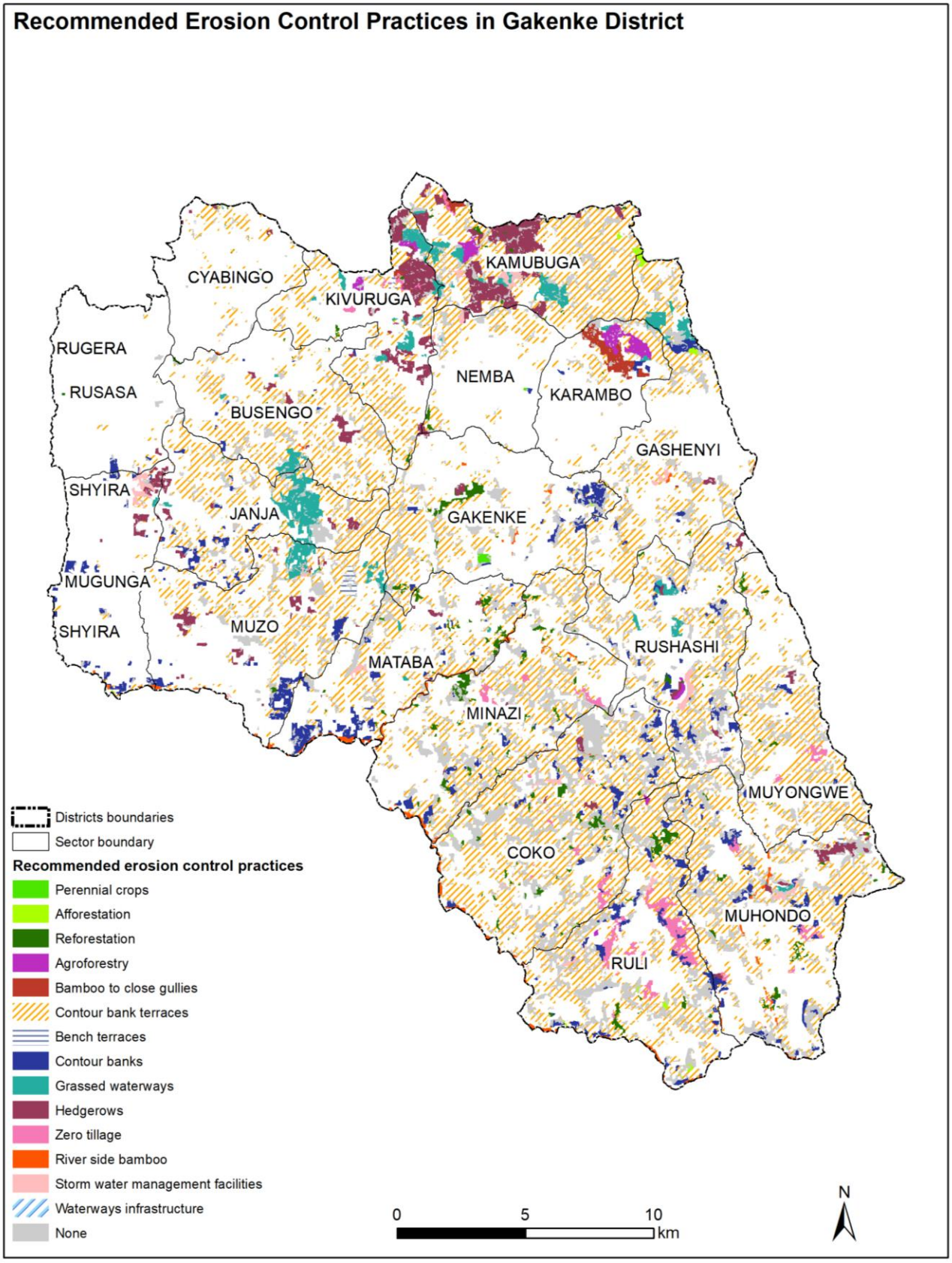


Figure 11: Recommended erosion control practices in Gakenke District

3.1.3. Erosion control status in Gicumbi District

Erosion risk in Musanze is summarised in Table 12 and presented in figure 12. Erosion risk in Gicumbi District is estimated to 14,295 hectares; about 17% of the total district land are highly susceptible to erosion of which 1,229 hectares are located in Miyove sector (44% of sector land), 1,083 hectares are located in Nyankenke sector (34% of sector land), 1,122 hectares are located in Nyamiyaga (68% of the sector land), and 1,015 hectares are found in Mukarange sector about 25% of the sector land. The least sectors are Kageyo with only 206 hectares (7% of the sector land) susceptible to erosion, Rukomo with 358 hectares (7%), and Bukure with 332 hectares, about 8% of the total sector land. As compare to other district in Northern Province, Gicumbi is the least susceptible to erosion, due to intensible protection of agricultural land by bench terraces and forests.

Table 12: Erosion risk per sector in Gicumbi District

SN	Sector Name	Erosion risk				Sector land (Ha)	%
		Extremely high	High	Very high	Grand Total (Ha)		
1.	MIYOVE	38	734	457	1,229	2,783	44 %
2.	NYANKENKE	32	923	129	1,083	3,174	34 %
3.	NYAMIYAGA	32	791	300	1,122	3,880	29 %
4.	MANYAGIRO	15	614	223	852	2,995	28 %
5.	MUKARANGE	41	701	273	1,015	4,045	25 %
6.	RUTARE	55	802	352	1,209	5,386	22 %
7.	RUBAYA	2	206	116	325	1,622	20 %
8.	KANIGA	18	522	205	745	3,926	19 %
9.	BYUMBA	26	684	218	928	4,896	19 %
10.	MUTETE	13	632	349	995	5,654	18 %
11.	RWAMIKO	51	222	211	484	2,849	17 %
12.	BWISIGE	105	457	185	747	4,730	16 %
13.	SHANGASHA	26	377	90	494	3,285	15 %
14.	MUKO	36	421	88	546	4,826	11 %
15.	RUSHAKI	30	308	177	515	4,675	11 %
16.	CYUMBA	3	221	19	244	2,255	11 %
17.	RUVUNE	35	331	174	540	5,930	9%

18.	GITI	21	230	77	328	3,603	9%
19.	BUKURE	20	295	17	332	3,966	8%
20.	RUKOMO	1	318	39	358	5,108	7%
21.	KAGEYO	1	187	18	206	3,134	7%
	Grand Total	**600**	**9,978**	**3,717**	**14,295**	**82,721**	**17 %**

Land areas affected by soil erosion features in Gicumbi District are summarized in Table 13 and the map of erosion features are presented in Figure 13. The results show that Rwamiko sector is the worst affected by gullies on areas estimated to 350 hectares (72% of sector land at risk), followed by Rutare sector on 388 hectares (32% of sector land at risk), and Manyagiro sector on 254 hectares (30% of sector land at risk). The presence of gullies in Rutare, Manyagiro, Nyankenke, and Mukarange sectors confirms the findings of CROM model; however the reduced presence of gullies in Miyove (155ha) which was originally predicted by CROM model as sector at high risk should not read that CROM model did not perform well in this sectors, but rather due to the time of image acquisition, the erosion features could be observed or erosion control measures have been already taken and therefore runoffs have been reduced, thus erosion features could not be formed in this case. Further analysis will demonstrate that in Table 14 and 15. The least sectors affected by gullies are Rushaki with only 14 hectares, Rukomo with only 12 hectares, Nyamiyaga with 46 hectares, Kageyo (13ha) and Bwisige with 66 hectares affected by Landslides.

Table 13: Erosion features types and areas affected in Gicumbi District

Sector name	Erosion feature types					Grand Total	% features
	Gullies	Rill erosion	Severe gullies	Total features	None		
RWAMIKO	350			350	134	484	72%
CYUMBA	109			109	135	244	45%
GITI	144	1		145	182	328	44%
BUKURE	120	11		131	201	332	39%
RUTARE	377	10		388	822	1,209	32%
MANYAGIRO	252		2	254	598	852	30%
RUBAYA	86		0	87	238	325	27%
MUKARANGE	228			228	787	1,015	22%
NYANKENKE	221			221	862	1,083	20%
MUKO	110			110	436	546	20%
BYUMBA	183			183	745	928	20%
SHANGASHA	74			74	420	494	15%
MIYOVE	159		18	177	1052	1,229	14%
MUTETE	135		0	135	859	995	14%
KANIGA	91			91	654	745	12%
BWISIGE	66			66	681	747	9%
KAGEYO	13			13	193	206	6%
RUVUNE	27			27	513	540	5%
NYAMIYAGA	46			46	1076	1,122	4%
RUKOMO	12			12	346	358	3%
RUSHAKI	14			14	501	515	3%
Grand Total	**2,818**	**22**	**21**	**2,861**	**11,434**	**14,295**	**20%**

In term of land use and management for areas at risk in Gicumbi, the results of land cover mapping (Table 14 and Figure 14) show that 8,494 hectares (about 59% of the total land at risk) are used for crop cultivation, 4,379 hectares (31% of the total land at risk) are covered by healthy forests and 530 hectares i.e. 4% are used for built-up and settlement.

Table 14: Land Use and Vegetation Cover (LUVC) for land area at risk in Gicumbi District

Sector name	Build-up area	Degraded forest	Dense forest	Mining concession	Seasonal crops	Water body	Total
BUKURE	3	96	35		198		332
BWISIGE		6	459		282		747
BYUMBA	101	3	323		501		928
CYUMBA	17	0	43		183		244
GITI	1	107	24		195		328
KAGEYO	30	1	82		94		206
KANIGA	81	1	179		484		745
MANYAGIRO	68	5	195		581	3	852
MIYOVE	62	5	236	0	916	10	1,229
MUKARANGE	33	10	314		658		1,015
MUKO	6	73	209		258		546
MUTETE	2	40	392	16	542	2	995
NYAMIYAGA	26	42	452		603		1,122
NYANKENKE	68	1	225		784	5	1,083
RUBAYA	19		91		211	5	325
RUKOMO	1	3	174		180		358
RUSHAKI	10	5	284		215		515
RUTARE	3	205	148	0	851	1	1,209
RUVUNE		36	285		218		540
RWAMIKO	0	207	51		226		484

SHANGASHA		3	177		315		494
Grand Total	**530**	**850**	**4,379**	**16**	**8,494**	**26**	**14,295**

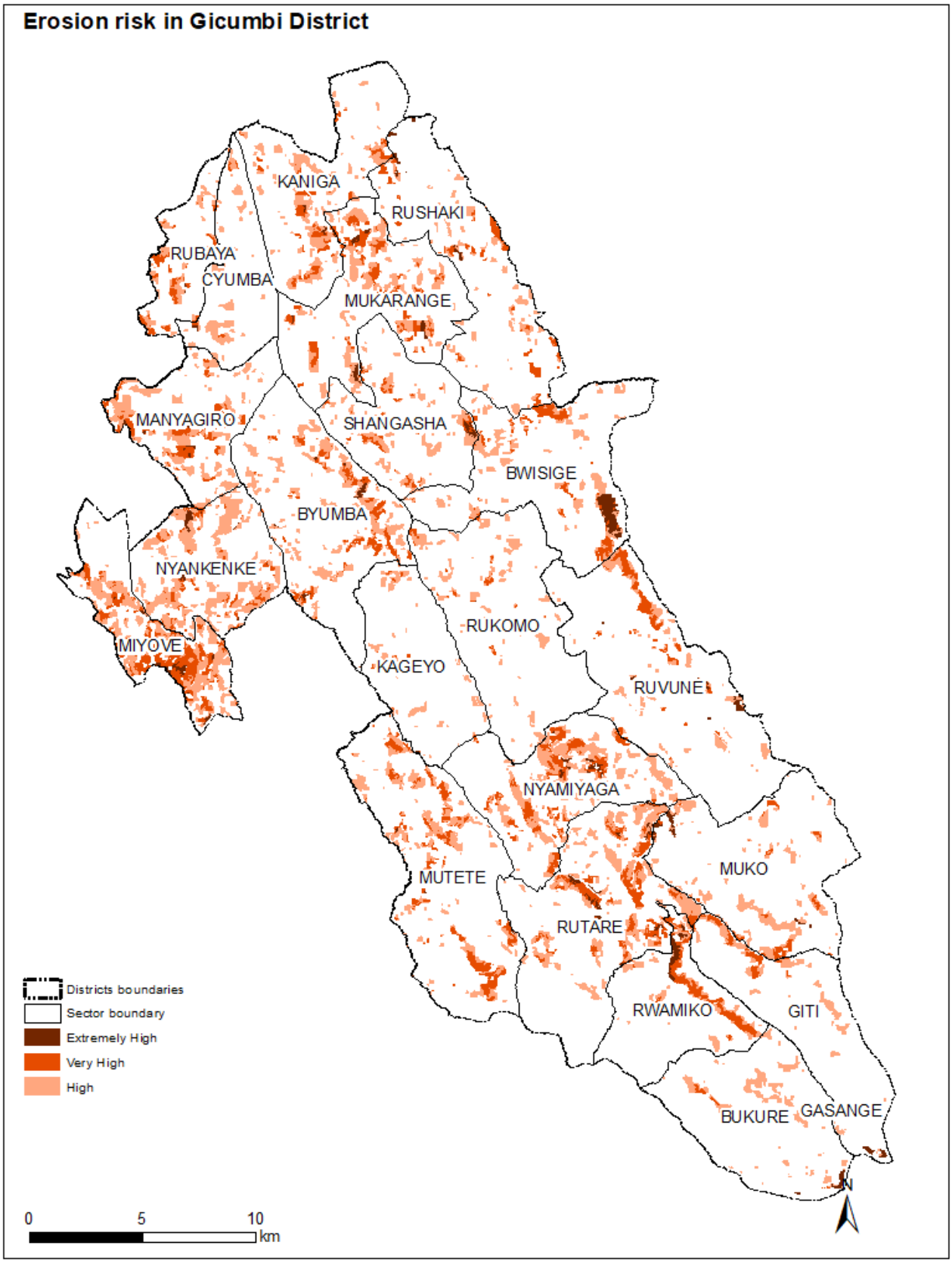


Figure 12: Erosion risk in Gicumbi District

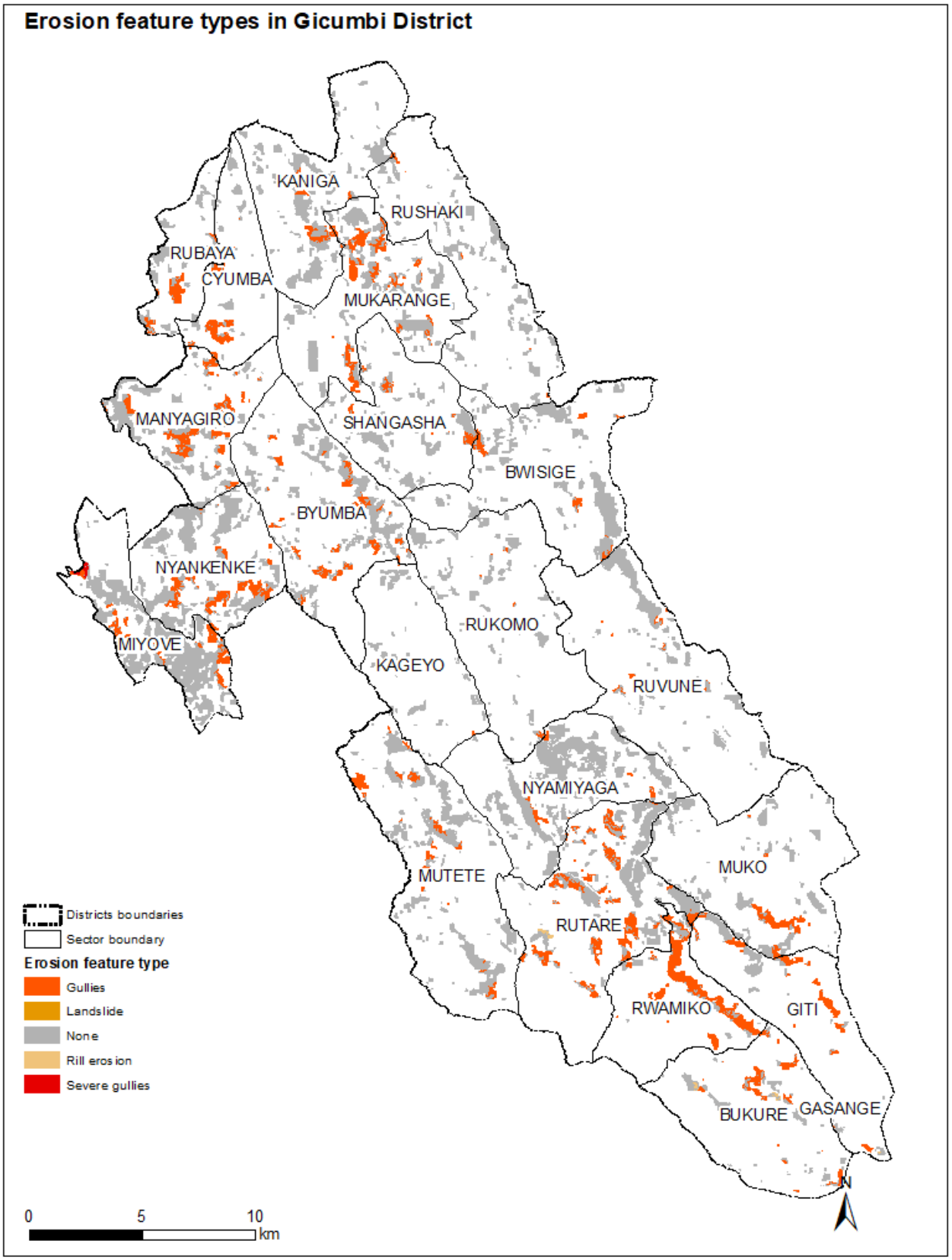


Figure 13: Erosion features detected in Gicumbi District

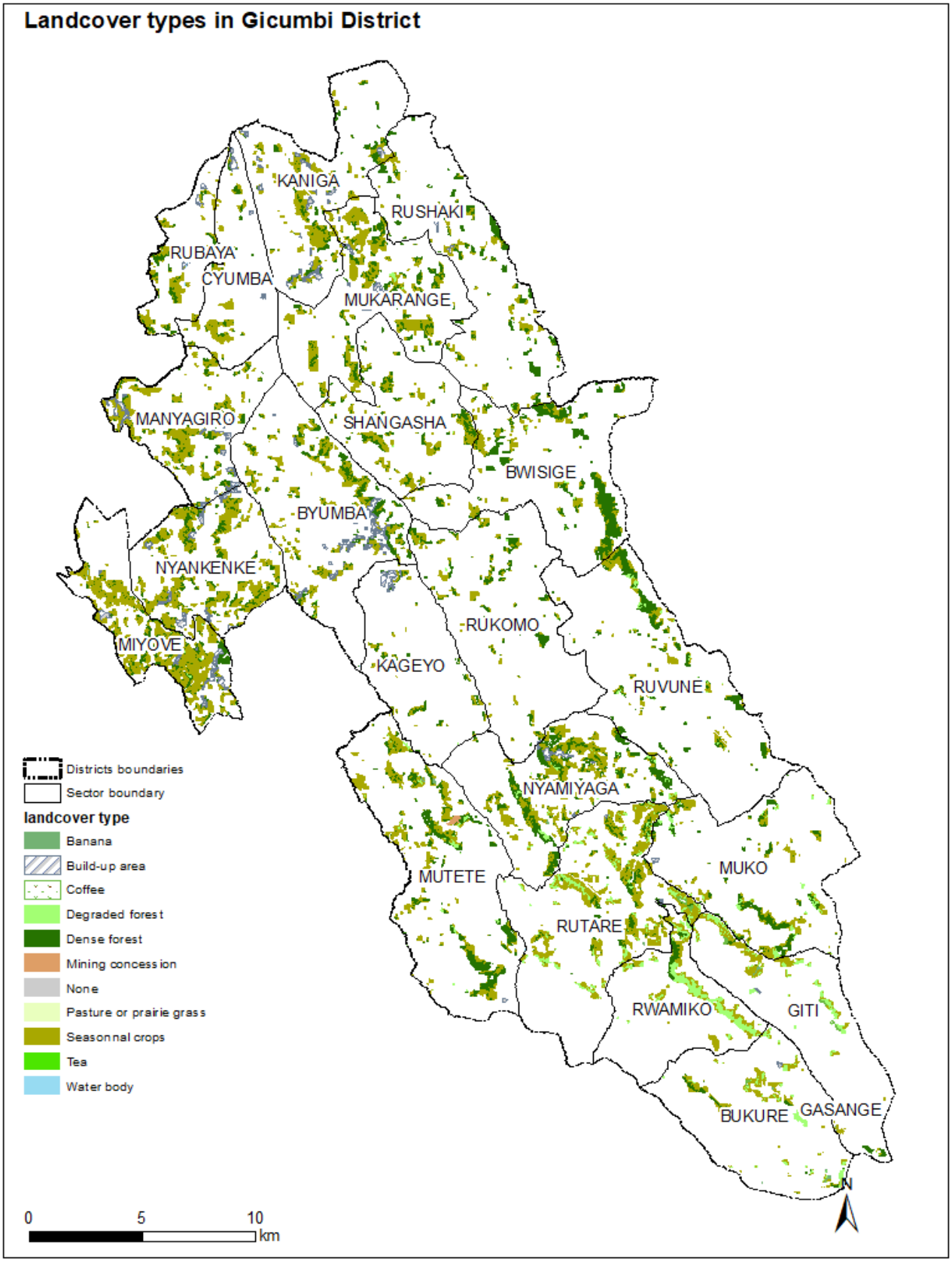


Figure 14: Land Cover types in Gicumbi District

About existing erosion control practices in Gicumbi district, only 46% of land at risk is protected by forests (4,376 hectares), contour bank terraces or progressive terraces with ditches (496 hectares), and bench terraces (1,642 hectares). Although still low, the highest protected sectors are Nyankenke with 69% of its land at risk protected, followed by Bwisige where 67% of the total land at risk is protected (651 hectares) and Miyove with 67% of land protected. The least protected sectors are Rwamiko with only 12% protected, Bukure (only 12% protected), Rutare (18%) and Cyumba (24% protected). The visual interpretation of World View images confirms earlier findings by CROM model that Rwamiko, Bukure, Rutare and Cyumba sectors remain at very high risk of soil erosion since more than 70% of their respective land are not protected

Table 15: Erosion control practices already in place in Gicumbi District

Sector name	Erosion control techniques in place				Unprotected	Grand Total	% protected
	Bench terraces	Contour bank terraces	Forest	Total protected			
NYANKENKE	527		225	752	331	1,083	69%
MIYOVE	496	87	236	820	410	1,229	67%
BWISIGE	14		459	473	274	747	63%
BYUMBA	192	32	323	547	380	928	59%
RUSHAKI		3	284	287	228	515	56%
RUVUNE			285	285	254	540	53%
RUKOMO	2	1	174	177	181	358	49%
MANYAGIRO	105	110	195	410	442	852	48%
MUKARANGE	92	56	314	463	552	1,015	46%
KAGEYO	9		82	91	116	206	44%
SHANGASHA	22	18	177	216	278	494	44%
NYAMIYAGA	11	10	452	473	649	1,122	42%
KANIGA	59	73	179	311	434	745	42%
MUKO	16	1	209	226	319	546	41%
MUTETE	7	2	392	401	593	995	40%
RUBAYA	29	6	91	126	199	325	39%
GITI	47	6	24	78	250	328	24%
CYUMBA	0	14	43	57	186	244	24%
RUTARE	10	67	145	222	987	1,209	18%
BUKURE	2	4	35	41	291	332	12%
RWAMIKO		5	51	56	428	484	12%
Grand Total	**1,642**	**496**	**4,376**	**6,513**	**7,782**	**14,295**	**46%**

Erosion control practices in Gicumbi District are recommended based on existing land uses, erosion control measures already in place, and predicted erosion risk by CROM model. Table 16 shows that about 5,121 hectares (which is 36% of the total land at risk) are suitable for contour bank terraces or progressive terraces, 2,107 hectares are hedge rows and 955 hectares are Afforestation & Reforestation. Others are storm water management facilities or water harvesting infrastructure (SWMF) (873 hectares).

Table 16: Recommended erosion control practices in Gicumbi District

Sector Name	Afforestation & Reforestation	Agroforestry	Riverside bamboos	Contour bank terraces	Hedgerows	SWMF	None	Total
BUKURE	96	1		185	4	3	34	332
BWISIGE	8	0		246	14		459	747
BYUMBA	9	1		72	225	101	323	928
CYUMBA	4	2		148	14	17	43	244
GITI	110	10		85	54	1	24	328
KAGEYO	1	2		74	9	30	82	206
KANIGA	5	3		317	132	81	179	745
MANYAGIRO	8	16	3	281	215	68	195	852
MIYOVE	10	24	10	89	583	61	236	1,229
MUKARANGE	35	42		399	149	33	314	1,015
MUKO	74	5	0	201	17	6	209	546
MUTETE	67	11	2	503	9	2	392	995
NYAMIYAGA	49	2	0	539	21	25	452	1,122
NYANKENKE	2	16	5	38	499	68	225	1,083
RUBAYA	1	0	5	134	35	19	91	325
RUKOMO	5	1		173	3	1	174	358
RUSHAKI	8	15		192	3	10	284	515
RUTARE	206	18	1	741	77	3	148	1,209
RUVUNE	40			214			285	540
RWAMIKO	208	6		220	5	0	45	484
SHANGASHA	5	3		269	40		177	494
Grand Total	**955**	**179**	**26**	**5,121**	**2,107**	**529**	**4,372**	**14,295**
Percentage	**7%**	**1%**	**0%**	**36%**	**15%**	**4%**	**31%**	**100%**

Note: No-till agriculture is recommended is recommended for perennial crops on extremely high risk area while Storm water management facilities **(SWMF) or water harvesting infrastructure** is recommended in built-up areas. None: means no-recommendation is provided because existing erosion control measures are adequate with reference made to the total land protected. Contour banks are recommended for existing forest without ditches. Bamboos are recommended to close gullies or for riverside buffers.

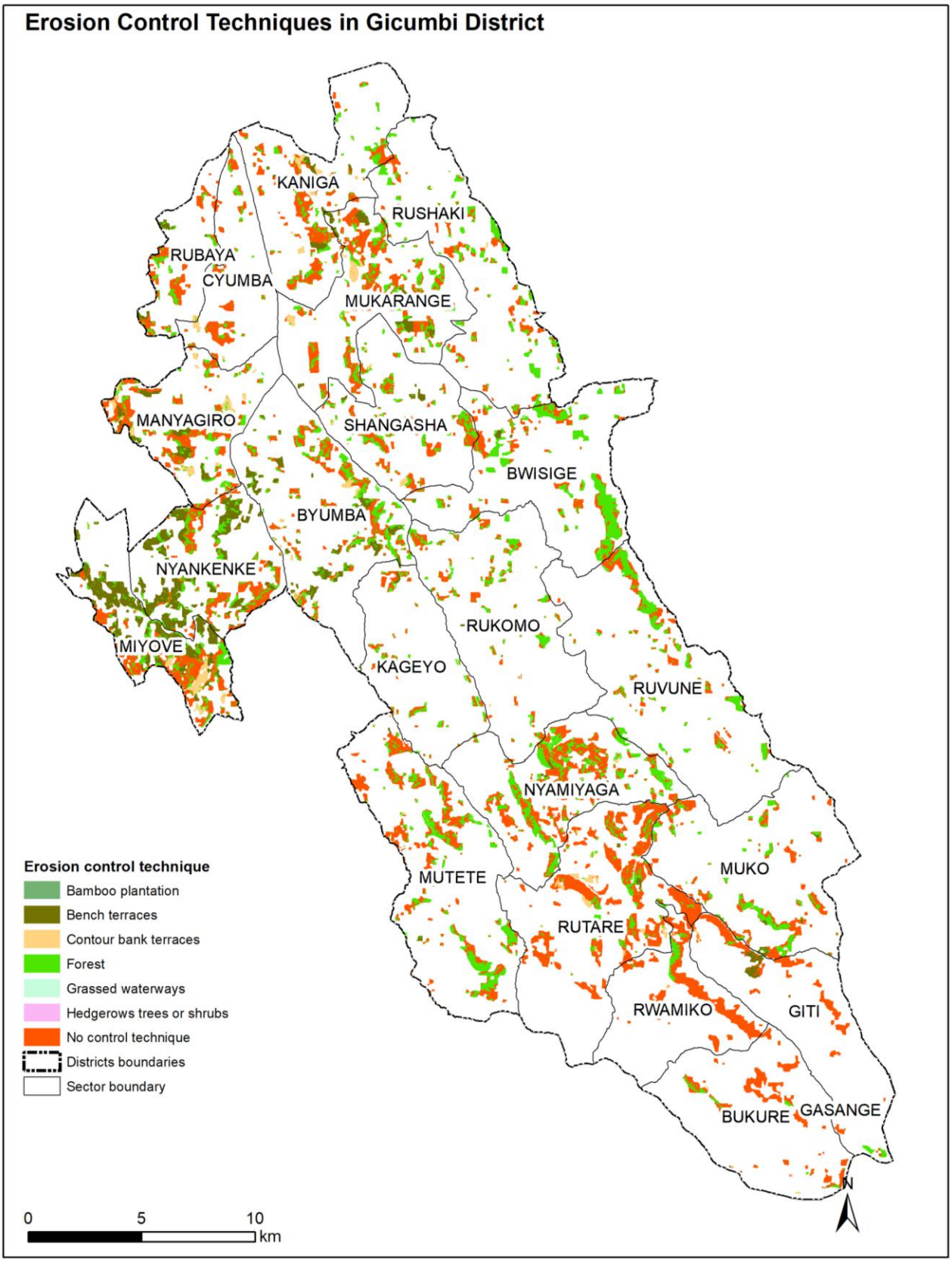


Figure 15: Erosion control techniques in place in Gicumbi District

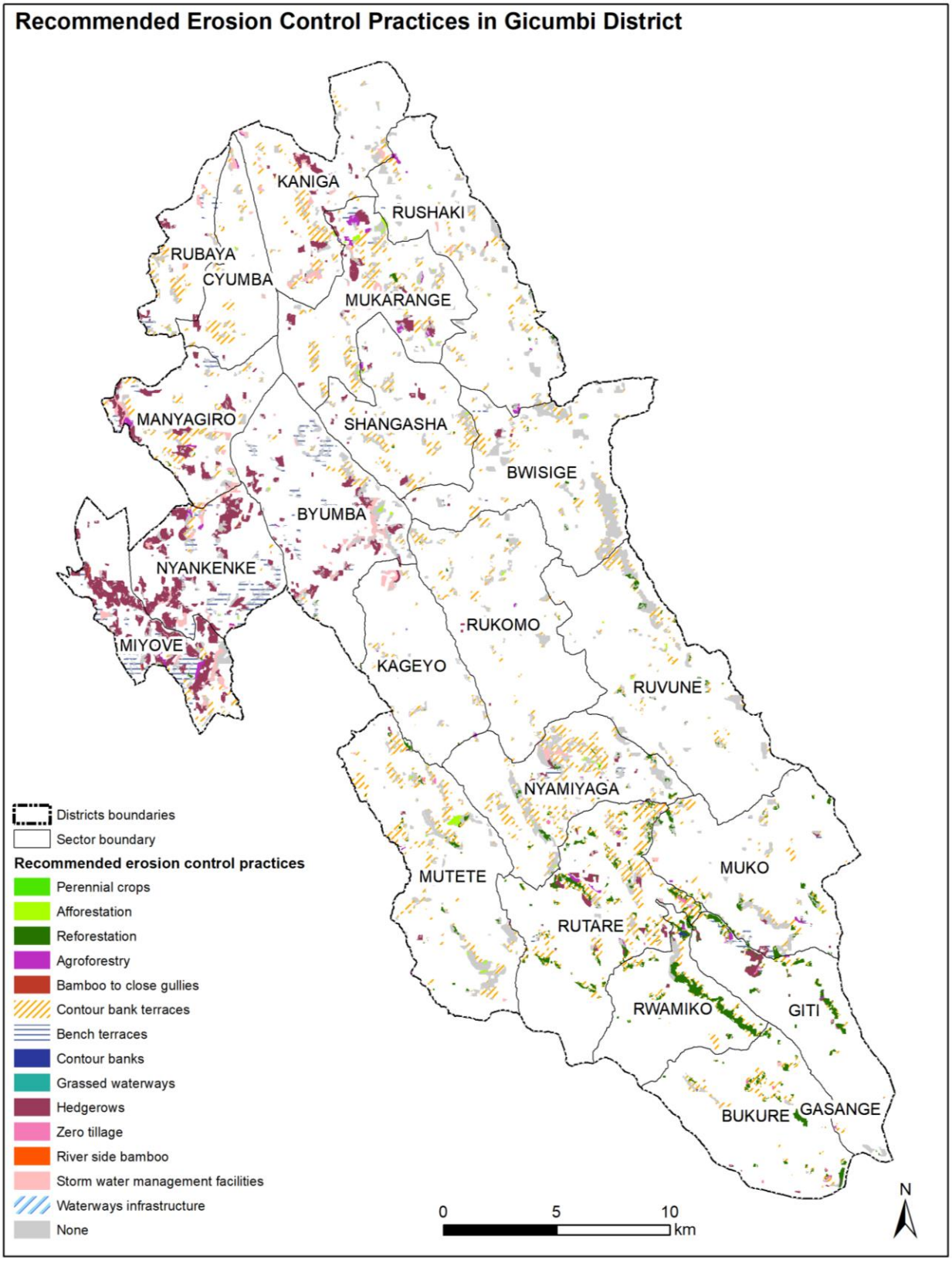


Figure 16: Recommended erosion control practices in Gicumbi District

3.1.4. Erosion control status in Musanze District

Erosion risk in Musanze is summarised in Table 17 and presented in figure 17. Erosion risk area is estimated to 9,053 hectares; about 18% of the total district land is highly susceptible to erosion of which 716 hectares are located in Gashaki sector (55% of sector land), 972 hectares are located in Gacaca sector (30% of sector land), and 2,417 hectares are located in Kinigi sector (30% of the sector land). The least sectors are Muko with only 1 hectare susceptible to erosion, Cyuve with 45 hectares (1%), and Kimonyi with 93 hectares, about 4% of the total sector land. Others like Nkotsi, Musanze and Rwaza also least prone to erosion.

Table 17: Erosion risk per sector in Musanze District

SN	Sector Name	Erosion risk				Sector land (Ha)	%
		Extremely high	High	Very high	Grand Total (Ha)		
1.	GASHAKI	44	384	289	716	1,299	55%
2.	GACACA	38	674	261	972	2,987	33%
3.	KINIGI	476	771	1,171	2,417	8,105	30%
4.	REMERA	27	335	171	533	2,298	23%
5.	SHINGIRO	277	475	458	1,210	5,341	23%
6.	GATARAGA	146	440	391	977	5,053	19%
7.	NYANGE	81	632	277	990	5,432	18%
8.	BUSOGO	21	192	114	328	2,006	16%
9.	MUHOZA	17	218	109	344	2,134	16%
10.	NKOTSI	6	81	62	148	2,432	6%
11.	MUSANZE	22	73	61	157	3,377	5%
12.	RWAZA	3	98	21	122	2,776	4%
13.	KIMONYI	2	65	25	93	2,159	4%
14.	CYUVE	2	30	14	45	3,377	1%
15.	MUKO	1			1	1,940	0%
	Grand Total	**1,161**	**4,468**	**3,423**	**9,053**	**50,717**	**18%**

The entire District of Musanze is reported as not having any erosion feature types (Figure 18) which is in contradiction with the findings of CROM model by which 18% of the District land is at high erosion risk. In fact this district is characterised of having topography with gentle slope a part from the volcanic mountains which are covered of protected natural forest. So the quasi absence of erosion features (gullies, rill erosion, landslide) in Musanze District in which CROM model predicted high risk areas in some sectors did not perform well in this sectors, but rather due to the time of image acquisition, the erosion features could be observed or erosion control measures have been already taken and therefore runoffs have been reduced, thus erosion features could not be formed in this case. Further analysis will demonstrate that in Table 14 and 15.

In term of land use and related management of areas at risk in Musanze, the results of land cover mapping (Table 18 and Figure 19) show 5,434 hectares (60% of the total land at risk) are used for seasonal cropping, 1.869 hectares (21 % of the total land at risk) are covered by healthy forests and 1,715 hectares i.e. 19% are covered by Built-up area.

Table 18: Land Use and Vegetation Cover (LUVC) for land area at risk in Musanze District

Sector name	Build-up area	Dense Forest	Mining concession	Seasonal crops	Water body	Total
BUSOGO	23	117		187		328
CYUVE	12	7		26		45
GACACA	116	146	5	700	6	972
GASHAKI	84	145	2	485		716
GATARAGA	165	236		576		977
KIMONYI	0	21		72		93
KINIGI	507	508		1,402	0	2,417
MUHOZA	54	71	5	205	6	344
MUKO		-			1	1
MUSANZE	46	34		77		157
NKOTSI	2	45		101		148
NYANGE	156	153		677	3	990
REMERA	68	113		351	1	533
RWAZA	22	29		69	2	122
SHINGIRO	459	244	0	507		1,210
Total	**1,715**	**1,869**	**14**	**5,434**	**19**	**9,053**

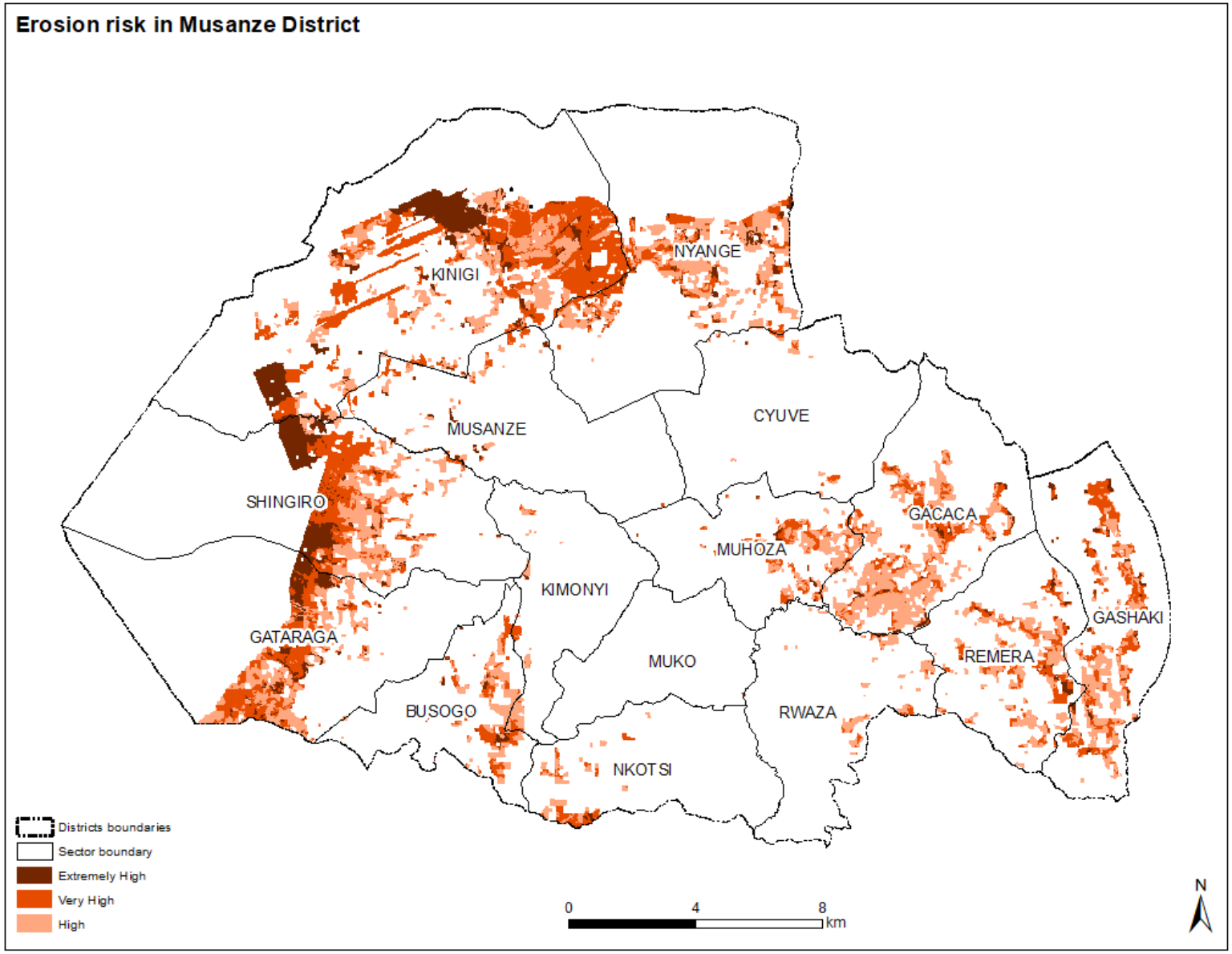


Figure 17: Erosion risk in Musanze District

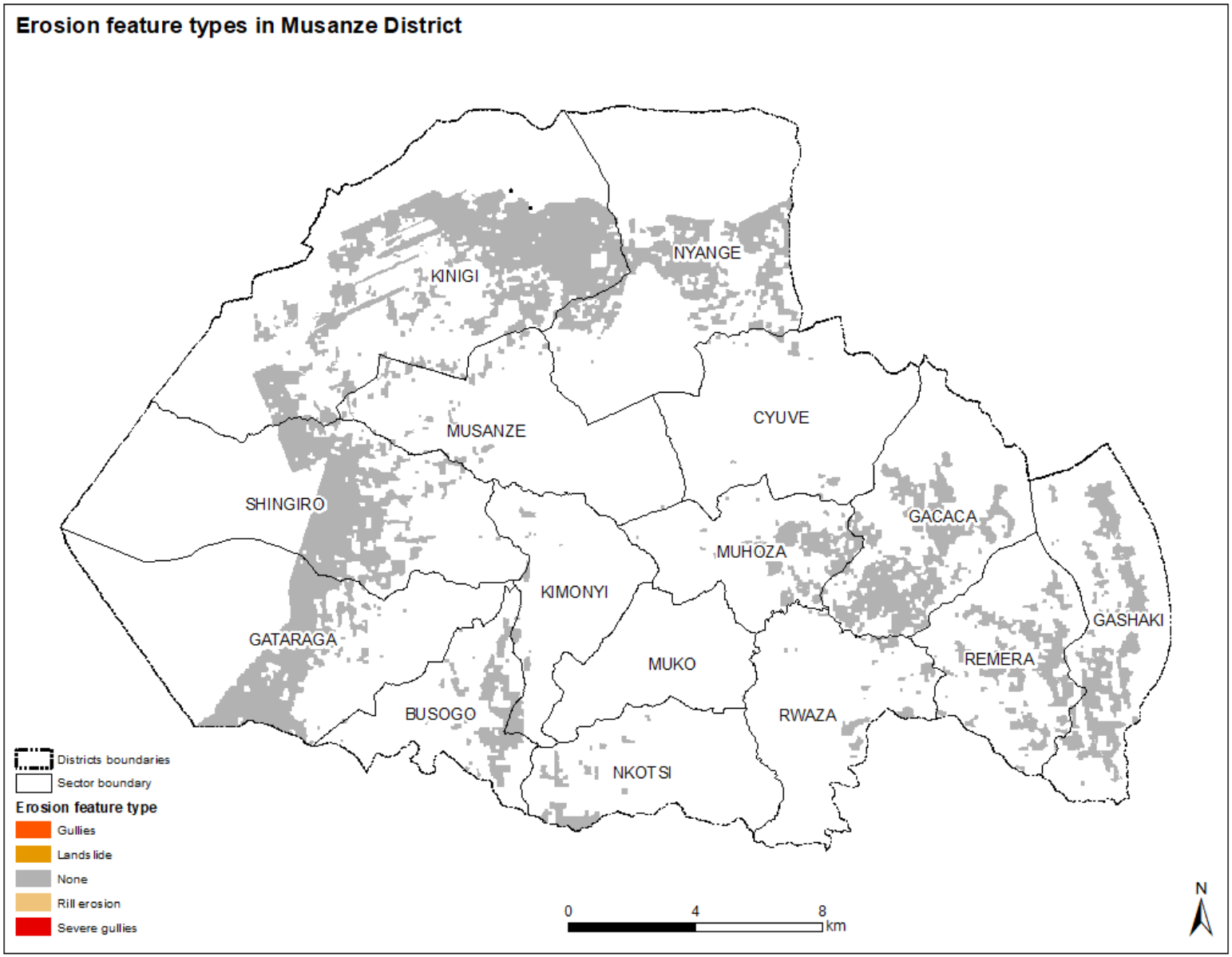


Figure 18: Erosion features detected in Musanze District

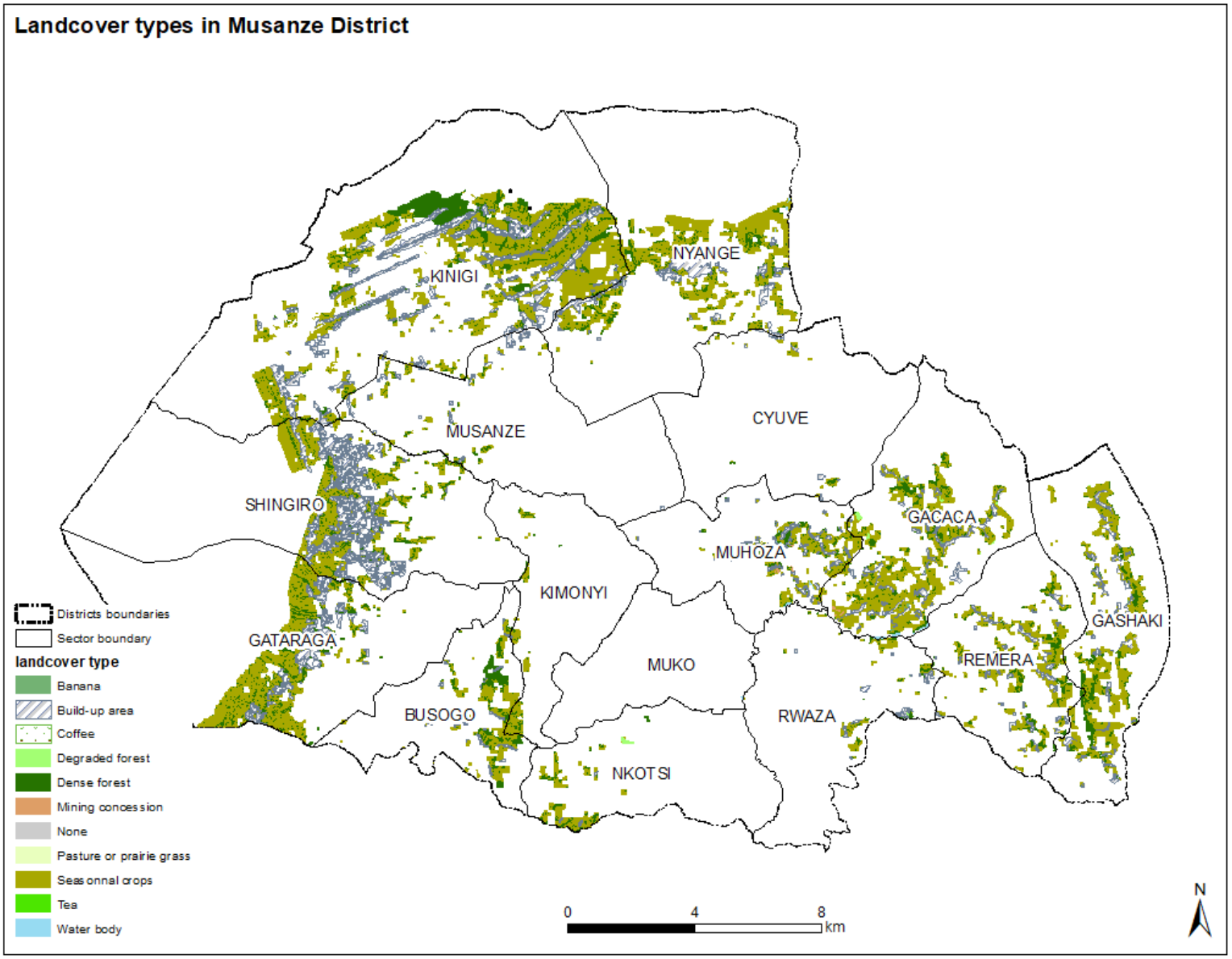


Figure 19: Land cover and Land Use in Musanze District

About existing erosion control practices in Musanze district, only 28% of land at risk is protected by forests (1866 hectares), contour bank terraces or progressive terraces with ditches (278 hectares), and bench terraces (345 hectares). Although still low, the highest protected sectors are Gashaki with 58% of its land at risk protected, followed by Remera where 49% of the total land at risk is protected (651 hectares) and Nkotsi with 46% of land protected. The least protected sectors are Nyange with only 12% protected, Bukure (only 16% protected), Cyuve (16%) and Shingiro (20% protected). The visual interpretation of World View images confirms earlier findings by CROM model that Nyange, Bukure, Cyuve and Shingiro sectors remain at very high risk of soil erosion since more than 80% of their respective land are not protected

Table 19: Erosion control practices already in place in Musanze District

Sector name	Erosion control techniques in place					Unprotected	Grand Total	% protected
	Bamboo plantation	Bench terraces	Contour bank terraces	Forests	Total protected			
GASHAKI		136	136	146	417	299	716	58%
REMERA		46	104	113	263	269	533	49%
NKOTSI		26	2	40	68	80	148	46%
BUSOGO				118	118	210	328	36%
GACACA		136	31	137	303	669	972	31%
RWAZA			1	29	30	92	122	24%
GATARAGA	0			236	236	741	977	24%
KIMONYI				21	21	72	93	22%
KINIGI	8		1	521	529	1,888	2,417	22%
MUHOZA		1	4	71	75	269	344	22%
MUSANZE	0			33	34	123	157	21%
SHINGIRO	1			243	244	966	1210	20%
CYUVE				7	7	38	45	16%
NYANGE	1			153	154	836	990	16%
MUKO					0	1	1	0%
Grand Total	**11**	**345**	**278**	**1,866**	**2,499**	**6,554**	**9053**	**28%**

Erosion control practices in Musanze District are recommended based on existing land uses, erosion control measures already in place, and predicted erosion risk by CROM model. Table 20 shows that about 4713 hectares (which is 32% of the total land at risk) are suitable for hedgerows, while Storm water management facilities (SWMF) are recommended on1.708 hectares of built-up areas and Contour bank terraces on 234 hectares of agricultural land with seasonal crops. Bench terraces are recommended on 154 hectares, agroforestry/alley cropping is recommended on 99 hectares and afforestation and reforestation are recommended on 52 hectares of extremely high risk areas.

Table 20: Recommended erosion control practices in Musanze District

Sector Name	Afforestation & Reforestation (Ha)	Agroforestry (Ha)	Bamboo to close gullies (Ha)	Bench terraces (Ha)	Contour bank terraces (Ha)	Hedgerows (Ha)	SWMF (Ha)	None (Ha)	Total (Ha)
BUSOGO		0				188	21	118	328
CYUVE						26	12	7	45
GACACA	26	3	7	118	156	380	116	159	972
GASHAKI	16	20	1	36	0	405	84	154	716
GATARAGA					0	575	166	236	977
KIMONYI						70	1	21	93
KINIGI		9	11			1241	505	650	2417
MUHOZA	5		5		74	129	55	76	344
MUKO			1						1
MUSANZE						77	46	34	157
NKOTSI	5	6				86	4	47	148
NYANGE		0	3		2	679	154	151	990
REMERA		1	1		2	343	67	119	533
RWAZA	1		2			71	20	29	122
SHINGIRO		59				442	457	252	1210
Grand Total	**52**	**99**	**30**	**154**	**234**	**4713**	**1708**	**2054**	**9053**
Percentage	**1%**	**1%**	**0%**	**2%**	**3%**	**52%**	**19%**	**23%**	**100%**

Note: Grassed waterways are recommended for existing terraces which was made without waterways or with but no grasses which can cause severe gullies and destruction of bench terraces created. No-till agriculture is recommended is recommended for perennial crops on extremely high risk area while Storm water management facilities (SWMF) or water harvesting infrastructure is recommended in built-up areas. None: means no-recommendation is provided because existing erosion control measures are adequate with reference made to the total land protected. Contour banks are recommended for existing forest without ditches. Bamboos are recommended to close gullies or for riverside buffers.

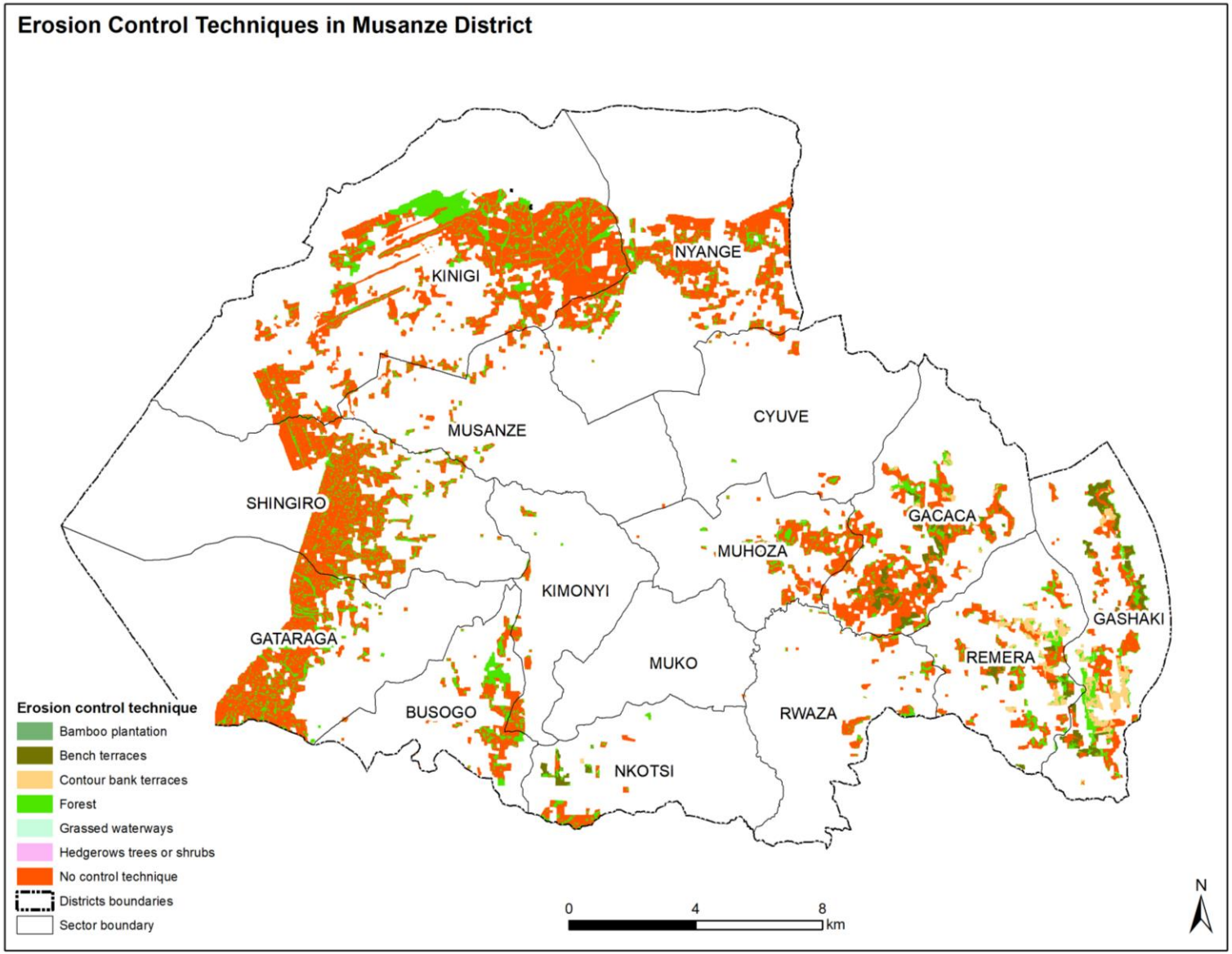


Figure 20: Erosion control techniques in place in Musanze District

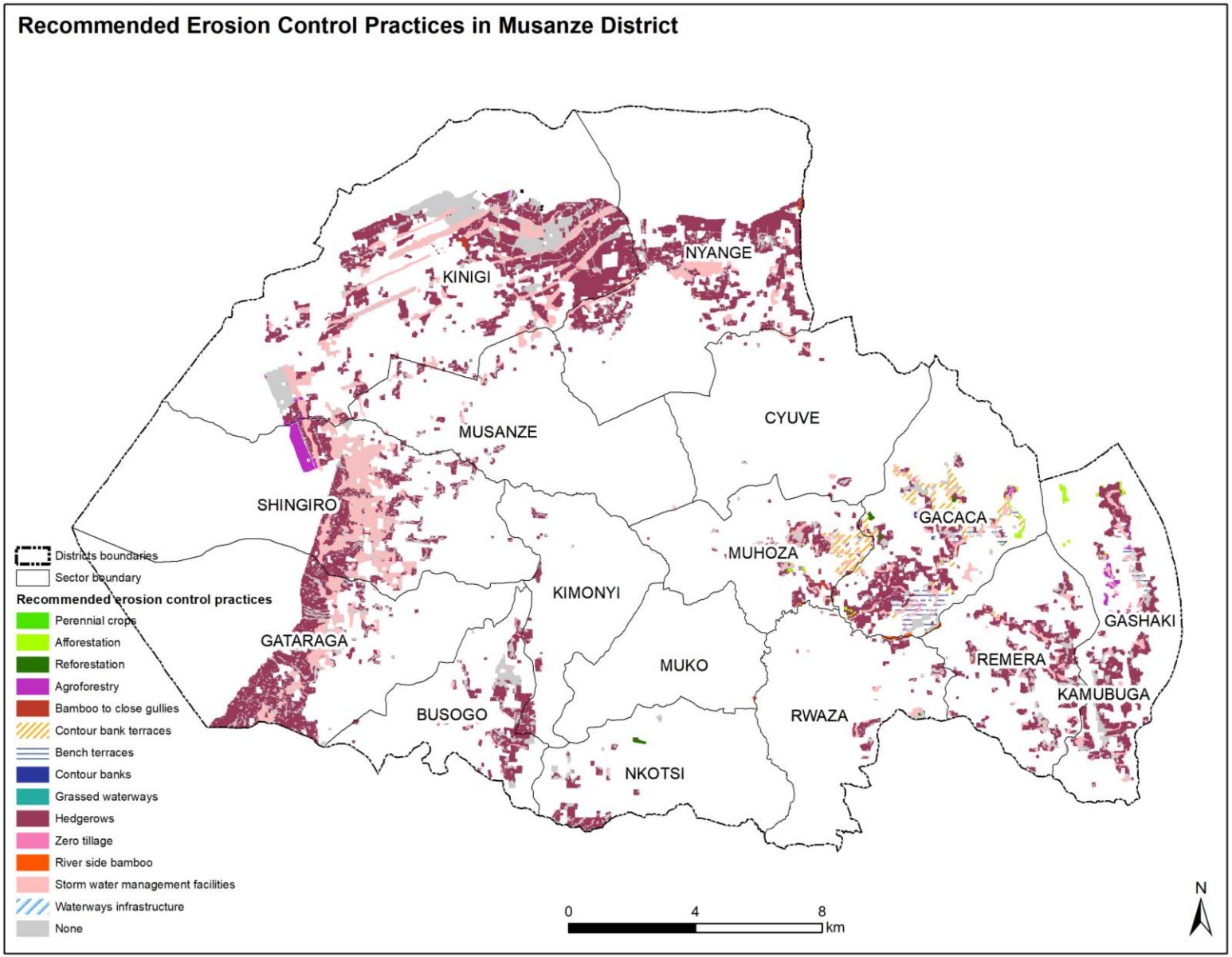


Figure 21: Recommended erosion control practices in Musanze District

3.1.5. Erosion control status in Rulindo District

Erosion risk in Rulindo is summarised in Table 26 and presented in figure 22. Erosion risk area is estimated to 22,926 hectares; i.e. 40% of the total district land is highly susceptible to erosion of which 2,297 hectares are located in Cyinzuzi sector (69% of sector land), 2,107 hectares are located in Rusiga sector (66% of sector land), and 2,667 hectares are located in Mbogo sector (65% of the sector land) and 2,248 hectares are located in Bushoki sector, about 63 % of the sector land. The least sectors (although still land at risk remains high) are Masoro with only 502 hectares susceptible to erosion (17% of sector land), and Base sector with 518 hectares, about 18% of the total sector land.

Table 21: Erosion risk per sector in Rulindo District

SN	Sector Name	Erosion risk				Sector land (Ha)	%
		Extremely high	High	Very high	Grand Total (Ha)		
1.	CYINZUZI	466	937	894	2,297	3,344	69 %
2.	RUSIGA	111	1,114	882	2,107	3,194	66 %
3.	MBOGO	283	1,629	755	2,667	4,104	65 %
4.	BUSHOKI	283	911	1,053	2,248	3,545	63 %
5.	CYUNGO	24	596	302	921	1,966	47 %
6.	NGOMA	239	591	607	1,437	3,163	45 %
7.	BUREGA	198	598	598	1,394	3,231	43 %
8.	SHYORONGI	159	984	810	1,953	4,609	42 %
9.	TUMBA	100	866	447	1,413	3,380	42 %
10.	MURAMBI	43	522	546	1,111	2,946	38 %
11.	RUKOZO	16	434	200	651	1,999	33 %
12.	KISARO	37	725	397	1,159	3,797	31 %
13.	KINIHIRA	65	328	297	690	2,692	26 %
14.	NTARABANA	86	422	238	747	3,500	21 %
15.	BUYOGA	102	718	292	1,112	5,391	21 %
16.	BASE	17	383	118	518	2,871	18 %
17.	MASORO	64	347	90	502	2,966	17 %
	Grand Total	**2,294**	**12,104**	**8,528**	**22,926**	**56,699**	**40 %**

Land areas affected by soil erosion features in Rulindo District are summarized in Table 21 and the map of erosion features are presented in Figure 23. The results show that Rukozo sector is the worst affected by gullies on areas estimated to 155 hectares (24% of sector land at risk), followed by Base sector on 97 hectares (19% of sector land at risk), and Rusiga sector on 347 hectares (16% of sector land at risk). The presence of gullies in Rukozo, Base, Rusiga, Cyinzuzi, Mbogo, Tumba and Kinihira sectors confirms the findings of CROM model; however the reduced presence of gullies in Kisaro (3ha) Ntarabana (2 ha) and Burega (33 ha) which was originally predicted by CROM model as sector at high risk should not read that CROM model did not perform well in this sectors, but rather due to the time of image acquisition, the erosion features could be observed or erosion control measures have been already taken and therefore runoffs have been reduced, thus erosion features could not be formed in this case. Further analysis will demonstrate that in Table 24 and 25.

Table 22: Erosion features types and land area affected in Rulindo District

Sector name	Erosion feature types				None	Grand Total	% Features
	Gullies	Landslide	Severe gullies	Total			
RUKOZO	154	1		155	496	651	24%
BASE	9		88	97	421	518	19%
RUSIGA	315	0	32	347	1,760	2,107	16%
CYINZUZI	321		44	365	1,932	2,297	16%
MBOGO	107		288	395	2,272	2,667	15%
TUMBA	204			204	1,210	1,413	14%
KINIHIRA	53		15	68	622	690	10%
MASORO	29	1	13	43	458	502	9%
MURAMBI	86		2	88	1,023	1,111	8%
BUYOGA	48		26	74	1,038	1,112	7%
CYUNGO	21		37	59	863	921	6%
NGOMA	76			76	1,362	1,437	5%
SHYORONGI	54		14	68	1,886	1,953	3%
BUSHOKI	70		0	70	2,177	2,248	3%
BUREGA	33			33	1,362	1,394	2%
NTARABANA		2		2	744	747	0%

KISARO	2	0	1	3	1,156	1,159	0%
Grand Total	**1,580**	**5**	**561**	**2,146**	**20,780**	**22,926**	**9%**

In term of land use and related management of areas at risk in Rulindo, the results of land cover mapping (Table 23 and Figure 24) show that 14,652 hectares (64% of the total land at risk) are used for seasonal cropping, 7,206 hectares (31% of the total land at risk) are covered by healthy forests and 336 hectares i.e. 1% are covered by Built-up and settlement, 249 hectares (1% of the total land at risk) are covered by Banana.

Table 23: Land Use and Vegetation Cover (LUVC) for land area at risk in Rulindo District

Sector name	Banana	Build-up area	Coffee	Dense forest	Mining concession	Seasonal crops	Water body	Grand Total
BASE	1	5	1	131	3	375	3	518
BUREGA		4	21	455	4	902	7	1,394
BUSHOKI	3	41	31	504	6	1,661	2	2,248
BUYOGA	5	16	16	383	12	661	20	1,112
CYINZUZI	31	15	26	780	21	1,411	14	2,297
CYUNGO	0	3		241	5	667	5	921
KINIHIRA		1		163	1	524	0	690
KISARO	3	76	4	309	3	754	11	1,159
MASORO	17	6	2	296	27	139	15	502
MBOGO	22	23	18	748	0	1,849	7	2,667
MURAMBI	70	39	15	477	0	507	4	1,111
NGOMA	29	6	6	503	4	875	14	1,437
NTARABANA	6	4		311	13	406	7	747
RUKOZO	0	1		157	1	489	3	651
RUSIGA	7	13	6	633	2	1,436	10	2,107
SHYORONGI	56	60	1	754	4	1,055	23	1,953
TUMBA	0	23	43	362	42	942	2	1,413
Grand Total	**249**	**336**	**188**	**7,206**	**149**	**14,652**	**146**	**22,926**

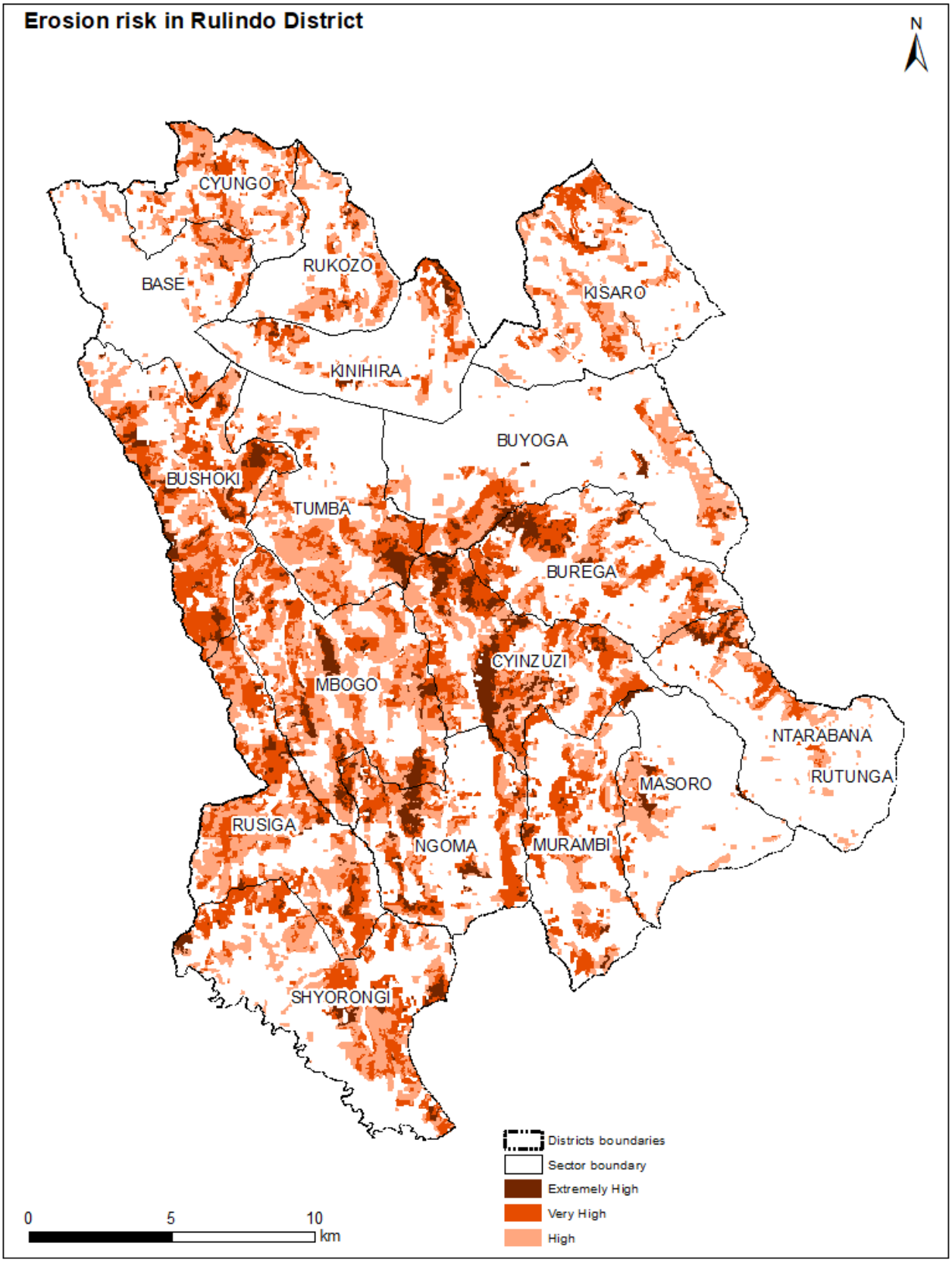


Figure 22: Erosion risk in Rulindo District

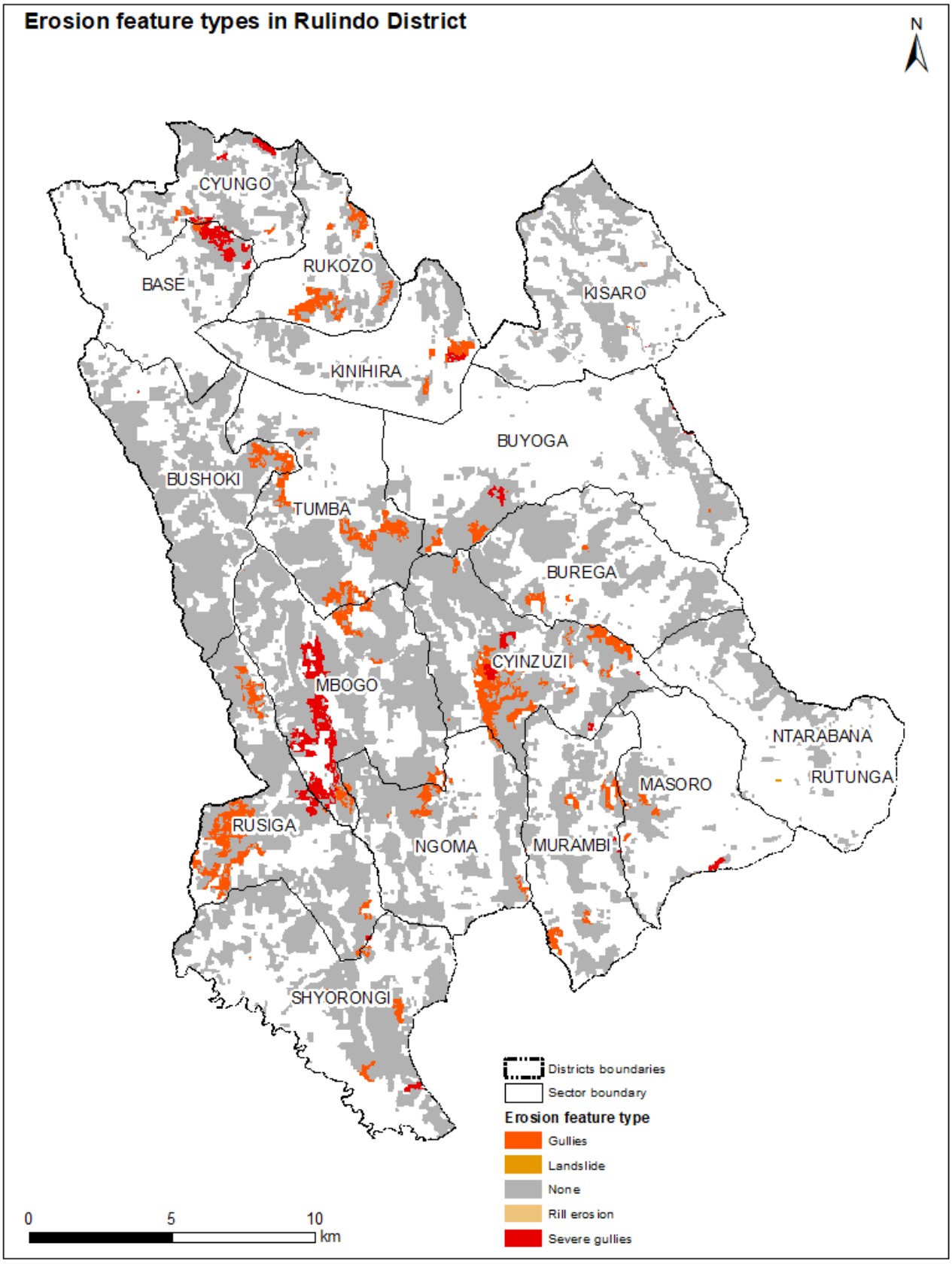


Figure 23: Erosion features detected in Rulindo District

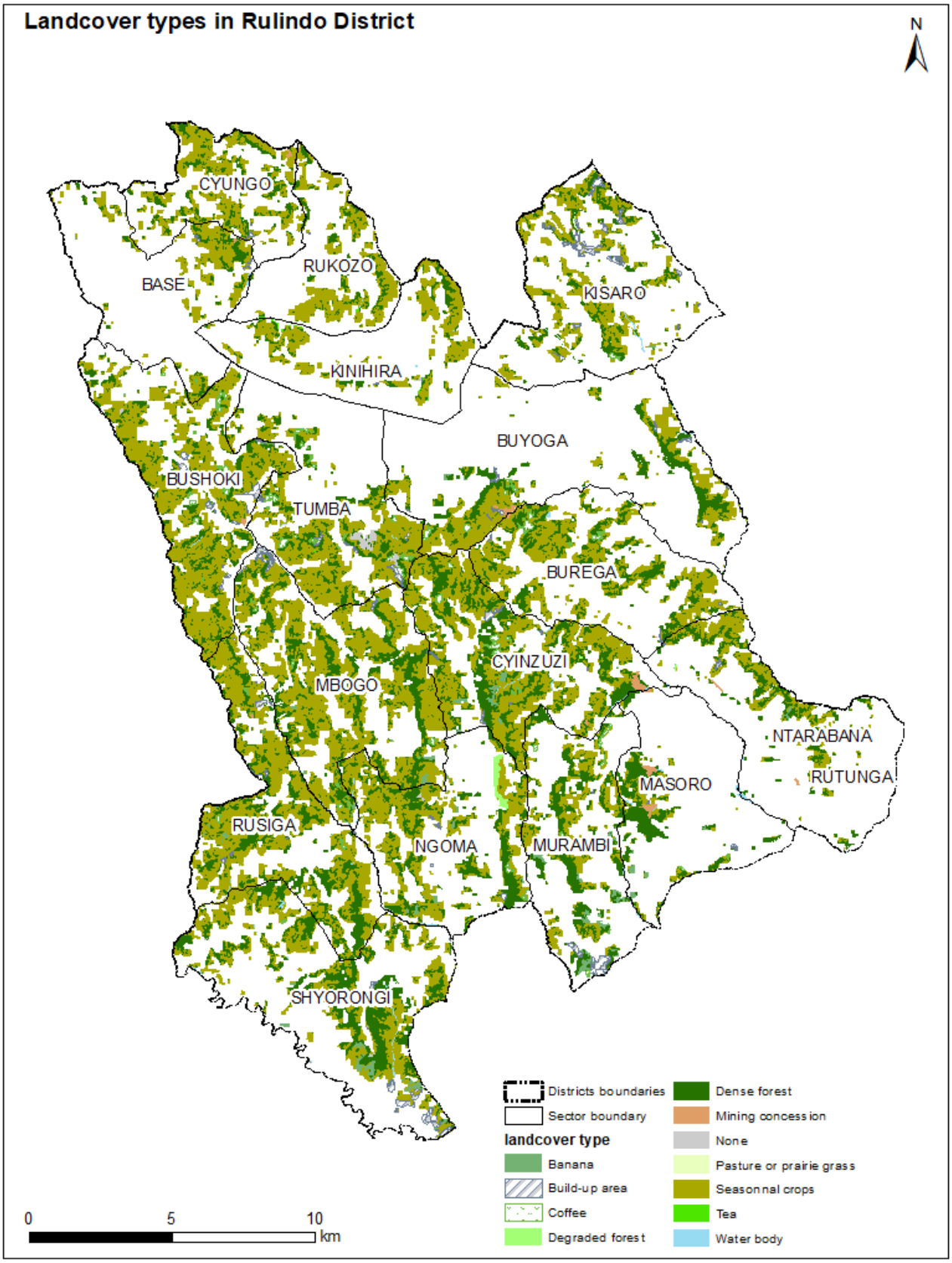


Figure 24: Land Use and Vegetation Cover for land at erosion risk in Rulindo District

About existing erosion control practices in Rulindo district, Table 24 indicates that 54% of land at risk is protected by forests (7,171 hectares), contour bank terraces or progressive terraces with ditches (3,366 hectares), and bench terraces (1,847 hectares). The highest protected sectors are Kisaro with 78% of its land at risk protected, followed by Tumba where 75% of the total land at risk is protected and Burega with 70% of land protected. The least protected sectors are Kinihira with only 34% protected, Rukozo (only 35% protected), Cyuve (35%) and Ngoma (37% protected). The visual interpretation of World View images confirms earlier findings by CROM model that Rukozo, Ngoma, and Rusiga sectors remain at very high risk of soil erosion since more than 60% of the sector land at risk are not protected.

Table 24: Erosion control practices already in place in Rulindo District

Sector name	Erosion control techniques in place (Ha)					Unprotected (Ha)	Grand Total (Ha)	% protected
	Bamboo plantation (Ha)	Bench terraces (Ha)	Contour bank terraces (Ha)	Forests (Ha)	Total protected (Ha)			
KISARO		300	302	306	909	250	1,159	78%
TUMBA		328	373	362	1,063	351	1,413	75%
BUREGA		416	99	455	970	424	1,394	70%
NTARABANA		150	37	309	495	251	747	66%
MASORO			34	296	329	172	502	66%
BUYOGA		243	97	383	722	389	1,112	65%
BUSHOKI			818	504	1,322	925	2,248	59%
CYINZUZI		119	378	780	1,278	1,019	2,297	56%
MBOGO		161	518	750	1,429	1,238	2,667	54%
MURAMBI			106	484	590	520	1,111	53%
CYUNGO		86	123	241	450	471	921	49%
SHYORONGI	3	14	55	755	826	1,127	1,953	42%
RUSIGA			183	633	816	1,291	2,107	39%
BASE		9	55	131	196	322	518	38%
NGOMA			67	462	529	908	1,437	37%
RUKOZO		21	47	157	225	425	651	35%
KINIHIRA		0	74	163	236	454	690	34%
Grand Total	**3**	**1,847**	**3,366**	**7,171**	**12,387**	**10,540**	**22,926**	**54%**

Erosion control practices in Rulindo District are recommended based on existing land uses, erosion control measures already in place, and predicted erosion risk by CROM model. Table 25 shows that about 7,763 hectares (which is 34% of the total land at risk) are suitable for Contour bank terraces, 5,158 hectares are hedgerows and 794 hectares are Bench terraces. Others are cropland that needs agroforestry/alley cropping (656 hectares) and afforestation and reforestation (365 hectares).

Table 25: Recommended erosion control practices in Rulindo District

Sector Name	Afforestation & Reforestation	Agroforestry	Bamboo to close gullies	Bench terraces	Contour bank terraces	Hedgerows	No till	SWMF	None	Total
BASE	11	4	3	6	287	62	2	5	139	518
BUREGA	27	98	7	85	185	506	23	4	456	1394
BUSHOKI	17	12	2		836	797	37	41	506	2248
BUYOGA	22	40	19	133	124	354	20	16	383	1112
CYINZUZI	49	263	14	91	471	519	57	15	816	2297
CYUNGO	10	8	3	170	276	209	0	4	241	921
KINIHIRA	1	3	0	0	435	72	8	1	170	690
KISARO	12	3	13	25	113	604	6	76	307	1159
MASORO	42	28	15		65	31	18	6	296	502
MBOGO	22	38	7	140	983	648	40	23	767	2667
MURAMBI	16	31	4		354	106	85	39	477	1111
NGOMA	55	21	11		766	70	35	6	473	1437
NTARABANA	22	3	7	93	138	162	6	4	313	747
RUKOZO	3	5	3	1	411	67	3	1	158	651
RUSIGA	28	20	11		1207	181	13	13	633	2107
SHYORONGI	19	49	20		920	69	56	60	760	1953
TUMBA	9	29	2	51	193	700	44	23	362	1413
Grand Total	**365**	**656**	**140**	**794**	**7,763**	**5,158**	**454**	**337**	**7,255**	**22,926**
Percentage	**2%**	**3%**	**1%**	**3%**	**34%**	**22%**	**2%**	**1%**	**32%**	**100%**

Note: Grassed waterways are recommended for existing terraces (see Table 10) which was made without waterways or with but no grasses which can cause severe gullies and destruction of bench terraces created. No-till agriculture is recommended is recommended for perennial crops on extremely high risk area while Storm water management facilities (SWMF) or water harvesting infrastructure is recommended in built-up areas. None: means no-recommendation is provided because existing erosion control measures are adequate with reference made to the total land protected. Contour banks are recommended for existing forest without ditches. Bamboos are recommended to close gullies or for riverside buffers.

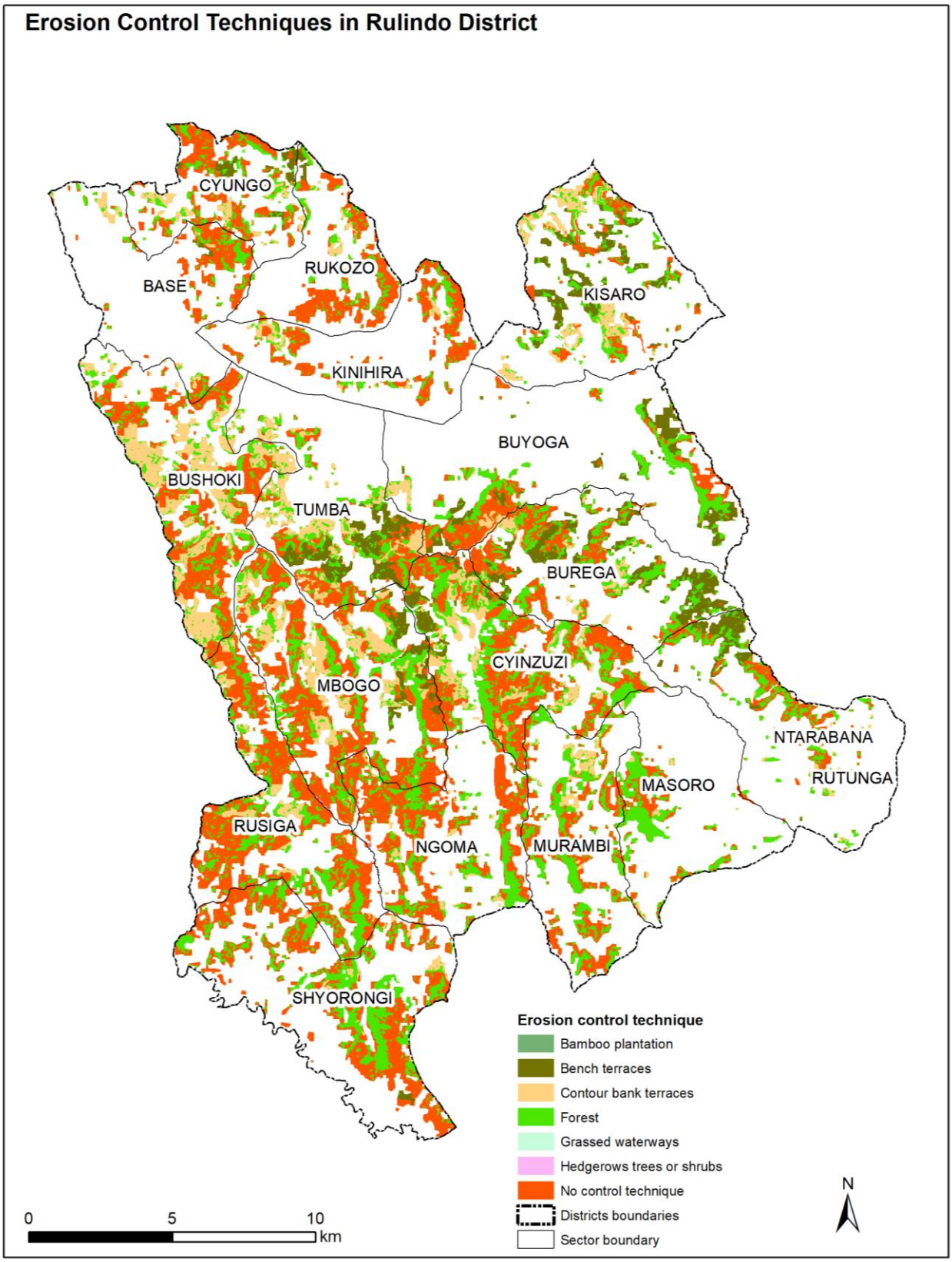


Figure 25: Erosion control techniques in place in Rulindo District

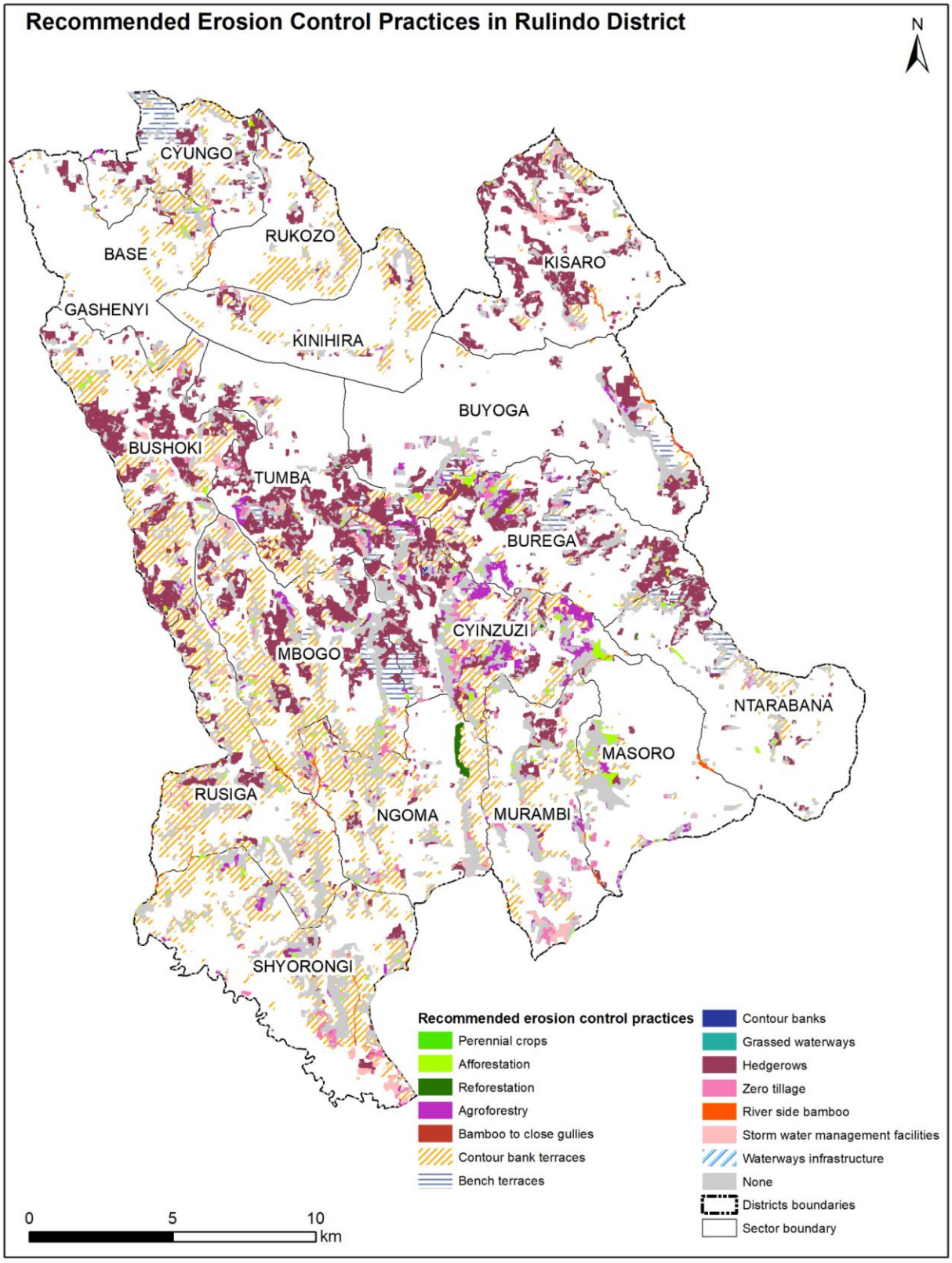


Figure 26: Recommended erosion control practices in Rulindo District

3.2. Erosion Control Status in Western Province

Erosion risk in Western Province is summarized in table 32 and presented in figure 29. The total land at high risk of erosion in Western Province is about 160,005 hectares (33% of the total province land). The highest amount of land at erosion risk are found in Ngororero with 41,450 hectares (i.e. 61% of the total district land) followed by Rutsiro District with 35,110 hectares (53% of the district land), Karongi with 34,525 hectares (44% of district land) and Nyabihu with 18,354 hectares which is about 35% of the total district land. The least district susceptible to erosion is Rusizi, where only 7% of its district land is at risk, about 6,084 hectares. The contribution of forests in protecting fragile land in Western Province is evident, particularly the Nyungwe National park in Rusizi and Nyamasheke districts as well as forest plantations in steep slopes in highlands of Western Province.

Table 26: Erosion risk per district in Western Province

Districts	Erosion risk				District land (ha)	%
	Extremely high	High	Very high	Grand Total (Ha)		
NGORORERO	8,260	17,278	15,912	41,450	67,899	61%
RUTSIRO	8,067	11,130	15,912	35,110	65,995	53%
KARONGI	5,454	17,897	11,175	34,525	79,298	44%
NYABIHU	2,334	9,195	6,824	18,354	52,958	35%
RUBAVU	1,683	2,467	2,402	6,552	34,090	19%
NYAMASHEKE	3,645	8,466	5,820	17,931	94,802	19%
RUSIZI	200	4,168	1,715	6,084	91,731	7%
Grand Total	**29,644**	**70,602**	**59,760**	**160,005**	**486,773**	**33%**

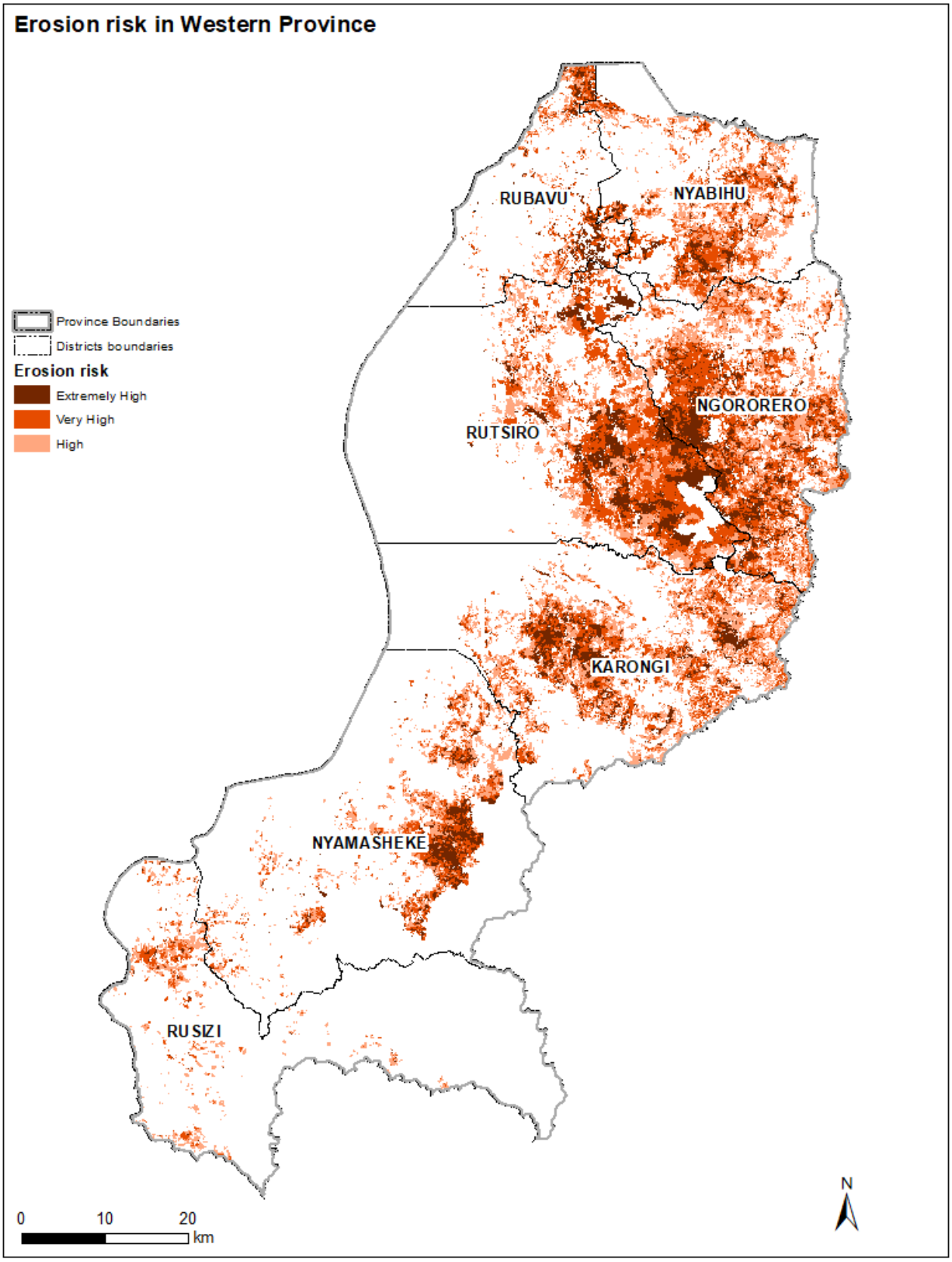


Figure 27: Erosion risk in Western Province

3.2.1. Erosion control status in Karongi District

Soil erosion risk in Karongi is summarised in Table 27 and presented in figure 28. Land area at risk is estimated to 34,525 hectares; about 44% of the total district land. Murundi sector is the highest susceptible to erosion with 4,174 hectares (66% of the sector land), followed by Rwankuba sector with 4,553 hectares (65% of sector land), Gitesi sector with 4,434 hectares (59% of the sector land), Gashari sector with 3,927 hectares, 57% of the sector land and Murambi with 2,957 hectares, which is 56% of the sector land. The least affected sectors are Rubengera with 462 hectares susceptible to erosion (about 11% of sector land), and Mutuntu sector with 982 hectares about 21% of the total sector land.

Table 27: Erosion risk per sector in Karongi District

SN	Sector Name	Erosion risk				Sector land (ha)	%
		Extremely high	High	Very high	Grand Total (Ha)		
1.	MURUNDI	734	2,456	983	4,174	6,342	66 %
2.	RWANKUBA	1,334	1,665	1,554	4,553	6,960	65 %
3.	GITESI	917	1,856	1,661	4,434	7,568	59 %
4.	GASHARI	459	1,938	1,530	3,927	6,931	57 %
5.	MURAMBI	327	1,715	915	2,957	5,246	56 %
6.	RUGANDA	381	1,530	878	2,788	6,183	45 %
7.	MUBUGA	446	873	676	1,995	4,536	44 %
8.	GISHYITA	119	1,237	550	1,906	4,704	41 %
9.	RUGABANO	152	1,728	1,008	2,888	8,054	36 %
10.	BWISHYURA	192	689	327	1,208	4,217	29 %
11.	TWUMBA	273	1,202	776	2,251	9,801	23 %
12.	MUTUNTU	64	736	183	982	4,709	21 %
13.	RUBENGERA	56	273	134	462	4,044	11 %
	Grand Total	**5,454**	**17,897**	**11,175**	**34,525**	**79,298**	**44 %**

Land areas affected by soil erosion features in Karongi District are summarized in Table 28 and the map of erosion features are presented in Figure 29. The results show that Gitesi sector is the worst affected by gullies on areas estimated to 1,639 hectares (37% of sector land at risk), followed by Gashari sector on 1,409 hectares (36% of sector land at risk), and Ruganda sector on 707 hectares (25% of sector land at risk). The presence of gullies in Gitesi, Gashari, Ruganda, and Ruganda sectors confirms the findings of CROM model; however the reduced presence of gullies in Gishyita (22ha) which was originally predicted by CROM model as sector at high risk should not read that CROM model did not perform well in this sectors, but rather due to the time of image acquisition, the erosion features could be observed or erosion control measures have been already taken and therefore runoffs have been reduced, thus erosion features could not be formed in this case. Further analysis on current land use and erosion control practices already in place (Table 29 & 30) will demonstrate that. The least sectors affected by gullies are Gishyita with only 22 hectares, Bwishyura with only 39 hectares and Rubengera with 61 hectares affected by gullies.

Table 28: Erosion features types and land area affected in Karongi District

Sector Name	Erosion feature types						Grand Total	% Features
	Gullies	Land slide	Rill erosion	Severe gullies	Total	None		
GITESI	1,607	0	12	20	1,639	2,795	4,434	37%
GASHARI	1,387	0		22	1,409	2,518	3,927	36%
RUGANDA	707			0	707	2,082	2,788	25%
MUTUNTU	238		0		238	744	982	24%
RWANKUBA	1,035	2		37	1,074	3,479	4,553	24%
TWUMBA	28			338	366	1,885	2,251	16%
MURUNDI	672			0	672	3,502	4,174	16%
RUGABANO	347		0	94	441	2,447	2,888	15%
RUBENGERA	61		0	0	61	401	462	13%
MUBUGA	147		2		149	1,846	1,995	7%
MURAMBI	220	0			220	2,737	2,957	7%
BWISHYURA	39			3	42	1,166	1,208	3%
GISHYITA	22	3		2	27	1,879	1,906	1%
Grand Total	**6,509**	**5**	**14**	**518**	**7,046**	**27,480**	**34,525**	**20%**

In term of land use and related management of areas at risk in Karongi, the results of land cover mapping (Table 29 and Figure 30) show that 21,402 hectares (62% of the total land at risk) are used for seasonal cropping, 10,056 hectares (29% of the total land at risk) are covered by healthy forests and 763 hectares (2% of the total area at risk) are covered by tea, 452 hectares (1% of the total area at risk) are covered by Built-up area and 712 hectares are covered by Banana crop.

Table 29: Land Use and Land Cover (LUVC) of areas at risk in Karongi District

Sector name	Banana	Build-up area	Coffee	Degraded forest	Dense forest	Mining concession	Seasonal crops	Tea	Water body	Total
BWISHYURA	14	47		19	587	2	528	-	10	1,208
GASHARI	134	2		44	1,150	3	2,474		119	3,927
GISHYITA	1	38	11	6	602	15	1,231		3	1,906
GITESI	353	35	1	106	1,028	1	2,837	38	35	4,434
MUBUGA	3	52		31	430	7	1,464		9	1,995
MURAMBI	24	23		14	739	7	2,120		29	2,957
MURUNDI	61	27	1	14	932	5	3,098		36	4,174
MUTUNTU				25	266	-	572	107	12	982
RUBENGERA	6	12		1	185	2	247		9	462
RUGABANO	18	83		11	926	1	1,767	71	11	2,888
RUGANDA	5	10		194	991	1	1,541	12	35	2,788
RWANKUBA	4	110	2	22	1,455	10	2,349	535	67	4,553

TWUMBA	88	15	3	130	766	22	1,176	-	51	2,251
Grand Total	**712**	**452**	**17**	**619**	**10,056**	**76**	**21,402**	**763**	**429**	**34,525**

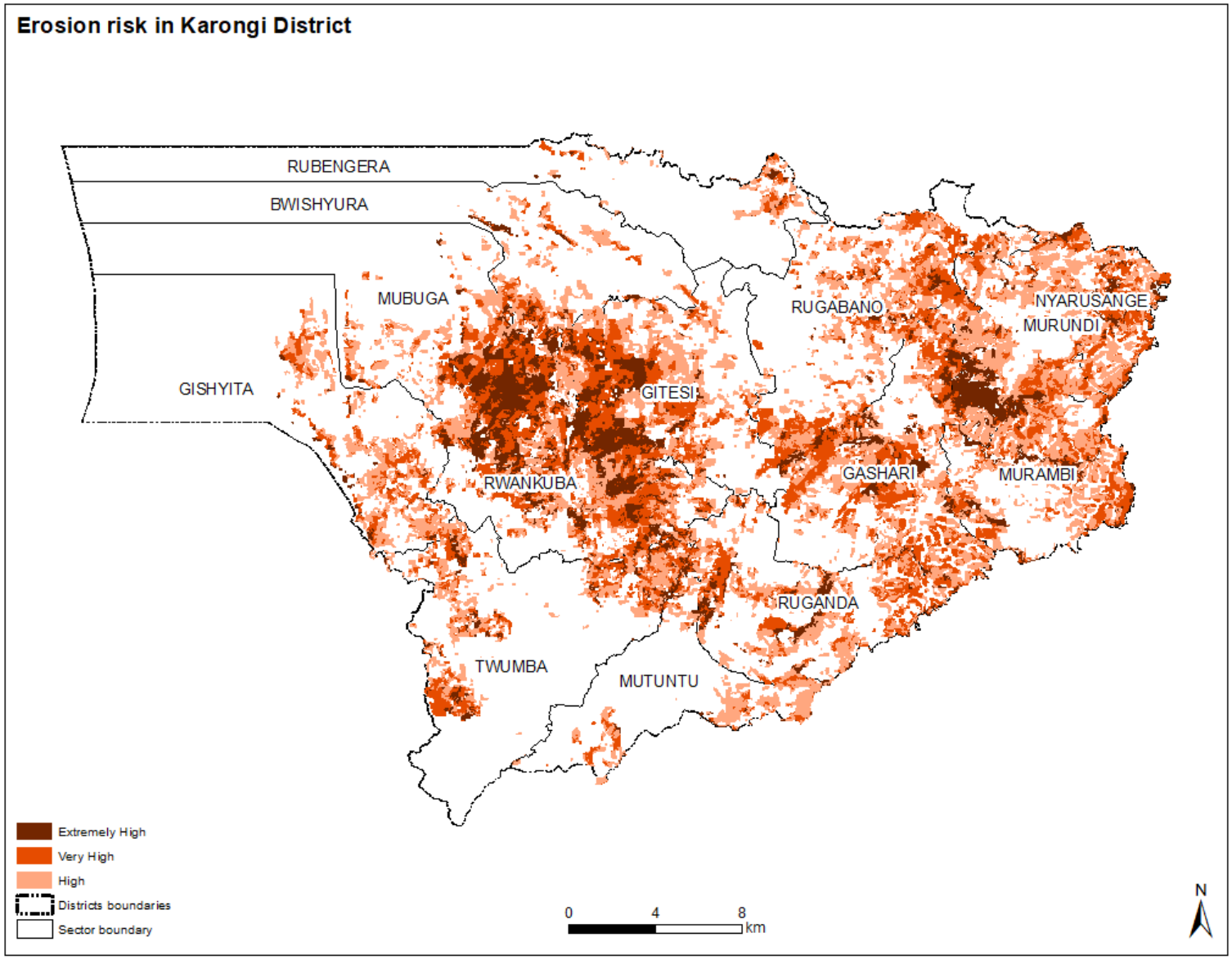


Figure 28: Erosion risk in Karongi District

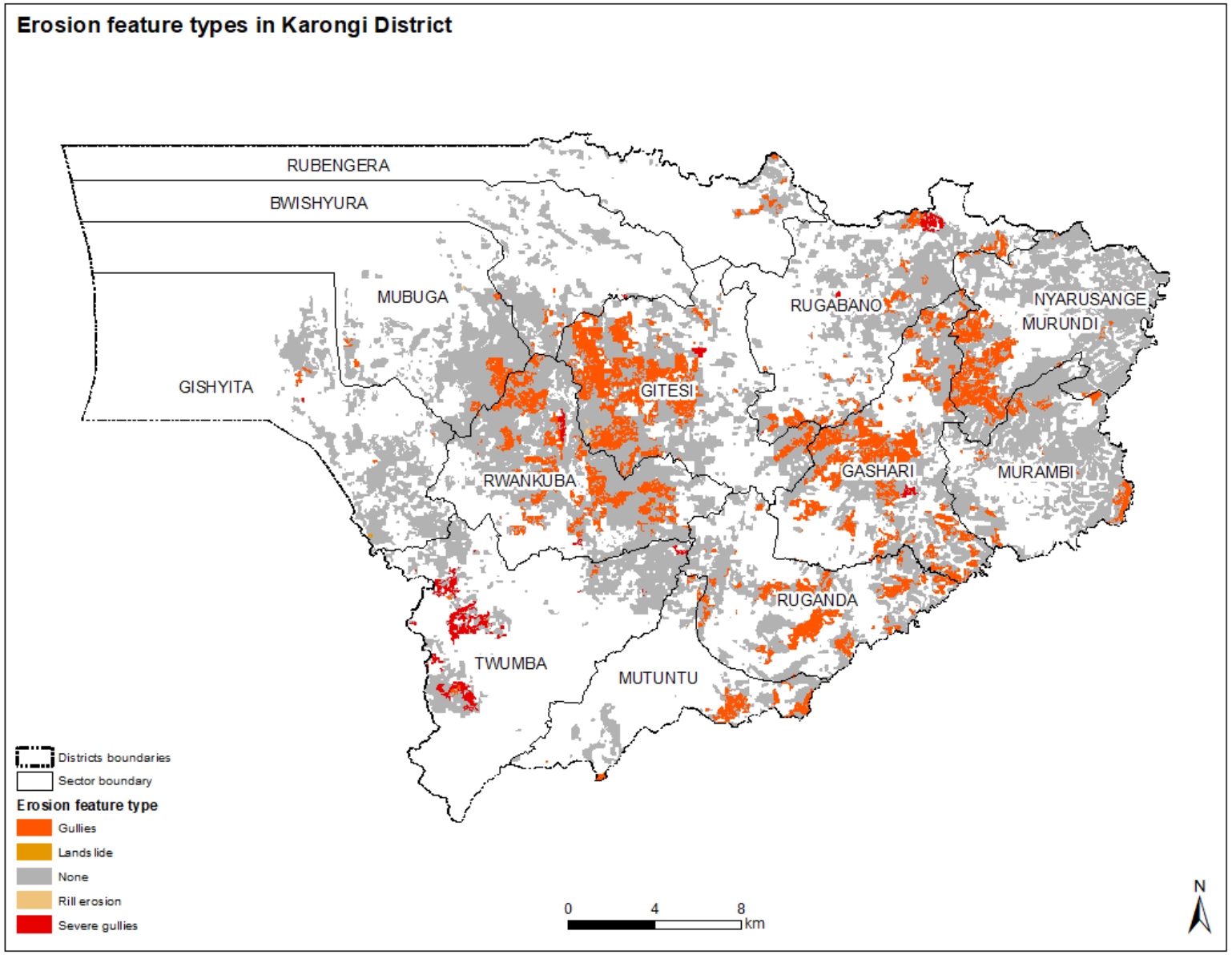


Figure 29: Erosion features detected in Karongi District

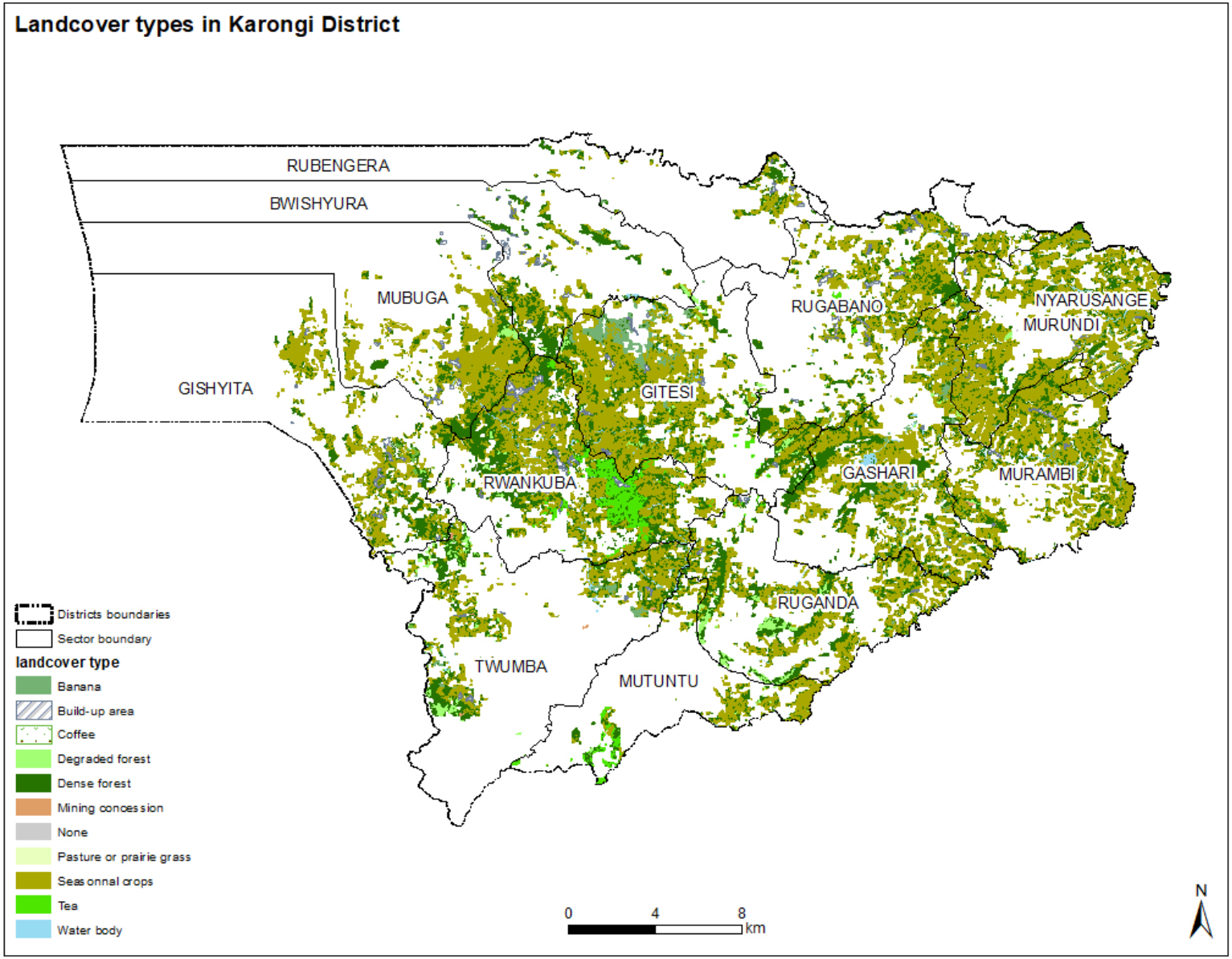


Figure 30: Land cover types in Karongi District

About existing erosion control practices in Karongi district, Table 30 indicates that 32% of land at risk is protected by forests (10,061 hectares), contour bank terraces or progressive terraces with ditches (426 hectares), and bench terraces (444 hectares). The highest protected sectors are Rubengera with 68% of its land at risk protected, followed by Bwishyura where 49% of the total land at risk is protected and Ruganda and Twumba with 39% of land protected. The least protected sectors are Mubuga with only 22% protected, Gitesi (only 24% protected), Murundi (25%) and Murambi (27% protected). The visual interpretation of World View images confirms earlier findings by CROM model that Mubuga, Gitesi, Murundi and Murambi sectors remain at very high risk of soil erosion since more than 70% of the sector land at risk are not protected.

Table 30: Erosion control practices already in place in Karongi District

Sector name	Erosion control techniques in place				Unprotected	Grand Total	% protected
	Bench terraces	Contour bank terraces	Forests	Total protected			
RUBENGERA	116	14	185	316	146	462	68%
BWISHYURA			587	587	621	1,208	49%
RUGANDA	94	2	993	1,089	1,698	2,788	39%
TWUMBA	39	59	768	867	1,384	2,251	39%
RUGABANO	39	101	926	1,066	1,822	2,888	37%
RWANKUBA	16	89	1,455	1,560	2,993	4,553	34%
GISHYITA		2	602	604	1,302	1,906	32%
GASHARI	55	8	1,150	1,213	2,714	3,927	31%
MUTUNTU	29	0	266	294	688	982	30%
MURAMBI	12	32	740	784	2,173	2,957	27%
MURUNDI	34	72	932	1,038	3,136	4,174	25%
GITESI	10	45	1,028	1,083	3,351	4,434	24%
MUBUGA			430	430	1,566	1,995	22%
Grand Total	**444**	**426**	**10,061**	**10,931**	**23,594**	**34,525**	**32%**

Erosion control practices in Karongi District are recommended based on existing land uses, erosion control measures already in place, and predicted erosion risk by CROM model. Table 31 shows that about 18,249 hectares (which is 53% of the total land at risk) are suitable for Contour bank terraces, 1,561 hectares are cropland that needs agroforestry/alley cropping (656 hectares) and 826 hectares are afforestation and reforestation. Others are gullies or riverbanks amounting to 769 hectares eroded which require bamboo trees for rehabilitation, contour bank (693 hectares) and bench terraces (406 hectares).

Table 31: Recommended erosion control practices in Karongi District

Sector Name	Afforestation & Refore-station	Agrofo-restry	Bamboo gullies & riverside	Bench terraces	Contour bank	Contour bank terraces	Hedgerows	No till	SWMF	None	Total
BWISHYURA	26	41	10			483		14	47	587	1,208
GASHARI	60	16	119	31	134	2,377	37	62	2	1,088	3,927
GISHYITA	26	71	3			1,146	2	11	38	607	1,906
GITESI	108	1	35	20	353	2,803	11	39	35	1,027	4,434
MUBUGA	40	263	9	1		1,197		3	52	430	1,995
MURAMBI	27	167	29	9		1,896	44	24	23	739	2,957
MURUNDI	28	481	36	26	1	2,468	106	63	27	940	4,174
MUTUNTU	39	2	12	21		507	29	107		266	982
RUBENGERA	7	16	9	36		60	131	6	12	185	462
RUGABANO	48	33	11	29	81	1,568	97	89	83	848	2,888
RUGANDA	212	55	35	151	34	1,190	94	17	10	991	2,788
RWANKUBA	52	384	67	26		1,871	38	540	110	1,465	4,553
TWUMBA	154	30	391	56	89	684	58	3	21	766	2,251
Grand Total	**826**	**1,561**	**769**	**406**	**693**	**18,249**	**647**	**977**	**458**	**9,939**	**3,4525**
Percentage	**2%**	**5%**	**2%**	**1%**	**2%**	**53%**	**2%**	**3%**	**1%**	**29%**	**100%**

Note: Grassed waterways are recommended for existing terraces (see Table 10) which was made without waterways or with but no grasses which can cause severe gullies and destruction of bench terraces created. No-till agriculture is recommended is recommended for perennial crops on extremely high risk area while Storm water management facilities (SWMF) or water harvesting infrastructure is recommended in built-up areas. None: means no-recommendation is provided because existing erosion control measures are adequate with reference made to the total land protected. Contour banks are recommended for existing forest without ditches. Bamboos are recommended to close gullies or for riverside buffers.

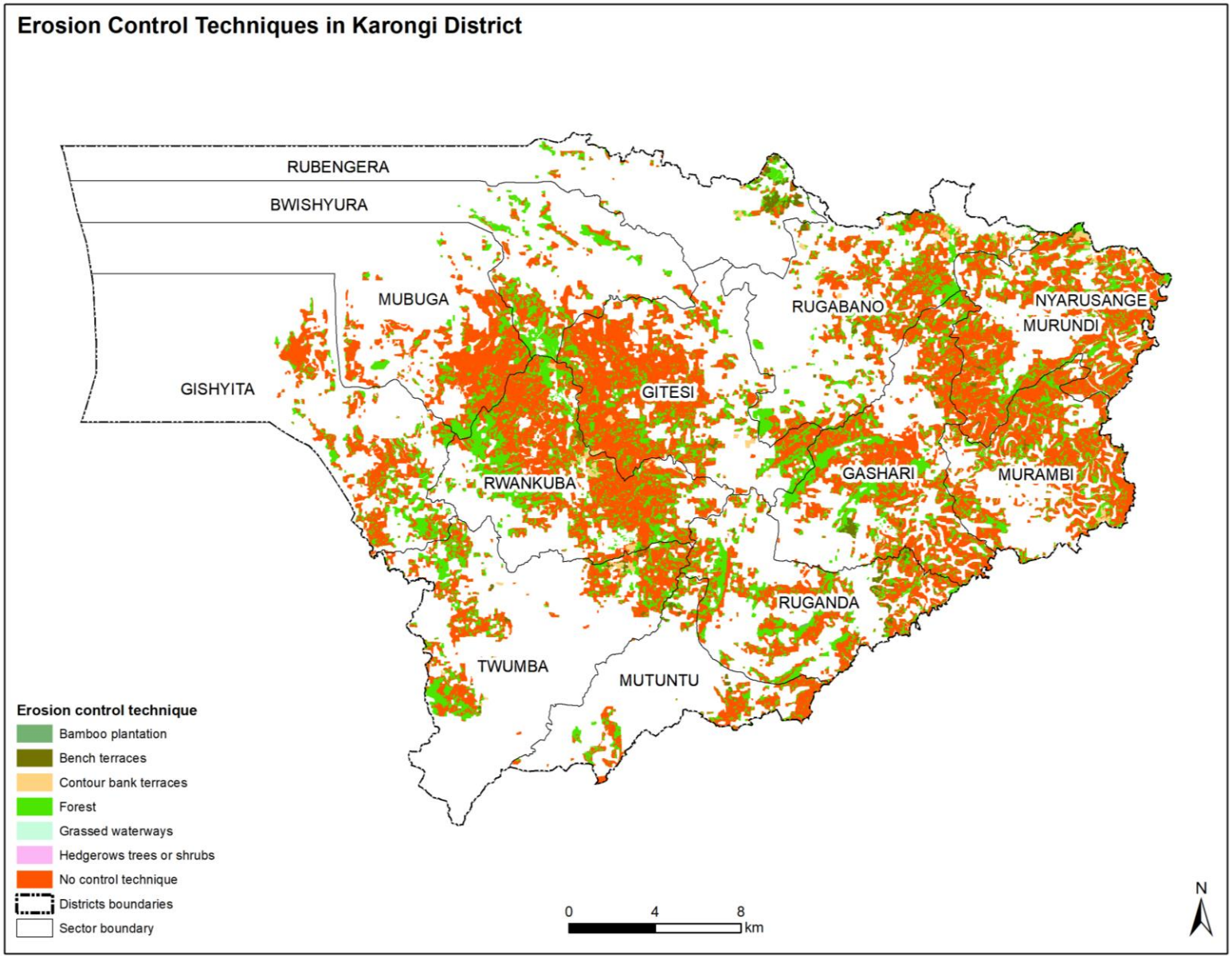


Figure 31: Erosion control techniques in place in Karongi District

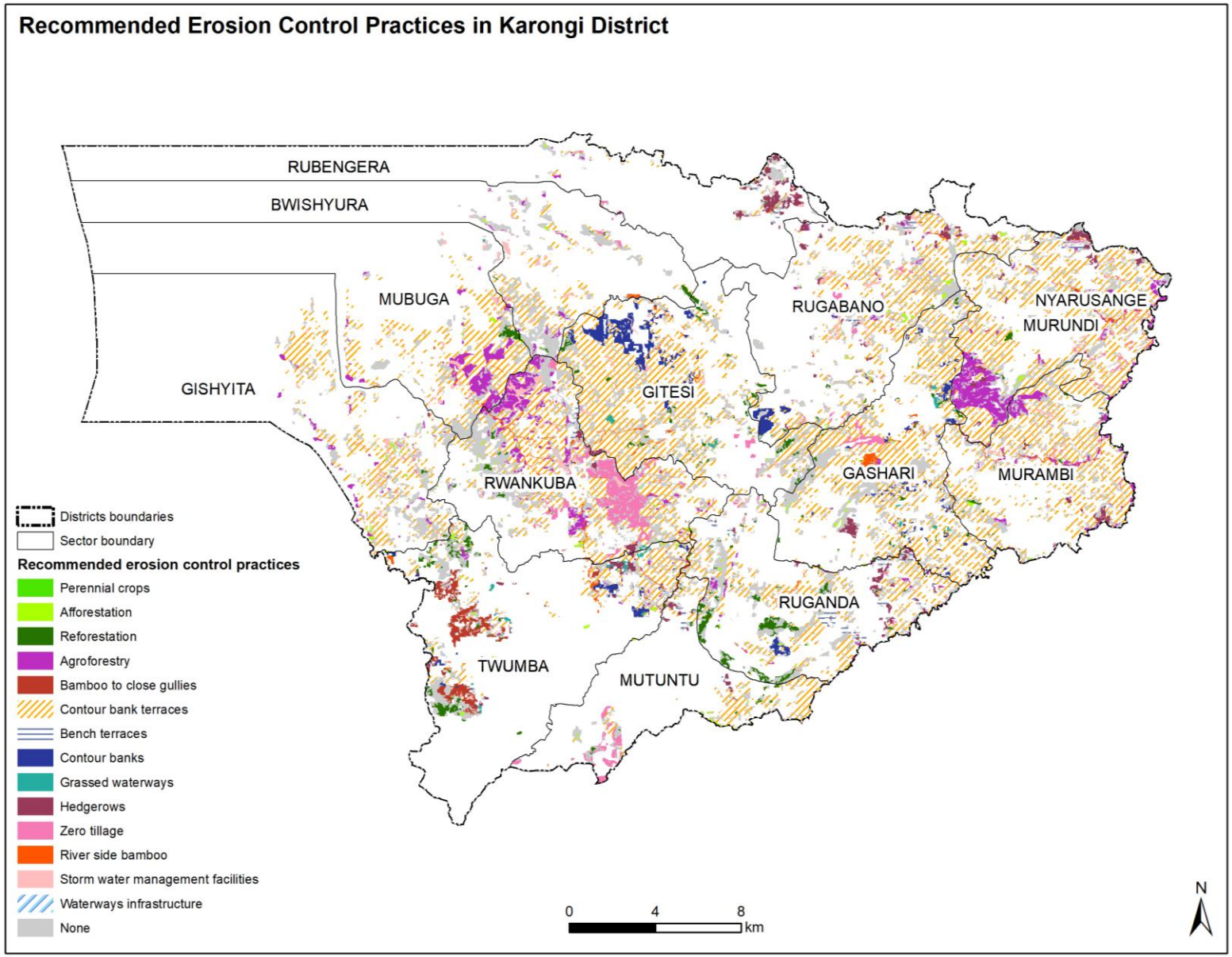


Figure 32: Recommended erosion control practices in Karongi District

3.2.2. Erosion control status in Ngororero District

Soil erosion risk in Ngororero is summarised in Table 32 and presented in Figure 33. Land area at risk is estimated to 41,450 hectares; about 61% of the total district land. Sovu sector is the highest susceptible to erosion with 4,686 hectares (86% of the sector land), followed by Ndaro sector with 4,687 hectares (85% of sector land), Muhororo sector with 3,014 hectares (81% of the sector land), Bwira sector with 3,122 hectares, 81% of the sector land, Kavumu with 4,412 hectares (78% of the sector land) among others. The least affected sectors (but still high) are Matyazo with 900 hectares susceptible to erosion (about 22% of sector land), and Hindiro sector with 996 hectares about 28% of the total sector land.

Table 32: Erosion risk per sector in Ngororero District

SN	Sector Name	Erosion risk				Sector land (ha)	%
		Extremely high	High	Very high	Total (Ha)		
1.	SOVU	1,899	949	1,838	4,686	5,463	86%
2.	NDARO	1,388	1,301	1,998	4,687	5,516	85%
3.	MUHORORO	432	1,478	1,103	3,014	3,721	81%
4.	BWIRA	619	1,340	1,163	3,122	3,862	81%
5.	KAVUMU	1,072	1,093	2,247	4,412	5,649	78%
6.	NYANGE	827	1,590	1,441	3,859	5,406	71%
7.	GATUMBA	529	1,178	1,146	2,853	4,388	65%
8.	KABAYA	148	2,048	832	3,028	4,983	61%
9.	KAGEYO	334	1,609	1,166	3,108	5,183	60%
10.	MUHANDA	635	2,277	2,033	4,945	10,836	46%
11.	NGORORERO	184	1,108	549	1,841	5,324	35%
12.	HINDIRO	82	763	151	996	3,500	28%
13.	MATYAZO	112	544	244	900	4,068	22%
	TOTAL	**8,260**	**17,278**	**15,912**	**41,450**	**67,899**	**61%**

Land areas affected by soil erosion features in Ngororero District as reflected on World View images are summarized in Table 33 and the map of erosion features are presented in Figure 34. The results show that Muhanda sector is the worst affected by gullies on areas estimated to 279 hectares (6% of sector land at risk), followed by Gatumba sector on 110 hectares (4% of sector land at risk), and Ndaro sector on 174 hectares (4% of sector land at risk). The presence of gullies in Muhanda, Gatumba, Ndaro, and Muhororo sectors confirms the findings of CROM model; however the reduced presence of gullies in Kabaya (1ha) and Hindiro (8 ha) which was originally predicted by CROM model as sector at high risk should not read that CROM model did not perform well in this sectors, but rather due to the time of image acquisition, the erosion features could be observed or erosion control measures have been already taken and therefore runoffs have been reduced, thus erosion features could not be formed in this case. Further analysis will demonstrate that in Table 35 and 36. The least sectors affected by gullies are Kabaya with only 1 hectare, Hindiro with only 8 hectares and Matyazo with 8 hectares affected by gullies.

Table 33: Erosion features types and land area affected in Ngororero District

`Sector Name	Erosion feature types					None	Grand Total	% Features
	Gullies	Landslide	Rill erosion	Severe gullies	Total			
MUHANDA	148		2	130	279	4,666	4,945	6%
GATUMBA	43	2		65	110	2,743	2,853	4%
NDARO	19		0	155	174	4,512	4,687	4%
MUHORORO	26			86	111	2,903	3,014	4%
SOVU	11	1	0	82	94	4,592	4,686	2%
KAVUMU	63	17		6	87	4,325	4,412	2%
KAGEYO	19	5	12	22	58	3,050	3,108	2%
NGORORERO	19	0	2	12	33	1,808	1,841	2%
BWIRA	17		4	11	32	3,090	3,122	1%
MATYAZO			8		8	892	900	1%
NYANGE	7		0	26	33	3,826	3,859	1%
HINDIRO	5		3		8	988	996	1%
KABAYA	0	1	0	0	1	3,027	3,028	0%
Grand Total	**377**	**27**	**30**	**595**	**1,029**	**40,421**	**41,450**	**2%**

In term of land use and related management of areas at risk in Ngororero District, the results of land cover mapping (Table 34 and Figure 35) show 26,688 hectares (64% of the total land at risk) are used for seasonal cropping, 7,069 hectares (17% of the total land at risk) are covered by healthy forests, 1,430 hectares (3% of the total land at risk) are covered by built-up area and 1,390 hectares are covered by Banana crop. To be noted that mining concession is covering an area of 1,396 hectares (3% of the total land at risk) and that tea is covering an area of 1% of the land at risk.

Table 34: Land Use and Vegetation Cover (LUVC) of areas at risk in Ngororero District

Sector name	Banana	Build-up area	Degraded forest	Dense forest	Mining concession	Seasonal crops	Tea	Water body	Total
BWIRA	17	104	88	610	31	2,097		174	3,122
GATUMBA	114	91	102	429	114	1,799		204	2,853
HINDIRO	13	18	5	184	13	691	3	69	996
KABAYA		179	7	596	6	2,156	47	37	3,028
KAGEYO	6	119	29	574	17	2,202	32	129	3,108
KAVUMU	23	253	49	780	30	3,086	86	104	4,412
MATYAZO	343	8	0	136	0	339		73	900
MUHANDA		150	84	745	911	2,604	280	172	4,945
MUHORORO	194	74	19	483	49	2,095		98	3,014
NDARO	214	78	316	791	140	2,853		295	4,687
NGORORERO	266	105	11	286	27	1,029		116	1,841
NYANGE	199	67	391	537	41	2,455		168	3,859
SOVU	3	183	35	917	17	3,282	101	149	4,686

Grand Total	**1,390**	**1,430**	**1,137**	**7,069**	**1,396**	**26,688**	**549**	**1,791**	**41,450**

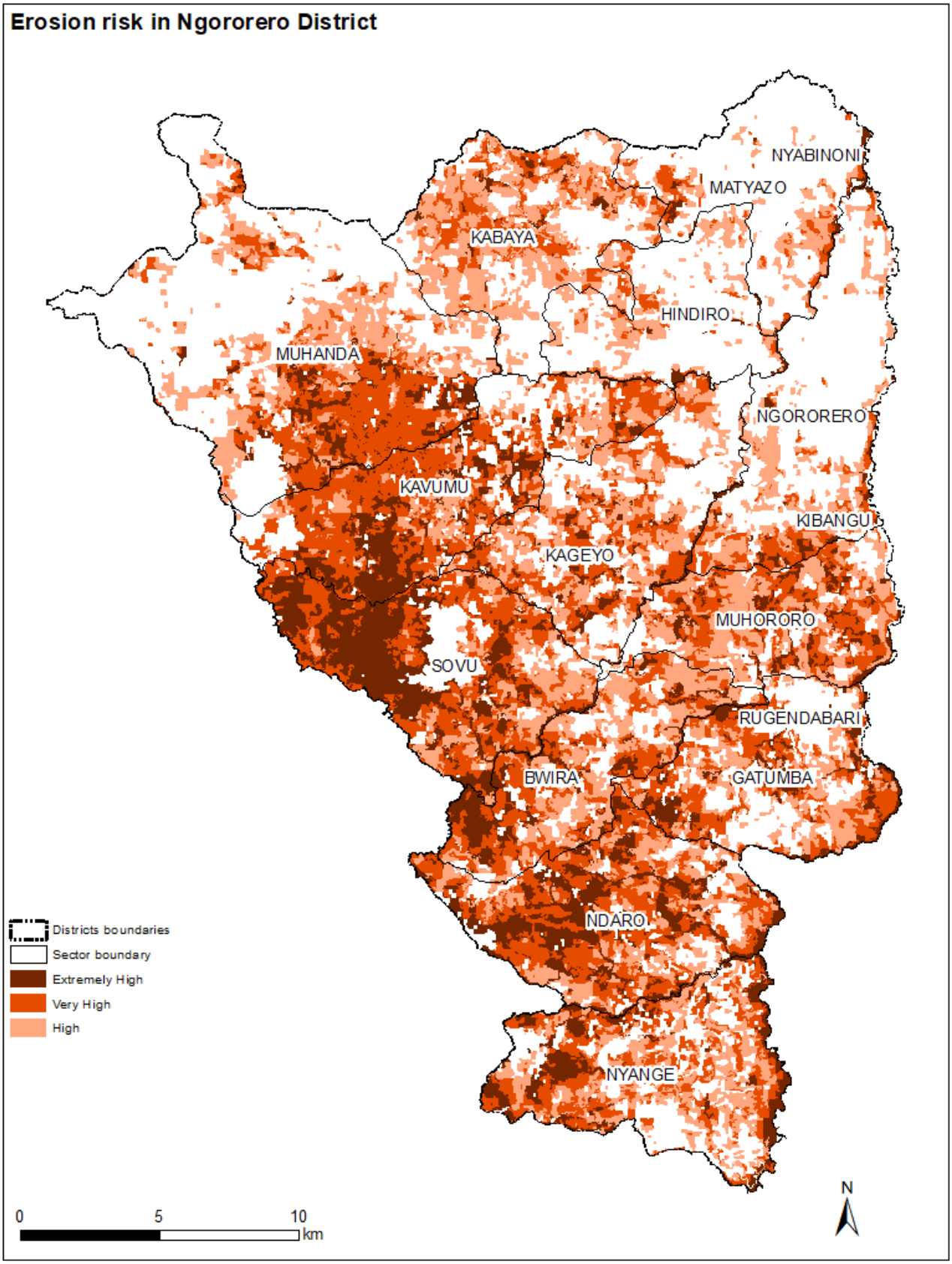


Figure 33: Erosion risk in Ngororero District

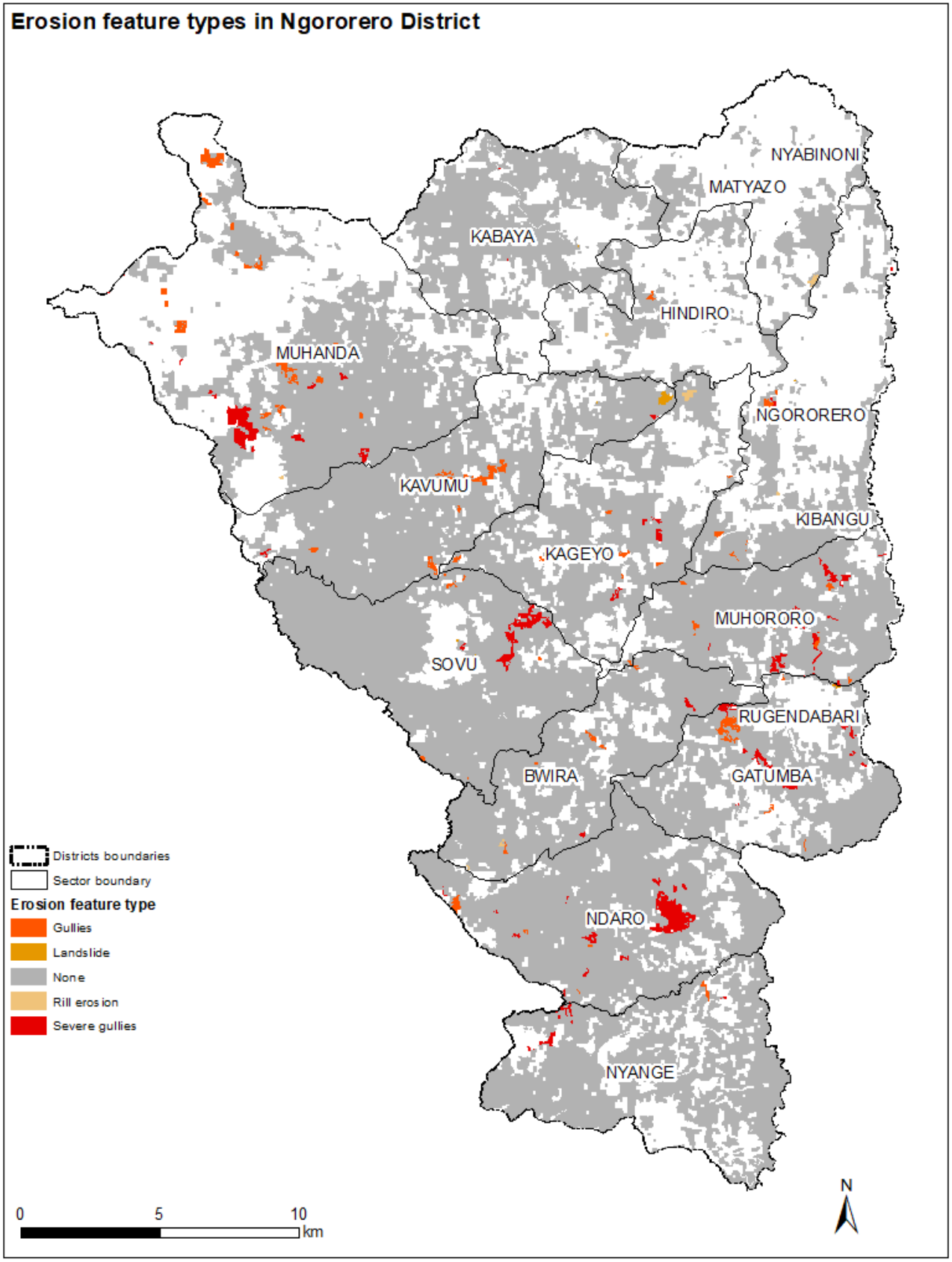


Figure 34: Erosion features detected in Ngororero District

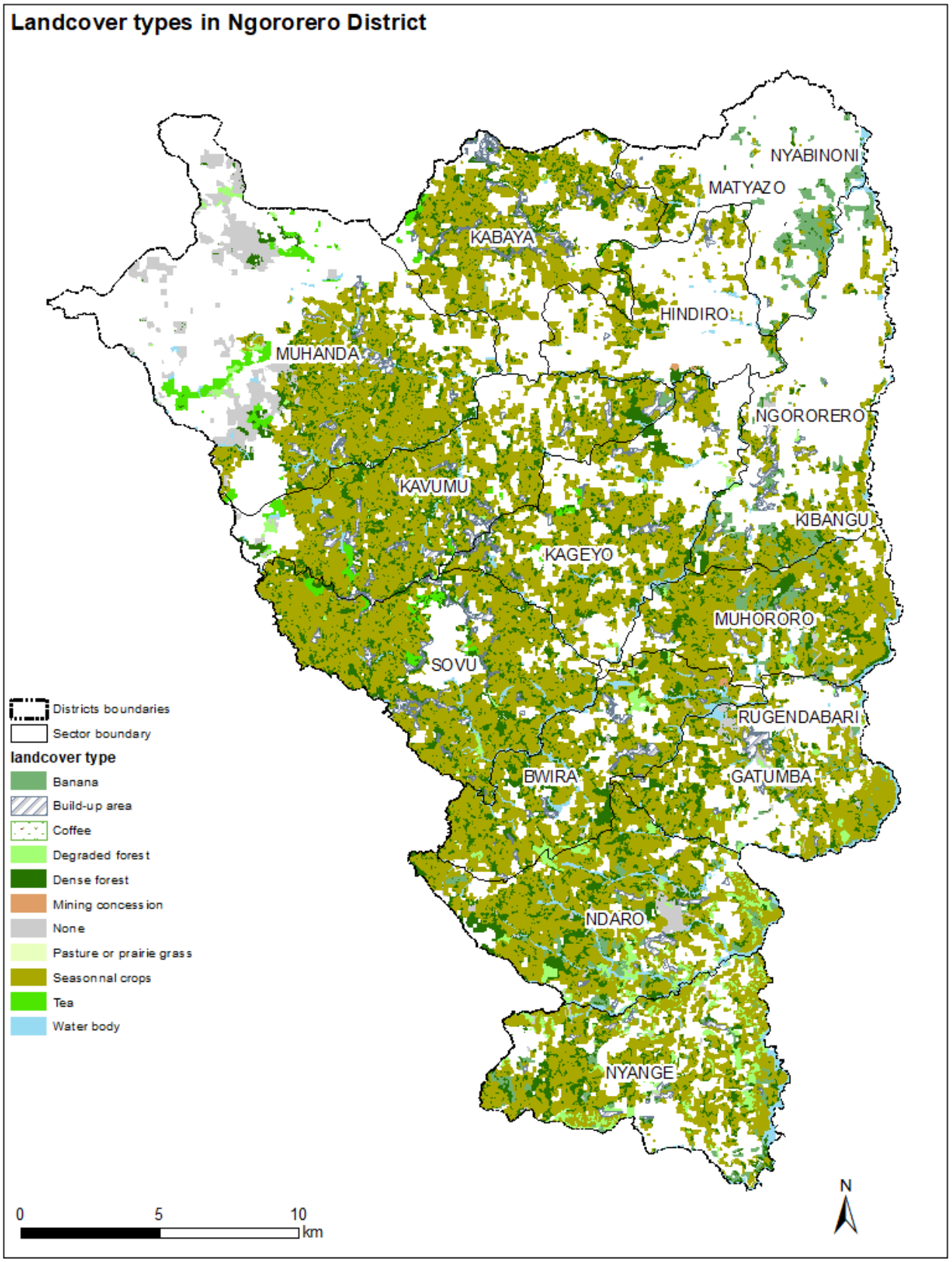


Figure 35: Land cover types in Ngororero District

About existing erosion control practices in Ngororero district, Table 35 shows that only 24% of land at risk is protected by forests (7,090 hectares), contour bank terraces or progressive terraces with ditches (54 hectares), and bench terraces (2,776 hectares). The highest protected sectors are Sovu with 32% of its land at risk protected, followed by Nyange where 32% of the total land at risk is protected and Muhororo with 30% of land protected. The least protected sectors are Muhanda with only 16% protected, Matyazo (only 16% protected), Ngororero (17%) and Gatumba (19% protected). The visual interpretation of World View images confirms earlier findings by CROM model that Muhanda, Matyazo, Ngororero and Gatumba sectors remain at very high risk of soil erosion since more than 80% of the sector land at risk are not protected.

Table 35: Erosion control practices already in place in Ngororero District

Sector name	Erosion control techniques in place				Unprotected	Grand Total	% protected
	Bench terraces	Contour bank terraces	Forests	Total protected			
SOVU	568	0	910	1,478	3,208	4,686	32%
NYANGE	656	24	537	1,217	2,642	3,859	32%
MUHORORO	408	11	483	902	2,112	3,014	30%
KABAYA	275		596	871	2,157	3,028	29%
KAGEYO	224		577	801	2,307	3,108	26%
BWIRA	184		619	802	2,319	3,122	26%
HINDIRO	27		188	215	781	996	22%
KAVUMU	150	0	788	938	3,473	4,412	21%
NDARO	110	17	794	921	3,766	4,687	20%
GATUMBA	92	2	434	528	2,325	2,853	19%
NGORORERO	34	0	287	321	1,520	1,841	17%
MATYAZO	9		136	145	755	900	16%
MUHANDA	39	0	741	780	4,166	4,945	16%
Grand Total	**2,776**	**54**	**7,090**	**9,920**	**31,530**	**41,450**	**24%**

Erosion control practices in Ngororero District are recommended based on existing land uses, erosion control measures already in place, and predicted erosion risk by CROM model. Table 36 shows that about 12,579 hectares (which is 30% of the total land at risk) are suitable for Contour bank terraces, 9,679 hectares are bench terraces (9,679 hectares) and 2,774 hectares are hedgerows. Others are gullies or riverbanks amounting to 2,638 hectares eroded which require bamboo trees for rehabilitation, Afforestation & Reforestation (2000 hectares), cropland that need agroforestry/alley cropping (1,294 hectares) and Storm water management facilities (SWMF) (1,442 hectares).

Table 36: Recommended erosion control practices in Ngororero District

Sector Name	Afforestation & Reforestation	Agroforestry	Bamboo for gullies & riverside	Bench terraces	Contour bank terraces	Hedgerows	No till	SWMF	None	Total
BWIRA	107	96	202	373	1,429	180	17	108	610	3,122
GATUMBA	104	92	317	97	1,515	94	114	91	429	2,853
HINDIRO	33	13	74	313	317	27	16	18	184	996
KABAYA	38	51	37	1,581	222	275	47	179	597	3,028
KAGEYO	47	71	162	1,108	768	222	35	120	574	3,108
KAVUMU	79	123	136	2,195	586	150	109	253	780	4,412
MATYAZO	0	11	73	84	234	9	343	8	136	900
MUHANDA	681	191	378	1,631	851	39	280	150	745	4,945
MUHORORO	36	45	213	532	1,018	419	194	74	483	3,014
NDARO	357	303	445	309	2,069	120	214	78	791	4,687
NGORORERO	30	48	149	14	905	33	266	109	286	1,841
NYANGE	415	178	202	45	1,541	639	200	67	571	3,859
SOVU	73	71	250	1,397	1,123	567	104	186	917	4,686
Grand Total	**2,000**	**1,294**	**2,638**	**9,679**	**12,579**	**2,774**	**1,939**	**1,442**	**7,104**	**41,450**
Percentage	**5%**	**3%**	**6%**	**23%**	**30%**	**7%**	**5%**	**3%**	**17%**	**100%**

Note: Grassed waterways are recommended for existing terraces which was made without waterways or with but no grasses which can cause severe gullies and destruction of bench terraces created. No-till agriculture is recommended is recommended for perennial crops on extremely high risk area while Storm water management facilities (SWMF) or water harvesting infrastructure is recommended in built-up areas. None: means no-recommendation is provided because existing erosion control measures are adequate with reference made to the total land protected. Contour banks are recommended for existing forest without ditches. Bamboos are recommended to close gullies or for riverside buffers.

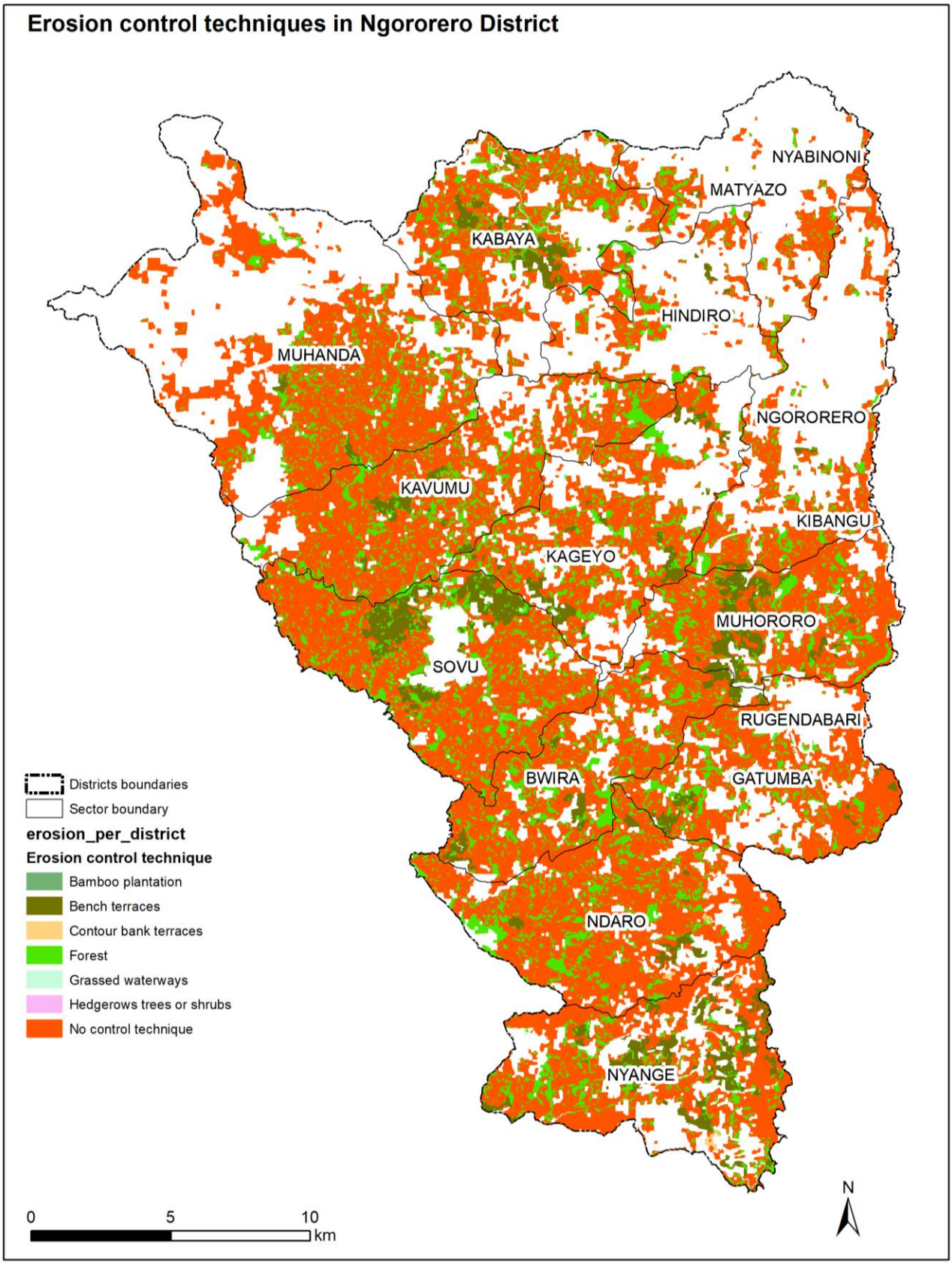


Figure 36: Erosion control techniques in place in Ngororero District

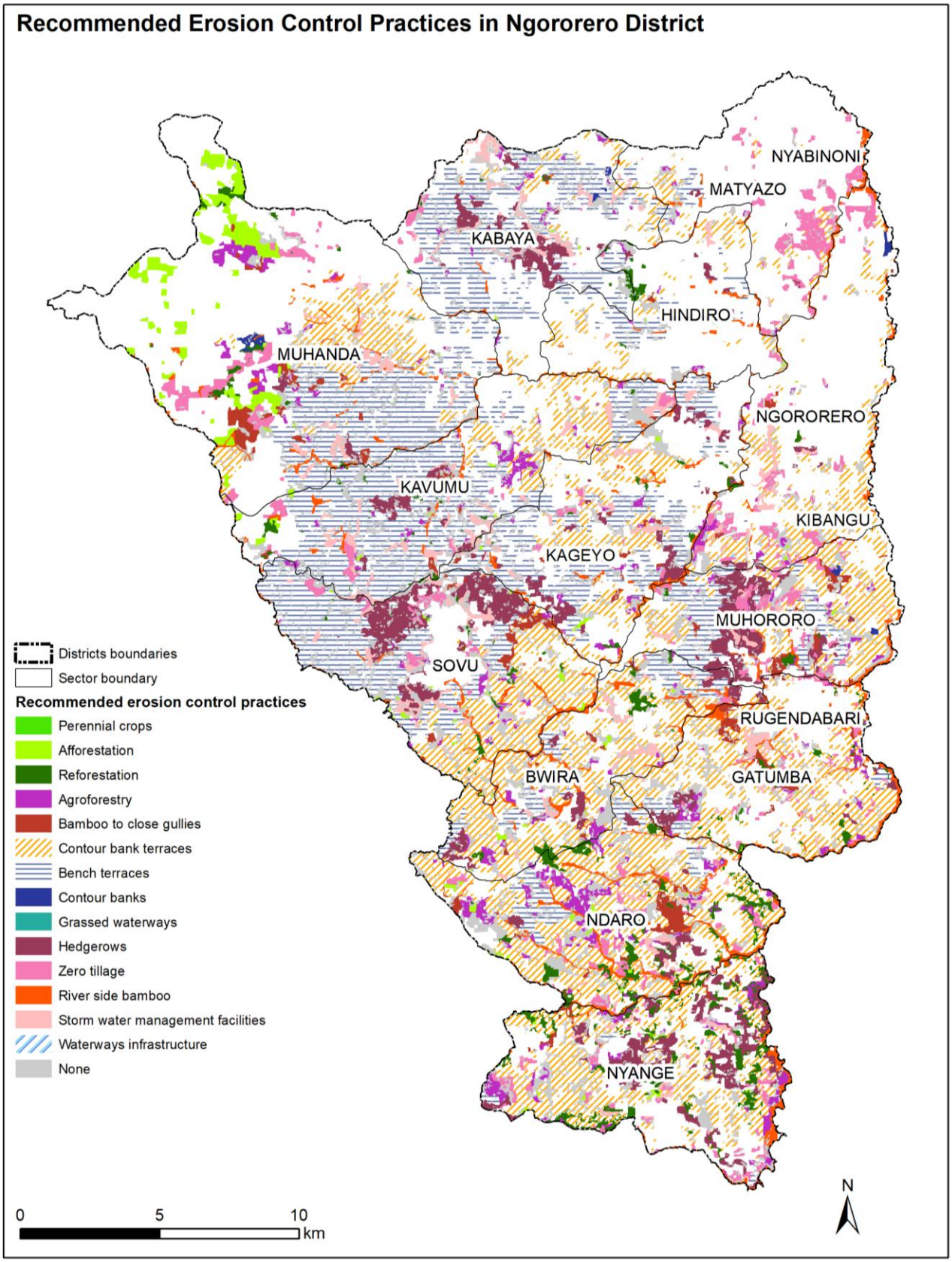


Figure 37: Recommended erosion control practices in Ngororero District

3.2.3. Erosion control status in Nyabihu District

Soil erosion risk in Nyabihu is summarised in Table 42 and presented in Figure 38. Land area at risk is estimated to 18,354 hectares; about 35% of the total district land. Muringa sector is the highest susceptible to erosion with 4,311 hectares (58% of the sector land), followed by Rurembo sector with 1,993 hectares (50% of sector land), Rambura sector with 2,833 hectares (49% of the sector land), Karago sector with 1,528 hectares, 42% of the sector land, Kintobo sector with 1,146 hectares (41% of the sector land) and Rugera sector with 1,640 hectares (40% of the sector land). The least affected sectors are Jenda with 1,640 hectares susceptible to erosion (about 11% of sector land), and Bigogwe sector with 743 hectares about 16% of the total sector land.

Table 37: Erosion risk per sector in Nyabihu District

SN	Sector Name	Erosion risk				Sector land (ha)	%
		Extremely high	High	Very high	Total (Ha)		
1.	MURINGA	938	1,254	2,119	4,311	7,473	58%
2.	RUREMBO	238	1,009	745	1,993	4,006	50%
3.	RAMBURA	257	1,508	1,068	2,833	5,726	49%
4.	KARAGO	124	944	460	1,528	3,679	42%
5.	KINTOBO	151	594	401	1,146	2,813	41%
6.	RUGERA	181	920	539	1,640	4,117	40%
7.	JOMBA	64	797	394	1,255	3,506	36%
8.	MUKAMIRA	47	539	275	861	3,436	25%
9.	SHYIRA	35	516	102	654	3,378	19%
10.	KABATWA	102	449	333	883	5,235	17%
11.	BIGOGWE	181	264	298	743	4,773	16%
12.	JENDA	16	401	91	507	4,814	11%
	TOTAL	**2,334**	**9,195**	**6,824**	**18,354**	**52,958**	**35%**

Land areas affected by soil erosion features in Nyabihu District are summarized in Table 38 and the map of erosion features are presented in Figure 39. The results show that Muringa sector is the worst affected by gullies on areas estimated to 878 hectares (20% of sector land at risk), followed by Rurembo sector on 341 hectares (17% of sector land at risk), and Jomba sector on 150 hectares (12% of sector land at risk). The presence of gullies and rill erosion in Muringa, Rurembo, Jomba, Kintobo and Rambura sectors confirms the findings of CROM model; however the reduced presence of gullies in Mukamira (1ha) and Bigogwe (12 ha) and the absence of erosion features in Kabatwa and Jenda which was originally predicted by CROM model as sector at high risk should not read that CROM model did not perform well in this sectors, but rather due to the time of image acquisition, the erosion features could be observed or erosion control measures have been already taken and therefore runoffs have been reduced, thus erosion features could not be formed in this case. Further analysis will demonstrate that in Table 14 and 15. The least sectors affected by gullies and rill erosion are Kabatwa (0 hectare), Jenda (0 hectare), Mukamira with only 1 hectare and Bigogwe with 8 hectares affected by gullies.

Table 38: Erosion features types and areas affected in Nyabihu District

Sector Name	Erosion feature types					None	Grand Total	% Features
	Gullies	Landslide	Rill erosion	Severe gullies	Total			
MURINGA	182	5	530	162	878	3,433	4311	20%
RUREMBO	26		288	27	341	1,651	1993	17%
JOMBA	18	2	129		150	1,106	1255	12%
KINTOBO	6		52	9	67	1,079	1146	6%
RAMBURA	35	7	36	52	130	2,702	2833	5%
SHYIRA	5		13	9	27	627	654	4%
RUGERA	25		27	0	51	1,588	1640	3%
KARAGO	5		5	17	26	1,502	1,528	2%
BIGOGWE	5			7	12	731	743	2%
MUKAMIRA	1				1	860	861	0%
JENDA					0	507	507	0%
KABATWA					0	883	883	0%
Grand Total	**306**	**14**	**1,080**	**283**	**1,684**	**16,669**	**18,354**	**9%**

In term of land use and related management of areas at risk in Nyabihu District, the results of land cover mapping (Table 39 and Figure 40) show 12,377 hectares (67% of the total land at risk) are used for seasonal cropping, 2,433 hectares (13% of the total land at risk) are covered by healthy forests, 945 hectares (5% of the total land at risk) are covered by built-up area. To be noted that mining concession is covering an area of 1,219 hectares (6% of the total land at risk) and that tea is covering an area of 675 hectares 3% of the land at risk.

Table 39: Land Use and Vegetation Cover (LUVC) of areas at risk in Nyabihu District

Sector name	Build-up area	Degraded forest	Dense forest	Mining concession	Seasonal crops	Tea	Water body	Total
BIGOGWE	78	28	8	17	332	280		743
JENDA	13		42	4	447			507
JOMBA	20	21	216	12	956		30	1,255
KABATWA	132	0	54	1	696			883
KARAGO	58	2	186	32	1,217	7	26	1,528
KINTOBO	73	43	217	39	766	1	7	1,146
MUKAMIRA	39	5	100	63	651	1	2	861
MURINGA	335	72	486	604	2,485	253	74	4,311
RAMBURA	117	90	430	321	1,713	133	29	2,833
RUGERA	35	72	272	25	1,220		15	1,640
RUREMBO	38	115	304	97	1,395		44	1,993
SHYIRA	6	6	117	4	498		23	654
Total	**945**	**455**	**2,433**	**1,219**	**12,377**	**675**	**250**	**18,354**

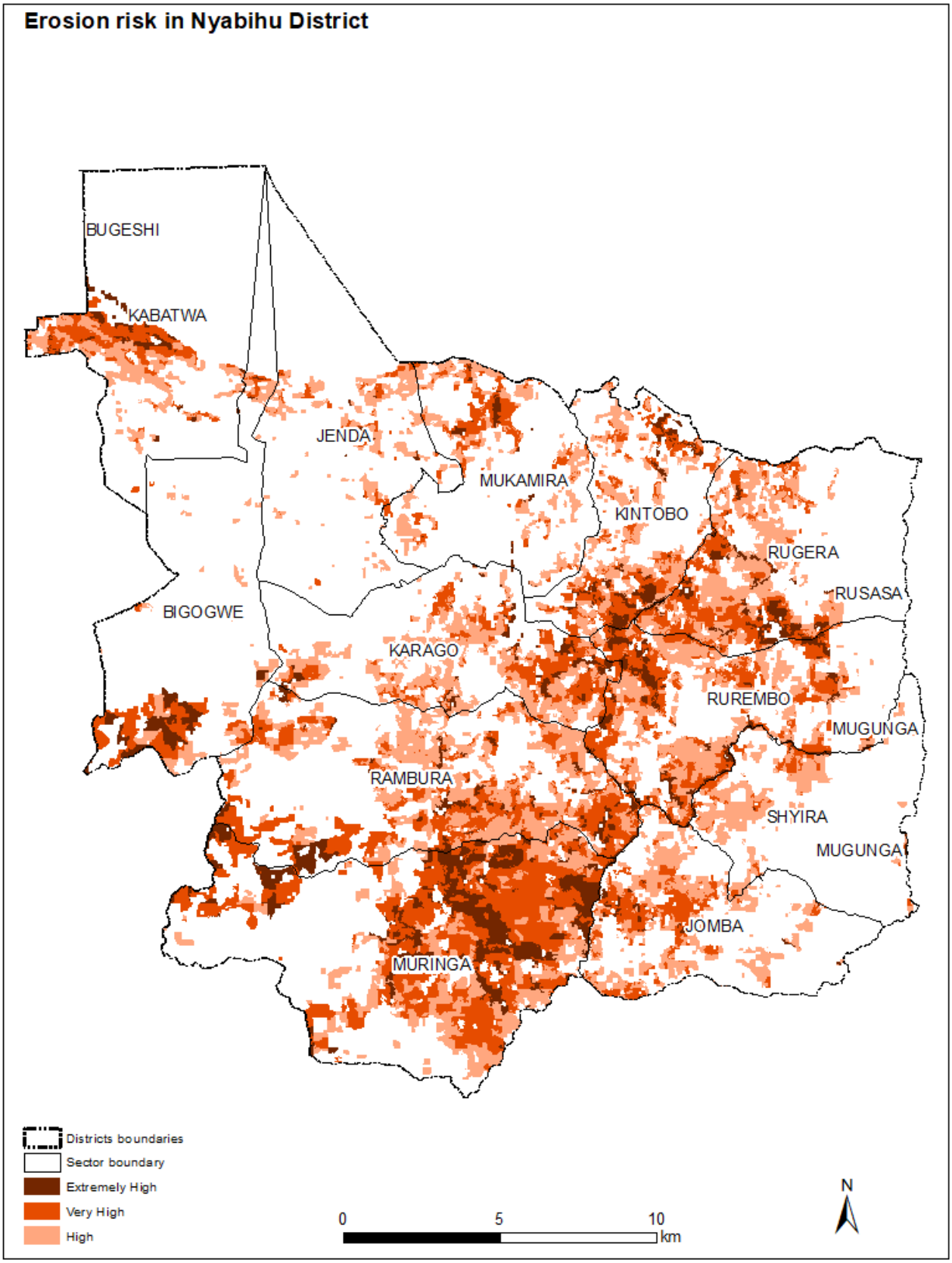


Figure 38: Erosion risk in Nyabihu District

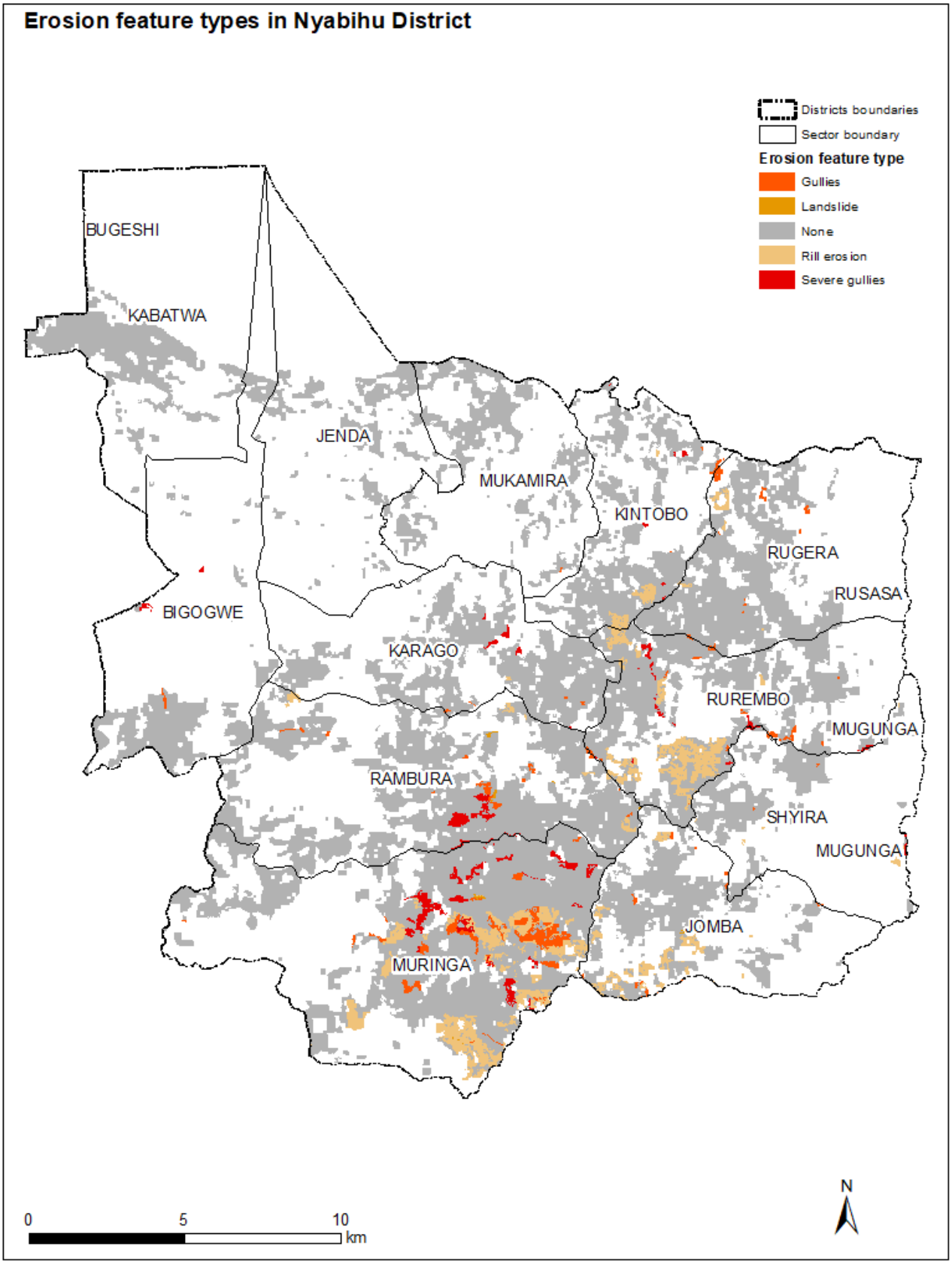


Figure 39: Erosion features detected in Nyabihu District

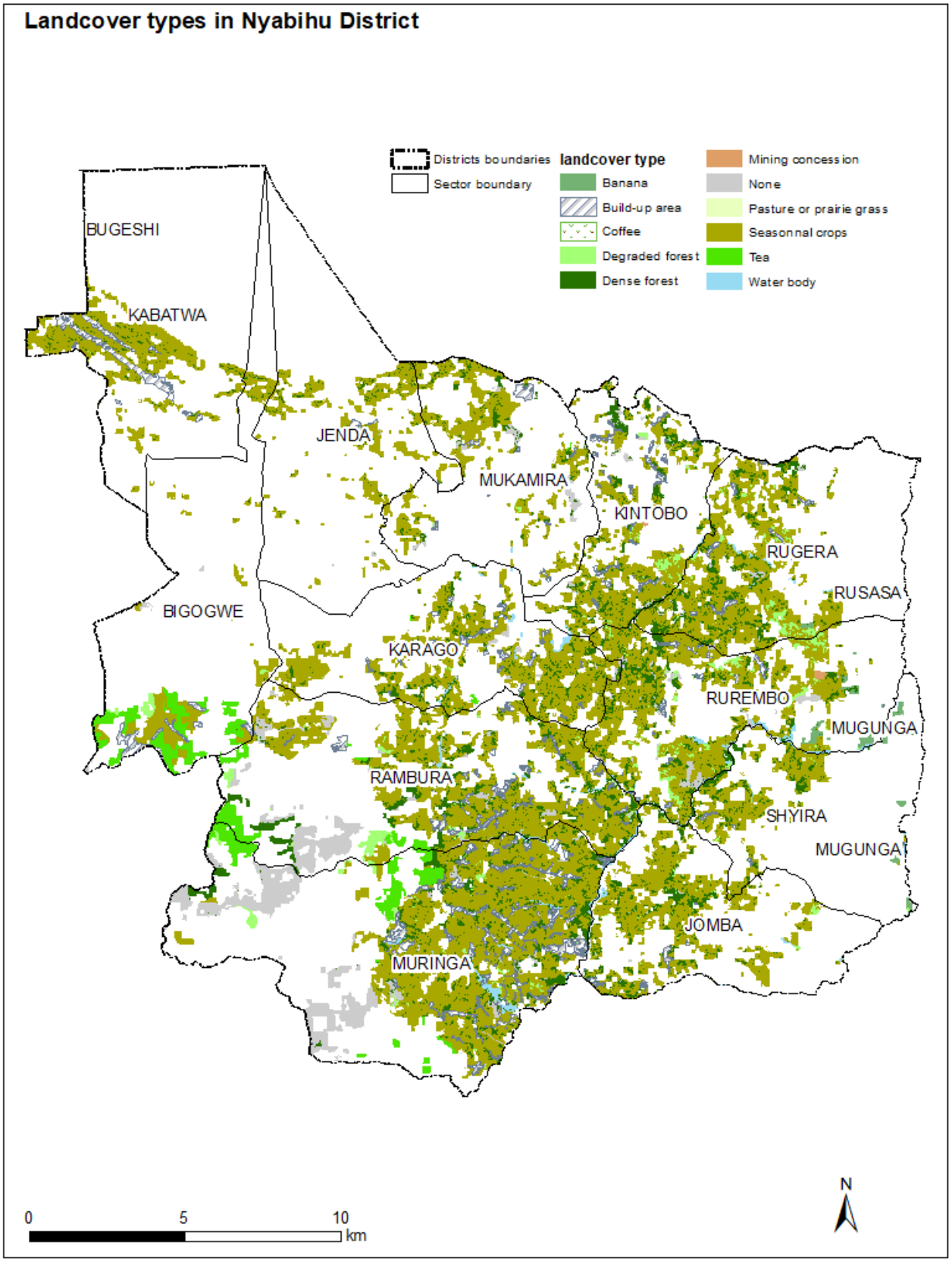


Figure 40: Land cover types in Nyabihu District

About existing erosion control practices in Nyabihu district, Table 40 shows that only 31% of land at risk is protected by forests (2,506 hectares), contour bank terraces or progressive terraces with ditches (237 hectares), and bench terraces (2,953 hectares). The highest protected sectors are Rambura with 52% of its land at risk protected, followed by Muringa where 36% of the total land at risk is protected and Bigogwe with 36% of land protected. The least protected sectors are Jenda with only 14% protected, Rugera (only 17% protected), Rurembo (18%) and Kabatwa (22% protected). The visual interpretation of World View images confirms earlier findings by CROM model that Jenda, Rugera, Rurembo and Kabatwa sectors remain at very high risk of soil erosion since more than 70% of the sector land at risk are not protected.

Table 40: Erosion control practices already in place in Nyabihu District

Sector name	Erosion control techniques in place				Unprotected	Grand Total	% protected
	Bench terraces	Contour bank terraces	Forest	Total protected			
RAMBURA	1,126		432	1,558	1,275	2,833	55%
MURINGA	860	166	545	1,570	2,741	4,311	36%
BIGOGWE	257		8	265	478	743	36%
KARAGO	299	11	187	496	1,032	1,528	32%
KINTOBO	39	19	221	279	867	1,146	24%
SHYIRA	4	32	117	153	501	654	23%
MUKAMIRA	93		100	193	668	861	22%
JOMBA	60	5	216	280	975	1,255	22%
KABATWA	139		54	193	690	883	22%
RUREMBO	54	3	307	364	1,629	1,993	18%
RUGERA			272	272	1,368	1,640	17%
JENDA	21	3	47	71	436	507	14%
Grand Total	**2,953**	**237**	**2,506**	**5,696**	**12,658**	**18,354**	**31%**

Erosion control practices in Nyabihu District are recommended based on existing land uses, erosion control measures already in place, and predicted erosion risk by CROM model. Table 41 shows that about 5,978 hectares (which is 33% of the total land at risk) are suitable for Contour bank terraces, 2,969 hectares are hedgerows and cropland that need agroforestry/alley cropping (2,195 hectares), Afforestation & Reforestation (1,7860 hectares). Others are Storm water management facilities (SWMF) (954 hectares), gullies or riverbanks amounting to 666 hectares eroded which require bamboo trees for rehabilitation, and contour banks (445 hectares).

Table 41: Recommended erosion practices in Nyabihu District

Sector Name	Afforestation & Reforestation	Agroforestry	Bamboo gullies & riverside	Bench terraces	Contour bank	Contour bank terraces	Hedge rows	No till	SWMF	None	Total
BIGOGWE	33	45	12			70	218	280	78	8	743
JENDA	27	63			30	302	21		13	51	507
JOMBA	54	248	43		8	610	56		20	207	1,255
KABATWA	19	151			332	78	116		132	54	883
KARAGO	22	265	46		17	619	307	7	58	186	1,528
KINTOBO	162	208	22		1	391	68	1	73	221	1,146
MUKAMIRA	46	107	3		29	443	93	1	39	100	861
MURINGA	689	154	280	65	14	1,029	938	253	338	486	4,311
RAMBURA	367	178	116	11	12	392	1,061	133	124	430	2,833
RUGERA	148	253	39			881		7	35	276	1,640
RUREMBO	204	470	75			802	54	45	38	304	1,993
SHYIRA	14	52	30			360	36	37	6	117	654
Grand Total	**1,786**	**2,195**	**666**	**76**	**445**	**5,978**	**2,969**	**765**	**954**	**2,440**	**18,354**
Percentage	**10%**	**12%**	**4%**	**0%**	**2%**	**33%**	**16%**	**4%**	**5%**	**13%**	**100%**

Note: Grassed waterways are recommended for existing terraces which was made without waterways or with but no grasses which can cause severe gullies and destruction of bench terraces created. No-till agriculture is recommended is recommended for perennial crops on extremely high risk area while Storm water management facilities (SWMF) or water harvesting infrastructure is recommended in built-up areas. None: means no-recommendation is provided because existing erosion control measures are adequate with reference made to the total land protected. Contour banks are recommended for existing forest without ditches. Bamboos are recommended to close gullies or for riverside buffers.

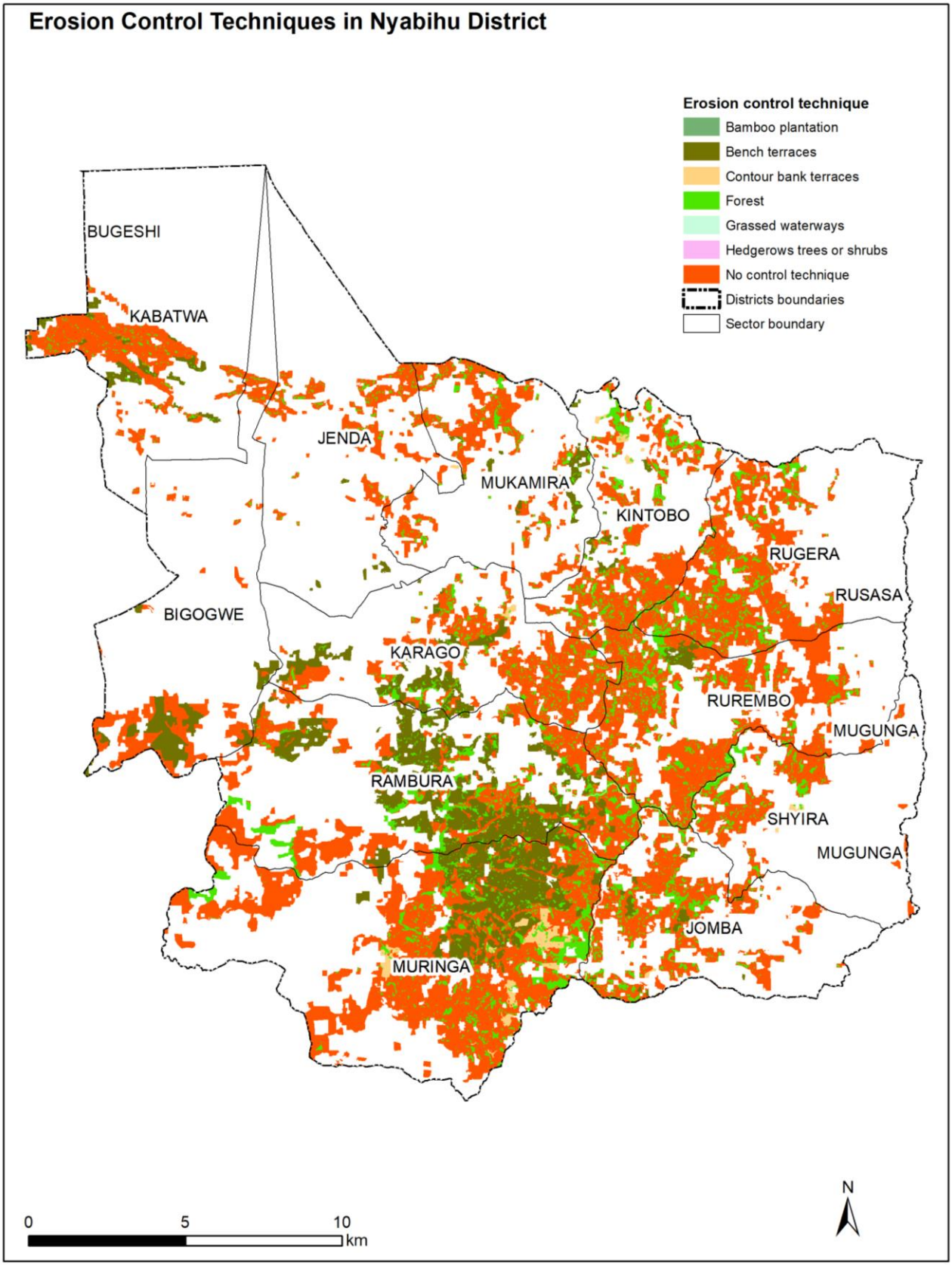


Figure 41: Erosion control techniques in place in Nyabihu District

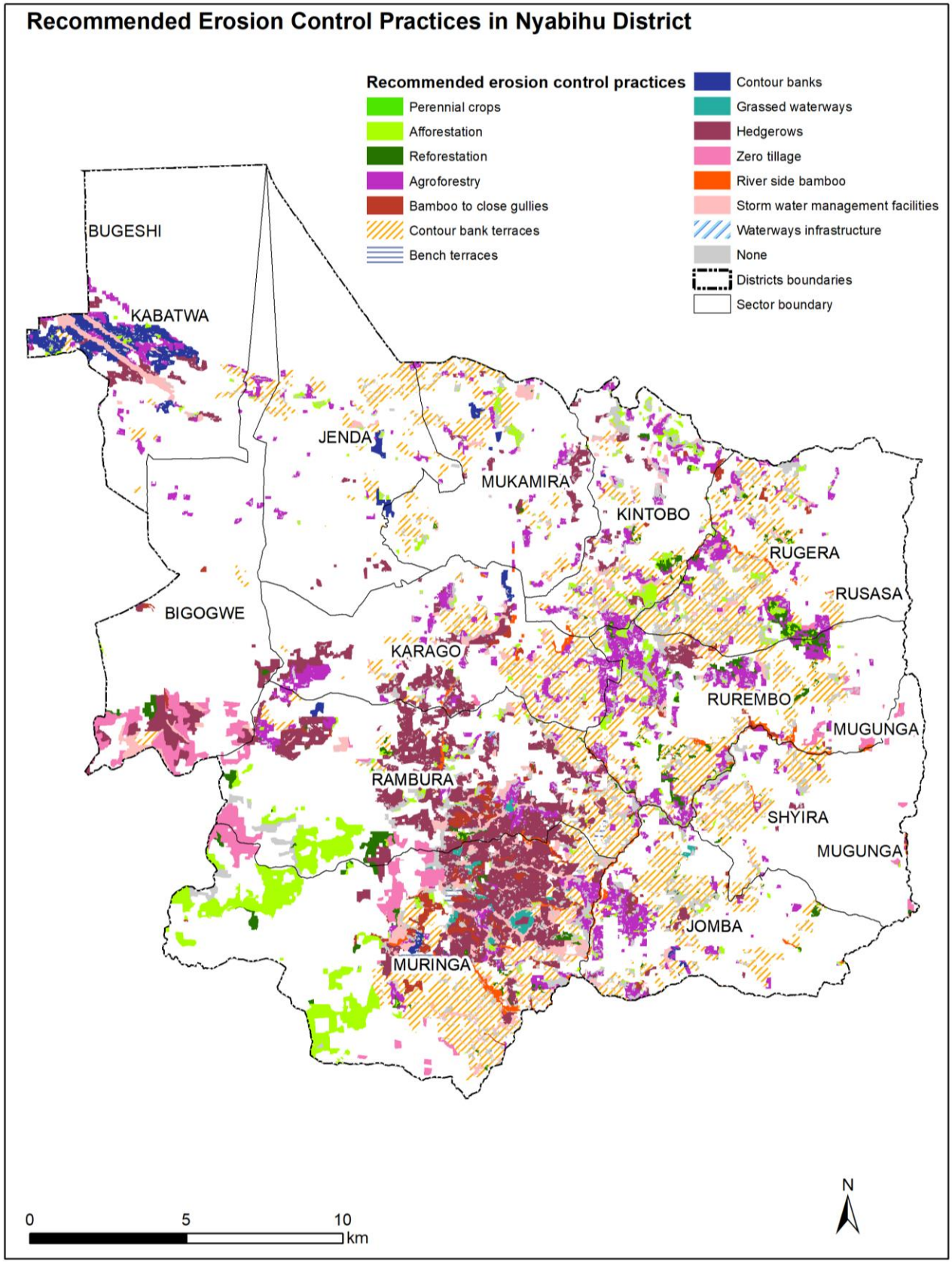


Figure 42: Recommended erosion control practices in Nyabihu District

3.2.4. Erosion control status in Nyamasheke District

Soil erosion risk in Nyamasheke is summarised in Table 42 and presented in Figure 43. Land area at risk is estimated to 17,931 hectares; about 19% of the total district land. Karambi sector is the highest susceptible to erosion with 3,566 hectares (45% of the sector land), followed by Mahembe sector with 1,909 hectares (35% of sector land), Kanjongo sector with 1,608 hectares (33% of the sector land), and Kirimbi sector with 1,256 hectares, 31% of the sector land.. The least affected sectors are many and among them Kagano is the lowest with only 140 hectares susceptible to erosion (3% of sector land), Karengera sector with 185 hectares (3% of the sector land) and Nyabitekeri sector with 111 hectares about 4% of the total sector land.

Table 42: Erosion risk per sector in Nyamasheke District

SN	Sector Name	Erosion risk				Sector land (ha)	%
		Extremely high	High	Very high	Total (Ha)		
1.	KARAMBI	1,192	1,257	1,118	3,566	7,956	45%
2.	MAHEMBE	191	1,369	348	1,909	5,381	35%
3.	KANJONGO	139	874	595	1,608	4,881	33%
4.	KIRIMBI	202	653	400	1,256	4,034	31%
5.	MACUBA	88	812	460	1,360	5,239	26%
6.	CYATO	1,340	872	1,526	3,738	17,369	22%
7.	GIHOMBO	70	706	329	1,105	5,488	20%
8.	BUSHENGE	22	277	101	399	3,183	13%
9.	SHANGI	12	250	88	350	3,444	10%
10.	BUSHEKERI	157	494	316	968	10,301	9%
11.	RANGIRO	174	286	284	745	8,084	9%
12.	RUHARAMBUGA	37	302	152	491	6,181	8%
13.	NYABITEKERI	3	81	27	111	3,156	4%
14.	KARENGERA		130	55	185	5,589	3%
15.	KAGANO	17	101	21	140	4,516	3%
	TOTAL	**3,645**	**8,466**	**5,820**	**17,931**	**94,802**	**19%**

Erosion features are clearly observed on World View images. Land areas affected by soil erosion features in Nyamasheke District are summarized in Table 43 and the map of erosion features are presented in Figure 44. The results show that Cyato sector is the worst affected by rill erosion on areas estimated to 855 hectares (23% of sector land at risk), followed by Karambi sectors. This confirms the findings of CROM model; however the reduced presence of gullies in Rangiro, Kirimbi, Bushenge, Karengera, Kanjongo (all thse sectors have less than 3 ha affected by gullies) and the absence of erosion features in Kagano and Ruharambuga which was originally predicted by CROM model as sector at high risk should not read that CROM model did not perform well in this sectors, but rather due to the time of image acquisition, the erosion features could be observed or erosion control measures have been already taken and therefore runoffs have been reduced, thus erosion features could not be formed in this case. Further analysis will demonstrate that in Table 14 and 15. The least sectors affected by gullies and rill erosion are Rangiro, Kirimbi, Bushenge, Karengera and Kanjongo where, in each sector, the areas affected by gullies is less than 3 hectares.

Table 43: Erosion features types and areas affected in Nyamasheke District

Sector Name	Erosion feature types					None	Grand Total	% Features
	Gullies	Landslide	Rill erosion	Severe gullies	Total			
CYATO	1		853		855	2,883	3,738	23%
KARAMBI	3		192		195	3,372	3,566	5%
BUSHEKERI	1	12	2	5	20	948	968	2%
NYABITEKERI	2				2	109	111	2%
GIHOMBO	1		17	1	18	1,087	1,105	2%
MAHEMBE			18	1	20	1,889	1,909	1%
MACUBA	2		6	4	13	1,347	1,360	1%
SHANGI				2	2	348	350	1%
KANJONGO	0	2	1	3	7	1,601	1,608	0%
KARENGERA	1				1	184	185	0%
BUSHENGE	1				1	398	399	0%
KIRIMBI	3				3	1,253	1,256	0%
RANGIRO	1		0		1	744	745	0%
RUHARAMBUGA	0				0	491	491	0%
KAGANO					0	140	140	0%
Grand Total	**16**	**15**	**1089**	**17**	**1,136**	**16,794**	**17,931**	**6%**

In term of land use and related management of areas at risk in Nyamasheke, the results of land cover mapping (Table 44 and Figure 45) show 10,507 hectares (59% of the total land at risk) are used for seasonal cropping, 3,643 hectares (20% of the total land at risk) are covered by degraded forests, 1,076 hectares (6% of the total land at risk) are covered by healthy forests, 1,221 hectare used for built-up (2%) and 378 hectares i.e. 2% are covered by Banana crop. In this district there are also mining concessions and tea plantations which cover respectively 102 hectares (0.5% of the total land at risk) and 641 hectares (3% of the total land at risk).

Table 44: Land Use and Vegetation Cover (LUVC) of areas at risk in Nyamasheke District

Sector name	Banana	Build-up area	Degraded forest	Dense forest	Mining concession	Seasonal crops	Tea	Water body	Total
BUSHEKERI	1	55	95	278	6	402	110	21	968
BUSHENGE	3	54	69	61	3	207		2	399
CYATO	23	117	356	263	39	2,880		60	3,738
GIHOMBO	41	19	422	18	10	573		23	1,105
KAGANO	1	6	21	20	1	71		19	140
KANJONGO	18	301	210	96	6	965		12	1,608
KARAMBI	78	252	640	127	9	1,875	516	69	3,566
KARENGERA	2	28	14	40	1	101			185
KIRIMBI	69	50	389	13	4	705		26	1,256
MACUBA	50	161	315	12	6	788		28	1,360
MAHEMBE	83	57	847	27	4	832		58	1,909
NYABITEKERI			25	0	2	78		6	111

RANGIRO	7	63	144	30	3	474		24	745
RUHARAMBUGA	1	13	55	73	6	328	15		491
SHANGI	1	46	41	17	2	228		14	350
Grand Total	**378**	**1,221**	**3,643**	**1,076**	**102**	**10,507**	**641**	**363**	**17,931**

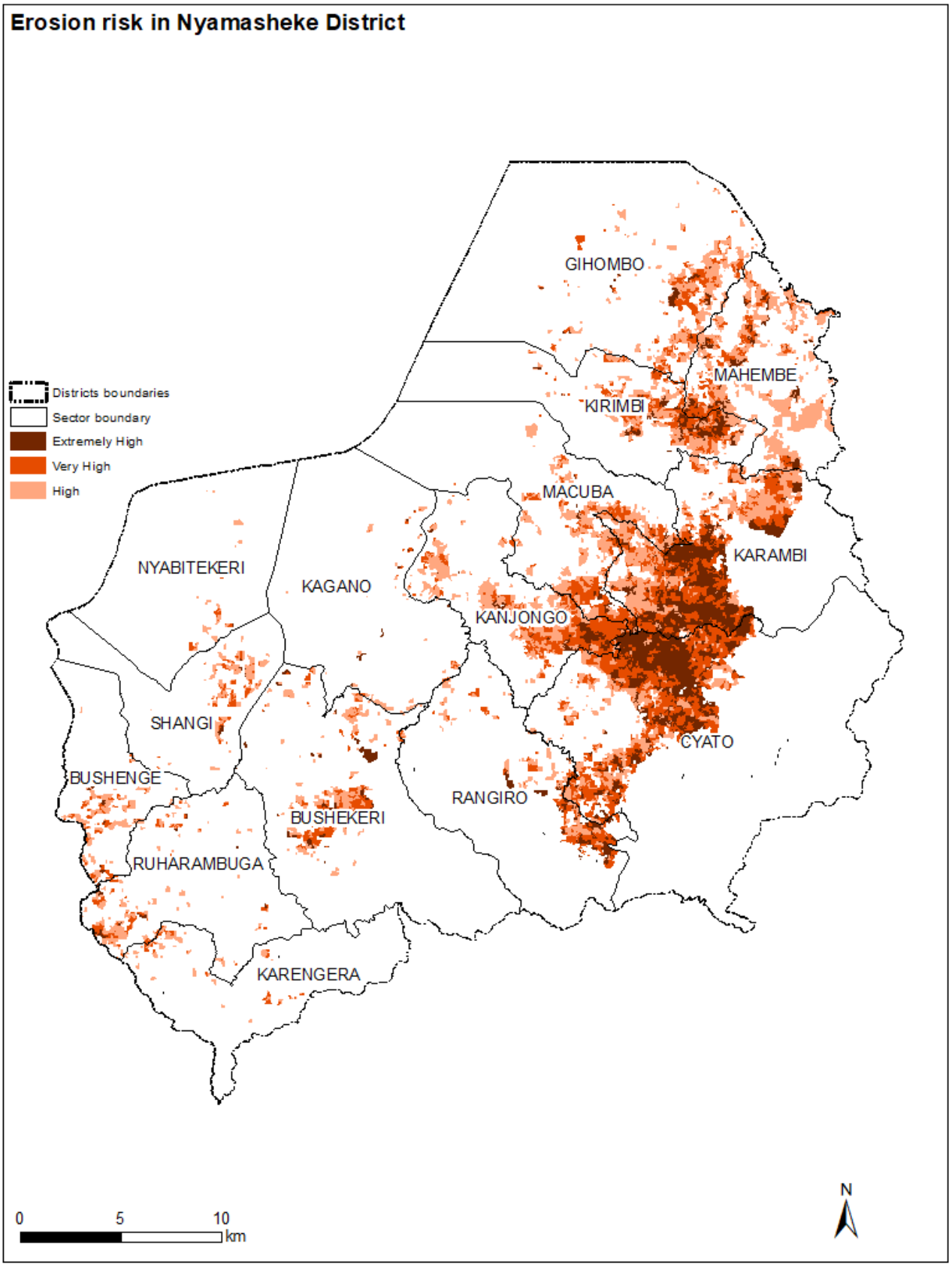


Figure 43: Erosion risk in Nyamasheke District

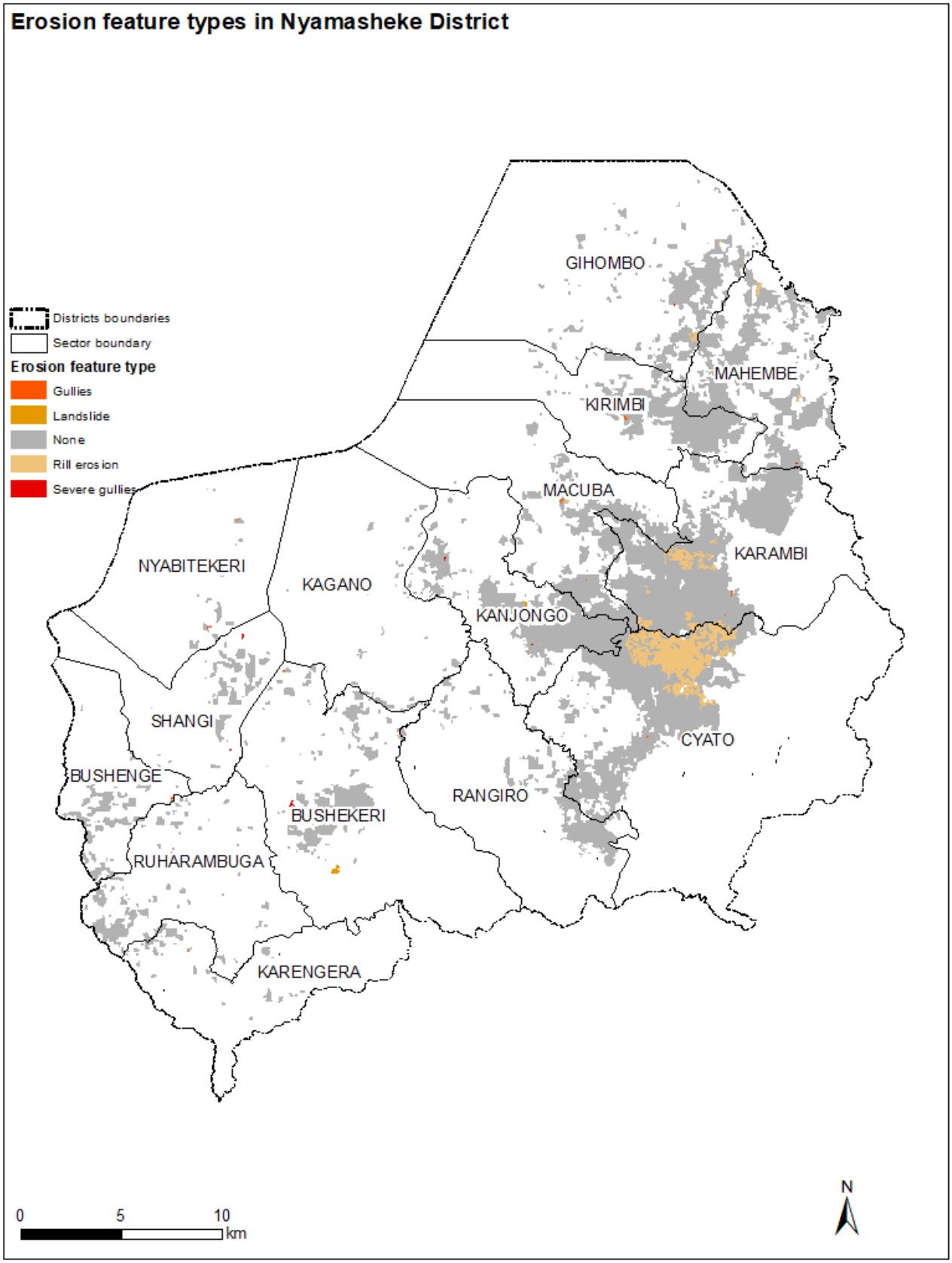


Figure 44: Erosion features detected in Nyamasheke District

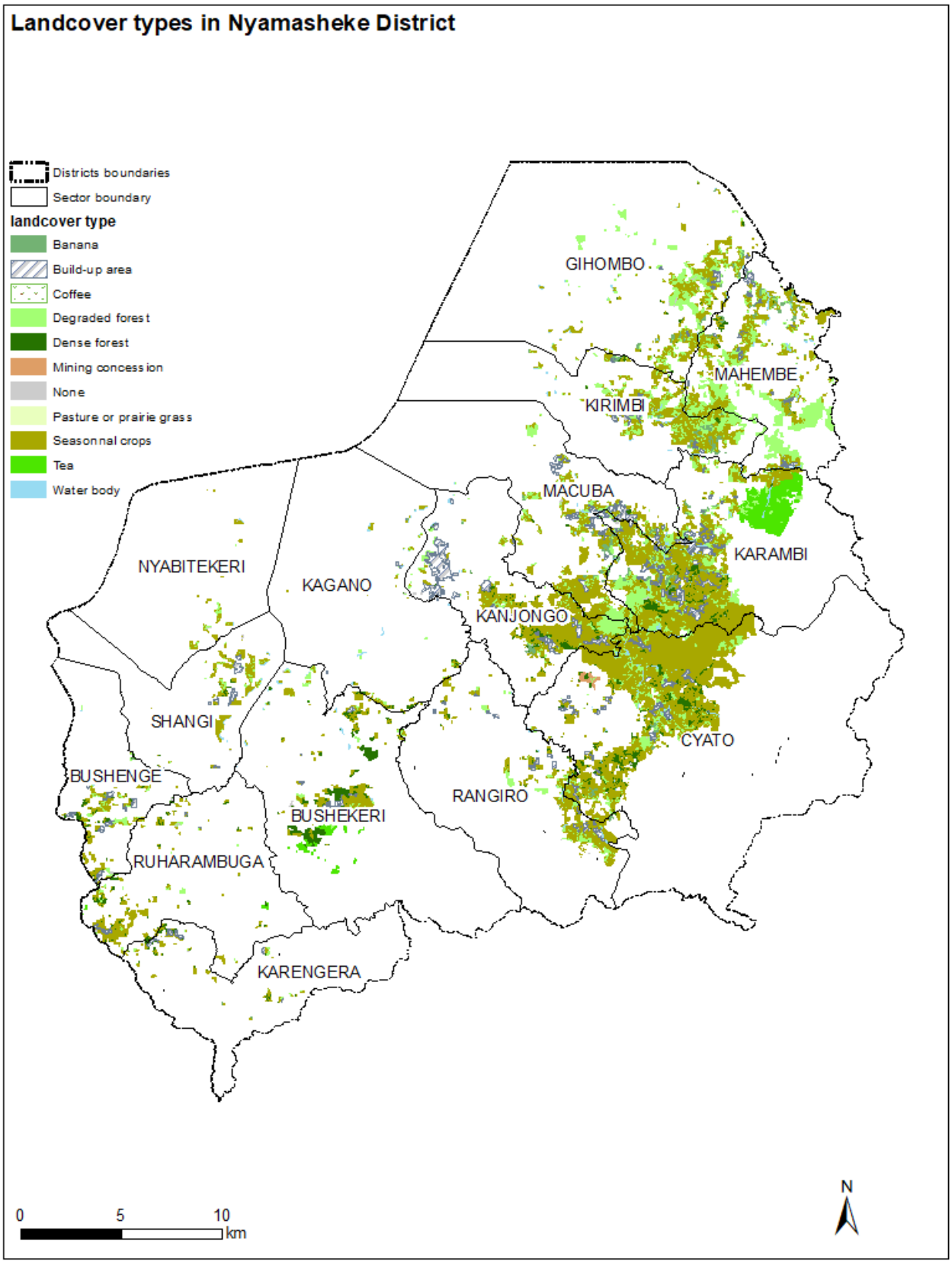


Figure 45: Land cover types in Nyamasheke District

About current erosion control practices in Nyamasheke district, only 8% of land at risk is protected by forests (1,075 hectares) and bench terraces (309 hectares). The highest protected sectors are Bushekeri with 29% of its land at risk protected, followed by Karengera where 24% of the total land at risk is protected and Bushenge with 15% of land protected. The least protected sectors are Nyabitekeri with only 0% protected, Gihombo (only 2% protected), Mahembe (2%) and Kirimbi (3% protected). The visual interpretation of World View images confirms earlier findings by CROM model that Nyabitekeri with only 0% protected, Gihombo, Mahembe and Kirimbi sectors remain at very high risk of soil erosion since more than 95% of the sector land at risk are not protected

Table 45: Erosion control practices already in place in Nyamasheke District

Sector name	Erosion control techniques in place			Unprotected (Ha)	Grand Total (Ha)	% protected
	Bench terraces (Ha)	Forests (Ha)	Total protected (Ha)			
BUSHEKERI	4	278	282	686	968	29%
KARENGERA	5	39	44	141	185	24%
BUSHENGE		60	60	339	399	15%
RUHARAMBUGA		73	73	418	491	15%
KAGANO	0	20	20	119	140	15%
CYATO	112	263	375	3,363	3,738	10%
KANJONGO	28	96	124	1,484	1,608	8%
MACUBA	64	12	76	1,283	1,360	6%
KARAMBI	58	127	184	3,382	3,566	5%
SHANGI		17	17	333	350	5%
RANGIRO	3	30	33	712	745	4%
KIRIMBI	22	13	35	1,221	1,256	3%
MAHEMBE	12	27	39	1,869	1,909	2%
GIHOMBO	2	18	20	1,085	1,105	2%
NYABITEKERI		0	0	111	111	0%
Grand Total	**309**	**1,075**	**1,384**	**16,547**	**17,931**	**8%**

Erosion control practices in Nyamasheke District are recommended based on existing land uses, erosion control measures already in place, and predicted erosion risk by CROM model. Table 46 shows that about 7,406 hectares (which is 41% of the total land at risk) are suitable for Contour bank terraces, 3,923 hectares are Afforestation & Reforestation and cropland that need agroforestry/alley cropping (2,558 hectares). Others are Storm water management facilities (SWMF) (1,231 hectares), gullies or riverbanks amounting to 393 hectares eroded which require bamboo trees for rehabilitation, hedgerows (302 hectares) and bench terraces (184 hectares).

Table 46: Recommended erosion control practices in Nyamasheke District

Sector Name	Afforestation & Reforestation	Agro forestry	Bamboo gullies & riverside	Bench terraces	Contour bank terraces	Hedge rows	No till	SWMF	None	Total
BUSHEKERI	99	32	27		363	4	111	55	278	968
BUSHENGE	73	9	4		196		3	54	61	399
CYATO	479	1,279	61	81	1,392	112	23	117	265	3,738
GIHOMBO	429	8	25	2	558	2	41	21	21	1,105
KAGANO	23	2	19		67	0	1	7	20	140
KANJONGO	227	89	17	16	829	28	18	304	96	1,608
KARAMBI	697	803	68	43	968	58	595	252	127	3,566
KARENGERA	14	0	1		95	5	2	28	41	185
KIRIMBI	400	82	29	5	592	22	69	50	13	1,256
MACUBA	349	59	34	35	629	63	51	161	13	1,360
MAHEMBE	850	67	59		753	7	83	57	33	1,909
NYABITEKERI	34	1	8		68			-	0	111
RANGIRO	149	97	25	2	371	3	7	63	30	745
RUHARAMBUGA	58	23	0		304		15	17	73	491
SHANGI	41	8	17		220		1	46	18	350
Grand Total	**3,923**	**2,558**	**393**	**184**	**7,406**	**302**	**1,020**	**1,231**	**1,088**	**17,931**
Percentage	**22%**	**14%**	**2%**	**1%**	**41%**	**2%**	**6%**	**7%**	**6%**	**100%**

Note: Grassed waterways are recommended for existing terraces which was made without waterways or with but no grasses which can cause severe gullies and destruction of bench terraces created. No-till agriculture is recommended is recommended for perennial crops on extremely high risk area while Storm water management facilities (SWMF) or water harvesting infrastructure is recommended in built-up areas. None: means no-recommendation is provided because existing erosion control measures are adequate with reference made to the total land protected. Contour banks are recommended for existing forest without ditches. Bamboos are recommended to close gullies or for riverside buffers.

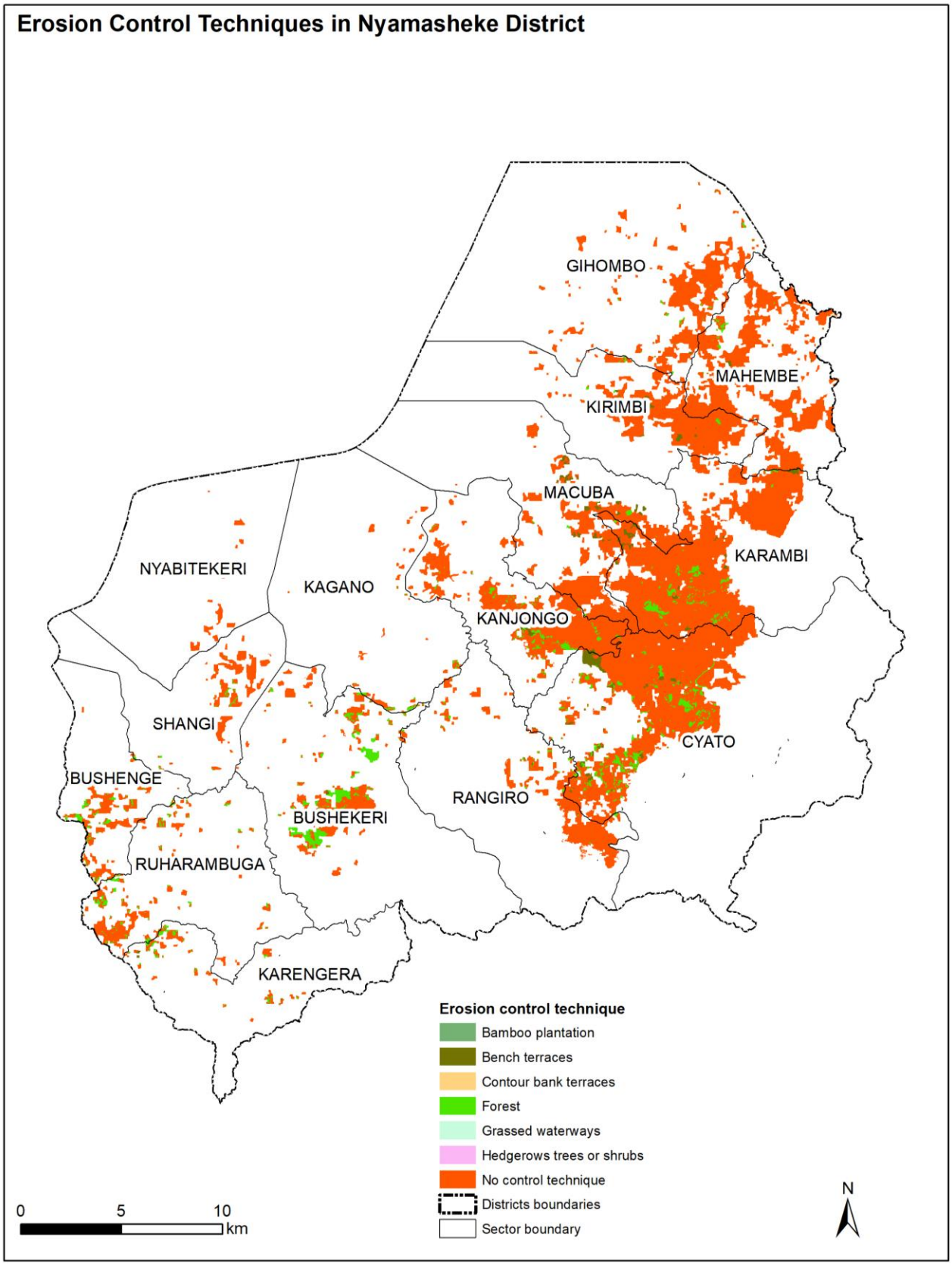


Figure 46: Erosion control techniques in place in Nyamasheke District

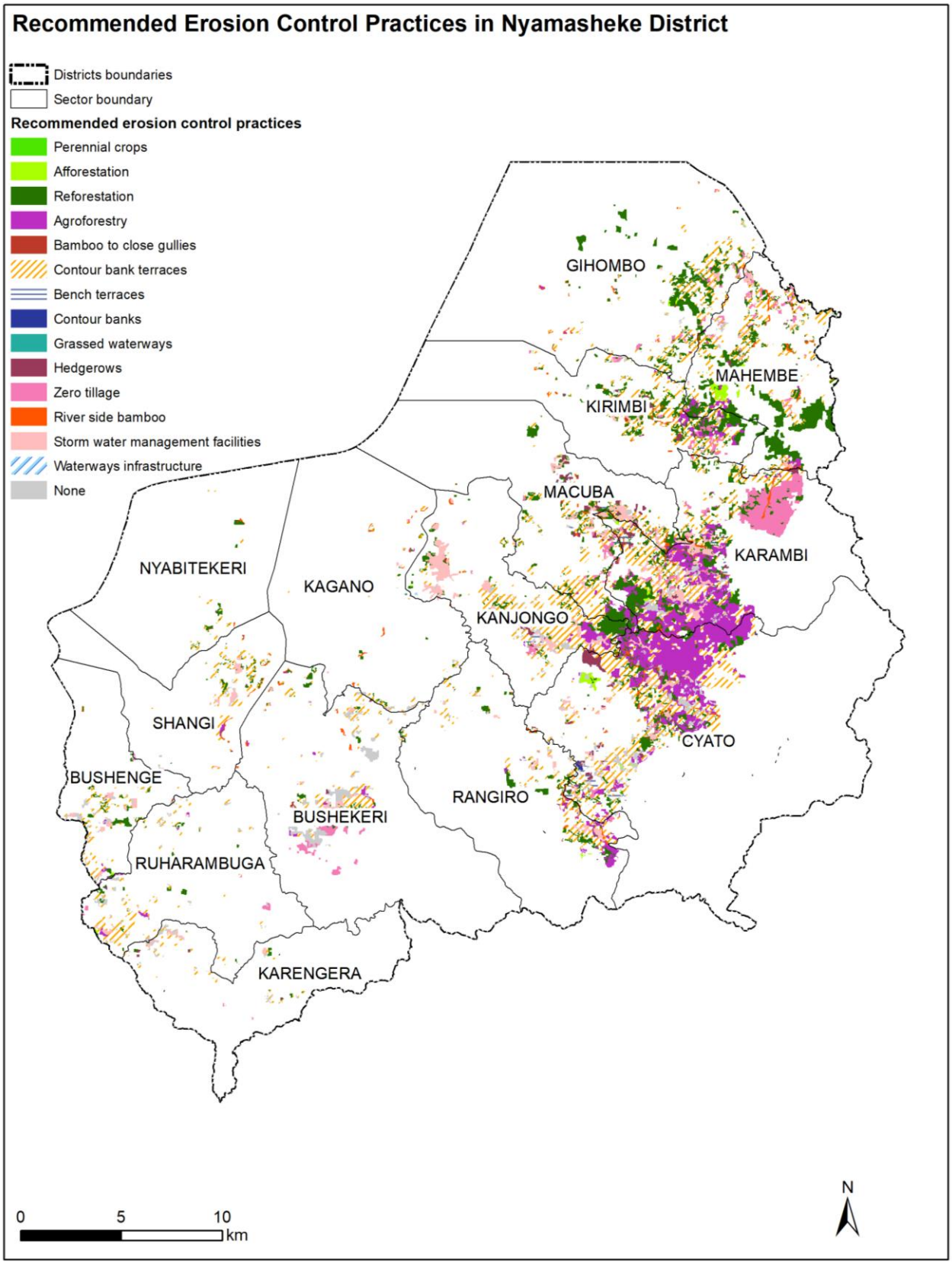


Figure 47: Recommended erosion control practices in Nyamasheke District

3.2.5. Erosion control status in Rubavu District

Soil erosion risk in Rubavu is summarised in Table 47 and presented in Figure 48. Land area at risk is estimated to 6,552 hectares; about 19% of the total district land. Bugeshi sector is the highest susceptible to erosion with 1,914 hectares (62% of the sector land), followed by Kanama sector with 1,862 hectares (43% of sector land), and Nyundo sector with 728 hectares (23% of the sector land). The least affected sectors are many and among them Rubavu is the lowest with only 11 hectares susceptible to erosion, Rugerero sector with 54 hectares (2% of the sector land) and Gisenyi sector with 62 hectares about 6% of the total sector land.

Table 47: Erosion risk per sector in Rubavu District

SN	Sector Name	Erosion risk				Sector land (ha)	%
		Extremely high	High	Very high	Total (Ha)		
1.	BUGESHI	503	621	789	1,914	3,083	62%
2.	KANAMA	841	353	668	1,862	4,363	43%
3.	NYUNDO	36	442	250	728	3,114	23%
4.	BUSASAMANA	41	329	192	562	3,447	16%
5.	NYAKILIBA	64	138	145	348	2,330	15%
6.	KANZENZE	100	64	156	319	2,232	14%
7.	NYAMYUMBA	19	124	48	191	2,344	8%
8.	MUDENDE	19	186	59	264	3,384	8%
9.	CYANZARWE	33	149	54	235	3,498	7%
10.	GISENYI	11	24	28	62	1,117	6%
11.	RUGERERO	10	31	13	54	2,535	2%
12.	RUBAVU	5	6	0	11	2,642	0%
	TOTAL	**1,683**	**2,467**	**2,402**	**6,552**	**34,090**	**19%**

The entire District of Rubavu is reported as not having any erosion feature types (Figure 49) which is in contradiction with the findings of CROM model by which 19% of the District land is at high erosion risk. In fact this district is characterised of having topography with gentle slope a part from the volcanic mountains in Bugeshi Sector which are covered of protected natural forest, and the southern Sectors of Kanama, Nyundo and Nyamyumba. So the quasi absence of erosion features (gullies, rill erosion, landslide) in Rubavu District in which CROM model predicted high risk areas in some sectors did not perform well in this sectors, but rather due to the time of image acquisition, the erosion features could be observed or erosion control measures have been already taken and therefore runoffs have been reduced, thus erosion features could not be formed in this case. Further analysis will demonstrate that in Table 49 and 50.

In term of land use and related management of areas at risk in Rubavu District, the results of land cover mapping (Table 48 and Figure 50) show that 5,647 hectares (86% of the total land at risk) are used for seasonal crops and 882 hectares (13% of the total land at risk) are covered by healthy forests.

Table 48: Land Use and Vegetation Cover (LUVC) of areas at risk in Rubavu District

Sector name	Dense forest	Seasonal crops	Tea	Total
BUGESHI	223	1,691		1,914
BUSASAMANA	75	487		562
CYANZARWE	21	214		235
GISENYI	17	46		62
KANAMA	226	1,635	-	1,862
KANZENZE	40	279	-	319
MUDENDE	43	222		264
NYAKILIBA	55	293		348
NYAMYUMBA	16	175		191
NYUNDO	158	549	21	728
RUBAVU	1	10		11
RUGERERO	7	47		54
Grand Total	**882**	**5,647**	**21**	**6,552**

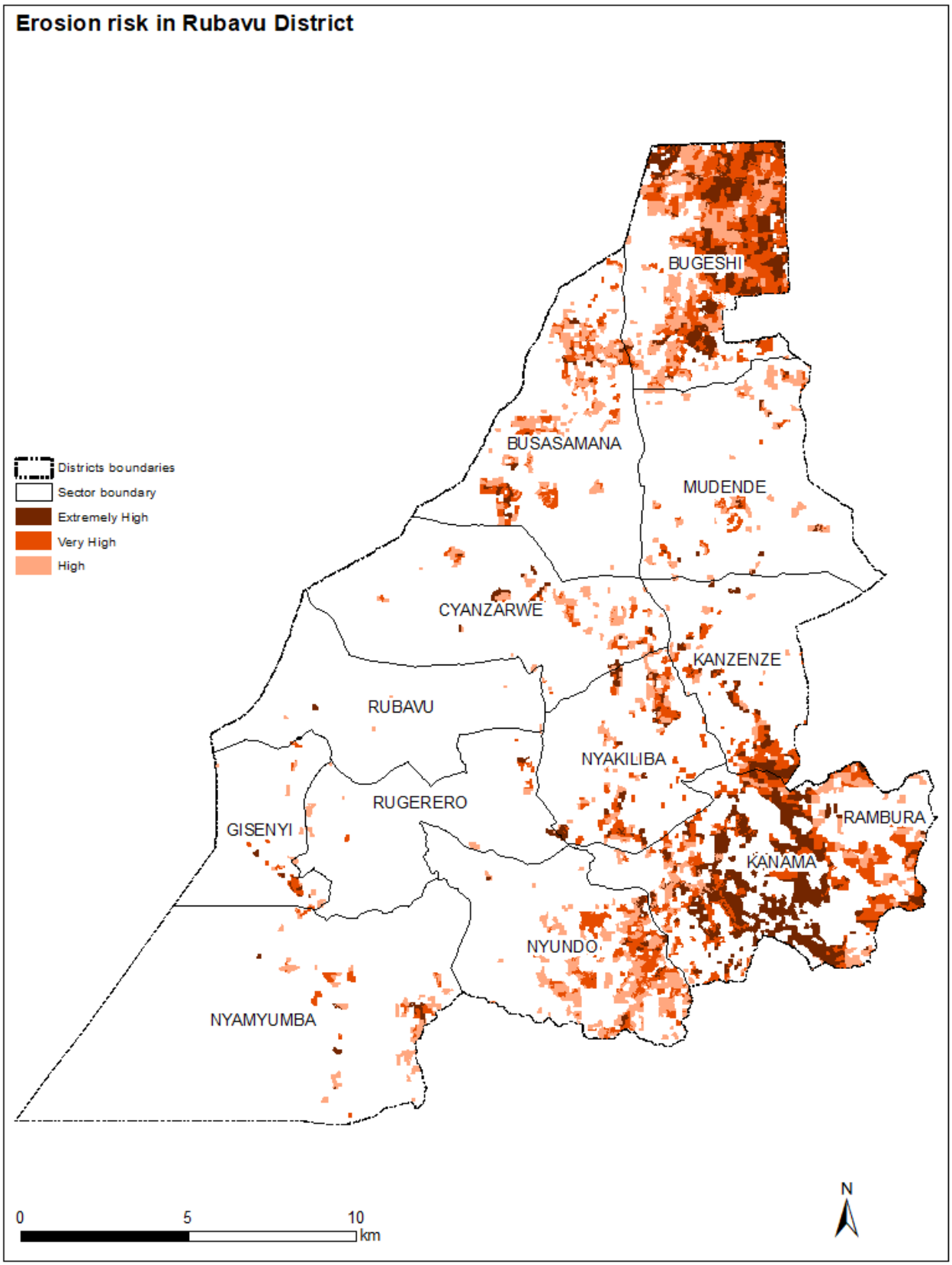


Figure 48: Erosion risk in Rubavu District

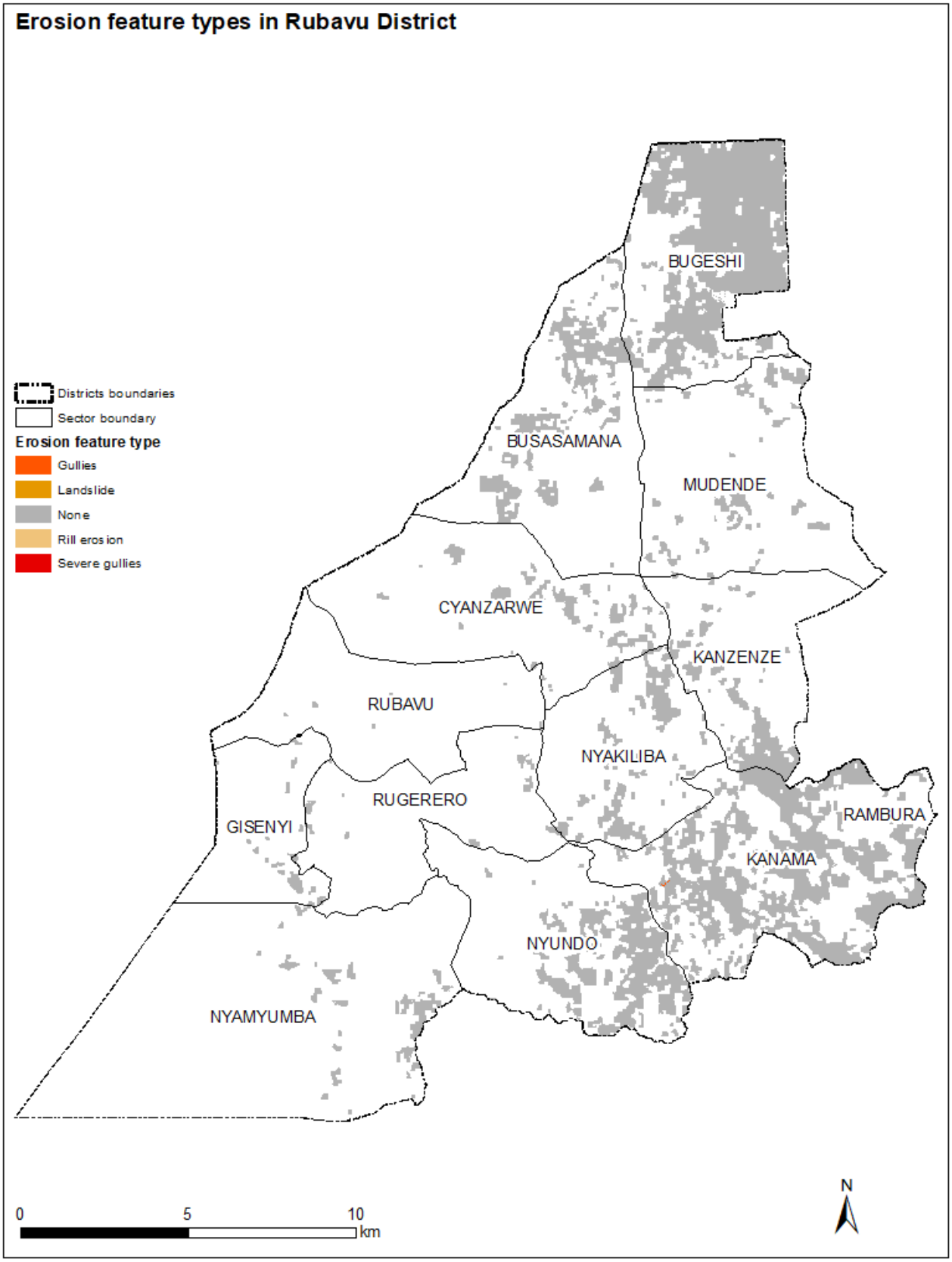


Figure 49: Erosion features detected in Rubavu District

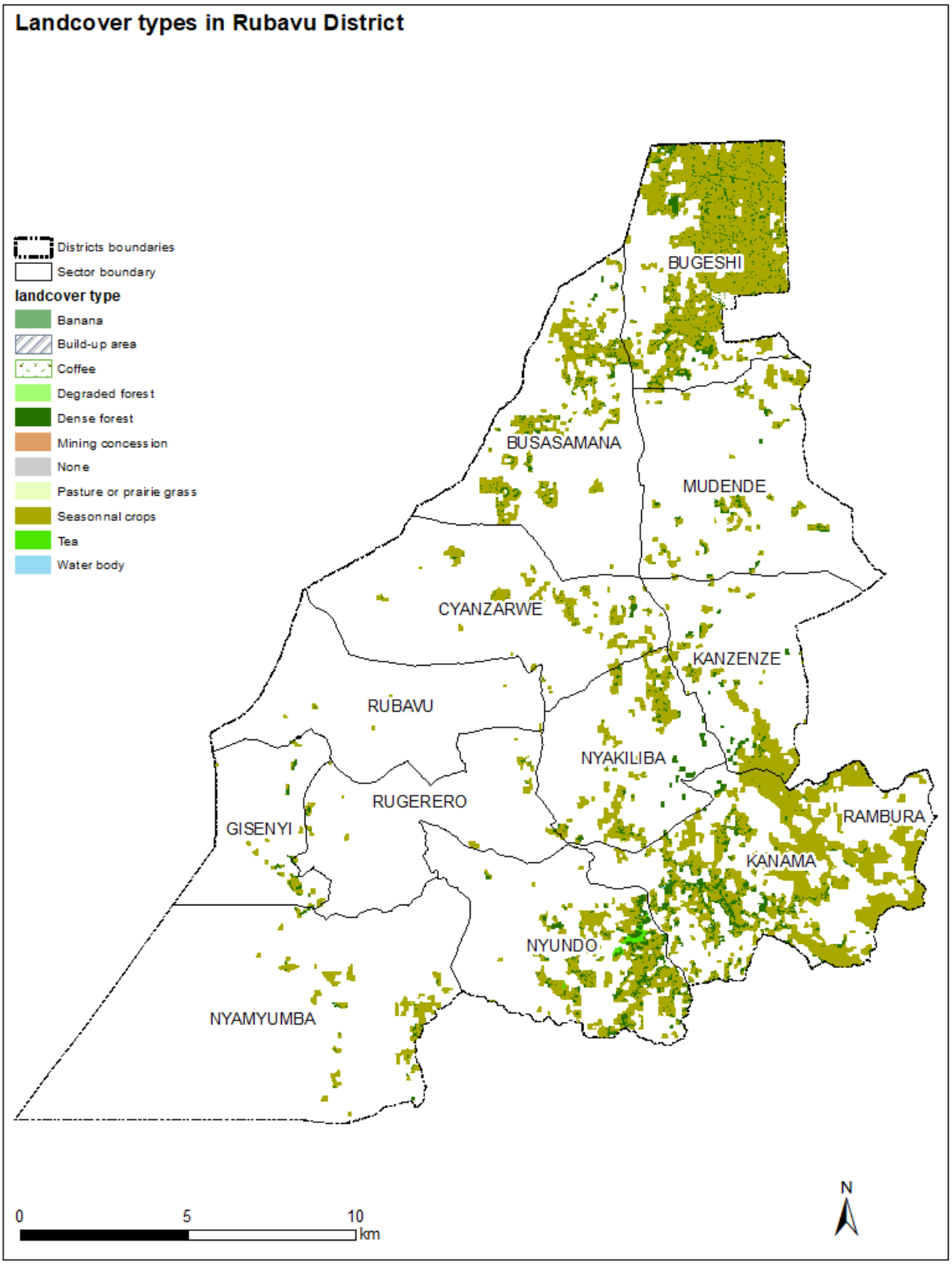


Figure 50: Land cover types in Rubavu District

About existing erosion control practices in Rubavu district, Table 49 shows that only 14% of land at risk is protected by forests (882 hectares) and bench terraces (45 hectares). The highest protected sectors are Gisenyi with 26% of its land at risk protected, followed by Nyundo where 22% of the total land at risk is protected and Mudende with 16% of land protected. The least protected sectors are Nyamyumba with only 8% protected, Rubavu (only 9% protected), Cyanzarwe (9%) and Rugeshi (12% protected). The visual interpretation of World View images confirms earlier findings by CROM model that Nyamyumba, Rubavu, Cyanzarwe sectors remain at very high risk of soil erosion since more than 90% of their respective land are not protected

Table 49: Erosion control practices already in Rubavu District

Sector name	Erosion control techniques in place			Unprotected	Grand Total	% protected
	Bench terraces	Forest	Total protected			
GISENYI		17	17	46	62	26%
NYUNDO		158	158	570	728	22%
MUDENDE	0	43	43	222	264	16%
NYAKILIBA		55	55	293	348	16%
KANAMA	43	226	270	1,592	1,862	14%
BUSASAMANA		75	75	487	562	13%
RUGERERO		7	7	47	54	13%
KANZENZE	1	40	41	278	319	13%
BUGESHI		223	223	1,691	1,914	12%
CYANZARWE		21	21	214	235	9%
RUBAVU		1	1	10	11	9%
NYAMYUMBA		16	16	175	191	8%
Grand Total	**45**	**882**	**927**	**5,625**	**6,552**	**14%**

Erosion control practices in Rubavu District are recommended based on existing land uses, erosion control measures already in place, and predicted erosion risk by CROM model. Table 50 shows that about 4,206 hectares (which is 64% of the total land at risk) are suitable for Contour bank terraces and 1,434 hectares are cropland that need agroforestry/alley cropping.

Table 50: Recommended erosion control practices in Rubavu District

Sector Name	Agroforestry (Ha)	Contour bank terraces (Ha)	None (Ha)	Total (Ha)
BUGESHI	434	1,256	223	1,914
BUSASAMANA	35	451	75	562
CYANZARWE	26	181	28	235
GISENYI	6	40	17	62
KANAMA	746	889	226	1,862
KANZENZE	94	186	40	319
MUDENDE	15	206	43	264
NYAKILIBA	48	224	77	348
NYAMYUMBA	16	159	16	191
NYUNDO	0	569	158	728
RUBAVU	4	6	1	11
RUGERERO	9	38	7	54
Grand Total	**1,434**	**4,206**	**911**	**6,552**
Percentage	**22%**	**64%**	**14%**	**100%**

Note: Grassed waterways are recommended for existing terraces which was made without waterways or with but no grasses which can cause severe gullies and destruction of bench terraces created. No-till agriculture is recommended is recommended for perennial crops on extremely high risk area while Storm water management facilities (SWMF) or water harvesting infrastructure is recommended in built-up areas. None: means no-recommendation is provided because existing erosion control measures are adequate with reference made to the total land protected. Contour banks are recommended for existing forest without ditches. Bamboos are recommended to close gullies or for riverside buffers.

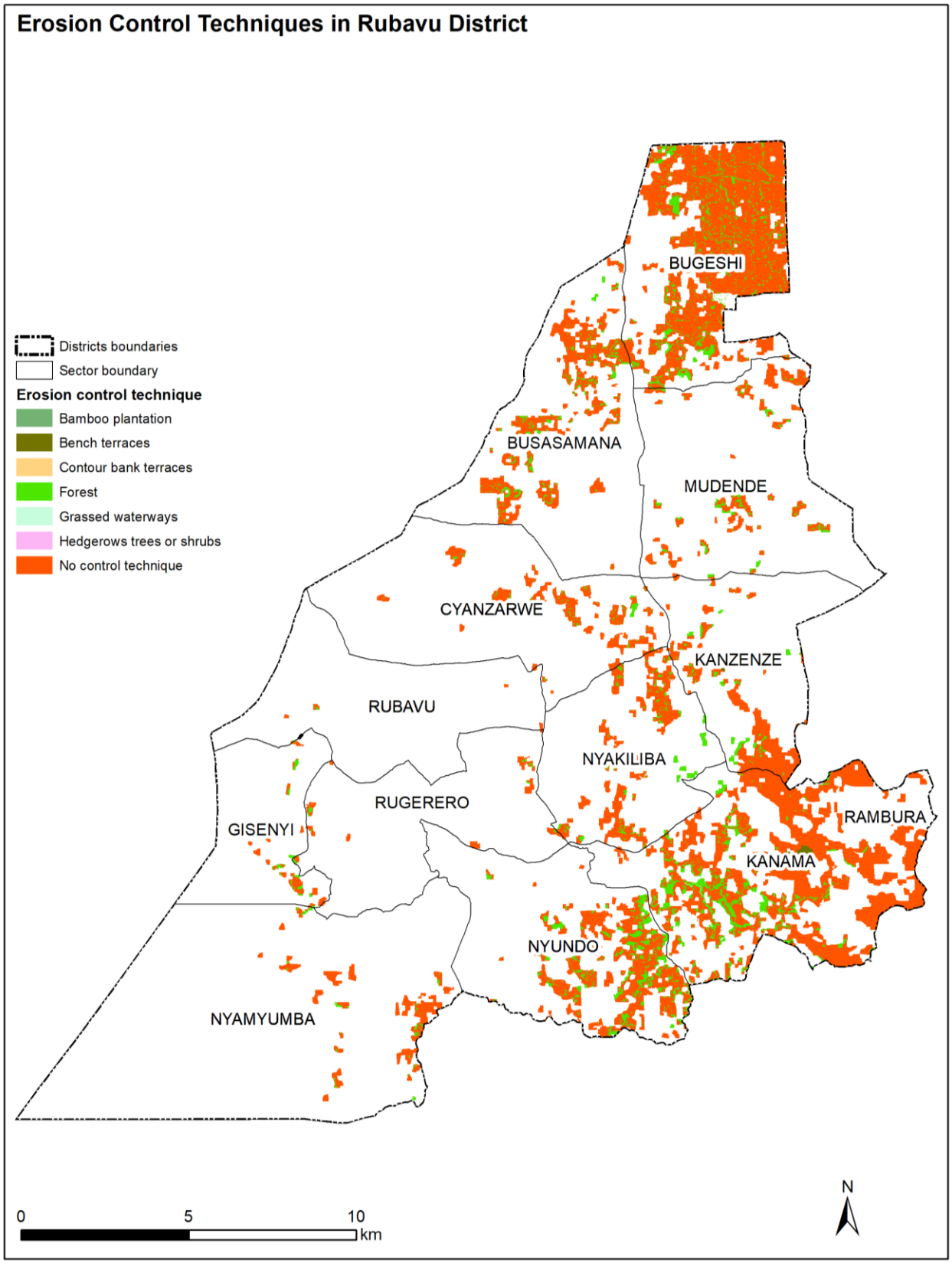


Figure 51: Erosion control techniques in place in Rubavu District

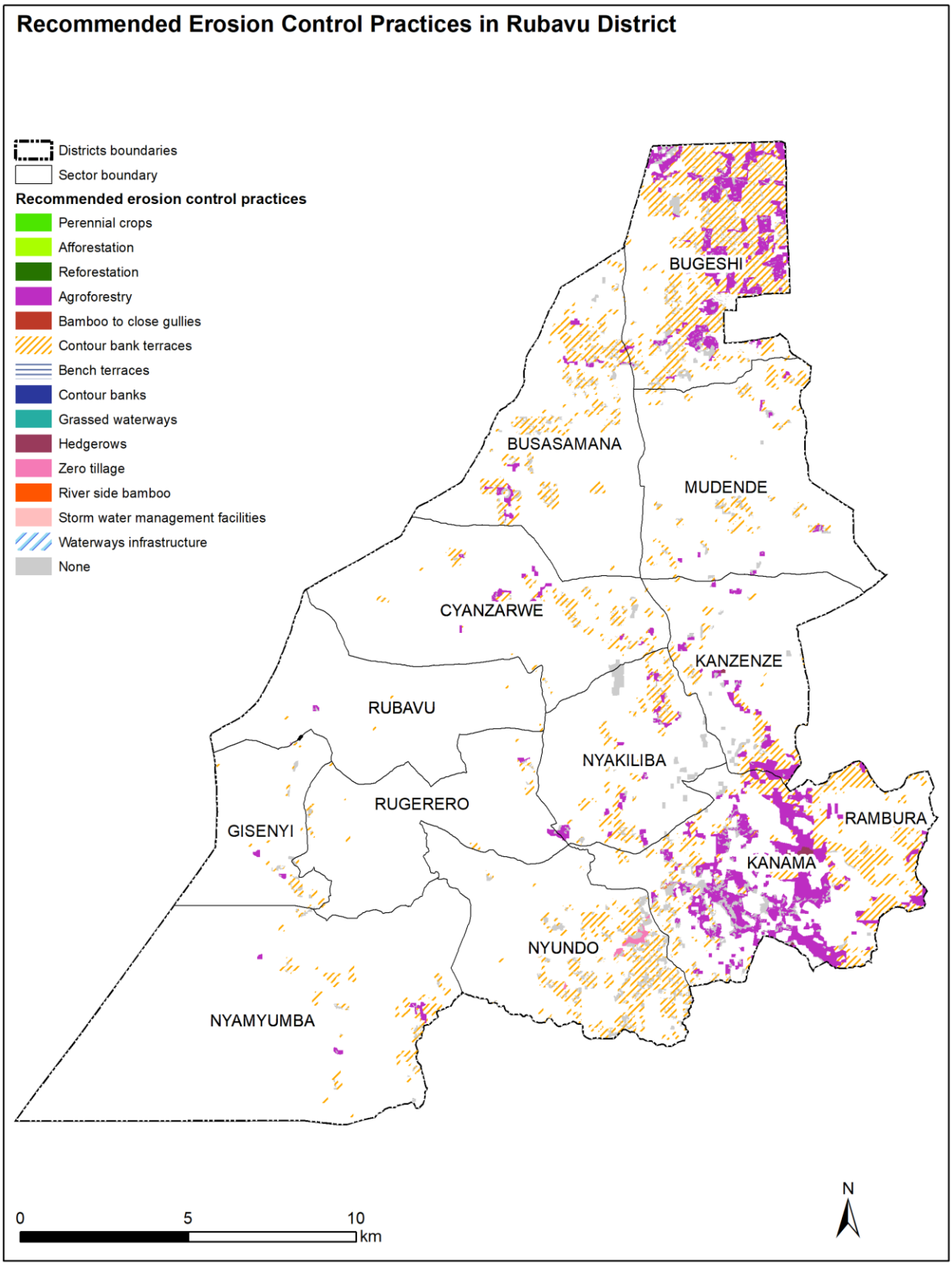


Figure 52: Recommended erosion control practices in Rubavu District

3.2.6. Erosion control in Rusizi District

Soil erosion risk in Rusizi is summarised in Table 51 and presented in Figure 53. Land area at risk is estimated to 6,084 hectares; about 7% of the total district land. Kamembe sector is the highest susceptible to erosion with 1 627 hectares (43% of the sector land), followed by Giheke sector with 1,408 hectares (40% of sector land), and Nkombo sector with 256 hectares (28% of the sector land) and Gihundwe sector with 595 hectares (23% of the sector land). The least affected sectors are Gikundamvura and Muganza sectors with only 9 hectares at erosion risk, Butare and Bweyeye sectors with about 200 hectares susceptible to erosion (1% of the total sector land), and Bugarama sector with 56 hectares (2% of the sector land) and Nyakabuye sector with 103 hectares about 3% of the total sector land. The influence of Nyungwe and Cyamudongo natural forest including its buffer zone as well as other forests plantations on reducing soil erosion is very high. In fact, the results of forest cover mapping 2019 has shown that Rusizi is the highest forested with 48,255ha of forest cover (i.e. 52.6% of the total district land area) followed by Nyamasheke District with 45,935ha of forests area (48.5%) in western province,

Table 51: Erosion risk per sector in Rusizi District

SN	Sector Name	Erosion risk				Sector land (ha)	%
		Extremely high	High	Very high	Total (Ha)		
1.	KAMEMBE	28	339	260	627	1,445	43%
2.	GIHEKE	47	932	429	1,408	3,535	40%
3.	NKOMBO	20	171	65	256	903	28%
4.	GIHUNDWE	32	359	203	595	2,556	23%
5.	NZAHAHA	6	573	186	765	5,992	13%
6.	NKANKA	10	161	89	259	2,035	13%
7.	MURURU	8	244	153	406	3,316	12%
8.	GITAMBI	3	273	62	338	3,104	11%
9.	RWIMBOGO	0	148	16	164	2,634	6%
10.	NYAKARENZO	16	103	52	171	3,116	5%
11.	NKUNGU	4	161	33	198	3,690	5%
12.	GASHONGA	14	162	58	233	4,603	5%
13.	NYAKABUYE		76	27	103	3,859	3%
14.	BUGARAMA		35	22	56	2,539	2%
15.	BWEYEYE	7	235	38	281	22,618	1%
16.	BUTARE	4	180	23	207	20,328	1%
17.	MUGANZA		9		9	1,760	1%
18.	GIKUNDAMVURA		9		9	3,698	0%
	TOTAL	**200**	**4,168**	**1,715**	**6,084**	**91,731**	**7%**

Land areas affected by soil erosion features in Rusizi District, as observed on World View images, are summarized in Table 53 and the map of erosion features are presented in Figure 54. The results show that Nzahaha sector is the worst affected by gullies on areas estimated to 416 hectares (54% of sector land at risk), followed by Nkombo sector affected by gullies and rill erosion on 138 hectares and Nkanka sector (97 hectares). The presence of gullies and rill erosion in Nzahaha, Nkombo and Nkanka sectors confirms the findings of CROM model; however the reduced presence of gullies in Gihundwe, Nyakarenzo, Mururu (all these sectors have less than 5 ha affected by gullies) and the absence of erosion features in Muganza, Kamembe and Gikundamvura which were originally predicted by CROM model as sectors at high risk should not read that CROM model did not perform well in this sectors, but rather due to the time of image acquisition, the erosion features could be observed or erosion control measures have been already taken and therefore runoffs have been reduced, thus erosion features could not be formed in this case. Further analysis will demonstrate that in Table 54 and 55. The least sectors affected by gullies and rill erosion are Gihundwe, Nyakarenzo, Mururu go where, in each sector, the areas affected by gullies is less than 5 hectares.

Table 52: Erosion features types and areas affected in Rusizi District

Sector Name	Erosion feature types					None	Grand Total	% Features
	Gullies	Landslide	Rill erosion	Severe gullies	Total			
NZAHAHA	316	82		17	416	349	765	54%
NKOMBO	70		41	27	138	118	256	54%
NKANKA	50	4	20	21	97	163	259	37%
BUGARAMA		18		0	19	38	56	33%
BUTARE	68				68	139	207	33%
RWIMBOGO	43				43	121	164	26%
BWEYEYE	43				43	238	281	15%
GIHEKE	165				165	1243	1408	12%
GASHONGA	21			4	25	209	233	11%
NYAKABUYE	5				5	98	103	5%
NKUNGU	10				10	188	198	5%
GITAMBI	16				16	321	338	5%
MURURU	5	4			10	396	406	2%
NYAKARENZO	1				1	170	171	0%
GIHUNDWE	0				0	594	595	0%
GIKUNDAMVURA					0	9	9	0%
KAMEMBE					0	627	627	0%
MUGANZA					0	9	9	0%
Grand Total	**814**	**109**	**61**	**69**	**1054**	**5030**	**6084**	**17%**

In term of land use and related management of areas at risk in Rusizi District, the results of land cover mapping (Table 53 and Figure 55) show that **3,193** hectares (52% of the total land at risk) are used for seasonal crops, 1,660 hectares (27% of the total land at risk) are covered by healthy forests and **989** hectares (16% of the total land at risk) are covered by built-up area.

Table 53: Land Use and Vegetation Cover (LUVC) of areas at risk in Rusizi District

Sector name	Banana	Build-up area	Degraded forest	Dense forest	Mining concession	Seasonal crops	Tea	Water body	Total
BUGARAMA				3	-	53			56
BUTARE	7	11	1	49	-	138			207
BWEYEYE	3	14	3	69	-	189		3	281
GASHONGA	1	1	8	84	6	134		0	233
GIHEKE	9	130	23	458	-	739	48		1,408
GIHUNDWE	6	222	6	180	3	175		1	595
GIKUNDAMVURA			2	5	-	2			9
GITAMBI	6	27		77	-	227		1	338
KAMEMBE	5	368	9	158	6	81	0		627
MUGANZA		8		1	-				9
MURURU		60	1	172	1	167	5		406
NKANKA	1	30		70	-	159			259
NKOMBO		44	1	33	2	176			256
NKUNGU	4	16	-	68	1	92	17	-	198
NYAKABUYE	2	6		26	26	43		1	103

NYAKARENZO	1	42	1	63	6	58			171
NZAHAHA		8	11	130	2	614		-	765
RWIMBOGO		1	1	14	-	146		1	164
Grand Total	**44**	**989**	**66**	**1,660**	**54**	**3,193**	**70**	**8**	**6,084**

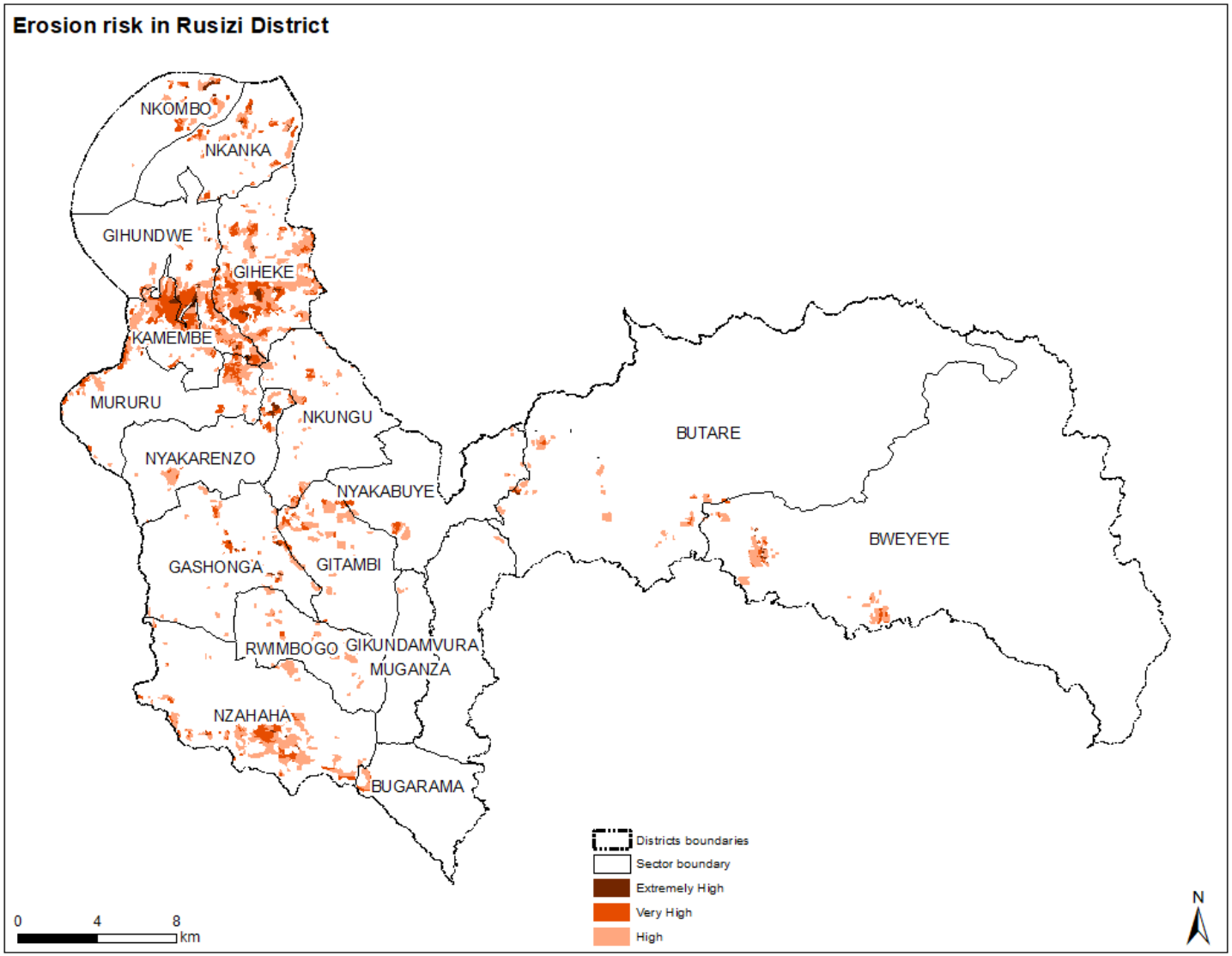


Figure 53: Erosion risk in Rusizi District

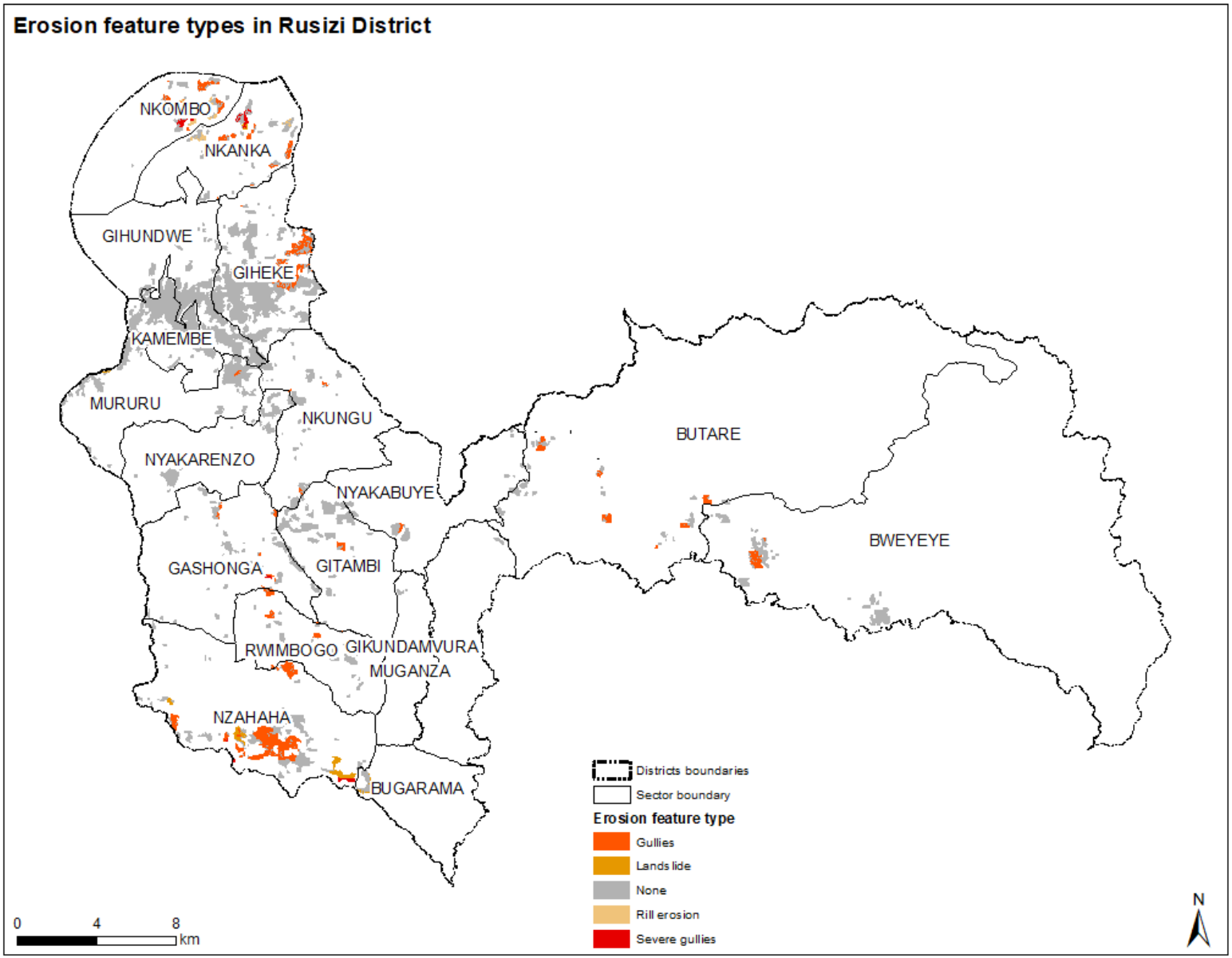


Figure 54: Erosion features detected in Rusizi District

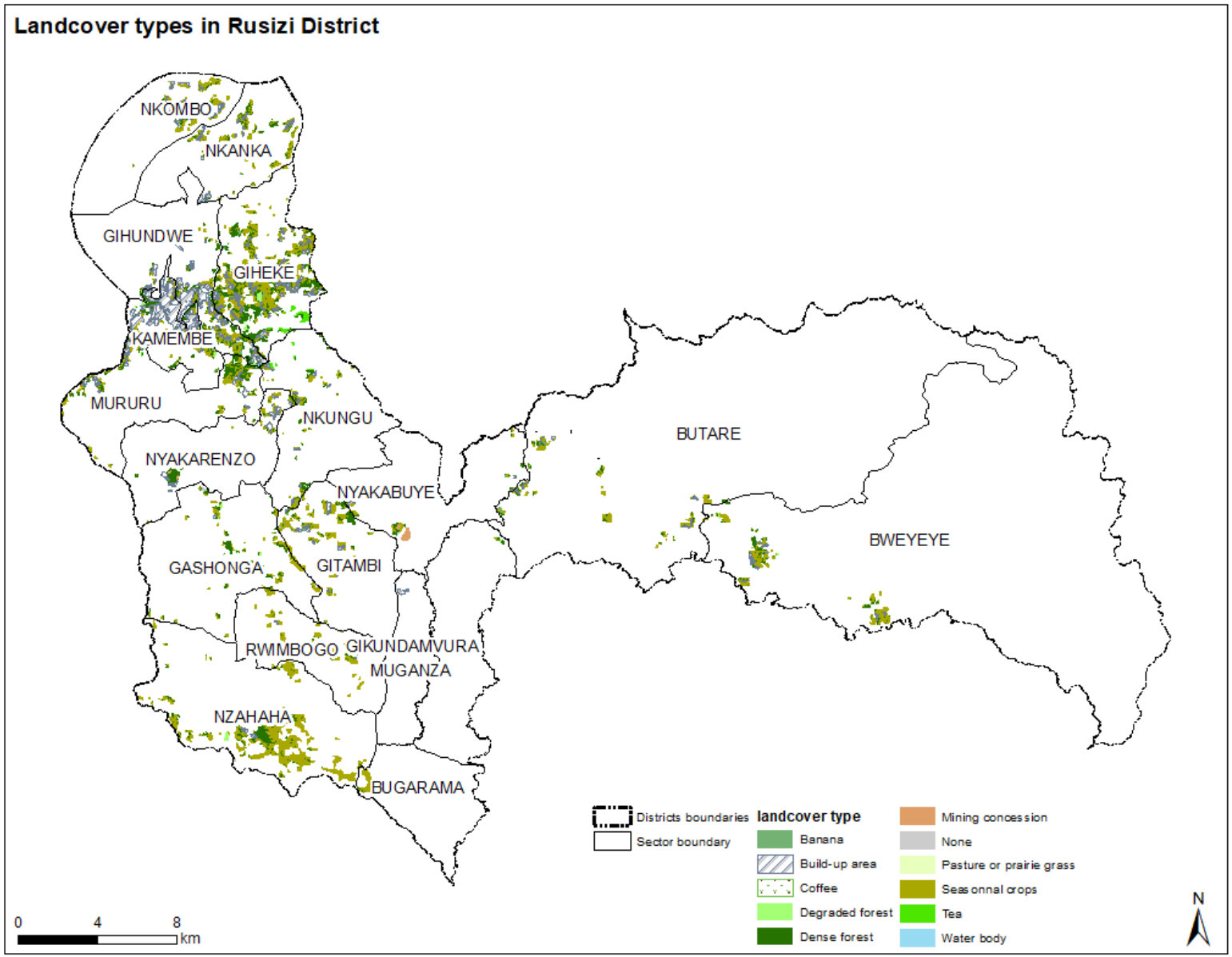


Figure 55: Land cover types in Rusizi District

About existing erosion control practices in Rusizi district, Table 54 shows that only 28% of land at risk is protected by forests (1,658 hectares) and Contour bank terraces (64 hectares). The highest protected sectors are Gikundamvura with 59% of its land at risk protected, followed by Mururu where 46% of the total land at risk is protected and Nyakarenzo with 45% of land protected. The least protected sectors are Bugarama with only 5% protected, Rwimbogo (only 11% protected), Muganza (11%) and Nkombo (14% protected). The visual interpretation of World View images confirms earlier findings by CROM model that Rwerere, Cyeru, Bungwe and Rusarabuge sectors remain at very high risk of soil erosion since more than 80% of their respective land are not protected.

Table 54: Erosion control practices already in place in Rusizi District

Sector name	Erosion control techniques in place				Grand Total (Ha)	% protected
	Contour bank terraces (Ha)	Forests (Ha)	Total protected (Ha)	None (Ha)		
GIKUNDAMVURA		5	5	4	9	59%
MURURU	14	172	185	221	406	46%
NYAKARENZO	13	63	76	95	171	45%
GASHONGA	4	83	86	147	233	37%
NKUNGU		68	68	130	198	35%
GIHEKE	1	458	459	949	1,408	33%
NKANKA	12	70	82	178	259	32%
GIHUNDWE		180	180	415	595	30%
KAMEMBE	6	158	164	463	627	26%
NYAKABUYE		26	26	77	103	25%
BWEYEYE		69	69	212	281	24%
BUTARE		49	49	157	207	24%
GITAMBI		77	77	261	338	23%
NZAHAHA	8	130	138	627	765	18%
NKOMBO	3	33	36	220	256	14%
MUGANZA		1	1	8	9	11%
RWIMBOGO	3	14	17	146	164	11%
BUGARAMA		3	3	53	56	5%
Grand Total	**64**	**1,658**	**1,722**	**4,361**	**6,084**	**28%**

Erosion control practices in Rusizi District are recommended based on existing land uses, erosion control measures already in place, and predicted erosion risk by CROM model. Table 55 shows that about 2,970 hectares (which is 49% of the total land at risk) are suitable for Contour bank terraces, 1,026 hectares are SWMF and 172 hectares are Afforestation & Reforestation. Others are cropland that needs agroforestry/alley cropping (112 hectares).

Table 55: Recommended erosion control practices in Rusizi District

Sector Name	Afforestation & Reforestation	Agro forestry	Contour bank terraces	No till	SWMF	None	Total
BUGARAMA			53			3	56
BUTARE	1		138	7	11	49	207
BWEYEYE	7	2	183	3	14	69	281
GASHONGA	18		127	1	1	86	233
GIHEKE	25	1	700	57	167	458	1,408
GIHUNDWE	13	7	165	6	222	181	595
GIKUNDAMVURA	2		2			5	9
GITAMBI	5	5	215	7	27	77	338
KAMEMBE	14	5	70	5	368	166	627
MUGANZA					8	1	9
MURURU	16	21	133	5	60	172	406
NKANKA	3	7	145	1	30	75	259
NKOMBO	10	43	132		44	27	256
NKUNGU	3		90	21	16	69	198
NYAKABUYE	26		43	2	6	27	103
NYAKARENZO	6	13	45	1	42	63	171
NZAHAHA	21	9	588		8	138	765
RWIMBOGO	1		143		1	17	164
Grand Total	**172**	**112**	**2,970**	**115**	**1,026**	**1,683**	**6,084**
Percentage	**3%**	**2%**	**49%**	**2%**	**17%**	**28%**	**100%**

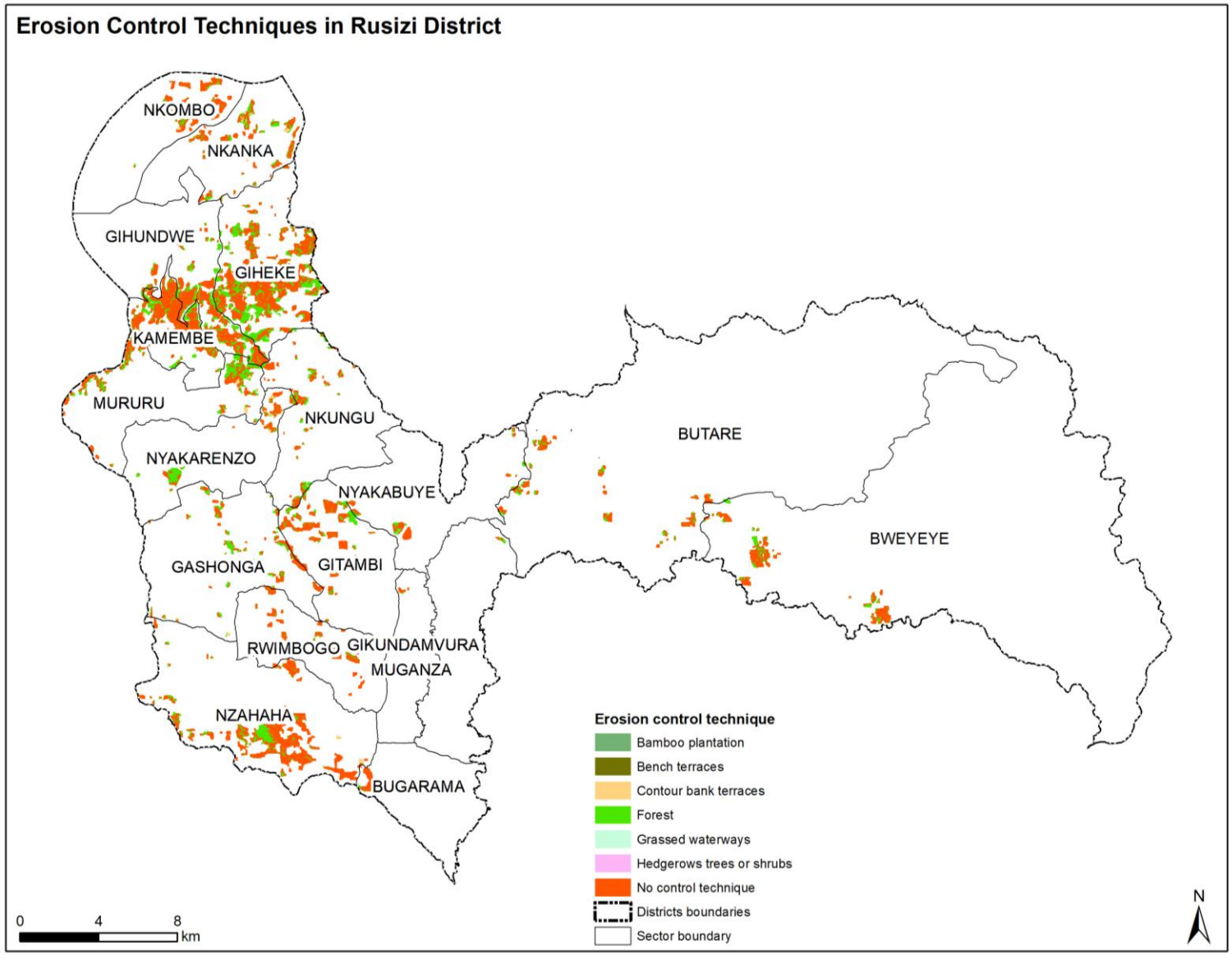


Figure 56: Erosion control techniques in place in Rusizi District

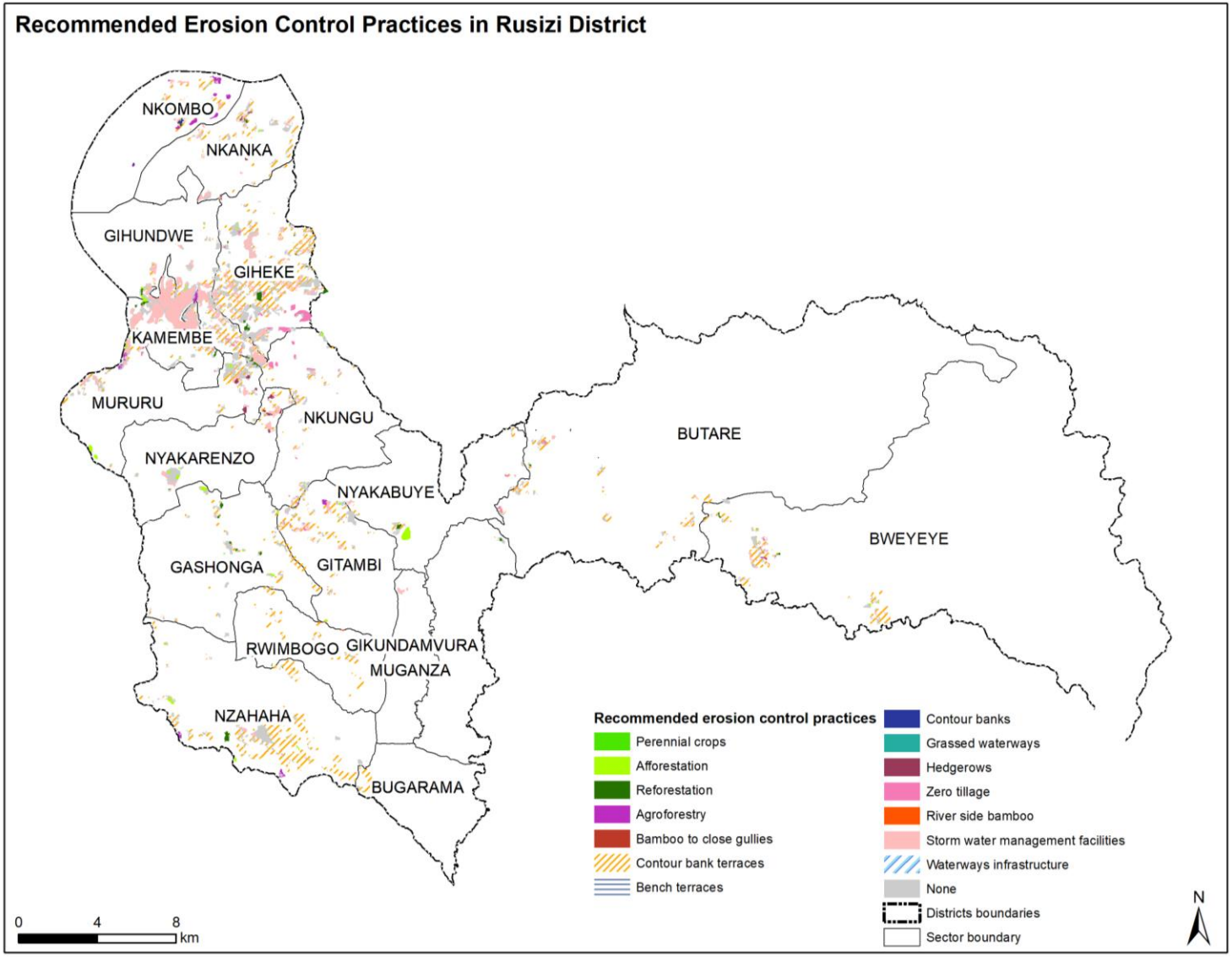


Figure 57: Recommended erosion control practices in Rusizi District

3.2.7. Erosion control status in Rutsiro District

Soil erosion risk in Rusizi is summarised in Table 56 and presented in Figure 58. Land area at risk is estimated to 35,110 hectares; about 53% of the total district land. Manihira sector is the highest susceptible to erosion with 3,301 hectares (89% of the sector land), followed by Rusebeya sector with 4,617 hectares (86% of sector land), and Mukura sector with 6,593 hectares (67% of the sector land), Gihango sector with 3,047 hectares (66% of the sector land), Mushubati sector with 3,225 hectares (62% of the sector land) and Murunda sector with 2,553 hectares (60% of the sector land). The least affected sectors (but still high) are Musasa sector with 931hectares (21% of the total sector land), and Kivumu sectors with 780 hectares at erosion risk (27% of the sector land).

Table 56: Erosion risk per sector in Rutsiro District

SN	Sector Name	Erosion risk				Sector land (ha)	%
		Extremely high	High	Very high	Total (Ha)		
1.	MANIHIRA	604	1,040	1,657	3,301	3,719	89%
2.	RUSEBEYA	1,846	674	2,097	4,617	5,370	86%
3.	MUKURA	1,367	1,913	3,313	6,593	9,887	67%
4.	GIHANGO	1,200	573	1,274	3,047	4,583	66%
5.	MUSHUBATI	579	975	1,671	3,225	5,189	62%
6.	MURUNDA	542	900	1,111	2,553	4,285	60%
7.	MUSHONYI	204	840	674	1,718	3,337	51%
8.	RUHANGO	108	1,037	1,240	2,384	5,400	44%
9.	NYABIRASI	1,213	899	1,519	3,632	9,351	39%
10.	KIGEYO	173	663	448	1,283	4,145	31%
11.	BONEZA	66	484	494	1,044	3,460	30%
12.	KIVUMU	55	569	157	780	2,883	27%
13.	MUSASA	111	563	257	931	4,388	21%
14.	**TOTAL**	**8,067**	**11,130**	**15,912**	**35,110**	**65,995**	**53%**

Land areas affected by soil erosion features in Rutsiro District are summarized in Table 57 and the map of erosion features are presented in Figure 59. The results show that Kavumu sector is the worst affected by gullies and rill erosion on areas estimated to 687 hectares (88% of sector land at risk), followed by Boneza sector with 842 hectares and Musasa sector (733 hectares). The presence of gullies and rill erosion in all sectors confirms the findings of CROM model. In fact, the erosion features types observed on World View images affect the entire District at 75% of its land, and each sector is affected at more than 60% of the sector land. The least sectors affected by gullies and rill erosion are Mushonyi and Kageyo have the areas affected by gullies and rill erosion of respectively 1142 hectares and 878 hectares.

Table 57: Erosion features types and areas affected in Rutsiro District

Sector Name	Erosion feature types					None	Grand Total	% Features
	Gullies	Landslide	Rill erosion	Severe gullies	Total			
KIVUMU	262	10	360	55	687	94	780	88%
BONEZA	408	16	317	101	842	203	1044	81%
MUSASA	329	8	259	138	733	198	931	79%
GIHANGO	837	9	1028	488	2362	685	3047	78%
NYABIRASI	774		1914	88	2776	855	3632	76%
RUHANGO	483	2	1318	20	1823	562	2384	76%
MUSHUBATI	1404	6	1032	10	2452	773	3225	76%
RUSEBEYA	1286		2000	210	3496	1121	4617	76%
MANIHIRA	1551	10	875	12	2449	852	3301	74%
MUKURA	2051		2187	623	4861	1732	6593	74%
MURUNDA	592	35	1172	4	1803	750	2553	71%
KIGEYO	336	7	528	8	878	406	1283	68%
MUSHONYI	594		488	61	1142	576	1718	66%
Grand Total	**10907**	**102**	**13476**	**1818**	**26303**	**8807**	**35110**	**75%**

In term of land use and related management of areas at risk in Rutsiro, the results of land cover mapping (Table 58 and Figure 60) show 21,945 hectares (63% of the total land at risk) are used for seasonal crops, and 7,420 hectares (21% of the total of the total land at risk) ares covered by healthy forests. In Rutsiro District there are also mining concessions and tea plantations which cover respectively areas of 1,337 hectares (4% of the total land at risk) and 273 hectares (less than 1% of the total land at risk).

Table 58: Land Use and Vegetation Cover (LUVC) of areas at risk in Rutsiro District

Sector name	Build-up area	Degraded forest	Dense forest	Mining &Quarry	Seasonal crops	Tea	Total
BONEZA	259	17	120	0	648		1,044
GIHANGO	487	103	520	6	1,927	4	3,047
KIGEYO	236	31	218	9	709	81	1,283
KIVUMU	387	7	71	12	264	39	780
MANIHIRA	74	1	796	-	2,340	90	3,301
MUKURA	277	0	1,719	39	4,558		6,593
MURUNDA	157	24	503	2	1,866		2,553
MUSASA	434	4	116	15	363		931
MUSHONYI	222	5	544	3	945		1,718
MUSHUBATI	46	45	714	6	2,365	48	3,225
NYABIRASI	108	140	560	1,243	1,568	12	3,632
RUHANGO	340	7	417	2	1,618		2,384
RUSEBEYA	724		1,121	0	2,772		4,617
Grand Total	**3,751**	**384**	**7,420**	**1,337**	**21,945**	**273**	**35,110**

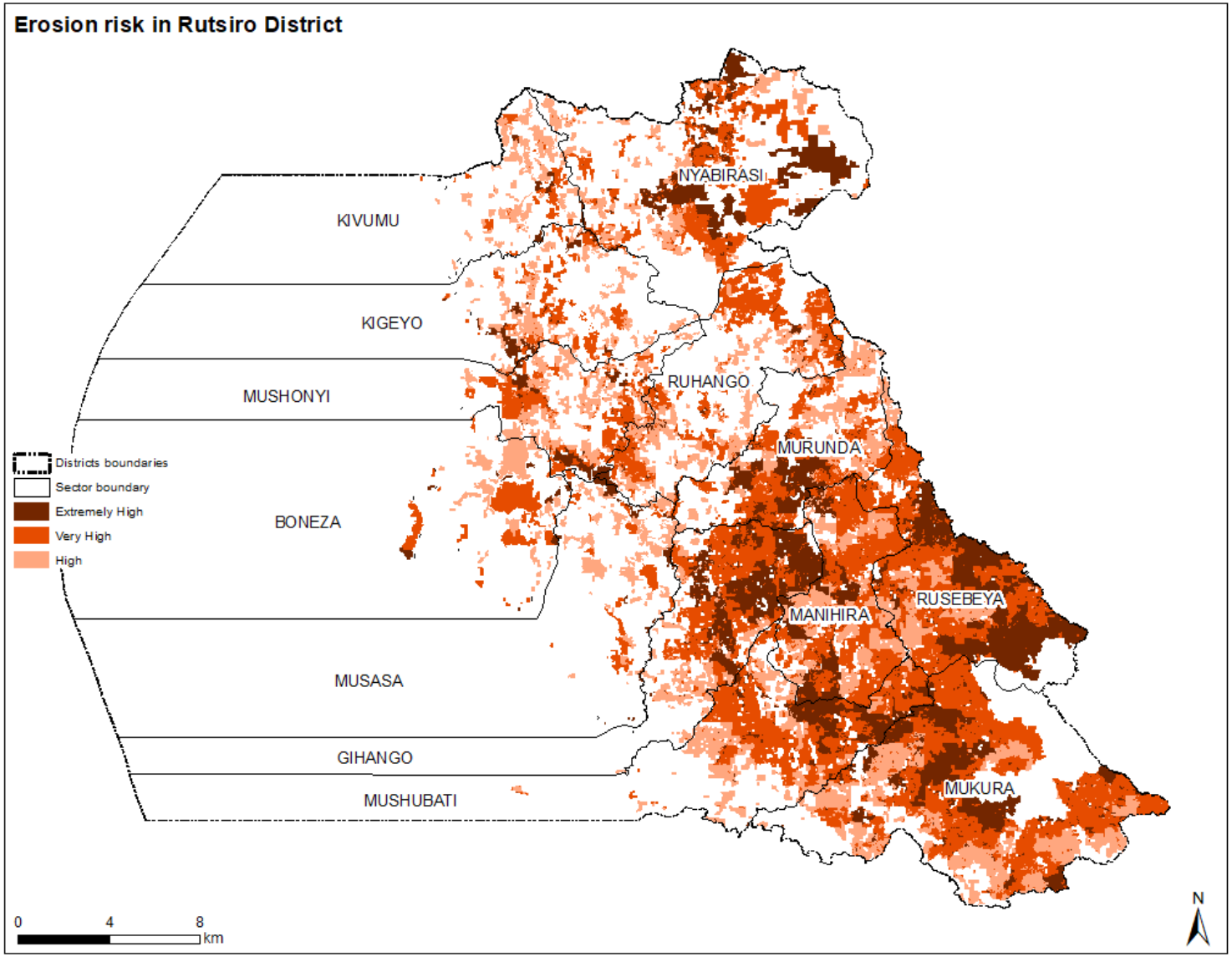


Figure 58: Erosion risk in Rutsiro District

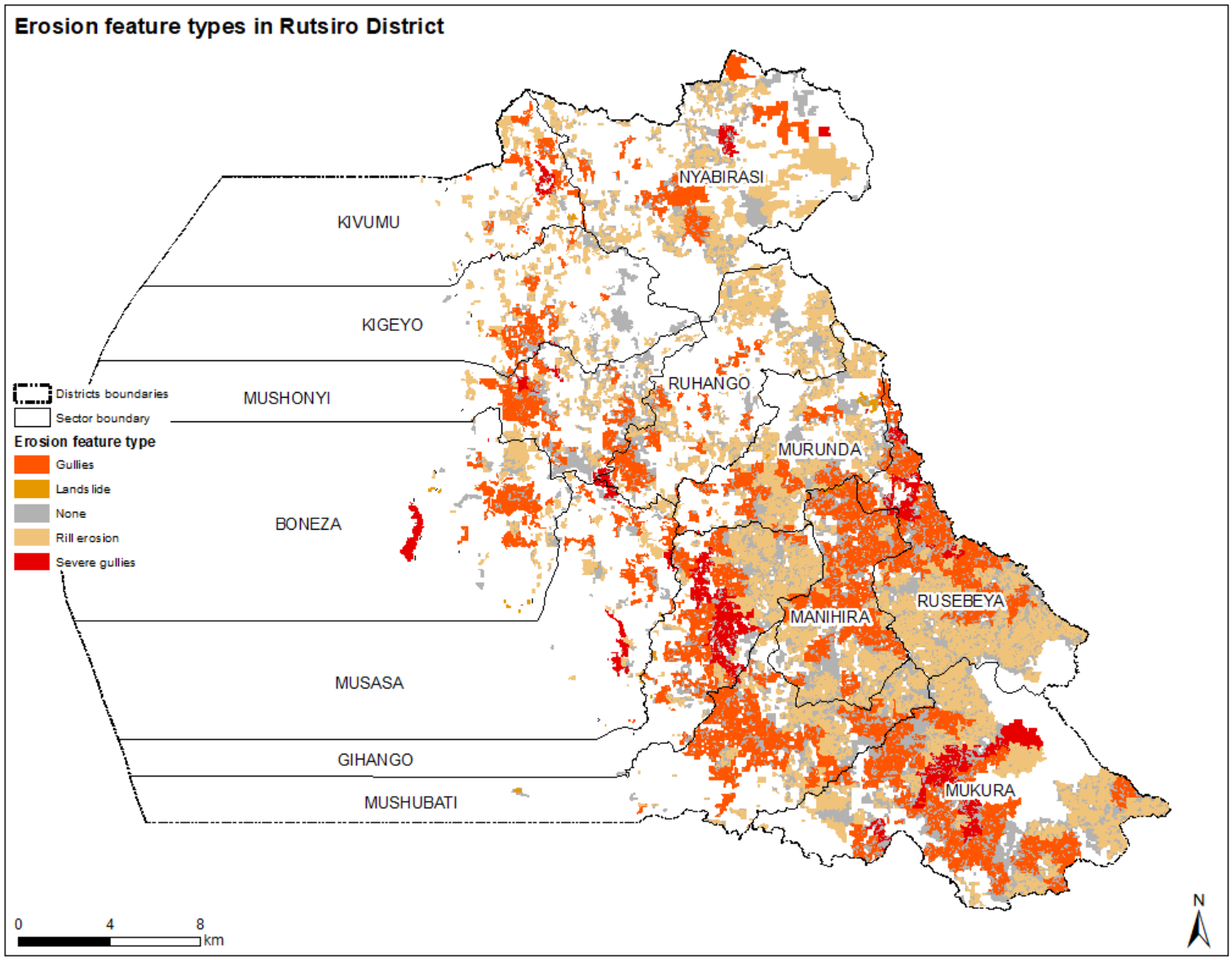


Figure 59: Erosion features detected in Rutsiro District

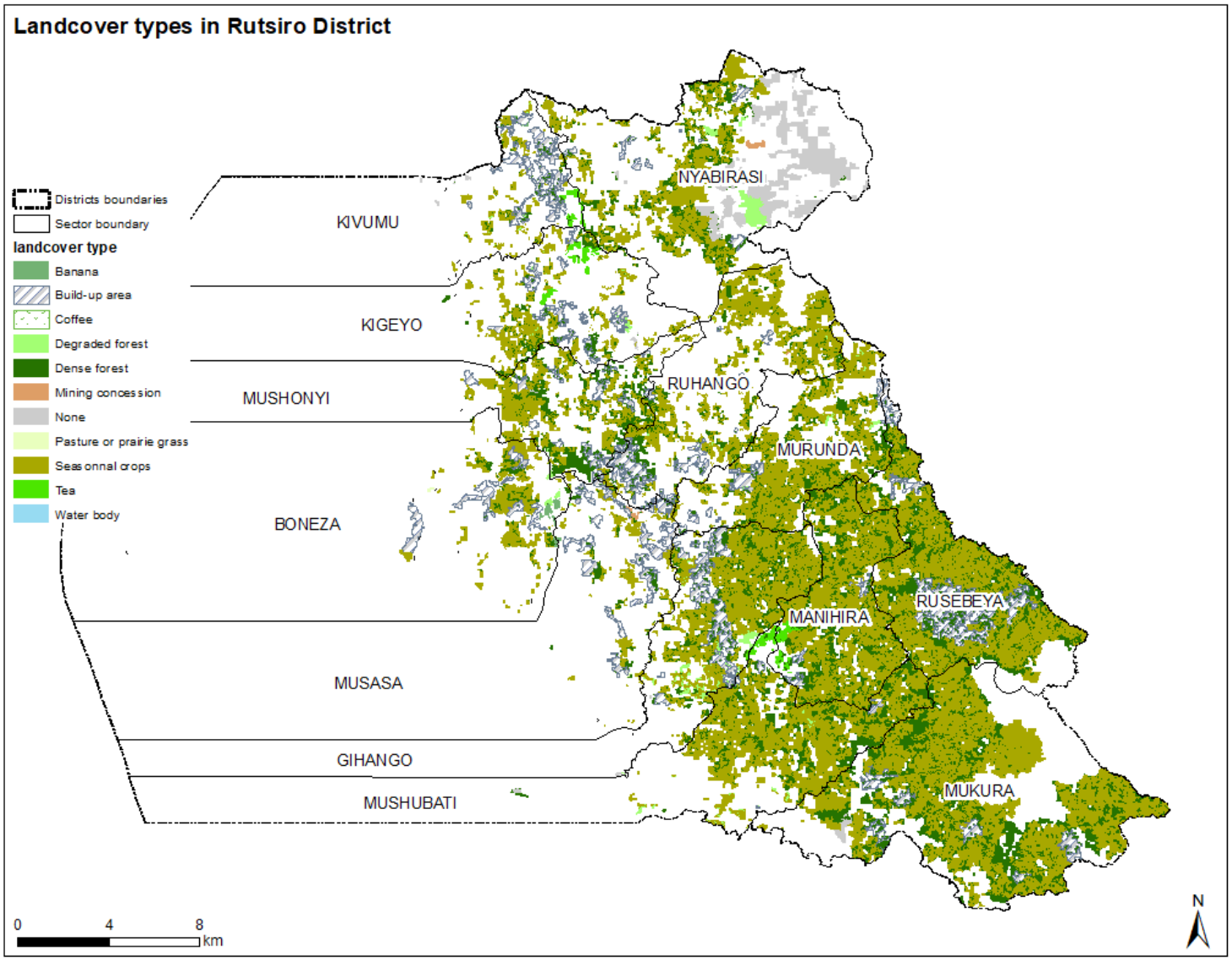


Figure 60: Land cover types in Rutsiro District

About existing erosion control practices in Rutsiro district, Table 60 shows that only 36% of land at risk is protected by forests (7,436 hectares) and Contour bank terraces (4,077 hectares) and bench terraces (1,021 hectares). The highest protected sectors are Murunda with 79% of its land at risk protected, followed by Gihango where 48% of the total land at risk is protected and Ruhango with 42% of land protected. The least protected sectors are Kivumu with only 14% protected, Musasa (only 15% protected), Boneza (16%) and Nyabirasi (20% protected). The visual interpretation of World View images confirms earlier findings by CROM model that Bugarama (95% not protected), Rwimbogo, Muganza and Nkombo sectors remain at very high risk of soil erosion since more than 80% of their respective land are not protected

Table 59: Erosion control practices already in place in Rutsiro District

Sector name	Erosion control techniques in place				Unprotected	Grand Total	% protected
	Bench terraces	Contour bank terraces	Forests	Total protected			
MURUNDA	269	1,250	507	2,026	527	2,553	79%
GIHANGO	38	890	534	1,462	1,585	3,047	48%
RUHANGO	2	589	411	1,002	1,382	2,384	42%
MANIHIRA	18	449	796	1,263	2,038	3,301	38%
MUKURA	633	145	1,719	2,497	4,096	6,593	38%
MUSHONYI	4	53	532	589	1,129	1,718	34%
RUSEBEYA	39	136	1,141	1,316	3,301	4,617	29%
MUSHUBATI		171	714	885	2,340	3,225	27%
KIGEYO	4	130	219	352	931	1,283	27%
NYABIRASI	3	161	560	724	2,908	3,632	20%
BONEZA		45	122	167	877	1,044	16%
MUSASA	9	14	116	139	792	931	15%
KIVUMU		45	66	110	670	780	14%
Grand Total	**1,021**	**4,077**	**7,436**	**12,533**	**22,577**	**35,110**	**36%**

Erosion control practices in Rutsiro District are recommended based on existing land uses, erosion control measures already in place, and predicted erosion risk by CROM model. Table 61 shows that about 10,887 hectares (which is 31% of the total land at risk) are suitable for cropland that need agroforestry/alley cropping, 6,824 hectares are Contour bank terraces and 3,528 hectares are Storm water management facilities (SWMF). Others are hedgerows (2,608 hectares), Afforestation & Reforestation (2,253 hectares), bench terraces (184 hectares) and gullies or riverbanks amounting to 1,181 hectares eroded which require bamboo trees for rehabilitation.

Table 60: Recommended erosion control practices in Rutsiro District

Sector Name	Afforestation & Reforestation	Agro forestry	Bamboo gullies & riverside	Bench terraces	Contour bank terraces	Hedge rows	No till	SWMF	None	Total
BONEZA	124	251	87	3	235		41	259	45	1,044
GIHANGO	114	1,424	4	52	347	95	4	487	520	3,047
KIGEYO	78	218	41		300	116	81	231	218	1,283
KIVUMU	75	39	27		126	37	43	398	28	780
MANIHIRA	26	1,452		189	528	147	90	74	796	3,301
MUKURA	53	1,968		294	1,561	778		221	1,719	6,593
MURUNDA	63	403	1	379	172	911		42	571	2,553
MUSASA	150	118	8		181	5	8	434	16	931
MUSHONYI	66	626	20	6	247	6		222	524	1,718
MUSHUBATI	59	1,228	17		1,009	104	48	21	738	3,225
NYABIRASI	1,356	705		161	691	3	12	144	558	3,632
RUHANGO	31	547		12	676	364		340	414	2,384
RUSEBEYA	57	1,907		86	751	41		654	1,120	4,617
Grand Total	**2,253**	**10,887**	**207**	**1,181**	**6,824**	**2,608**	**326**	**3,528**	**7,266**	**35,110**
Percentage	**6%**	**31%**	**1%**	**3%**	**19%**	**7%**	**1%**	**10%**	**21%**	**100%**

Note: Grassed waterways are recommended for existing terraces which was made without waterways or with but no grasses which can cause severe gullies and destruction of bench terraces created. No-till agriculture is recommended is recommended for perennial crops on extremely high risk area while Storm water management facilities (SWMF) or water harvesting infrastructure is recommended in built-up areas. None: means no-recommendation is provided because existing erosion control measures are adequate with reference made to the total land protected. Contour banks are recommended for existing forest without ditches. Bamboos are recommended to close gullies or for riverside buffers.

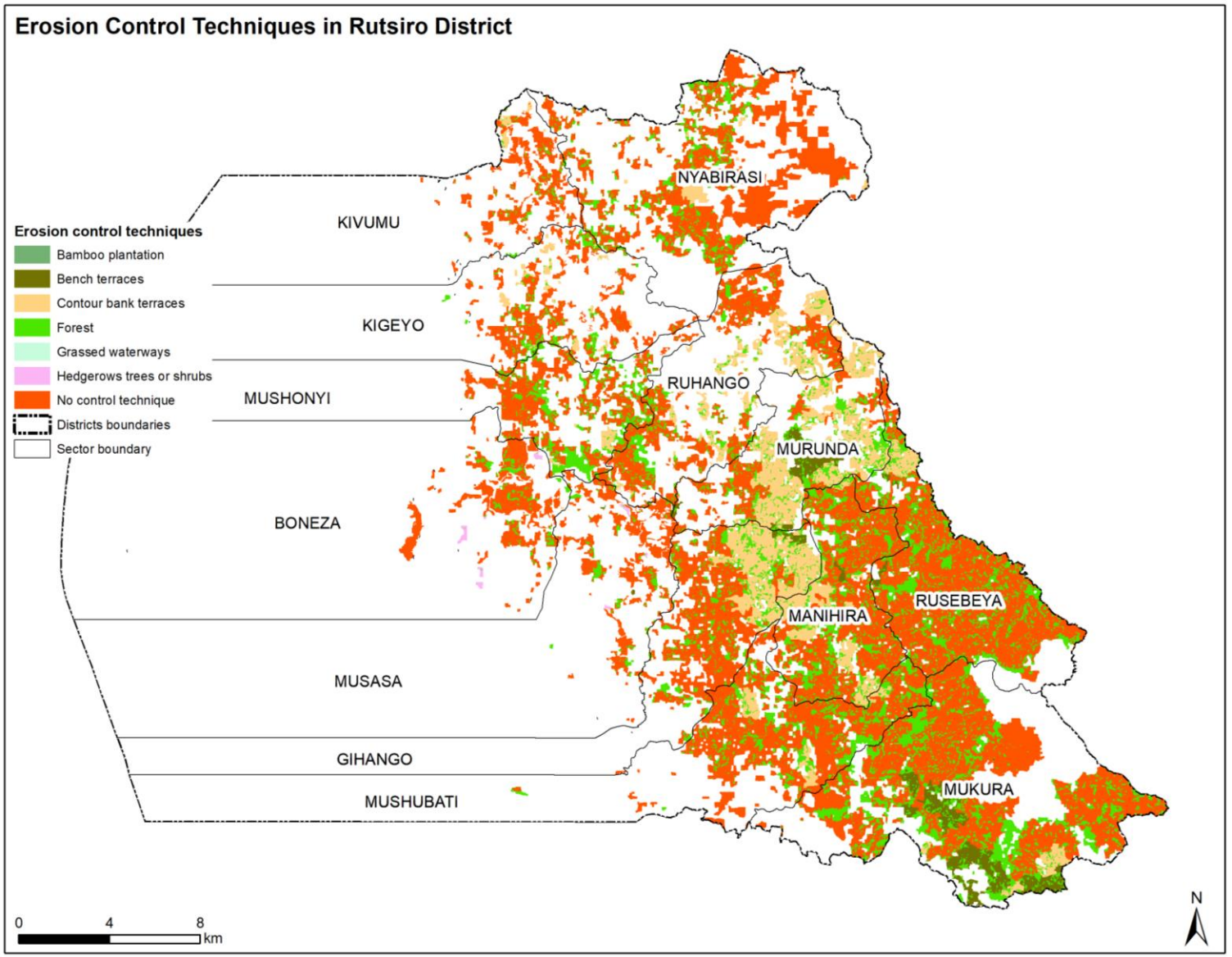


Figure 61: Erosion control techniques in place in Rutsiro District

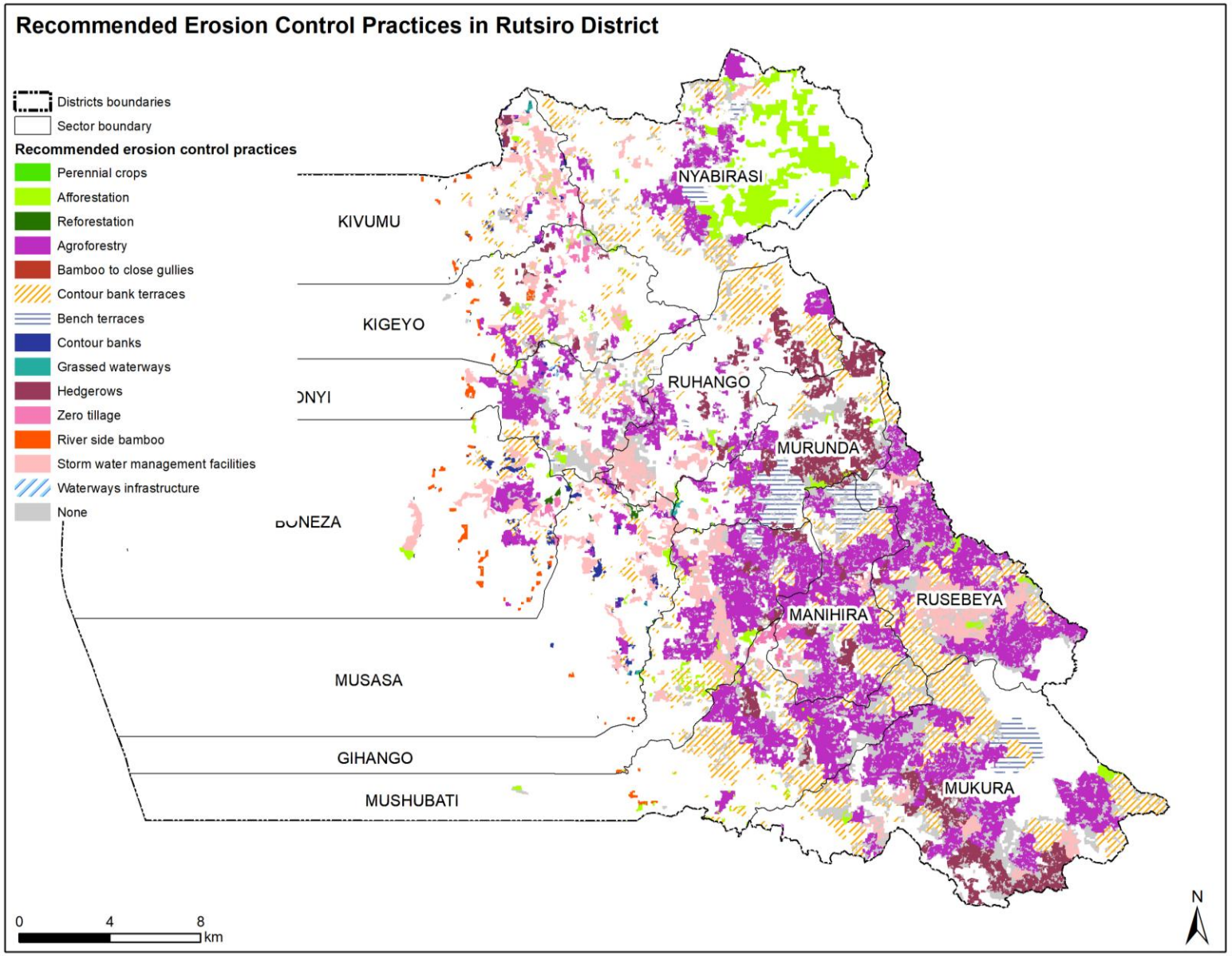


Figure 62: Recommended erosion control practices in Rutsiro District

3.3. Erosion Control Status in Southern Province

Erosion risk in Southern Province is summarized in table 61 and presented in figure 63. The total land at high risk of erosion in Southern Province is about 201,251hectares (34% of the total province land). The highest amount of land at erosion risk are found in Muhanga with 40,514 hectares (i.e. 63% of the total district land) followed by Nyamagabe District with 43,452 hectares (40% of the district land), and Nyaruguru with 37,836 hectares (40% of district land). The least district susceptible to erosion is Gisagara, where 21% of its district land is at risk, about 14,537 hectares. The contribution of forests in protecting fragile land in Southern Province is evident, particularly the Nyungwe National park in Nyamagabe and Nyaruguru districts as well as forest plantations in steep slopes of Southern mountains and plateau.

Table 61: Erosion risk in Southern Province

District	Erosion risk (Ha)				District land (Ha)	% District at erosion risk
	Extremely high	High	Very high	Grand Total (Ha)		
MUHANGA	7,255	17,743	15,515	40,514	64,772	63%
NYAMAGABE	6,192	19,398	17,862	43,452	109,036	40%
NYARUGURU	6,971	16,670	14,195	37,836	101,027	37%
KAMONYI	2,195	9,920	7,003	19,118	65,553	29%
HUYE	2,165	9,053	4,796	16,013	58,153	28%
RUHANGO	1,225	9,743	3,796	14,764	62,678	24%
NYANZA	891	9,791	4,336	15,018	67,215	22%
GISAGARA	353	11,048	3,137	14,537	67,920	21%
Grand Total	**27,246**	**103,365**	**70,640**	**201,251**	**596,355**	**34%**

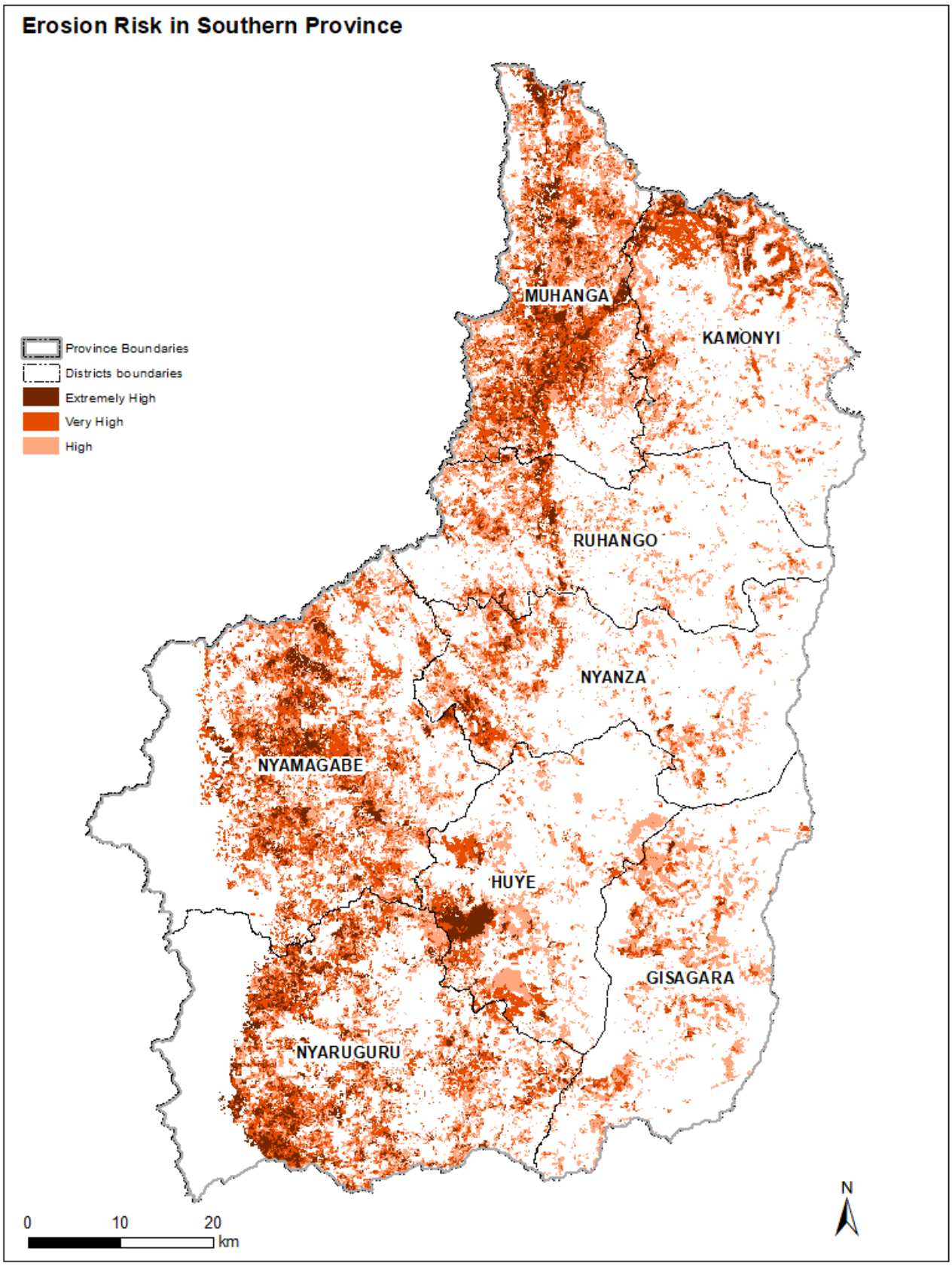


Figure 63: Erosion risk in Southern Province

3.3.1. Erosion control in Gisagara District

Erosion risk in Gisagara is summarised in Table 62 and presented in figure 64. Erosion risk in Gisagara District is estimated to 67,920 hectares; about 21% of the total district land are highly susceptible to erosion of which 2,224 hectares are located in Musha sector (45% of sector land), 2,299 hectares are located in Ndora sector (38% of sector land), 1,355 hectares are located in Kigembe (30% of the sector land), and 1,093 hectares are found in Save sector about 27% of the sector land. The least sectors are Mukindo with only 310 hectares (6% of the sector land) susceptible to erosion, Mamba with 718 hectares (9%), and Mugombwa with 527 hectares, about 11% of the total sector land. As compare to other district in Southern Province, Gisagara is the least susceptible to erosion.

Table 62: Erosion risk per sector in Gisagara District

Sector Name	Erosion risk				Sector land (Ha)	%
	Extremely high	Very high	High	Total (Ha)		
MUSHA	36	557	1,632	2,224	4,977	45%
NDORA	55	673	1,572	2,299	6,103	38%
KIGEMBE	58	435	862	1,355	4,482	30%
SAVE	62	301	730	1,093	4,108	27%
GISHUBI	25	250	1,274	1,549	6,143	25%
GIKONKO	63	112	1,000	1,175	4,929	24%
MUGANZA	15	305	1,121	1,440	7,039	20%
NYANZA	2	88	650	739	3,876	19%
KANSI	10	85	497	592	4,241	14%
KIBILIZI	11	111	392	514	3,983	13%
MUGOMBWA	17	93	418	527	4,985	11%
MAMBA	0	103	614	718	8,011	9%
MUKINDO		23	287	310	5,044	6%
Grand Total	**353**	**3137**	**11,048**	**14,537**	**67,920**	**21%**

Land areas affected by soil erosion features in Gisagara District are summarized in Table 63 and the map of erosion features are presented in Figure 65. The results show that Gishubi sector is the worst affected by rill erosion on areas estimated to 1375 hectares (89% of sector land at risk), followed by Gikonko , Mamba and Mugombwa sectors affected by gullies and rill erosion on 79% of sector land at risk. The presence of gullies in all sectors, except Mukindo and Nyanza confirms the findings of CROM model; however the absence of gullies in Mukindo (310 ha) and Nyanza (564 ha) which was originally predicted by CROM model as sector at high risk should not read that CROM model did not perform well in this sectors, but rather due to the time of image acquisition, the erosion features could be observed or erosion control measures have been already taken and therefore runoffs have been reduced, thus erosion features could not be formed in this case. Further analysis of Land cover and erosion control practices in place will demonstrate that (Table 64 and 65).

Table 63: Erosion features types and areas affected in Gisagara District

Sector Name	Erosion Feature types (Ha)					None	Grand Total	% features
	Gullies	Landslide	Rill erosion	Severe gullies	Total			
GISHUBI	9		1,367		1,375	174	1,549	89%
GIKONKO	365		569	0	934	242	1,175	79%
MAMBA	68		498		566	152	718	79%
MUGOMBWA	72		336	7	414	113	527	79%
MUKINDO			243		243	67	310	78%
MUGANZA	40		1,084		1,124	316	1,440	78%
NYANZA			564		564	176	739	76%
KIBILIZI	19	8	359		386	128	514	75%
NDORA	23		1,683		1,706	593	2,299	74%
MUSHA	382		1,265	0	1,646	578	2,224	74%
KANSI	18		417		436	157	592	74%
SAVE	19	11	722		753	340	1,093	69%
KIGEMBE	7		906		913	442	1,355	67%
Grand Total	**1,022**	**19**	**10,012**	**7**	**1,1060**	**3,477**	**14,537**	**76%**

In term of land use and related management of areas at risk in Gisagara, the results of land cover mapping (Table 64 and Figure 66) show that **10,574** hectares (73% of the total land at risk) are used for seasonal cropping, **3,033**hectares (21% of the total of the total land at risk) are covered by healthy forests and 924 hectares (6% of the total land at risk) are covered by built-up area. In Gisagara District there are also coffee plantations which cover an area of 6 hectares (less than 1% of the total land at risk).

Table 64: Land Use and Vegetation Cover (LUVC) for land at risk in Gisagara District

Sector name	Build-up area	Coffee	Dense forest	Seasonal crops	Total
GIKONKO	76		211	888	1,175
GISHUBI	266		174	1,109	1,549
KANSI	60		152	381	592
KIBILIZI	2		110	402	514
KIGEMBE	14		437	904	1,355
MAMBA	101		83	534	718
MUGANZA	109	4	286	1,041	1,440
MUGOMBWA	35		111	381	527
MUKINDO	17		66	227	310
MUSHA	93		431	1,701	2,224
NDORA	79	1	501	1,718	2,299
NYANZA	9		176	555	739
SAVE	64		297	732	1,093
Grand Total	**924**	**6**	**3,033**	**10,574**	**14,537**

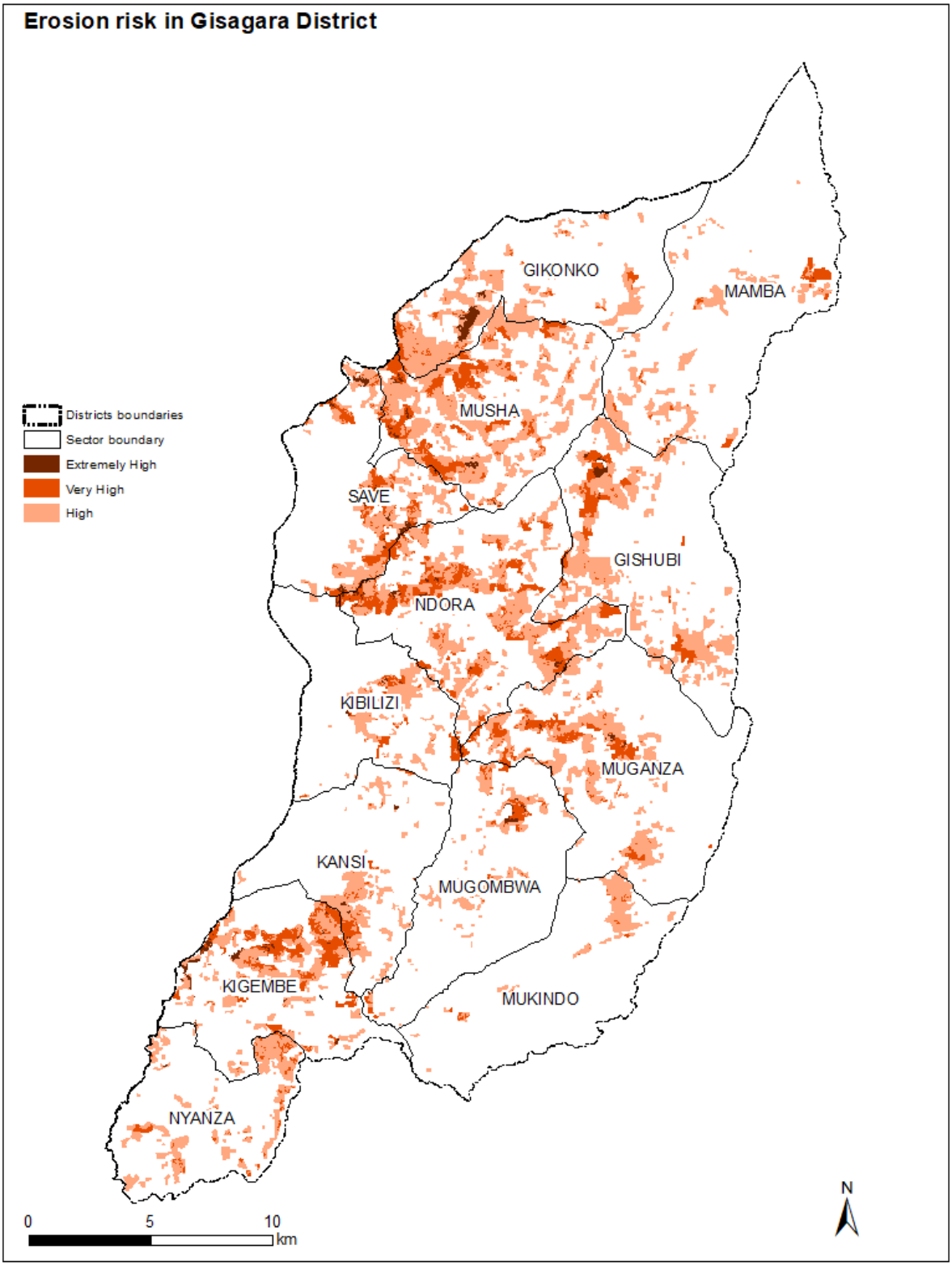


Figure 64: Erosion risk in Gisagara District

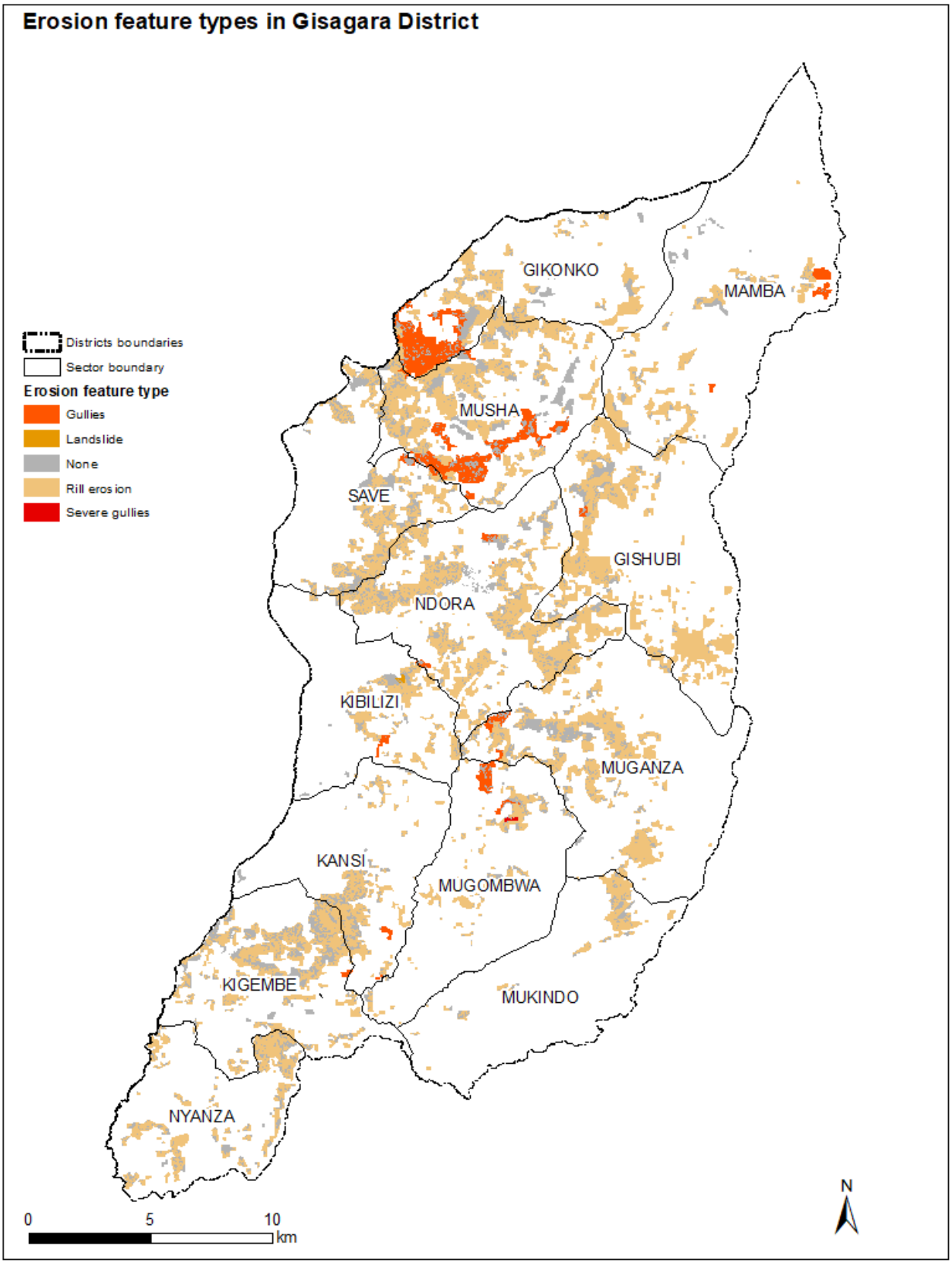


Figure 65: Erosion features detected in Gisagara District

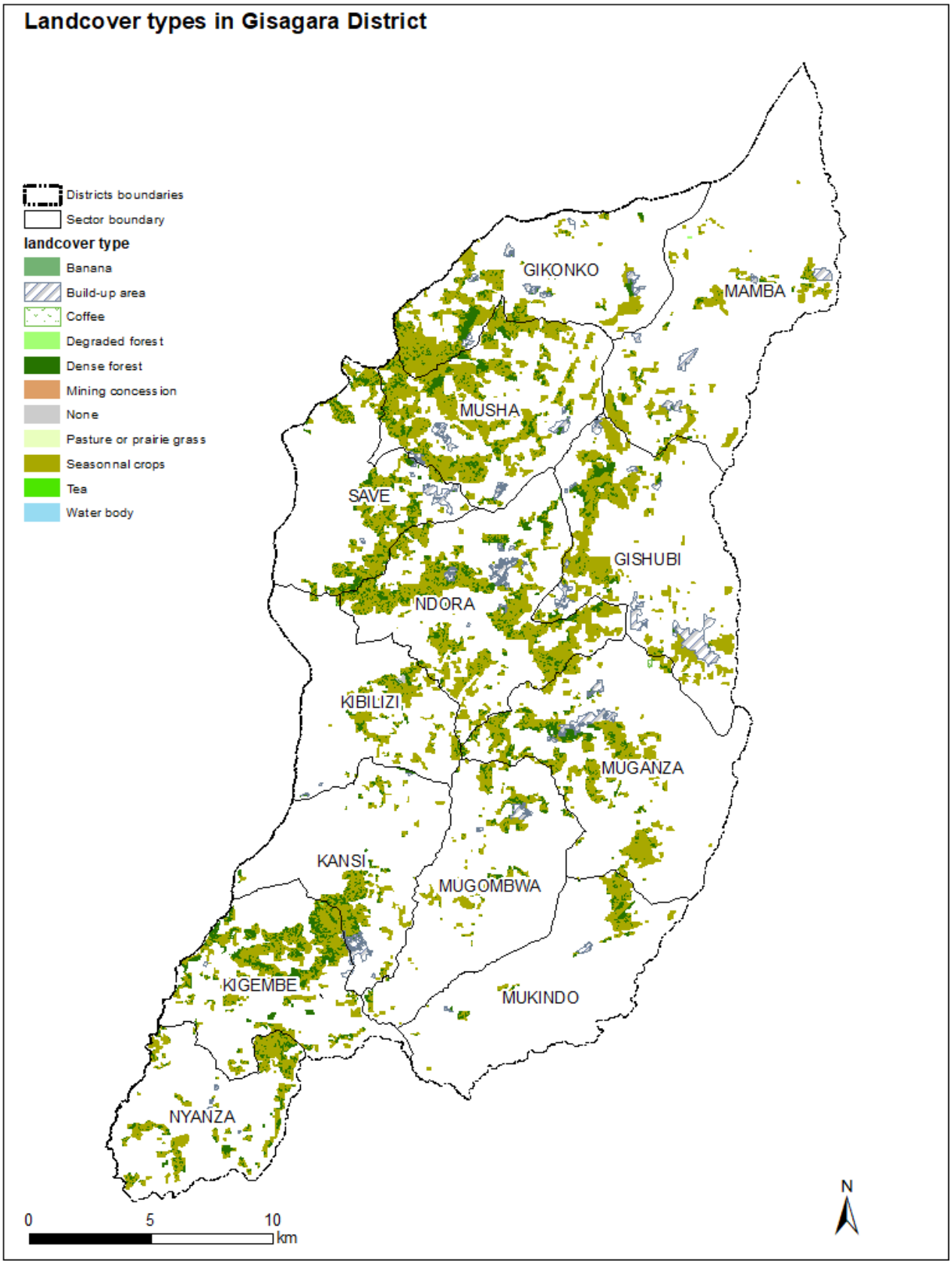


Figure 66: Land cover types in Gisagara District

About existing erosion control practices in Gisagara district, Table 54 shows that only 30% of land at risk is protected by forests (3,057 hectares), contour bank terraces (406 hectares), bench terraces (916 hectares) and bamboo (18 hectares). The highest protected sectors are Kigembe with 44% of its land at risk protected, followed by Kansi where 44% of the total land at risk is protected and Nyanza with 37% of land protected. The least protected sectors are Gishubi with only 13% protected, Mamba (only 14% protected), Mugombwa (23%) and Kibirizi (24% protected). The visual interpretation of World View images confirms earlier findings by CROM model that Gishubi, Mamba, Mugombwa and Kibirizi sectors remain at very high risk of soil erosion since more than 70% of their respective land are not protected

Table 65: Erosion control practices already in place in Gisagara District

Sector name	Erosion control techniques in place					Unprotected	Grand Total	% protected
	Bamboo plantation	Bench terraces	Contour bank terraces	Forests	Total protected			
KIGEMBE		105	55	436	596	759	1,355	44%
KANSI		86	22	152	260	333	592	44%
NYANZA	18	82		176	276	463	739	37%
MUSHA		318	63	431	812	1,413	2,224	36%
MUGANZA		214	18	286	517	923	1,440	36%
SAVE			91	297	388	705	1,093	36%
GIKONKO		54	77	211	343	832	1,175	29%
MUKINDO		4	8	66	79	231	310	25%
NDORA		10	45	527	582	1,718	2,299	25%
KIBILIZI		10	6	109	125	389	514	24%
MUGOMBWA		4	8	111	123	404	527	23%
MAMBA		18		83	101	617	718	14%
GISHUBI		10	12	174	196	1,353	1,549	13%
Grand Total	**18**	**916**	**406**	**3,057**	**4,397**	**10,140**	**14,537**	**30%**

Erosion control practices in Gisagara District are recommended based on existing land uses, erosion control measures already in place, and predicted erosion risk by CROM model. Table 66 shows that about 9,446 hectares (which is 65 % of the total land at risk) are suitable for Contour bank terraces, 1,269 hectares are Hedge rows and 681 hectares are Storm water management facilities (SWMF).

Table 66: Recommended erosion control practices in Gisagara District

Sector Name	Afforestation & Reforestation	Bamboo to close gullies	Bench terraces	Contour bank terraces	Hedge rows	SWMF	None	Total
GIKONKO				757	132	76	211	1,175
GISHUBI			0	1,255	19	101	174	1,549
KANSI	2			273	107	58	152	592
KIBILIZI	9			378	16	2	109	514
KIGEMBE	7		14	738	146	14	436	1,355
MAMBA				549	18	68	83	718
MUGANZA				827	214	109	286	1,440
MUGOMBWA	7	16		354	4	35	111	527
MUKINDO				223	4	17	66	310
MUSHA				1,324	355	92	453	2,224
NDORA	2		1	1,703	55	36	501	2,299
NYANZA				441	114	9	176	739
SAVE	12		11	623	85	64	297	1,093
Grand Total	**38**	**16**	**28**	**9,446**	**1,269**	**681**	**3,054**	**14,537**
Percentage	**0%**	**0%**	**0%**	**65%**	**9%**	**5%**	**21%**	**100%**

Note: Grassed waterways are recommended for existing terraces which was made without waterways or with but no grasses which can cause severe gullies and destruction of bench terraces created. No-till agriculture is recommended is recommended for perennial crops on extremely high risk area while Storm water management facilities (SWMF) or water harvesting infrastructure is recommended in built-up areas. None: means no-recommendation is provided because existing erosion control measures are adequate with reference made to the total land protected. Contour banks are recommended for existing forest without ditches. Bamboos are recommended to close gullies or for riverside buffers.

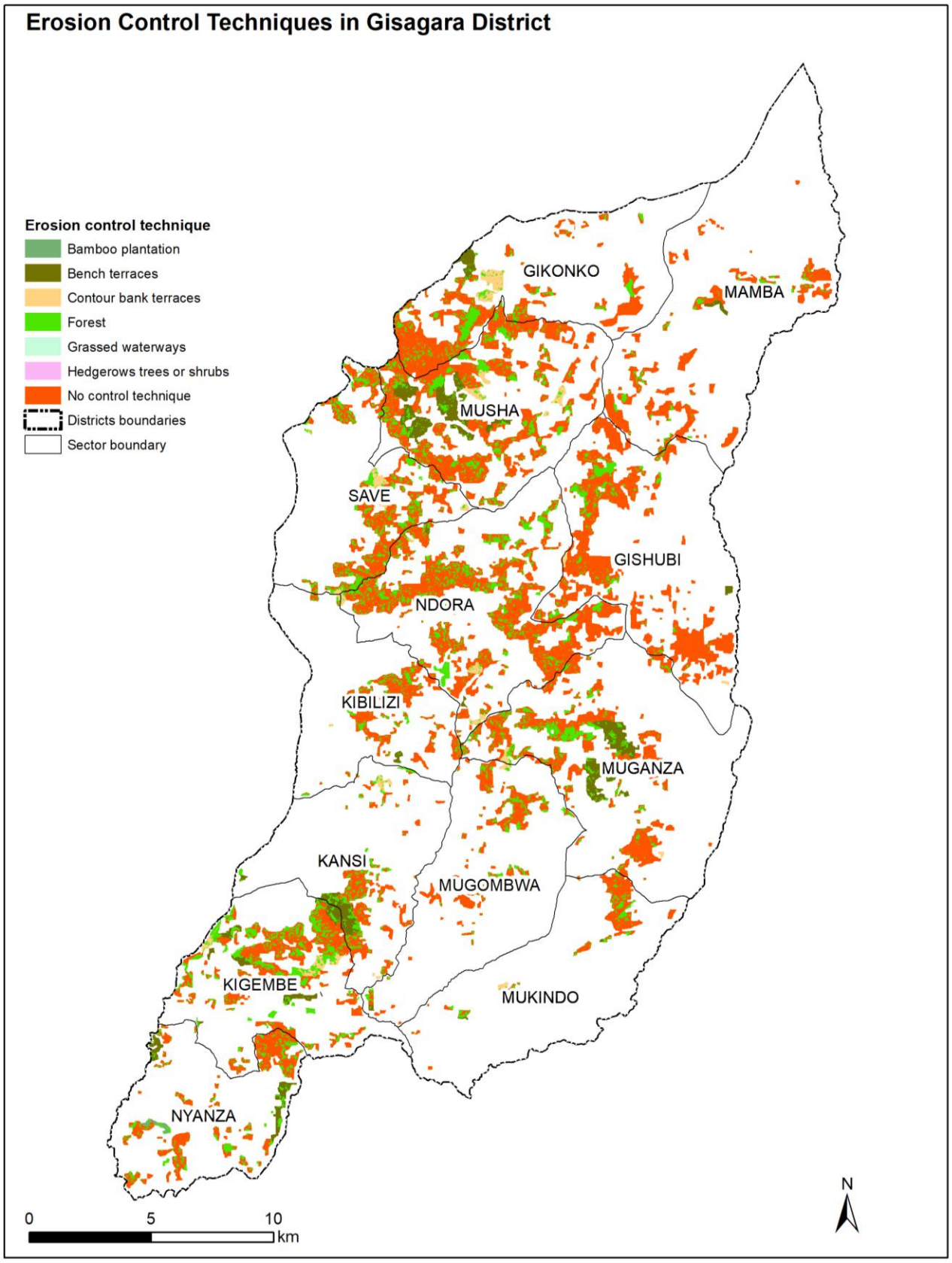


Figure 67: Erosion control techniques in place in Gisagara District

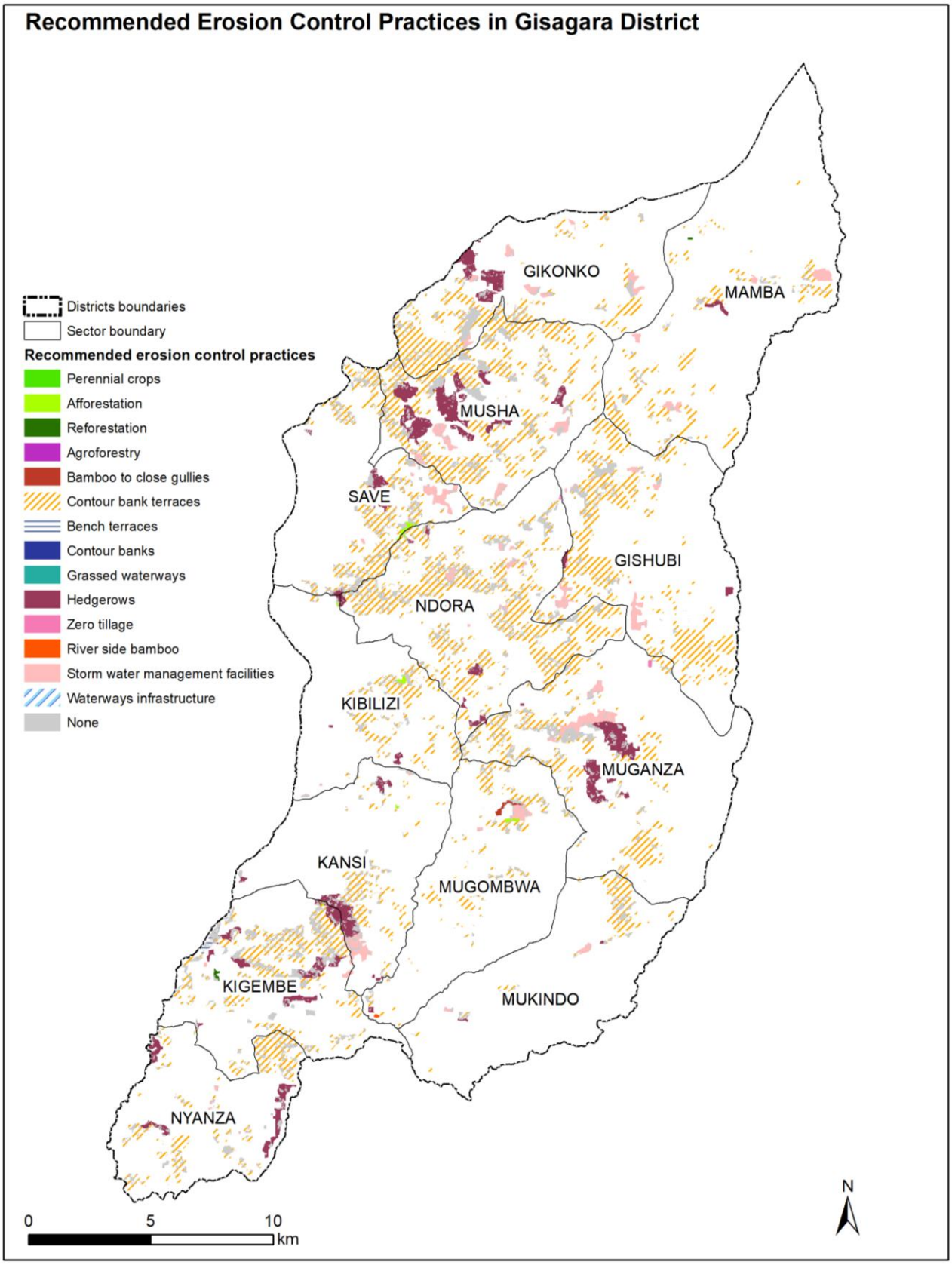


Figure 68: Recommended erosion control practices in Gisagara District

3.3.2. Erosion control status in Huye District

Erosion risk in Huye is summarised in Table 67 and presented in figure 69. Erosion risk in Huye District is estimated to 16,013 hectares; about 28% of the total district land are highly susceptible to erosion of which 3,362 hectares are located in Karama sector (63% of sector land), 5,161 hectares are located in Maraba sector (54% of sector land), 3,028 hectares are located in Gishamvu (48% of the sector land), and 3,528 hectares are found in Huye sector about 41% of the sector land. The least sectors are Kinazi with only 318 hectares (5% of the sector land) susceptible to erosion, Mbazi with 611 hectares (15%), and Rwaniro with 801 hectares, about 15% of the total sector land. As compared to other districts in Southern Province, Huye is the fifth susceptible to erosion, due to intensible protection of agricultural land by bench terraces and forests.

Table 67: Erosion risk per sector in Huye District

Sector Name	Erosion risk				Sector land (Ha)	%
	Extremely high	Very high	High	Total (Ha)		
KARAMA	783	1,152	1,427	3,362	5,377	63%
MARABA	1,054	751	991	2,796	5,161	54%
GISHAMVU	68	824	560	1,452	3,028	48%
HUYE	63	232	1,138	1,432	3,523	41%
KIGOMA	66	862	479	1,407	5,102	28%
RUHASHYA	24	290	574	887	4,189	21%
SIMBI	64	117	689	870	4,264	20%
NGOMA	3	103	280	386	2,070	19%
RUSATIRA	6	50	875	932	5,155	18%
TUMBA	20	51	246	317	1,801	18%
MUKURA		20	422	442	2,804	16%
RWANIRO	12	166	623	801	5,445	15%
MBAZI	1	132	478	611	4,153	15%
KINAZI	2	45	271	318	6,081	5%
Grand Total	**2,165**	**4,796**	**9,053**	**16,013**	**58,153**	**28%**

Land areas affected by soil erosion features in Huye District are summarized in Table 68 and the map of erosion features are presented in Figure 70. The results show that Rusatira sector is the worst affected by gullies and severe gullies on areas estimated to 531 hectares (72% of sector land at risk), followed by Karama sector on 1,636 hectares (49% of sector land at risk), and Gishamvu sector on 517 hectares (36% of sector land at risk). The presence of gullies in Rusatira, Karama, Gishamvu and Maraba sectors confirms the findings of CROM model; however the reduced presence of gullies in Mukura (1 ha), Ngoma and Tumba which were originally predicted by CROM model as sectors at high risk should not read that CROM model did not perform well in this sectors, but rather due to the time of image acquisition, the erosion features could be observed or erosion control measures have been already taken and therefore runoffs have been reduced, thus erosion features could not be formed in this case. Further analysis will demonstrate that in Table 14 and 15. The least sectors affected by gullies are Mukura with only 1 hectare, Ngoma with only 4 hectares and Tumba with 4 hectares affected by gullies.

Table 68: Erosion features types and areas affected in Huye District

Sector Name	Erosion feature types					None	Grand Total	%
	Gullies	Landslide	Rill erosion	Severe gullies	Total			Features
RUSATIRA	239		0	292	531	401	932	57%
KARAMA	1602			33	1,636	1726	3,362	49%
GISHAMVU	478	7		32	517	935	1,452	36%
MARABA	859	15	0	43	917	1878	2,796	33%
KIGOMA	389	1			390	1016	1,407	28%
RUHASHYA	130			2	132	755	887	15%
KINAZI	38		0		38	280	318	12%
HUYE	167	0			167	1265	1,432	12%
MBAZI	55	15	0		71	540	611	12%
RWANIRO	49			5	54	747	801	7%
SIMBI	49			2	51	819	870	6%
TUMBA	1			3	4	314	317	1%
NGOMA	2	2			4	382	386	1%
MUKURA	1				1	441	442	0%
Grand Total	**4060**	**41**	**0**	**412**	**4,513**	**11,499**	**16,013**	**28%**

In term of land use and related management of areas at risk in Huye District, the results of land cover mapping (Table 69 and Figure 71) show that 7,934hectares (50% of the total land at risk) are used for seasonal cropping, 6,307hectares (39% of the total land at risk) are covered by healthy forests, 374 hectares (2% of the total land at risk) are covered by built-up area.

Table 69: Land Use and Vegetation Cover (LUVC) for land at risk in Huye District

Sector name	Banana	Build-up area	Coffee	Degraded forest	Dense forest	Mining concession	Seasonnal crops	Water body	Total
GISHAMVU	4	15	7	48	799	0	579		1452
HUYE		34	113	4	729	5	547		1432
KARAMA		19	34	69	1736	3	1500		3362
KIGOMA	2	20	82	21	386	0	881	15	1407
KINAZI		26		1	70	0	217	4	318
MARABA	8	28	371	314	1157	13	901	4	2796
MBAZI		6	2	25	193	1	385		611
MUKURA		15		3	188	3	233		442
NGOMA	0	66		39	107	4	170		386
RUHASHYA	2	18		10	273	0	584		887
RUSATIRA		77		17	104	0	726	8	932
RWANIRO	2	7		37	194	6	540	14	801
SIMBI		11	32	36	245	1	528	17	870
TUMBA	1	31		16	127	0	142		317
Grand Total	**20**	**374**	**640**	**640**	**6307**	**36**	**7934**	**61**	**16013**

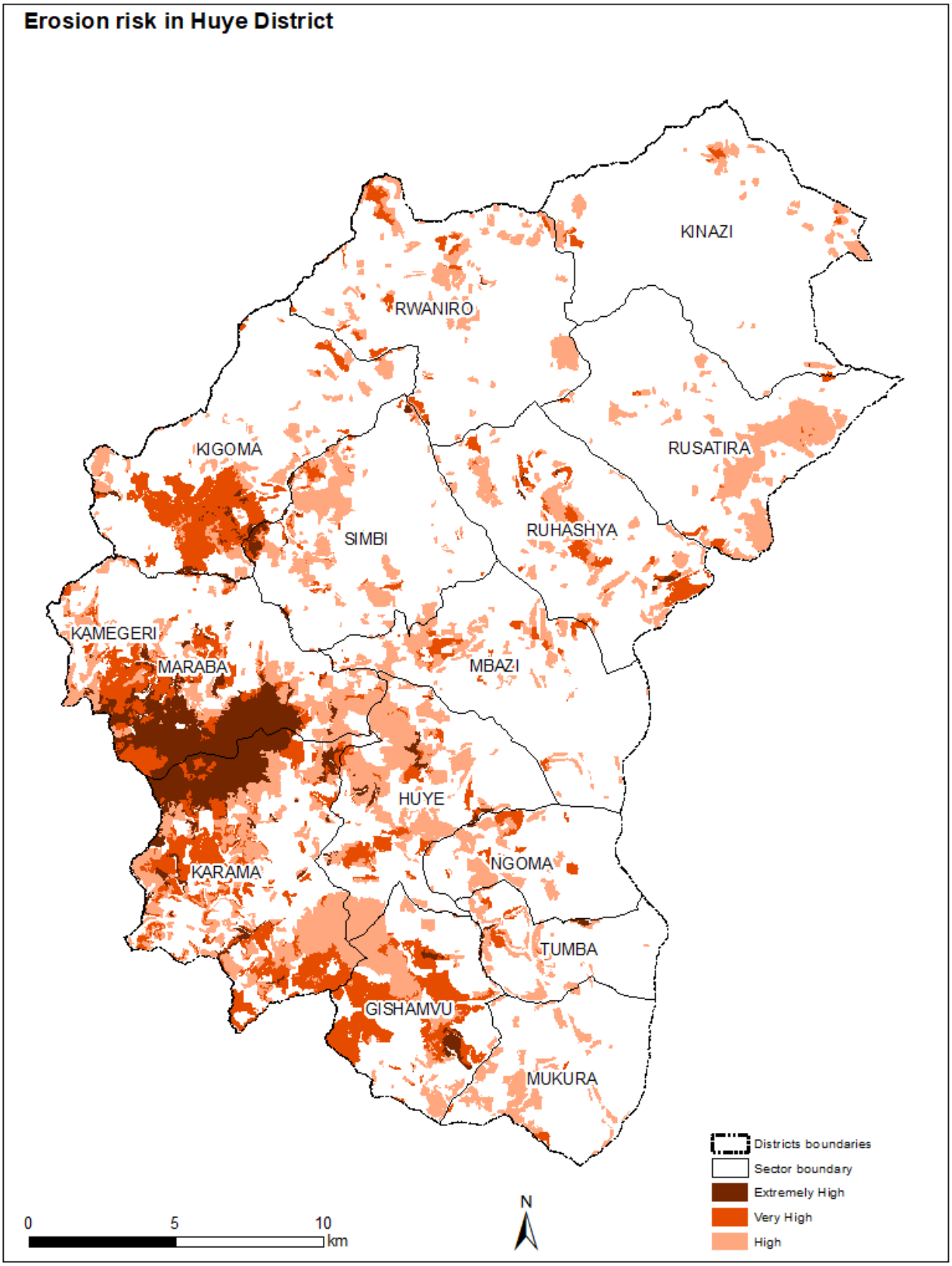


Figure 69: Erosion risk in Huye District

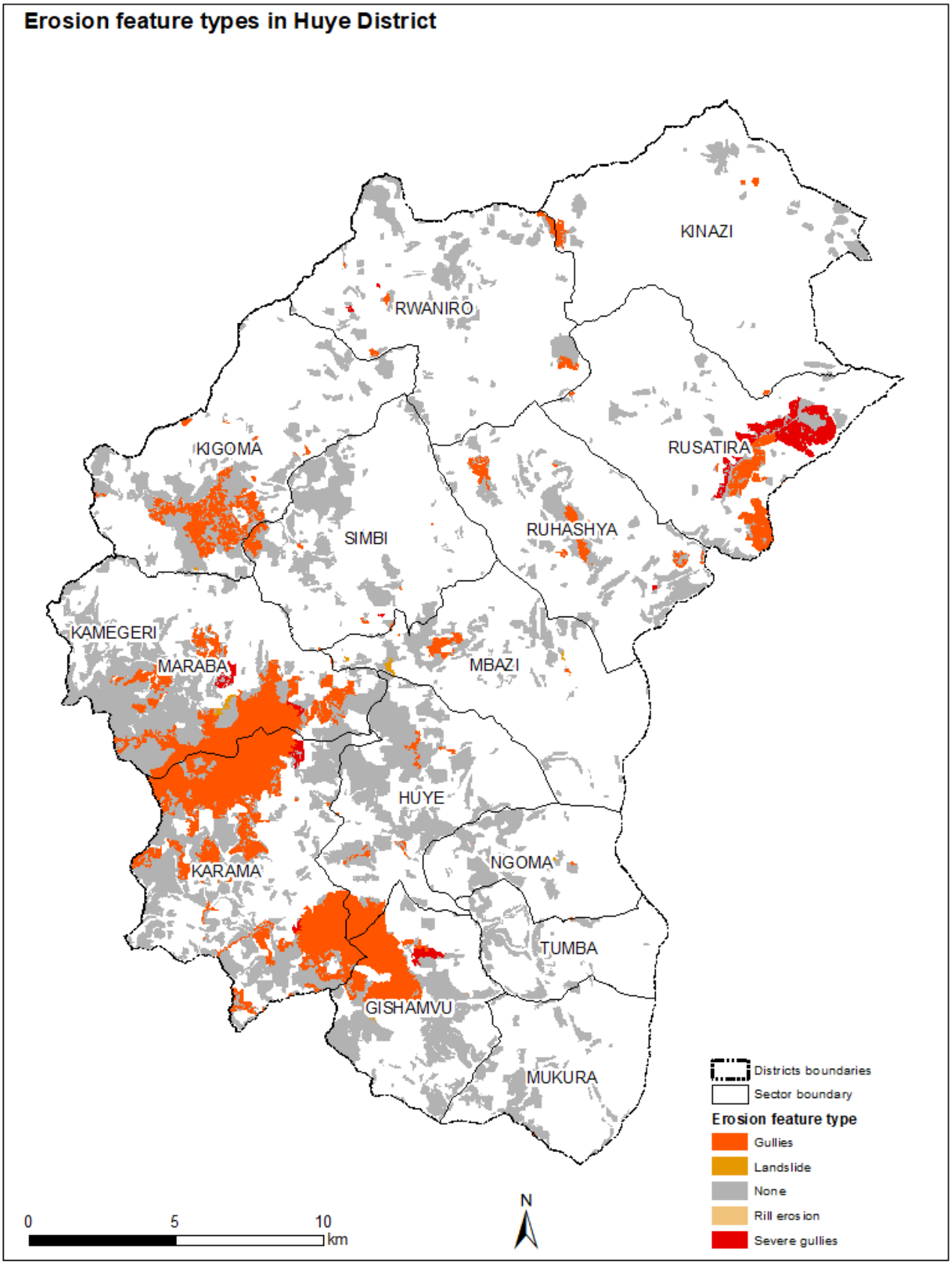


Figure 70: Erosion features detected in Huye District

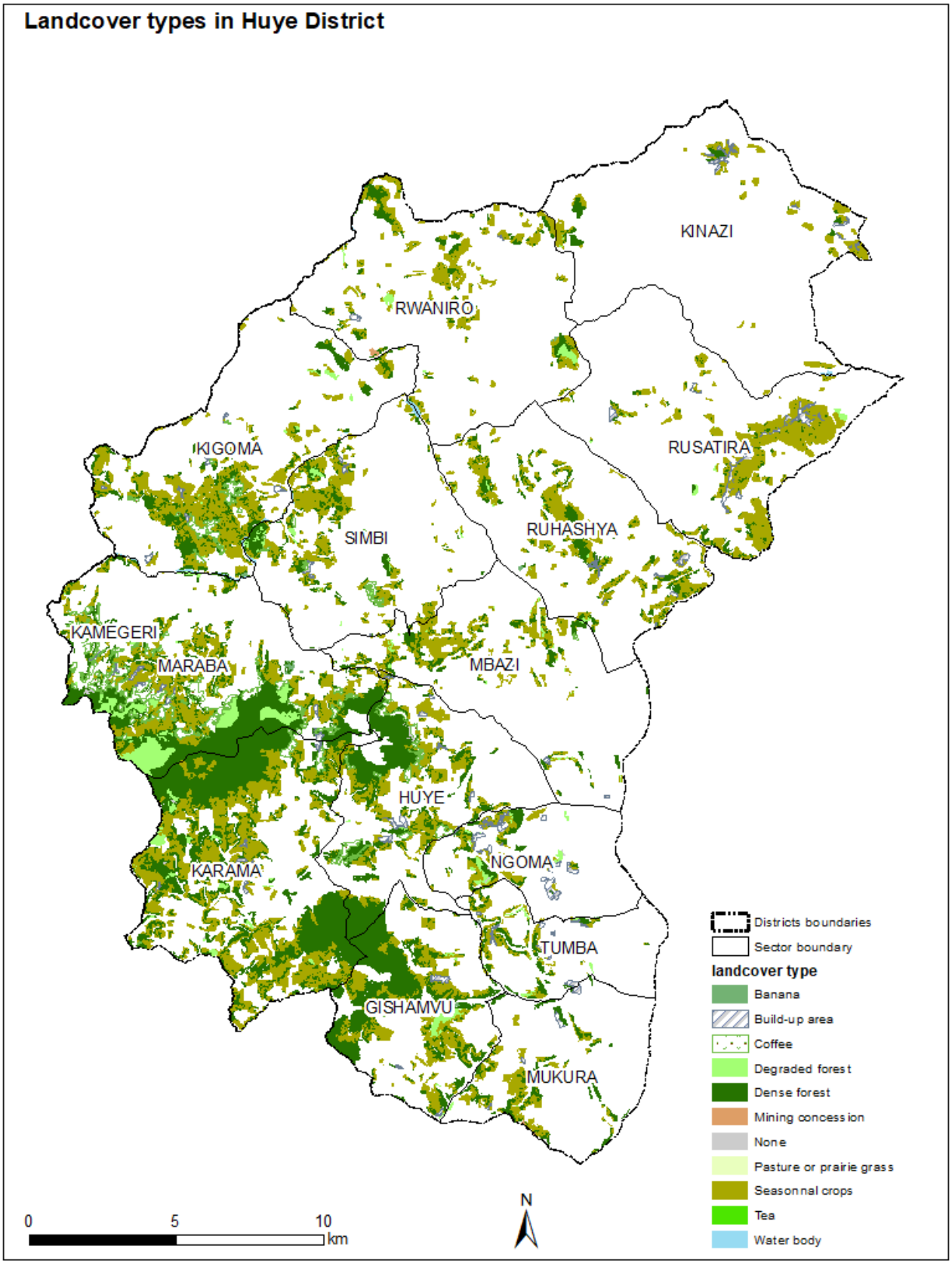


Figure 71: Land cover types in Huye District

About existing erosion control practices in Huye district, Table 70 shows that 51% of land at risk is protected by forests (6,313 hectares), contour bank terraces (1,044 hectares) and bench terraces (329 hectares). The highest protected sectors are Gishamvu with 66% of its land at risk protected, followed by Kigoma where 64% of the total land at risk is protected and Karama with 61% of land protected. The least protected sectors are Kinazi with only 22% protected, Simbi (only 33% protected), Ruhashya (35%) and Ngoma (37% protected). The visual interpretation of World View images confirms earlier findings by CROM model that Kinazi, Simbi, Ruhashya and Ngoma sectors remain at very high risk of soil erosion since more than 65% of their respective land are not protected

Table 70: Erosion control practices already in place in Huye District

Sector name	Erosion control techniques in place					Unprotected	Grand Total	% protected
	Bench terraces	Contour bank terraces	Forest	Hedge rows trees	Total protected			
GISHAMVU		157	799		956	496	1,452	66%
KIGOMA		45	386	469	900	507	1,407	64%
KARAMA	2	318	1,736		2,057	1,305	3,362	61%
HUYE	3	89	732		824	608	1,432	58%
TUMBA		38	125		163	154	317	51%
RUSATIRA	316	53	104		474	457	932	51%
MUKURA		7	187		194	248	442	44%
RWANIRO	7	142	194		343	458	801	43%
MARABA		34	1,157		1,191	1,605	2,796	43%
MBAZI		48	197		244	367	611	40%
NGOMA		32	109		142	244	386	37%
RUHASHYA		40	273		313	574	887	35%
SIMBI		39	245	0	285	585	870	33%
KINAZI			70		70	248	318	22%
Grand Total	**329**	**1,044**	**6,313**	**469**	**8,155**	**7,858**	**16,013**	**51%**

Erosion control practices in Huye District are recommended based on existing land uses, erosion control measures already in place, and predicted erosion risk by CROM model. Table 71 shows that about 6,261 hectares (which is 31% of the total land at risk) are suitable for Contour bank terraces, 1,320 hectares are Hedgerows and 745 hectares are Afforestation & Reforestation. Other interventions are 12 ha for agroforestry, 98 hectares of contour bank, 59 hectares of grassed waterways and 140 hectares of bench terraces.

Table 71: Recommended erosion control practices in Huye District

Sector Name	Afforestation & Reforestation	Bamboo to close gullies	Bench terraces	Contour bank terraces	Hedge rows	No till	SWMF	None	Total
GISHAMVU	50	5		412	135	14	15	807	1452
HUYE	4			453	92	118	34	731	1432
KARAMA	115	2		1115	321	34	19	1718	3362
KIGOMA	24	16		825	45	84	20	386	1407
KINAZI	2		0	217			26	59	318
MARABA	332	5	0	852	19	379	28	1,157	2796
MBAZI	26			338	46	2	6	158	611
MUKURA	7			226	7		15	183	442
NGOMA	43			121	36	0	66	107	386
RUHASHYA	12			540	40	2	18	272	887
RUSATIRA	17	7	140	217	369		77	106	932
RWANIRO	45	8		380	149	2	7	200	801
SIMBI	48	10		460	39	32	11	249	870
TUMBA	19			105	22	1	31	130	317
Grand Total	**745**	**54**	**140**	**6,261**	**1,320**	**667**	**374**	**6,263**	**16,013**
Percentage	**5%**	**0%**	**1%**	**39%**	**8%**	**4%**	**2%**	**39%**	**100%**

Other interventions: 12 ha agroforestry, 98hectares contour bank; 59hectares grassed waterways

Note: Grassed waterways are recommended for existing terraces which was made without waterways or with but no grasses which can cause severe gullies and destruction of bench terraces created. No-till agriculture is recommended is recommended for perennial crops on extremely high risk area while Storm water management facilities (SWMF) or water harvesting infrastructure is recommended in built-up areas. None: means no-recommendation is provided because existing erosion control measures are adequate with reference made to the total land protected. Contour banks are recommended for existing forest without ditches. Bamboos are recommended to close gullies or for riverside buffers.

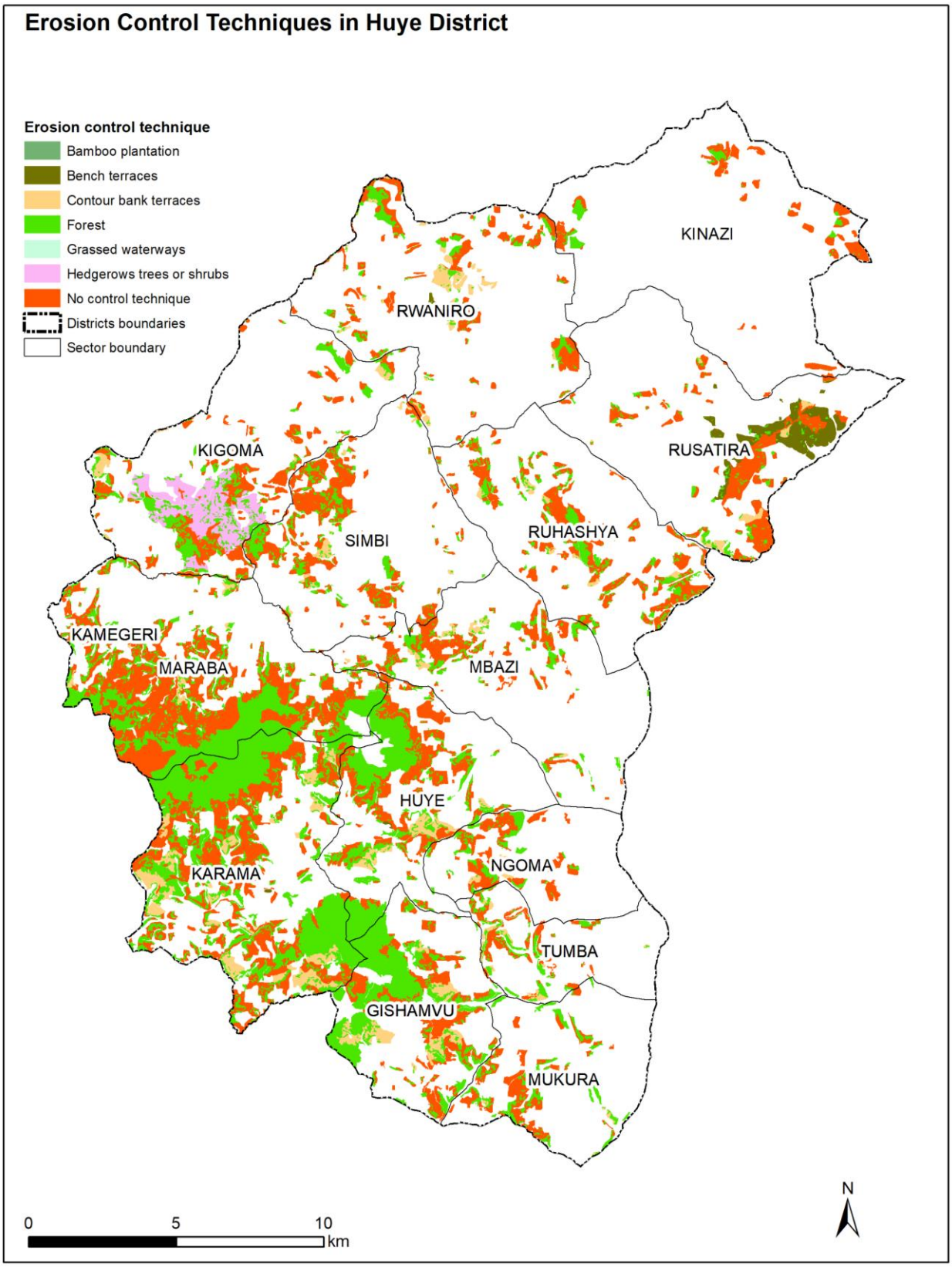


Figure 72: Erosion control techniques in place in Huye District

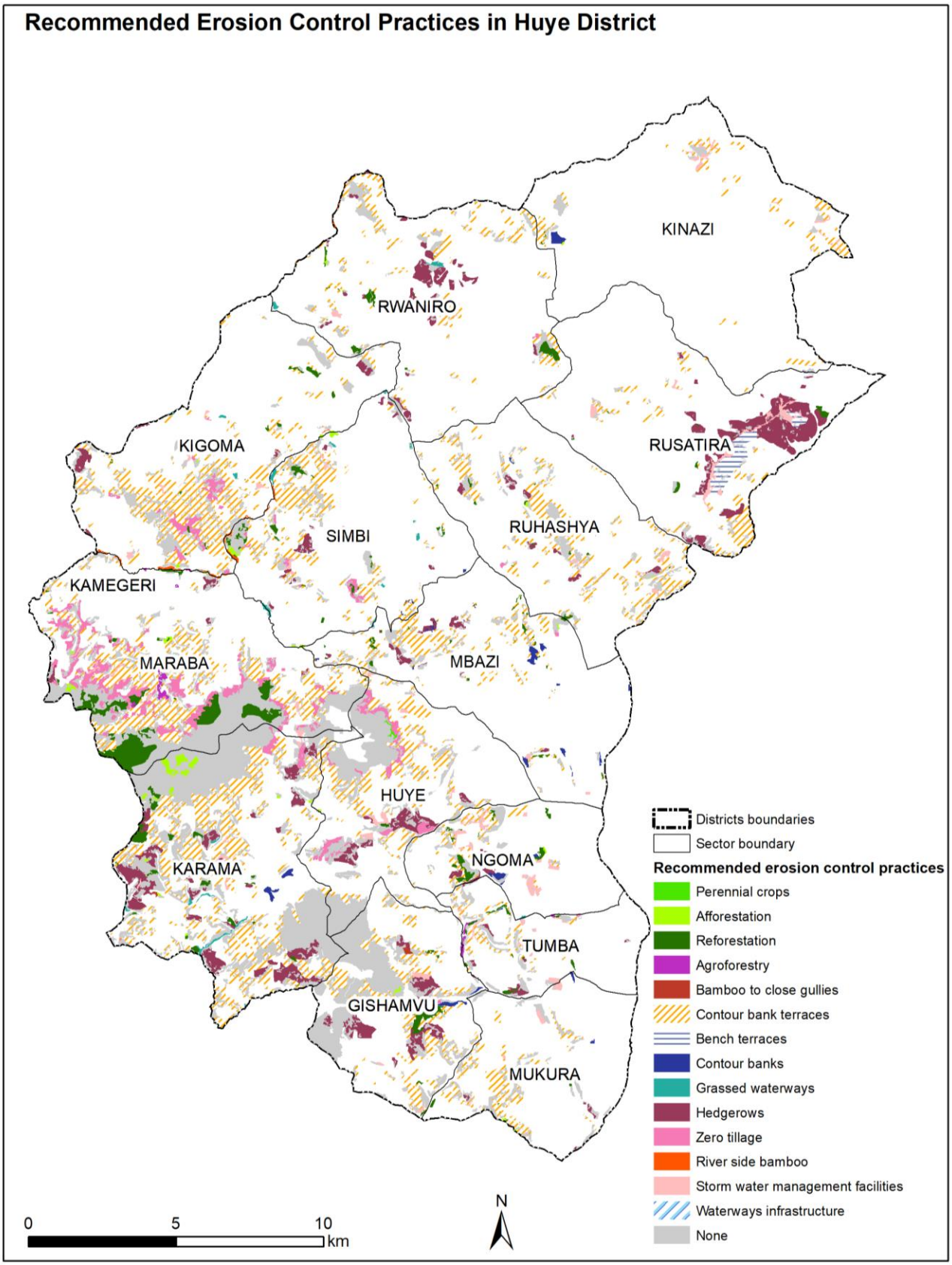


Figure 73: Recommended erosion control practices in Huye District

3.3.3. Erosion status in Kamonyi District

Erosion risk in Kamonyi is summarised in Table 72 and presented in figure 74. Erosion risk in Kamonyi District is estimated to 19,118 hectares; about 29% of the total district land are highly susceptible to erosion of which 2,691 hectares are located in Kayenzi sector (75% of sector land), 1,904 hectares are located in Ngamba sector (60% of sector land), 1,750 hectares are located in Kayumbu (52% of the sector land), and 2,640 hectares are found in Rukoma sector about 51% of the sector land. The least sectors are Mugina with only 582 hectares (8% of the sector land) susceptible to erosion, Rugalika with 754 hectares (10%), Gacurabwenge with 570 hectares, about 11% of the total sector land and Nyamiyaga with 824 hectares of the total sector land. As compared to other districts in Southern Province, Kamonyi is the fourth susceptible to erosion.

Table 72: Erosion risk per sector in Kamonyi District

Sector Name	Erosion risk				Sector land (Ha)	%
	Extremely high	Very high	High	Total (Ha)		
KAYENZI	574	1,717	400	2,691	3,588	75%
NGAMBA	398	782	724	1,904	3,157	60%
KAYUMBU	257	402	1,091	1,750	3,372	52%
RUKOMA	454	1,058	1,127	2,640	5,154	51%
RUNDA	95	647	972	1,714	5,009	34%
MUSAMBIRA	150	513	1,497	2,160	6,317	34%
KARAMA	189	975	554	1,717	5,231	33%
NYARUBAKA	41	287	1,096	1,425	4,486	32%
NYAMIYAGA	7	223	828	1,058	7,785	14%
GACURABWENGE	23	162	384	570	5,108	11%
RUGALIKA		89	664	754	7,475	10%
MUGINA	7	147	582	735	8,871	8%
Grand Total	**2,195**	**7,003**	**9,920**	**19,118**	**65,553**	**29%**

Land areas affected by soil erosion features in Kamonyi District are summarized in Table 73 and the map of erosion features are presented in Figure 75. The results show that Kayumbu sector is the worst affected by gullies on areas estimated to 1,131 hectares (65% of sector land at risk), followed by Karama sector on 885 hectares (52% of sector land at risk), and Gacurabwenge sector on 230 hectares (40% of sector land at risk) and Kayenzi on 941 hectares (35% of sector land at risk). The presence of gullies in Kayumbu, Karama, Gacurabwenge and Kayenzi sectors confirms the findings of CROM model; however reduced presence of gullies in Nyarubaka, Musambira and Nyamiyaga and the absence of gullies in Mugina which were originally predicted by CROM model as sectors at high risk should not read that and this shows that CROM model did not perform well in this sectors, but rather due to the time of image acquisition, the erosion features could be observed or erosion control measures have been already taken and therefore runoffs have been reduced, thus erosion features could not be formed in this case. Further analysis will demonstrate that in Table 74 and 75. The least sectors affected by gullies are Mugina (0 ha), Rugalika with only 48 hectares, Musambira with only 102 hectares and Nyamiyaga with 89 hectares, affected by Gullies, Landslides and Rill erosion.

Table 73: Erosion features types and areas affected in Kamonyi District

Sector Name	Erosion feature types					None	Grand Total	% Features
	Gullies	Land slide	Rill erosion	Severe gullies	Total			
KAYUMBU	1,029	5	56	42	1,131	619	1,750	65%
KARAMA	808		61	15	885	833	1,717	52%
GACURABWENGE	101	1	124	4	230	340	570	40%
KAYENZI	908		6	26	941	1,751	2,691	35%
RUKOMA	259	17	6	501	784	1,856	2,640	30%
RUGALIKA	84	2	135		221	533	754	29%
NGAMBA	364	69		99	532	1,372	1,904	28%
RUNDA	78	9	1	111	199	1,515	1,714	12%
NYAMIYAGA	12	4	63	11	89	969	1,058	8%
MUSAMBIRA	47	7	35	13	102	2,058	2,160	5%
NYARUBAKA	29	1	13	5	48	1,376	1,425	3%
MUGINA					-	735	735	0%
Grand Total	**3,719**	**115**	**500**	**827**	**5,161**	**13,956**	**19,118**	**27%**

In term of land use and related management of areas at risk in Kamonyi, the results of land cover mapping (Table 74 and Figure 76) show 10,503 hectares (55% of the total land at risk) are used for seasonal cropping, 3,619 hectares (19% of the total land at risk) are covered by healthy forests, 476 hectares (2% of the total land at risk) are covered by built-up areas and 1,553 hectares i.e. 8% are covered by Banana crop. In Kamonyi district there are also mining and quarries sites, and coffee plantations which cover respectively 1,134 hectares (6% of the total land at risk) and 243 hectares (less than 1% of the total land at risk).

Table 74: Land Use and Vegetation Cover (LUVC) for land at risk in Kamonyi District

Sector name	Banana	Build-up area	Coffee	Degraded forest	Dense forest	Mining & Quarry	Seasonal crops	Water body	Total
GACURABWENGE		8	1	114	71	15	360	2	570
KARAMA	50	4	1	88	361	7	1,185	20	1,717
KAYENZI	326	193	12	122	619	23	1,386	11	2,691
KAYUMBU	285	6	445	187	225	45	542	14	1,750
MUGINA	9	32	4	42	129	1	517		735
MUSAMBIRA	71	13	363	109	250	22	1,319	14	2,160
NGAMBA	463	18	127	260	403	5	623	4	1,904
NYAMIYAGA	2	43	2	43	203	4	759	3	1,058
NYARUBAKA	14	41	20	20	246	9	1,067	7	1,425
RUGALIKA	12	6		81	109	26	520		754
RUKOMA	62	8	150	350	586	55	1,417	13	2,640
RUNDA	260	105	7	77	417	31	811	6	1,714
Grand Total	**1,553**	**476**	**1,134**	**1,495**	**3,619**	**243**	**10,503**	**93**	**19,118**

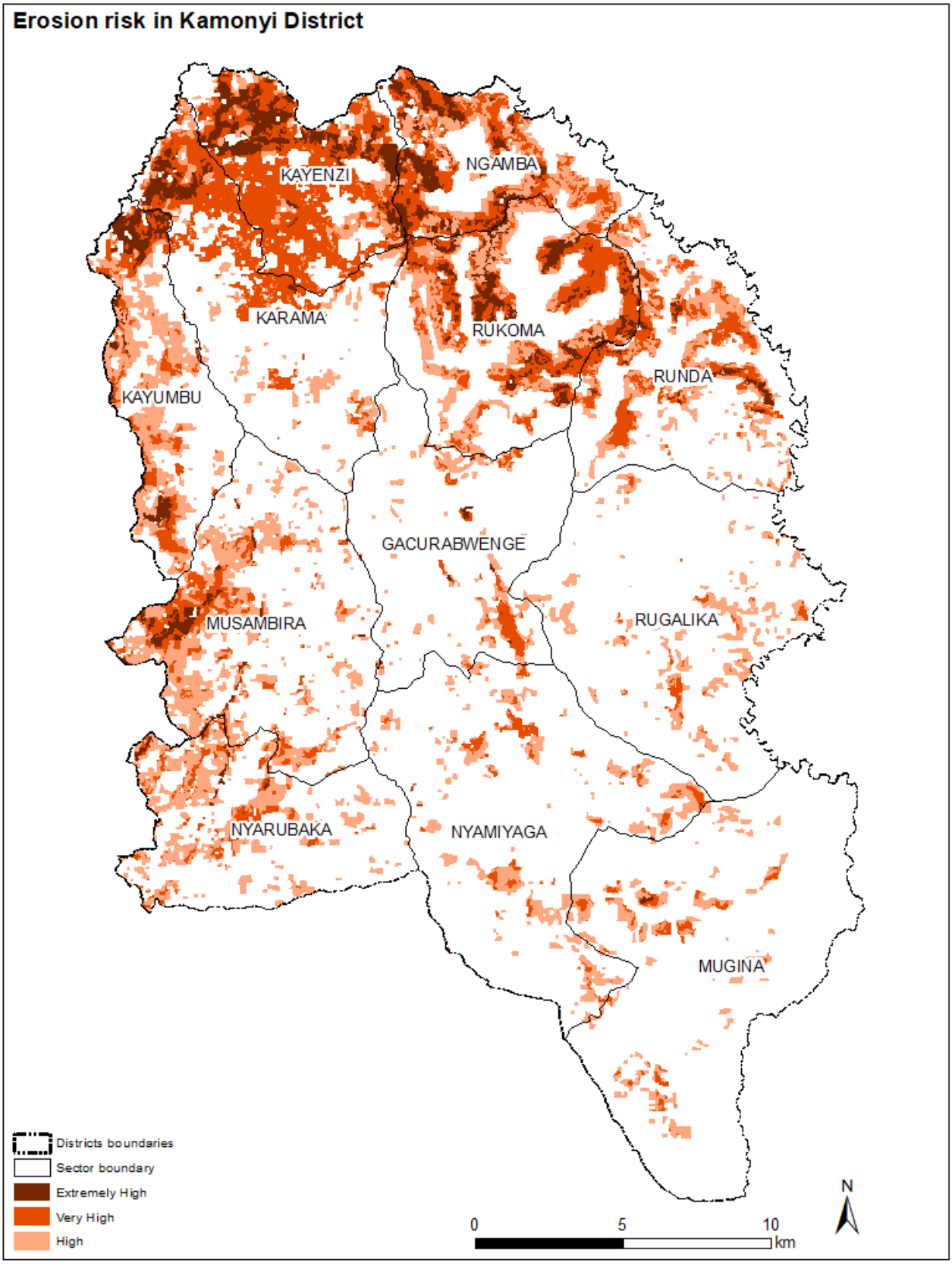


Figure 74: Erosion risk in Kamonyi District

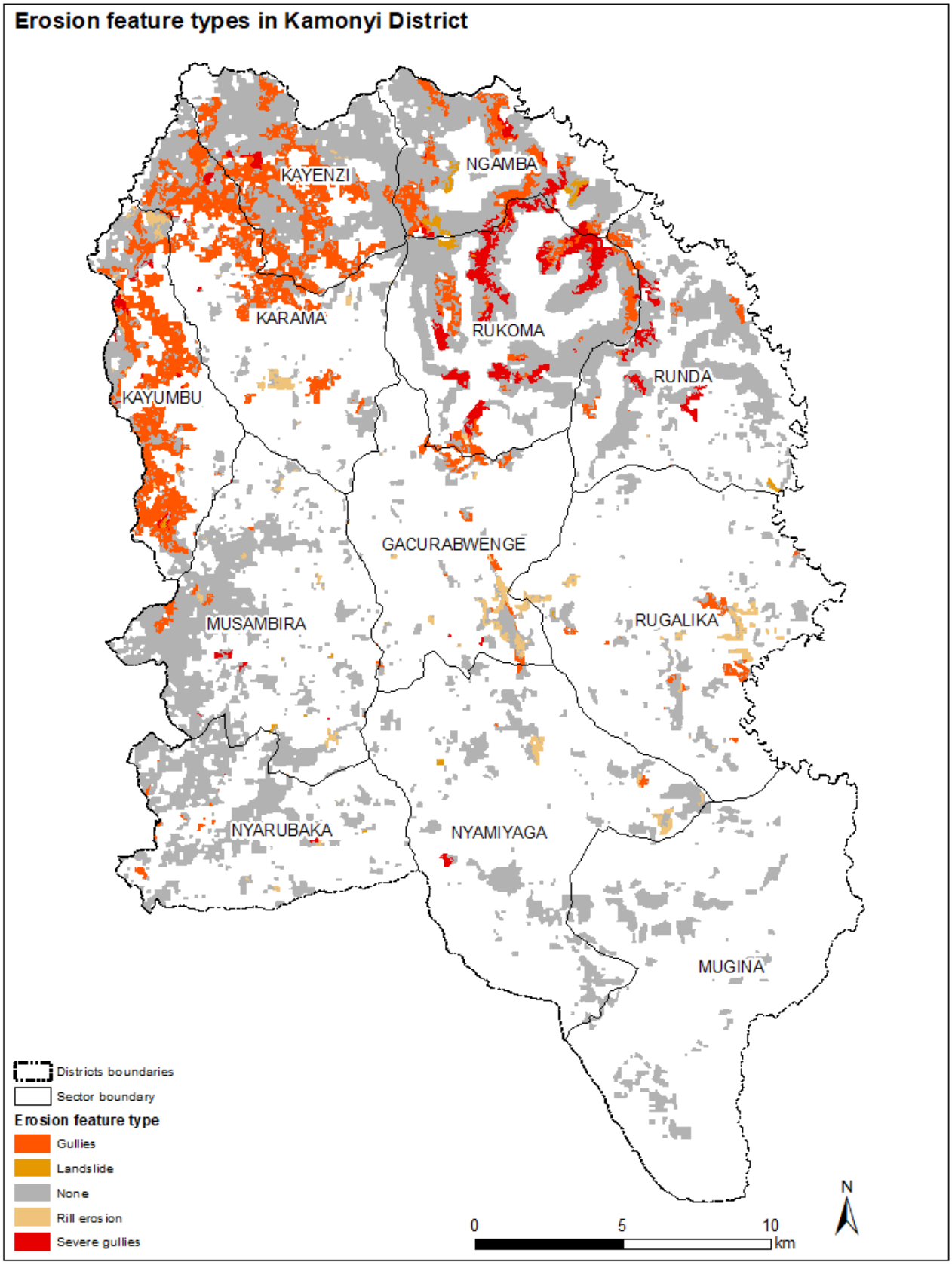


Figure 75: Erosion features detected in Kamonyi District

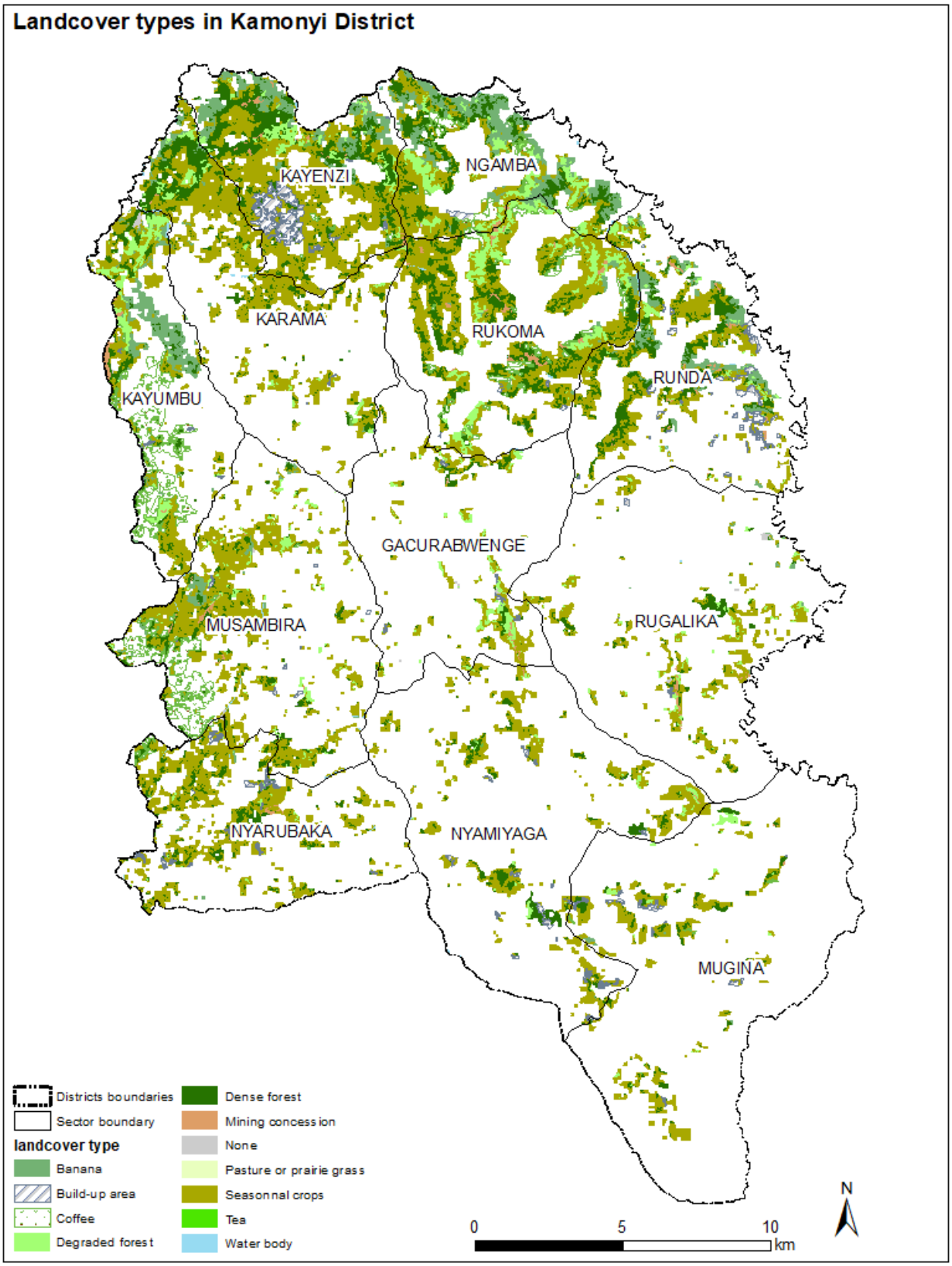


Figure 76: Land cover types in Kamonyi District

About existing erosion control practices in Kamonyi district, Table 75 shows that only 21% of land at risk is protected by forests (3,693 hectares) and Contour bank terraces (158 hectares), bench terraces (60 hectares) and bamboo (16 hectares). The highest protected sectors are Runda with 27% of its land at risk protected, followed by Kayenzi where 25% of the total land at risk is protected and Rukoma with 24% of land protected. The least protected sectors are Rugalika with only 12% protected, Musambira (only 12% protected), Gacurabwenge (14%) and Kayumbu (16% protected). The visual interpretation of World View images confirms earlier findings by CROM model that Rugalika, Musambira, Gacurabwenge and Kayumbu sectors remain at very high risk of soil erosion since more than 80% of their respective land are not protected.

Table 75: Erosion control practices already in place in Kamonyi District

Sector name	Erosion control techniques in place					Unprotected	Grand Total	% protected
	Bamboo plantation	Bench terraces	Contour bank terraces	Forests	Total protected			
RUNDA	1	39	12	420	471	1,243	1,714	27%
KAYENZI	5		33	627	665	2,026	2,691	25%
RUKOMA	0	17	8	611	636	2,004	2,640	24%
NGAMBA	9		28	404	442	1,461	1,904	23%
KARAMA	1	2	7	376	386	1,331	1,717	22%
NYAMIYAGA			9	204	213	845	1,058	20%
NYARUBAKA			23	256	279	1,145	1,425	20%
MUGINA			3	131	134	601	735	18%
KAYUMBU			12	261	273	1,477	1,750	16%
GACURABWENGE			6	71	77	493	570	14%
MUSAMBIRA			12	251	264	1,896	2,160	12%
RUGALIKA			5	81	87	667	754	12%
Grand Total	**16**	**60**	**158**	**3,693**	**3,927**	**15,191**	**19,118**	**21%**

Erosion control practices in Kamonyi District are recommended based on existing land uses, erosion control measures already in place, and predicted erosion risk by CROM model. Table 76 shows that about 8,940 hectares (which is 47% of the total land at risk) are suitable for Contour bank terraces, 1,675 hectares are Afforestation & Reforestation and 981 hectares of cropland that need agroforestry/alley cropping. Other interventions are 364 hectares for Bamboo to close gullies, 265 hectares of hedgerows, 35Ha Contour bank and 16Ha Grassed waterways.

Table 76: Recommended erosion control practices in Kamonyi District

Sector Name	Afforestation & Reforestation	Agroforestry	Bamboo to close gullies	Bench terraces	Contour bank terraces	Hedgerows	No till	SWMF	None	Total
GACURABWENGE	122	118	3		216	29	1	10	71	570
KARAMA	93	80	45	0	1,087	10	46	4	348	1,717
KAYENZI	144	139	32	1	1,186	39	336	193	620	2,691
KAYUMBU	254	118	102	22	355	8	698	6	170	1,750
MUGINA	43	1			494	7	13	33	145	735
MUSAMBIRA	130	76	29	9	1,132	59	433	12	280	2,160
NGAMBA	192	139	10		473	14	636	19	420	1,904
NYAMIYAGA	48	4	3		678	12	4	42	266	1,058
NYARUBAKA	35	3	15		987	65	35	38	245	1,425
RUGALIKA	98	137	3		422		12	6	76	754
RUKOMA	400	133	108		1,159	13	204	6	598	2,640
RUNDA	117	33	13		751	10	254	114	423	1,714
Grand Total	**1,675**	**981**	**364**	**31**	**8,940**	**265**	**2,672**	**484**	**3,663**	**19,118**
Percentage	**9%**	**5%**	**2%**	**0%**	**47%**	**1%**	**14%**	**3%**	**19%**	**100%**

Others interventions: 35Ha Contour bank, 16Ha Grassed waterways

Note: Grassed waterways are recommended for existing terraces which was made without waterways or with but no grasses which can cause severe gullies and destruction of bench terraces created. No-till agriculture is recommended is recommended for perennial crops on extremely high risk area while Storm water management facilities (SWMF) or water harvesting infrastructure is recommended in built-up areas. None: means no-recommendation is provided because existing erosion control measures are adequate with reference made to the total land protected. Contour banks are recommended for existing forest without ditches. Bamboos are recommended to close gullies or for riverside buffers.

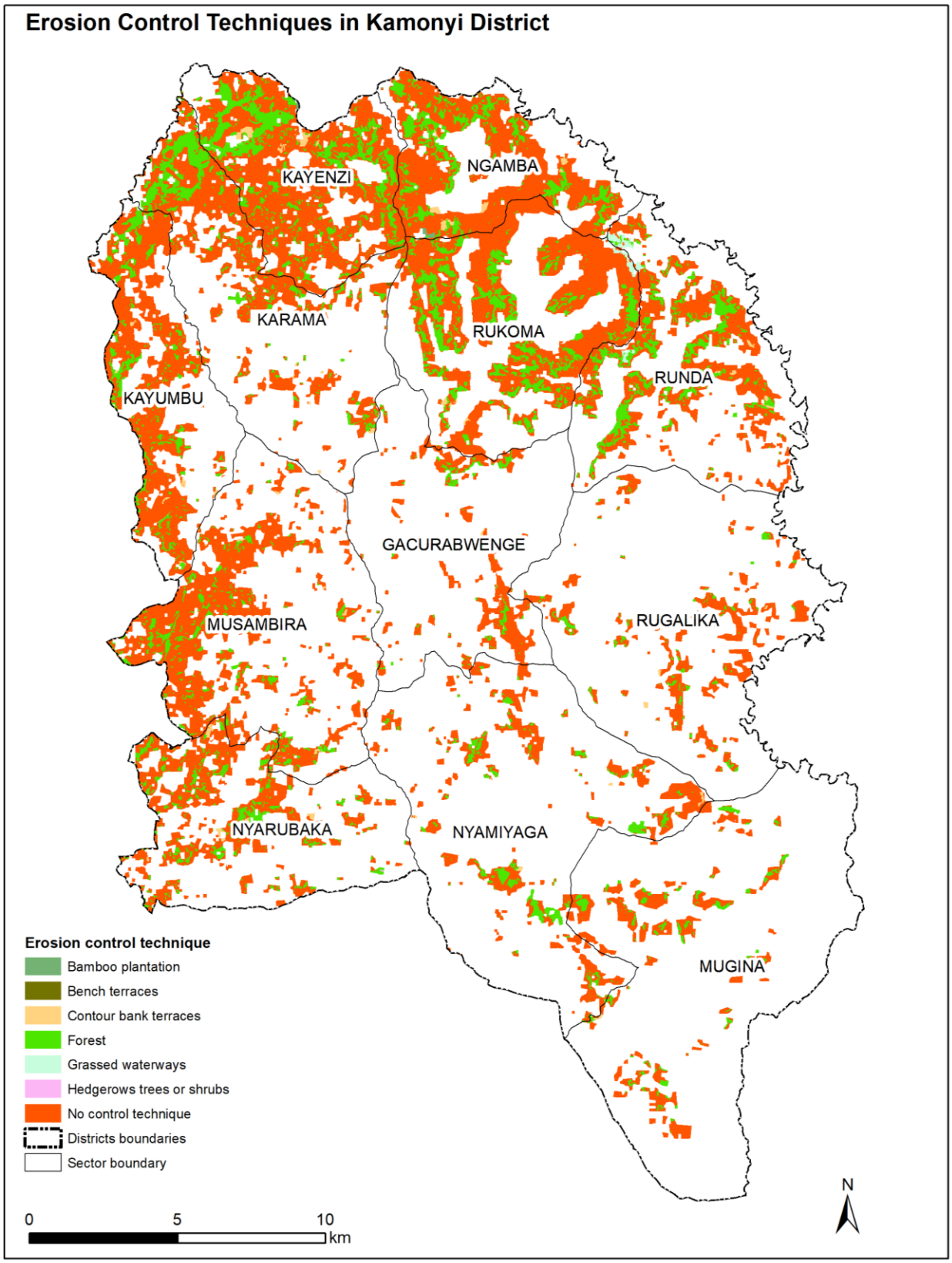


Figure 77: Erosion control techniques in place in Kamonyi District

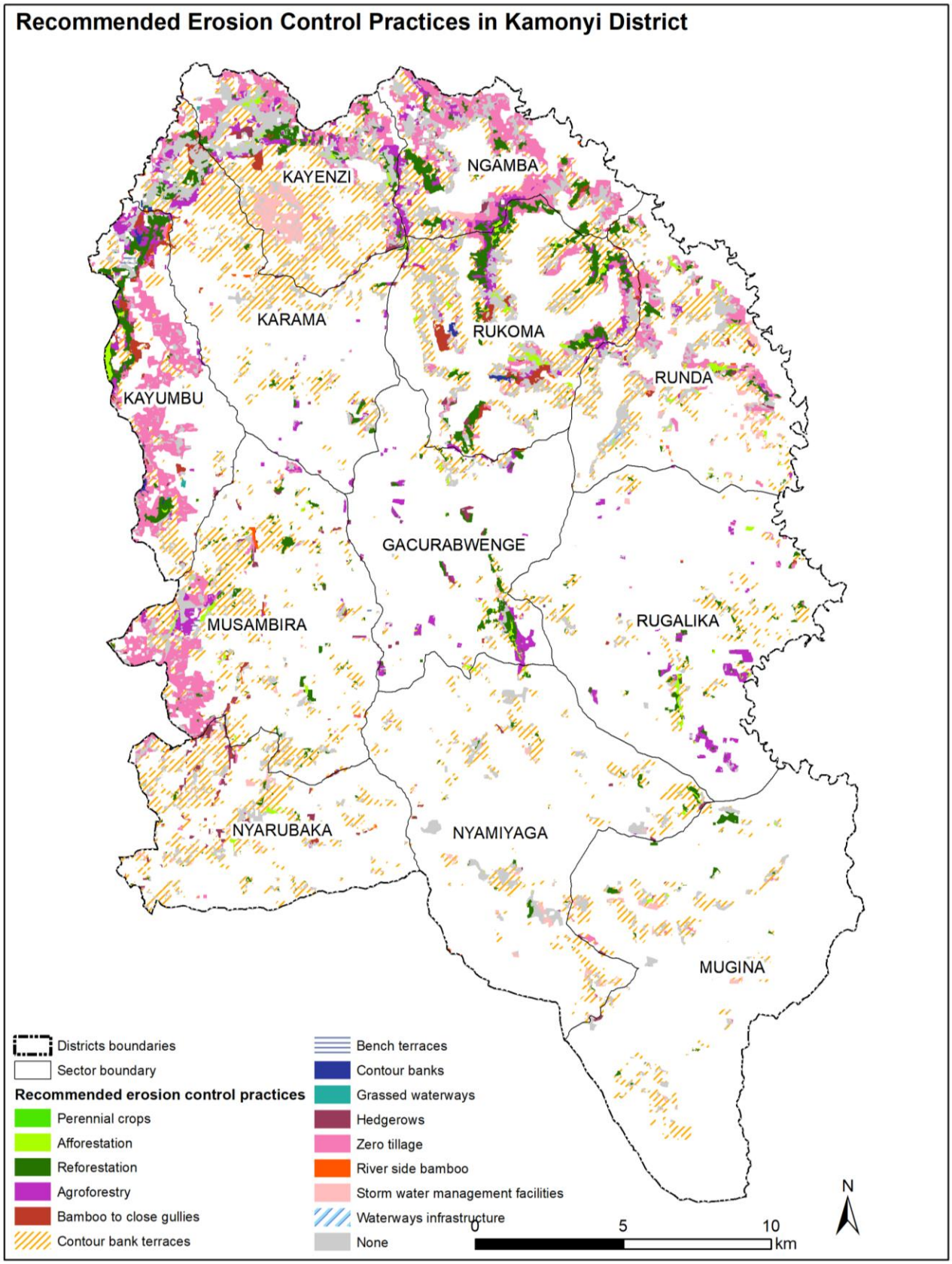


Figure 78: Recommended erosion control practices in Kamonyi District

3.3.4. Erosion control status Muhanga District

Erosion risk in Muhanga is summarised in Table 77 and presented in figure 44. Erosion risk in Muhanga District is estimated to 40,514 hectares; about 63% of the total district land are highly susceptible to erosion of which 5,373 hectares are located in Muhanga sector (86% of sector land), 6,164 hectares are located in Kabacuzi sector (82% of sector land), 1,976 hectares are located in Nyarusange (78% of the sector land), and 3,637 hectares are found in Mushishiro sector about 68% of the sector land. The least sectors are Shyogwe with only 394 hectares (11% of the sector land) susceptible to erosion and Nyamabuye with 799 hectares (27%). Other sectors are affected by high erosion risk at more than 40% of their respective total land. As compared to other districts in Southern Province, Muhanga is the first susceptible to erosion.

Table 77: Erosion risk per sector in Muhanga District

Sector Name	Erosion risk				Sector land (Ha)	%
	Extremely high	Very high	High	Total (Ha)		
MUHANGA	1,474	2,878	1,020	5,373	6,252	86%
KABACUZI	1,245	2,116	2,802	6,164	7,505	82%
NYARUSANGE	771	2,140	1,976	4,887	6,253	78%
MUSHISHIRO	552	1,336	1,749	3,637	5,315	68%
KIYUMBA	538	1,646	2,654	4,838	7,277	66%
RUGENDABARI	461	1,282	946	2,689	4,215	64%
RONGI	709	1,769	1,928	4,406	6,931	64%
CYEZA	452	876	2,071	3,399	5,758	59%
KIBANGU	566	733	975	2,274	4,680	49%
NYABINONI	406	429	820	1,655	3,900	42%
NYAMABUYE	64	269	467	799	2,938	27%
SHYOGWE	16	41	337	394	3,748	11%
Grand Total	**7,255**	**15,515**	**17,743**	**40,514**	**64,772**	**63%**

Land areas affected by soil erosion features in Muhanga District are summarized in Table 78 and the map of erosion features are presented in Figure 80. The results show that Muhanga sector is the worst mostly affected by rill erosion on areas estimated to 2,196 hectares (41% of sector land at risk), followed by Nyarusange sector on 1,890 hectares (39% of sector land at risk), and Mushishiro sector on 1,318 hectares (36% of sector land at risk). The presence of rill erosion in most of Muhanga sectors confirms the findings of CROM model; however the reduced presence of erosion features (rill and gullies) in Shyogwe (394ha) and Nyamabuye (799ha) which was originally predicted by CROM model as sectors at high risk should not read that CROM model which did not perform well in this sectors, but rather due to the time of image acquisition, the erosion features could be observed or erosion control measures have been already taken and therefore runoffs have been reduced, thus erosion features could not be formed in this case. Further analysis will demonstrate that in Table 80 and 81. The least sectors affected by rill erosion are Kibangu with 7 hectares and Nyabinoni with 19 hectares affected by affected by rill erosion and some gullies.

Table 78: Erosion features types and areas affected in Muhanga District

Sector Name	Erosion feature types						Grand Total	% Features
	Gullies	Landslide	Rill erosion	Severe gullies	Total	None		
MUHANGA	4		2,174	18	2,196	3,176	5,373	41%
NYARUSANGE	36	7	1,812	34	1,890	2,998	4,887	39%
MUSHISHIRO	3	8	1,296	13	1,319	2,318	3,637	36%
CYEZA	1		969	3	973	2,426	3,399	29%
NYAMABUYE	1		102	1	104	694	799	13%
SHYOGWE	2	5	35	3	44	350	394	11%
KIYUMBA	3		404	2	409	4,429	4,838	8%
KABACUZI	11		393	18	421	5,742	6,164	7%
RUGENDABARI	2	10	120	27	159	2,530	2,689	6%
RONGI	1	4	56		61	4,346	4,406	1%
NYABINONI	4		13	2	19	1,636	1,655	1%
KIBANGU	3		4		7	2,267	2,274	0%
Grand Total	**72**	**34**	**7,376**	**120**	**7,602**	**32,913**	**40,514**	**19%**

In term of land use and related management of areas at risk in Muhanga, the results of land cover mapping (Table 79 and Figure 81) show that 22,582 hectares (56% of the total land at risk) are used for seasonal cropping, 9,250 hectares (23% of the total land at risk) are covered by healthy forests, 1,996 hectares (5% of the total land at risk) are covered by built-up areas and 3,106 hectares i.e. 8% are covered by Banana crop.

Table 79: Land Use and Vegetation Cover (LUVC) for land at risk in Muhanga District

Sector name	Banana	Build-up area	Degraded forest	Dense forest	Mining concession	Seasonal crops	Water body	Total
CYEZA	99	308	152	708	30	2,097	4	3,399
KABACUZI	571	51	437	1,709	70	3,198	127	6,164
KIBANGU	111	61	29	419	1	1,614	40	2,274
KIYUMBA	780	164	133	1,132	21	2,552	57	4,838
MUHANGA	208	347	938	950	116	2,778	34	5,373
MUSHISHIRO	189	242	184	743	55	2,069	155	3,637
NYABINONI	125	52	41	458	10	921	48	1,655
NYAMABUYE	21	234	56	245	18	214	10	799
NYARUSANGE	692	289	132	900	126	2,545	203	4,887
RONGI	218	60	141	1,237	8	2,666	76	4,406
RUGENDABARI	80	101	24	655	36	1,741	52	2,689
SHYOGWE	11	86	3	93	6	186	8	394
Grand Total	**3,106**	**1,996**	**2,271**	**9,250**	**498**	**22,582**	**812**	**40,514**

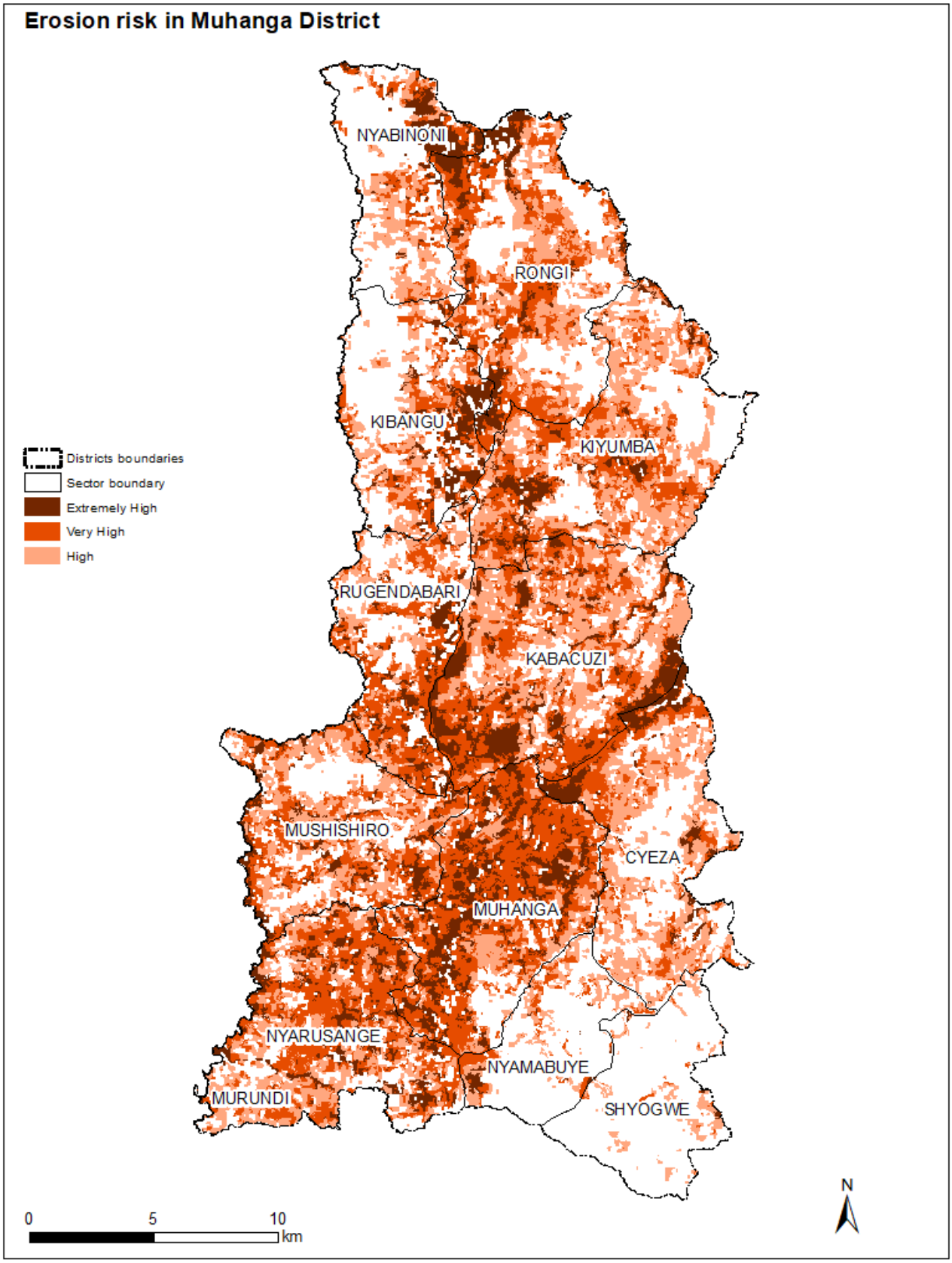


Figure 79: Erosion risk in Muhanga District

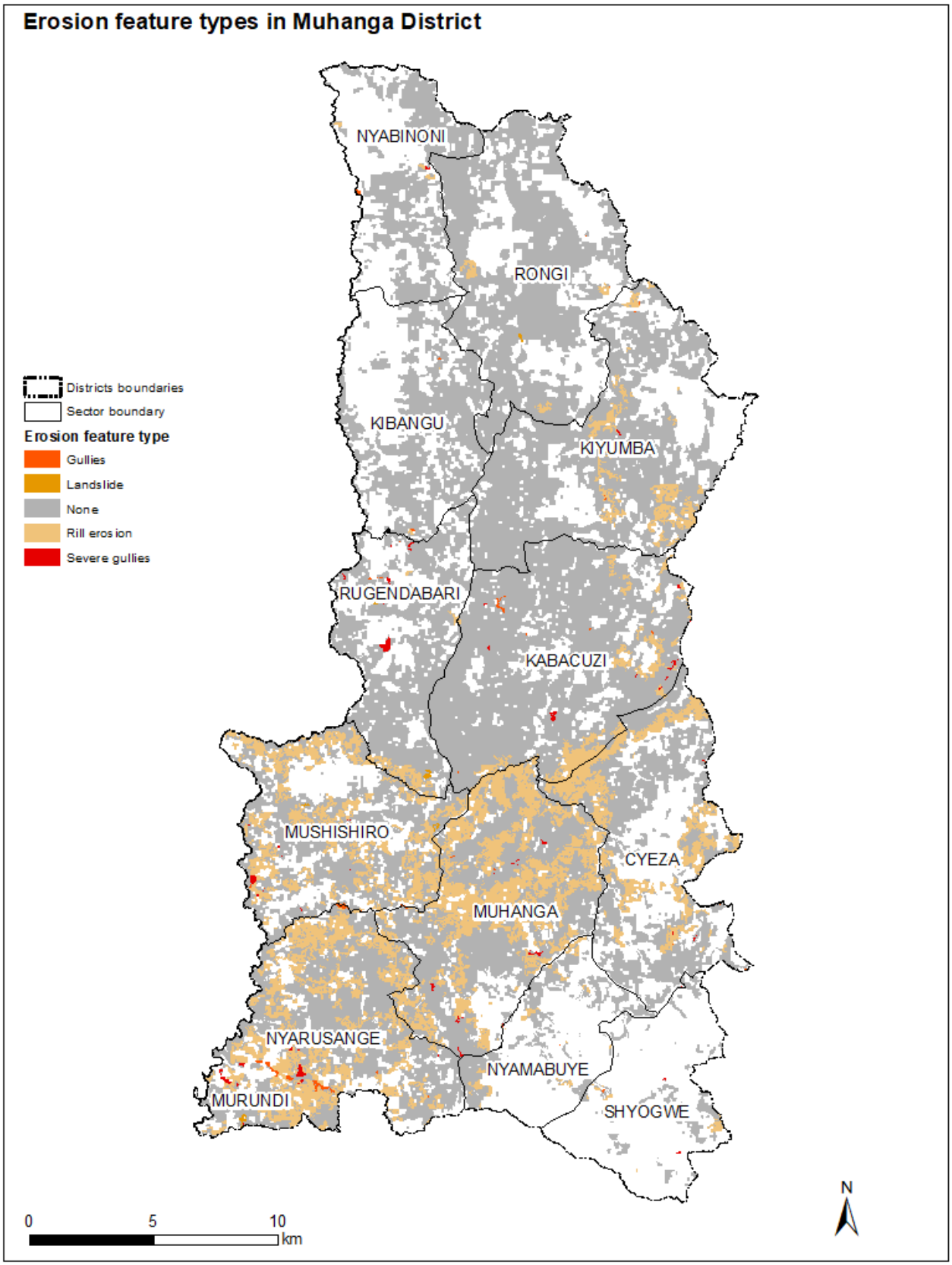


Figure 80: Erosion features detected in Muhanga District

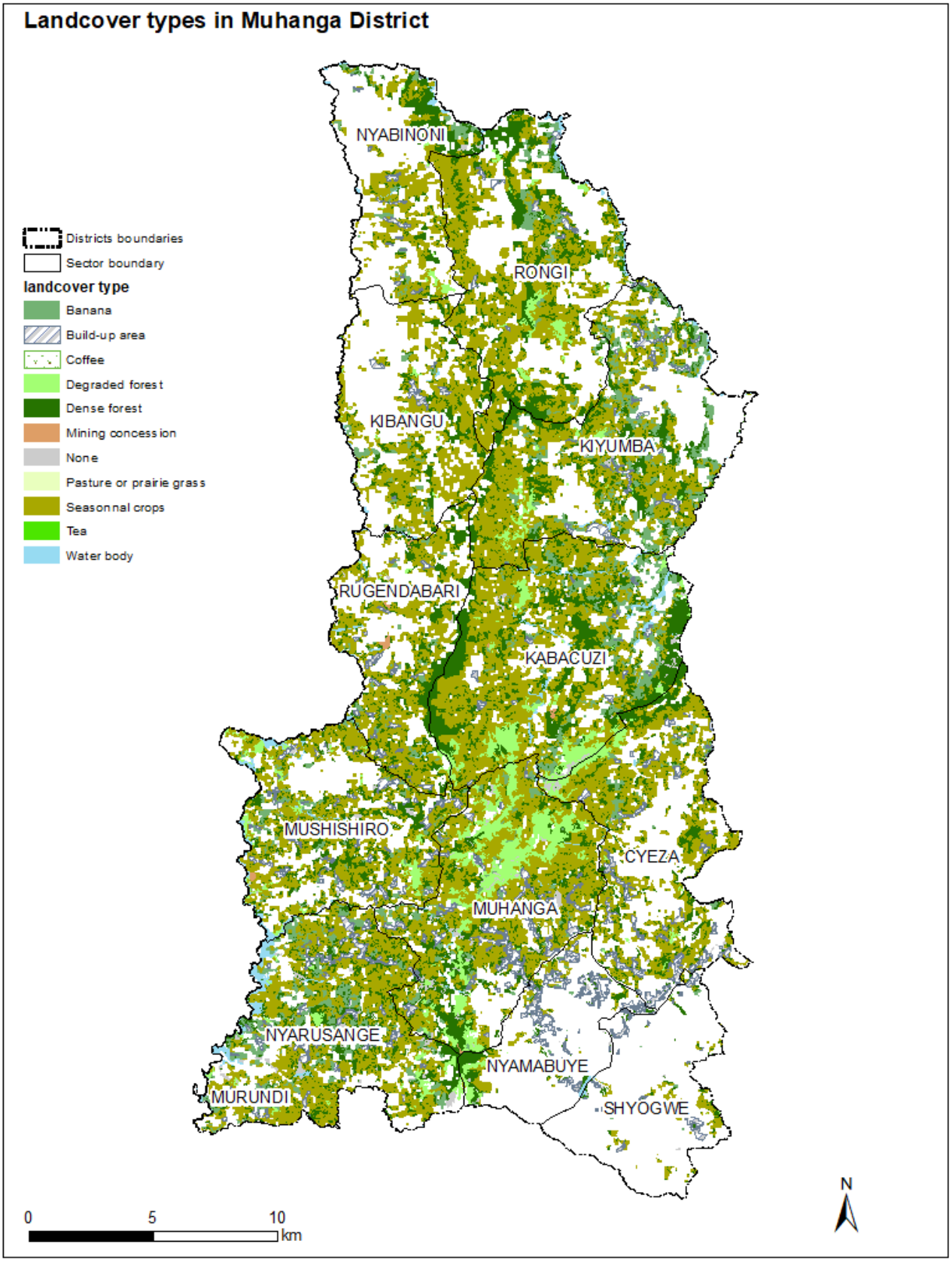


Figure 81: Land cover types in Muhanga District

About existing erosion control practices in Muhanga district, Table 80 shows that only 24% of land at risk is protected by forests (9,284 hectares) and Contour bank terraces (29 hectares) and bench terraces (364 hectares). The highest protected sectors are Nyamabuye with 32% of its land at risk protected, followed by Kabacuzi where 29% of the total land at risk is protected and Rongi with 29% of land protected. The least protected sectors are Nyarusange with only 19% protected, Muhanga (only 19% protected), Kibangu (19%) Mushishiro(21% protected) and Cyeza (21% protected). The visual interpretation of World View images confirms earlier findings by CROM model that Rwerere, Cyeru, Bungwe and Rusarabuge sectors remain at very high risk of soil erosion since more than 80% of their respective land are not protected

Table 80: Erosion control practices already in place in Muhanga District

Sector name	Erosion control techniques in place				Unprotected	Grand Total	% protected
	Bench terraces	Contour bank terraces	Forests	Total protected			
CYEZA	7		708	715	2,684	3,399	21%
KABACUZI	65	4	1,729	1,798	4,366	6,164	29%
KIBANGU	12		415	427	1,847	2,274	19%
KIYUMBA	122	1	1,132	1,255	3,583	4,838	26%
MUHANGA	55	22	949	1,026	4,346	5,373	19%
MUSHISHIRO	5	0	744	749	2,888	3,637	21%
NYABINONI			462	462	1,193	1,655	28%
NYAMABUYE			255	255	544	799	32%
NYARUSANGE	5	1	899	905	3,982	4,887	19%
RONGI	46		1,242	1,288	3,118	4,406	29%
RUGENDABARI	46		657	703	1,986	2,689	26%
SHYOGWE			93	93	301	394	24%
Grand Total	**364**	**29**	**9,284**	**9,677**	**30,837**	**40,514**	**24%**

Erosion control practices in Muhanga District are recommended based on existing land uses, erosion control measures already in place, and predicted erosion risk by CROM model. Table 81 shows that about 18,694 hectares (which is 46% of the total land at risk) are suitable for Contour bank terraces, 2,920 hectares are Afforestation & Reforestation and 2,964 hectares of cropland that need agroforestry/alley cropping. Other interventions are 2,025 hectares for Storm water management facilities (SWMF), gullies or riverbanks amounting to 959 hectares eroded which require bamboo trees for rehabilitation, 378 hectares of Hedgerows and 182 hectares of bench terraces.

Table 81: Recommended erosion control practices in Muhanga District

Sector Name	Afforestation & Reforestation	Agroforestry	Bamboo gullies & riverside	Bench terraces	Contour bank terraces	Hedgerows	No till	SWMF	None	Total
CYEZA	192	418	8	2	1,648	14	100	310	708	3,399
KABACUZI	510	224	146	42	2,842	69	571	51	1,709	6,164
KIBANGU	29	364	42		1,238	12	111	61	417	2,274
KIYUMBA	148	187	62	34	2,199	124	780	164	1,140	4,838
MUHANGA	1,081	798	62	4	1,837	55	207	373	956	5,373
MUSHISHIRO	332	158	162	2	1,794	6	189	242	753	3,637
NYABINONI	50	90	49		831		125	52	458	1,655
NYAMABUYE	69	20	12		187		21	235	255	799
NYARUSANGE	243	131	266		2,364	5	692	289	896	4,887
RONGI	164	326	77	63	2,212	46	218	60	1,241	4,406
RUGENDABARI	98	249	61	36	1,362	46	80	101	655	2,689
SHYOGWE	6		12		180		11	86	98	394
Grand Total	**2,920**	**2,964**	**959**	**182**	**18,694**	**378**	**3,106**	**2,025**	**9,287**	**40,514**
Percentage	**7%**	**7%**	**2%**	**0.5%**	**46%**	**1%**	**8%**	**5%**	**23%**	**100%**

Note: Grassed waterways are recommended for existing terraces which was made without waterways or with but no grasses which can cause severe gullies and destruction of bench terraces created. No-till agriculture is recommended is recommended for perennial crops on extremely high risk area while Storm water management facilities (SWMF) or water harvesting infrastructure is recommended in built-up areas. None: means no-recommendation is provided because existing erosion control measures are adequate with reference made to the total land protected. Contour banks are recommended for existing forest without ditches. Bamboos are recommended to close gullies or for riverside buffers.

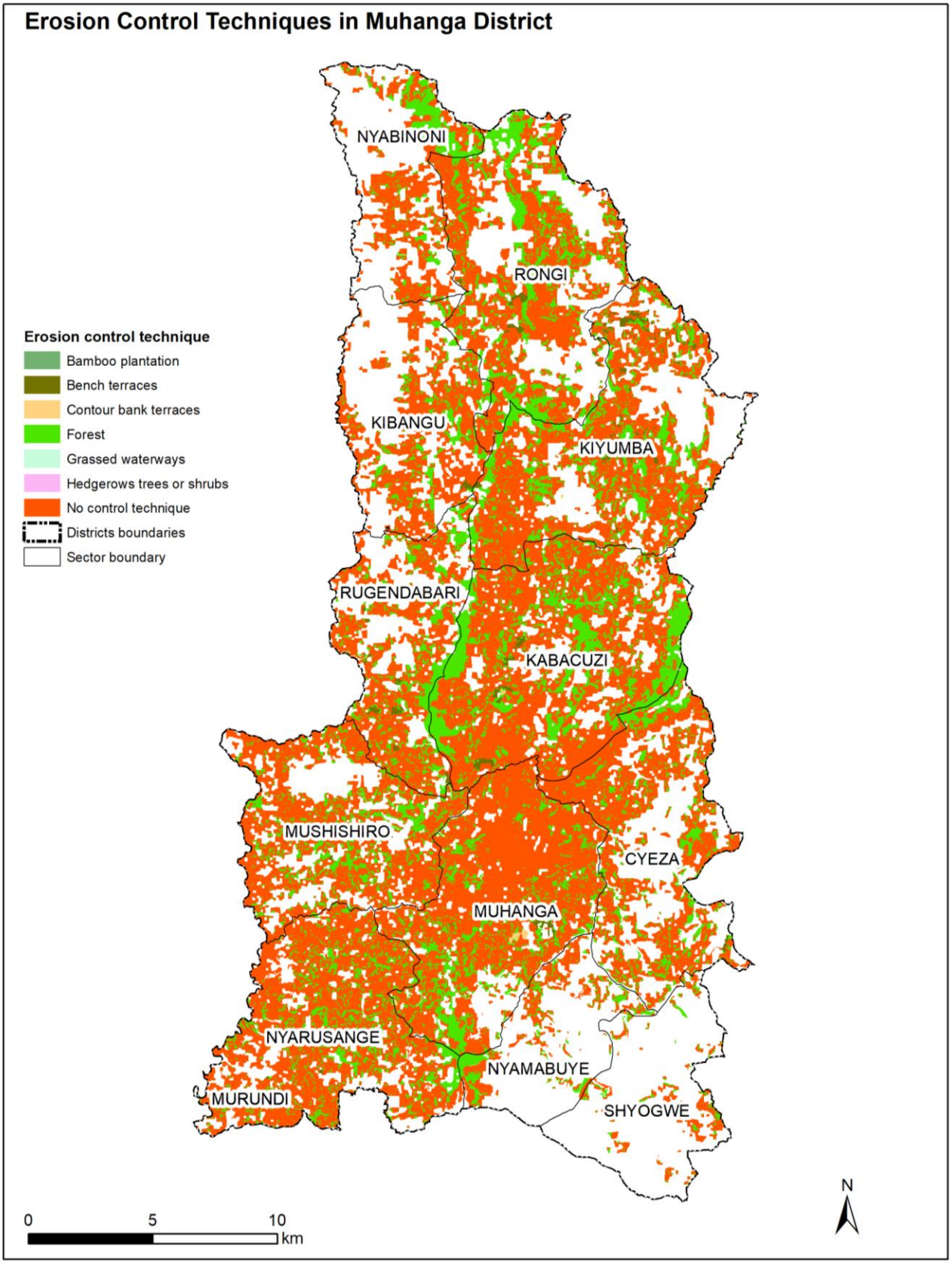


Figure 82: Erosion control techniques in place in Muhanga District

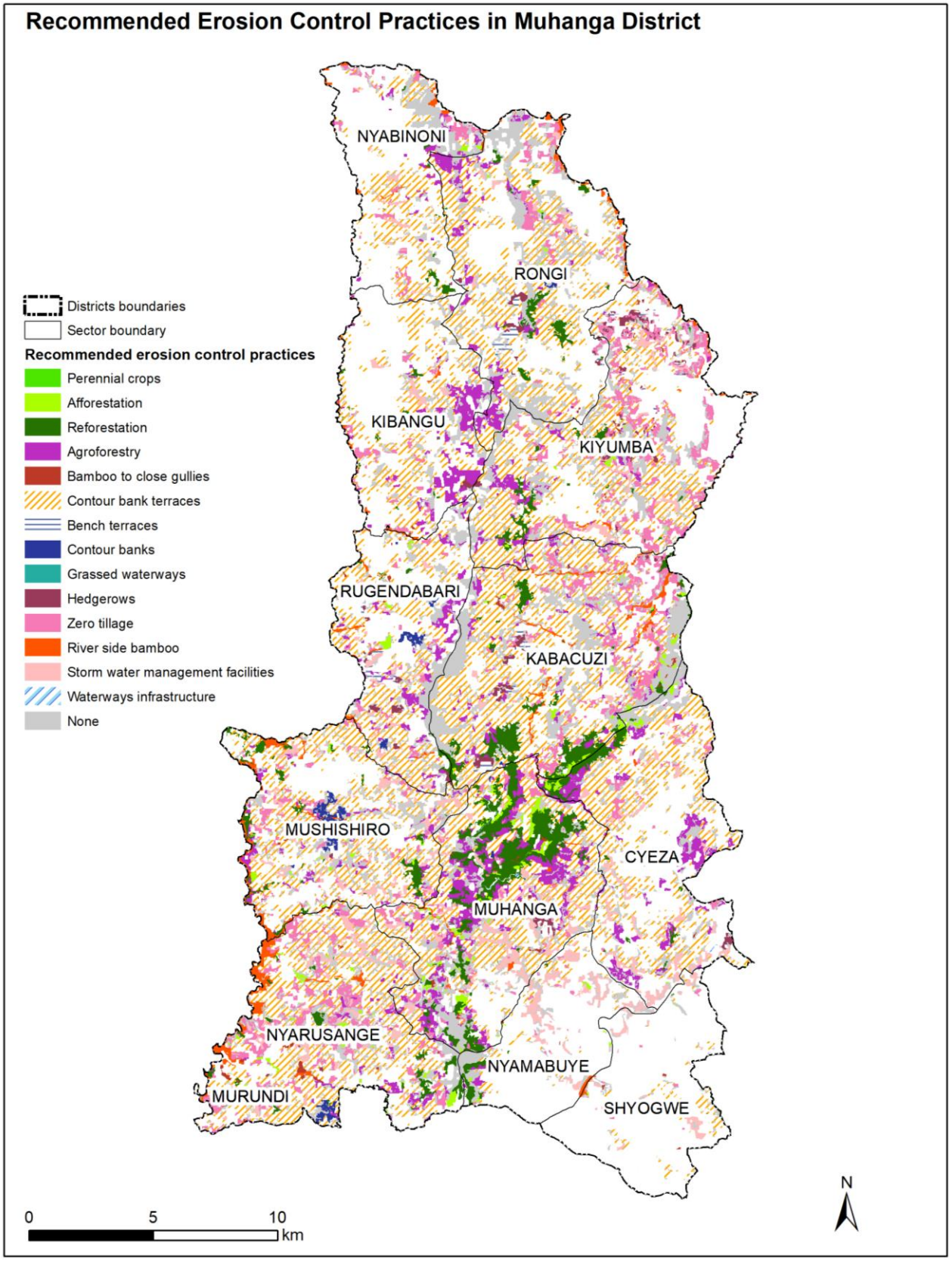


Figure 83: Recommended erosion control practices in Muhanga District

3.3.5. Erosion control status Nyamagabe District

Erosion risk in Nyamagabe District is summarised in Table 82 and presented in figure 84. Erosion risk in Nyamagabe District is estimated to 43,452 hectares; about 40% of the total district land are highly susceptible to erosion of which 5,024 hectares are located in Musebeya sector (74% of sector land), 2,393 hectares are located in Mushubi sector (66% of sector land), 3,319 hectares are located in Kibirizi (65% of the sector land), and 2,860 hectares are found in Kibumbwe sector about 62% of the sector land. The least sectors are Nkomane with 1,449 hectares (18% of the sector land) susceptible to erosion, Buruhukiro with 3,155 hectares (20%), and Cyanika with 1,159 hectares, about 22% of the total sector land. As compared to other districts in Southern Province, Nyamagabe is the second district susceptible to erosion.

Table 82: Erosion risk per sector in Nyamagabe District

Sector Name	Erosion risk				Sector land (Ha)	%
	Extremely high	Very high	High	Total (Ha)		
MUSEBEYA	1,314	2,236	1,474	5,024	6,826	74%
MUSHUBI	403	923	1,067	2,393	3,630	66%
KIBIRIZI	477	1,195	1,647	3,319	5,138	65%
KIBUMBWE	232	1,369	1,260	2,860	4,623	62%
MUGANO	945	1,639	1,960	4,543	8,020	57%
TARE	206	1,177	1,131	2,514	4,470	56%
KAMEGERI	134	780	892	1,807	3,247	56%
GASAKA	309	637	1,256	2,201	4,046	54%
MUSANGE	109	543	1,358	2,010	4,578	44%
UWINKINGI	681	1,771	1,089	3,541	8,974	39%
MBAZI	165	365	615	1,145	3,335	34%
KADUHA	86	964	1,200	2,250	7,092	32%
GATARE	411	792	666	1,869	6,409	29%
KITABI	209	1,076	928	2,212	9,654	23%
CYANIKA	17	226	916	1,159	5,390	22%
BURUHUKIRO	408	1,540	1,206	3,155	15,723	20%
NKOMANE	88	629	732	1,449	7,880	18%
Grand Total	**6,192**	**17,862**	**19,398**	**43,452**	**109,036**	**40%**

Land areas affected by soil erosion features in Nyamagabe District are summarized in Table 83 and the map of erosion features are presented in Figure 85. The results show that Musange sector is the worst affected by gullies, landslide and rill erosion on areas estimated to 1,686 hectares (84% of sector land at risk), followed by Kaduha sector on 1517 hectares (67% of sector land at risk), and Mushubi sector on 1,386 hectares (58% of sector land at risk). The presence of gullies and rill erosion in most of Nyamagabe Districts such as in Musange, Kaduha, Mushubi, and Kamegeri sectors, among others, confirms the findings of CROM model; however the reduced presence of gullies and rill erosion in Mbazi (145 ha) which was originally predicted by CROM model as sector at high risk should not read that CROM model did not perform well in this sectors, but rather due to the time of image acquisition, the erosion features could be observed or erosion control measures have been already taken and therefore runoffs have been reduced, thus erosion features could not be formed in this case. Further analysis will demonstrate that in Table 14 and 15. The least sectors affected by gullies and rill erosion are Mbazi with only 145 hectares and Kitabi with only 523 hectares affected by gullies and rill erosion.

Table 83: Erosion features types and areas affected in Nyamagabe District

Sector Name	Erosion feature types						Grand Total	% Features
	Gullies	Landslide	Rill erosion	Severe gullies	Total	None		
MUSANGE	424	358	576	329	1,686	324	2,010	84%
KADUHA	505	102	790	120	1,517	733	2,250	67%
MUSHUBI	325		763	298	1,386	1,007	2,393	58%
KAMEGERI	233	26	722	0	981	826	1,807	54%
MUSEBEYA	154		2,363	40	2,557	2,466	5,024	51%
BURUHUKIRO	4		1,597		1,601	1,553	3,155	51%
GATARE	18		927		945	924	1,869	51%
NKOMANE	73		652	1	726	723	1,449	50%
MUGANO	343	18	1,767	144	2,271	2,272	4,543	50%
KIBUMBWE	0		1,402		1,402	1,458	2,860	49%
TARE	133		1,003		1,135	1,379	2,514	45%
UWINKINGI	29		1,391		1,421	2,120	3,541	40%
KIBIRIZI	112		869	4	985	2,335	3,319	30%
GASAKA	36	194	399	1	631	1,571	2,201	29%
CYANIKA	1		323		325	835	1,159	28%
KITABI	133		390		523	1,689	2,212	24%
MBAZI	69		76		145	1,000	1,145	13%
Grand Total	**2,592**	**697**	**16,011**	**937**	**20,237**	**23,215**	**43,452**	**47%**

In term of land use and related management of areas at risk in Nyamagabe, the results of land cover mapping (Table 84 and Figure 86) show that 23,196 hectares (53% of the total land at risk) are used for seasonal cropping, 15,503 hectares (36% of the total land at risk) are covered by healthy forests and 1,463 hectares (3% of the total land at risk) are covered by built-up areas.

Table 84: Land Use and Vegetation Cover (LUVC) for land at risk in Nyamagabe District

Sector name	Banana	Build-up area	Degraded forest	Dense forest	Mining concession	Seasonal crops	Tea	Water body	Total
BURUHUKIRO		18	1	1,214	2	1,623	297		3,155
CYANIKA		61	38	367	7	687			1,159
GASAKA	3	139	38	1,047	11	963			2,201
GATARE		92	1	736	-	1,026	14		1,869
KADUHA	81	289	627	358	4	886		4	2,250
KAMEGERI		11	22	697	17	1,059		0	1,807
KIBIRIZI		437	9	1,364	17	1,492			3,319
KIBUMBWE		124	28	1,133	-	1,577			2,860
KITABI		46	2	1,066	18	724	357		2,212
MBAZI		16	2	294	-	833			1,145
MUGANO	29	70	634	1,412	31	2,339		29	4,543
MUSANGE	12	16	349	205	18	1,369		41	2,010
MUSEBEYA		44	63	2,021	55	2,841		0	5,024
MUSHUBI	2	3	70	568	53	1,686		10	2,393
NKOMANE			1	576	1	725	144	2	1,449
TARE		87	1	1,159	-	1,225	42		2,514
UWINKINGI		10	2	1,287	9	2,143	91		3,541
Grand Total	**128**	**1,463**	**1,886**	**15,503**	**243**	**23,196**	**946**	**87**	**43,452**

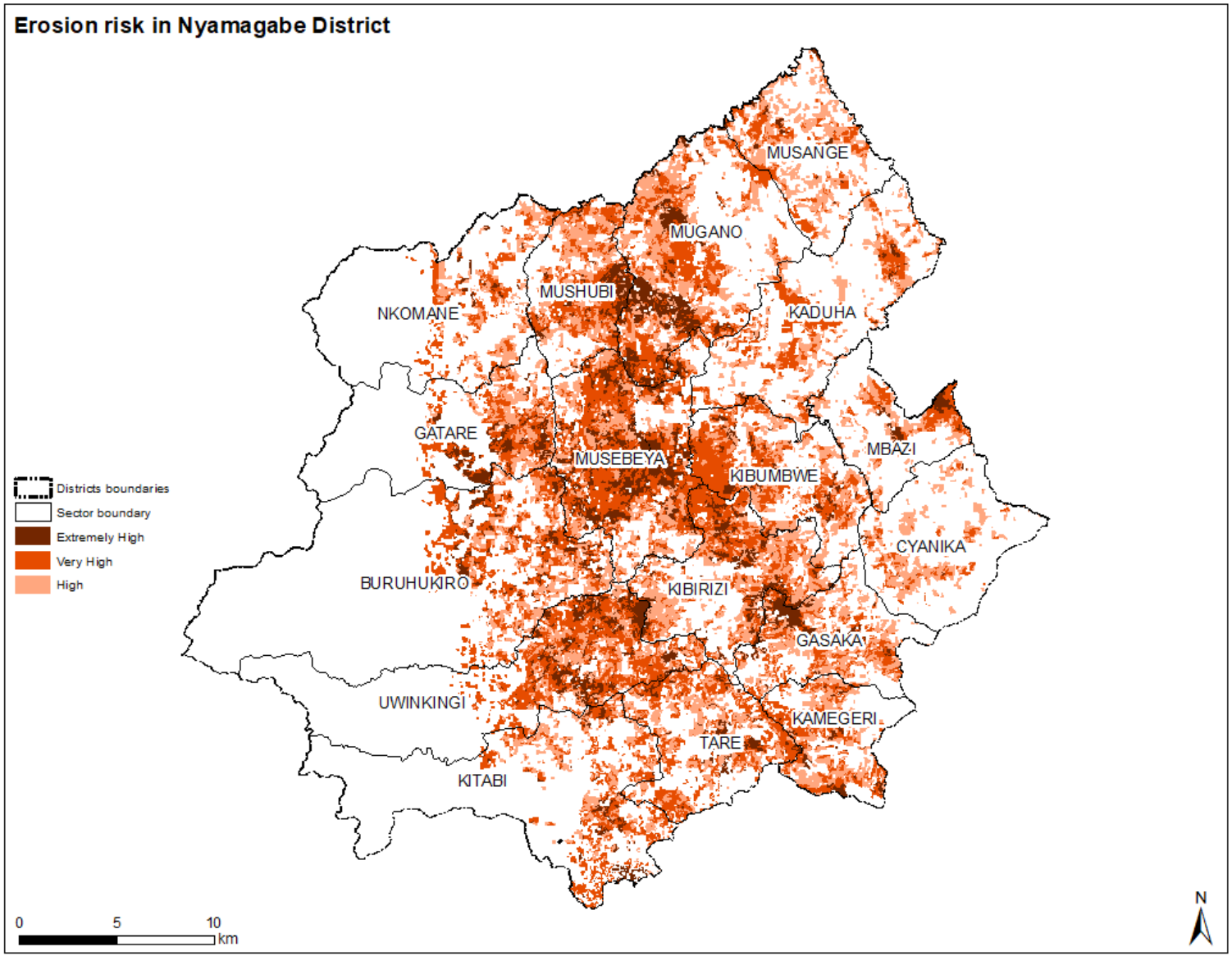


Figure 84: Erosion risk in Nyamagabe District

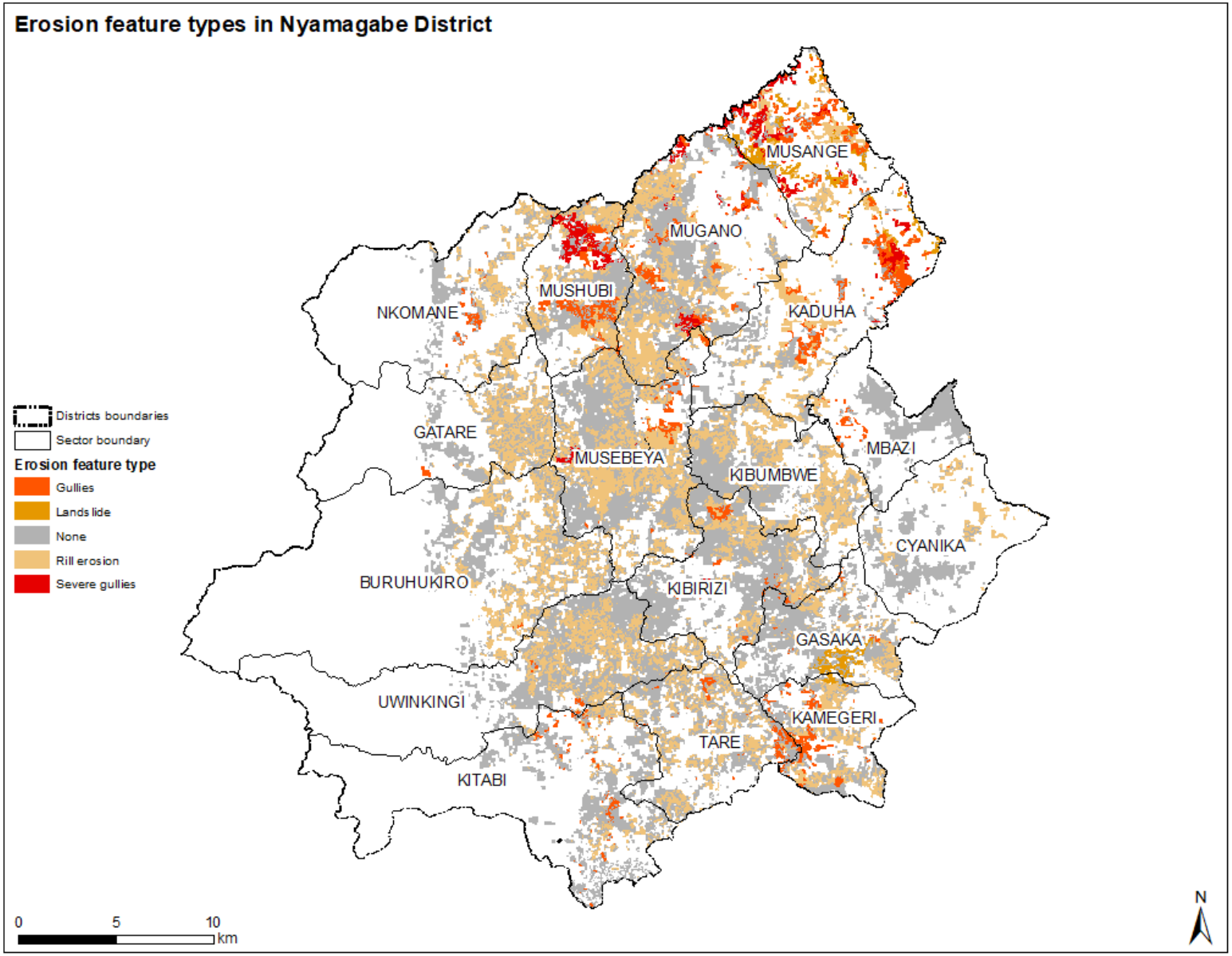


Figure 85: Erosion features detected in Nyamagabe District

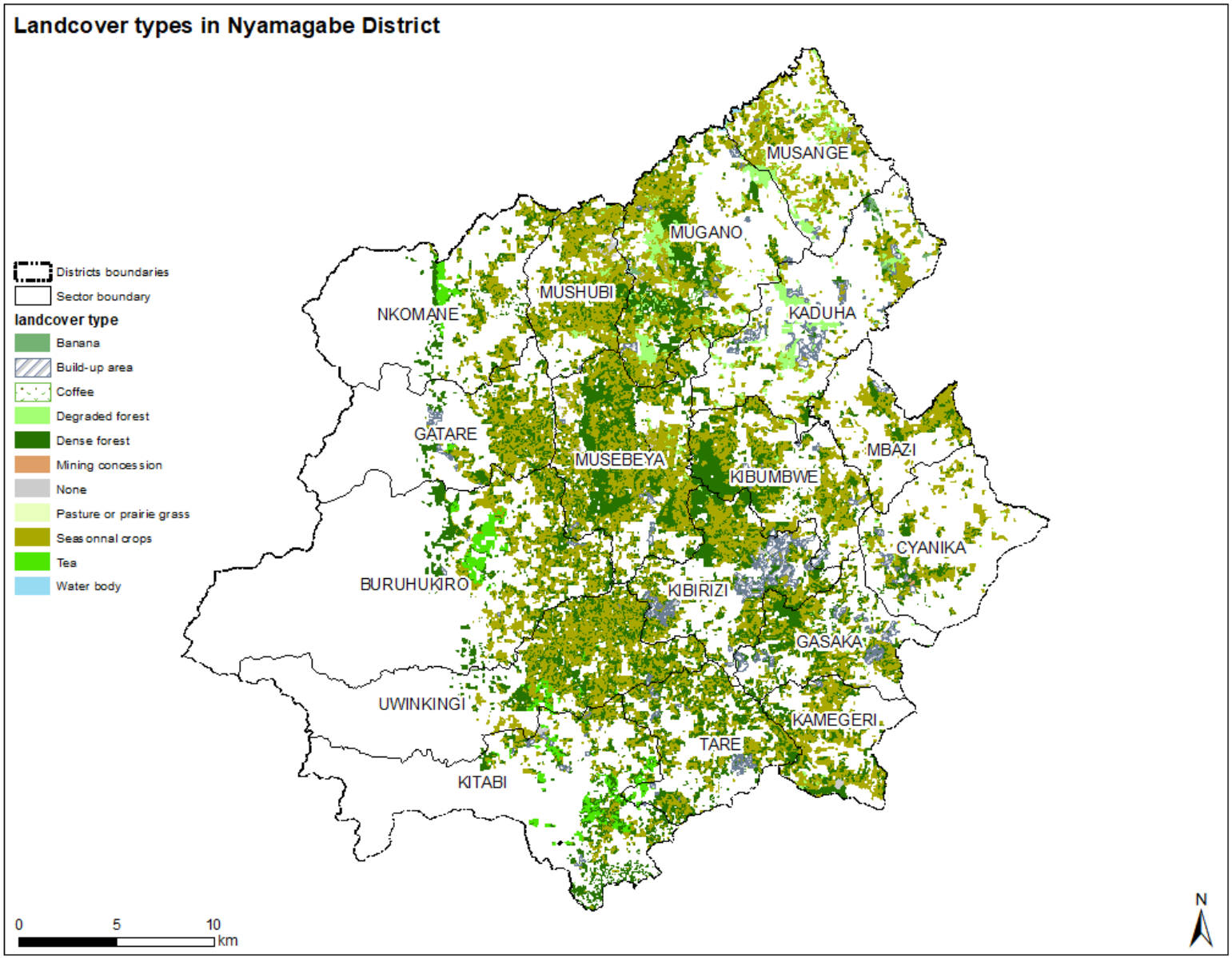


Figure 86: Land cover types in Nyamagabe District

About existing erosion control practices in Nyamagabe district, Table 85 indicates that only 50% of land at risk is protected by forests (15,668 hectares) and Contour bank terraces (4,014 hectares) and bench terraces (2,252 hectares). The highest protected sectors are Uwinkingi with 77% of its land at risk protected, followed by Buruhukiro where 69% of the total land at risk is protected and Nkomane with 69% of land protected. The least protected sectors are Mushubi with only 25% protected, Kaduha (only 27% protected), Mugano (35%) and Musange (40% protected). The visual interpretation of World View images confirms earlier findings by CROM model that Mushubi, Kaduha and Mugano sectors remain at very high risk of soil erosion since more than 65% of their respective land are not protected.

Table 85: Erosion control practices already in place in Nyamagabe District

Sector name	Erosion control techniques in place				Unprotected (Ha)	Total Area at risk (Ha)	% protected
	Bench terraces (Ha)	Contour bank terraces (Ha)	Forests (Ha)	Total protected (Ha)			
UWINKINGI	454	990	1,287	2,731	810	3,541	77%
BURUHUKIRO	287	680	1,214	2,181	974	3,155	69%
NKOMANE	70	348	577	995	454	1,449	69%
KAMEGERI	2	504	697	1,203	604	1,807	67%
GATARE	105	308	736	1,150	719	1,869	62%
GASAKA	67	203	1,061	1,331	871	2,201	60%
KITABI	102	131	1,066	1,299	914	2,212	59%
TARE	29	61	1,159	1,250	1,264	2,514	50%
KIBIRIZI	191	66	1,363	1,620	1,699	3,319	49%
MUSEBEYA	518	169	1,758	2,445	2,579	5,024	49%
CYANIKA	113	16	367	497	662	1,159	43%
KIBUMBWE	0	29	1,133	1,162	1,699	2,860	41%
MBAZI	142	26	294	462	683	1,145	40%
MUSANGE	22	248	530	800	1,210	2,010	40%
MUGANO	56	112	1,436	1,604	2,939	4,543	35%

KADUHA	93	122	386	601	1,650	2,250	27%
MUSHUBI	-	1	604	605	1,788	2,393	25%
Grand Total	**2,252**	**4,014**	**15,668**	**21,934**	**21,518**	**43,452**	**50%**

Erosion control practices in Nyamagabe District are recommended based on existing land uses, erosion control measures already in place, and predicted erosion risk by CROM model. Table 86 shows that about 15,855 hectares (which is 36% of the total land at risk) are suitable for Contour bank terraces, 3,110 hectares are Afforestation & Reforestation and 4,013 hectares of Bench terraces. Other interventions are 1,981 hectares for Hedgerows, 688 hectares of Storm water management facilities (SWMF) and 573 hectares of agroforestry in cropland.

Table 86: Recommended erosion control practices in Nyamagabe District

Sector Name	Afforestation & Reforestation	Agroforestry	Bamboo gullies & riverside	Bench terraces	Contour bank terraces	Hedgerows	Grassed waterways	No till	SWMF	None	Total
BURUHUKIRO	3	18		685	651	6	280	297		1,214	3,155
CYANIKA	45	51			569	118			10	367	1,159
GASAKA	38	90		206	697	63	2		49	1,056	2,201
GATARE	1	92		322	580	19	105	14		736	1,869
KADUHA	946	4	5	106	678	65	7	33	51	355	2,250
KAMEGERI	21	9		504	572	2	0		2	697	1,807
KIBIRIZI	13	172		22	1,238	193	53		265	1,363	3,319
KIBUMBWE	44	13		3	1,531	26			111	1,133	2,860
KITABI	2	35		131	493	100	0	375	11	1,066	2,212
MBAZI	4			1	680	149			16	294	1,145
MUGANO	777	29	30	35	2,025	79	53	29	67	1,419	4,543
MUSANGE	439	0	41	156	1,056	98	12	11	17	181	2,010
MUSEBEYA	537			342	1,561	498	22		44	2,020	5,024
MUSHUBI	175	3	9	1	1,597		1	2	3	602	2,393
NKOMANE	1		1	348	307	70		144		577	1,449
TARE	1	56		27	1,131	27	39	42	31	1,159	2,514

UWINKINGI	65	0		1,125	487	469	1	97	11	1,287	3,541
Grand Total	**3,110**	**573**	**86**	**4,013**	**15,855**	**1,981**	**575**	**1,045**	**688**	**15,526**	**43,452**
Percentage	**7%**	**1%**	**0%**	**9%**	**36%**	**5%**	**1%**	**2%**	**2%**	**36%**	**100%**

Note: Grassed waterways are recommended for existing terraces which was made without waterways or with but no grasses which can cause severe gullies and destruction of bench terraces created. No-till agriculture is recommended is recommended for perennial crops on extremely high risk area while Storm water management facilities (SWMF) or water harvesting infrastructure is recommended in built-up areas. None: means no-recommendation is provided because existing erosion control measures are adequate with reference made to the total land protected. Contour banks are recommended for existing forest without ditches. Bamboos are recommended to close gullies or for riverside buffers.

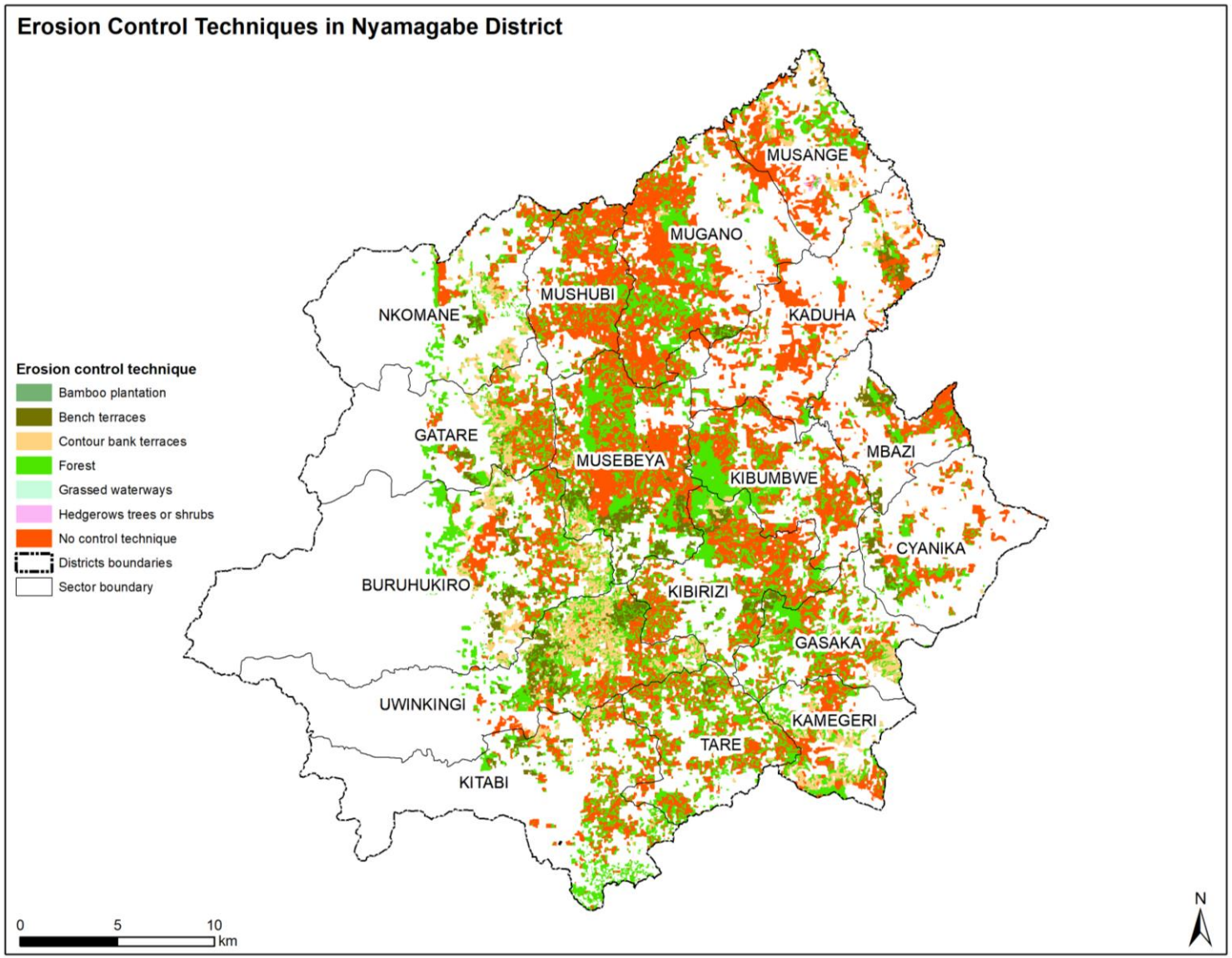


Figure 87: Erosion control techniques in place in Nyamagabe District

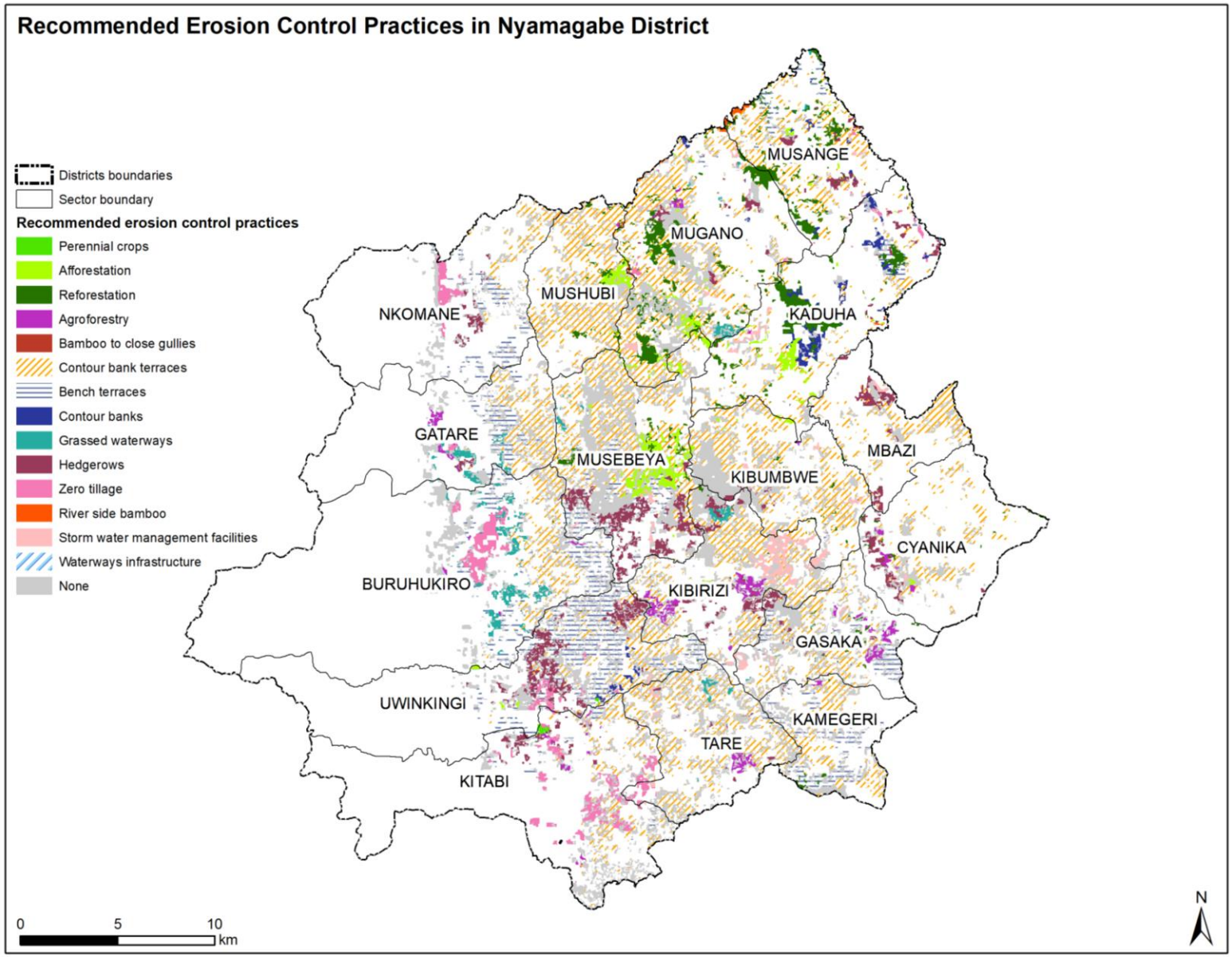


Figure 88: Recommended erosion control practices in Nyamagabe District

3.3.6. Erosion control status in Nyanza District

Erosion risk in Nyanza is summarised in Table 87 and presented in figure 89. Erosion risk in Nyanza District is estimated to 67,215 hectares; about 22% of the total district land are highly susceptible to erosion of which 3,560 hectares are located in Nyagisozi sector (49% of sector land), 2,9053 hectares are located in Cyabakamyi sector (48% of sector land), 2,256 hectares are located in Mukingo (30% of the sector land), and 1,217 hectares are found in Rwabicuma sector about 26% of the sector land. The least sectors are Busasamana with only 275 hectares (6% of the sector land) susceptible to erosion, Ntyazo with 548 hectares (10%), and Busoro with 766 hectares, about 10% of the total sector land. As compared to other district in Southern Province, Nyanza is the second least susceptible to erosion (after Gisagara).

Table 87: Erosion risk per sector in Nyanza District

Sector Name	Erosion risk				Sector land (Ha)	%
	Extremely high	Very high	High	Total (Ha)		
NYAGISOZI	439	1273	1849	3560	7253	49%
CYABAKAMYI	209	944	1752	2905	6042	48%
MUKINGO	105	808	1343	2256	7614	30%
RWABICUMA	44	359	814	1217	4765	26%
KIBIRIZI	5	211	1097	1312	8327	16%
KIGOMA	14	111	852	977	6597	15%
MUYIRA	55	276	869	1200	8787	14%
BUSORO	3	155	609	766	7361	10%
NTYAZO	15	164	369	548	5564	10%
BUSASAMANA	2	36	237	275	4903	6%
Grand Total	**891**	**4336**	**9791**	**15018**	**67215**	**22%**

Land areas affected by soil erosion features in Nyanza District are summarized in Table 88 and the map of erosion features are presented in Figure 90. The results show that Nyagisozi sector is the worst affected by rill erosion on areas estimated to 1,959 hectares (55% of sector land at risk), followed by Mukingo sector on 1,177 hectares (48% of sector land at risk), and Kibirizi sector on 946 hectares (30% of sector land at risk). The presence of rill erosion in Nyagisozi, Mukingo, Kibirizi, and Muyira sectors confirms the findings of CROM model; however the reduced presence of rill erosion in Busoro (48 ha), Ntyazo (52 ha) and Busasamana (44 ha) which was originally predicted by CROM model as sector at high risk should not read that CROM model did not perform well in this sectors, but rather due to the time of image acquisition, the erosion features could be observed or erosion control measures have been already taken and therefore runoffs have been reduced, thus erosion features could not be formed in this case. Further analysis will demonstrate that in Table 14 and 15. The least sectors affected by rill erosion are Busoro with only 48 hectares, Ntyazo with only 42 hectares, Busasamana with 46 hectares and Kigoma with 184 hectares affected by rill erosion.

Table 88: Erosion features types and areas affected in Nyanza District

Sector Name	Erosion feature types				None	Grand Total	% Features
	Gullies	Landslide	Rill erosion	Total			
NYAGISOZI	1	0	1,958	1,959	1,602	3,560	55%
MUKINGO	2		1,078	1,080	1,177	2,256	48%
KIBIRIZI			366	366	946	1,312	28%
MUYIRA			281	281	919	1,200	23%
CYABAKAMYI	7	0	633	640	2,265	2,905	22%
RWABICUMA	14		242	257	960	1,217	21%
KIGOMA			184	184	793	977	19%
BUSASAMANA	1		44	46	230	275	17%
NTYAZO			52	52	496	548	9%
BUSORO			48	48	718	766	6%
Grand Total	**25**	**0**	**4,886**	**4,911**	**10,106**	**15,018**	**33%**

In term of land use and related management of areas at risk in Nyanza, the results of land cover mapping (Table 89 and Figure 91) show that **10,227** hectares (68% of the total land at risk) are used for seasonal cropping and **3,290 hectares** (22% of the total land at risk) are covered by healthy forests, **881** hectares (6% of the total land at risk) are covered by built-up areas.

Table 89: Land Use and Vegetation Cover (LUVC) for land at risk in Nyanza District

Sector name	Build-up area	Degraded forest	Dense forest	Seasonal crops	Water body	Total
BUSASAMANA	127		59	89		275
BUSORO	106	29	140	491		766
CYABAKAMYI	1	0	541	2,356	7	2,905
KIBIRIZI	51	357	211	688	5	1,312
KIGOMA	68	27	168	714		977
MUKINGO	14		778	1,464	0	2,256
MUYIRA	140	162	175	722		1,200
NTYAZO	161	14	152	218	2	548
NYAGISOZI	12	0	777	2,759	11	3,560
RWABICUMA	201	3	287	726		1,217
Grand Total	**881**	**594**	**3,290**	**10,227**	**26**	**15,018**

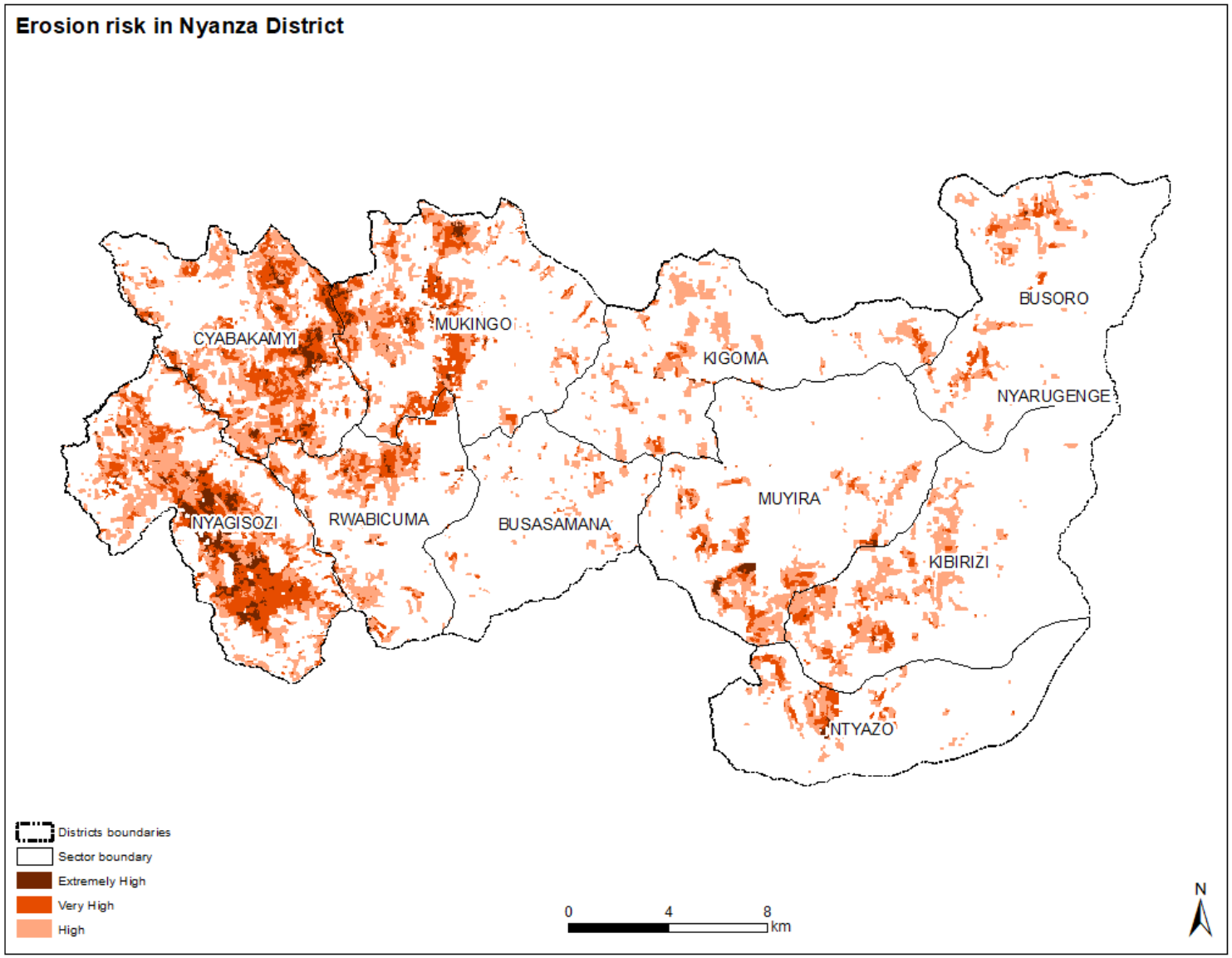


Figure 89: Erosion risk in Nyanza District

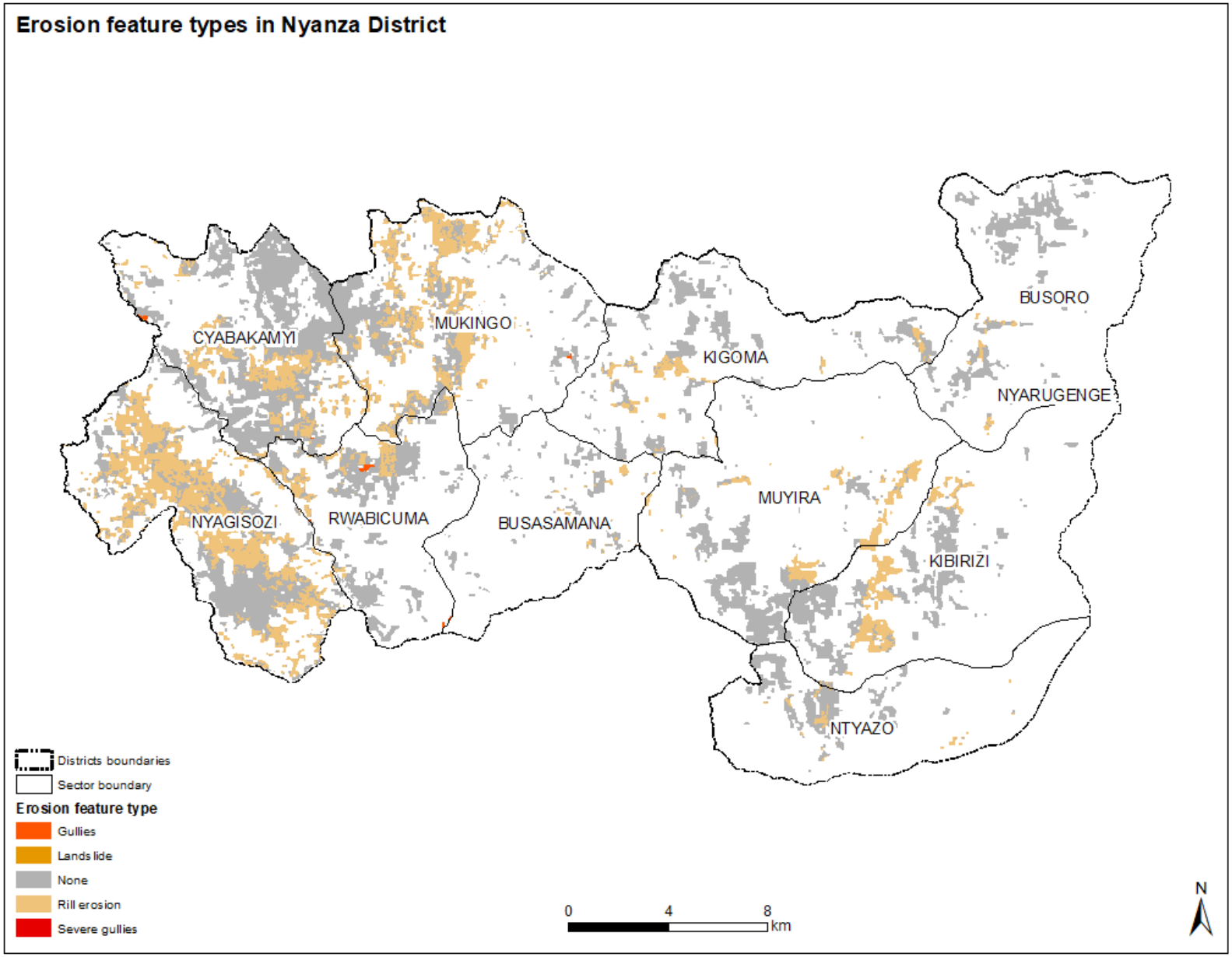


Figure 90: Erosion features detected in Nyanza District

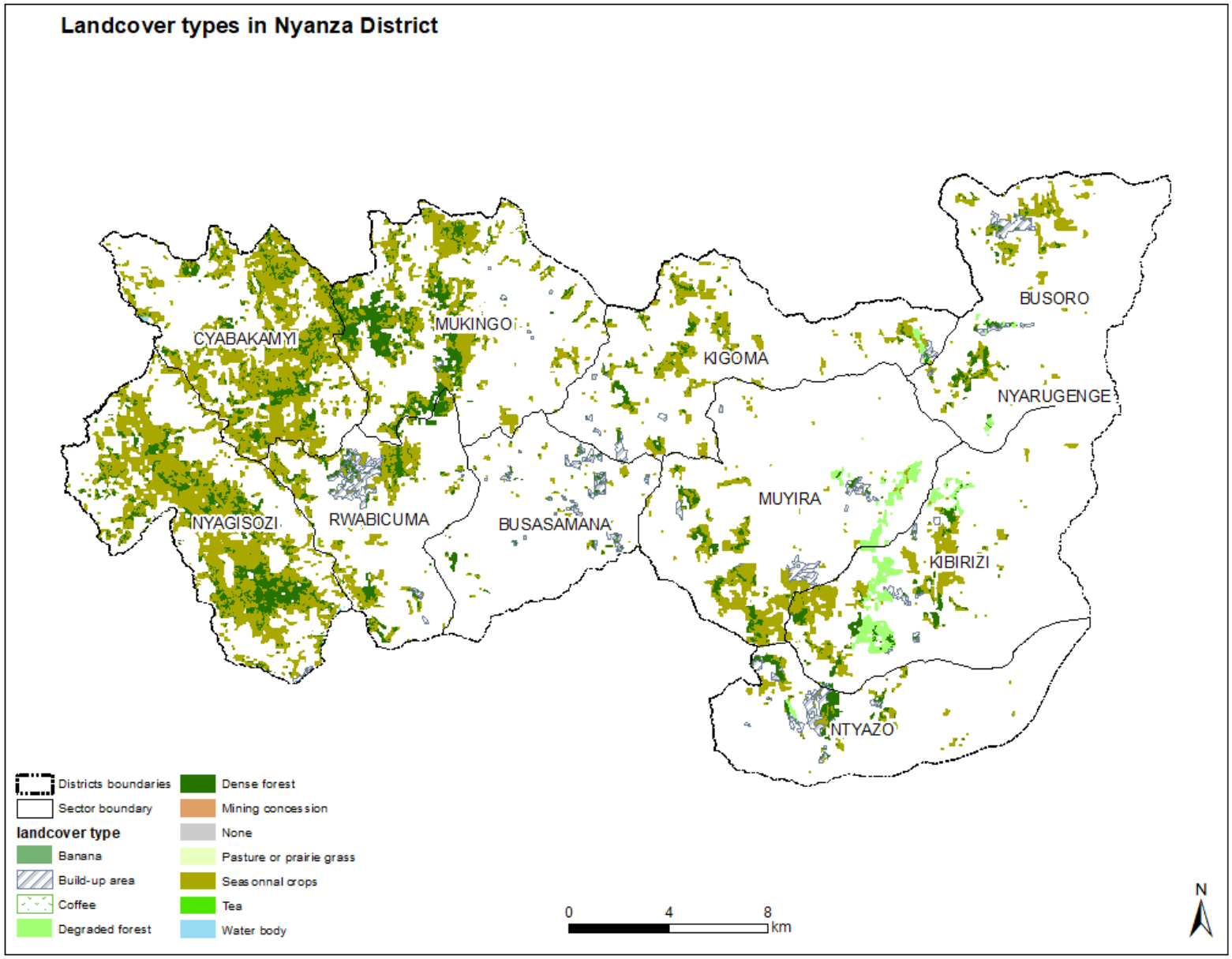


Figure 91: Land cover types in Nyanza District

About existing erosion control practices in Nyanza district, Table 90 shows that only 29% of land at risk is protected by forests (3,427 hectares) and bench terraces (938 hectares). Although still low, the highest protected sectors are Rwabicumba with 46% of its land at risk protected, followed by Cyabakamyi where 40% of the total land at risk is protected and Mukingo (only 35% protected). The least protected sectors are Muyira with only 15% protected, Kibirizi (only 16% protected), Kigoma (17%) and Busoro (18% protected). The visual interpretation of World View images confirms earlier findings by CROM model that Muyira, Kibirizi, Kigoma and Busoro sectors remain at very high risk of soil erosion since more than 80% of their respective land are not protected.

Table 90: Erosion control practices already in place in Nyanza District

Sector name	Erosion control techniques in place			Unprotected land (Ha)	Total land at risk (Ha)	% protected
	Bench terraces (Ha)	Forests (Ha)	Total protected (Ha)			
RWABICUMA	227	328	555	662	1,217	46%
CYABAKAMYI	631	541	1,172	1,733	2,905	40%
MUKINGO	0	778	779	1,478	2,256	35%
NTYAZO		152	152	396	548	28%
NYAGISOZI	80	873	953	2,607	3,560	27%
BUSASAMANA		59	59	216	275	22%
BUSORO		140	140	626	766	18%
KIGOMA		168	168	809	977	17%
KIBIRIZI		211	211	1,101	1,312	16%
MUYIRA		175	175	1,025	1,200	15%
Grand Total	**938**	**3,427**	**4,365**	**10,653**	**15,018**	**29%**

Erosion control practices in Nyanza District are recommended based on existing land uses, erosion control measures already in place, and predicted erosion risk by CROM model. Table 91 shows that about 8,803 hectares (which is 59% of the total land at risk) are suitable for Contour bank terraces, 1,105 hectares are cropland that needs agroforestry/alley cropping and 1,069 hectares of Grassed waterways. Other interventions are 602 hectares for Afforestation & Reforestation, 30 hectares are for gullies or riverbanks amounting to 959 hectares eroded which require bamboo trees for rehabilitation and 10 hectares of Hedgerows.

Table 91: Recommended erosion control practices in Nyanza District

Sector Name	Reforestation	Agroforestry	Bamboo gullies & riverside	Grassed waterways	Contour bank terraces	SWMF	None	Total
BUSASAMANA		124	1		73	18	59	275
BUSORO	29	122			469	3	142	766
CYABAKAMYI	0	3	7	627	1,723		541	2,905
KIBIRIZI	357	197	5		522	20	211	1,312
KIGOMA	27	68			688	26	168	977
MUKINGO	7	6		0	1,440	25	778	2,256
MUYIRA	163	176			671	15	175	1,200
NTYAZO	14	196	2		184		152	548
NYAGISOZI	0	12	11	173	2,582		777	3,560
RWABICUMA	3	201	3	269	452		287	1,217
Grand Total	**602**	**1,105**	**30**	**1,069**	**8,803**	**108**	**3,291**	**15,018**
Percentage	**4%**	**7%**	**0%**	**7%**	**59%**	**1%**	**22%**	**100%**

Note: Grassed waterways are recommended for existing terraces which was made without waterways or with but no grasses which can cause severe gullies and destruction of bench terraces created. No-till agriculture is recommended is recommended for perennial crops on extremely high risk area while Storm water management facilities (SWMF) or water harvesting infrastructure is recommended in built-up areas. None: means no-recommendation is provided because existing erosion control measures are adequate with reference made to the total land protected. Contour banks are recommended for existing forest without ditches. Bamboos are recommended to close gullies or for riverside buffers.

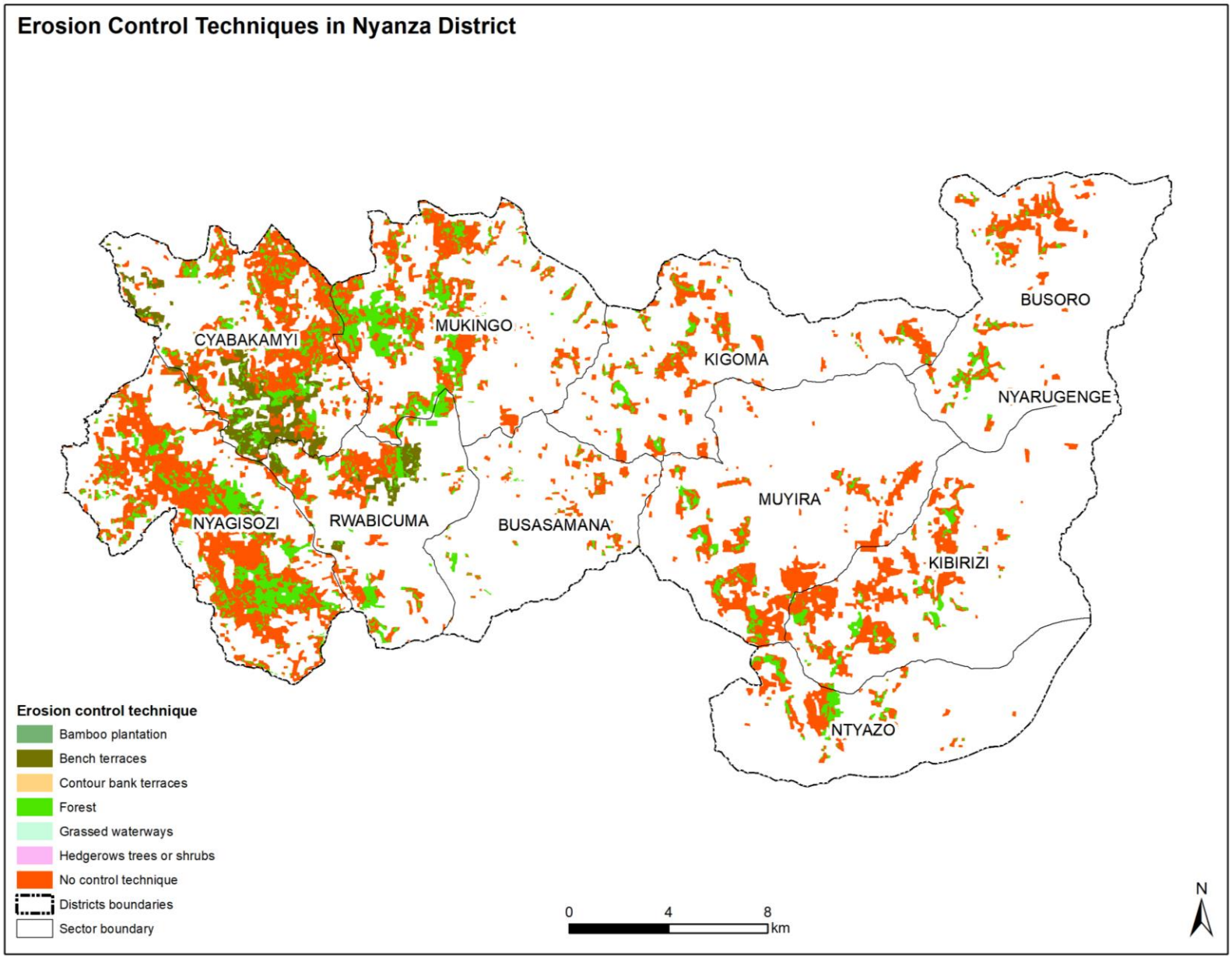


Figure 92: Erosion control techniques in place in Nyanza District

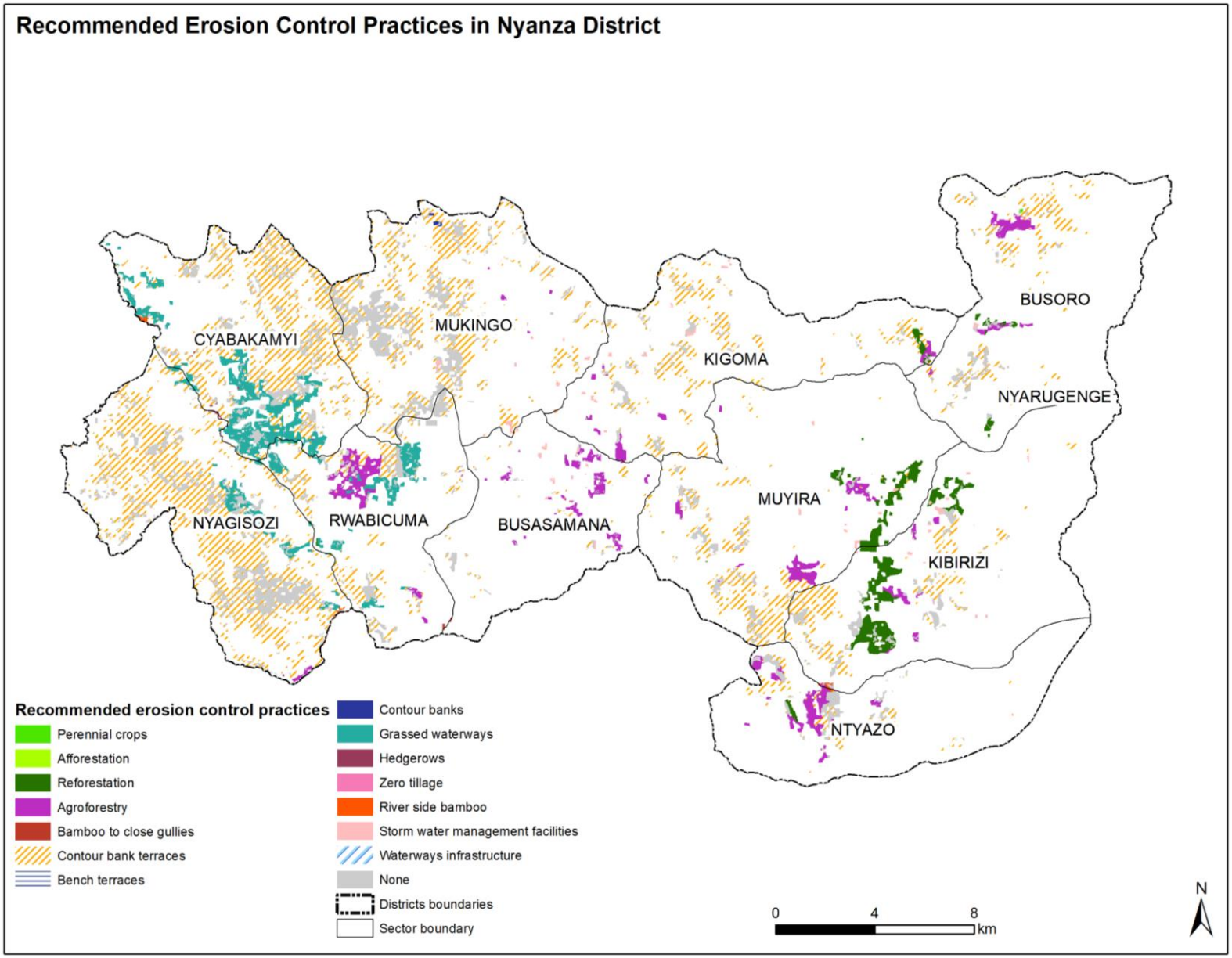


Figure 93: Recommended erosion control practices in Nyanza District

3.3.7. Erosion control status in Nyaruguru District

Erosion risk in Nyaruguru is summarised in Table 92 and presented in figure 94. Erosion risk in Nyaruguru District is estimated to 37,836 hectares; about 37% of the total district land are highly susceptible to erosion of which 2,943 hectares are located in Ruramba sector (60 of sector land), 3,329 hectares are located in Busanze sector (59% of sector land), 3,160 hectares are located in Munini (52% of the sector land), and 1,701 hectares are found in Nyagisozi sector about 49% of the sector land. The least sectors are Cyahinda with only 1,314 hectares (25% of the sector land) susceptible to erosion, Kibeho with 1,974 hectares (25%), and Muganza with 2,350 hectares, about 27% of the total sector land. As compared to other districts in Southern Province, Nyaruguru is the third susceptible to erosion.

Table 92: Erosion risk per sector in Nyaruguru District

Sector Name	Erosion risk				Sector land (Ha)	%
	Extremely high	Very high	High	Total (Ha)		
RURAMBA	524	1,280	1,139	2,943	4,939	60%
BUSANZE	413	1,341	1,575	3,329	5,651	59%
MUNINI	556	1,212	1,392	3,160	6,130	52%
NYAGISOZI	114	528	1,059	1,701	3,482	49%
RUSENGE	255	1,141	1,362	2,758	5,993	46%
MATA	292	723	1,676	2,691	6,202	43%
RUHERU	1,635	2,143	1,146	4,924	11,392	43%
NGERA	221	801	1,435	2,457	5,928	41%
NYABIMATA	896	1,193	1,360	3,449	11,949	29%
KIVU	1,031	1,526	982	3,539	12,372	29%
NGOMA	71	356	818	1,245	4,695	27%
MUGANZA	650	913	787	2,350	9,167	26%
KIBEHO	169	597	1,209	1,974	7,827	25%
CYAHINDA	144	441	730	1,314	5,301	25%
Grand Total	**6,971**	**14,195**	**16,670**	**37,836**	**101,027**	**37%**

Land areas affected by soil erosion features in Nyaruguru District are summarized in Table 93 and the map of erosion features are presented in Figure 95. The results show that Busanze sector is the worst affected by rill erosion and gullies on areas estimated to 471 hectares (14% of sector land at risk), followed by Ruheru sector on 306 hectares (32% of sector land at risk), and Cyahinda sector on 17 hectares (1.3% of sector land at risk). These affected sectors confirm the findings of CROM model; however the reduced presence of gullies and rill erosion in Ruramba, Mata, Nyagisozi, Munini and Kibeho which was originally predicted by CROM model as sectors at high risk should not read that CROM model did not perform well in this sectors, but rather due to the time of image acquisition, the erosion features could be observed or erosion control measures have been already taken and therefore runoffs have been reduced, thus erosion features could not be formed in this case. Further analysis will demonstrate that in Table 94 and 95. The least affected sectors are Ruramba, Mata, Nyagisozi and Rusenge which are affected by few gullies and rill erosion.

Table 93: Erosion features types and areas affected in Nyaruguru District

Sector Name	Erosion feature types						Grand Total	% Features
	Gullies	Landslide	Rill erosion	Severe gullies	Total	None		
BUSANZE	63	11	366	31	471	2,858	3,329	14.2%
RUHERU	15		276	15	306	4,619	4,924	6.2%
CYAHINDA			17		17	1,297	1,314	1.3%
NGOMA	1		10		11	1,234	1,245	0.9%
NYABIMATA	21	2			23	3,426	3,449	0.7%
MUGANZA	8	3			11	2,340	2,350	0.5%
NGERA	5				5	2,453	2,457	0.2%
KIVU	2	3	1		6	3,533	3,539	0.2%
KIBEHO		3			3	1,971	1,974	0.2%
MUNINI		4			4	3,157	3,160	0.1%
RUSENGE	1				1	2,757	2,758	0.0%
NYAGISOZI				0	0	1,701	1,701	0.0%
MATA	0				0	2,691	2,691	0.0%
RURAMBA	0		0		0	2,943	2,943	0.0%
Grand Total	**116**	**27**	**670**	**46**	**859**	**36,977**	**37,836**	**2.3%**

In term of land use and related management of areas at risk in Nyaruguru, the results of land cover mapping (Table 94 and Figure 96) show that 19,034 hectares (50% of the total land at risk) are used for seasonal cropping, 16,806 hectares (44% of the total land at risk) are covered by healthy forests, 1,407 hectares (4% of the total land at risk) covered by tea plantations and 99 hectares (0.3% of the total land at risk) are covered by built-up areas.

Table 94: Land Use and Vegetation Cover (LUVC) for land at risk in Nyaruguru District

Sector name	Build-up area	Degraded forest	Dense forest	Mining concession	Seasonal crops	Tea	Water body	Total
BUSANZE	16	41	1,254	14	1,952	48	3	3,329
CYAHINDA		27	757		530			1,314
KIBEHO		35	1,040		807	92		1,974
KIVU	4	97	1,578	2	1,709	150	0	3,539
MATA	16	4	1,557		1,084	29	1	2,691
MUGANZA		34	1,229	3	856	220	9	2,350
MUNINI	29	3	1,464		1,570	93	1	3,160
NGERA		6	895	10	1,523		23	2,457
NGOMA		0	288		945		11	1,245
NYABIMATA	7	33	1,367	1	1,378	658	5	3,449
NYAGISOZI		12	810		879			1,701
RUHERU	28	62	1,820		2,886	107	22	4,924
RURAMBA		2	1,441		1,490	10		2,943
RUSENGE		23	1,307	1	1,423	0	3	2,758
Grand Total	**99**	**380**	**16,806**	**30**	**19,034**	**1,407**	**78**	**37,836**

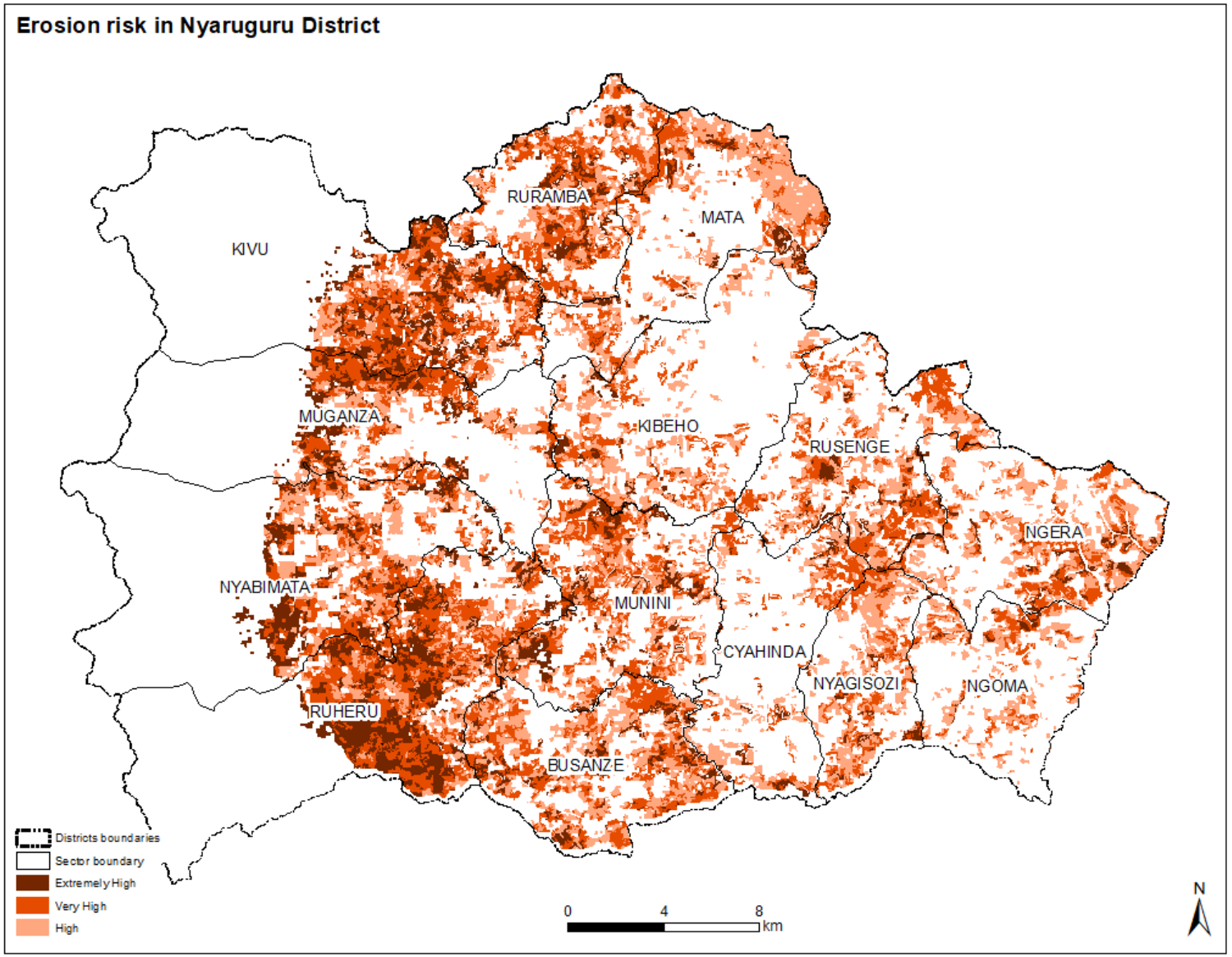


Figure 94: Erosion risk in Nyaruguru District

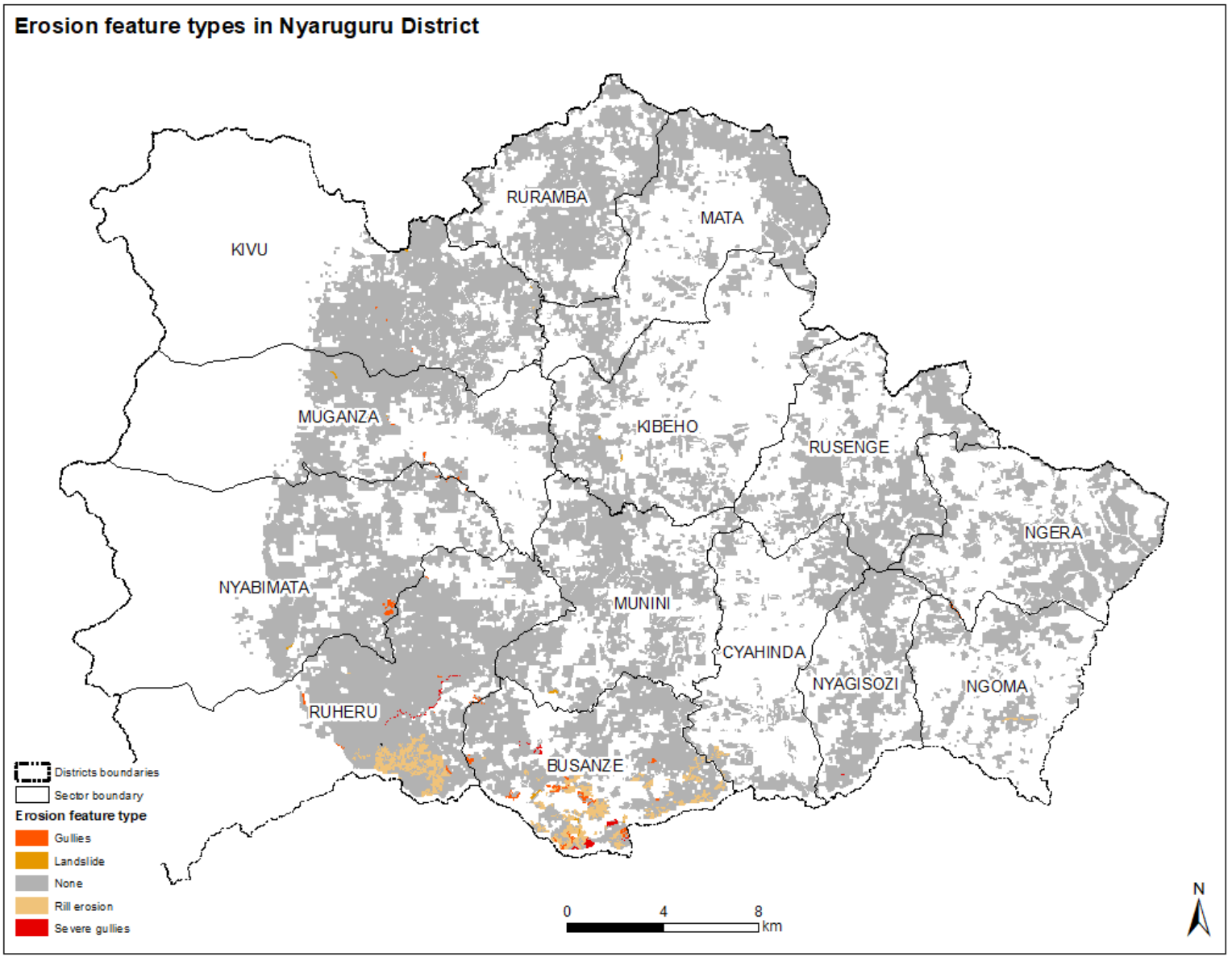


Figure 95: Erosion features detected in Nyaruguru District

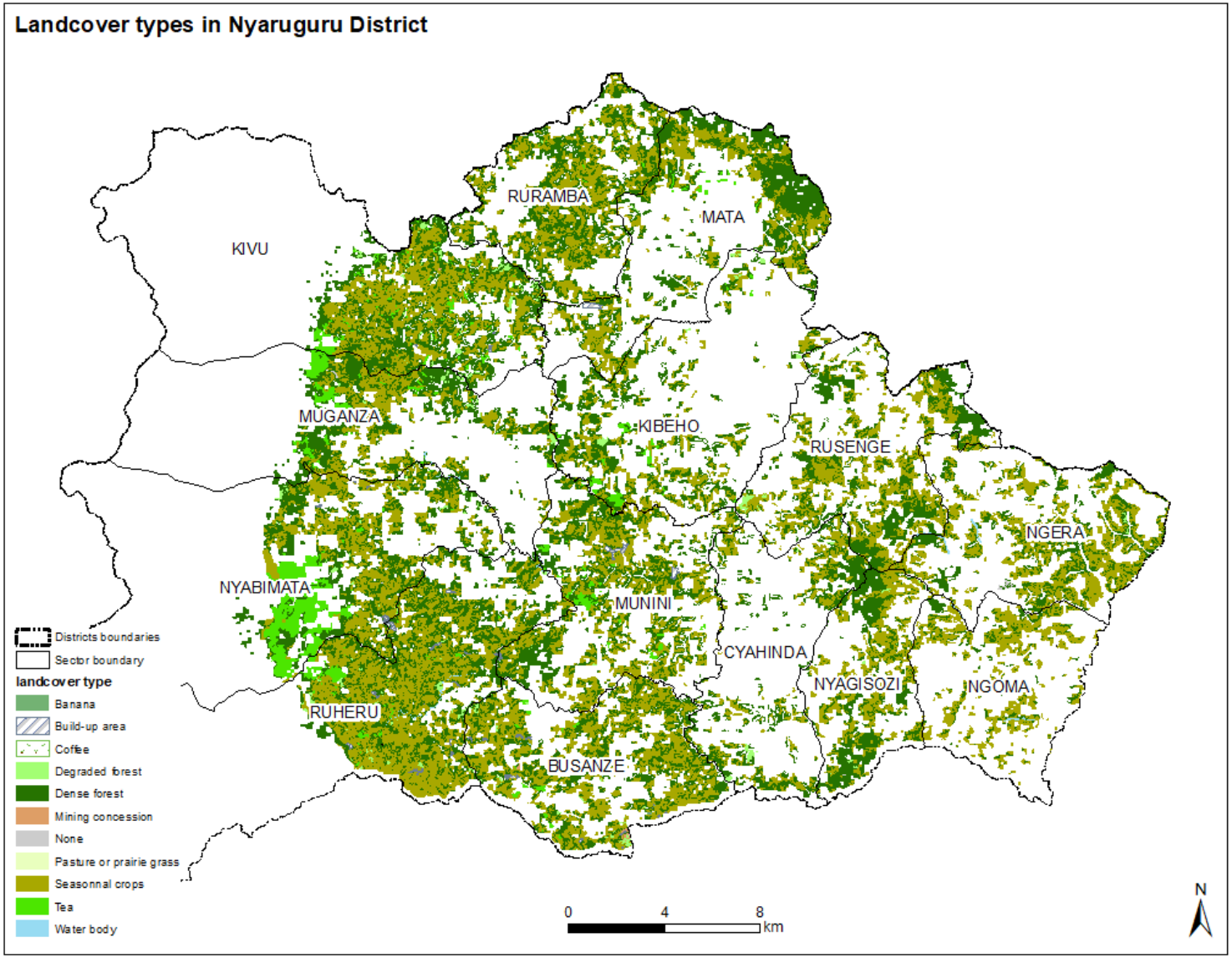


Figure 96: Land cover types in Nyaruguru District

About existing erosion control practices in Nyaruguru district, Table 95 shows that only 46% of land at risk is protected by forests (16,856 hectares), contour bank terraces (121 hectares) and bench terraces (427 hectares). The highest protected sectors are Cyahinda with 59% of its land at risk protected, followed by Mata where 58% of the total land at risk is protected and Kibeho with 55% of land protected. The least protected sectors are Ngoma with only 24% protected, Ngera (only 37% protected), Busanze (39%) and Ruheru (40% protected). The visual interpretation of World View images confirms earlier findings by CROM model that Busanze, and Ngera, sectors remain at very high risk of soil erosion since more than 60% of their respective land are not protected.

Table 95: Erosion control practices already in place in Nyaruguru District

Sector name	Erosion control techniques in place				Unprotected (Ha)	Grand Total (Ha)	% protected
	Bench terraces (Ha)	Contour bank terraces	Forests (Ha)	Total protected (Ha)			
CYAHINDA	23		757	780	535	1,314	59%
MATA	15		1,557	1,573	1,118	2,691	58%
KIBEHO	55		1,040	1,095	880	1,974	55%
MUGANZA	50		1,229	1,279	1,071	2,350	54%
RURAMBA	1	0	1,441	1,442	1,501	2,943	49%
NYAGISOZI	15		810	825	877	1,701	48%
MUNINI	68		1,464	1,532	1,628	3,160	48%
RUSENGE		0	1,307	1,307	1,451	2,758	47%
KIVU	11	9	1,583	1,602	1,937	3,539	45%
NYABIMATA	87	1	1,409	1,497	1,952	3,449	43%
RUHERU	68	80	1,820	1,967	2,957	4,924	40%
BUSANZE	15	32	1,256	1,303	2,026	3,329	39%
NGERA	7		895	902	1,555	2,457	37%
NGOMA	13		288	301	944	1,245	24%
Grand Total	**427**	**121**	**16,856**	**17,404**	**20,432**	**37,836**	**46%**

Erosion control practices in Nyaruguru District are recommended based on existing land uses, erosion control measures already in place, and predicted erosion risk by CROM model. Table 96 shows that about 16,472 hectares (which is 44% of the total land at risk) are suitable for Contour bank terraces, 1,799 hectares are cropland that need agroforestry/alley cropping and 933 hectares Afforestation & Reforestation. Other interventions are 134 hectares for Afforestation & Reforestation, 134 hectares of bamboo plantations on gullies or riverbanks, 378 hectares of hedgerows and 288 hectares of bench terraces.

Table 96: Recommended erosion control practices in Nyaruguru District

Sector Name	Afforestation & Reforestation	Agroforestry	Bamboo gullies & riverside	Bench terraces	Contour bank terraces	Hedgerows	No till	SWMF	None	Total
BUSANZE	429	200	55	95	1,610	12	50	16	862	3,329
CYAHINDA	27	28			483	23	3		751	1,314
KIBEHO	35	12			741	52	92		1,043	1,974
KIVU	94	248	2		1,445	11	155	4	1,582	3,539
MATA	1	36	1		1,048		29	16	1,559	2,691
MUGANZA	49	79	9	13	701	50	214		1,236	2,350
MUNINI	3	101	1		1,401	68	93	29	1,464	3,160
NGERA	16	63	23		1,453	7			895	2,457
NGOMA	0	39	1		892	13	1		298	1,245
NYABIMATA	67	162	10	0	1,117	68	728	6	1,292	3,449
NYAGISOZI	12	24			841	15			810	1,701
RUHERU	172	665	29	181	1,973	58	106	28	1,713	4,924
RURAMBA	2	30		0	1,458	1	10		1,441	2,943
RUSENGE	24	113	3		1,310	0			1,307	2,758
Grand Total	**933**	**1,799**	**134**	**288**	**16,472**	**378**	**1,482**	**98**	**16,252**	**37,836**
Percentage	**2%**	**5%**	**0.4%**	**1%**	**44%**	**1%**	**4%**	**0.3%**	**43%**	**100%**

Note: Grassed waterways are recommended for existing terraces which was made without waterways or with but no grasses which can cause severe gullies and destruction of bench terraces created. No-till agriculture is recommended is recommended for perennial crops on extremely high risk area while Storm water management facilities (SWMF) or water harvesting infrastructure is recommended in built-up areas. None: means no-

recommendation is provided because existing erosion control measures are adequate with reference made to the total land protected. Contour banks are recommended for existing forest without ditches. Bamboos are recommended to close gullies or for riverside buffers.

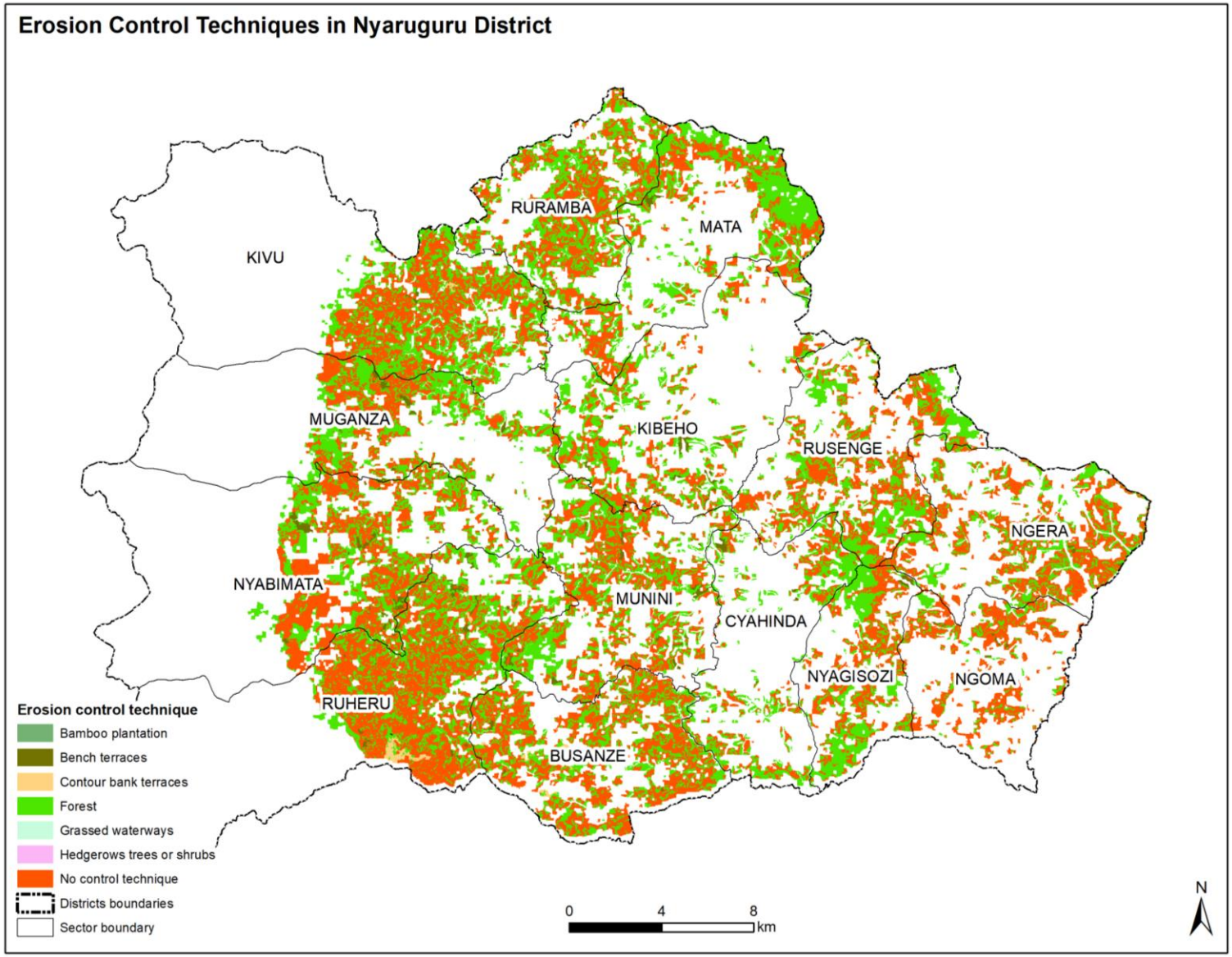


Figure 97: Erosion control techniques in place in Nyaruguru District

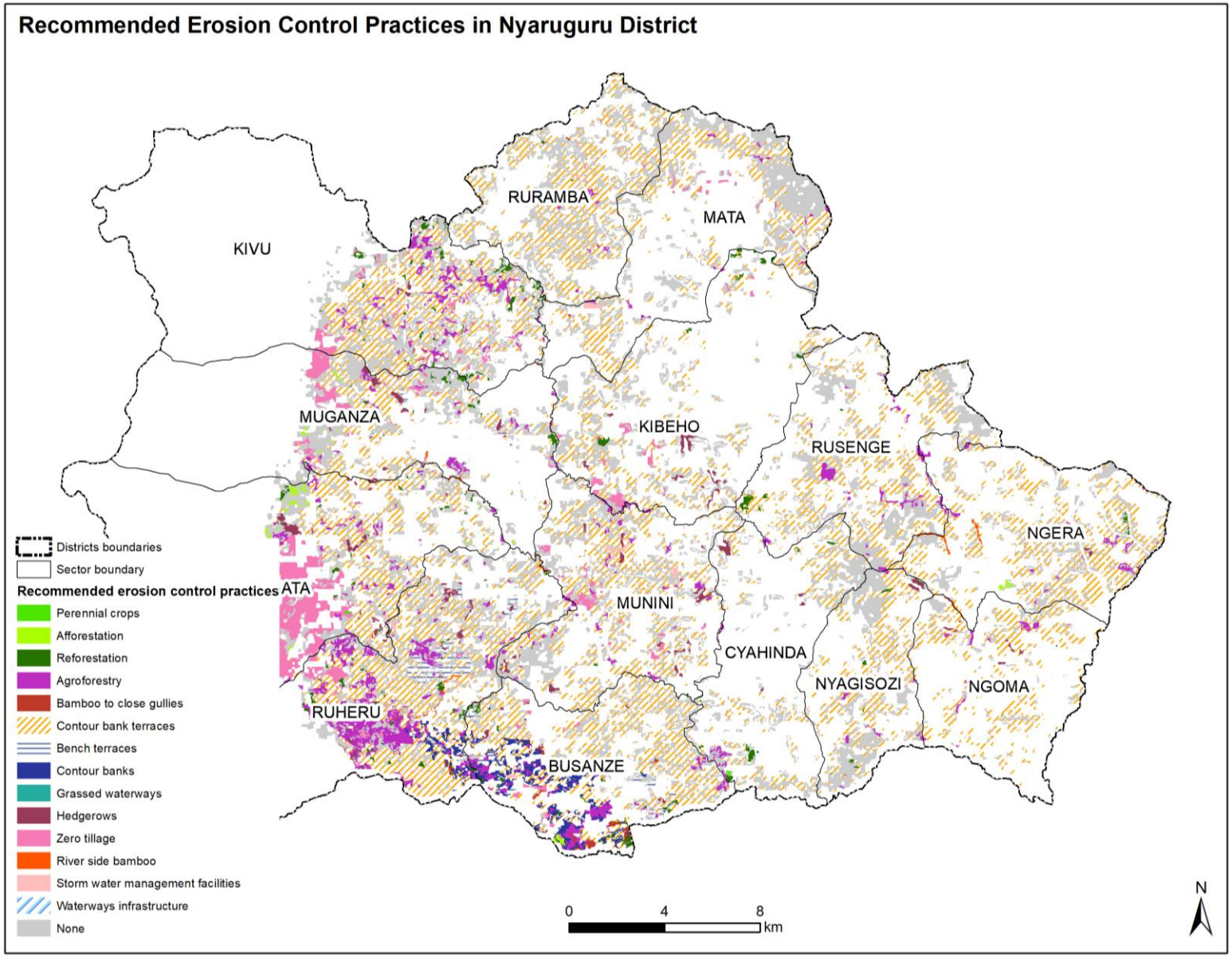


Figure 98: Recommended erosion control practices in Nyaruguru District

3.3.8. Erosion control status in Ruhango District

Erosion risk in Ruhango is summarised in Table 97 and presented in figure 99. Erosion risk in Ruhango District is estimated to 14,764 hectares; about 24% of the total district land are highly susceptible to erosion of which 3,261 hectares are located in Mwendo sector (59% of sector land), 2,826 hectares are located in Kinihira sector (46% of sector land), 1,250 hectares are located in Bweramana (37% of the sector land), and 980 hectares are found in Byimana sector about 30% of the sector land. The least sectors are Kinazi with only 602 hectares (7% of the sector land) susceptible to erosion, Ntongwe with 757 hectares (9%), and Mbuye with 933 hectares, about 12% of the total sector land. As compared to other districts in Southern Province, Ruhango is the second least susceptible to erosion.

Table 97: Erosion risk per sector in Ruhango District

Sector Name	Erosion risk				Sector land (Ha)	%
	Extremely high	Very high	High	Total (Ha)		
MWENDO	349	1,046	1,866	3,261	5,555	59%
KINIHIRA	184	857	1,785	2,826	6,084	46%
BWERAMANA	266	518	1,250	2,033	5,492	37%
BYIMANA	289	559	980	1,828	6,182	30%
KABAGALI	102	278	719	1,099	6,059	18%
RUHANGO	4	160	1,260	1,424	9,426	15%
MBUYE	21	190	722	933	7,784	12%
NTONGWE	5	82	670	757	8,897	9%
KINAZI	5	106	491	602	7,198	8%
Grand Total	**1,225**	**3,796**	**9,743**	**14,764**	**62,678**	**24%**

Land areas affected by soil erosion features in Ruhango District are summarized in Table 98 and the map of erosion features are presented in Figure 100. The results show that Kabagali sector is the worst affected by gullies on areas estimated to 191 hectares (17% of sector land at risk), followed by Bweramana sector on 183 hectares (9% of sector land at risk), and Mwendo sector on 282 hectares (9% of sector land at risk) and Byimana sector on 155 hectares (9% of sector land at risk). The presence of gullies in Bweramana, Mwendo, Kanbagali and Mwendo sectors confirms the findings of CROM model; however the absence of gullies in Ntongwe and Kinazi and the reduced presence of gullies in Ruhango (5ha) and Mbuye (9 ha) which were originally predicted by CROM model as sectors at high risk should not read that CROM model did not perform well in this sectors, but rather due to the time of image acquisition, the erosion features could be observed or erosion control measures have been already taken and therefore runoffs have been reduced, thus erosion features could not be formed in this case. Further analysis will demonstrate that in Table 100 and 101. The least sectors affected by gullies are Ntongwe, Kinali and Ruhango affected some severe gullies.

Table 98: Erosion features types and areas affected in Ruhango District

Sector Name	Erosion feature types						Grand Total	% Features
	Gullies	Landslide	Rill erosion	Severe gullies	Total	None		
KABAGALI	162	0	0	29	191	909	1,099	17%
BWERAMANA	182	2	0	0	183	1,850	2,033	9%
MWENDO	236	1	0	45	282	2,979	3,261	9%
BYIMANA	108		0	48	155	1,672	1,828	9%
KINIHIRA	149	1		2	153	2,674	2,826	5%
MBUYE	9		0		9	924	933	1%
RUHANGO				5	5	1,419	1,424	0%
KINAZI					0	602	602	0%
NTONGWE					0	757	757	0%
Grand Total	**846**	**3**	**0**	**129**	**978**	**13,785**	**14,764**	**7%**

In term of land use and related management of areas at risk in Ruhango, the results of land cover mapping (Table 99 and Figure 101) show that 11,150 hectares (76% of the total land at risk) are used for seasonal cropping and 3,107 hectares (21% of the total land at risk) are covered by healthy forests, 21 hectares (0.1% of the total land at risk) are covered by built-up areas. Degraded forest covers about 293 hectares while banana covers 77 hectares (0.4% of the total land at risk), and mining and quarries cover 34 hectares (0.2% of the total land at risk).

Table 99: Land Use and Vegetation Cover (LUVC) for land at risk in Ruhango District

Sector name	Banana	Build-up area	Degraded forest	Dense forest	Mining & Quarries	Seasonal crops	Water body	Total
BWERAMANA			35	471		1,518	9	2,033
BYIMANA		3	89	517	3	1,215	1	1,828
KABAGALI	1		28	312	2	731	26	1,099
KINAZI		3	3	81	2	511	1	602
KINIHIRA	58	5	48	573	23	2,086	33	2,826
MBUYE			7	190		728	8	933
MWENDO	18	5	42	689	4	2,498	4	3,261
NTONGWE			28	97		631		757
RUHANGO		4	13	175		1,231		1,424
Grand Total	**77**	**21**	**293**	**3,107**	**34**	**11,150**	**83**	**14,764**

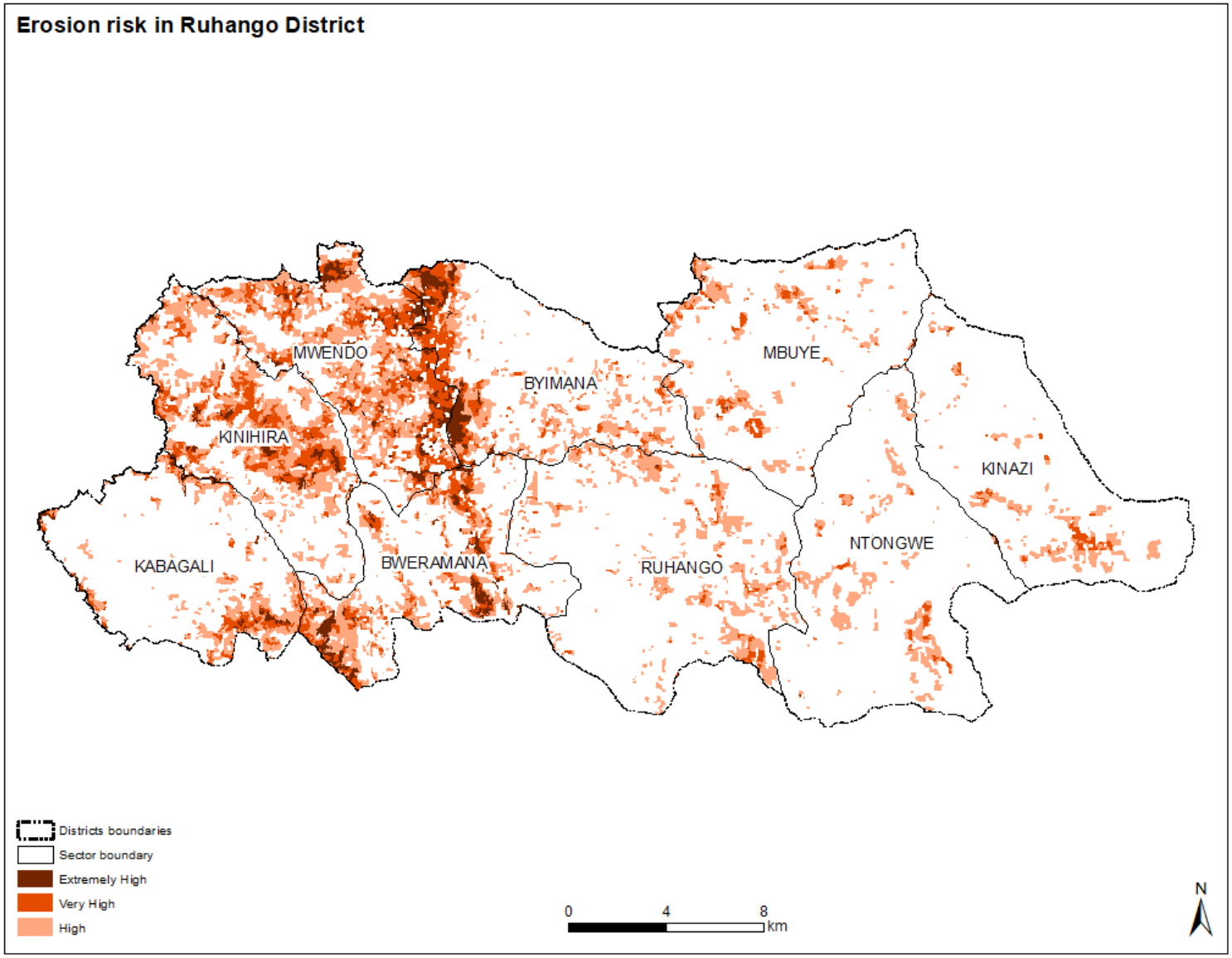


Figure 99: Erosion risk in Ruhango District

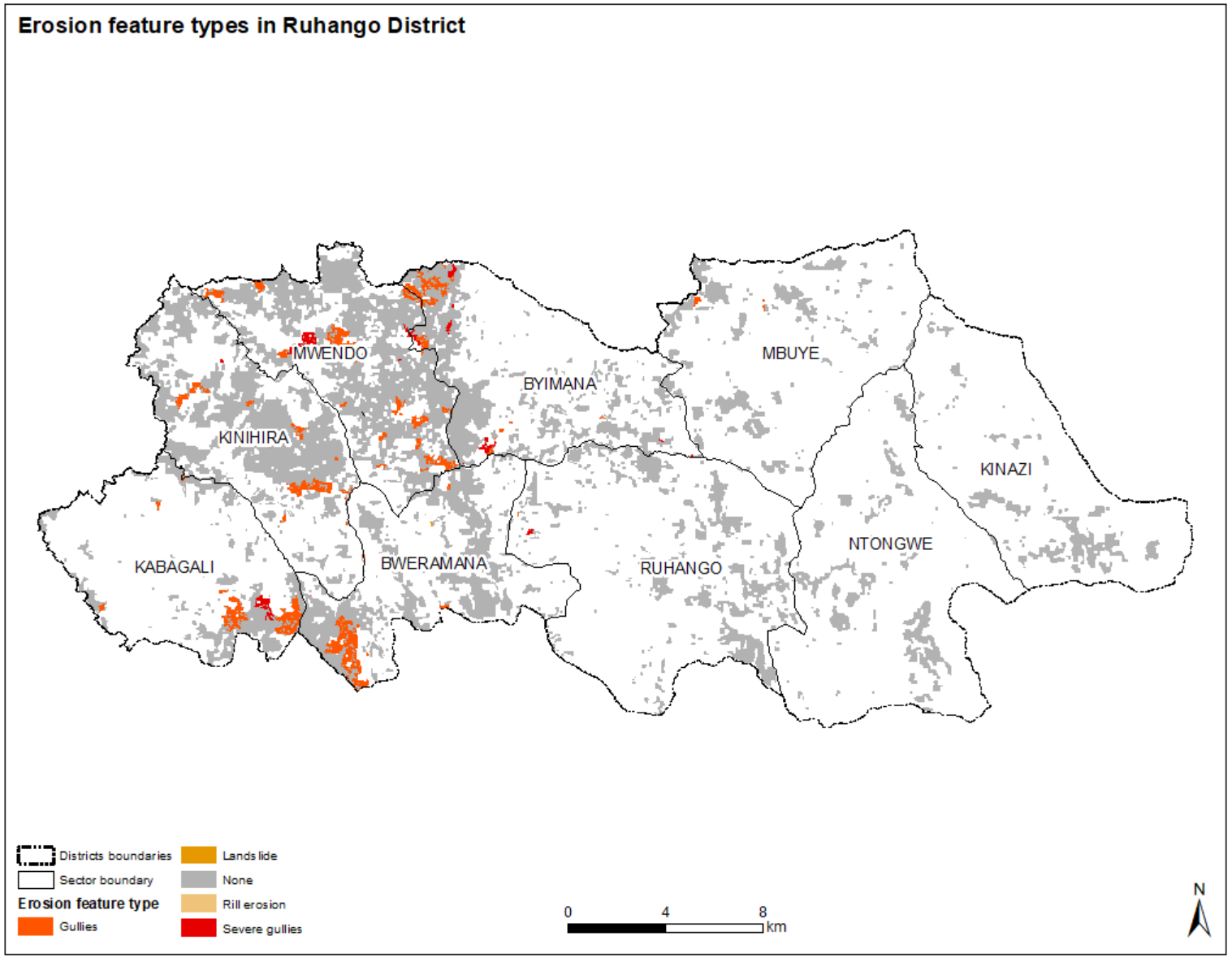


Figure 100: Erosion features detected in Ruhango District

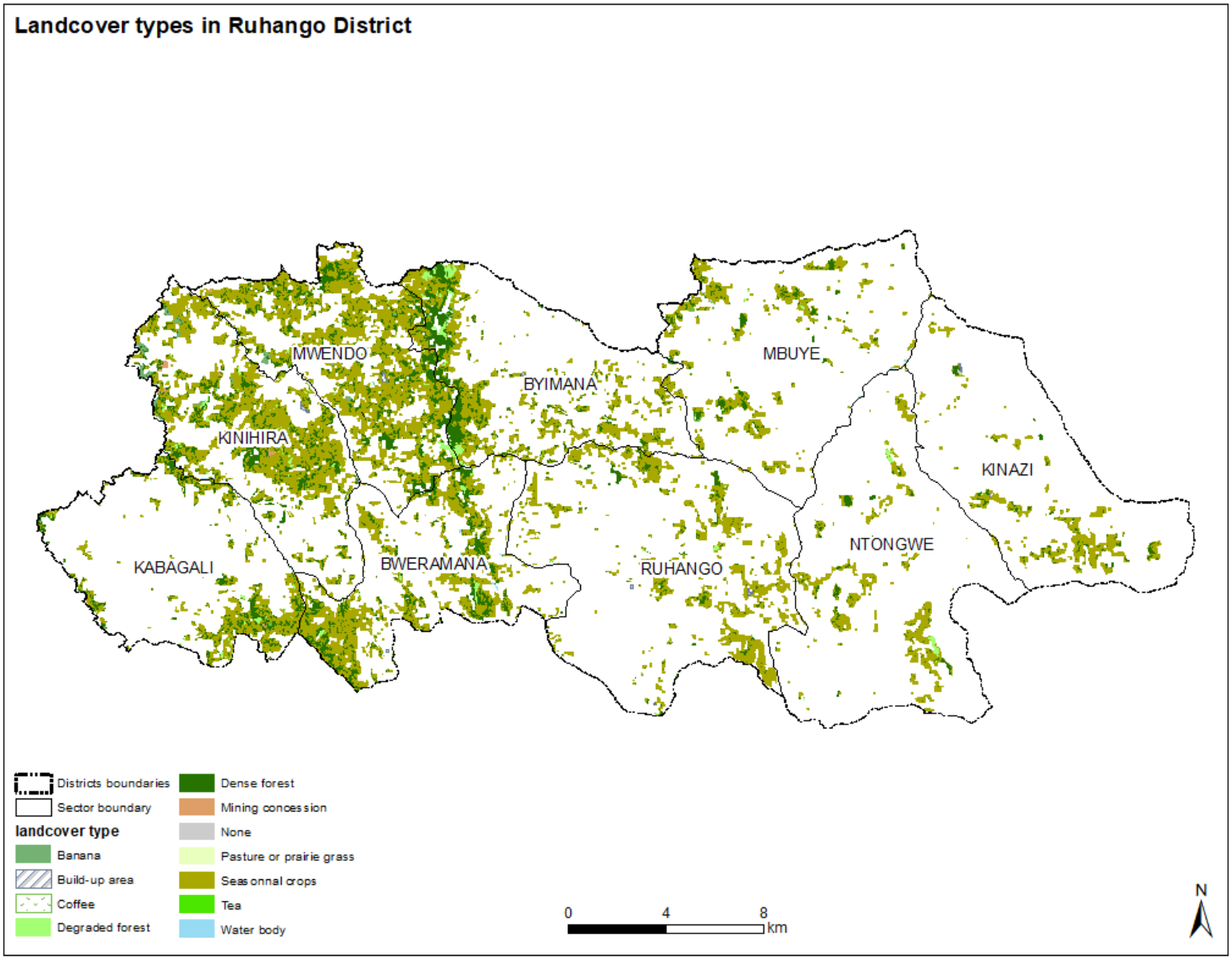


Figure 101: Land cover types in Ruhango District

About existing erosion control practices in Ruhango district, only 21% of land at risk is protected by forests (3,134 hectares) and Contour bank terraces (29 hectares). The highest protected sectors are Byimana with 29% of its land at risk protected, followed by Kabagari where 29% of the total land at risk is protected and Bweramana (only 23% protected). The least protected sectors are Ntongwe with only 13% protected Ruhango (only 13% protected) and Kinazi (14% protected). The visual interpretation of World View images confirms earlier findings by CROM model that Ruhango Ntongwe, and Kinazi sectors remain at very high risk of soil erosion since more than 80% of their respective land are not protected.

Table 100: Erosion control practices already in place in Ruhango District

Sector name	Erosion control techniques in place			Unprotected	Grand Total	% protected
	Contour bank terraces	Forests	Total protected			
BYIMANA		525	525	1,303	1,828	29%
KABAGALI	2	312	314	786	1,099	29%
BWERAMANA		472	472	1,561	2,033	23%
MWENDO	17	691	708	2,553	3,261	22%
KINIHIRA	3	590	593	2,233	2,826	21%
MBUYE		190	190	743	933	20%
KINAZI		81	81	520	602	14%
RUHANGO	7	176	183	1,241	1,424	13%
NTONGWE		97	97	660	757	13%
Grand Total	**29**	**3,134**	**3,163**	**11,601**	**14,764**	**21%**

Erosion control practices in Ruhango District are recommended based on existing land uses, erosion control measures already in place, and predicted erosion risk by CROM model. Table 101 shows that about 11,070 hectares (which is 75% of the total land at risk) are suitable for Contour bank terraces, 421 hectares are Afforestation & Reforestation and 102 hectares of Bamboo to close gullies and protect riverside. Other interventions are 30 hectares for Hedgerows and 22 hectares are for SWMF.

Table 101: Recommended erosion practices in Ruhango District

Sector Name	Afforestation & Reforestation	Bamboo gullies & riverside	Contour bank terraces	Hedge rows	No till	SWMF	None	Total
BWERAMANA	38	9	1,516				470	2,033
BYIMANA	118	1	1,185		29	4	491	1,828
KABAGALI	30	26	730	2	10		302	1,099
KINAZI	5	1	511			3	81	602
KINIHIRA	113	33	2,098	4	8	5	566	2,826
MBUYE	11	8	723				190	933
MWENDO	65	4	2,481	17	0	5	689	3,261
NTONGWE	28	0	621				107	757
RUHANGO	13	20	1,205	7		4	175	1,424
Grand Total	**421**	**102**	**11,070**	**30**	**46**	**22**	**3,073**	**14,764**
Percentage	**3%**	**1%**	**75%**	**0.2%**	**0.3%**	**0.1%**	**21%**	**100%**

Note: Grassed waterways are recommended for existing terraces which was made without waterways or with but no grasses which can cause severe gullies and destruction of bench terraces created. No-till agriculture is recommended is recommended for perennial crops on extremely high risk area while Storm water management facilities (SWMF) or water harvesting infrastructure is recommended in built-up areas. None: means no-recommendation is provided because existing erosion control measures are adequate with reference made to the total land protected. Contour banks are recommended for existing forest without ditches. Bamboos are recommended to close gullies or for riverside buffers.

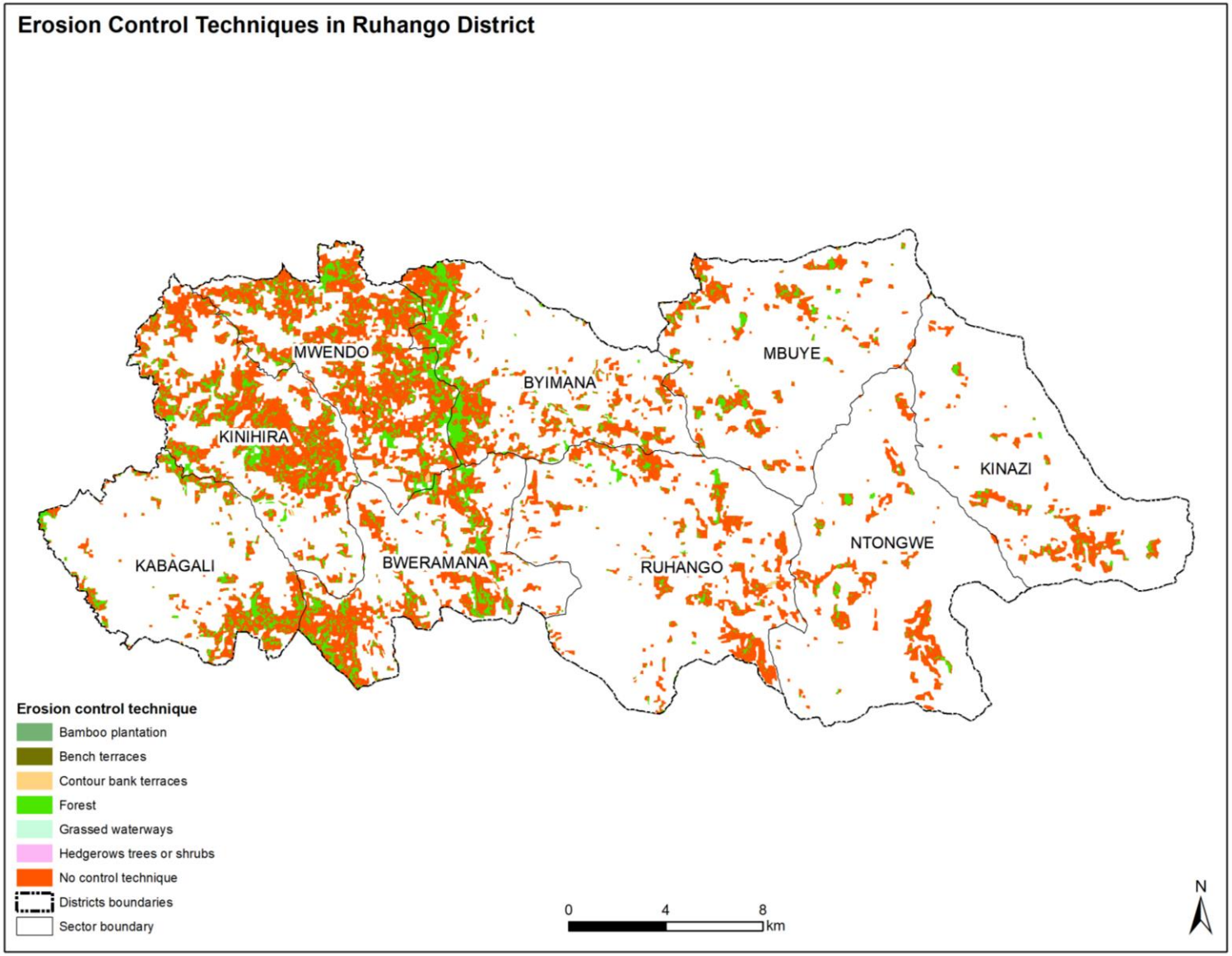


Figure 102: Erosion control techniques in place in Ruhango District

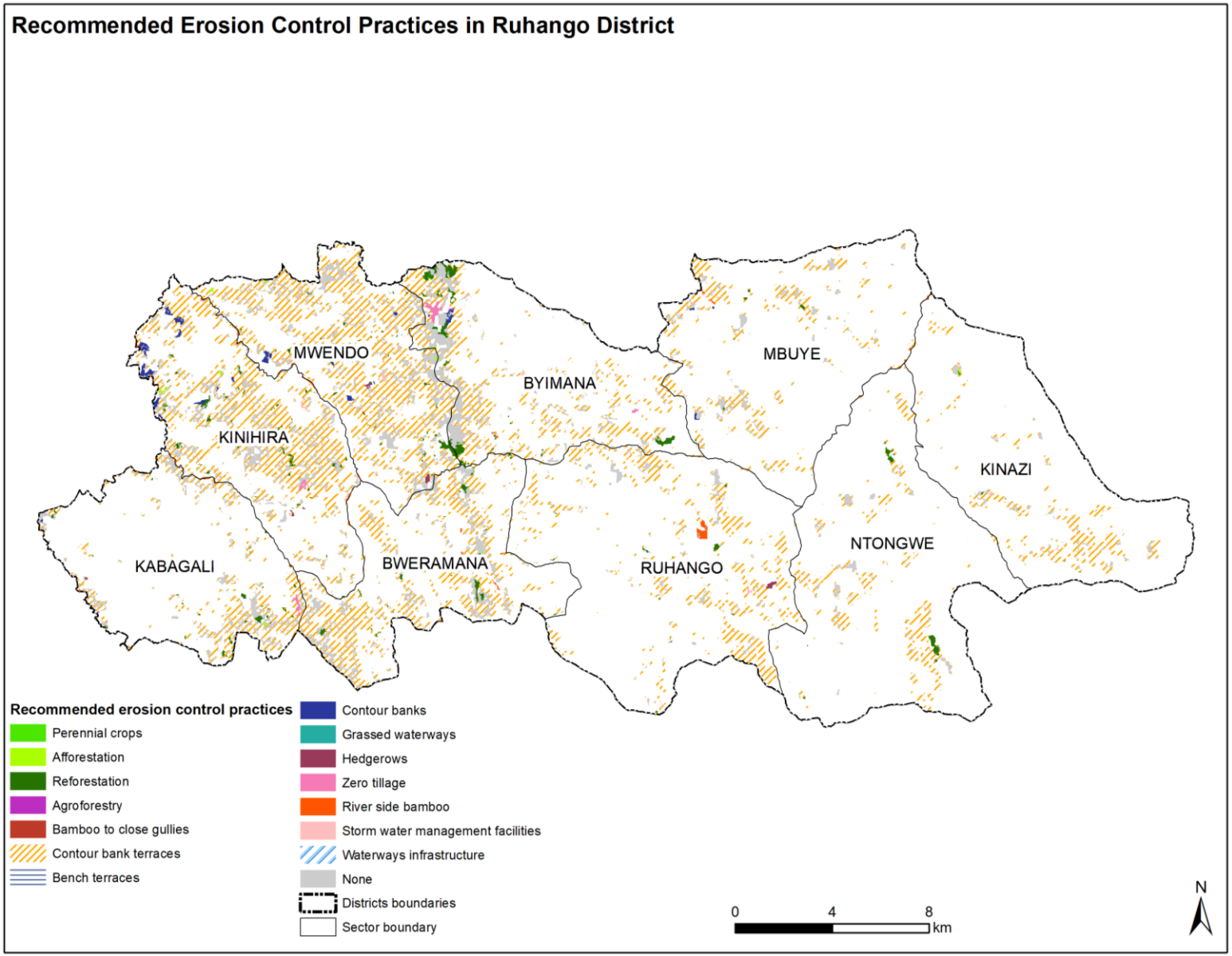


Figure 103: Recommended erosion control practices in Ruhango District

Annex 1: Persons who contributed to the 2019 Erosion control mapping report

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- Mr. Karangwa Charles, FLR-Regional Coordinator, IUCN
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- Mr. Njue Joseph, Focal Point GIS specialist, IUCN
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