CULTIVATED LANDS IN THE UPPER TSITSA RIVER CATCHMENT T35 A-E

Cultivated Land Mapping:

LEVEL OF DEGRADATION and VULNERABILITY TO EROSION

Cultivated lands on the banks of the Tsitsa River

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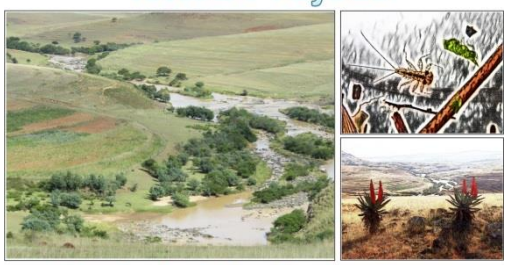
Tsitsa Project



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EXECUTIVE SUMMARY

This report focuses on the results of the mapping and classification of cultivated lands in terms of their degradation and vulnerability to erosion in Catchment T35 A-E and the implications for landscape restoration. The fields were digitised off 0.5 m colour aerial images that were captured in 2015 and vegetation vigour assessed using 10 m resolution 2018 NDVI images. A large proportion of cultivated lands in the catchment are classified as abandoned, highly degraded, often poorly vegetated and vulnerable to further erosion. Due to the degraded state, these fields are unlikely to provide the ecosystem services and livelihood benefits to an optimal extent. These lands act as important sources of sediment and need remedial action in order for indigenous vegetation growth and cover to be restored.

A total of 7 892 cultivated lands were identified and mapped in Catchment T35 A-E. These cover a total area of 31 454 ha which constitutes 16% of the total catchment area of T35 A-E (201 601 ha). The sub-catchments in Quaternary Catchment T35 A-E vary in size and area covered by cultivated lands. Catchment T35 E exhibits the largest area covered by cultivated lands (43%), followed by Catchment T35 D (19%). The area covered by cultivated lands in Catchment T35 A (12%) and Catchment T35 B (7%) are proportionately smaller and the area covered by cultivated lands in Catchment T35 C (2%) is minimal when compared to the other sub-catchments. Catchment T35 A, D and E fall in Traditional Authority areas with Catchment T35 E having the highest area under Traditional Authorities. The highest proportion of abandoned cultivated lands, moderate to highly degraded cultivated lands, cultivated lands vulnerable to further erosion and encroached cultivated lands are found in the sub-catchments that include Traditional Authorities with Catchment T35 E exhibiting the highest area covered by the above classes of cultivated lands. Therefore there is a need to prioritise Traditional Authority areas for rehabilitation practices.

To determine areas with good and poor vegetation growth vigour (used as proxy for dense and poor vegetation cover), a mid-summer Normalised Difference Vegetation Index (NDVI) created from ten meter resolution Sentinel satellite images was used. This data set was used to extract areas with poor vegetation cover (key erosion sites) which augment the degradation and vulnerability scores set out in this report and identify cultivated lands as areas that need intervention.

All cultivated lands, irrespective of status, act as sediment sources to a certain extent. Used cultivated lands are ploughed on an annual basis which results in disturbance of the soil structure leading to easy entrainment and movement of sediment. Partly used fields are ploughed on a less regular basis but the initial disturbance of the soil structure results in continual movement of sediment from these areas. A large proportion of abandoned fields can be classified as degraded with very low vegetation cover. Only very few abandoned lands have 'recovered' from the disturbance of cultivation and exhibit a good vegetation cover.

Cultivated lands can easily be targeted for restoration as they are located on relatively flat land, are easily accessible and have measurable boundaries from which areas can be calculated for restoration and appropriate budgets can be worked out. To revegetate degraded areas one should start by introducing hardy vegetation types that can protect exposed soils and create an

environment for further vegetation cover development. This can be achieved by planting grasses and/or ruderals (plants that grow on disturbed soils).

Abandoned fields can easily be used to create a form of income and improved livelihoods for local communities. There are many grass species that thrive on degraded or abandoned lands and when combined act as good erosion controls (by binding soil and acting as silt traps) and many are highly nutritive. A list of a multitude of grass species that could be planted on abandoned and degraded fields in the Tsitsa catchment to help reduce their future vulnerability to erosion are given in this report. In addition examples of potentially suitable ruderals and other potentially suitable pioneer species are detailed in this report.

The abandoned fields that can potentially be restored could once again contribute to that part of the catchment that can be utilised for sustainable livestock grazing practices. If managed appropriately abandoned fields can be turned from degraded lands into areas of high grazing potential and productive pastures.

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1. INTRODUCTION

1.1. BACKGROUND TO CULTIVATED LANDS IN THE UPPER TSITSA RIVER CATCHMENT

Land use has a major effect on land cover and vegetation cover. Cultivation exposes the soil surface to the erosive effects of rainfall with the overall impact depending on crop type and seasonal growth patterns. Ploughing transforms the existing soil structure and increases the risk of soil erosion. However, the status, level of degradation and vulnerability to further erosion play an important role in the amount of sediment sourced from a respective cultivated land (Kakembo & Rowntree, 2003; Koulouri & Giourga, 2007).

Marginal agricultural areas, such as those that characterise the upper Tsitsa River catchment, are prone to the abandonment of cultivated lands. This is due to economic and social shifts that make it no longer worthwhile to cultivate land (Kakembo & Rowntree, 2003). When agricultural land is abandoned soil can remain bare for several years before being recolonised by vegetation (Harvey, 2001). Sediment yields peak after land abandonment and eventually normalises if and when vegetation cover increases, possibly only after several decades (Fryirs & Brierley, 1999; López-Vicente *et al*., 2013). If erosion strips the topsoil from abandoned cultivated lands they may never recover their original vegetation cover and become "erosion hotspots" (Kakembo & Rowntree, 2003).

Due to this, there is an opportunity for landscape and vegetation restoration as well as improved land management in Catchment T35 A-E. The prevention of future ecological infrastructure degradation is a key step towards improved land management (Millennium Ecosystem Assessment, 2005).

2. METHODS

2.1. DIGITISING CULTIVATED LANDS

Cultivated lands in Catchment T35 A-E were identified and digitised using 2015/2016 digital aerial photographs. Colour aerial photographs were sourced from National Geo-Spatial Information, Pretoria. These photographs have a suitable resolution (1:10 000 orthophotos, with 50 cm resolution) in the area of interest. To aid in the identification of cultivated lands, digitising was performed using a high definition screen with a clear display.

Small fields (< 10 ha) were digitised at a scale of 1:800. Large fields (> 10 ha) were digitised at a courser scale of 1:4 000. The accuracy of the true extent of old cultivated lands is limited due to their faint outline and degradation of the original field perimeters. Smaller fields around villages that exhibited similar characteristics were lumped into a single larger polygon. Some of the cultivated lands (particularly in and around villages) may include houses or livestock pens.

2.2. CLASSIFYING CULTIVATED LANDS

Table 1-3 were set up as a guideline to classify cultivated lands (Schlegel *et al.,* 2018). Codes in the attribute table of the GIS shapefile correspond to the relevant code in the tables below.

2.2.1. STATUS

Cultivated lands were classified into one of three different usage status classes using Table 1.

TABLE 1: STATUS OF THE USE OF CULTIVATED LANDS

Status Code	Description
1	Used
2	Partly used (sections of cultivated lands still ploughed)
3	Abandoned (old) e.g. old terraced lands

FIGURE 1: EXAMPLE OF USED CULTIVATED LANDS WITH NO DEGRADATION, VULNERABILITY TO EROSION OR ALIEN TREE ENCROACHMENT

FIGURE 2: EXAMPLE OF CULTIVATED LANDS THAT ARE PARTLY USED

2.2.2. VISIBLE SIGNS OF DEGRADATION AND VULNERABILITY TO EROSION

Each cultivated land was assigned a degradation and vulnerability code (Schlegel *et al.,* 2018). The degradation code was divided into three classes, of which each class is subdivided into a vulnerability code, as explained in Table 2. The degradation code speaks to the current condition of the cultivated land in terms of erosional features. The vulnerability of the cultivated land is a subset of its degradation. The vulnerability of the cultivated land speaks to the probable future deterioration of the land, e.g. due to large gully formation, if no mitigation measures are taken, or the encroachment of gullies from the landscape in the vicinity of the cultivated land boundary. It is important to note that all cultivated lands will contribute to sediment but the degradation and vulnerability codes speak to the augmentation of the sediment load being sourced from the respective cultivated lands.

TABLE 2: DEGRADATION OF CULTIVATED LANDS AND THEIR VULNERABILITY TO EROSION

Degradation Code	Description		Vulnerability Code	Description
1	Low degradation: No gullies		**1**	Unlikely to degrade (low)
			2	Erosion encroaching on cultivated land (moderate)
			3	n/a
2	Moderate degradation: Rills, small gullies, lack of vegetation and/or sheet erosion		**1**	Low erosion risk (erosion stable, low)
			2	Moderate erosion risk (moderate)
			3	High erosion risk (formation of larger gullies visible, high)
3	High degradation: Abundant erosion		**1**	n/a
			2	Moderate erosion risk (moderate)
			3	High erosion risk (high)

For example: Small cultivated lands around village houses are still mostly in use. Many of these fields are not degraded (degradation score=1) but erosion is encroaching on these fields making them vulnerable (vulnerability score=2). In addition cultivated lands situated on or close to drainage lines commonly exhibited a high vulnerability to gully erosion, thus high likelihood of degradation (vulnerability score=3).

FIGURE 3: EXAMPLE OF OLD TERRACED LANDS (ABANDONED) SHOWING SIGNS OF DEGRADATION IN THE FORM OF GULLY AND RILL EROSION AND HIGH VULNERABILITY TO FUTURE EROSION

FIGURE 4: CULTIVATED LANDS, ON A LOW GRADIENT FLOOD BENCH, EXHIBIT MINIMAL EROSION

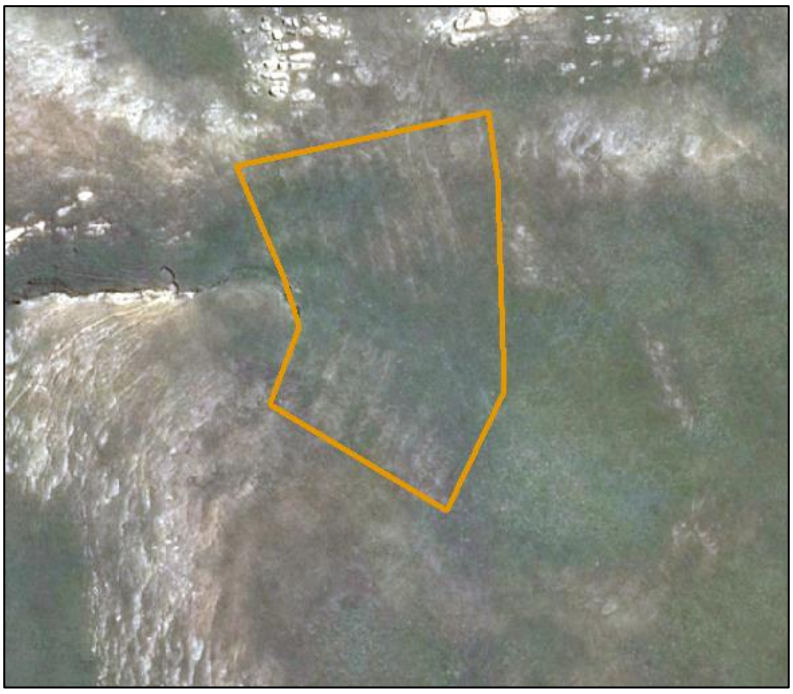

FIGURE 5: ABANDONED LAND WITH GOOD GRASS COVER EXHIBITS LOW EROSION RISK

2.2.3. Level of encroachment by woody vegetation

Encroached vegetation can potentially be invasive weeds, shrubs or trees. These plants thrive on degraded and exposed soils and could pose a threat as they spread into the surrounding landscape causing secondary issues such as reduced grazing potential (Kakembo, 2001; Wigley *et al.*, 2009).

An encroachment code was assigned to each cultivated land in Catchment T35 A-E using Table 3. Encroached fields can be verified in the field prior to restoration efforts being carried out in order to map the species composition and its potential threat as being invasive and non-palatable. In the unlikely event that the encroached vegetation is found to have a species composition of palatable species with good erosion mitigation properties they can positively contribute to the restoration efforts.

Table 3: Encroachment of vegetation in cultivated lands

Encroachment code	Description
1	Little or no encroachment (0-10 %)
2	Moderate encroachment (11-50 %)
3	Heavily encroached (> 50 %)

Moderate encroachment of trees (likely wattles)

Heavy encroachment of shrubs

Figure 6: Example of encroached, unused, land

2.3. Normalised Difference Vegetation Index: Vegetation growth vigour and vegetation cover

The Normalised Difference Vegetation Index (NDVI) measures vegetation growth vigour and is closely correlated with vegetation cover (Purevdorj *et al.*, 1998). NDVI can be used as proxy for vegetation cover and should give a good account of poorly and well vegetated pixels during the peak

of the growing season. NDVI calculations were based on Sentinel satellite imagery with 10 meter resolution for mid-summer (dated 2018/02/06; image number: S2A_MSIL1C_2018 02 06 T075111_N0206_R135_T35JNF_2018 02 06 T113203). Areas with poor and low vegetation growth vigour and cover were identified as potential erosion sites within cultivated lands and can be used to augment the degradation and vulnerability score assigned to a cultivated land. It is important to note that recently ploughed/used cultivated lands will exhibit poor or low vegetation cover. However a summer image was chosen as ploughed fields should be less prominent as used fields will have crops growing on them.

3. Results and Key Findings

3.1. Cultivated lands in Catchment T35 A-E

A total of 7 892 cultivated lands were identified and mapped in Catchment T35 A-E (Table 4 and Figure 7). These cover a total area of 31 454 ha which constitutes 16% of the total catchment area of T35 A-E (201 601 ha). Figure 7 shows that a high proportion of cultivated lands are found close to the road network and settlements with large tracts of cultivated lands in the Traditional Authorities. The highest density of cultivated lands is found in the lower and middle catchment as well as in river valleys where soils are more fertile. Smaller cultivated lands, mostly in and around settlements, are also found on steeper slopes. Some of the settlements and their corresponding cultivated lands, which are located further away from the main road network, have been abandoned due to social and economic shifts in the catchment.

Table 4: Summary of cultivated lands in Catchment T35 A-E

	Area (ha)	No. of cultivated lands	Area (ha) covered by cultivated lands	Percentage (%) of catchment
Catchment T35 A-E	201 601	7 892	31 454	16

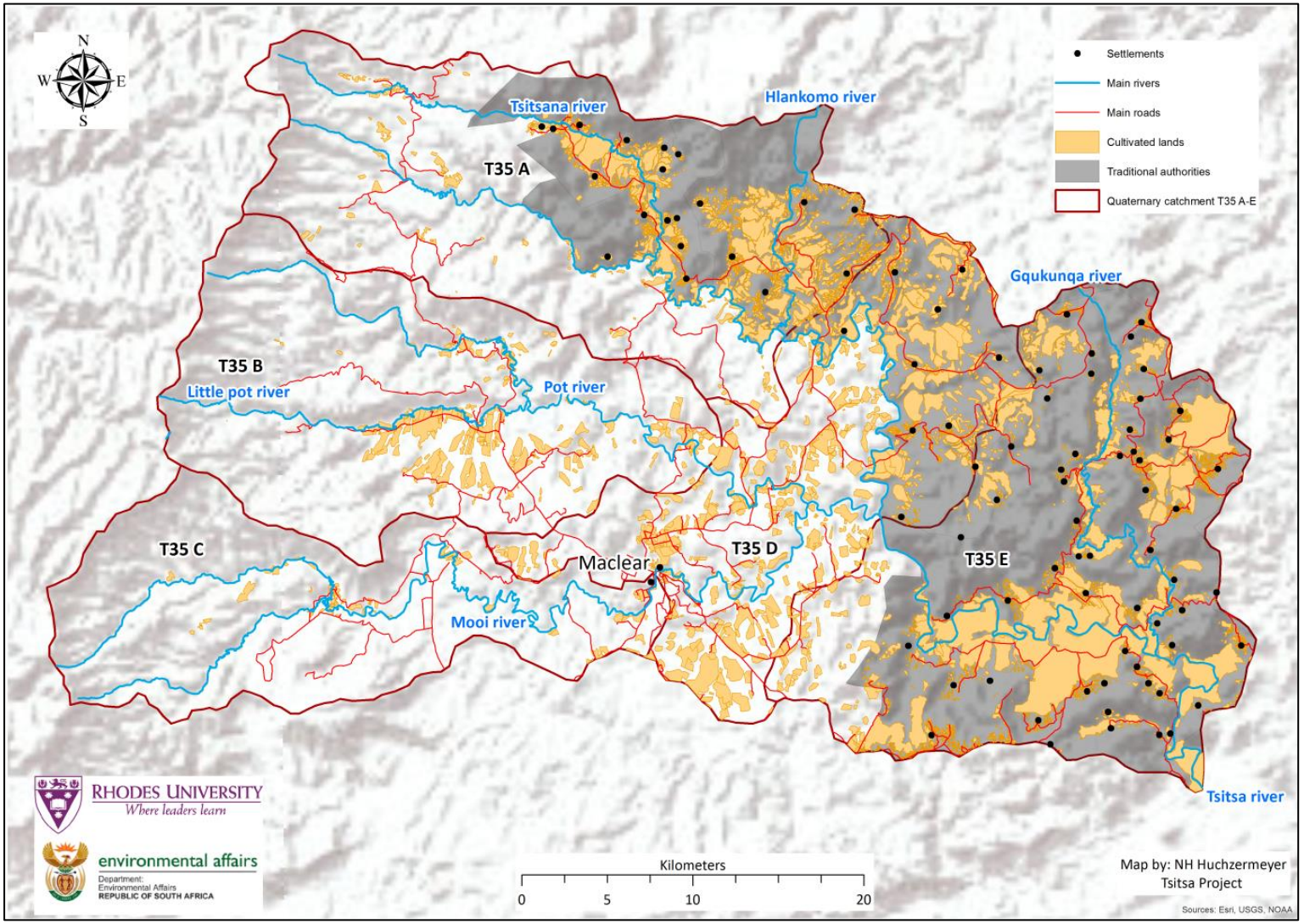

FIGURE 7: LOCATION OF CULTIVATED LANDS IN CATCHMENT T35 A-E

The results for cultivated lands in terms of current use status, degradation, level of vulnerability to further degradation and level of encroachment by woody vegetation are given below.

3.1.1. Status of cultivated lands in Catchment T35 A-E

A total of 2 755 (6 493 ha) of the cultivated lands were used (21% of total cultivated land area), 3 052 (11 940 ha) partly used (38% of total cultivated land area) and 2 085 (13 021 ha) were abandoned (41% of total cultivated land area) (Table 5 and Figure 8). Abandoned fields make up the greatest proportion of the cultivated lands. In total, used fields make up 3% of Catchment T35 A-E, partly used fields 6% and abandoned fields 7% (Figure 9). Figure 9 also shows the position of gullies in and around cultivated lands. Gullies are particularly evident in abandoned cultivated lands.

The abandoned fields are mostly located further away from villages in inaccessible locations. This highlights the effects that economic and social shifts have on the local communities, which contributes to fewer resources for accessing or cultivating these areas. Many of the large cultivated lands are only partially used or abandoned for the same reasons. Abandoned fields are left fallow with no remedial actions taking place to restore soil carbon or natural vegetation cover. The soil structure in these areas have been disturbed and leached of nutrients making the natural regrowth of vegetation very slow. Therefore, degradation and vulnerability in these cultivated lands is evident as discussed in the sections below.

Table 5: Summary of the status of cultivated lands in Catchment T35 A-E

Status	No. of cultivated lands	Area H (ha)	Percentage (%) area of cultivated lands	Percentage (%) of Catchment T35 A-E
Used	2 755	6 493	21	3
Partly used	3 052	11 940	38	6
Abandoned	2 085	13 021	41	7

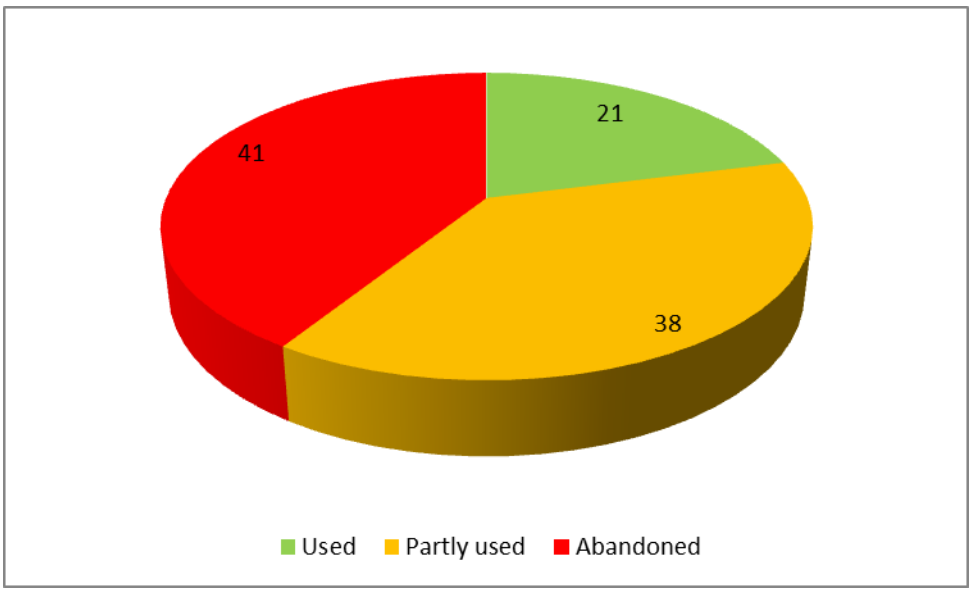

Figure 8: Percentage area, out of the total cultivated land area, covered by each category of cultivated lands

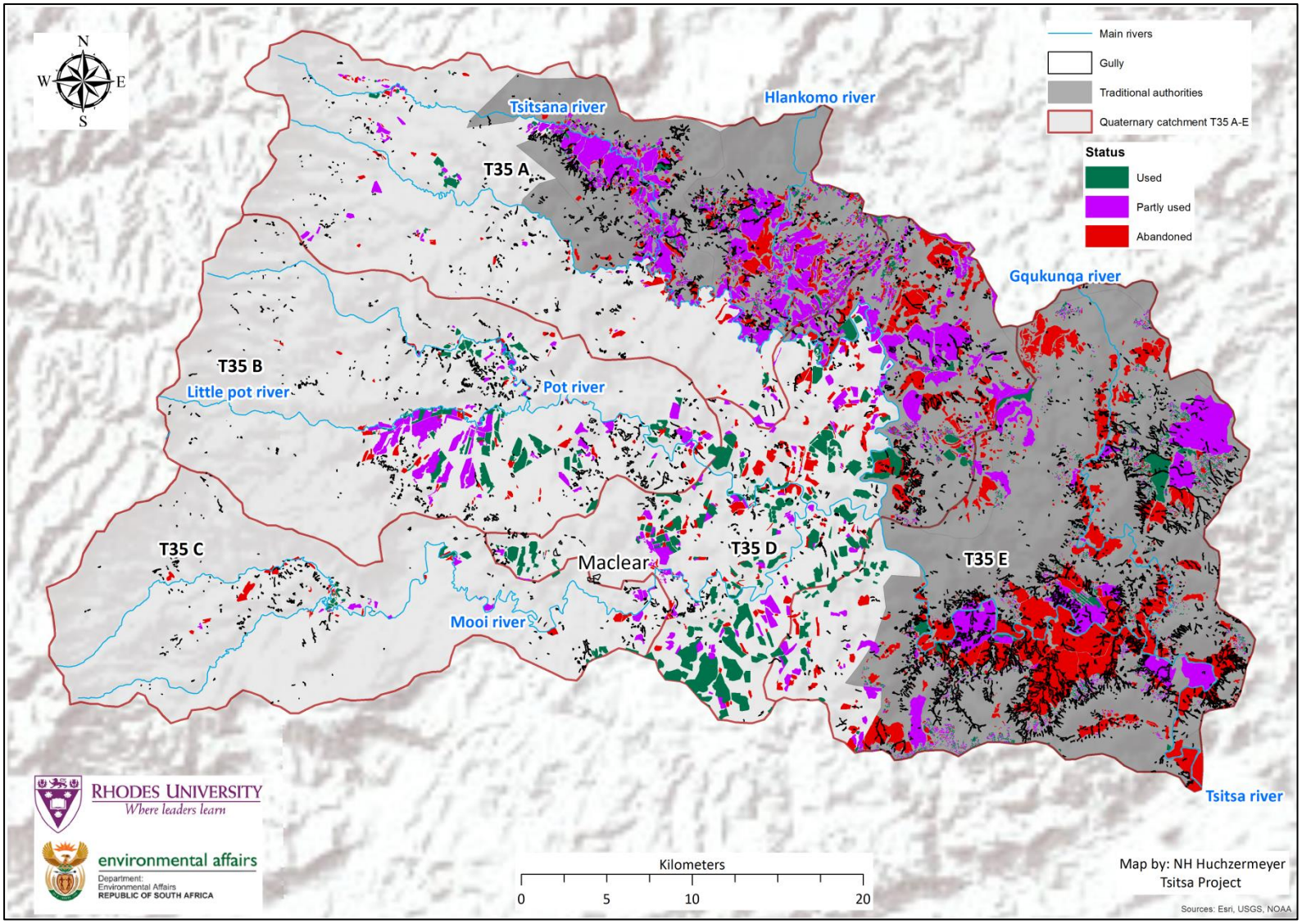

FIGURE 9: CULTIVATED LANDS CLASSIFIED INTO USAGE STATUS IN CATCHMENT T35 A-E. NOTE THE PRESENCE OF GULLIES IN AND AROUND CULTIVATED LANDS

3.1.2. Degradation of cultivated lands in Catchment T35 A-E

A total of 4 977 (8 812 ha) cultivated lands showed little or no degradation (28% of total cultivated land area), 2 256 (10 878 ha) showed moderate levels of degradation (35% of total cultivated land area) and 659 (11 764 ha) showed widespread degradation (37% of total cultivated land area) (Table 6 and Figure 10). In total, cultivated lands exhibiting low degradation make up 4%, moderately degraded cultivated lands make up 5% and highly degraded cultivated lands make up 6% of the greater Catchment T35 A-E (Figure 11).

The greatest proportion of cultivated fields showed signs of degradation. This is irrespective of their usage status which implies that cultivated lands are sensitive parts of the landscape most probably because agricultural practices disturb the topsoil. The effects of disturbances to the soil structure are most notable in the middle and lower catchment where the soils are naturally prone to degradation once disturbed. Proper management of these areas and remedial action on degraded areas will play a significant role in restoring the catchment.

Table 6: Summary of degraded cultivated lands, irrespective of status, in Catchment T35 A-E

Degradation	No. of cultivated lands	Area H (ha)	Percentage (%) area of cultivated lands	Percentage (%) of Catchment T34 A-C
Low	4 977	8 812	28	4
Moderate	2 256	10 878	35	6
High	659	11 764	37	6

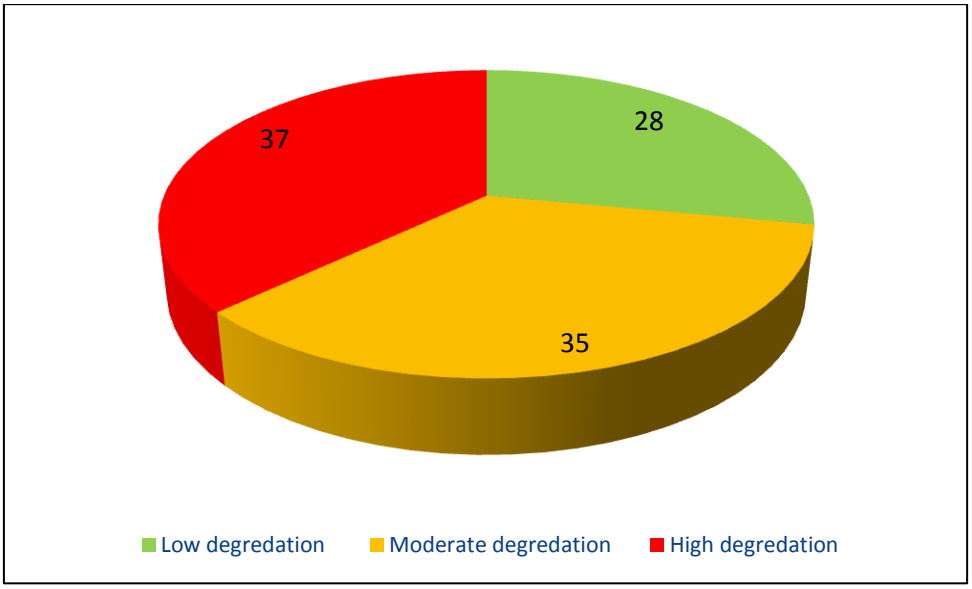

Figure 10: Percentage area, out of the total cultivated land area, covered by different categories of cultivated land degradation.

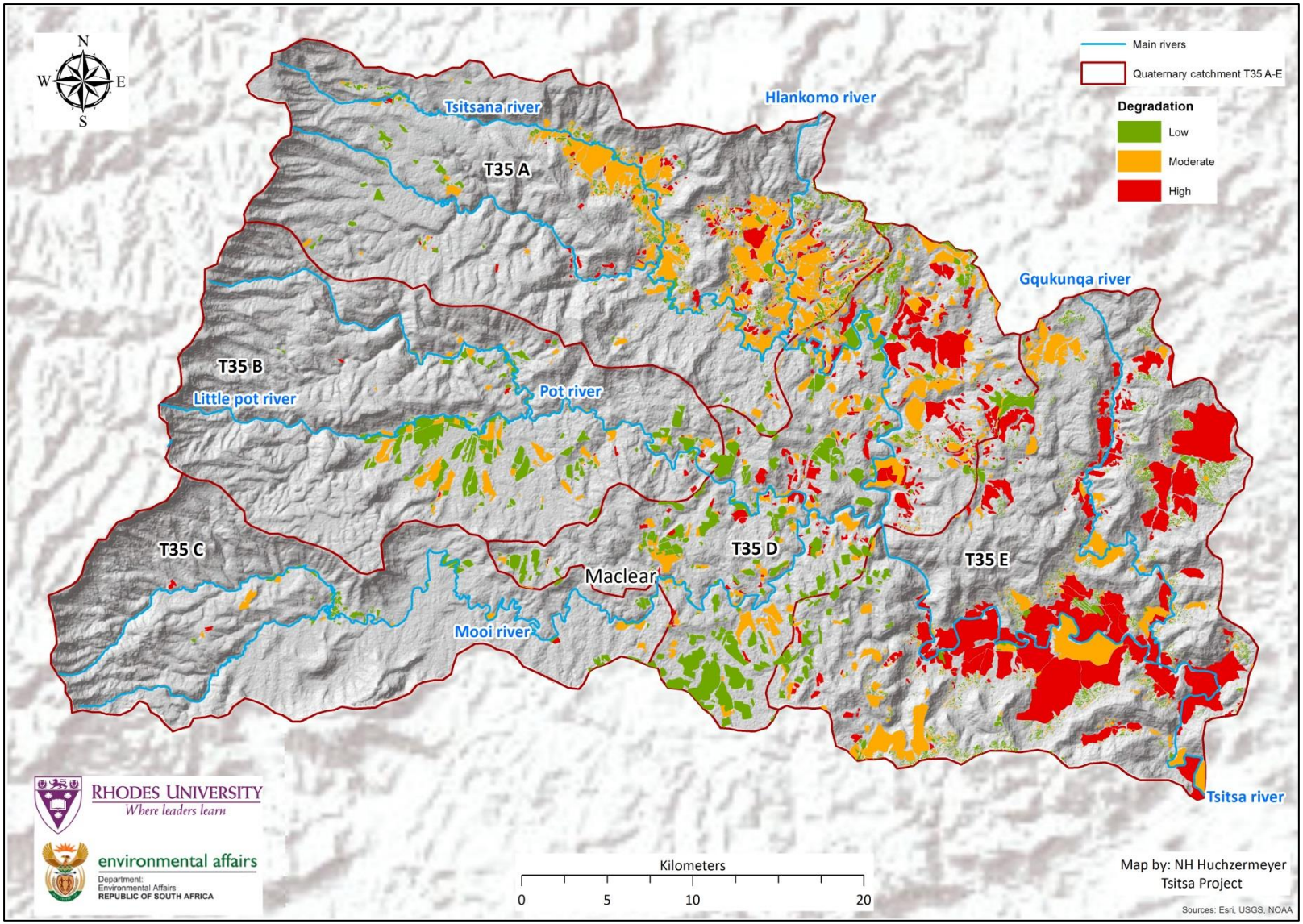

FIGURE 11: CULTIVATED LANDS IN CATCHMENT T35 A-E CLASSIFIED INTO THREE CLASSES OF DEGRADATION

3.1.3. Vulnerability of cultivated lands in Catchment T35 A-E to erosion

A total of 3 989 (10 787 ha) of the cultivated lands exhibited low vulnerability to erosion (34% of total cultivated land area), 3 293 (7 651 ha) exhibited moderate vulnerability (24% of total cultivated land area) to erosion and 610 (13 016 ha) were highly vulnerable (41% of total cultivated land area) to erosion (Table 7 and Figure 12). Overall, cultivated lands exhibiting low vulnerability to erosion make up 5% of Catchment T35 A-E, those exhibiting moderate vulnerability make up 4% and highly vulnerable cultivated lands make up 7% (Figure 13).

It is clear that cultivated lands, irrespective of their usage status, are vulnerable to erosion. Areas around the cultivated lands are mostly made up of grasslands. However, these grasslands are also commonly highly degraded, with poor vegetation cover and low vegetation growth vigour (see Figure 24), particularly in the lower catchment, implying that erosion initiated on these grasslands is also threatening the cultivated lands and vice versa. Therefore, a management plan that encompasses all the land use types is imperative to reduce vulnerability in these areas.

Table 7: Summary of the vulnerability of cultivated lands, irrespective of their status or degradation, in Catchment T35 A-E

Vulnerability	No. of cultivated lands	Area H (ha)	Percentage (%) area of cultivated lands	Percentage (%) of Catchment T34 A-C
Low	3 989	10 787	35	5
Moderate	3 293	7 651	24	4
High	610	13 016	41	7

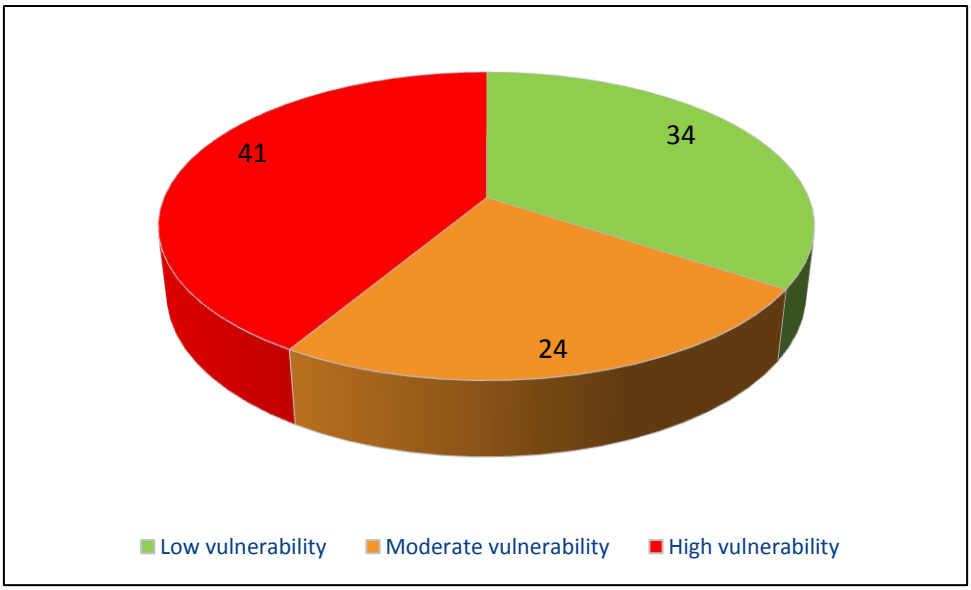

Figure 12: Percentage area, out of the total cultivated land area, covered by different categories of cultivated land vulnerability to erosion

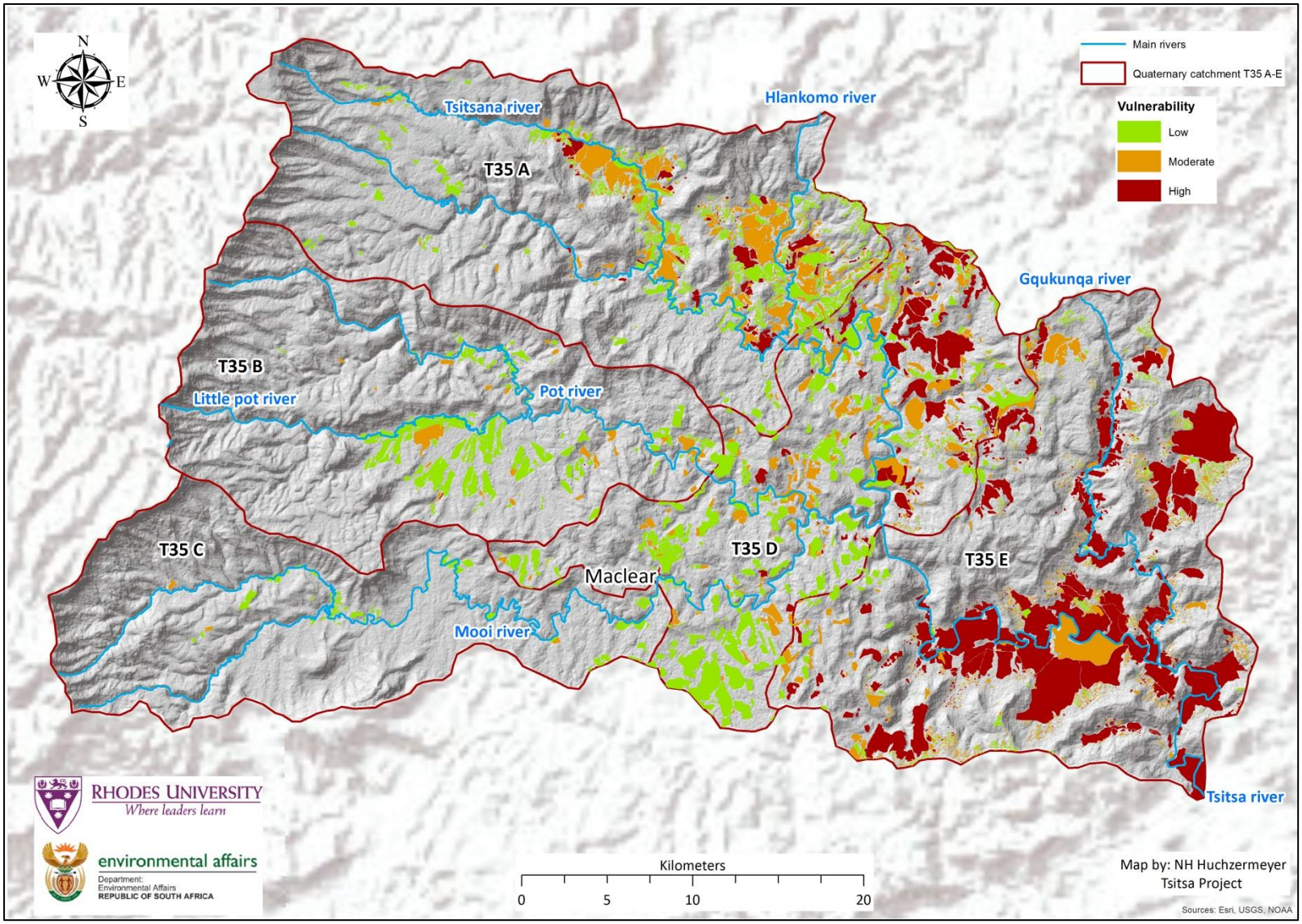

FIGURE 13: CULTIVATED LANDS IN CATCHMENT T35 A-E CLASSIFIED INTO THREE CLASSES OF VULNERABILITY TO EROSION

3.1.4. Encroachment of cultivated land in Catchment T35 A-E by vegetation

A total of 7 513 (27 207 ha) of cultivated lands showed little or no encroachment (86% of total cultivated land area) of vegetation, 299 (3 741 ha) showed moderate encroachment (12% of total cultivated land area) and 80 (506 ha) showed heavy encroachment (2% of total cultivated land area) (Table 8 and Figure 14). Overall cultivated lands that exhibit little or no encroachment make up 14% of Catchment T35 A-E, those that exhibit moderate encroachment make up 2% and heavily encroached lands make up less than 1% (Figure 15).

This shows that a high proportion of cultivated lands are not highly threatened by potentially invasive vegetation. However, field observations showed that cultivated lands that do exhibit alien vegetation encroachment are mostly fields in more inaccessible areas that have been abandoned for a considerable amount of time allowing for the establishment of woody species. Cultivated lands close to riparian zones are also encroached from alien invasive riparian vegetation such as *Acacia dealbata* (Silver Wattle).

Table 8: Summary of encroachment in cultivated lands in Catchment T35 A-E.

Encroachment	No. of cultivated lands	Area H (ha)	Percentage (%) area covered	Percentage (%) of catchment
Little/ none	7 513	27 207	86	14
Moderate	299	3 741	12	2
Heavy	80	506	2	<1

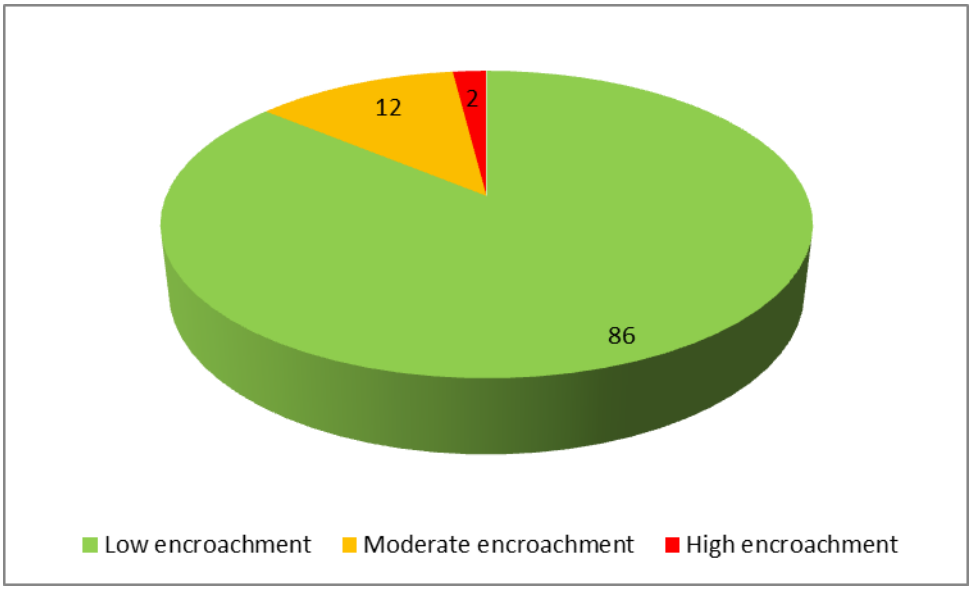

Figure 14: Percentage area, out of the total cultivated land area, covered by different categories of cultivated land encroachment by vegetation

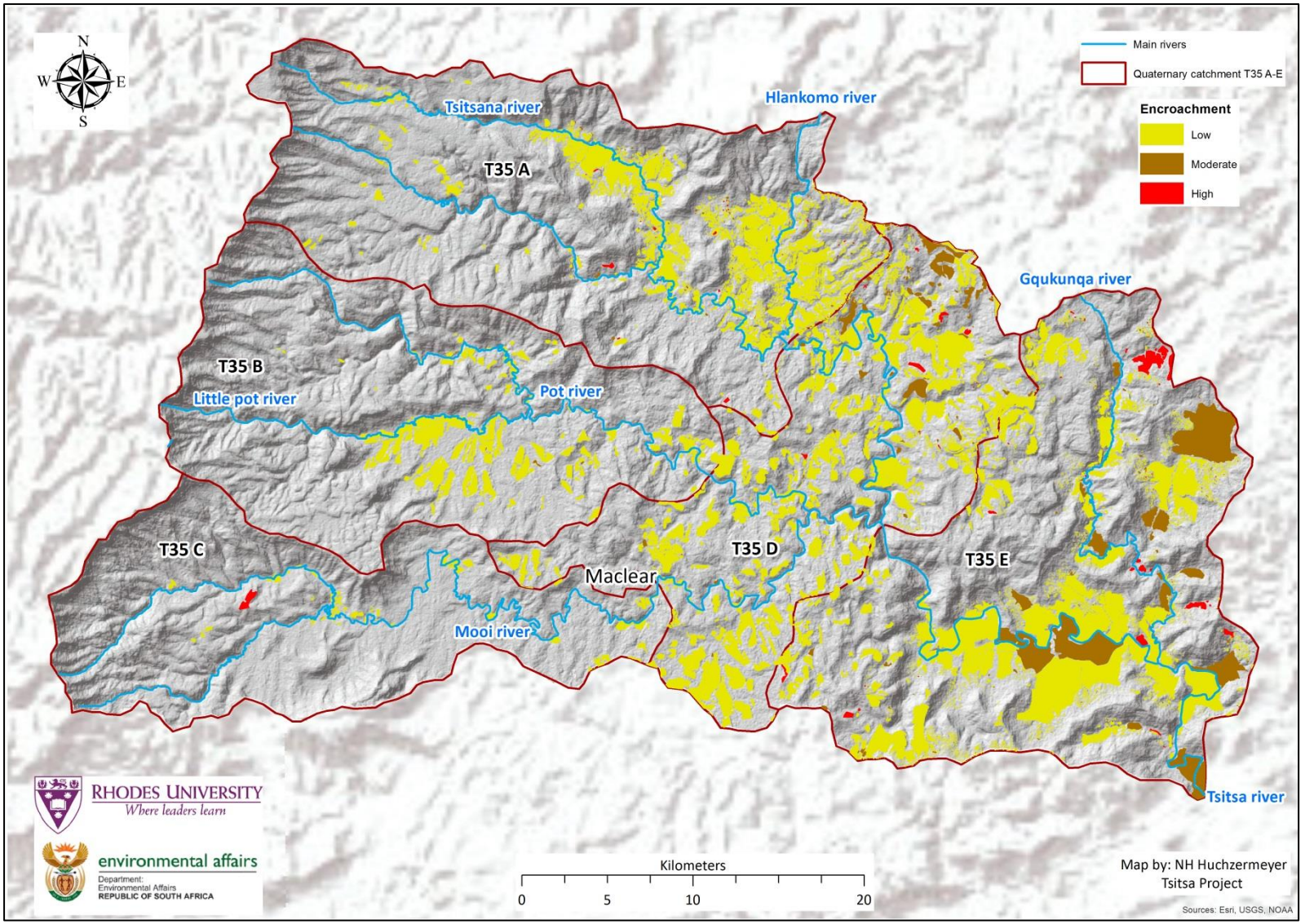

FIGURE 15: CULTIVATED LANDS IN CATCHMENT T35 A-E CLASSIFIED INTO DIFFERENT LEVELS OF VEGETATION ENCROACHMENT

3.1.5. Summary of the state of cultivated lands in Catchment T35 A-E

Table 9-11 and Figure 16 show the overall state of cultivated lands in Catchment T35 A-E. The greatest proportions of cultivated lands in the catchment are classified as abandoned, highly degraded and vulnerable to further erosion. These fields are important sources of sediment and need remedial action in order to restore natural vegetation growth in these areas. The only cultivated lands that don't act as sediment sources are abandoned fields that show little or no degradation and low vulnerability to erosion (have good vegetation cover); however, these cultivated lands only make up 0.5% of the greater catchment. The abandoned fields that currently have good vegetation cover and those that can be potentially restored could once again contribute to that part of the catchment that can be utilised for sustainable livestock grazing practices. Cultivated lands can be easily targeted for restoration as they have measurable boundaries from which areas can be calculated for restoration and appropriate budgets can be calculated. These boundaries are commonly fenced making it possible to manage grazing within these areas to ensure that it is done in a sustainable manner and that restoration efforts are successful.

Table 9: Summary of the degradation and corresponding vulnerability of used cultivated lands in Catchment T35 A-C

Degradation (Used fields)	No. of cultivated lands	Area H (ha)	Percentage (%) area covered (all cultivated lands)	Percentage (%) of catchment		Vulnerability (Used fields)	No. of cultivated lands	Area H (ha)	Percentage (%) area covered (all cultivated lands)	Percentage (%) of catchment
Low	2 466	5 090	16.2	2.52		Low	1 331	4 453	14.2	2.21
						Moderate	1 135	637	2.02	0.32
Moderate	278	1 124	3.6	0.56		Low	175	740	2.4	0.37
						Moderate	68	314	1.0	0.16
						High	35	71	0.2	0.04

High	11	279	0.9	0.14		Moderate	0	0	0	0
						High	11	279	0.9	0.14

TABLE 10: SUMMARY OF THE DEGRADATION AND CORRESPONDING VULNERABILITY OF PARTLY USED CULTIVATED LANDS IN CATCHMENT T35 A-C

Degradation (Partly used fields)	No. of cultivated lands	Area H (ha)	Percentage (%) area covered (all cultivated lands)	Percentage (%) of catchment		Vulnerability (Partly used fields)	No. of cultivated lands	Area H (ha)	Percentage (%) area covered (all cultivated lands)	Percentage (%) of catchment
Low	1 689	2 541	8.1	1.26		Low	896	1 835	5.83	0.91
						Moderate	793	706	2.25	0.4
Moderate	1 330	5 873	18.7	2.91		Low	749	2 180	7	1.1
						Moderate	464	2 726	8.7	1.4
						High	117	967	3.1	0.5
High	33	3 526	11.2	1.75		Moderate	4	118	0.4	0.1
						High	29	3 408	10.8	1.7

TABLE 11: SUMMARY OF THE DEGRADATION AND CORRESPONDING VULNERABILITY OF ABANDONED CULTIVATED LANDS IN CATCHMENT T35 A-C

Degradation (Abandoned)	No. of cultivated lands	Area H (ha)	Percentage (%) area covered (all cultivated lands)	Percentage (%) of catchment		Vulnerability (Abandoned)	No. of cultivated lands	Area H (ha)	Percentage (%) area covered (all cultivated lands)	Percentage (%) of catchment
Low	822	1 181	3.8	0.6		Low	636	1012	3.2	0.5
						Moderate	186	169	0.54	0.1
Moderate	648	3 881	12.3	1.93		Low	202	568	1.8	0.3
						Moderate	279	1 601	5.1	0.8
						High	167	1 711	5.4	0.9
High	615	7 959	25.3	3.9		Moderate	364	1 379	4.4	0.7
						High	251	6 580	21	3.3

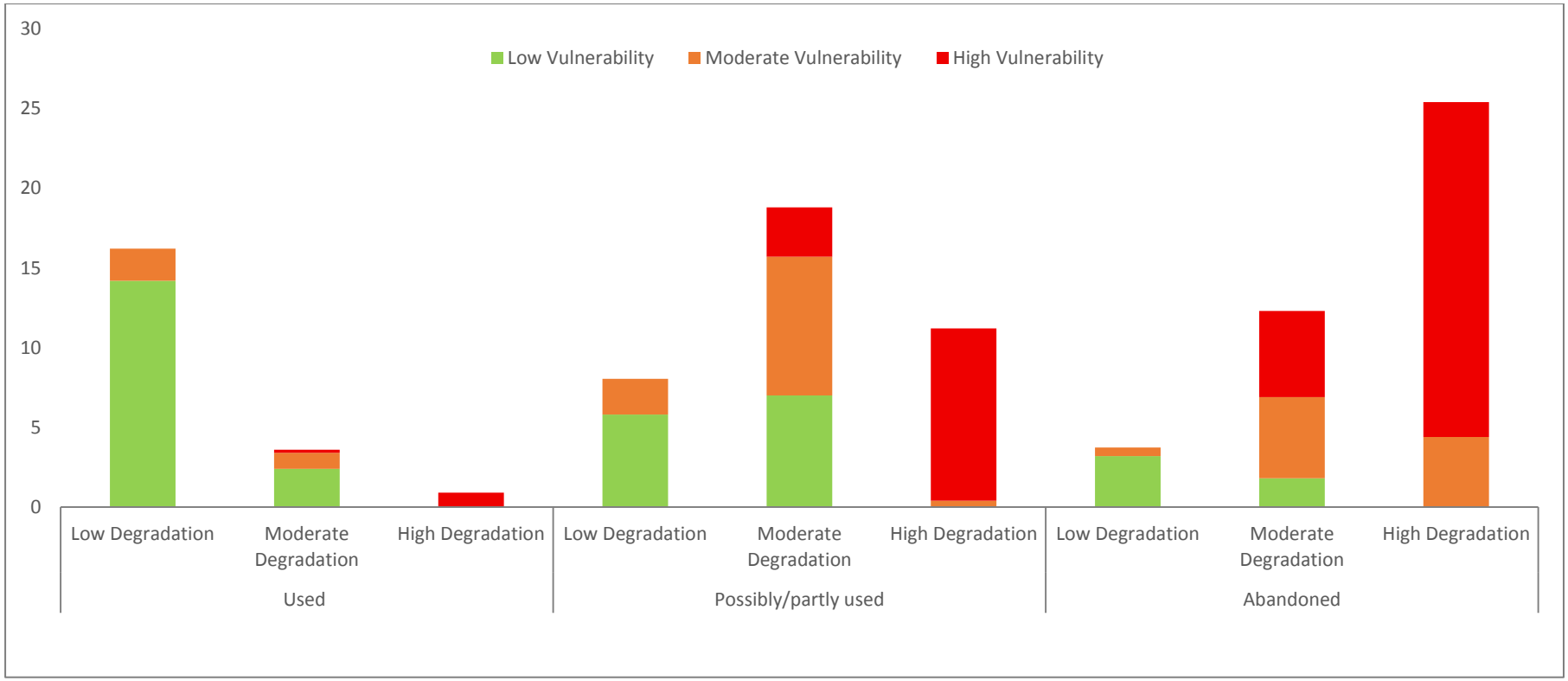

FIGURE 16: STATE OF CULTIVATED LANDS IN CATCHMENT T35 A-E

3.2. CULTIVATED LANDS IN EACH SUB-CATCHMENT

The sub-catchments in Quaternary Catchment T35 A-E vary in size. Catchment T35 D has the biggest area (49 176 ha) followed by Catchment T35 A (47 498 ha), Catchment T35 B (39 566 ha) and Catchment T35 E (30 610 ha) respectively. The smallest catchment is Catchment T35 C (34 751 ha).. Catchment T35 E exhibits the largest area covered by cultivated lands (43%), followed by Catchment T35 D (19%). The area covered by cultivated lands in Catchment T35 A (12%) and Catchment T35 B (7%) are proportionately smaller and the area covered by cultivated lands in Catchment T35 C (2%) is minimal when compared to the other sub-catchments. Catchment T35 A, D and E fall within Traditional Authority areas (Figure 7) with Catchment T35 E having the highest area that falls under Traditional Authorities. Figure 17 depicts the percentage covered by cultivated lands in each sub-catchment out of the total area covered by cultivated lands in Catchment T35 A-E.

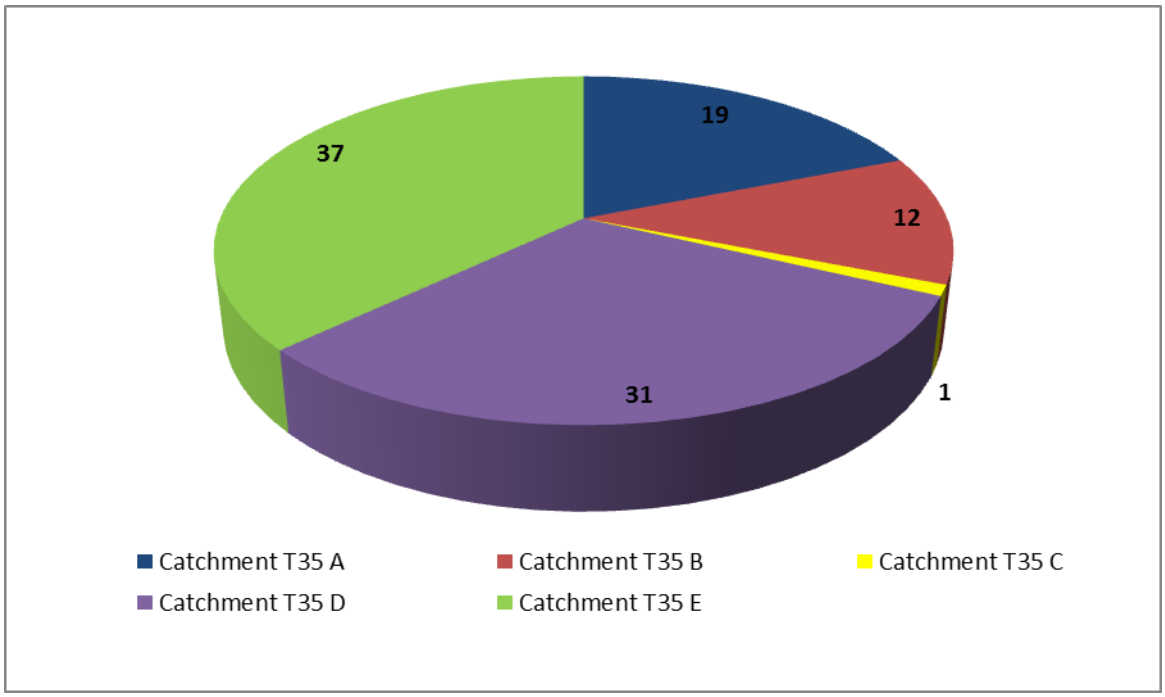

FIGURE 17: PERCENTAGE (%) COVERED BY CULTIVATED LANDS IN EACH SUB-CATCHMENT OUT OF THE TOTAL AREA COVERED BY CULTIVATED LANDS IN CATCHMENT T35 A-E

Figure 18 depicts the percentage area covered by different usage statuses of cultivated lands in each sub-catchment. Catchment T35 B and C show a low proportion of abandoned fields. Catchment D exhibits the highest percentage area covered by used cultivated lands, followed by Catchment T35 E and B, and to a lesser extent Catchment T35 A and C. Partly used fields cover a large proportion of the cultivated land area in each sub-catchment with Catchment T35 E exhibiting the highest area covered by partly used cultivated lands followed by Catchment T35 A and D, and to a lesser extent Catchment T35 B and C. Catchment T35 E exhibits the highest area covered by abandoned cultivated lands followed by Catchment T35 D and to a lesser extent Catchment T35 A.

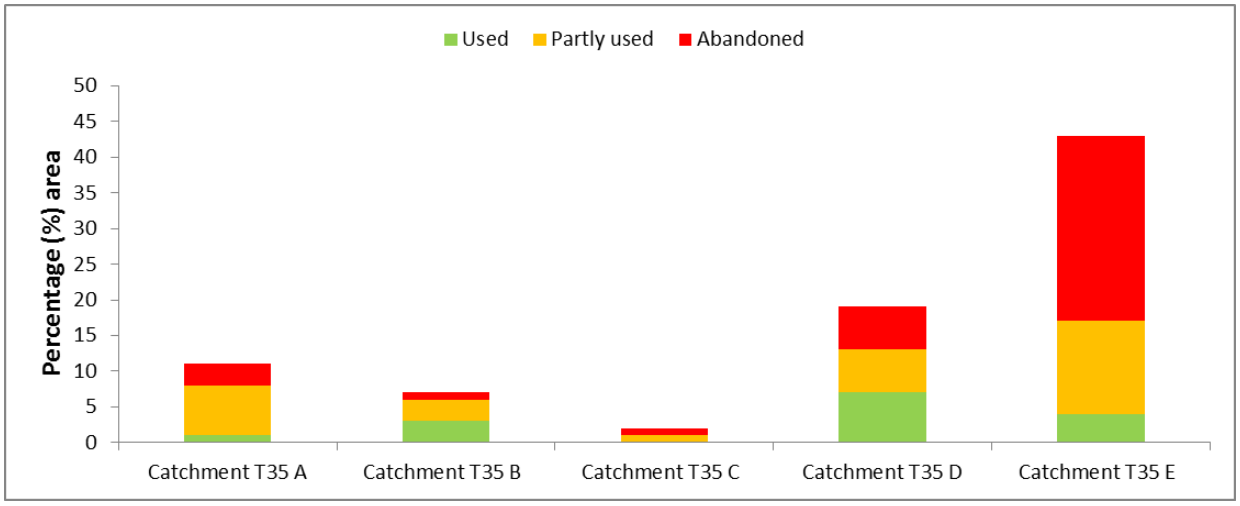

FIGURE 18: PERCENTAGE AREA COVERED BY DIFFERENT USAGE STATUSES OF CULTIVATED LANDS IN EACH SUB-CATCHMENT

Figure 19 depicts the percentage area covered by different levels of degraded cultivated lands in each sub-catchment. Catchment T35 E shows the highest area covered by degraded and moderately degraded fields with a low proportion of cultivated lands exhibiting low degradation. Catchment T35 D depicts a smaller area covered by degraded and moderately degraded fields with a good proportion of cultivated lands showing little or no degradation. The greatest proportion of cultivated lands in Catchment T35 A show moderate degradation. A low proportion of cultivated fields in Catchment T35 B are highly and moderately degraded with the largest proportion exhibiting low degradation. Cultivated lands in Catchment T35 C show equal proportions of low to high degradation.

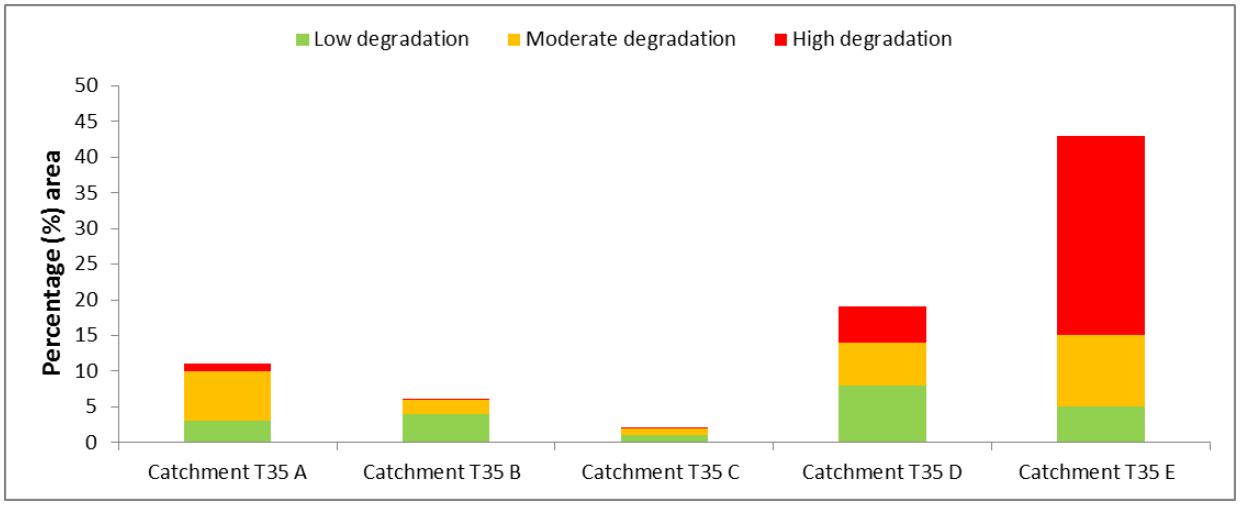

FIGURE 19: PERCENTAGE AREA COVERED BY DIFFERENT LEVELS OF DEGRADED CULTIVATED LANDS IN EACH SUB-CATCHMENT

Figure 20 depicts the percentage area covered by cultivated lands classified into different levels of vulnerability to erosion. Catchment T35 E exhibits the highest area covered by highly vulnerable cultivated lands with very few exhibiting moderate to low vulnerability. The rest of the sub-catchments exhibit smaller areas covered by highly vulnerable cultivated lands with more cultivated lands exhibiting a low to moderate vulnerability to erosion.

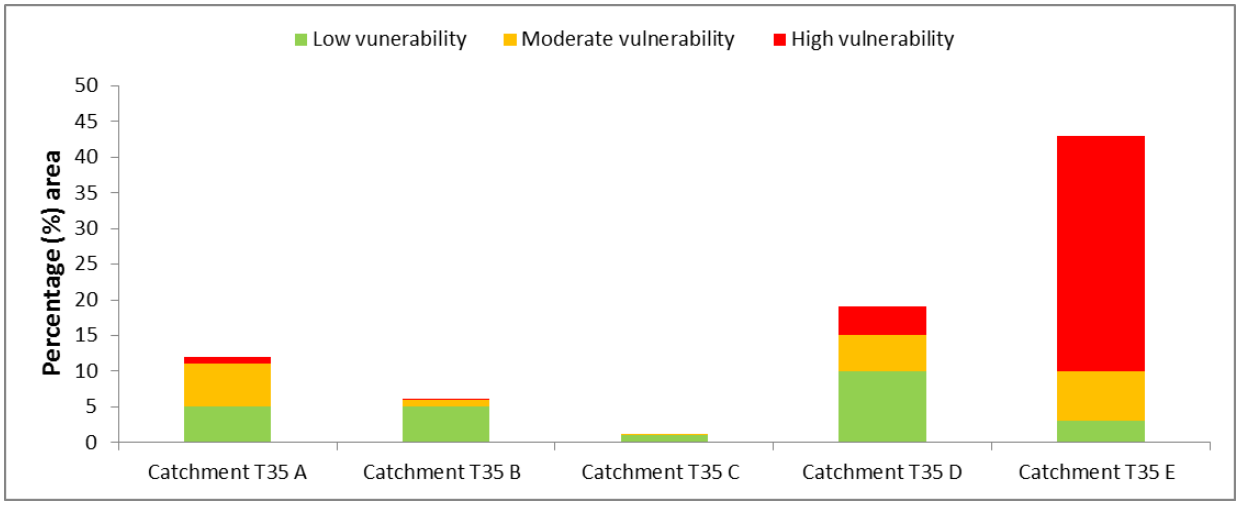

FIGURE 20: PERCENTAGE AREA COVERED BY DIFFERENT LEVELS OF VULNERABLE CULTIVATED LANDS IN EACH SUB-CATCHMENT

Figure 21 depicts cultivated land area covered by different levels of encroachment of alien vegetation. Overall the sub-catchments exhibit low encroachment of vegetation. Catchment T35 E shows the highest encroachment of vegetation followed by Catchment T35 D. Catchment T35 A, B and C shows little or no encroachment of vegetation on cultivated lands.

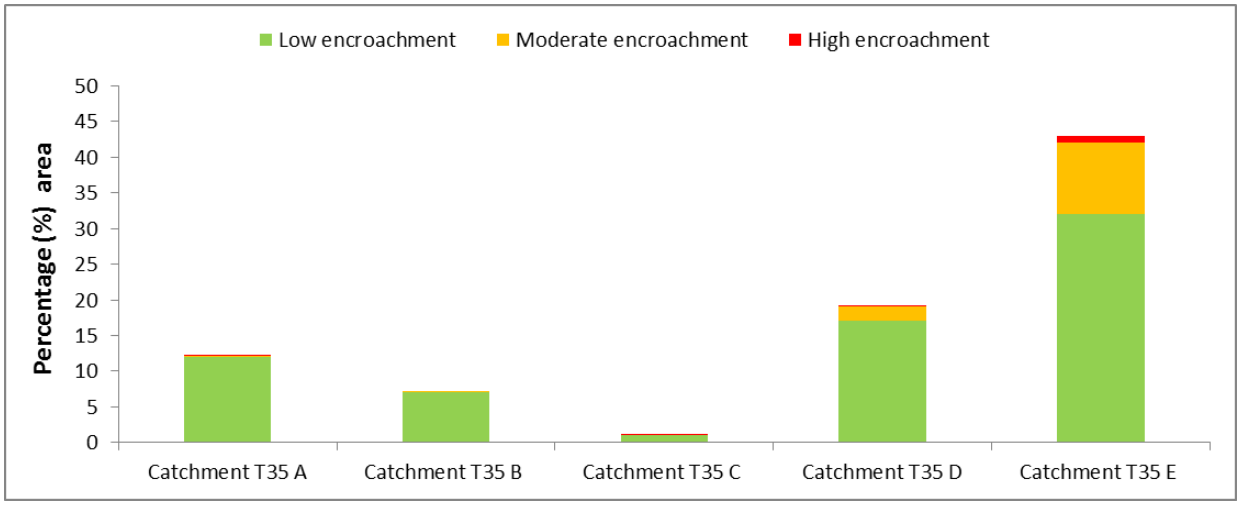

FIGURE 21: PERCENTAGE AREA COVERED BY DIFFERENT LEVELS OF ENCROACHED CULTIVATED LANDS IN EACH SUB-CATCHMENT

Appendixes 1-5 provide separate details and maps for each sub-catchment.

3.3. NORMALISED DIFFERENCE VEGETATION INDEX

Table 12 shows the percentage of cultivated land area for a range of NDVI values and corresponding vegetation cover classes. Out of the total cultivated land area poor vegetation cover made up 8% of the cultivated land area, low vegetation cover made up 20%, moderate vegetation cover 55% and good vegetation cover 16%. It is clear from Figure 22 that the cultivated lands within the Traditional Authority areas have the lowest vegetation cover. This corresponds to the status, degradation and

vulnerability codes assigned to cultivated lands as depicted in Figure 23 and Figure 24. It is important to note that the NDVI analysis was carried out on an image taken during the rainy season.

TABLE 12: PERCENTAGE OF CULTIVATED LAND AREA FOR A RANGE OF NDVI VALUES AND VEGETATION COVER CLASSES IN CATCHMENT T35 A-E

NDVI Values	Vegetation cover classes	Percentage of cultivated land area (%)
-0.3 to 0.28	Poor (no vegetation)	8
0.29 to 0.40	Low	20
0.41 to 0.60	Moderate	55
0.61 to 0.85	Good	16

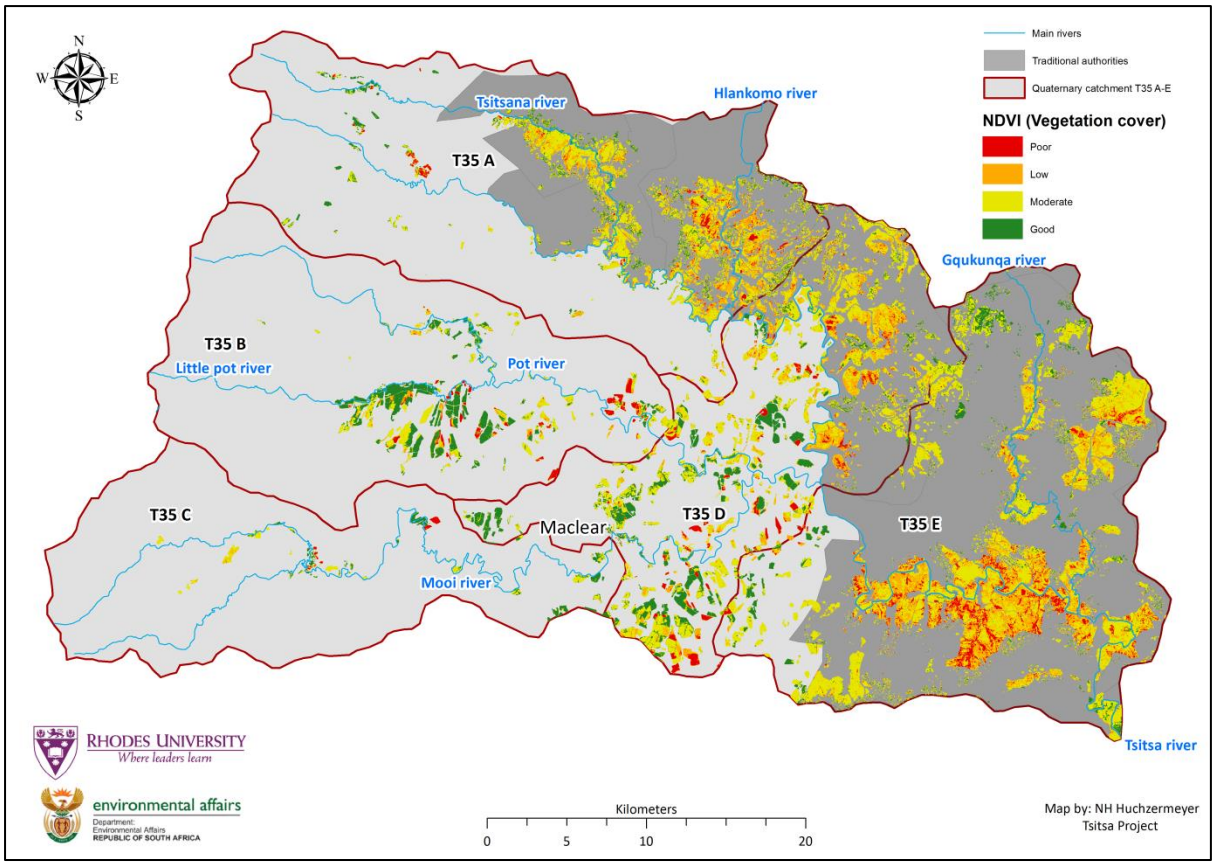

FIGURE 22: RANGE OF NDVI VALUES FOR CULTIVATED LANDS IN CATCHMENT T35 A-E

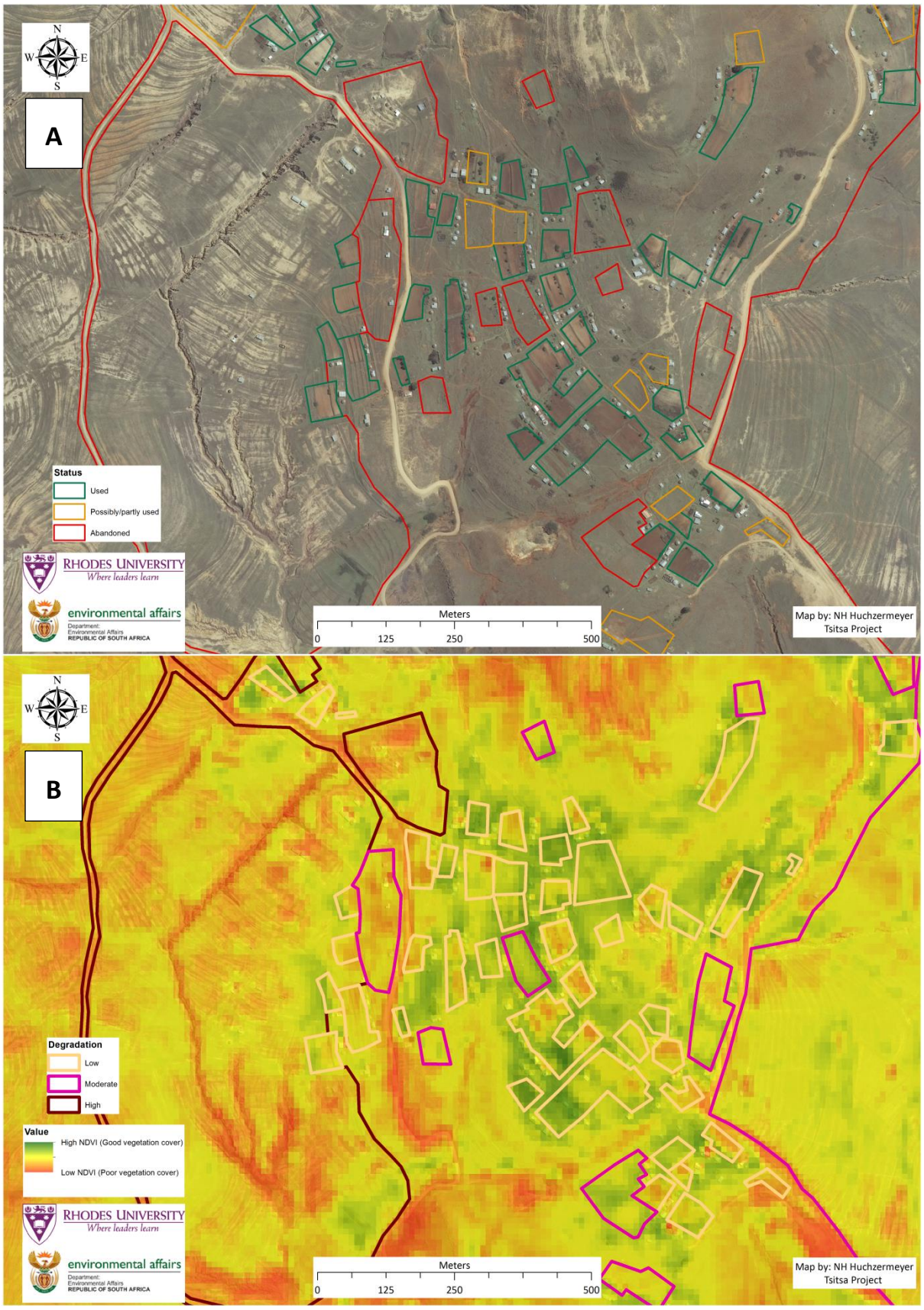

FIGURE 23: A: LOCATION AND STATUS OF CULTIVATED LANDS; B: DEGRADATION STATUS AND VEGETATION GROWTH VIGOUR IN CULTIVATED LANDS

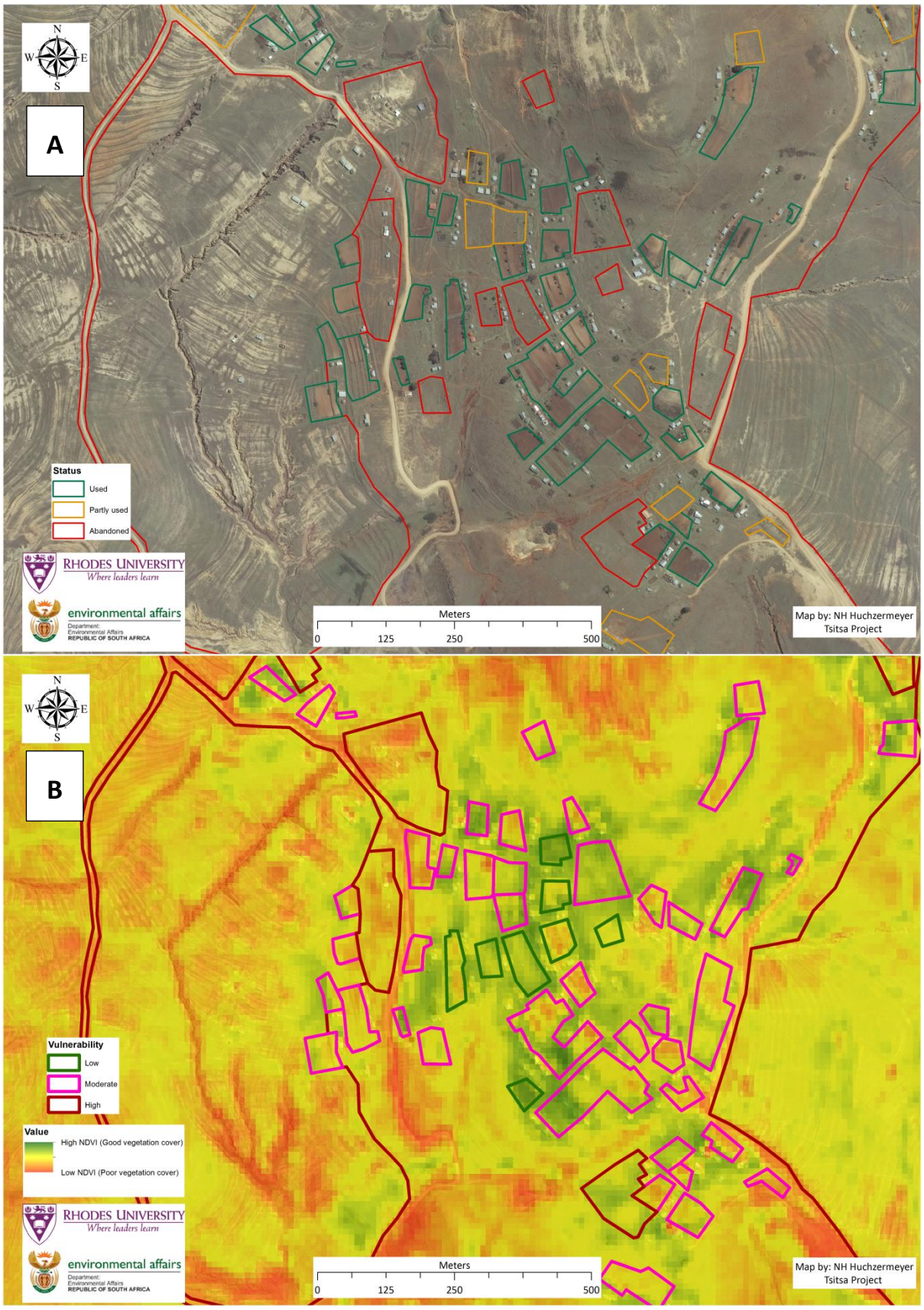

FIGURE 24: A: LOCATION AND STATUS OF CULTIVATED LANDS; B: VULNERABILITY STATUS AND VEGETATION GROWTH VIGOUR IN CULTIVATED LANDS

3.4. Accuracy of the mapping of cultivated lands (T35 A-E)

Field verification of a selection of the digitised and classified cultivated lands was undertaken to ensure that the dataset is accurate. A total of 372 (5%) of the cultivated lands were verified in the field. There was 25% error in the verified fields. Out of this, 22% of the error was due to incorrect assignment of the cultivated land status, which changed in most cases from partly used or used to abandoned. This could be a function of the delay between aerial image date (2016) and field verification (2018). However, the status is expected to vary as some fields remain fallow for several years before they are partly ploughed or vice versa. 2% of the error was due to misclassification of the degradation status and 1% due to misclassification of the vulnerability status. 7 out of the 372 cultivated lands were misidentified as cultivated lands as they were not fields but rather fenced livestock camps.

4. Discussion and Conclusions

All cultivated lands, irrespective of status, act as sediment sources to a certain extent (Collins & Walling, 2007; Mohammad & Mohammad, 2010). Used cultivated lands are ploughed on an annual basis which results in vegetation removal, exposing the soils to erosive rainfall and disturbance of the soil structure leading to easy entrainment of sediment. Partly used fields are ploughed on a less regular basis but the initial disturbance of the soil structure results in continual movement of sediment from these areas. A large proportion of abandoned fields can be classified as degraded with very low vegetation cover and often have large erosional features, such as rills and gullies, associated with them. Only very few abandoned lands have 'recovered' from the disturbance of cultivation and exhibit good vegetation cover throughout. Abandoned fields that are no longer used for active cultivation can easily be targeted for landscape restoration efforts, especially the poorly vegetated areas, as they are easily accessible and located on fairly gentle slopes.

4.1. Revegetation of degraded areas

Little work can be done within used cultivated lands to ensure that they produce minimal sediment. As long as the soil structure is ploughed and exposed the cultivated lands will act as sediment sources. Short periods of no vegetation cover on used fields combined with the rehabilitation of the surrounding landscape and grasslands are vital for decreasing the entrapment and transport of sediment. Vegetation can act as sediment traps for sediment washing out of used lands. Reducing the landscape connectivity, surrounding cultivated lands, through the restoration and mitigation of gullies and livestock paths can also help reduce sediment pathways in turn reducing the volume of sediment travelling down the catchment (Figure 9).

Abandoned fields with improved/good grass cover can improve livelihoods for local communities (through planting pastures or improving grazing). In order to rehabilitate abandoned cultivated lands it is important to restore vegetation growth and cover. There are many grass species that thrive on degraded or abandoned lands and when combined act as good erosion controls (by binding soil and acting as silt traps) and many are highly nutritive. A list of a multitude of grass species that could be planted on abandoned and degraded fields in the Tsitsa catchment to help reduce their future

vulnerability to erosion can be found in Appendix 6. Several of the species are characterised by being both useful for erosion mitigation and having a good grazing and pasture potential.

For example *Eragrostis tef* (Tef) is known for both grain and forage production (Heuzé *et al.,* 2017). It is valued for its high yields and rapid growth in low rainfall and drought prone areas. Tef is easy and cheap to grow. Harvesting is quick and Tef can be stored as fodder for drier winter months to reduce grazing pressures on grasslands during this time period. Good ground cover combined with fast germination and fibrous root systems makes it ideal for erosion control.

Clark (2018) proposed that to revegetate degraded areas one should start by introducing hardy vegetation types that can protect exposed soils and create an environment for further vegetation cover development. This can be achieved by planting grasses or ruderals (plants that grow on disturbed soils).

The following details for revegetation of degraded lands, including abandoned cultivated fields, are taken from Clark (2018):

4.1.2. Use of grasses

To improve grassland diversity and health in dryland grasslands suitable indigenous pioneer grasses can be distributed and sowed in identified areas. Residual and tough grasses, such as *Cynodon incompetus*/*C. dactylon* (Couch Grass/Kweek), *Eragrostis plana* (Tough Love Grass) and *Sporobolus africana* (Ratstail Dropseed), that already occur in the Tsitsa Catchment (to be confirmed) can be augmented by sowing pioneer tufted grasses such as *Eragrostis curvula* (Weeping Love Grass), *E. chloromelas* (Narrow Curley Leaf), *Digitaria eriantha* (Common Finger Grass), and later on *Themeda triandra* (Rooigras), to increase surface roughness that would reduce surface water flow velocity (and thus erosive power), and increase rainfall infiltration. A wide variety of climatically suitable indigenous grasses is available for rehabilitation measures – these are just some examples. It is imperative that the restoration interventions be informed by Local Ecological Knowledge (LEK) and the wishes of the local beneficiaries. In a preliminary study Ngwenya (2016) noted that the following species would be accepted as part of rehabilitation measures by at least one local community: *Hyparrhenia hirta* (Common Thatching Grass), *Cymbopogon* spp. (Turpentine Grasses), *Panicum* spp. (Guinea Grasses), *Juncus kraussii* (Incema) and *Cyperus marginatus* (no common name). It is worth noting that these species (except for *Panicum*) have non-grazing utility value, as they are not palatable. It is recommended that an extensive consultative process needs to be completed to identify both species that have significant importance of the local beneficiaries as well as a high grazing value.

1.1.3. Use of Ruderals on highly degraded lands:

Grime *et al.* (1988) define ruderals as those plants '*that have the ability to thrive where there is disturbance through partial or total destruction of plant biomass*.' In other words, ruderals are species that favour disturbed environments such as roadsides, old lands, dongas, fallow fields, degraded watercourses, landfill sites, gardens, pavements, etc. (Holzner & Numata, 1982, Cilliers & Bredenkamp, 1998, García-Palacios *et al*., 2011). They represent lower successional levels (Holzner & Numata, 1982) and generally die out once the ground stabilises/the disturbance ceases, i.e. they

create an interface between the disturbed environment and plants that require more stable conditions. As a result they are typically replaced by species higher up the successional gradient over time if the disturbance is not repeated (assuming the basic, original concepts of successional theory; Pearcy, 2003).

Theoretically, each Biome in South Africa has its own suit of indigenous and naturalised ruderals: for instance, annual Mesembryanthemaceae and annual Asteraceae (the latter comprising 'Namaqualand Daisies') are typical ruderals in the Succulent Karoo Biome; various *Metalasia* species, Geraniaceae and some Ericaceae in the Fynbos Biome; the introduced *Alternanthera pungens* (Paperthorn) and *Cichorium intybus* (Chicory) in the Nama-Karoo Biome; the introduced *Bidens formosa* (Cosmos) in the Grassland Biome; *Vachellia karroo* in the Thicket and Savannah Biomes (overlapping here with the concept of bush encroachment); and *Trema orientalis* in the Forest Biome. Some vegetation types are even dominated by ruderal strategies and have a high proportion of ruderals among their endemics (an example is the Upper Guinea forest region in West Africa; Holmgren & Poorter, 2007). There is an indistinct nuanced separation between 'pioneer' and 'ruderal' which we do not consider here, as both definitions combine the same ecological function of these plants (as evidenced by a variety of literature). In a Grassland Biome context – which the Project falls into – roadside verges provide an excellent and abundant example of ruderal and primary to secondary successional plant communities that can be considered for grassland rehabilitation (e.g. Forman & Alexander, 1998 for the Prairies). Practically, this means that seed can be mass harvested (e.g. 'vacuum-sucked') from roadside colonies.

The use of ruderals as an alternative to conventional grass rehabilitation is appealing because they are successful colonisers with the following characteristics: (1) massive seed production; (2) seeds are wind or animal dispersed; (3) seeds have great longevity; (4) sun-loving; (5) seedlings whose nutritional requirements are modest; (6) fast-growing roots; (7) independence from mycorrhizae; (8) and often exhibit polyploidy (Holzner & Numata, 1982). Ruderals require no maintenance and are self-perpetuating for as long as the disturbance persists or they are outcompeted by plants higher up the successional ladder (representing increased ecological stability). Globally, ruderals are being used/considered for rehabilitation in a large number of contexts, from the Atlantic Rainforests of Brazil, to urban environments in North America, to quarries in the Mediterranean region (Cortines & Valcarcel, 2009; Riano, 2012, CNRS-L/AFDC/IUCN/Holcim, 2014). Pungent ruderals (or even poisonous ones) can also be explored for use as nursery plants to protect more palatable ruderals and grass plantings from grazing: excellent examples of pungent ruderals in the Project's Grassland Biome context are *Artemisia afra*, *Tagetes minuta*, and *Hyparrhenia* grasses

Overall, the intentional use of non-graminoid ruderals in rehabilitation appears to be a bit of a 'Blue Skies' concept in the Grassland Biome of South Africa that could be much better explored to accompany classical graminoid-dominated rehabilitation measures in high pressure/grazing environments. Many of the plants listed in Appendix 7 require experimentation to better understand their life cycles and ecological suitability, but the fact that they appear to exhibit either strong ruderal tendencies or pioneer capabilities in adverse conditions supports consideration of their use. It is possible that these concepts are being used extensively in the private sector through *inter alia* Environmental Management Plans and are not reflected in an extensive scientific literature

(especially for brownfields and industrial site rehabilitation; a UK example is The Bumblebee Conservation Trust *sine anno*). For instance, as an example, Cilliers (1999) states that '*Relatively little is known about ruderal and degraded natural vegetation in urban open spaces in the Grassland Biome of South Africa*'. While the phytosociological and floristic components have been somewhat explored, the practical applications appear to be wanting from more recent research

Examples of potentially suitable ruderals and other potentially suitable pioneer species are detailed in Appendix 7.

If managed appropriately abandoned fields can be turned from degraded lands into areas of high grazing potential and productive pastures.

REFERENCES

Cilliers, S.S. 1999. Ruderal and degraded natural vegetation on vacant lots in the Potchefstroom Municipal Area, North West Province, South Africa. *South African Journal of Botany* 65: 163–173.

Cilliers, S.S. & Bredenkamp, G.J. 1998. Vegetation analysis of railway reserves in the Potchefstroom municipal area, North West Province, South Africa. *South African Journal of Botany,* 64: 271–280.

Clark, R. 2018. Alien Management and Revegetation of Degraded Areas in the Tsitsa Catchment. Draft Report, Tsitsa Project, Rhodes University.

CNRS-L/AFDC/IUCN/Holcim. 2014. Mediterranean Quarry Rehabilitation Manual: Learning from the Holcim Experience. IUCN, Gland, Switzerland.

Collins, A.L. & Walling, D.E. 2007. Sources of fine sediment recovered from the channel bed of lowland groundwater-fed catchments in the UK. *Geomorphology,* 88: 120-138.

Cortines, E. & Valcarcel, R. 2009. Influence of pioneer-species combinations on restoration of disturbed ecosystems in the Atlantic Forest, Rio de Janeiro, Brazil. *Revista Árvore,* 33: 927–936.

Fish, L., Mashau, A.C., Moeaha, M.J. & Nembudani, M.T. 2015. Identification guide to southern African grasses. An identification manual with keys, descriptions and distributions. *Strelizia 36.* South African National Biodiversity Institute, Pretoria.

Forman, R.T.T. & Alexander, L.E. 1988. Roads and their major ecological effects. *Annual Review of Ecology and Systematics*, 29: 207–231.

Fryirs, K. & Brierley, G.J. 1999. Slope–channel decoupling in Wolumla catchment, New South Wales, Australia: the changing nature of sediment sources following European settlement. *Catena,* 35: 41–63. doi:10.1016/S0341-8162(98)00119-2.

García-Palacios, P., Bowker, M.A., Maestre, F.T., Soliveres, S., Valladares, F., Papadopoulos, J. & Escudero, A. 2011. Ecosystem development in roadside grasslands: biotic control, plant–soil interactions and dispersal limitations. *Ecological Applications,* 21: 2806–2821.

Grime, J.P., Hodgson, J.G. & Hunt, R. 1988. Comparative Plant Ecology. A Functional Approach to Common British Species. London: Unwin Hyman.

Harvey, A.M. 2001. Coupling between hillslopes and channels in upland fluvial systems: implications for landscape sensitivity, illustrated from the Howgill Fells, northwest England. *Catena,* 42: 225–250. doi:10.1016/S0341-8162(00)00139-9

Heuzé V., Thiollet H., Tran G. & Lebas F. 2017. *Tef (Eragrostis tef) hay. Feedipedia, a programme by INRA, CIRAD, AFZ and FAO.* [Online]. Available: https://www.feedipedia.org/node/22768.[13/09/2018].

Holmgren, M. & Poorter, L. 2007. Does a Ruderal Strategy Dominate the Endemic Flora of the West African Forests? *Journal of Biogeography,* 34: 1100–1111.

Holzner, W. & Numata, M. (Eds). 1982. Biology and ecology of weeds. Junk, The Hague.

Kakembo, V. 2001. Trends in vegetation degradation in relation to land tenure, rainfall, and population changes in Peddie District, Eastern Cape, South Africa. *Environmental Management*, 28(1): 39–46.

Kakembo, V. & Rowntree, K. M. 2003. The relationship between land use and soil erosion in the communal lands near Peddie town, Eastern Cape, South Africa. *Land Degradation and Development,* 14: 39–49.

Koulouri, M. & Giourga, C. 2007. Land abandonment and slope gradient as key factors of soil erosion in Mediterranean terraced lands. *Catena*, 69: 274–281.

López-Vicente, M., Poesen, J., Navas, A. & Gaspar, L. 2013. Predicting runoff and sediment connectivity and soil erosion by water for different land use scenarios in the Spanish Pre-Pyrenees. *Catena,* 102: 62–73. doi:10.1016/j.catena.2011.01.001

Millennium Ecosystem Assessment. 2005. Ecosystems and Human Well-being: Desertification Synthesis. World Resources Institute, Washington, DC.

Mohammad, A.G. & Mohammad, A.A. 2010. The impact of vegetative cover type on runoff and soil erosion under different land uses. *Catena,* 81: 97-103.

Ngwenya, M. 2016. Participatory identification of key places and species valued by Shukunxa residents in the Ntabelanga dam catchment. Honours Dissertation. Department of Environmental Science, Rhodes University.

Pearcy, R. 2003. *Plant Ecology. Topic 16. Fall, 2003. University of California, Davis*. [Online]. Available: http://www-eve.ucdavis.edu/pearcy/PLB%20117%20topic%2016%202003.pdf. [21/04/2017].

Purevdorj, T., Tateishi, R., Ishiyama, T. & Honda, Y. 1998. Relationships between percent vegetation cover and vegetation indices. *International Journal of Remote Sensing*. 19: 3519–3535. https://doi.org/10.1080/014311698213795

Riano, I. 2012. Just a Bunch Of Weeds: An Interview With Peter Del Tredici. Scenario 02: Performance. *Scenario Journal*. [Online]. Available: http://scenariojournal.com/article/peter-del-tredici/ [20/04/2017].

Schlegel, P., Huchzermeyer, N. & Van der Waal., B. 2018. Cultivated lands in sub-catchment T35 E. Cultivated land mapping: level of degradation and vulnerability to erosion. Mapping report, Tsitsa Project, Rhodes University.

Wigley, B.J. Bond, W.J. & Hoffman, M.T. 2009. Bush encroachment under three contrasting land-use practices in a mesic South African savanna. *African Journal of Ecology*, 47: 62–70.

APPENDIX 1: CULTIVATED LANDS T35 A

A total of 2 310 cultivated lands were identified in Catchment T35 A (Table 13, Figure 25). These cover a total area of 5 910 ha which constitutes 12% of the total sub-catchment area of T35 A (47 498 ha) and 3% of the total catchment area of Catchment T35 A-E.

TABLE 13: SUMMARY OF CULTIVATED LANDS IN CATCHMENT T35 A

	Area (ha)	No. of cultivated lands	Area (ha) covered by cultivated lands	Percentage (%) of Catchment T35 A	Percentage (%) of Catchment T35 A-E
Catchment T35 A	47 498	2 310	5 910	12	3

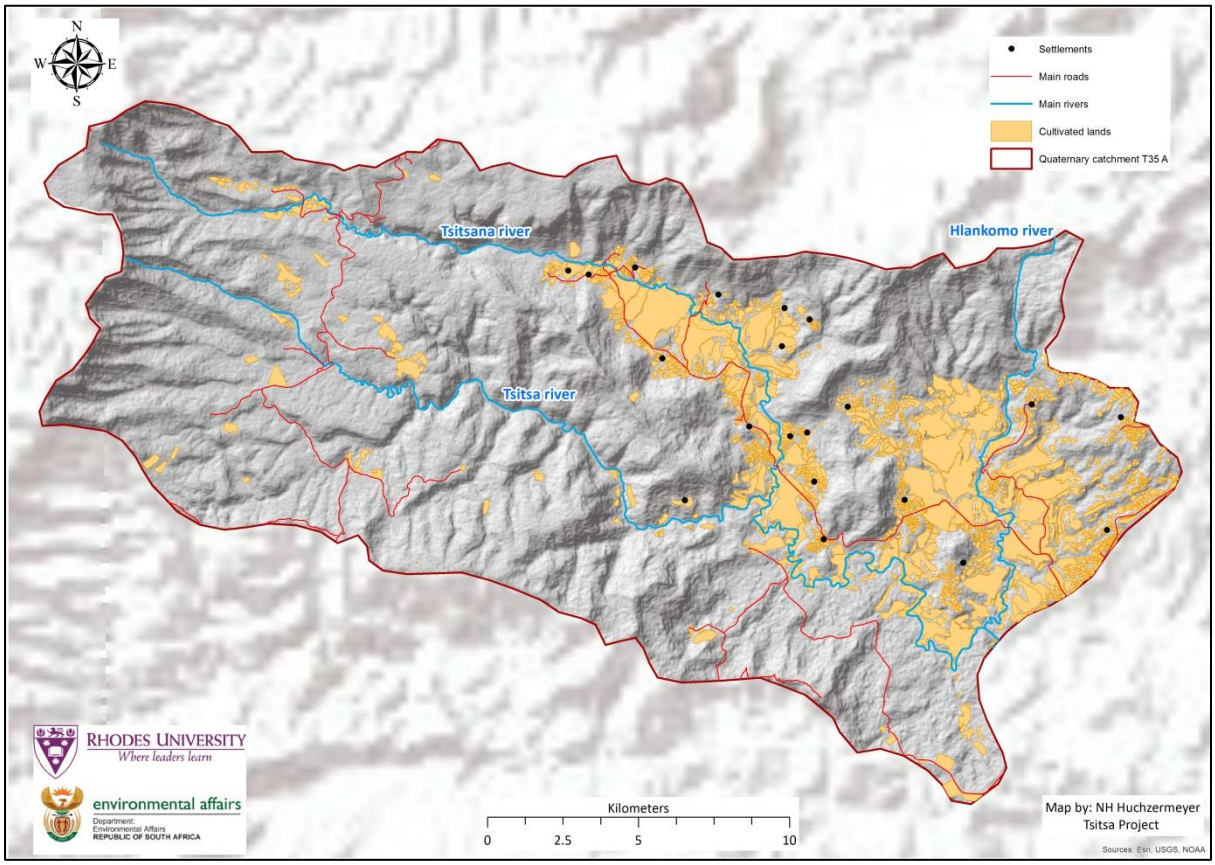

FIGURE 25: LOCATION OF CULTIVATED LANDS IN CATCHMENT T35 A

The results for cultivated lands in terms of current use status, degradation, level of vulnerability to further degradation and level of encroachment by woody vegetation for Catchment T35 A are given below.

Status

A total of 517 (490 ha) of the cultivated lands were used (8% of total cultivated land area), 1 119 (3 888 ha) partly used (66% of total cultivated land area) and 674 (1 534 ha) were abandoned (26% of total cultivated land area) (Table 14 and Figure 26). Partly used fields make up the greatest proportion of the cultivated lands. In total used fields make up 1% of Catchment T35 A, partly used fields 8% and abandoned fields 3% (Figure 27).

Table 14: Summary of the status of cultivated lands in Catchment T35 A

Status	No. of cultivated lands	Area H (ha)	Percentage (%) area of cultivated lands	Percentage (%) of Catchment T35 A
Clearly used	517	490	8	1
Partly used	1 119	3 886	66	7
Abandoned	674	1 534	26	3

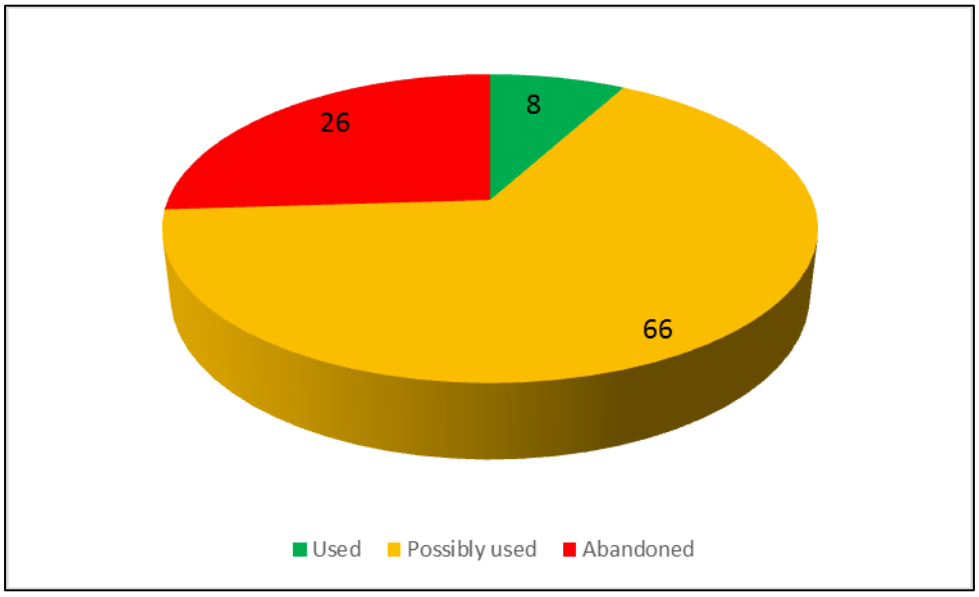

Figure 26: Percentage area, out of the total cultivated land area, covered by each category of cultivated lands in Catchment T35 A

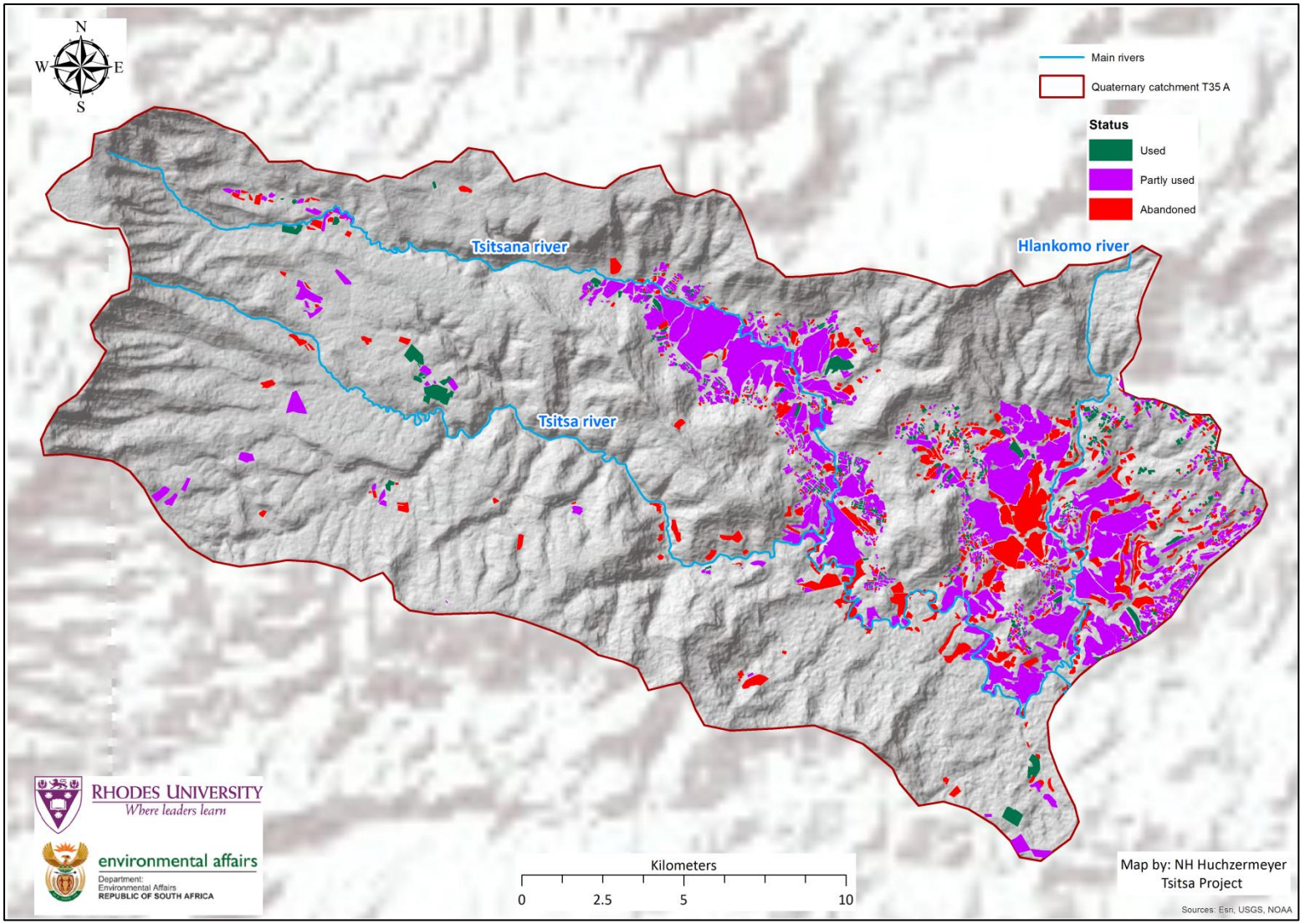

FIGURE 27: CULTIVATED LANDS CLASSIFIED INTO USAGE STATUS IN CATCHMENT T35 A

DEGRADATION

A total of 1 104 (1 214 ha) cultivated lands showed little or no degradation (21% of total cultivated land area), 966 (3 961 ha) showed moderate levels of degradation (67% of total cultivated land area) and 240 (734 ha) showed widespread degradation (12% of total cultivated land area) (Table 15 and Figure 28). In total cultivated lands exhibiting low degradation make up 3%, moderately degraded cultivated lands make up 8% and highly degraded cultivated lands make up 1% of Catchment T35 A (Figure 29).

TABLE 15: SUMMARY OF DEGRADED CULTIVATED LANDS, IRRESPECTIVE OF STATUS, IN CATCHMENT T35 A

Degradation	No. of cultivated lands	Area H (ha)	Percentage (%) area of cultivated lands	Percentage (%) of Catchment T35 A
Low	1 104	1 214	21	3
Moderate	966	3 962	67	7
High	240	734	12	1

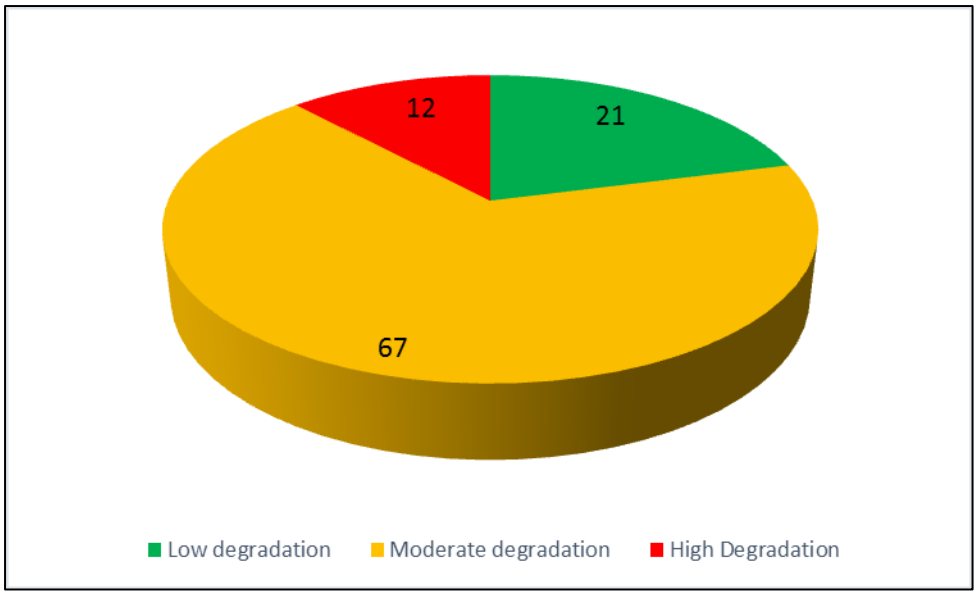

FIGURE 28: PERCENTAGE AREA, OUT OF THE TOTAL CULTIVATED LAND AREA IN CATCHMENT T35 A, COVERED BY DIFFERENT CATEGORIES OF CULTIVATED LAND DEGRADATION

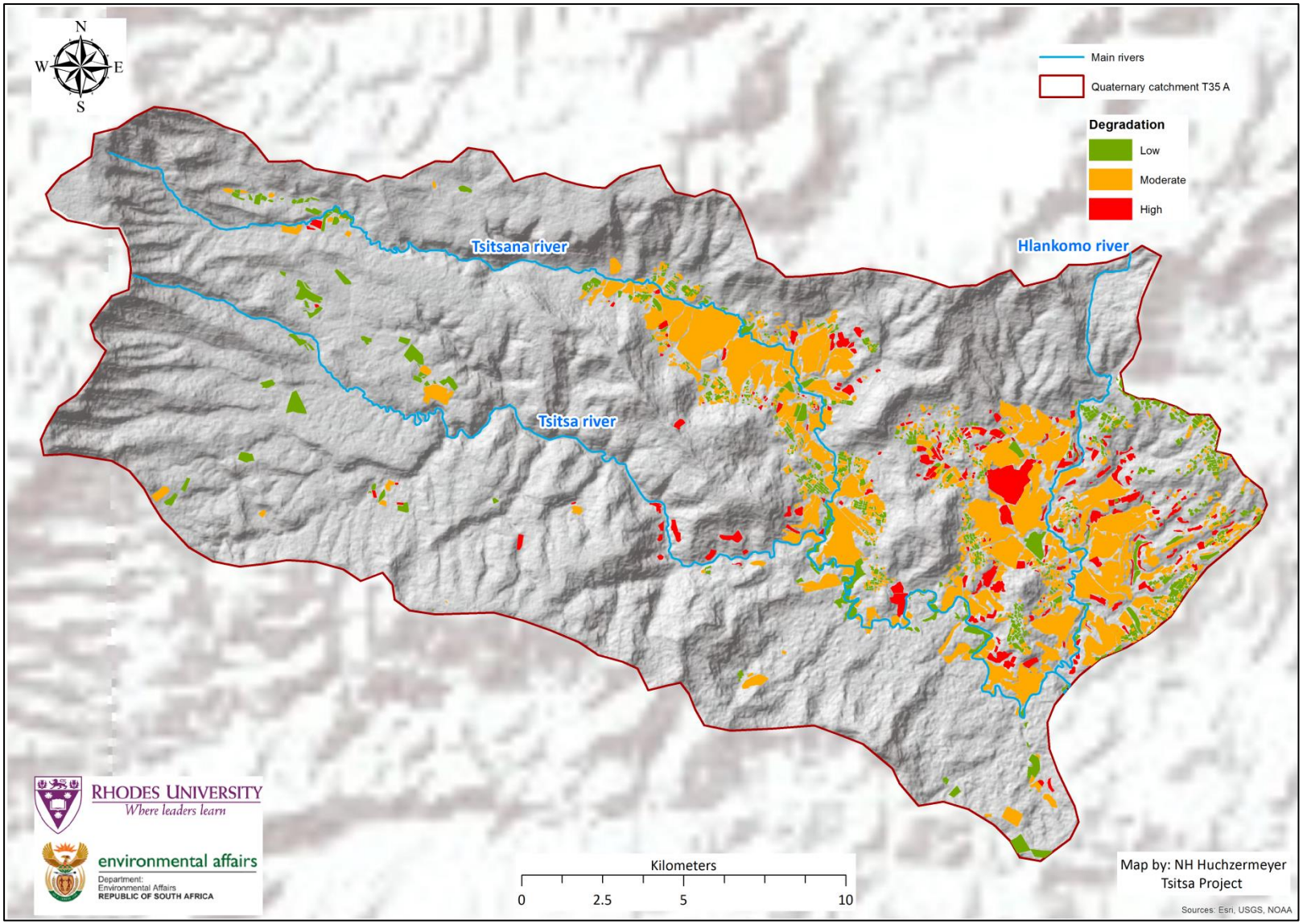

FIGURE 29: CULTIVATED LANDS IN CATCHMENT T35 A CLASSIFIED INTO THREE CLASSES OF DEGRADATION

VULNERABILITY TO EROSION

A total of 1 772 (2 592 ha) of the cultivated lands exhibited low vulnerability to erosion (44% of total cultivated land area), 471 (2 678 ha) exhibited moderate vulnerability (45% of total cultivated land area) to erosion and 67 (640 ha) were highly vulnerable (11% of total cultivated land area) to erosion (Table 16 and Figure 30). Overall, cultivated lands exhibiting low vulnerability to erosion make up 5% of Catchment T35 A, those exhibiting moderate vulnerability make up 6% and highly vulnerable cultivated lands make up 1% (Figure 31).

TABLE 16: SUMMARY OF THE VULNERABILITY OF CULTIVATED LANDS, IRRESPECTIVE OF THEIR STATUS OR DEGRADATION, IN CATCHMENT T35 A

Vulnerability	No. of cultivated lands	Area H (ha)	Percentage (%) area of cultivated lands	Percentage (%) of Catchment T35 A
Low	1 772	2 592	44	5
Moderate	471	2 678	45	6
High	67	640	11	1

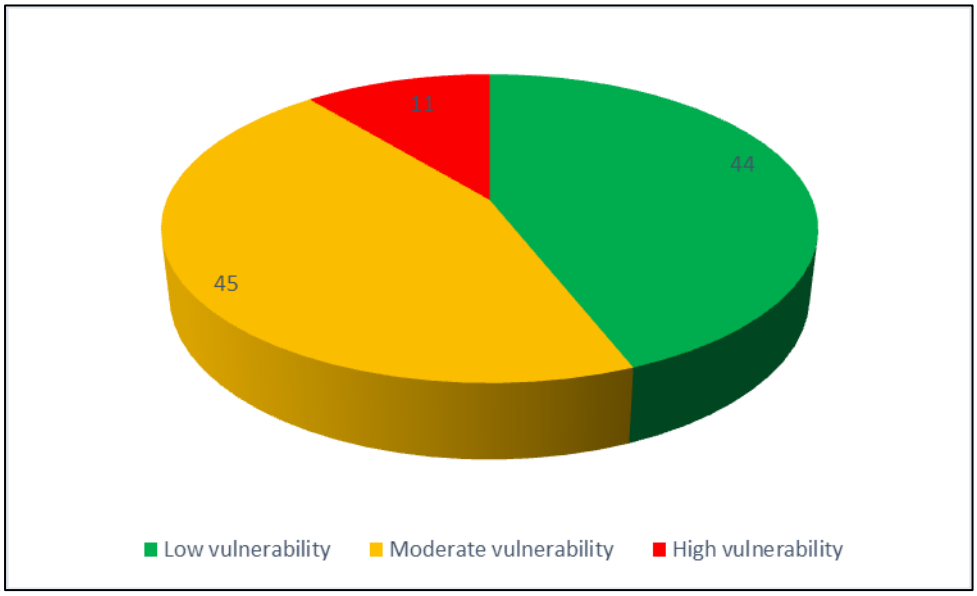

FIGURE 30: PERCENTAGE AREA, OUT OF THE TOTAL CULTIVATED LAND AREA IN CATCHMENT T35 A, COVERED BY DIFFERENT CATEGORIES OF CULTIVATED LAND VULNERABILITY TO EROSION

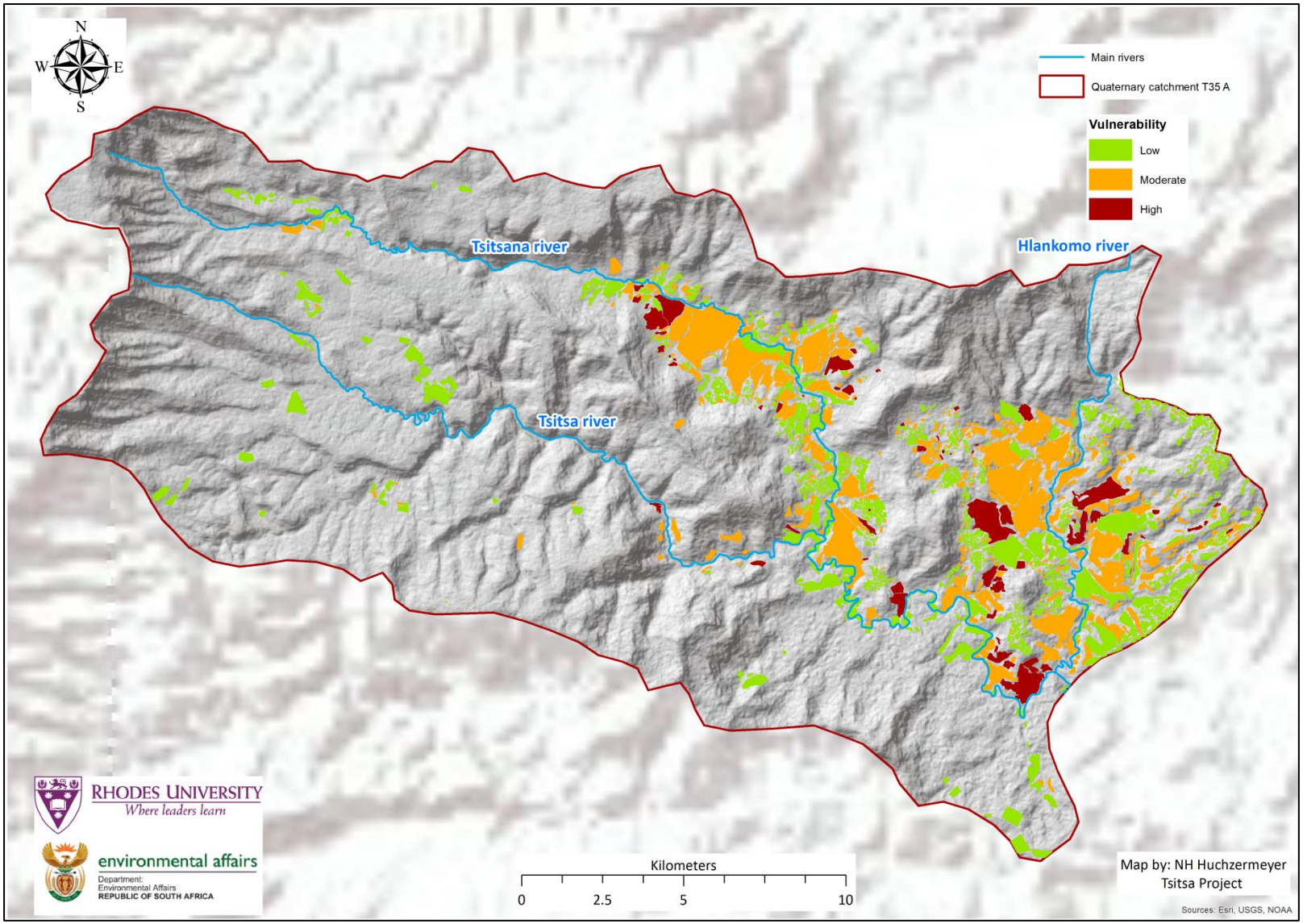

FIGURE 31: CULTIVATED LANDS IN CATCHMENT T35 A-E CLASSIFIED INTO THREE CLASSES OF VULNERABILITY TO EROSION

ENCROACHMENT

A total of 2 235 (5 820 ha) of cultivated lands showed little or no encroachment (98% of total cultivated land are) of alien vegetation, 51 (52 ha) showed moderate encroachment (1% of total cultivated land are) and 24 (38 ha) showed heavy encroachment (1% of total cultivated land area) (Table 17 and Figure 32) and Overall cultivated lands that exhibit little or no encroachment make up 12% of Catchment T35 A, those that exhibit moderate encroachment make up <1% and heavily encroached lands make up less than <1% (Figure 33).

TABLE 17: SUMMARY OF ENCROACHMENT IN CULTIVATED LANDS IN CATCHMENT T35 A

Encroachment	No. of cultivated lands	Area H (ha)	Percentage (%) area covered	Percentage (%) of Catchment T35 A
Little/ none	2 235	5 820	98	12
Moderate	51	52	1	<1
Heavy	24	38	1	<1

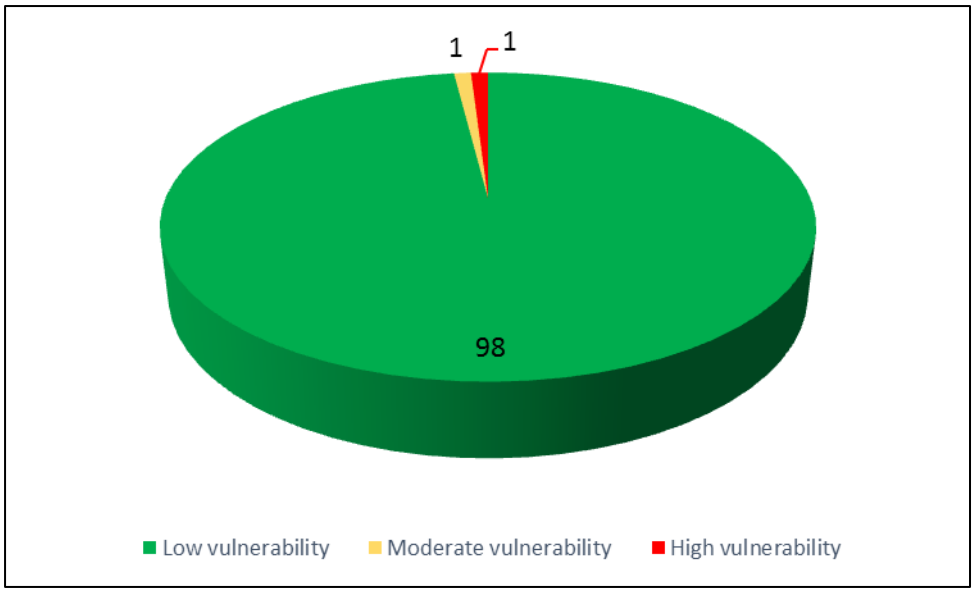

FIGURE 32: PERCENTAGE AREA, OUT OF THE TOTAL CULTIVATED LAND AREA IN CATCHMENT T35 A, COVERED BY DIFFERENT CATEGORIES OF CULTIVATED LAND ENCROACHMENT BY UNWANTED VEGETATION

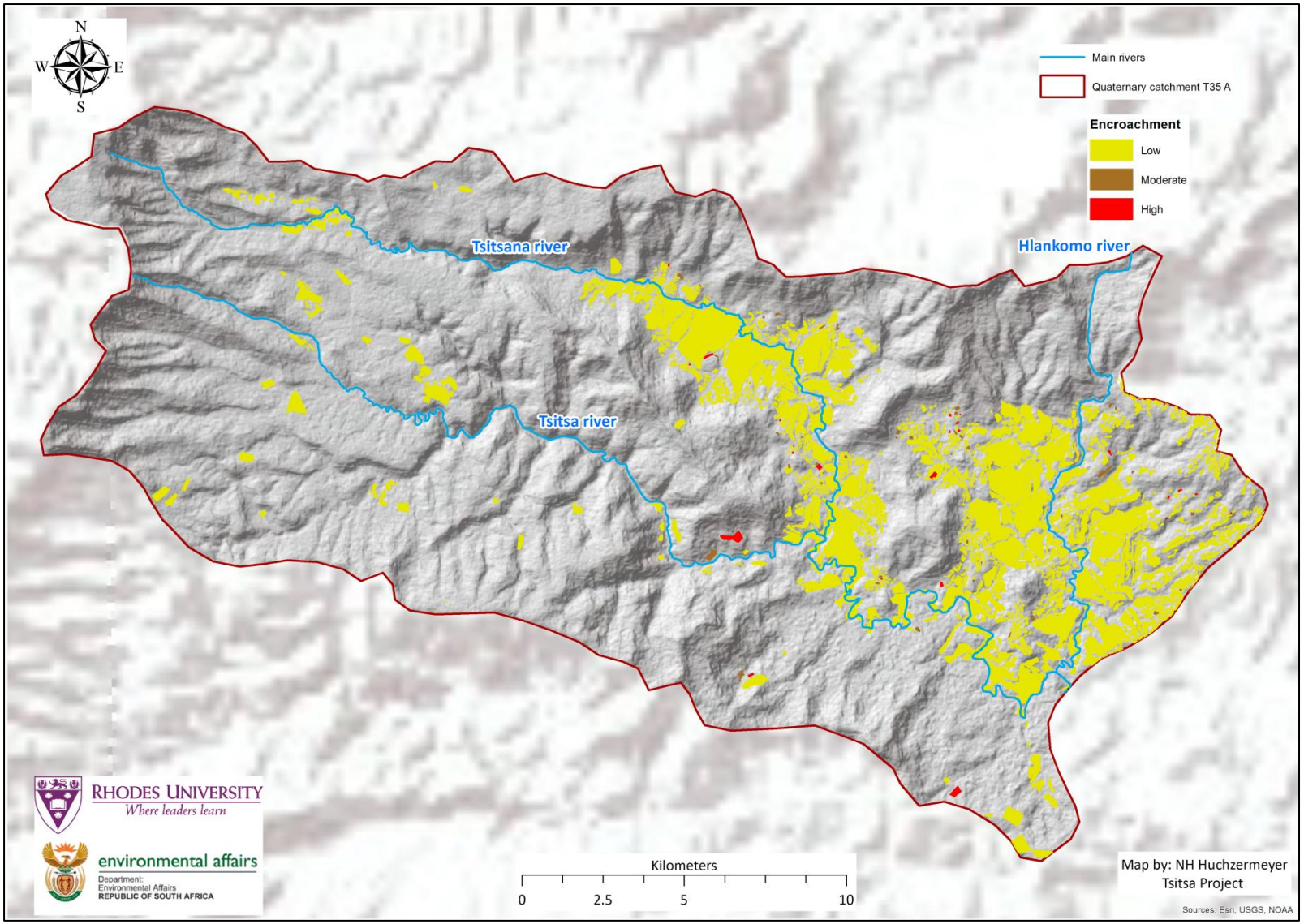

FIGURE 33: CULTIVATED LANDS IN CATCHMENT T35 A CLASSIFIED INTO DIFFERENT LEVELS OF VEGETATION ENCROACHMENT

APPENDIX 2: CULTIVATED LANDS T35 B

A total of 253 cultivated lands were identified in Catchment T35 B (Table 18 and Figure 34). These cover a total area of 2 567 ha which constitutes 7% of the total catchment area of T35 B (39 566 ha).

TABLE 18: SUMMARY OF CULTIVATED LANDS IN CATCHMENT T35 B

	Area (ha)	No. of cultivated lands	Area (ha) covered by cultivated lands	Percentage (%) of Catchment T35 B	Percentage (%) of Catchment T35 A-E
Catchment T35 B	39 566	253	2 567	7	2

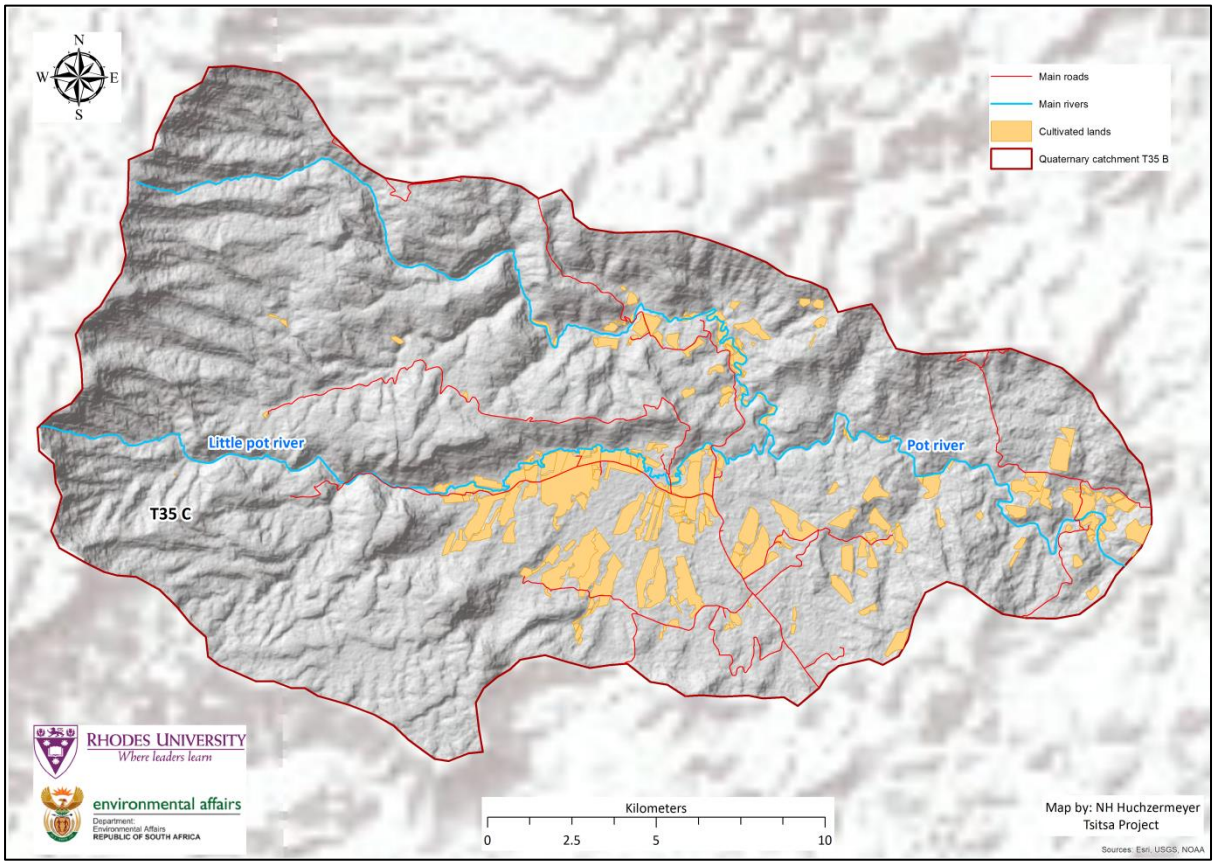

FIGURE 34: LOCATION OF CULTIVATED LANDS IN CATCHMENT T35 B

The results for cultivated lands in terms of current use status, degradation, level of vulnerability to further degradation and level of encroachment by woody vegetation in Catchment T35 B are given below.

Status

A total of 88 (937 ha) of the cultivated lands were used (36% of total cultivated land area), 89 (1 257 ha) partly used (49% of total cultivated land area) and 76 (373 ha) were abandoned (15% of total cultivated land area) (Table 19 and Figure 35). Partly used fields make up the greatest proportion of the cultivated lands. In total used fields make up 3% of Catchment T35 B, used fields 3% and abandoned fields 1% (Figure 36).

Table 19: Summary of the status of cultivated lands in Catchment T35 B

Status	No. of cultivated lands	Area H (ha)	Percentage (%) area of cultivated lands	Percentage (%) of Catchment T35 B
Clearly used	88	937	36	3
Partly used	89	1 257	49	3
Abandoned	76	373	15	1

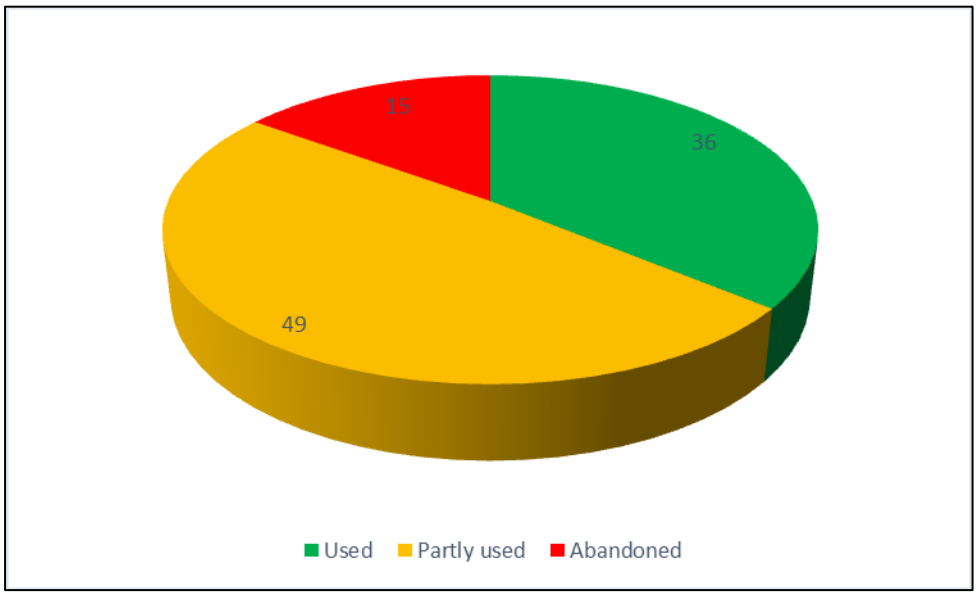

Figure 35: Percentage area, out of the total cultivated land area in Catchment T35 B, covered by each category of cultivated lands

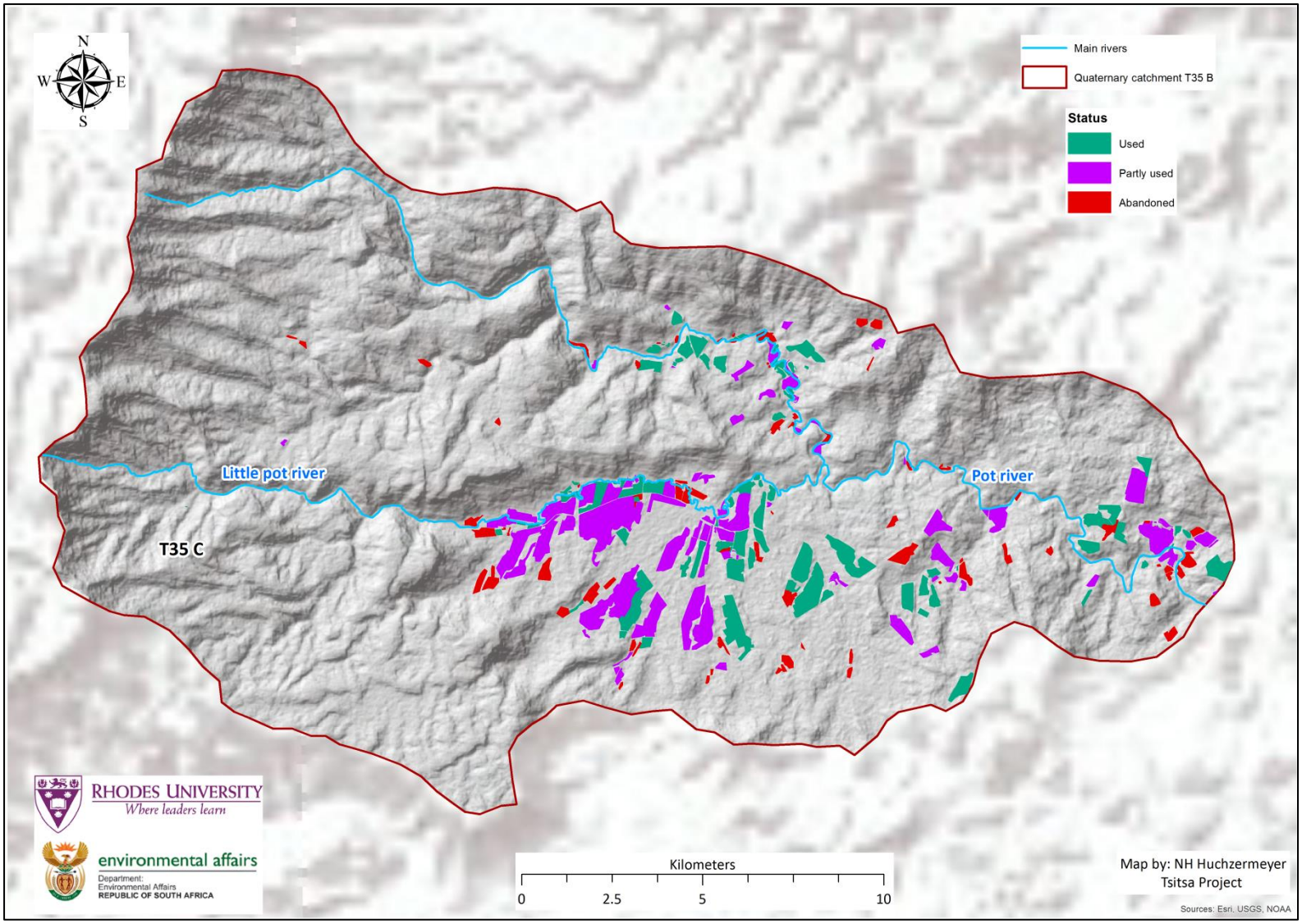

FIGURE 36: CULTIVATED LANDS CLASSIFIED INTO USAGE STATUS IN CATCHMENT T35 B

DEGRADATION

A total of 174 (1 699 ha) cultivated lands showed little or no degradation (66% of total cultivated land area), 67 (803 ha) showed moderate levels of degradation (31% of total cultivated land area) and 12 (65 ha) showed widespread degradation (3% of total cultivated land area) (Table 20 and Figure 37). In total cultivated lands exhibiting low degradation make up 4%, moderately degraded cultivated lands make up 2% and highly degraded cultivated lands make up less than one percent of Catchment T35 B (Figure 38).

TABLE 20: SUMMARY OF DEGRADED CULTIVATED LANDS, IRRESPECTIVE OF STATUS, IN CATCHMENT T35 B

Degradation	No. of cultivated lands	Area H (ha)	Percentage (%) area of cultivated lands	Percentage (%) of Catchment T34 B
Low	174	1 699	66	4
Moderate	67	803	31	2
High	12	65	3	<1

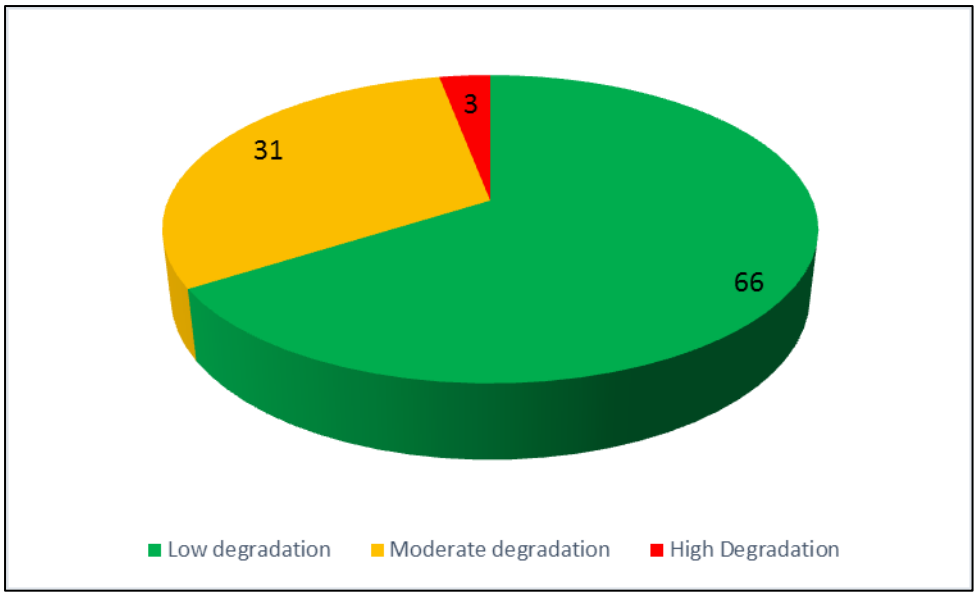

FIGURE 37: PERCENTAGE AREA, OUT OF THE TOTAL CULTIVATED LAND AREA IN CATCHMENT T35 B, COVERED BY DIFFERENT CATEGORIES OF CULTIVATED LAND DEGRADATION

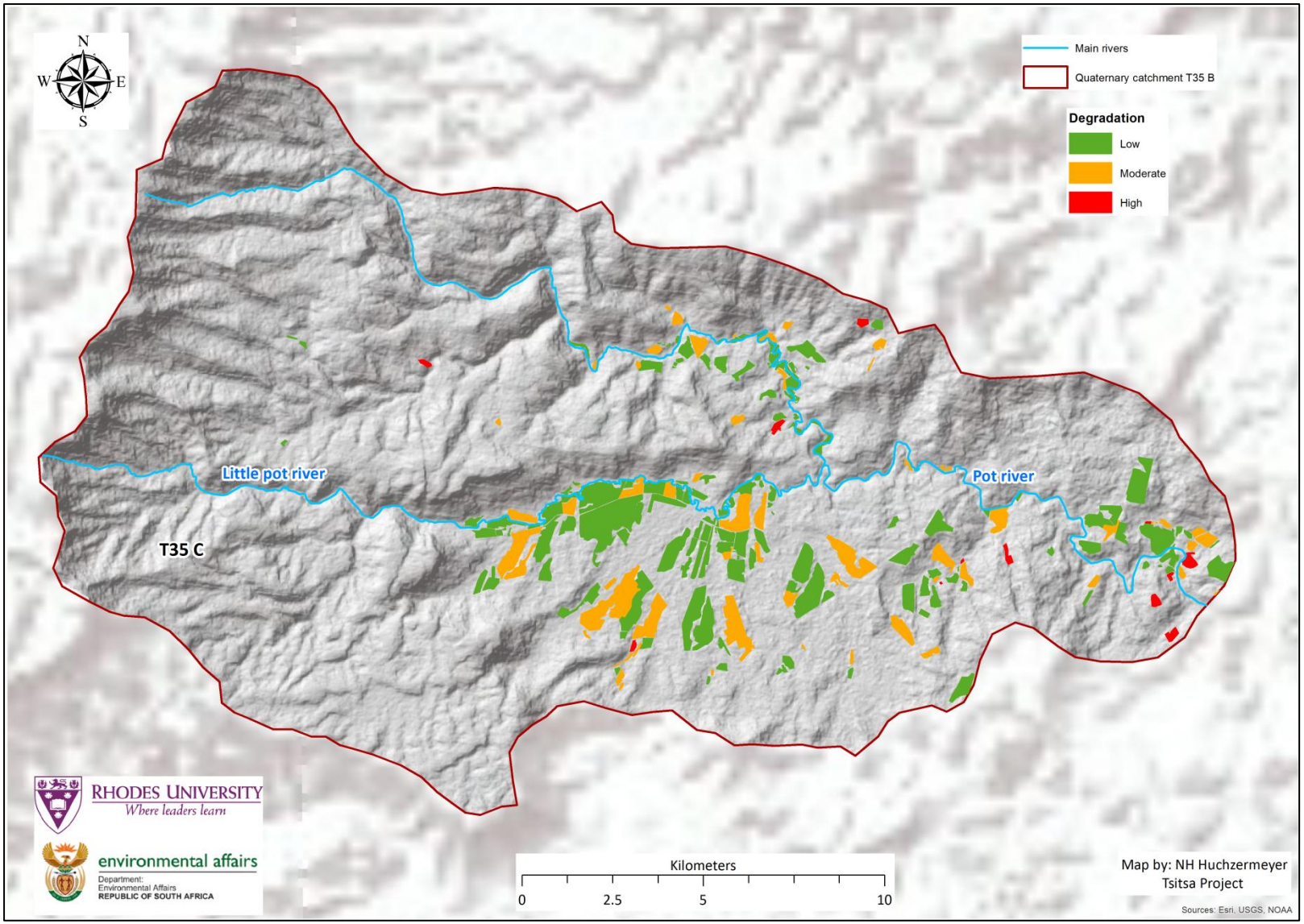

FIGURE 38: CULTIVATED LANDS IN CATCHMENT T35 B CLASSIFIED INTO THREE CLASSES OF DEGRADATION

VULNERABILITY TO EROSION

A total of 216 (2 112 ha) of the cultivated lands exhibited low vulnerability to erosion (82% of total cultivated land area), 35 (452 ha) exhibited moderate vulnerability (18% of total cultivated land area) to erosion and 2 (3 ha) were highly vulnerable (<1% of total cultivated land area) to erosion (Table 21 and Figure 39). Overall, cultivated lands exhibiting low vulnerability to erosion make up 5% of Catchment T35 B, those exhibiting moderate vulnerability make up 1% and highly vulnerable cultivated lands make up 0.01% (Figure 40). This shows that the majority of cultivated lands in Catchment T35 B are not vulnerable to erosion.

TABLE 21: SUMMARY OF THE VULNERABILITY OF CULTIVATED LANDS, IRRESPECTIVE OF THEIR STATUS OR DEGRADATION, IN CATCHMENT T35 B

Vulnerability	No. of cultivated lands	Area H (ha)	Percentage (%) area of cultivated lands	Percentage (%) of Catchment T35 B
Low	216	2 112	82	5
Moderate	35	452	18	1
High	2	3	<1	<1

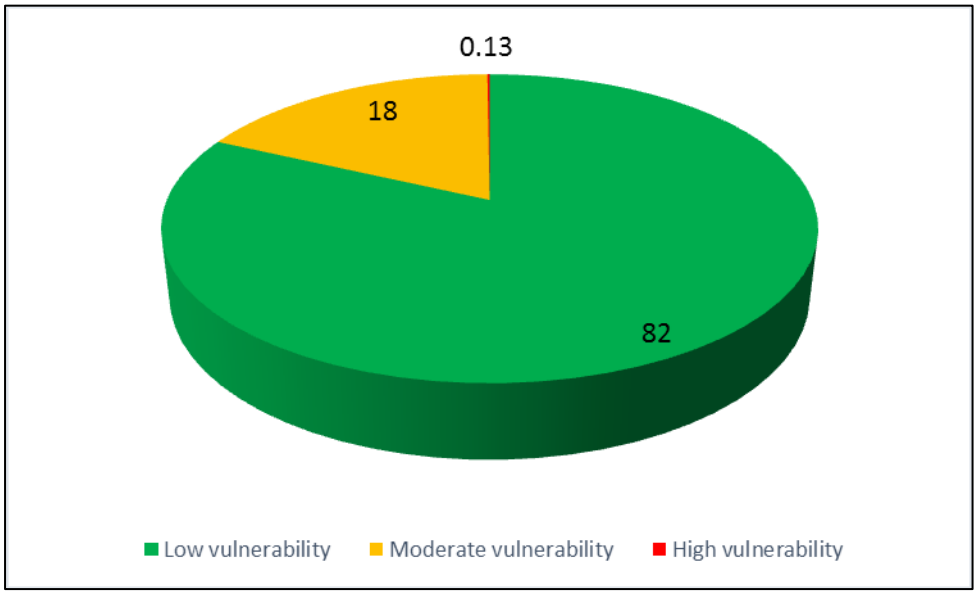

FIGURE 39: PERCENTAGE AREA, OUT OF THE TOTAL CULTIVATED LAND AREA IN CATCHMENT T35 B, COVERED BY DIFFERENT CATEGORIES OF CULTIVATED LAND VULNERABILITY TO EROSION

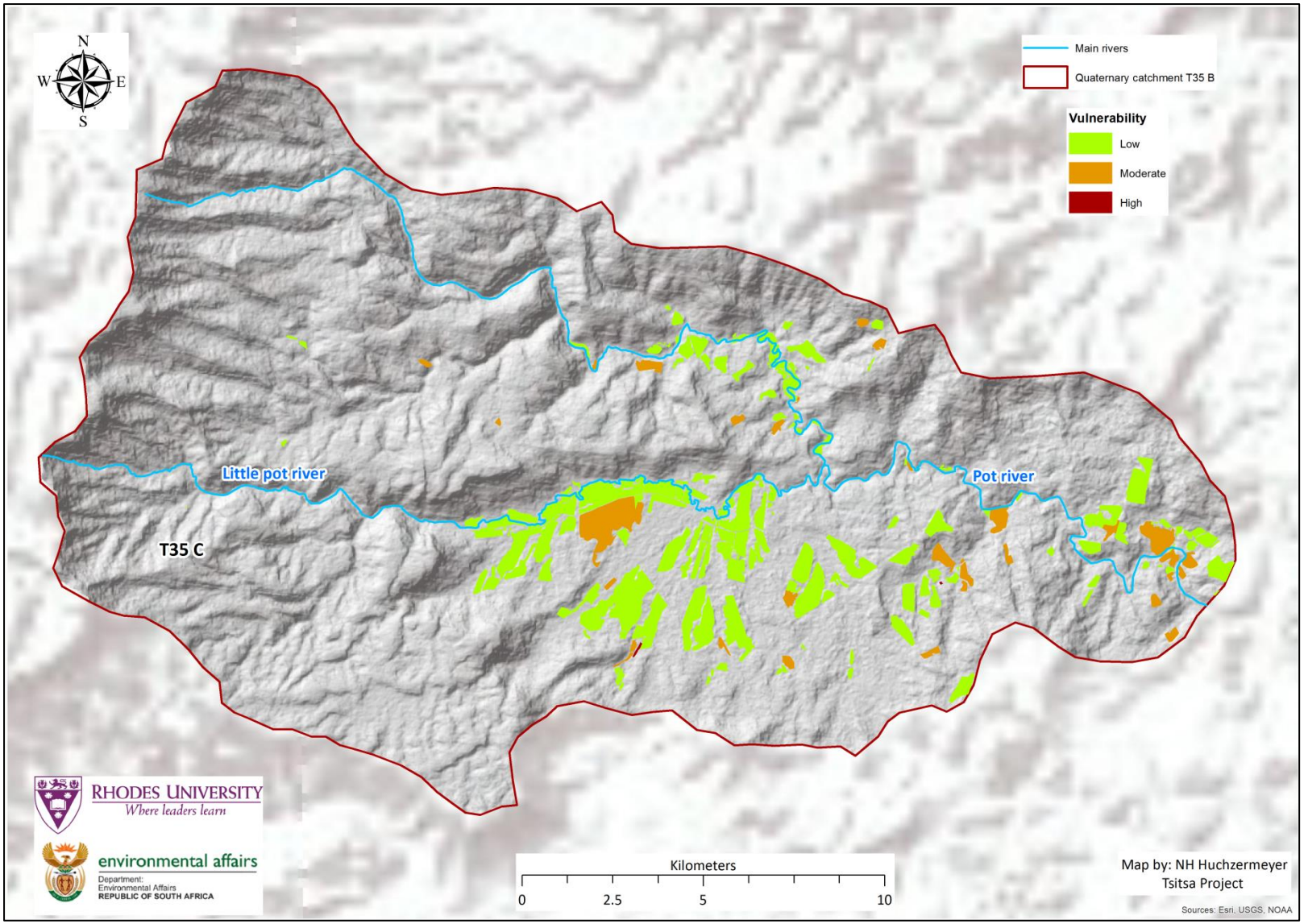

FIGURE 40: CULTIVATED LANDS IN CATCHMENT T35 B CLASSIFIED INTO THREE CLASSES OF VULNERABILITY TO EROSION

ENCROACHMENT

A total of 249 (2 558 ha) of cultivated lands showed little or no encroachment (99% of total cultivated land area) of alien vegetation, 4 (9 ha) showed moderate encroachment (<1% of total cultivated land area) and none showed heavy encroachment (Table 22 and Figure 41). Overall cultivated lands that exhibit little or no encroachment make up 7% of Sub-Catchment T35 B and those that exhibit moderate encroachment make up 0.02% (Figure 42).

TABLE 22: SUMMARY OF ENCROACHMENT IN CULTIVATED LANDS IN CATCHMENT T35 B

Encroachment	No. of cultivated lands	Area H (ha)	Percentage (%) area covered	Percentage (%) of catchment
Little/ none	249	2558	99	7
Moderate	4	9	<1	<1
Heavy	0	0	0	0

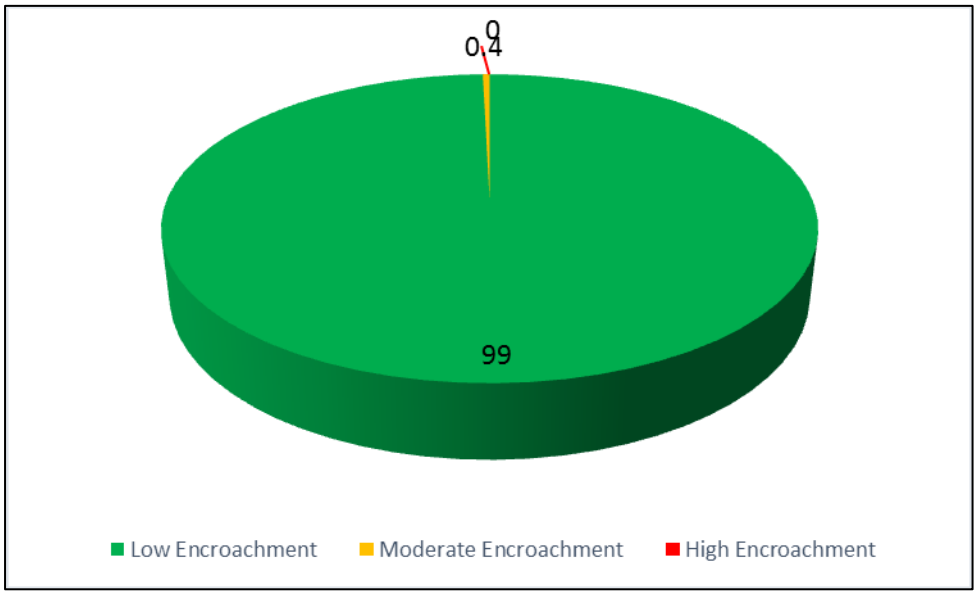

FIGURE 41: PERCENTAGE AREA, OUT OF THE TOTAL CULTIVATED LAND AREA IN CATCHMENT T35 B, COVERED BY DIFFERENT CATEGORIES OF CULTIVATED LAND ENCROACHMENT BY UNWANTED VEGETATION

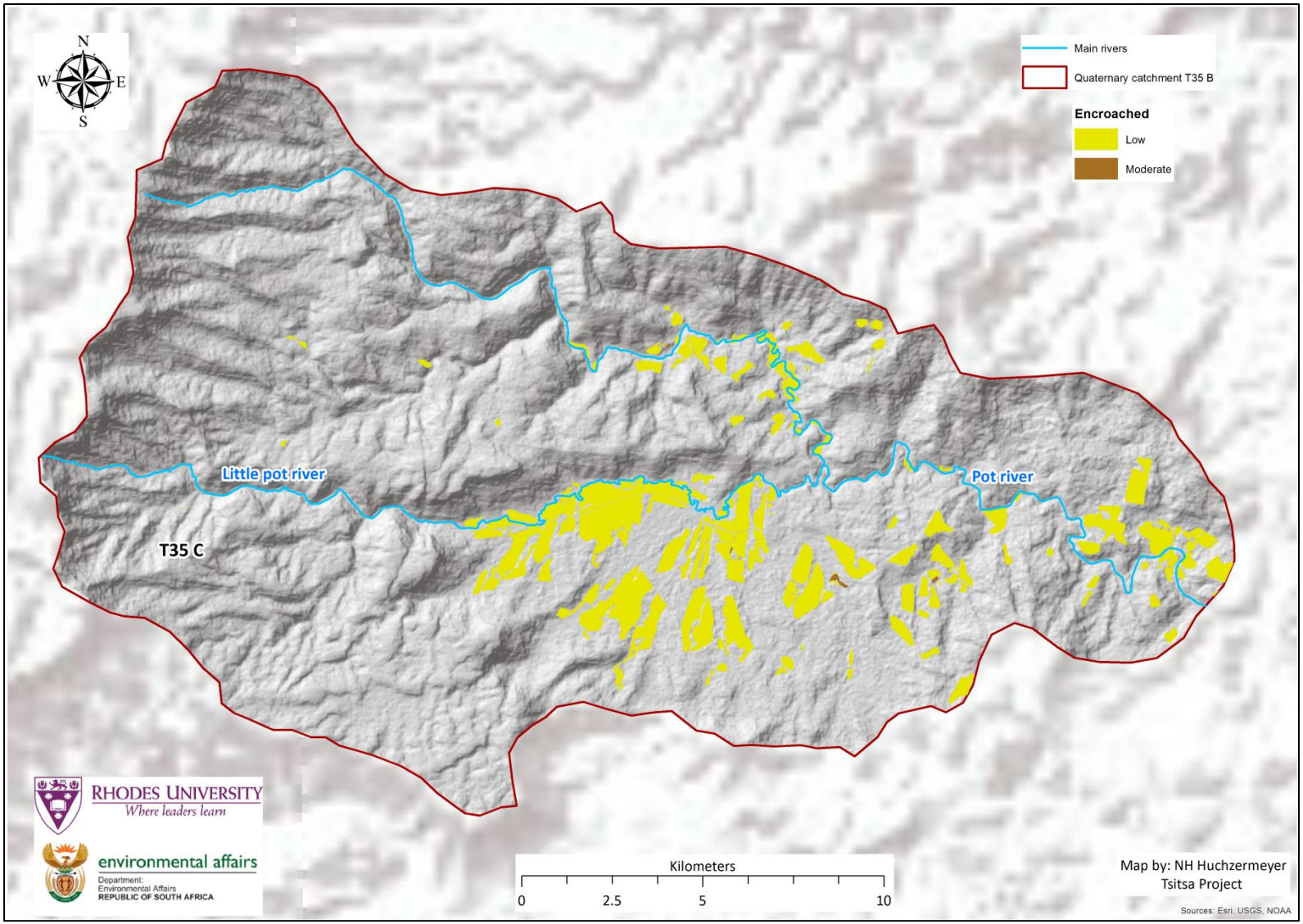

FIGURE 42: CULTIVATED LANDS IN CATCHMENT T35 B CLASSIFIED INTO DIFFERENT LEVELS OF VEGETATION ENCROACHMENT

APPENDIX 3: CULTIVATED LANDS T35 C

A total of 90 cultivated lands were identified in Catchment T35 C (Table 23 and Figure 43). These cover a total area of 531 ha which constitutes 2% of the total catchment area of Catchment T35 C (34 751 ha).

TABLE 23: SUMMARY OF CULTIVATED LANDS IN CATCHMENT T35 C

	Area (ha)	No. of cultivated lands	Area (ha) covered by cultivated lands	Percentage (%) of Catchment T35 C	Percentage (%) of Catchment T35 A-E
Catchment T35 C	34 751	90	531	2	<1

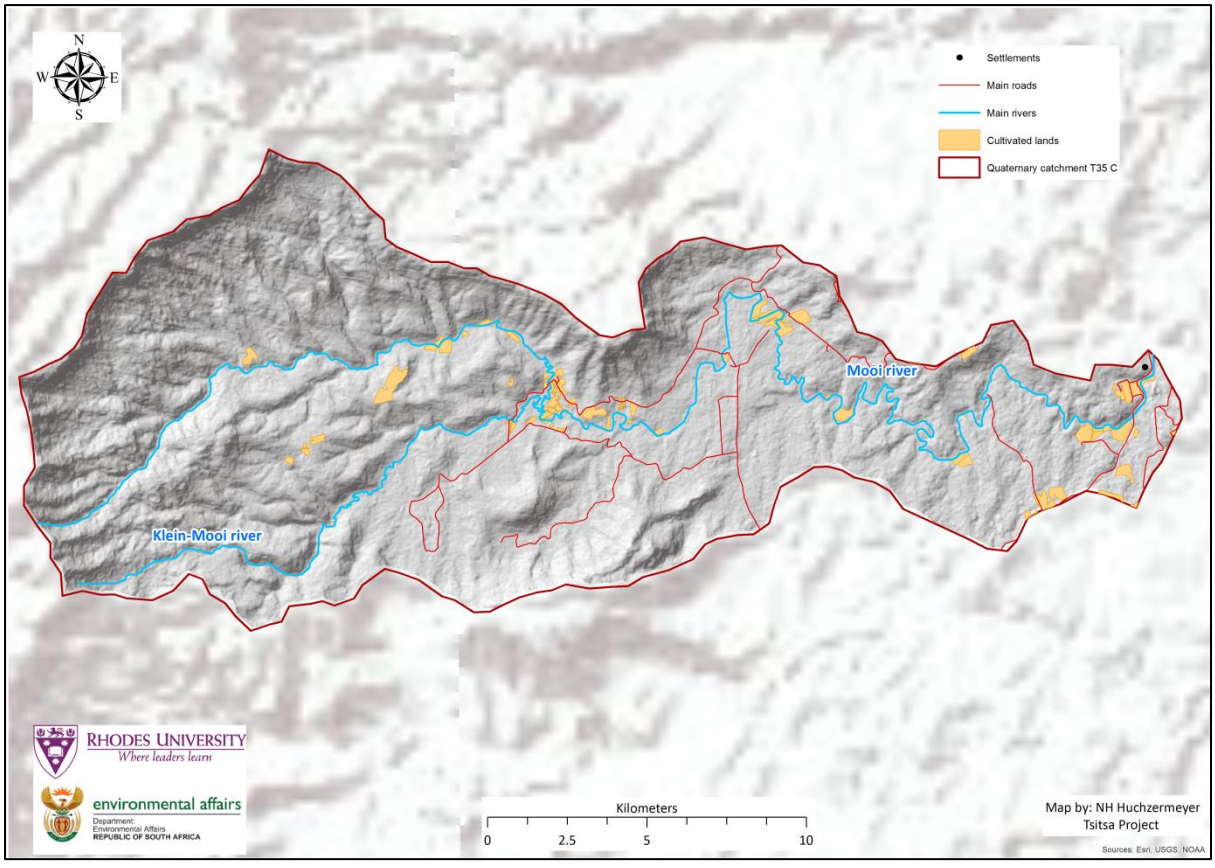

FIGURE 43: LOCATION OF CULTIVATED LANDS IN CATCHMENT T35 C

The results for cultivated lands in terms of current use status, degradation, level of vulnerability to further degradation and level of encroachment by woody vegetation in Catchment T35 C are given below.

Status

A total of 25 (150 ha) of the cultivated lands were used (28% of total cultivated land area), 29 (163 ha) partly used (31% of total cultivated land area) and 36 (218 ha) were abandoned (41% of total cultivated land area) (Table 24 and Figure 44). Abandoned fields make up the greatest proportion of the cultivated lands. In total used fields make up <1% of Catchment T35 C, partly used fields 1 % and abandoned fields 1% (Figure 45).

Table 24: Summary of the status of cultivated lands in Catchment T35 C

Status	No. of cultivated lands	Area H (ha)	Percentage (%) area of cultivated lands	Percentage (%) of Catchment T35 C
Clearly used	25	150	28	<1
Partly used	29	163	31	1
Abandoned	36	218	41	1

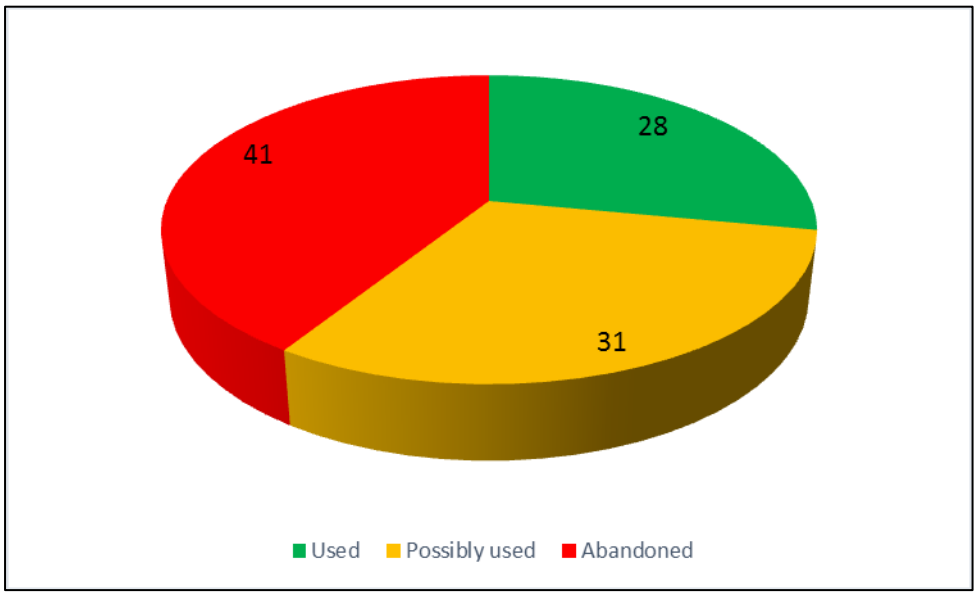

Figure 44: Percentage area, out of the total cultivated land area in Catchment T35 C, covered by each category of cultivated lands

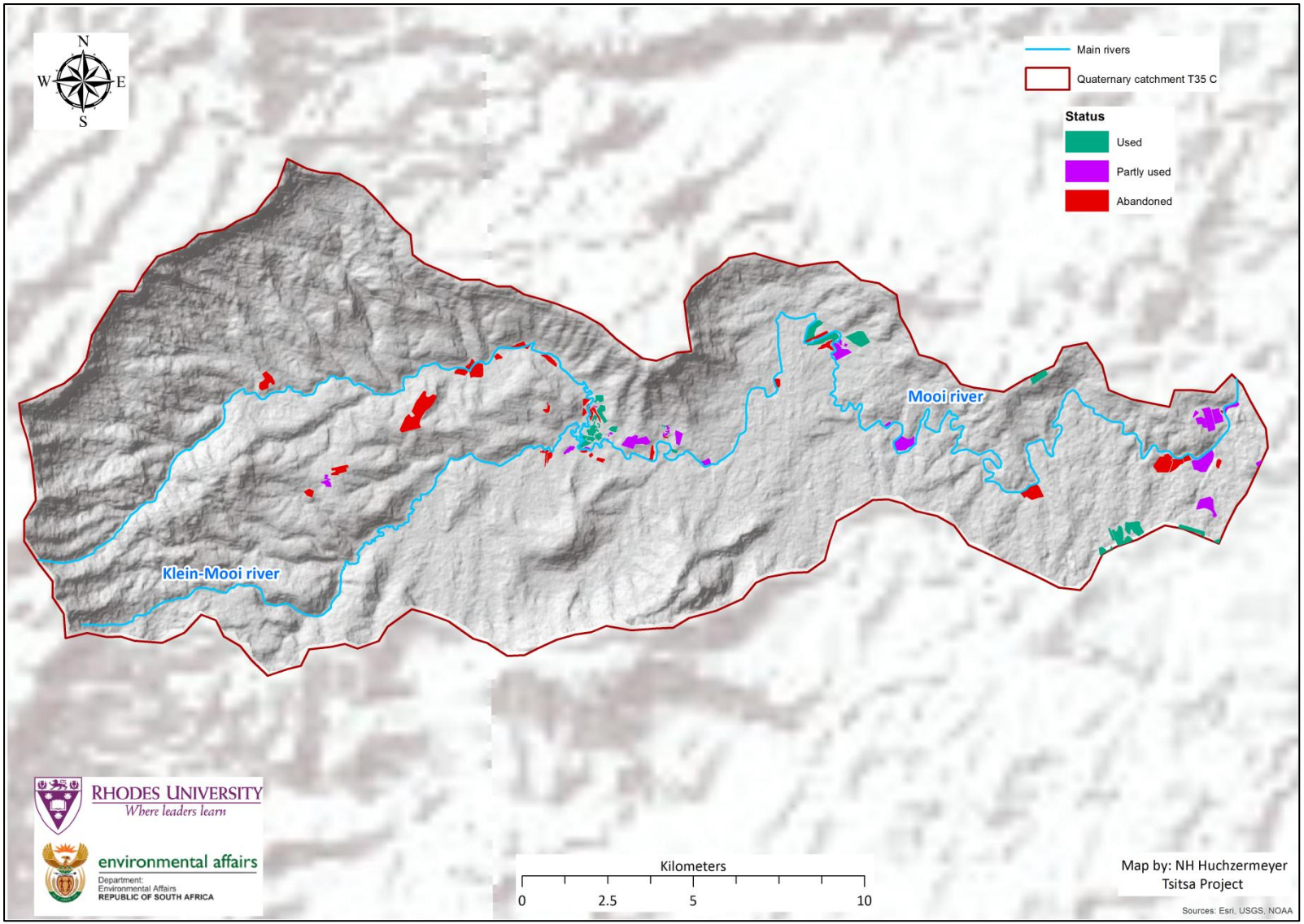

FIGURE 45: CULTIVATED LANDS CLASSIFIED INTO USAGE STATUS IN CATCHMENT T35 C

DEGRADATION

A total of 73 (330 ha) cultivated lands showed little or no degradation (62% of total cultivated land area), 14 (168 ha) showed moderate levels of degradation (32% of total cultivated land area) and 3 (33 ha) showed widespread degradation (6% of total cultivated land area) (Table 25 and Figure 46). In total cultivated lands exhibiting low degradation make up 1%, moderately degraded cultivated lands make up 1% and highly degraded cultivated lands make up <1% of Catchment T35 C (Figure 47).

TABLE 25: SUMMARY OF DEGRADED CULTIVATED LANDS, IRRESPECTIVE OF STATUS, IN CATCHMENT T35 C

Degradation	No. of cultivated lands	Area H (ha)	Percentage (%) area of cultivated lands	Percentage (%) of Catchment T35 C
Low	73	330	62	1
Moderate	14	168	32	1
High	3	33	6	<1

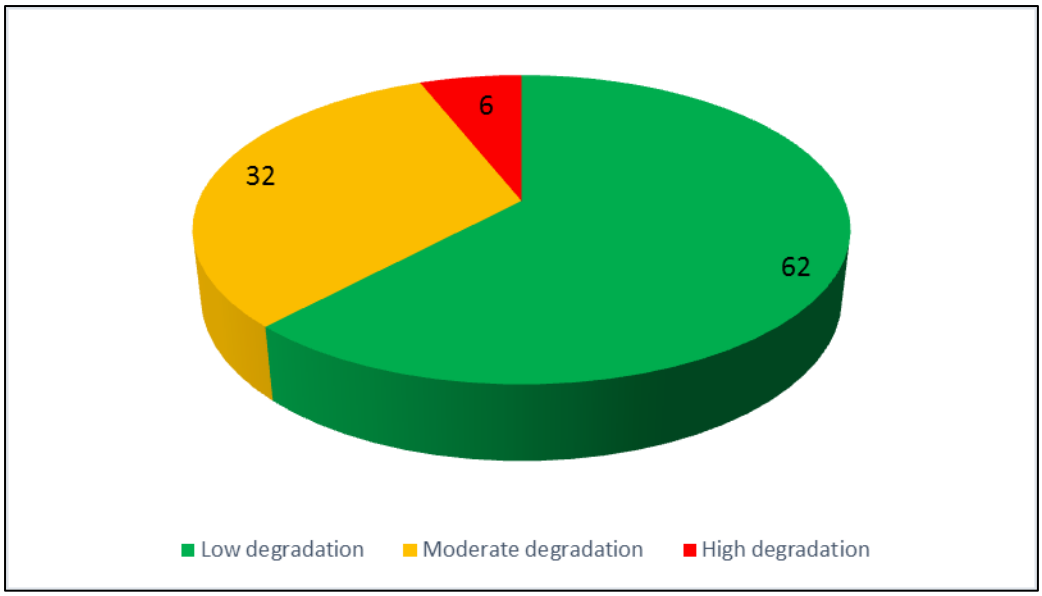

FIGURE 46: PERCENTAGE AREA, OUT OF THE TOTAL CULTIVATED LAND AREA IN CATCHMENT T35 C, COVERED BY DIFFERENT CATEGORIES OF CULTIVATED LAND DEGRADATION

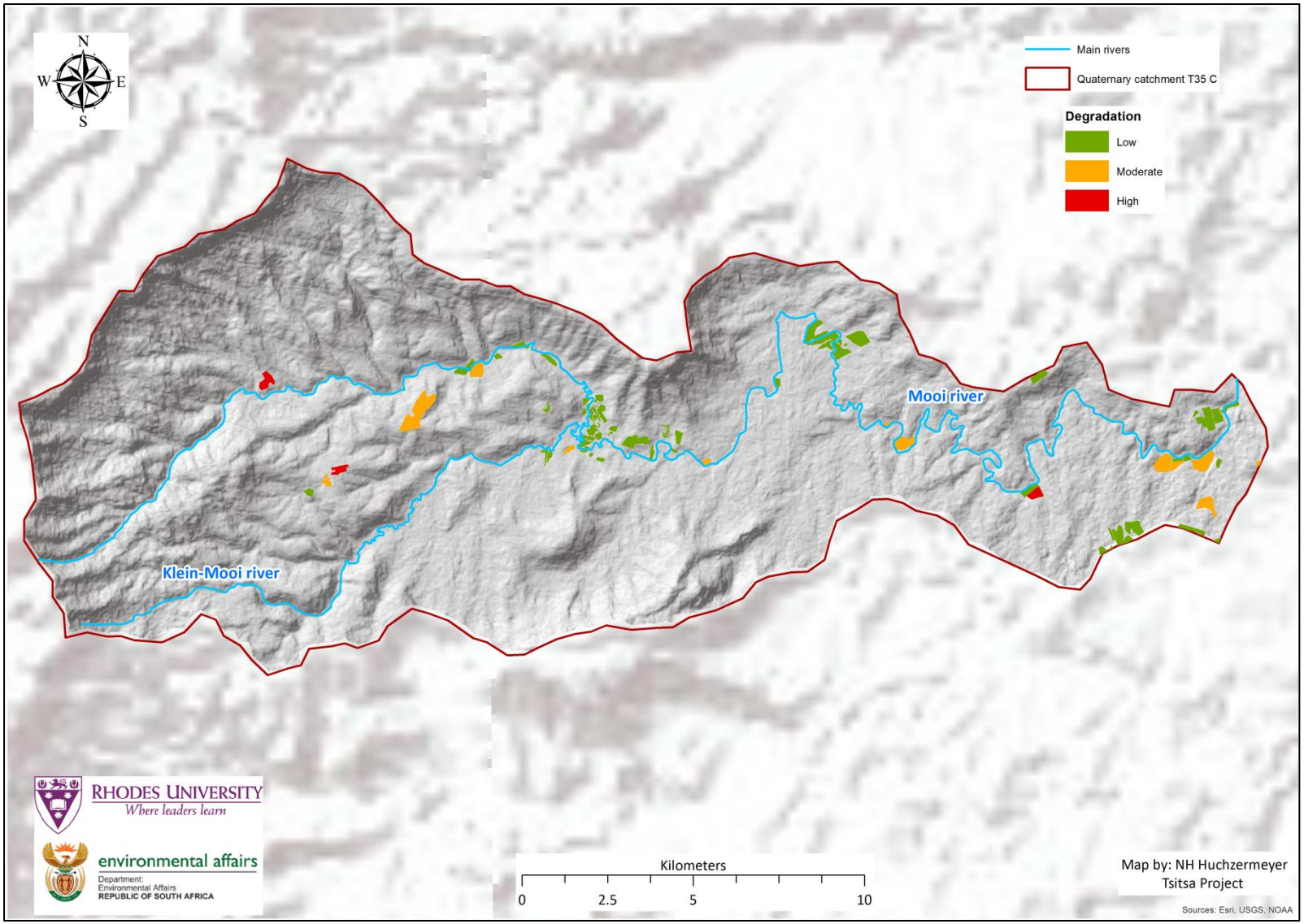

FIGURE 47: CULTIVATED LANDS IN CATCHMENT T35 C CLASSIFIED INTO THREE CLASSES OF DEGRADATION

VULNERABILITY TO EROSION

A total of 87 (498 ha) of the cultivated lands exhibited low vulnerability to erosion (94% of total cultivated land area), 3 (33 ha) exhibited moderate vulnerability (6% of total cultivated land area) to erosion and none were highly vulnerable to erosion (Table 26 and Figure 48). Overall, cultivated lands exhibiting low vulnerability to erosion make up 1.4% of Catchment T35 C, those exhibiting moderate vulnerability make up 0.1% (Figure 49).

TABLE 26: SUMMARY OF THE VULNERABILITY OF CULTIVATED LANDS, IRRESPECTIVE OF THEIR STATUS OR DEGRADATION, IN CATCHMENT T35 A-E

Vulnerability	No. of cultivated lands	Area H (ha)	Percentage (%) area of cultivated lands	Percentage (%) of Catchment T35 C
Low	87	498	94	1
Moderate	3	33	6	<1
High	0	0	0	0

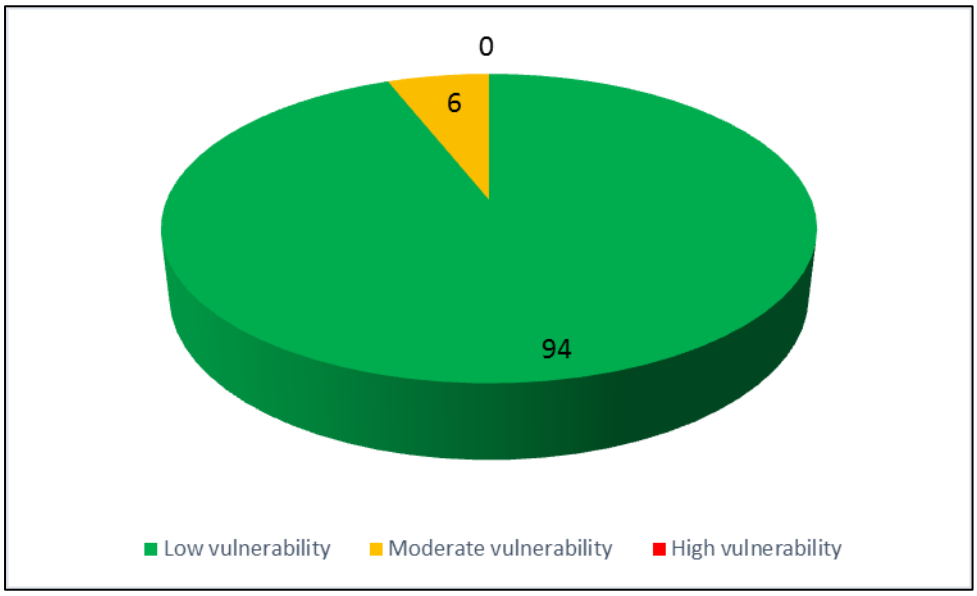

FIGURE 48: PERCENTAGE AREA, OUT OF THE TOTAL CULTIVATED LAND AREA IN CATCHMENT T35 C, COVERED BY DIFFERENT CATEGORIES OF CULTIVATED LAND VULNERABILITY TO EROSION

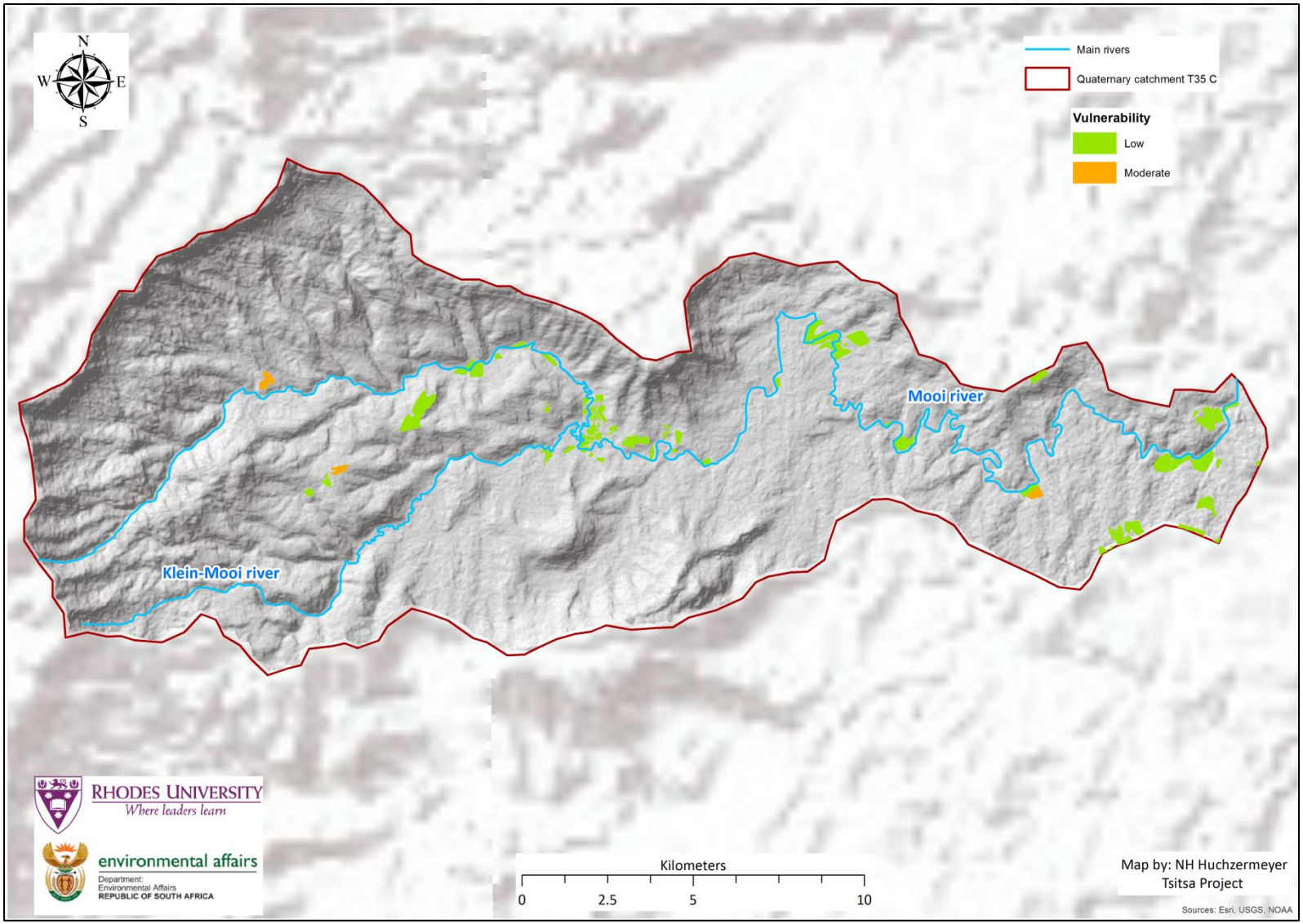

FIGURE 49: CULTIVATED LANDS IN CATCHMENT T35 C CLASSIFIED INTO THREE CLASSES OF VULNERABILITY TO EROSION

ENCROACHMENT

A total of 89 (481 ha) of cultivated lands showed little or no encroachment (91% of total cultivated land area) of alien vegetation no cultivated lands showed moderate encroachment, while only 1 (50 ha) showed heavy encroachment (9% of total cultivated land area) (Table 27 and Figure 50). Overall cultivated lands that exhibit little or no encroachment make up 1% of Catchment T35 C and heavily encroached lands make up less than 1% (Figure 51).

TABLE 27: SUMMARY OF ENCROACHMENT IN CULTIVATED LANDS IN CATCHMENT T35 C

Encroachment	No. of cultivated lands	Area H (ha)	Percentage (%) area covered	Percentage (%) of catchment
Little/ none	89	481	91	1
Moderate	0	0	0	0
Heavy	1	50	9	<1

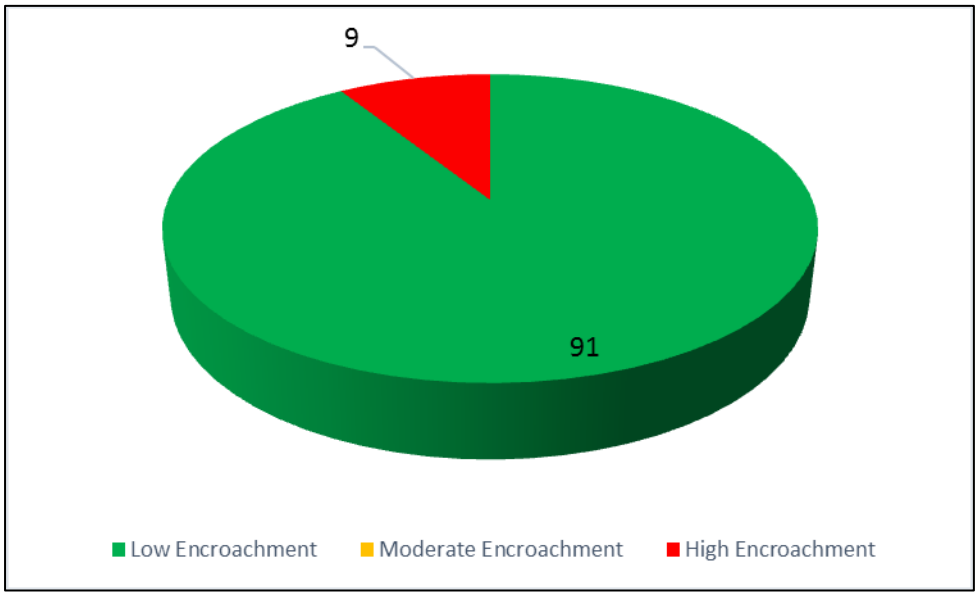

FIGURE 50: PERCENTAGE AREA, OUT OF THE TOTAL CULTIVATED LAND AREA IN CATCHMENT T35 C, COVERED BY DIFFERENT CATEGORIES OF CULTIVATED LAND ENCROACHMENT BY UNWANTED VEGETATION

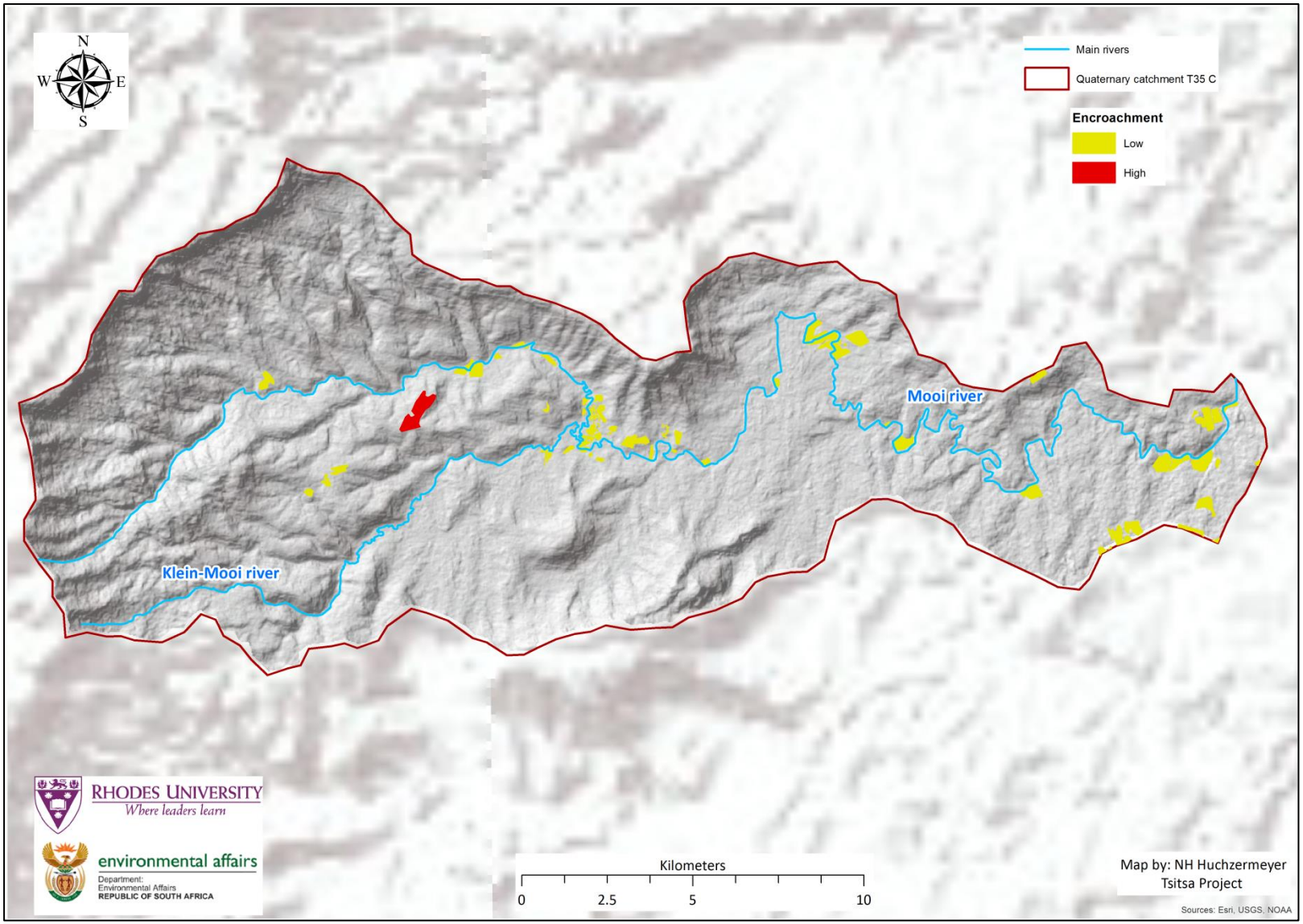

FIGURE 51: CULTIVATED LANDS IN CATCHMENT T35 C CLASSIFIED INTO DIFFERENT LEVELS OF VEGETATION ENCROACHMENT

APPENDIX 4: CULTIVATED LANDS T35 D

A total of 1 317 cultivated lands were identified in Catchment T35 D (Table 28 and Figure 52). These cover a total area of 9 147 ha which constitutes 19% of the total catchment area of T35 D (49 176 ha).

TABLE 28: SUMMARY OF CULTIVATED LANDS IN CATCHMENT T35 D

	Area (ha)	No. of cultivated lands	Area (ha) covered by cultivated lands	Percentage (%) of Catchment T35 D	Percentage (%) of Catchment T35 A-E
Catchment T35 D	49 176	1317	9 147	19	5

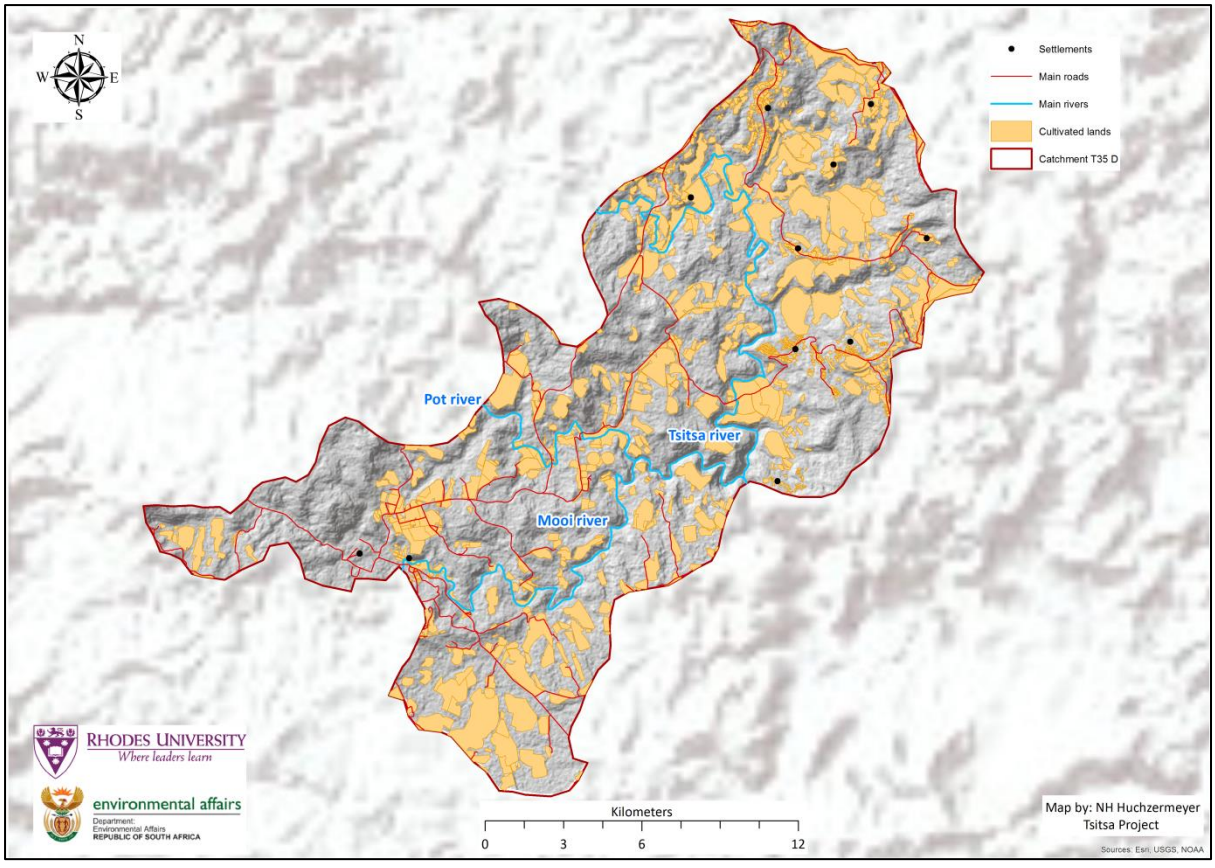

FIGURE 52: LOCATION OF CULTIVATED LANDS IN CATCHMENT T35 D

The results for cultivated lands in terms of current use status, degradation, level of vulnerability to further degradation and level of encroachment by woody vegetation for Catchment T35 D are given below.

Status

A total of 397 (3 579 ha) of the cultivated lands were used (39% of total cultivated land area), 483 (2 732 ha) partly used (30% of total cultivated land area) and 437 (2 836 ha) were abandoned (31% of total cultivated land area) (Table 29 and Figure 53). In total used fields make up 7% of Catchment T35 D, partly used fields 6% and abandoned fields 6% (Figure 54).

Table 29: Summary of the status of cultivated lands in Catchment T35 D

Status	No. of cultivated lands	Area H (ha)	Percentage (%) area of cultivated lands	Percentage (%) of Catchment T35 D
Clearly used	397	3 579	39	7
Partly used	483	2 732	30	6
Abandoned	437	2 836	31	6

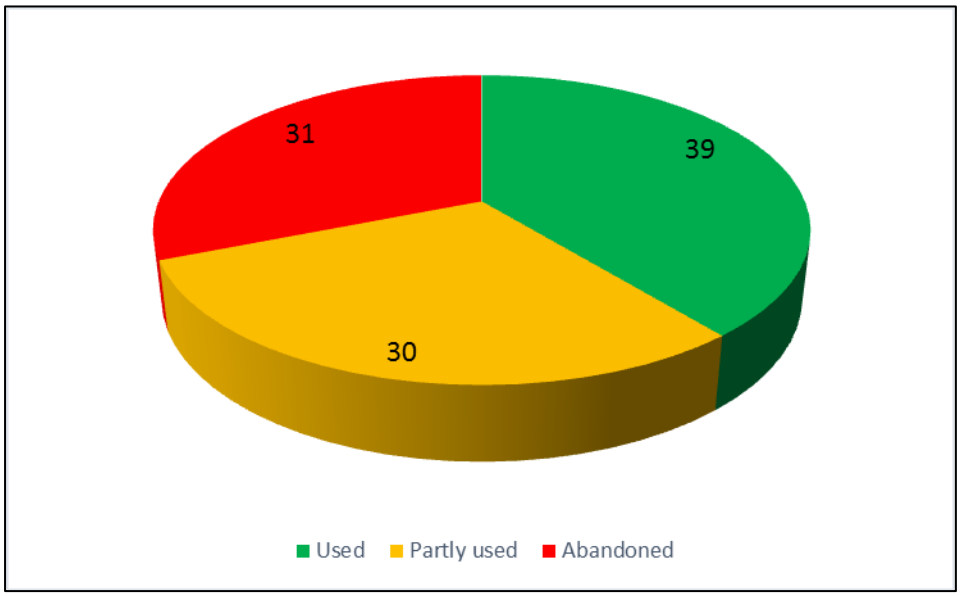

Figure 53: Percentage area, out of the total cultivated land area in Catchment T35 D, covered by each category of cultivated lands

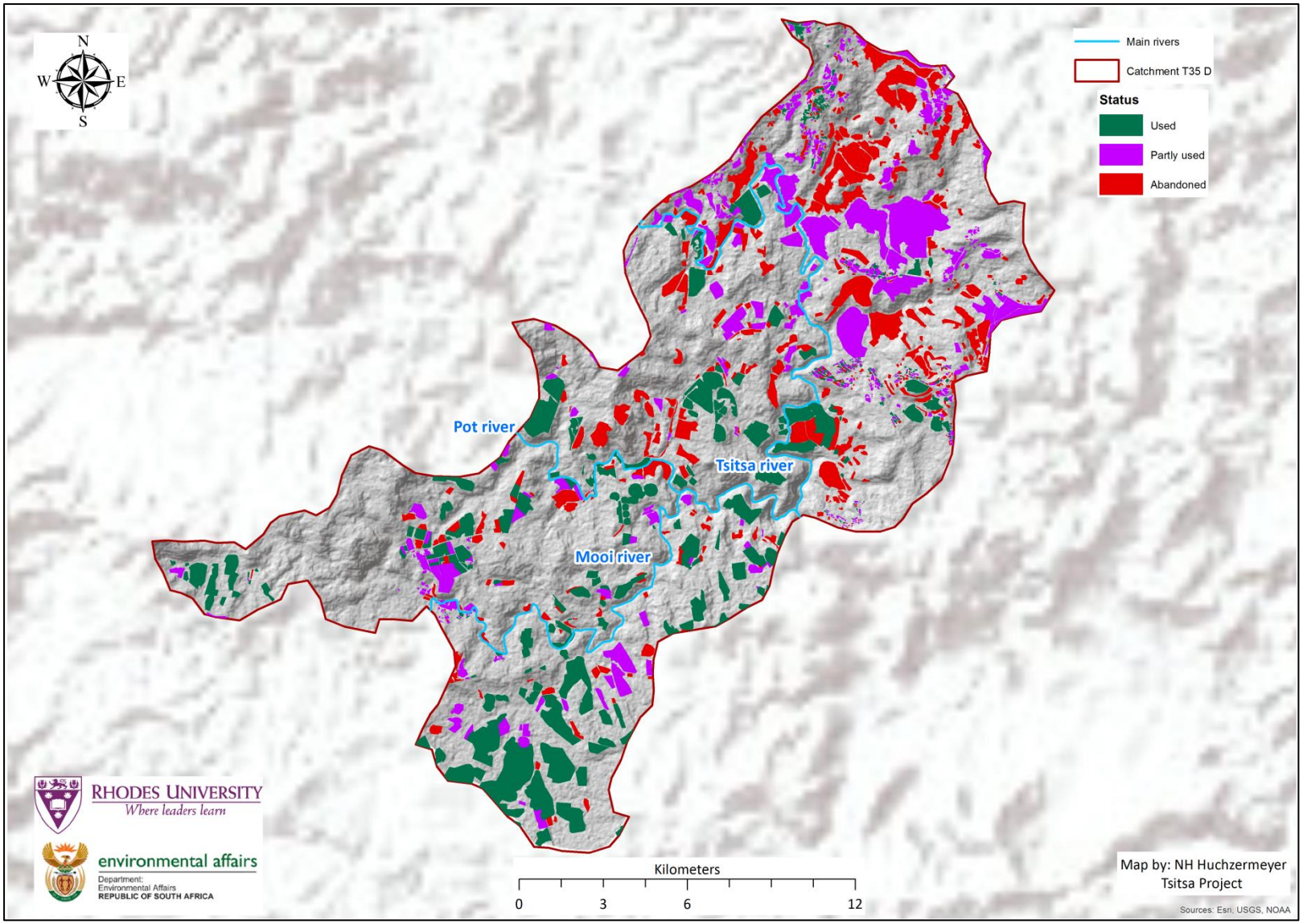

FIGURE 54: CULTIVATED LANDS CLASSIFIED INTO USAGE STATUS IN CATCHMENT T35 D

DEGRADATION

A total of 653 (3 937 ha) cultivated lands showed little or no degradation (43% of total cultivated land area), 467 (2 847 ha) showed moderate levels of degradation (31% of total cultivated land area) and 197 (2 363 ha) showed degradation (26% of total cultivated land area) (Table 30 and Figure 55). In total, cultivated lands exhibiting low degradation make up 8%, moderately degraded cultivated lands make up 6% and highly degraded cultivated lands make up 5% of Catchment T35 D (Figure 56).

TABLE 30: SUMMARY OF DEGRADED CULTIVATED LANDS, IRRESPECTIVE OF STATUS, IN CATCHMENT T35 D

Degradation	No. of cultivated lands	Area H (ha)	Percentage (%) area of cultivated lands	Percentage (%) of Catchment T35 D
Low	653	3 937	43	8
Moderate	467	2 847	31	6
High	197	2 363	26	5

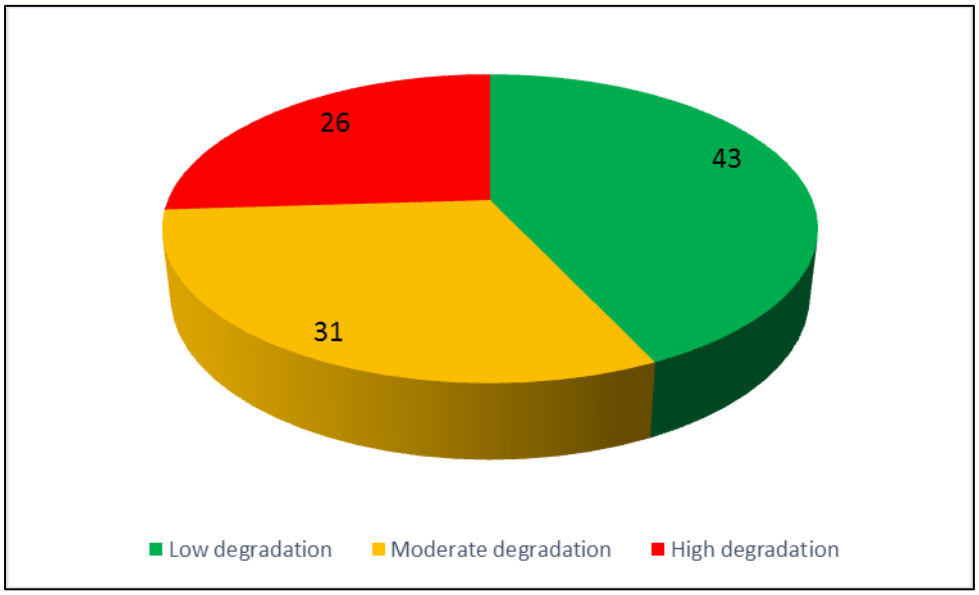

FIGURE 55: PERCENTAGE AREA, OUT OF THE TOTAL CULTIVATED LAND AREA IN CATCHMENT T35 D, COVERED BY DIFFERENT CATEGORIES OF CULTIVATED LAND DEGRADATION

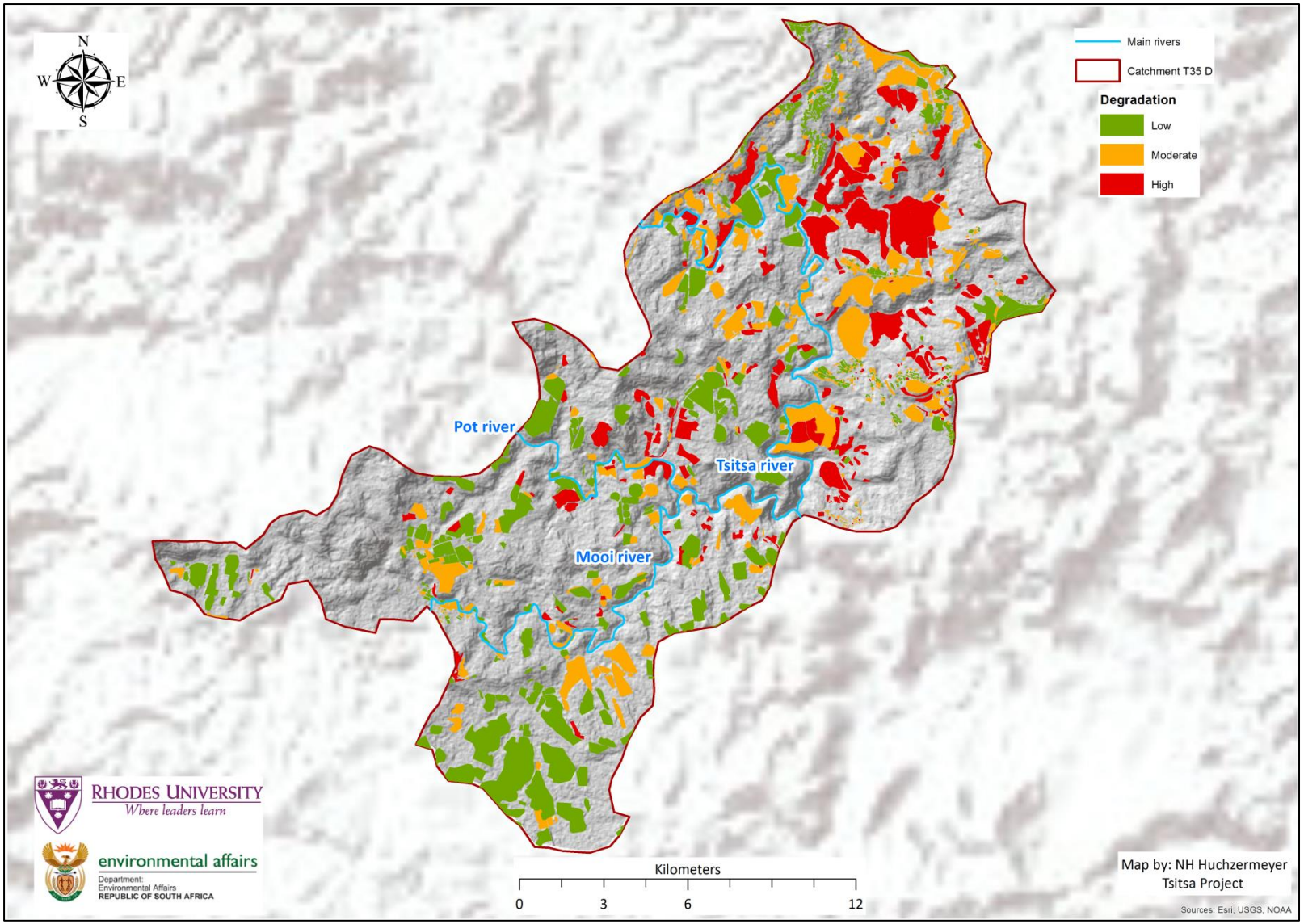

FIGURE 56: CULTIVATED LANDS IN CATCHMENT T35 D CLASSIFIED INTO THREE CLASSES OF DEGRADATION

VULNERABILITY TO EROSION

A total of 846 (4 775 ha) of the cultivated lands exhibited low vulnerability to erosion (52% of total cultivated land area), 373 (2 231 ha) exhibited moderate vulnerability (25% of total cultivated land area) to erosion and 98 (2 141 ha) were highly vulnerable (23% of total cultivated land area) to erosion (Table 31 and Figure 57). Overall, cultivated lands exhibiting low vulnerability to erosion make up 10% of Catchment T35 D, those exhibiting moderate vulnerability make up 5% and highly vulnerable cultivated lands make up 4% (Figure 58).

TABLE 31: SUMMARY OF THE VULNERABILITY OF CULTIVATED LANDS, IRRESPECTIVE OF THEIR STATUS OR DEGRADATION, IN CATCHMENT T35 D

Vulnerability	No. of cultivated lands	Area H (ha)	Percentage (%) area of cultivated lands	Percentage (%) of Catchment T35 D
Low	846	4 775	52	10
Moderate	373	2 231	25	5
High	98	2 141	23	4

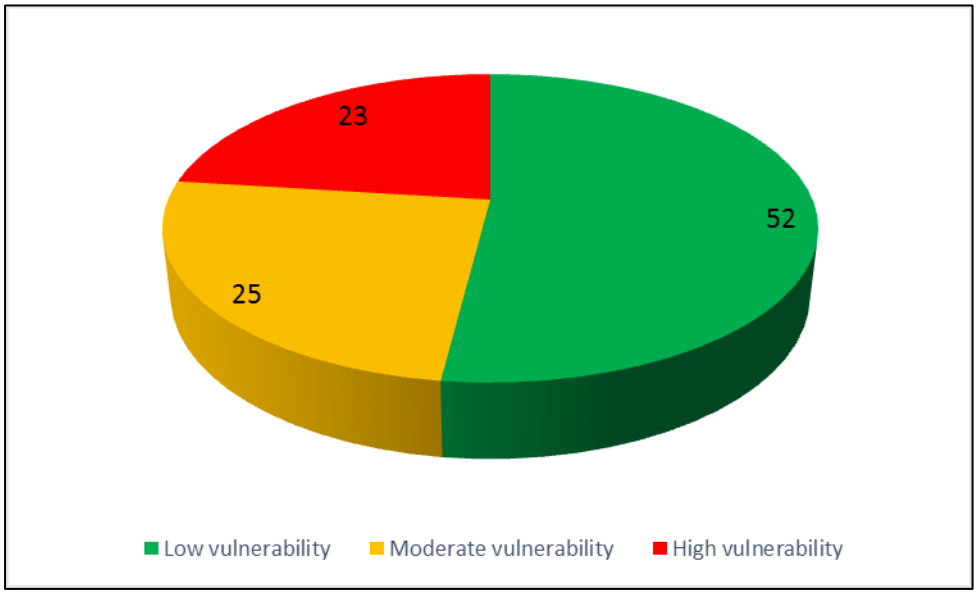

FIGURE 57: PERCENTAGE AREA, OUT OF THE TOTAL CULTIVATED LAND AREA IN CATCHMENT T35 D, COVERED BY DIFFERENT CATEGORIES OF CULTIVATED LAND VULNERABILITY TO EROSION

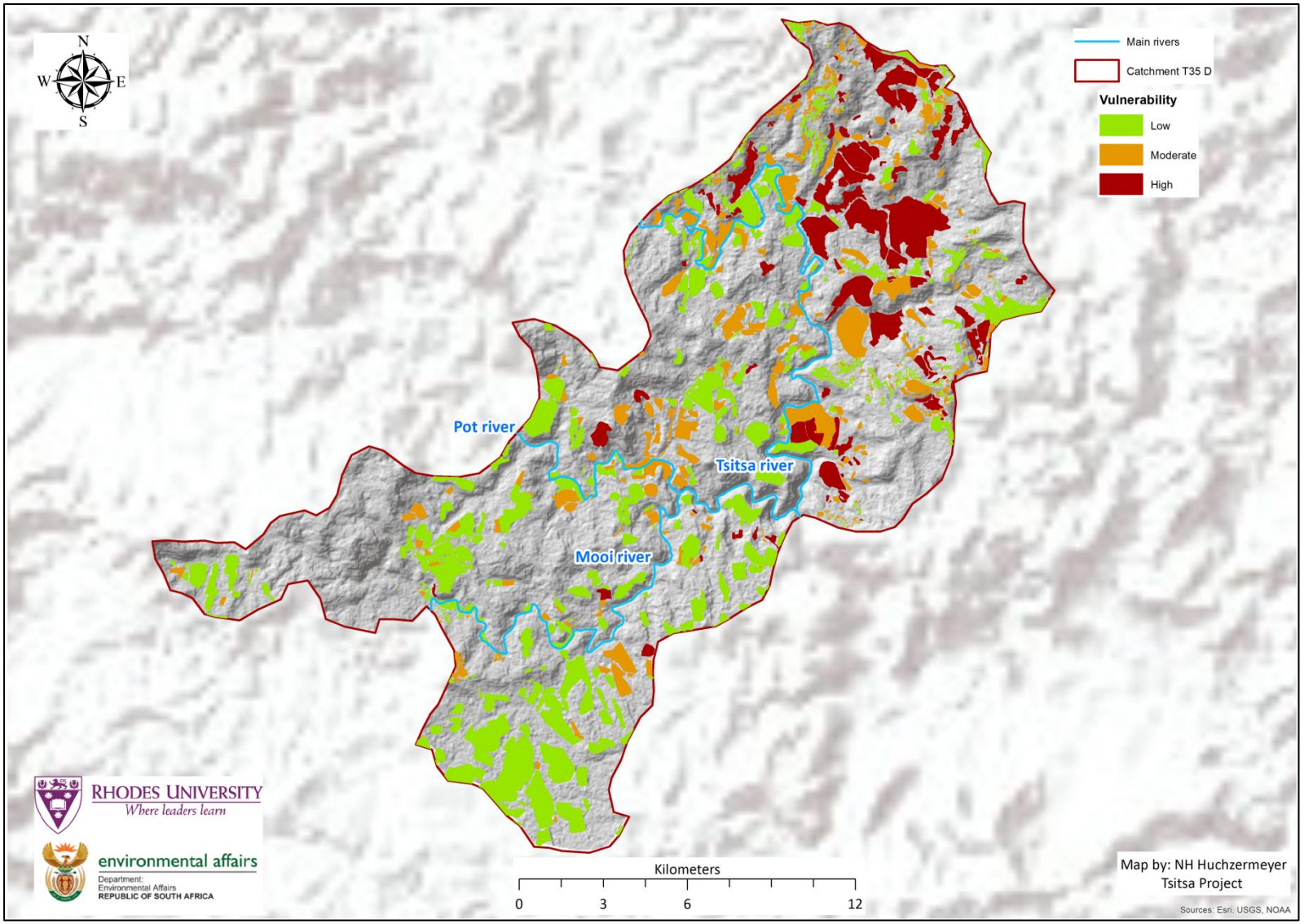

FIGURE 58: CULTIVATED LANDS IN CATCHMENT T35 D CLASSIFIED INTO THREE CLASSES OF VULNERABILITY TO EROSION

ENCROACHMENT

A total of 1 231 (8 373 ha) of cultivated lands showed little or no encroachment (92% of total cultivated land area) of alien vegetation, 71 (710 ha) showed moderate encroachment (7% of total cultivated land area) and 15 (64 ha) showed heavy encroachment (1% of total cultivated land area) (Table 32 and Figure 59). Overall cultivated lands that exhibit little or no encroachment make up 17% of Catchment T35 D, those that exhibit moderate encroachment make up 2% and heavily encroached lands make up less than 1% (Figure 60).

TABLE 32: SUMMARY OF ENCROACHMENT IN CULTIVATED LANDS IN CATCHMENT T35 D

Encroachment	No. of cultivated lands	Area H (ha)	Percentage (%) area covered	Percentage (%) of catchment
Little/ none	1 231	8 373	92	17
Moderate	71	710	7	2
Heavy	15	64	1	<1

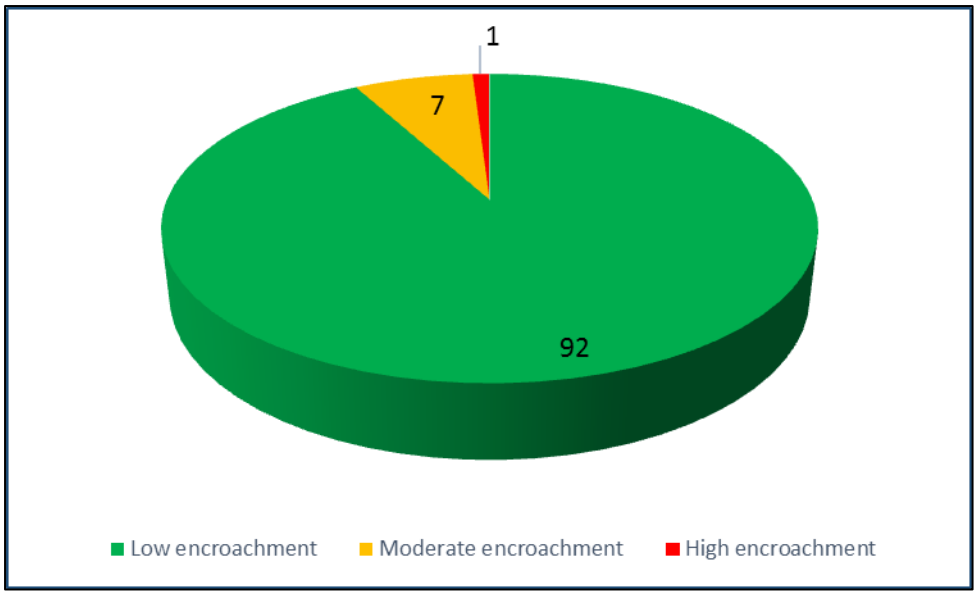

FIGURE 59: PERCENTAGE AREA, OUT OF THE TOTAL CULTIVATED LAND AREA IN CATCHMENT T35 D, COVERED BY DIFFERENT CATEGORIES OF CULTIVATED LAND ENCROACHMENT BY UNWANTED VEGETATION

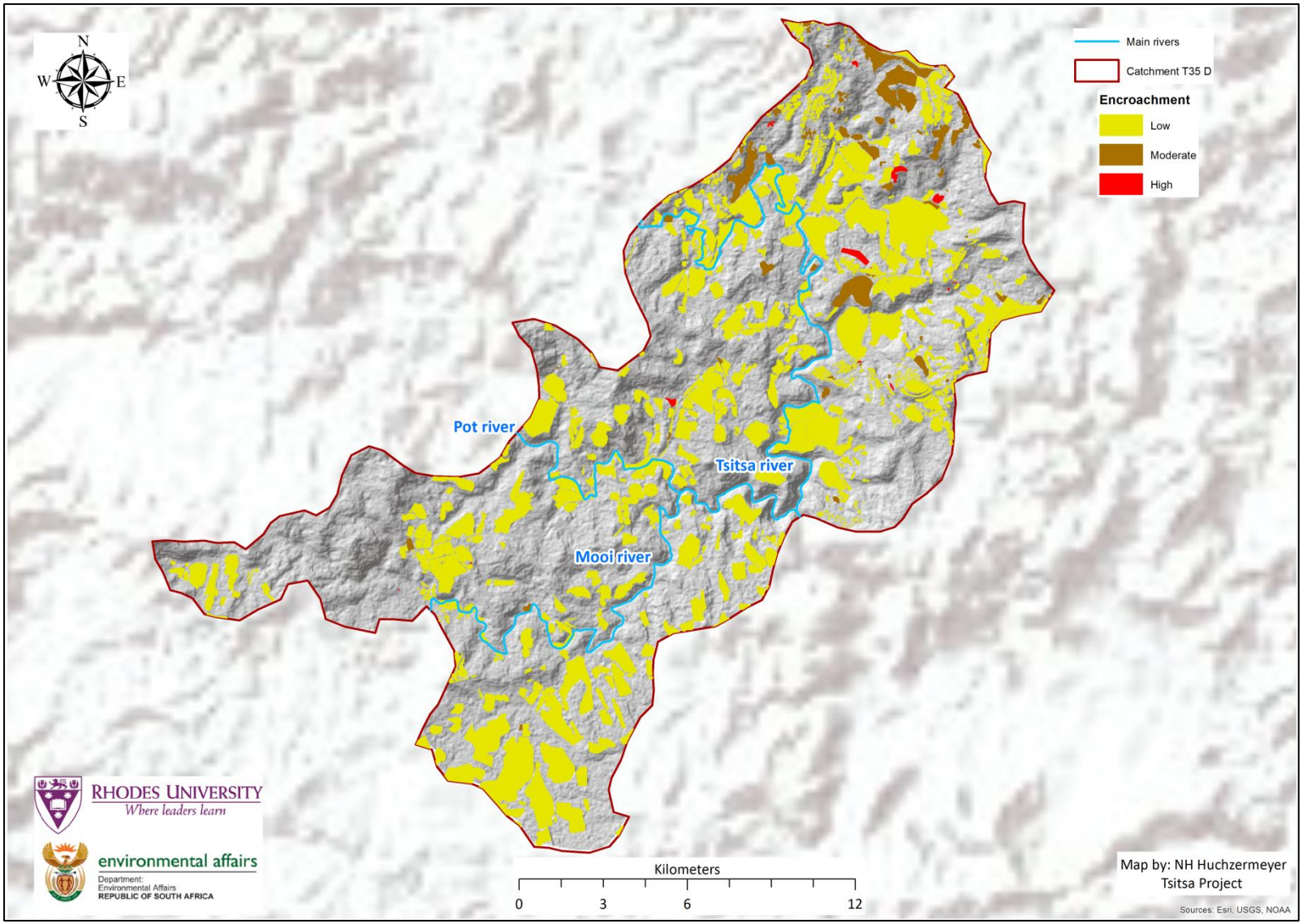

FIGURE 60: CULTIVATED LANDS IN CATCHMENT T35 D CLASSIFIED INTO DIFFERENT LEVELS OF VEGETATION ENCROACHMENT

APPENDIX 5: CULTIVATED LANDS T35 E

A total of 3 964 cultivated lands were identified in Catchment T35 E (Table 33 and Figure 61). These cover a total area of 13 298 ha which constitutes 43% of the total catchment area of T35 E (30 610 ha).

TABLE 33: SUMMARY OF CULTIVATED LANDS IN CATCHMENT T35 E

	Area (ha)	No. of cultivated lands	Area (ha) covered by cultivated lands	Percentage (%) of Catchment T35 E	Percentage (%) of Catchment T35 A-E
Catchment T35 E	30 610	3 954	13 298	43	6

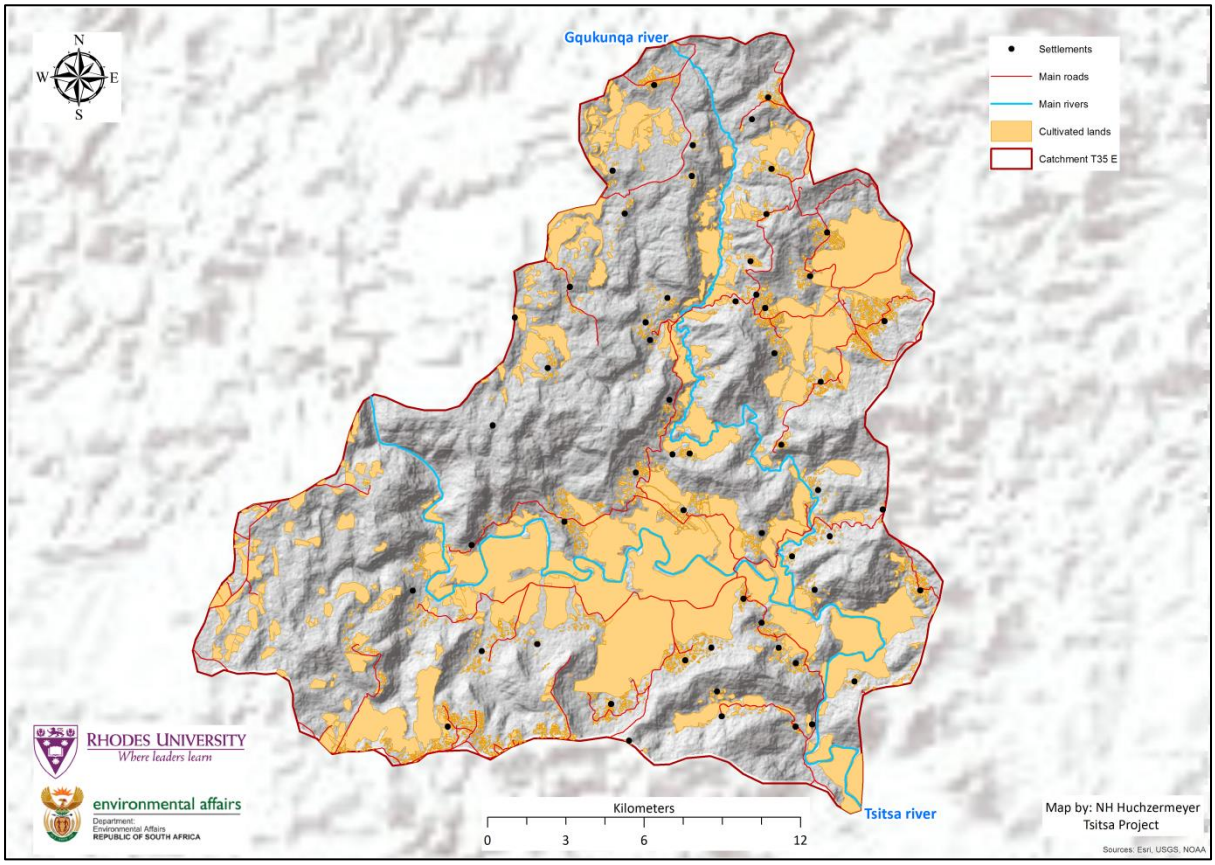

FIGURE 61: LOCATION OF CULTIVATED LANDS IN CATCHMENT T35 E

The results for cultivated lands in terms of current use status, degradation, level of vulnerability to further degradation and level of encroachment by woody vegetation for Catchment T35 E are given below.

Status

A total of 1 737 (1 336 ha) of the cultivated lands were used (10% of total cultivated land area), 1 357 (3 901 ha) partly used (29% of total cultivated land area) and 860 (8 061 ha) were abandoned (61% of total cultivated land area) (Table 34 and Figure 62). Abandoned fields make up the greatest proportion of the cultivated lands. In total used fields make up 4% of Catchment T35 E, partly used fields 13% and abandoned fields 26% (Figure 63).

Table 34: Summary of the status of cultivated lands in Catchment T35 E

Status	No. of cultivated lands	Area H (ha)	Percentage (%) area of cultivated lands	Percentage (%) of Catchment T35 E
Clearly used	1 737	1 336	10	4
Partly used	1 357	3 901	29	13
Abandoned	860	8 061	61	26

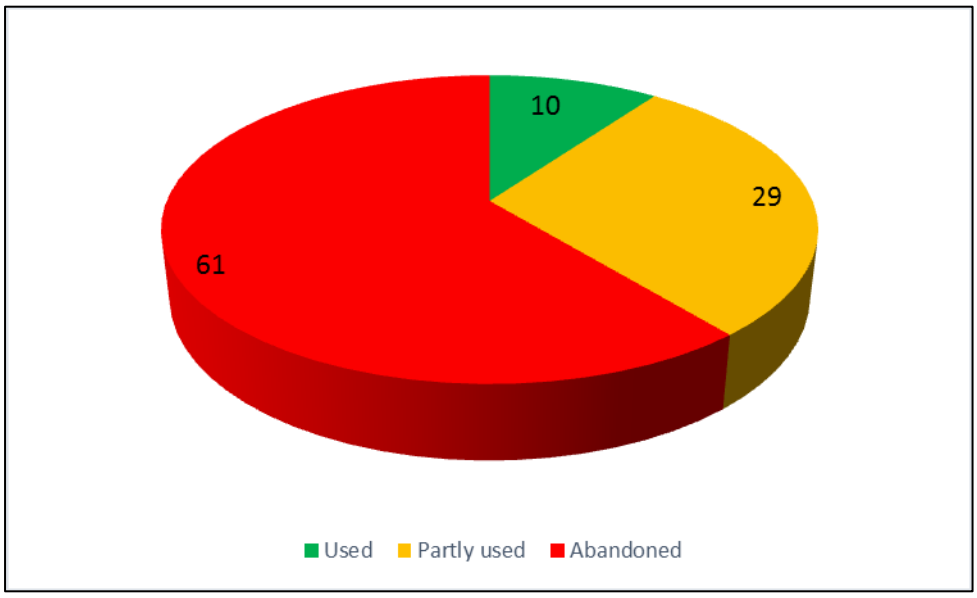

Figure 62: Percentage area, out of the total cultivated land area in Catchment T35 E, covered by each category of cultivated lands

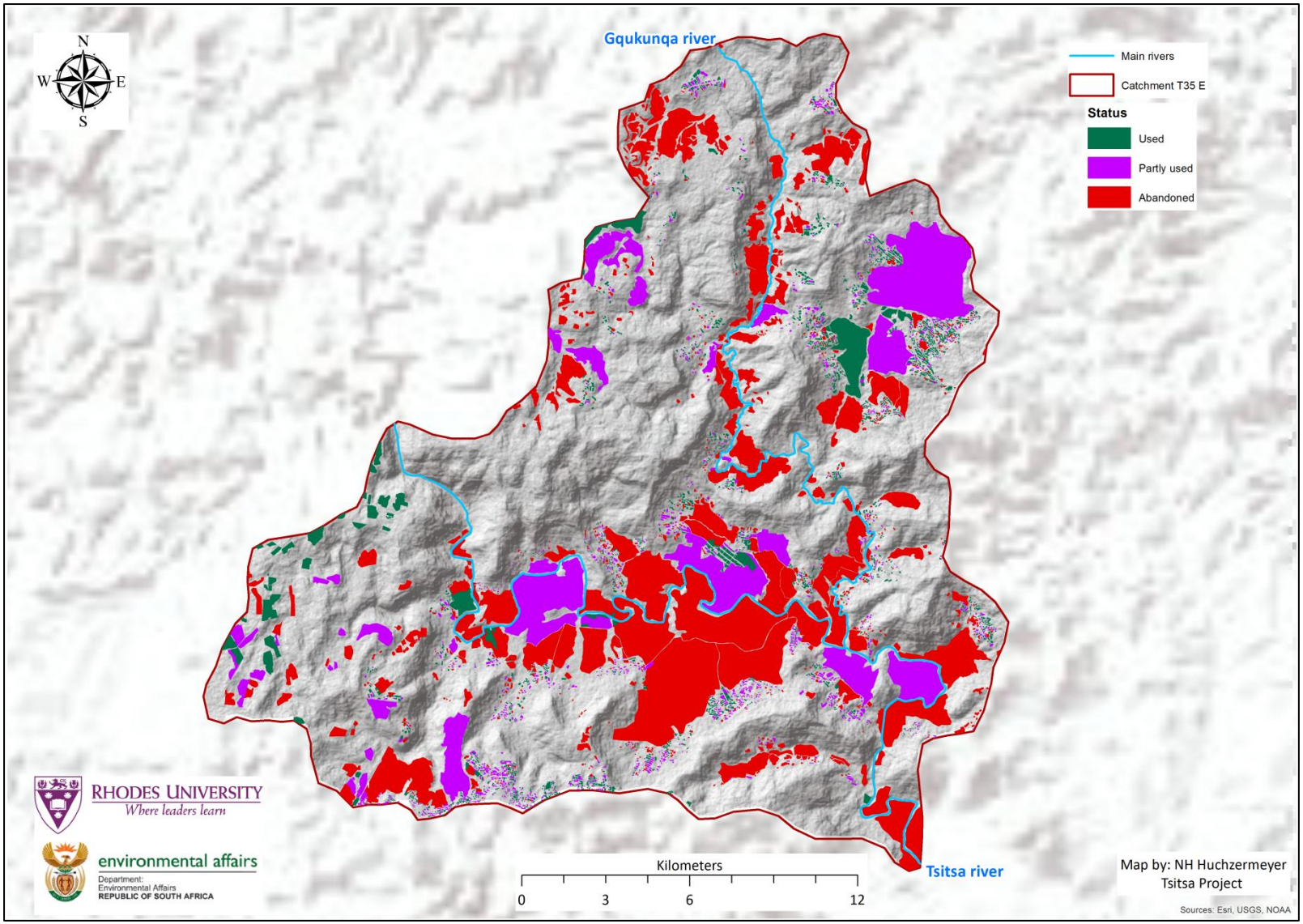

FIGURE 63: CULTIVATED LANDS CLASSIFIED INTO USAGE STATUS IN CATCHMENT T35 E

DEGRADATION

A total of 2 990 (1 632 ha) cultivated lands showed little or no degradation (13% of total cultivated land area), 759 (3 098 ha) showed moderate levels of degradation (23% of total cultivated land area) and 205 (8 568 ha) showed widespread degradation (64% of total cultivated land area) (Table 35 and Figure 64). In total cultivated lands exhibiting low degradation make up 5%, moderately degraded cultivated lands make up 10% and highly degraded cultivated lands make up 28% of Catchment T35 E (Figure 65).

TABLE 35: SUMMARY OF DEGRADED CULTIVATED LANDS, IRRESPECTIVE OF STATUS, IN CATCHMENT T35 E

Degradation	No. of cultivated lands	Area H (ha)	Percentage (%) area of cultivated lands	Percentage (%) of Catchment T35 E
Low	2 990	1 632	13	5
Moderate	759	3 098	23	10
High	205	8 568	64	28

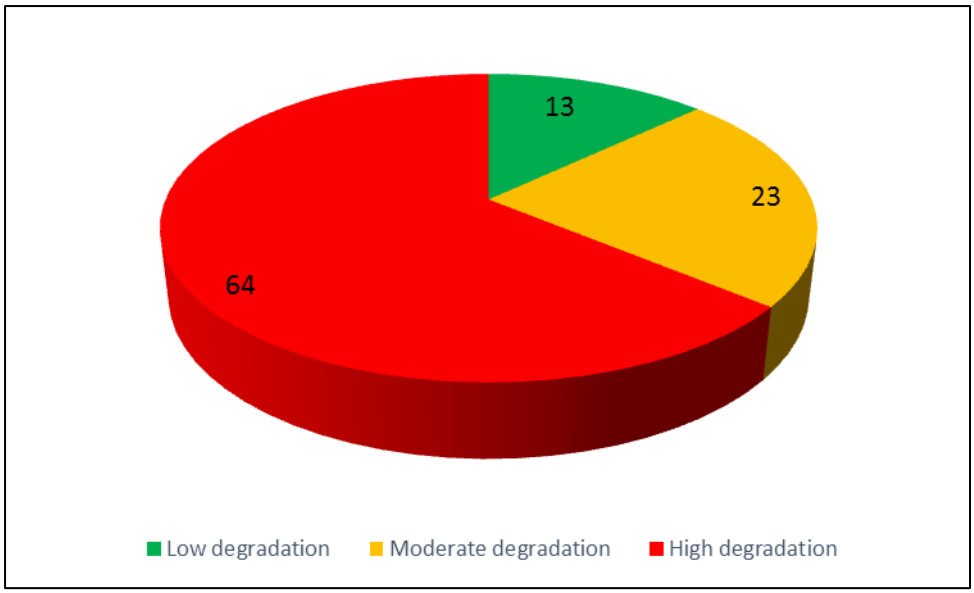

FIGURE 64: PERCENTAGE AREA, OUT OF THE TOTAL CULTIVATED LAND AREA IN CATCHMENT T35 E, COVERED BY DIFFERENT CATEGORIES OF CULTIVATED LAND DEGRADATION

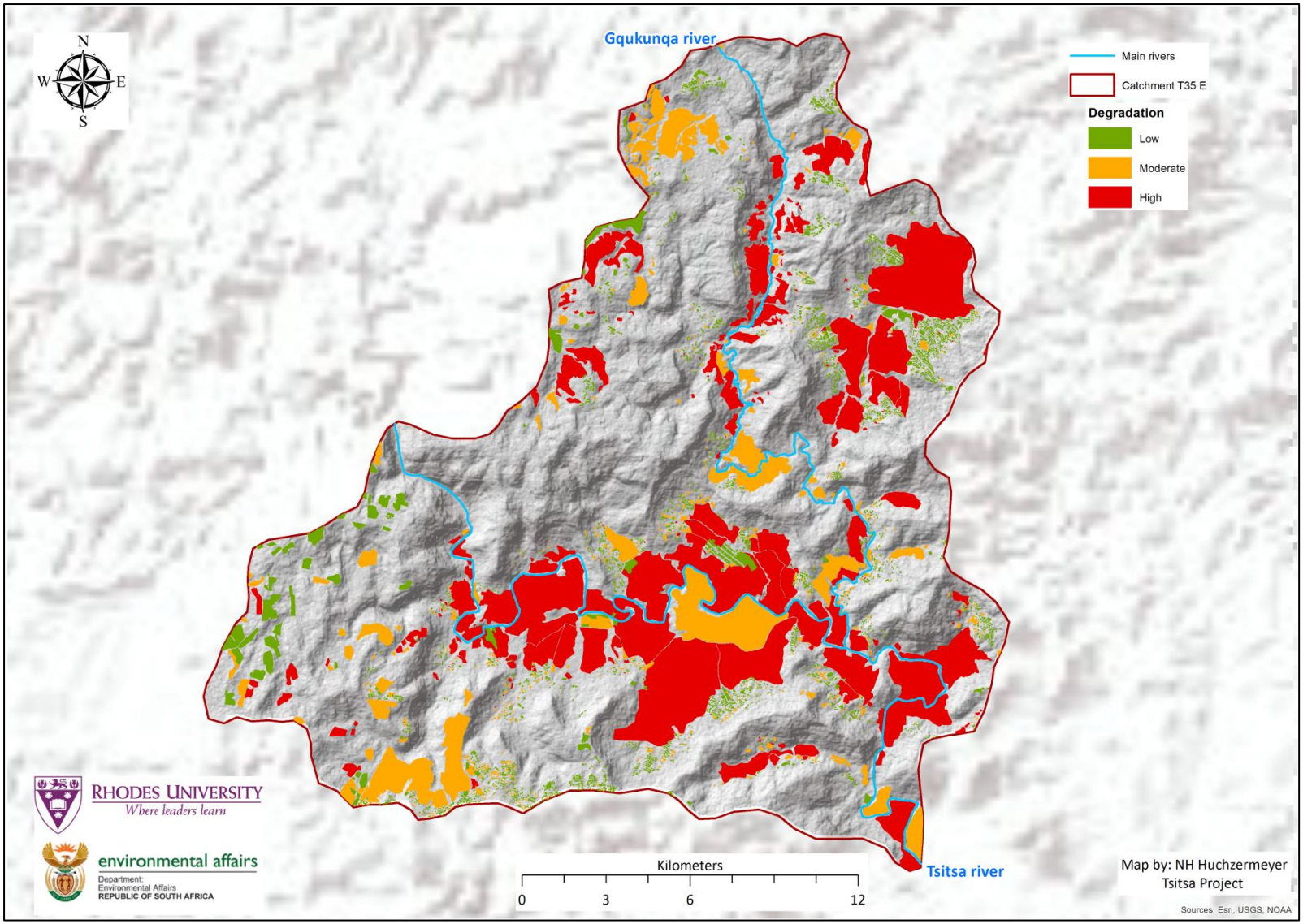

FIGURE 65: CULTIVATED LANDS IN CATCHMENT T35 E CLASSIFIED INTO THREE CLASSES OF DEGRADATION

VULNERABILITY TO EROSION

A total of 1 101 (811 ha) of the cultivated lands exhibited low vulnerability to erosion (6% of total cultivated land area), 2 410 (2 257 ha) exhibited moderate vulnerability (17% of total cultivated land area) to erosion and 443 (10 230 ha) were highly vulnerable (77% of total cultivated land area) to erosion (Table 36 and Figure 66). Overall, cultivated lands exhibiting low vulnerability to erosion make up 3% of Catchment T35 E, those exhibiting moderate vulnerability make up 7% and highly vulnerable cultivated lands make up 33% (Figure 67).

TABLE 36: SUMMARY OF THE VULNERABILITY OF CULTIVATED LANDS, IRRESPECTIVE OF THEIR STATUS OR DEGRADATION, IN CATCHMENT T35 E

Vulnerability	No. of cultivated lands	Area H (ha)	Percentage (%) area of cultivated lands	Percentage (%) of Catchment T35 E
Low	1 101	811	6	3
Moderate	2 410	2 257	17	7
High	443	10 230	77	33

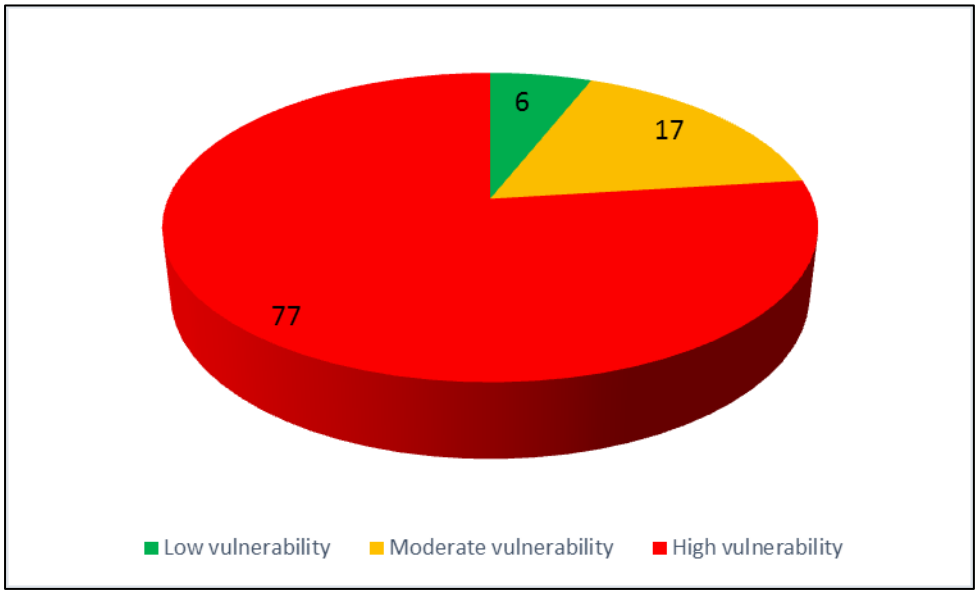

FIGURE 66: PERCENTAGE AREA, OUT OF THE TOTAL CULTIVATED LAND AREA IN CATCHMENT T35 E, COVERED BY DIFFERENT CATEGORIES OF CULTIVATED LAND VULNERABILITY TO EROSION

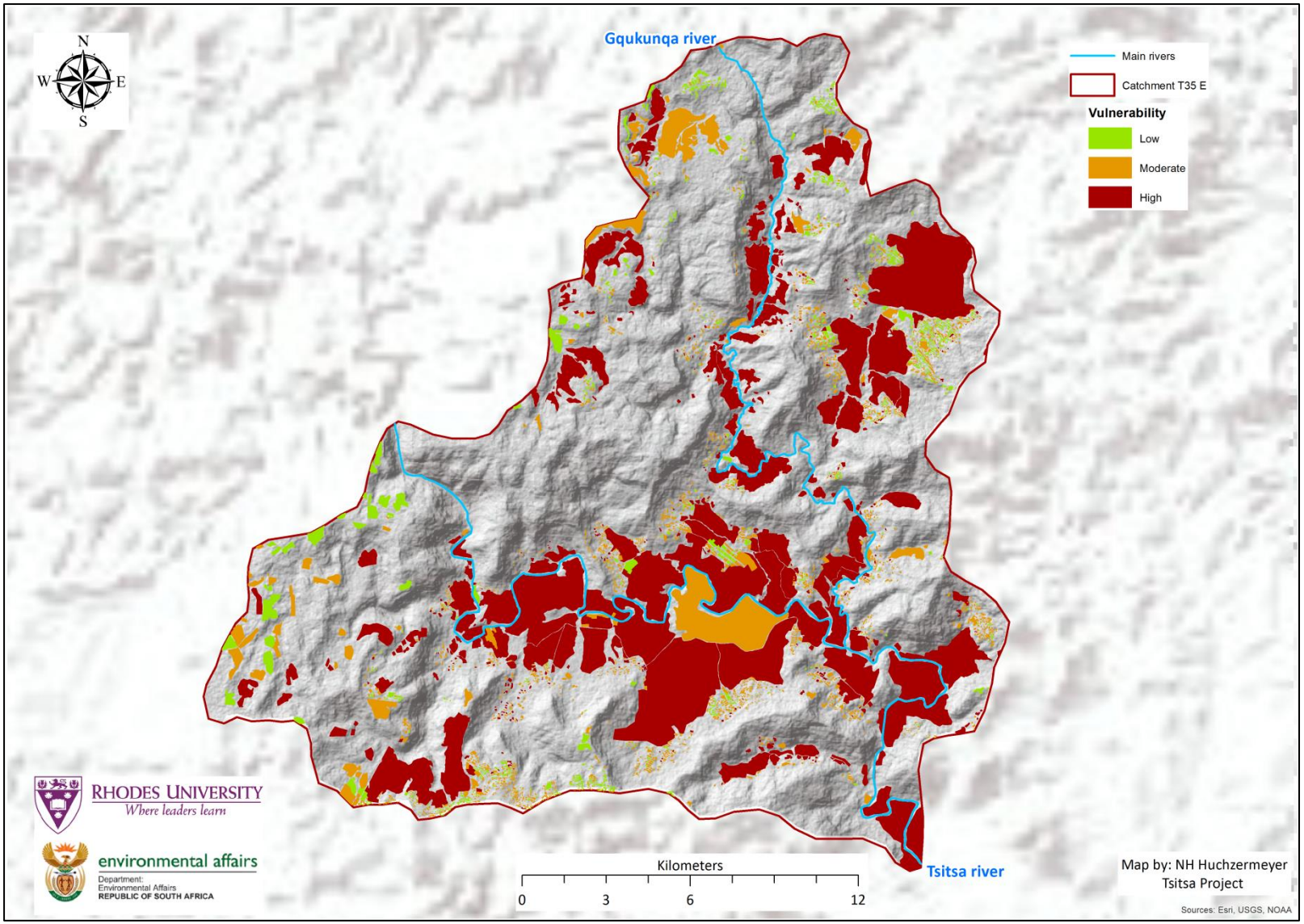

FIGURE 67: CULTIVATED LANDS IN CATCHMENT T35 E CLASSIFIED INTO THREE CLASSES OF VULNERABILITY TO EROSION

ENCROACHMENT

A total of 3 741 (9 975 ha) of cultivated lands showed little or no encroachment (75% of total cultivated land area) of alien vegetation, 173 (2 970 ha) showed moderate encroachment (22% of total cultivated land area) and 40 (353 ha) showed heavy encroachment (3% of total cultivated land area) (Table 37 and Figure 68). Overall cultivated lands that exhibit little or no encroachment make up 32% of Catchment T35 E, those that exhibit moderate encroachment make up 10% and heavily encroached lands make up 1% (Figure 69).

TABLE 37: SUMMARY OF ENCROACHMENT IN CULTIVATED LANDS IN CATCHMENT T35 E

Encroachment	No. of cultivated lands	Area H (ha)	Percentage (%) area covered	Percentage (%) of catchment
Little/ none	3 741	9 975	75	32
Moderate	173	2 970	22	10
Heavy	40	353	3	1

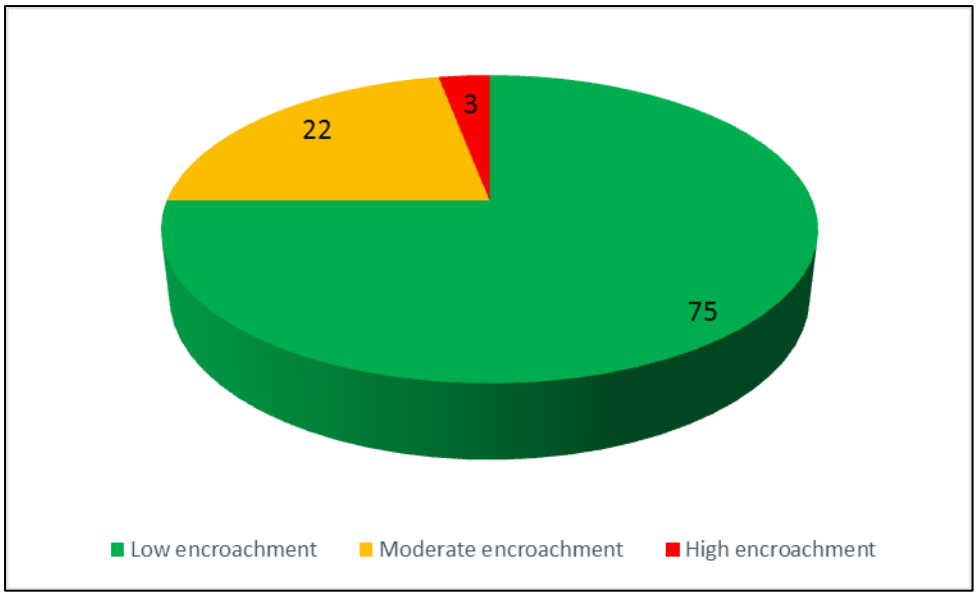

FIGURE 68: PERCENTAGE AREA, OUT OF THE TOTAL CULTIVATED LAND AREA IN CATCHMENT T35 E, COVERED BY DIFFERENT CATEGORIES OF CULTIVATED LAND ENCROACHMENT BY UNWANTED VEGETATION

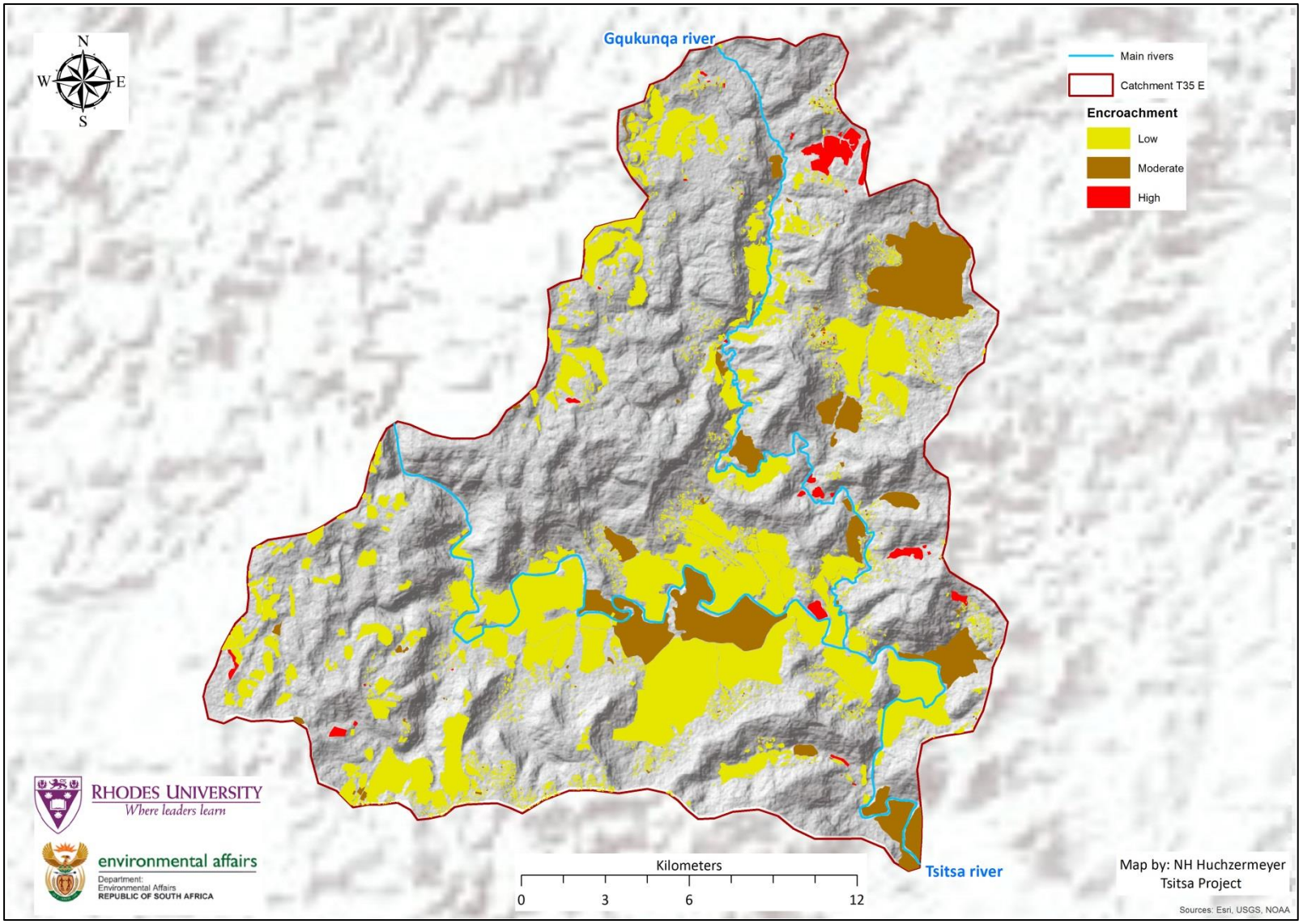

FIGURE 69: CULTIVATED LANDS IN CATCHMENT T35 E CLASSIFIED INTO DIFFERENT LEVELS OF VEGETATION ENCROACHMENT

APPENDIX 6: SOUTH AFRICAN GRASS SPECIES, WITH DISTRIBUTIONS IN THE VICINITY OF THE TSITSA RIVER CATCHMENT, THAT CAN POTENTIALLY BE USED FOR EROSION MITIGATION, GRAZING AND PASTURES ON DISTURBED SOILS (INFORMATION SUMMARISED FROM FISH ET AL. 2015)

Genus	Species (*non-native)	Ecology: soil types	Ecology: Grows on disturbed areas (old lands; roadsides; overgrazed areas)	Good grazing potential	Cultivated for pastures	Used for erosion control and rehab.	Annual/ winter	Potential invader	Hardy/ pioneer species
Axonopus	*fissifolius	Moist soils	✓		✓	✓		✓	
Bothriochloa	insculpta	Overgrazed areas				✓			
Bromus	*catharticus	Moist to wet shady places	✓		✓	✓	✓		
Catalepis	gracilis	Shallow sandy soil, more often black clay; vleis	✓	✓	✓	✓			✓
Chloris	gayana	Moist to drained soils; riverine woodland to open grassland; high nutritional value	✓	✓	✓	✓			
Chloris	pycnothrix	Shallow stony soils	✓			✓			✓
Cynodon	aethiopicus	Rich soils, abandoned kraals and fields	✓		✓	✓			
Cynodon	dactylon	Most soils; disturbed areas and nitrogen rich areas	✓	✓	✓	✓	✓		✓
Cynodon	hirsutus	Well-drained loam soils				✓			
Cynodon	nlemfuensis	Disturbed areas and old lands	✓		✓	✓			
Dactyloctenium	asutrale	Sandy soils; light shade		✓		✓			
Digitaria	monodactyla	Open grassland, highland sourveld				✓			

Enneapogon	scoparius	Dry grassland, rocky hillsides and often on calcrete				✓			✓
Eragrostis	bergiana	Limestone soils and frequents eroded places			✓	✓			✓
Eragrostis	curvula	High rainfall areas; sandy or acid to loamy soils	✓		✓	✓			
Eragrostis	lehmanniana	Sand or sandy loam usually over limestone	✓		✓	✓			
Eragrostis	racemosa	Shallow sandy, stony or clayey soils	✓			✓			
Eragrostis	superba	Sandy and stony soils	✓	✓	✓	✓			
Eragrostis	*tef	Naturalised	✓	✓	✓	✓			
Fingerhuthia	sesleriiformis	Black clay in vleis or clayey soils near rivers				✓			
Melinis	repens	Ruderal	✓			✓			✓
Paspalum	*dilatatum	Damp places, disturbed areas	✓	✓	✓	✓		✓	
Paspalum	*notatum	High rainfall areas on sandy or clayey soils	✓		✓	✓			
Pentameris	airoides	Richer soils, absent from sandstone derived soils				✓			
Phragmites	australis	Riverbeds and wetlands				✓			
Setaria	pumila	Damp soils or drier shady areas	✓			✓			✓
Stripagrostis	namaquensis	Loose gravelly soils, dry river courses; sand binder and silt catcher		✓		✓			✓

APPENDIX 7: EXAMPLES OF POTENTIALLY SUITABLE PLANTS FOR REHABILITATION CONSIDERATION AND RELATED NOTES (TAKEN FROM CLARK, 2018)

The following is a selection of ruderals that can be considered for the Project, based on site observations and extensive knowledge and experience of plants in this regional context.

Indigenous ruderals	
Berkheya carlinifolia (drier areas)	Wild Thistle/African Thistle/Dissel
Berkheya heterophylla (drier areas)	Wild Thistle/African Thistle/Dissel
Berkheya maritima (wetter areas)	Wild Thistle/African Thistle/Dissel
Nidorella podocephala (perennial trailer)	Unknown
Non-native ruderals	
Bidens formosa (*Cosmos bipinnatus*)	Cosmos
Bidens pilosa	Common Blackjack
Chenopodium spp.	Goosefoots
Cichorium intybus	Chicory
Melilotus alba	White Sweet Clover
Plantago lanceolata	Narrow-leafed/Ribwort Plantain
Schkuhria pinnata	Dwarf Marigold
Tagetes minuta	Khakibos
Indigenous Karoo-Type Shrubs for Semi-Arid/Highly Denuded Areas:	
The following tough karroid shrubs could be considered for rehabilitating west- and north-facing and semi-arid areas, by planting in contoured rows. They are often the natural consequence of prolonged overgrazing and the accompanying 'Nama-Karoo-ification' of Grassland. They can be used to kick-start recovery in areas where it would be futile to start with planting grass first – e.g. areas that are virtually barren and on which sheet erosion is very high; steep denuded slopes; hot, dry areas where grasses will struggle as the pioneers; and highly degraded areas that will remain under unacceptable grazing risk indefinitely if planted to anything vaguely palatable. These plants also have strong root systems to help bind what soil is left, and will help accumulate organic matter to slowly create a viable seed-bed for other, more palatable plants. They have no grazing value, and so would be left alone where any other form of rehabilitation would be nullified by selective grazing.	
Aloe ferox	Bitter Aloe
Aloe striata	Coral Aloe
Artemisia afra – potentially an excellent nursery plant for grass rehabilitation as livestock appear to avoid it	Wormwood
Chrysocoma ciliata	Bitterbos
Cotyledon orbiculata	Pig's Ears
Eriocephalus spp.	Kapokbosse
Felicia filifolia	Fine-leaved Felicia
Helichrysm rosum	Unknown
Kalanchoe spp. (e.g. *K. thyrsiflora*)	Geelplakkie
Lycium spp.	Honeythorns
Indigenous Montane Shrubs for Steep Slopes, Gullies Etc.	
These would be suitable for higher rainfall, steep, rocky slopes that are fire refugia. They naturally occur along the base of cliffs, in rock screes, along boulder-strewn riverlines, along cliff-tops in the eastern Great Escarpment, and as a forest and thicket margins.	
Buddleja auriculata	Weeping Buddleja
Buddleja salviifolia	Sage-leaved Buddleja

Euclea undulata	Common Guarri
Leucosidea sericea	Ouhout
Myrsine africana	Cape Myrtle
Rhamnus prinoides	Dogwood, Blinkblaar
Searsia divaricata (high altitude i.e. >1,600 m)	Rusty-leaved Currant/Mountain Kuni-bush
Searsia dregeana	Unknown
Nutrient-Deficient Bare Gully Slopes, Bare Steep Slopes & Rock Shelves	
These would be suitable for high rainfall slopes with highly leached soils (subsoils if heavily eroded, and even on bare rock). They typically form dense colonies in such habitats, and their dense growth-forms create valuable silt-traps. They can occur on highly degraded soil, overgrazed land, on cliff-edges, rock sheets, and in eroded gullies and dongas.	
Cliffortia linearifolia	Unknown
Helichrysum anomalum	Unknown
Metalasia densa	White Bristle Bush
Stoebe vulgaris (*Seriphium plumosum*)	Slangbos, Bankruptbush
Plants suited for wetlands	
These would be suitable riparian or wetland pioneer plants for revegetating denuded but seasonally or perennially wet areas. Most wetland species are naturally pioneer species and colonise available habitats easily (provided there is some sense of 'stability', i.e. no subject to flash floods, sediment inundation, etc.).	
Cyperus congestus	Dense flat-sedge
Cyperus dives (e.g. behind weirs/donga reclamation devices)	Giant Sedge
Cyperus marginatus	Unknown
Helichrysum aureonitens	Golden Everlasting
Juncus inflexus	Blue Rush
Nidorella spp.	Common Reed
Phragmites australis	Unknown
Pseudognaphalium luteo-album	Jersey Cudweed
Pycreus polystachyos	Sedge
Typha capensis	Bulrush
Plants suited for gulley bottoms	
These would be plants suitable for planting in deep gullies that have been stabilised, to increase organic matter in them and to increase roughness from woody debris so that water-flow is slowed. They would be safe from fire, given the *de facto* fire refugia formed by the gullies. Not all of these are necessarily ruderal, but all can occupy lower successional levels successfully.	
Asclepias fruticosus	African Milkweed
Buddleja auriculata	Weeping Buddleja
Buddleja salviifolia	Sage-leaved Buddleja
Gymnosporia buxifolia	Common Spike-Thorn
Leonotis spp.	Wild Dagga
Leucosidea sericea	Ouhout
Myrsine africana	Cape Myrtle
Phragmites australis	Common Reed
Rubus rigidus	Wild Bramble; not to be confused with numerous invasive species
Salix mucronata	Safsaf Willow
Typha capensis	Bulrush
Vachellia karroo	Sweet-thorn

APPENDIX 8: SPATIAL DATASET

This data is available in .shp and .kml format to allow the user to interact with the data at various scales and run queries. The database column headings and units are given in Table 38 below.

TABLE 38: GEOGRAPHIC INFORMATION SYSTEMS METADATA FOR CULTIVATED LANDS IN CATCHMENT T35 A-E

File name: Cultivated lands T35 A-E	
Description	Cultivated lands T35 A-E: status, current condition, vulnerability to erosion and encroachment
Data Origin	N. Huchzermeyer and S. Sibiya
Scale Captured	Small fields (< 10 ha) were digitised at a scale of 1:800. Large fields (> 10 ha) were digitised at a courser scale of 1:4 000
Date Captured	May to September 2018 from 2015/2016 aerial images (1:10 000 orthophotos, 5 cm resolution)
Layer Properties	
Feature Type	Vector format (polygon)
Projection	
Projection Name	Geographic Coordinate System – GCS_WGS_1984
Datum	D_WGS_1984
Prime Meridian	Greenwich
Angular Unit	Degree
Attribute Fields	
Field Name	**Description**
FID	Feature Identification
Shape	Polygon
Status	Usage status
Degradatio	Degradation code
Vuln	Vulnerability code
Encroach	Encroachment code
Area_ha	Area of cultivated lands in hectares