Land use map of Tanzania

Prepared during a workshop held in Butare, Rwanda
at the CGIS centre,
from the 22nd of November until the 3rd of december Dec 2010
in the framework of the Kagera TAMP project,
implemented by FAO, funded by GEF

Workshop participants names (authors of the Rwanda maps are the member of the Tanzania team)

COUNTRY	NAME	INSTITUTE	E-MAIL
RWANDA	Ernest Uwayezu	CGIS NUR, HUYE (BUTARE)	ernest@cgisnur.org
	Elias Nyandwi	CGIS NUR, HUYE (BUTARE)	enyandwi@nur.ac.rw nyaneli@yahoo.fr
	Antoine Nsengiyumva Kagabo	NATIONAL LAND CENTRE, KIGALI	nsengiyumvak@yahoo.fr
	Theodomir Mugiraneza	CGIS NUR, HUYE (BUTARE)	theodomir@cgisnur.org
	Marie Christine Simbizi	CGIS NUR, HUYE (BUTARE)	msimbizi@nur.ac.rw
	Rachel Murekatete	CGIS NUR, HUYE (BUTARE)	
	Jules Mutabazi	ISAR, LIVESTOCK UNIT, KARAMA	mutajules@yahoo.fr
U. R. OF TANZANIA	Kipondya Winfrida	SCC-VI AGROFORESTRY KAGERA PROJECT, BUKOBA	winfrida.kipondya@viafp.org
	Godwin Safari Edmund Athanas	SCC-VI AGROFORESTRY MARA PROJECT, MUSOMA	safariag05@yahoo.com
	Frank Onesmo Mkiramwinyi	UKINGURU TRAINING INSTITUTE, MWANZA	framwinyi@yahoo.com
	Elmens Kaboni	MINISTRY OF AGRICULTURE AND FOOD SECURITY, MWANZA	ekaboni@yahoo.com
UGANDA	Dennis Babaasa	INSTITUTE OF TROPICAL FOREST CONSERVATION, BWINDI FOREST NATIONAL PARK	dbabaasa@nrc.umass.edu
	Grace Nangendo	WILDLIFE CONSERVATION SOCIETY, KAMPALA	nangendo@alumni.itc.nl nangendo@hotmail.com

National Coordinator, Fidelis Kahiura, FAO
International Consultant: Grace Nangendo
National Consultant: Kimambe Lyoba, Ministry of Agriculture Food Security and Cooperatives,
Land use Planning and Management Department
Coordination of activities and facilitator Monica Petri, FAO
Kagera TAMP project contact: Kagera-Secretariat@fao.org

The method used in this workshop has been developed within the project LADA FAO/UNEP GEF and is available in the document: Freddy Nachtergaele, Monica Petri, 2011. Mapping Land Use Systems at global and regional scales for Land Degradation Assessment Analysis. LADA technical report (http://www.fao.org/docrep/017/i3242e/i3242e.pdf).

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1. Introduction, Kagera TAMP project and national LADA method used at the Kagera basin scale

The Kagera TAMP project is funded through the Global Environment Facility (GEF) in partnership and with co-funding from the governments, partner programmes and donors at country and regional levels. The project is executed by the UN Food and Agriculture Organization (FAO). The project goal is to adopt an integrated ecosystems approach for the management of land resources in the Kagera basin that will generate local, national and global benefits including: restoration of degraded lands, carbon sequestration and climate change adaptation and mitigation, protection of international waters, agro-biodiversity conservation and sustainable use and improved agricultural production, leading to increased food security and improved rural livelihoods.

Kagera Trans-boundary Agroenvironmental Management Programme is going to select its intervention areas on the base of the more advanced technologies of definitions and assessment of the land degradation and of the sustainable land management. The selection of most degraded zones or of the areas with a higher impact of land degradation will provide the basis for the identification of locations of the next project phases, particularly the implementation of the Farmer Field Schools. This work will be realised in Rwanda, Uganda, and United Republic of Tanzania, and also in the entire Kagera Basin (the workshop in Burundi was held from 9th up to 16th of November). The method will be used fro the first time at a hydrographical basin scale.

The selection of intervention areas will be based on the method implemented by the project LADA (FAO/UNEP GEF) that developed a national assessment method for the land degradation and sustainable land management that has been tested in six countries (South Africa, Argentina, China, Cuba, Senegal, Tunis). The method, very rapid, is composed by two main axes:
- the preparation of a land use systems (LUS) map by using all best available data,
- the preparation of the land degradation and sustainable land management map using the method LADA WOCAT QM, that use the LUS as cartographic unit.

A workshop was organized by Kagera TAMP in Butare (Huye) between the 22nd of November and the 3rd of December 2010 with the participation of GIS experts having different background (agronomy, livestock, land cover, GRID, etc.) with the objective of preparing a LUS map of the area. Data used are prepared by NELSAP (*Nile Equatorial Lakes Subsidiary Action Program*) in 2008 and have been provided to the Kagera TAMP team within the preparation of a Memorandum of Understanding.

The present report give the complete description of the preparation of a land use map and also the preparation of a national map of livestock intensity, needed as LUS input. The present method allows the preparation of a multi-country land use map in two weeks with the work of 13 experts, and is comparable to the continuous of 130 working days. Further to that, the LUS has been validated with the support of GIS consultants.

The report details the work realised during the workshop describing the LUS preparation for Tanzania.

2. Inputs, formats, scale, resolution and precision

Table 1Land use systems data for map and database

Used for	Name	Year of measure	Year / periodicity of publication	Scale / resolution / extent	Format	Availability or copyright	Producer	Metadata	Unity of measurements
Admin units	**Tanzania**	**2002**	**2006**	1:2,000,000	**shp**	country (modified)	**URT**	**-**	**classes**
Land cover based eco-systems	**Africover**	1997	2002	1:200.000	shp	country	FAO / Survey and Mapping Division, Ministry of Land	www.africover.org	classes
Livestock density	**Livestock statistics**	2007	2009	Report	stats	free	DALDO	report	heads per animals
Livestock natural distribution regions	**Agro-ecological zones**	1980 circa	1984	1:2,000,000	shp	free	URT/FAO	report	classes
Protected areas	**World database protected areas**	2009	yearly	1:1.000.000	shp (polygons)	free	UNEP	www.wdpa.org	classes
Protected areas	**Game parks**	1959/1974/1977/1980	Unknown	1:2,000,000	shp (polygons)	Unknown	URT	web/report	classes
Wetlands	**Africover**	1999	2000	1:100.000	shp	country	FAO/min	web	classes

Table 2 Information on resolution, scale, format and precision

Resolution	1 km (based on DEM SRTM resampled)
Scale	1 : 2,000,000 based on the data (Land Use Systems)
Format	ESRI GRID
Précision	In the tab general, C:\LUSworkshops_RWANDA_workshopLus_PRACTISE_TZ\lustz In the tab extent, select the analysis extent In the tab extent, Snap extent to In cell size, select the cell size Correction by using Generalization commands have been used as needed.
Validation	Results are based on experience of the work group. Results are not validated.

3. Africover re-classification

The LUS map is based on land cover, that represents the ecosystems where that are used by human being to establish the land use, or to obtain good and services from an areas. The LUS need to be prepared over a very reduced land units. The reclassification can be realised by using the class name (LC_NAME) of the Aggregated Africover version.

The simplification took place in a participate manner, with the collaboration of national experts that use Africover in their regular work or that participated on Africover preparation. The work has been realised only in the areas included in the Kagera TAMP project.

Table 3 Reclassification of Africover

LCNAME	new_class
Closed herbaceous vegetation on permanently flooded land	Wetlands
Closed shrubs	Savanna
Closed to open woody vegetation (thicket)	Natural_Forest
Closed trees on temporarily flooded land	Natural_Forest
Closed trees	Natural_Forest
Forest plantation - undifferentiated	Forest_plantation
Irrigated herbaceous crop	Irrigated_crops
Isolated (in natural vegetation or other) Post flooding herbaceous crop (field density 10-20% polygon area)	Seasonal_crops
Isolated (in natural vegetation or other) Rainfed herbaceous crop (field density 10-20% polygon area)	Seasonal_crops
Isolated (in natural vegetation or other) Rainfed shrub crop (field density 10-20% polygon area)	Seasonal_crops
Multilayered trees (broadleaved evergreen)	Natural_Forest
Natural waterbodies	Surface_water
Open shrubs (65-40% crown cover)	Savanna
Open to closed herbaceous vegetation on temporarily flooded land	Savanna
Open to closed herbaceous vegetation	Perennial_crops
Open to closed shrubs on temporarily flooded land	Savanna
Open trees (65-40% crown cover)	Forest_plantation
Open trees (65-40% crown cover)	Savanna
Post flooding herbaceous crop	Seasonal_crops
Rainfed herbaceous crop (mixed unit with natural vegetation or other) (field area approx. 60% polygon area)	Perennial_crops

Rainfed herbaceous crop	Seasonal_crops
Rainfed shrub crop	Seasonal_crops
Rainfed tree crop (mixed unit with natural vegetation or other) (field area approx. 60% polygon area)	Perennial_crops
Rainfed tree crop	Perennial_crops
Rice fields (mixed unit with natural vegetation or other) (field area approx. 60% polygon area)	Irrigated_crops
Scattered (in natural vegetation or other) Rainfed herbaceous crop (field density 20-40% of polygon area)	Perennial_crops
Scattered (in natural vegetation or other) Rainfed shrub crop (field density 20-40% of polygon area)	Perennial_crops
Scattered (in natural vegetation or other) Rainfed tree crop (field density 20-40% of polygon area)	Perennial_crops
Shrub savannah	Savanna
Trees and shrubs savannah	Savanna
Urban and associated areas, rural settlements	Urban areas and rural settlements
Very open shrubs (40-15% crown cover)	Savanna
Very open trees (40-15% crown cover)	Forest_plantation

4. Validation of the land cover classes

The exercise of validating the land cover/use and the Land Use System (LUS) maps of the Kagera TAMP region of Tanzania was carried out from February to April 2012. The objectives of the mission were to reclassify the Africover map into a simplified Africover map with fewer classes, cross check land use/cover using field validation, recent satellite, and other remote sensing information like Google earth, to rebuild the LUS, to rest join the LUS and the QM database, and to prepare QM maps. An assessment of the initially created Simplified Africover had initially been carried out in 2010 to check if the assigned classes during the simplification tarried with what was on the ground. It was at that time observed that there was need to reclassify the Africover map because some of the classes had been misclassified. It was also observed that the land cover had changed tremendously and thus the need for a full validation of the reclassified map and thereafter recreate the LUS.

The reclassification of the Africover map was carried out because it had been observed that the existing simplified Africover map was wrong. The purpose of the reclassification exercise was, therefore, to generate a map that best represented the existing land cover. The generated map would then be further validated during the field mission. The corrected table that was in the "Tanzania EN Report" (Table 3, this report) and the recommended changes based on the assessment tour carried out in March 2010 (Table 2) were used to guide the reclassification. The obtained map is shown in Figure 1

Table 4: The relationship between the Africover classes and the simplified Africover classes

LCNAME	New class (simplified Africover)
Closed herbaceous vegetation on permanently flooded land	Wetlands
Closed shrubs	Savanna
Closed to open woody vegetation (thicket)	Natural Forest
Closed trees on temporarily flooded land	Natural Forest
Closed trees	Natural Forest

LCNAME	New class (simplified Africover)
Forest plantation - undifferentiated	Forest plantation
Irrigated herbaceous crop	Irrigated crops
Isolated (in natural vegetation or other) Post flooding herbaceous crop (field density 10-20% polygon area)	Seasonal crops
Isolated (in natural vegetation or other) Rainfed herbaceous crop (field density 10-20% polygon area)	Seasonal crops
Isolated (in natural vegetation or other) Rainfed shrub crop (field density 10-20% polygon area)	Seasonal crops
Multilayered trees (broadleaved evergreen)	Natural Forest
Natural waterbodies	Surface water
Open shrubs (65-40% crown cover)	Savanna
Open to closed herbaceous vegetation on temporarily flooded land	Savanna
Open to closed herbaceous vegetation	Perennial crops (savanna)
Open to closed shrubs on temporarily flooded land	Savanna
Open trees (65-40% crown cover)	Forest plantation (natural forest or savanna)
Open trees (65-40% crown cover)	Savanna
Post flooding herbaceous crop	Seasonal crops
Rainfed herbaceous crop (mixed unit with natural vegetation or other) (field area approx. 60% polygon area)	Perennial crops (seasonal crops)
Rainfed herbaceous crop	Seasonal crops
Rainfed shrub crop	Seasonal crops
Rainfed tree crop (mixed unit with natural vegetation or other) (field area approx. 60% polygon area)	Perennial crops
Rainfed tree crop	Perennial crops
Rice fields (mixed unit with natural vegetation or other) (field area approx. 60% polygon area)	Irrigated crops (seasonal crops)
Scattered (in natural vegetation or other) Rainfed herbaceous crop (field density 20-40% of polygon area)	Perennial crops (seasonal crops)
Scattered (in natural vegetation or other) Rainfed shrub crop (field density 20-40% of polygon area)	Perennial crops (seasonal crops)
Scattered (in natural vegetation or other) Rainfed tree crop (field density 20-40% of polygon area)	Perennial crops
Shrub savannah	Savanna
Trees and shrubs savannah	Savanna
Urban and associated areas, rural settlements	Urban areas and rural settlements
Very open shrubs (40-15% crown cover)	Savanna
Very open trees (40-15% crown cover)	Forest plantation (savanna or natural forest)

Further to this a study tour has been undertaken. Based on the study tour results further modifications have been prepared as reported in table 5

Table 5: Action taken concerning issues raised in the Assessment tour.

Class in map	GPS point/ place name	Test of	Cause of the error	Correct Class	Results/ Possible options	Action
Perennial	Ngara area	LUS	Error in land	Crops	The following classes are	Classes changed

Class in map	GPS point/ place name	Test of	Cause of the error	Correct Class	Results/ Possible options	Action
crops moderate livestock			cover classification		wrongly classified: - Scattered (in natural vegetation or other) Rainfed shrub crop (field density 20-40% of polygon area); - Rainfed shrub crops.	to **Seasonal crops**
Forest plantation moderate livestock	Ngara area	LUS	Error in land cover classification	Savannah with trees	The following Africover class is wrongly reclassified: Open trees (65-40% crown cover).	Changed to **savannah**
Perennial crops moderate livestock	Ngara area	LUS	Error in land cover classification	Crops	The following class is wrongly classified: - Scattered (in natural vegetation or other) Rainfed tree crop (field density 20-40% of polygon area).	Class changed to **Seasonal crops**
Protected savannah	Ngara near Sekeseke	LUS	Error in protected area map	Other uses	There are some 7 km distance from the boundary of protected area in the map and the start of the protected area in the reality: the protected area starts 7 km before than the real physical entrance to the park. The following should be undertaken: - check if a better protected area map exists; - if not possible to obtain a better data, no improvement can be done.	An updated shape file for the protected area was obtained and so this anomaly has been corrected.
Several	Protected savannah in Ngara	LUS	Error in land cover classification	Other uses	Several details are missing, including wetlands.	
Protected plantation	Ngara	LUS	Error in land cover classification	Protected savannah	The following Africover class is wrongly reclassified: Open trees (65-40% crown cover)	Changed to **Savannah**
Savana moderate livestock	Karagwe	LUS	Error in land cover classification	Around the stop point there is no plantation	Grassland in the stop point is correct. The following class are wrongly classified: - Scattered (in natural vegetation or other) Rainfed tree crop (field density 20-40% of polygon area); - Isolated (in natural vegetation or other) Rainfed herbaceous crop (field density 10-20% polygon area).	Specific point mentioned here could not be identified but the areas where classes mentioned occur in Karagwe were checked and corrections made appropriately
Perennial crops moderate livestock	Missenyi area, near FFS	LUS	Error in land cover classification	Crops	The class 'Rainfed herbaceous crop (mixed unit with natural vegetation or other) (field area approx. 60% polygon area)' is wrongly classified.	Changed to **seasonal crops**

Class in map	GPS point/ place name	Test of	Cause of the error	Correct Class	Results/ Possible options	Action

**Figure 1 Reclassified land cover map (Tanzania)**
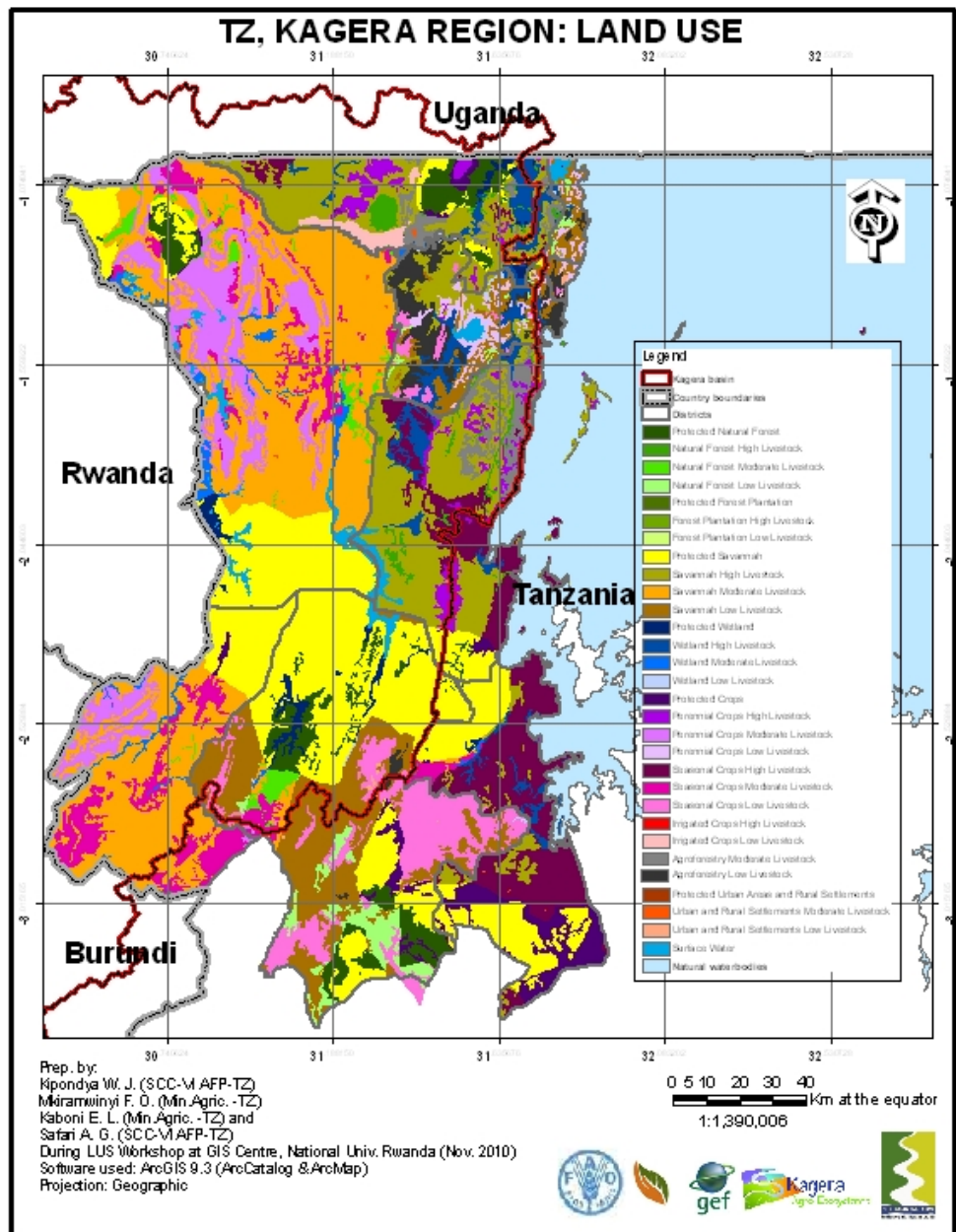
5. Other data used to prepare the land use map

5.1 Protected area

A map of protected areas was prepared by WDPA in 2009, Scale1:2,000,000, Produced by UNEP. The resulting map, presented hereafter, was used without any further classification during LUS preparation. Original map is presented hereafter.

Figure 2 Protected areas of Kagera TAMP zones
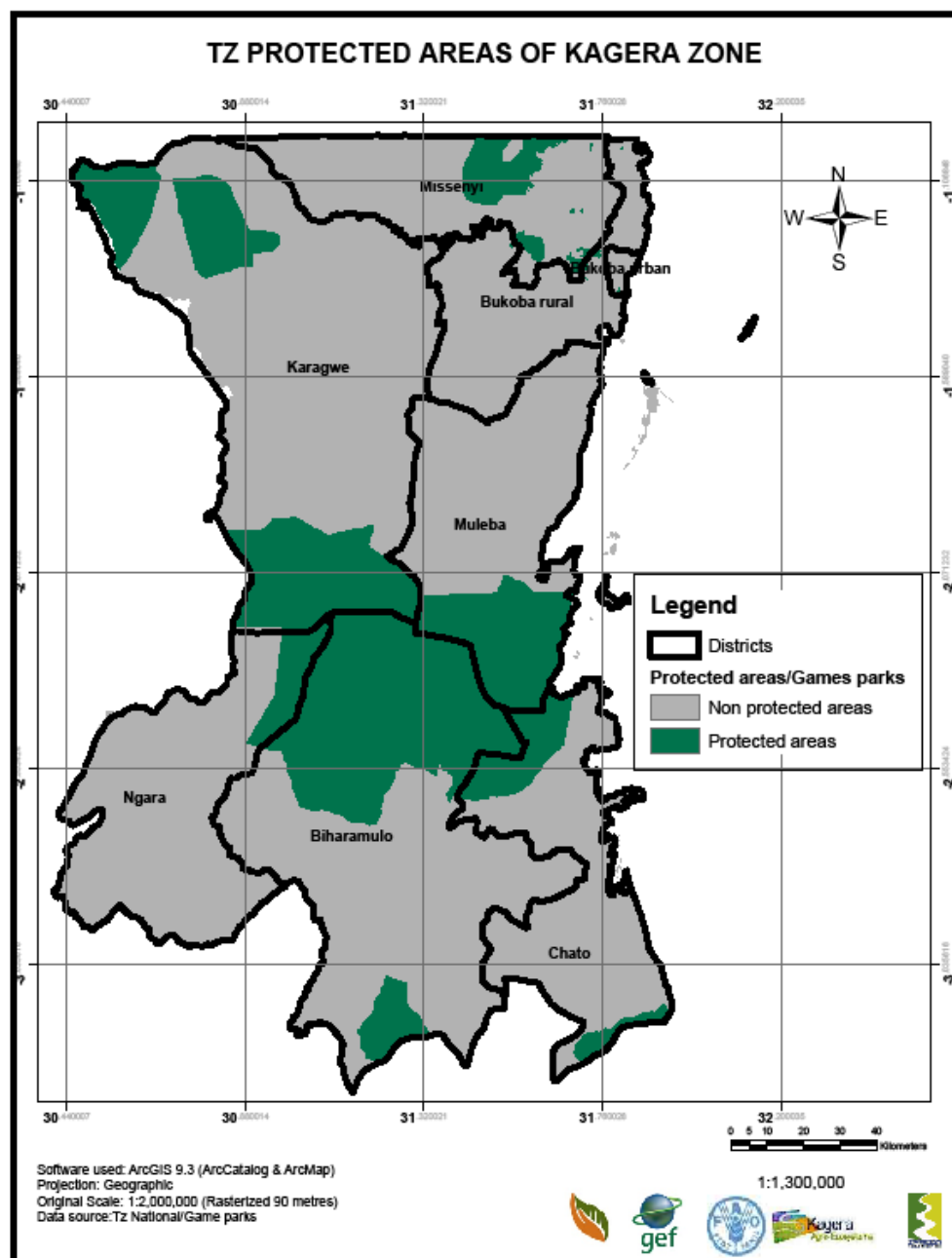
5.2 Livestock intensity

The livestock map has been prepared by using 3 phases:
- classification and conversion of administrative level livestock map In such a way to make them comparable between species and areas
- preparation of a map of natural livestock distribution region
- geographic distribution of administrative data by using dominant presence of livestock species for each district, based on experience

5.2.1 Classification of livestock statistical data

The data from the latest livestock census, prepared by the District Agricultural Livestock Development Offices in 2007 have been used as baseline.

Table 6 Livestock heads in Kagera area from census.

DISTRICT	Cattle	Sheep	Goats	Pigs
Biharmulo	79632	12054	93990	114
Bukoba rural	33,041	5,686	66,961	1,277
Karagwe	164,396	13,220	134,345	1,256
Muleba	87,375	5741	100,403	2277
Ngara	19858	6463	90367	749
Chato	72,603	8,234	70222	153
Missenyi	58,329	4,750	54,797	1,366
Bukoba urban	0	0	0	0

Those data has been converted to tropical livestock units (TLU) using the same conversion factors as defined by NBI-NELSAP for the Kagera basin: cattle 0.75, goats 0.1, ovins 0.1, and pigs 0.2. With the aim of having a data that is comparable between species and districts of different dimension, the results have been calibrated basing on extent, obtaining an indication of TLU/km2

Table 7 Table with TLU/km2 (important)

DISTRICT	CATTLU_KM^2	GOATTLU_KM^2	SHEEPTLU_KM^2	PIGSTLU_KM^2
Biharamulo	8.58	13.50	1.73	0.02
Bukoba urban	0.00	0.00	0.00	0.00
Karagwe	15.98	17.41	1.71	0.16
Muleba	18.73	28.69	1.64	0.65
Ngara	4.35	26.37	1.89	0.22
Chato	17.06	22.00	2.58	0.05
Missenyi	17.21	21.56	1.87	0.54
Bukoba urban	0.00	0.00	0.00	0.00

5.2.2 Use of a base map as natural regions for livestock in Tanzania

Name of Map	Year	Scale	Produces	Classes used
Agroecological zones	1984	1:2,000,000	URT/FAO	Low, Moderate and High

Figure 3 Map for Agroecological zones for Kagera region (TZ)
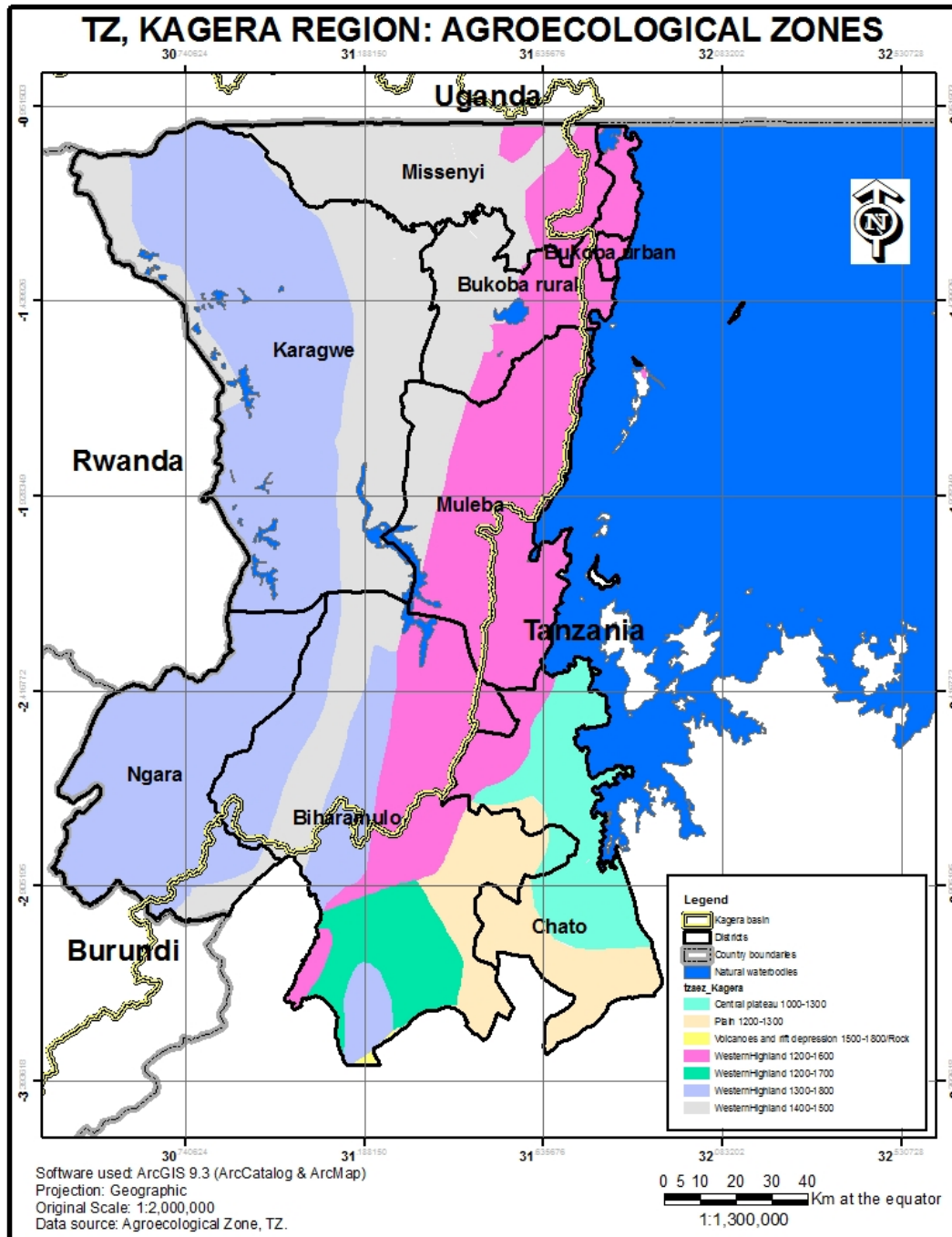
5.2.3 Natural region classification based on livestock dominant presence

Natural regions are classified in relation to the dominance of livestock presence. A table is prepared to establish which species is dominant for each natural region.
For each region the value of TLU/km2 are summed. The classification has been done in ArcGIS.

Table 8 Classification in relation to dominance of Livestock presence in Districts (Kagera region) .

Name	WesternHighland 1400-1500				WesternHighland 1200-1600			
DISTRICT	CATTLE	GOATS	SHEEP	PIGS	CATTLE	GOATS	SHEEP	PIGS
Biharamulo	y	y				y		
Bukoba Rural	y	y			y	y		y
Karagwe	y	y						
Muleba	y	y			y	y		
Ngara		y						
Chato						y		
Missenyi					y	y		
Bukoba Urban								

Name	WesternHighland 1300-1800				WesternHighland 1200-1700			
DISTRICT	"							
Biharamulo	CATTLE	GOATS	SHEEP	PIGS	CATTLE	GOATS	SHEEP	PIGS
Bukoba Rural		y	y			y	y	
Karagwe								
Muleba	y	y						
Ngara								
Chato		y						
Missenyi								
Bukoba Urban								

Name	Plain 1200-1300				Volcanoes and rift depression 1500-1800/Rock				Central plateau 1000-1300			
DISTRICT	CATTLE	GOATS	SHEEP	PIGS	CATTLE	GOATS	SHEEP	PIGS	CATTLE	GOATS	SHEEP	PIGS
Biharamulo		y				y	y			y		
Bukoba Rural												
Karagwe												
Muleba												
Ngara												
Chato	y	y							y	y		
Missenyi												
Bukoba												

Urban													

Figure 4 Livestock intensity map

TZ, KAGERA REGION: LIVESTOCK INTENSITY
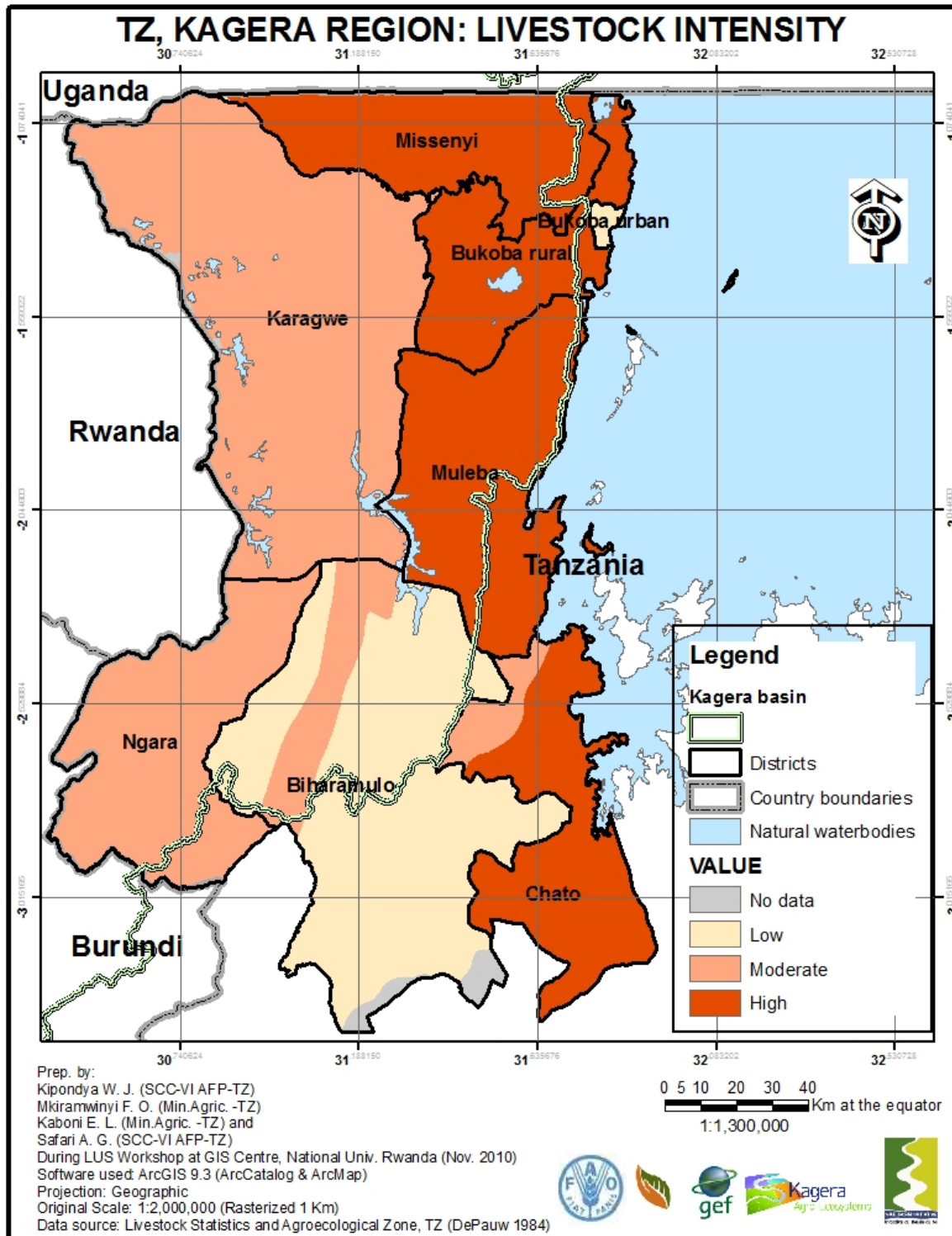
6. Land use map implementation

The baseline for land use preparation is land cover. The preparation of land use has been prepared by using livestock intensity, protected areas and wetlands areas. Data have been classified using the conditional command ("CON") of ArcGIS Spatial Analyst. Threshold used for high livestock was above 32 TLU/ km^2, for moderate livestock was between 20 and 32 TLU/ km^2 and for low livestock was between 0 and 20 TLU/km^2

Table 9 Main land use systems table

| LUS_class	Utilization
Natural forest	Protected
	High livestock
	Moderate livestock
	Low livestock
Forest plantation	Protected
	Moderate livestock
	Low livestock
Savanna	Protected
	High livestock
	Moderate livestock
	Low livestock
Wetland	Protected
	High livestock
	Moderate livestock
	Low livestock
Perennial Crops	Protected (perennial, seasonal, irrigated)
	High livestock
	Moderate livestock
	Low livestock
Seasonal crops	High livestock
	Moderate livestock
	Low livestock
Irrigated crops	High livestock
	Moderate and low livestock
Urban areas and rural settlements	With livestock
	Without livestock
Surface water	Protected
	Fish, high livestock
	Fish, low livestock

7. Land use map improvements
The land use map is needed in the second part of the LADA (FAO/UNEP GEF) method, that include the assessment of the land degradation and of the sustainable land management practices.

This exercise is realised using the participatory method LADA WOCAT QM throughout the involvement of local experts. During the assessment LUS units are calibrated and improved basing on participants suggestion. The final LUS map is presented in Figure 7, and the modification are presented in table 6.

Table 10 Principal modification to the LUS units are indicated by experts during the QM phase

Modification	Where	Why
Convert to low livestock in forest, wetlands, perennial crops, seasonal crops, urban areas, water	Bukoba rural	Statistics may be incorrect
Convert protected crops to protected forest in northern part of the districts	Karagwe (north)	Error in land cover map or discrepancy due to non recent land cover data
Convert protected crops to protected savanna in southern part of the districts	Karagwe (south)	Error in land cover map or discrepancy due to non recent land cover data
Irrigated crop has not high but low livestock	Missenyi	Statistics may be incorrect
Protected crops converted to protected savanna	Ngoro, Biharamulo, Muleba	Error in land cover map or discrepancy due to non recent land cover data

Figure 5 land use map
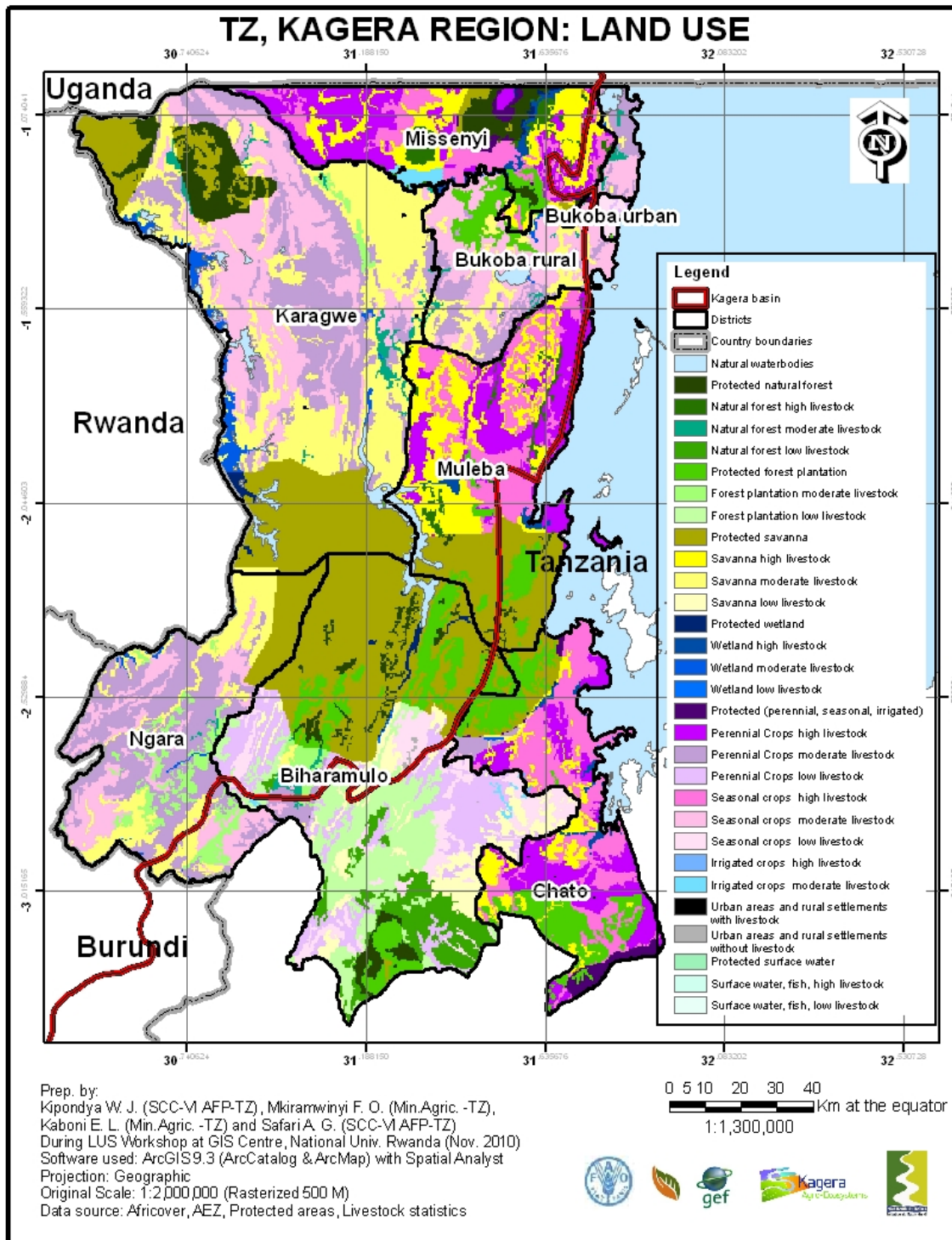
8. Land use map database implementation

The database will be utilized during land degradation and sustainable land management assessment as supporting material of the LADA WOCAT QM method. It gives additional information for the groups of assessment. The use of the GRID formal allows converting all data to the baseline resolution. The list of input data is available in table 10.

8.1 Livestock natural region and livestock species

The map of livestock region was prepared basing on the description in a previous chapter. In the preparation of the land use map, the carte has been used as input. With a slight modification the map can list the dominant livestock species. The groups of dominant livestock species are the following:

- Cattle and goats
- Cattle, goats and pigs
- Goats
- Goats and pigs

8.2 Annual rainfall

The annual average rainfall amount is calculated by summing up monthly values downloaded from the World Clim database, published in 2005. Although the data is at 30 arc seconds resolution, the data is considered the best available to have an indicative representation of the rainfall of the area. The data is presented in Figure 6.

8.3 Elevation and slope

The elevation (meters) at a resolution of 90 meters is obtained using SRTM 2000 data included in the Hydrosheds database published in 2007. The slope (degrees) is interpolated from the same dataset. The data are presented in Figure 7.

The elevation map use the following elevation classes in the database: 712-1200, 1200-1300,1300-1500,>1500. The slope classes are: 0-2,2-5,5-10,10-15,>15.

8.4 Soil

The soil map is downloaded from the Harmonized would soil database with a resolution of 30 arc seconds and is presented in Figure 8.

Table 10. Data used for the preparation of the LUS database

| Used for	Name	Year of measure	Year / periodicity of publication	Scale / resolution / extent	Format	Availability or copyright	Producer	Metadata	Unity of measurements
Admin units	**Tanzania**	2002	2006	1:2,000,000	shp	country (modified)	URT	-	**classes**
Temperature	**Wordclim**	-	2005	30 arc seconds	GRID	free	www.worldclim.org	www.worldclim.org	degree centigrads
Livestock density	**Livestock statistics**	2007	2009	Report	stats	free	DALDO	report	heads per animals
Livestock natural distribution regions	**Agro-ecological zones**	1980 circa	1984	1:2,000,000	shp	free	URT/FAO	report	classes
Rainfall	**Wordclim**	-	2005	30 arc seconds	GRID	free	www.worldclim.org	www.worldclim.org	mm
Elevation	**SRTM Hydrosheds**	2000	2007	90 m	GRID	free	NASA Hydrosheds	Hydrosheds.er.usgs.org	m
Slope	**SRTM Hydrosheds**	2000	2007	90 m	GRID	free	NASA Hydrosheds	Hydrosheds.er.usgs.org	degree
Soil	**HWSD**	2008	2008	30 arc seconds	GRID	free	FAO IIASA ISRIC ISSCAS JRC	http://www.iiasa.ac.at/Research/LUC/External-World-soil-database/HTML/	-
Population density	**Population statistics**		yearly	-	stats	country			inhabit /sq km
Poverty	**Poverty in Kagera, Region (TZ)**	2004	2008	-	-	free	Julie Liotchfield and Thomas McGregor	http://www.sussex.ac.uk/Units/PRU/wps/wp42.pdf	classes

Figure 6 Temperature map

TZ: KAGERA PRECIPITATION
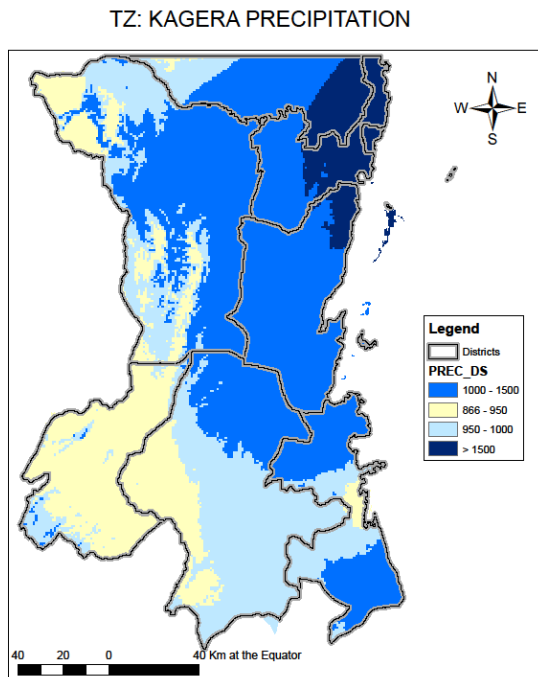
Figure 7 Terrain maps, elevation and slope

TZ: KAGERA ELEVATION

TZ: KAGERA SLOPE
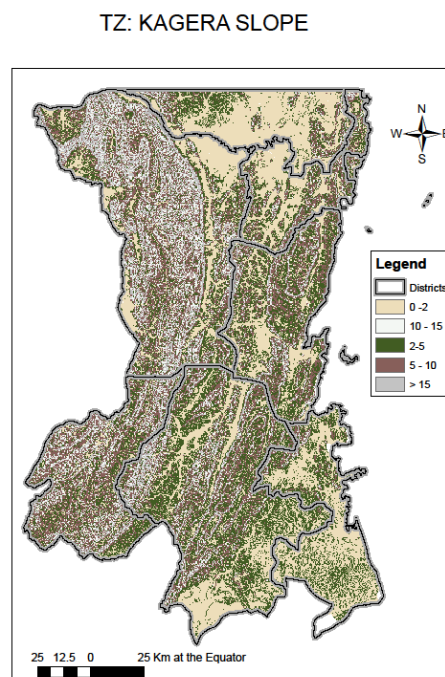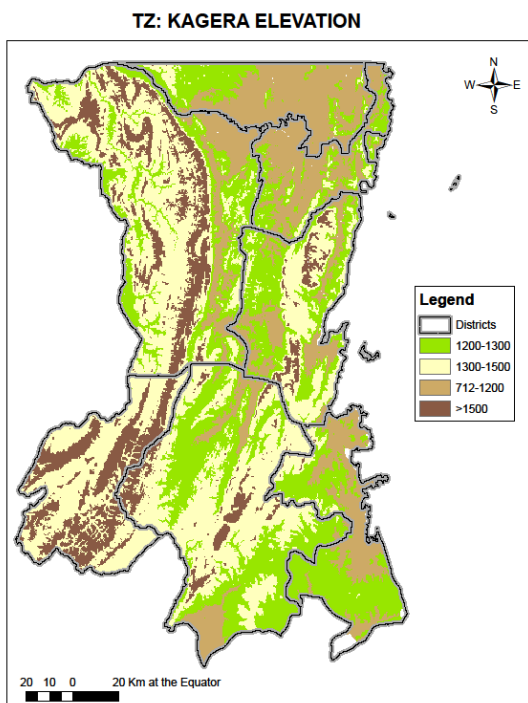
Figure 8 Soil map
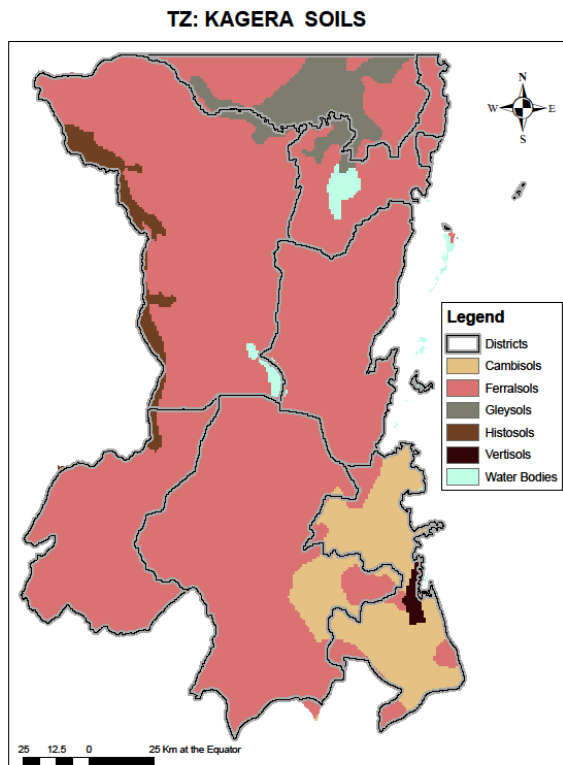
8.5 Population density

Population data (inhabitants per districts) are available from the national census. To be able to compare data between district, the population density has been calculated by dividing the population for the area in square kilometres. The list of classes used in the database is the following: 45-50,50-80,80-100,>100. The map is presented in figure 9.

8.6 Poverty

Julie Liotchfield and Thomas McGregor published in 2008 the report "Poverty in Kagera, Tanzania: Characteristics, Causes and Constraints" (PRUS Working Paper no. 42), relating the poverty severity index for the year 2004. The map is presented in figure 9.

Figure 9 Socio-economical maps: population density and poverty

TZ: KAGERA POPULATION DENSITY

Legend

Districts
45 -50
50-80
80 -100
> 100

20 10 0   20 Km at the Equator