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Standardizing land cover mapping for tsetse and trypanosomiasis decision making

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Contents

Abstract

The habitat of tsetse fly (*Glossina* spp.) depends upon climatic conditions, host availability and land cover characteristics. In this paper, the Land Cover Classification System (LCCS), developed by the Food and Agriculture Organization (FAO) and the United Nations Environment Programme (UNEP), is proposed as a tool to harmonize land cover mapping exercises carried out in the context of tsetse and trypanosomiasis (T&T) research and control. The potential of land cover maps to describe and predict tsetse habitat at different resolutions is also explored.

In Chapter 1, the LCCS-compliant Global Land Cover 2000 (GLC2000) of Africa and the predicted areas of suitability for tsetse provided by the Programme Against African Trypanosomiasis Information System (PAAT-IS) were matched to study the relationship between land cover and the habitat of the three groups of tsetse flies (i.e. *fusca*, *palpalis* and *morsitans*). The results are in accordance with the literature (e.g. one single class, 'Closed evergreen lowland forest', accounts for about 40 percent of the *fusca* group habitat and for about 27 percent of the *palpalis* group habitat, while two savannah classes, i.e. 'Deciduous woodland' and 'Deciduous shrubland with sparse trees', cover more than 50 percent of the area suitable for the *morsitans* group). Limitations in the analysis due to the resolution of the datasets are discussed and possible future developments are pointed out.

In Chapter 2, a standardized legend for land cover mapping in T&T decision-making is proposed. Based on the products and methodology developed by the FAO Africover project, the legend derives from thematic aggregation of the land cover classes defined for the maps available for eight T&T affected countries (i.e. Burundi, Democratic Republic of the Congo, Kenya, Rwanda, Somalia, Sudan, United Republic of Tanzania and Uganda). The 26 classes legend summarizes more than 500 classes present in the original Africover databases and it allows delineation of tsetse habitat across several countries in a harmonized and coherent manner. The aggregation procedure and the proposed legend are fully documented and in line with LCCS principles and rules.

A review of the literature allowed suitability for tsetse to be matched with the standardized land cover classes. Even though it stems from the Africover maps of East Africa, the proposed legend and methodology are applicable to any area in Africa. The practical and conceptual difficulties posed by the validation of the estimated classes of suitability are discussed; in this regard, a method linking the datasets at different resolutions gave positive results. It is important to note that the literature-based suitability assigned to each class only relates to the land cover and does not translate directly into a more general environmental suitability; additional conditions of altitude, climate, availability of host animals and habitat integrity must be met for tsetse to be present. Thus, land cover should be regarded as one parameter in a thorough study of tsetse ecology, which calls for the integrated analysis of a set of geospatial layers, including land-use maps, temperature and humidity datasets, digital elevation models (DEMs), hydrological network, livestock and wild animals' density maps. However, the

paper shows that many of the environmental variables are to some extent implicit in or related to land cover, making it a key element in any tsetse habitat study.

In Chapter 3 one case study, namely Uganda, illustrates how country maps compliant with LCCS can be analysed in more detail and customized to better meet the requirements of tsetse habitat mapping.

Standardization of land cover mapping is an important step towards the harmonization of the Information Systems (ISs) and the Decision Support Systems (DSSs), based on the Geographic Information System (GIS), for trypanosomiasis intervention. The adoption of LCCS within T&T control programmes would also benefit regional cooperation and it would facilitate the use of existing and upcoming land cover maps. In this regard, the West African component of the Global Land Cover Network (GLCN) has planned the production of LCCS-compliant datasets for several countries.

The high resolution of the available and future land cover datasets (within a range of scales from 1:200 000 to 1:50 000) will make possible the production of a new generation of risk maps, based on a deeper understanding of the landscape and environmental dynamics that drive the distribution of tsetse in Africa. Habitat modifications are increasingly induced by human actions, either at a global scale, as in the case of climatic change, or at a local scale, as in the processes of urbanization and agricultural expansion. The challenges posed in the future by trypanosomiasis are likely to be shaped by those factors to the extent that no appropriate intervention can possibly be contemplated without considering them.

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Acronyms

ATSR	Along Track Scanning Radiometer
COCTU	Coordinating Office for Control of Trypanosomiasis in Uganda
DEM	Digital Elevation Model
DFID	Department for International Development
DMSP	Defense Meteorological Satellites Program
DSS	Decision Support System
ERGO	Environmental Research Group Oxford
ERS	European Remote Sensing Satellite
FAO	Food and Agriculture Organization
FAOSTAT	FAO Statistical Database
GIS	Geographic Information System
GLC2000	Global Land Cover for the year 2000
GLCN	Global Land Cover Network
IFAD	International Fund for Agricultural Development
IS	Information System
ISO	International Organization for Standardization
HAT	Human African Trypanosomiasis
JERS	Japanese Earth Resources Satellite
JRC	Joint Research Centre
LCCS	Land Cover Classification System
MMA	Minimum Mappable Area
NFPI	National Focal Points Institution
PAAT	Programme Against African Trypanosomiasis
PAAT-IS	Programme Against African Trypanosomiasis-Information System
PATTEC	Pan African Tsetse and Trypanosomiasis Eradication Campaign
ppm	parts per million
RGB	Red-Green-Blue
SPOT	Satellite Pour l'Observation de la Terre
SWALIM	Somalia Water and Land Information Management System
T&T	Tsetse and trypanosomiasis
TALA	Trypanosomiasis and Land-use in Africa
TDS	Total Dissolved Solids
TM	Thematic Mapper
UNEP	United Nations Environment Programme
UTM	Universal Transverse Mercator
WGS 84	World Geodetic System 1984

Introduction

An accurate and detailed knowledge of the habitat of tsetse flies (*Glossina* spp.) is of paramount importance for planning and implementing T&T intervention activities. Remote sensing and GIS proved extremely powerful in describing tsetse distribution at continental and regional scale (Rogers and Randolph, 1993; Rogers *et al.*, 1996; Hay *et al.*, 1996; Robinson *et al.*, 1997; FAO, 2000; FAO/IAEA Joint Division, 2001; Rogers and Robinson, 2004). The high revisit frequency of several meteorological satellites allowed the application of sophisticated techniques (e.g. temporal Fourier analysis) that appeared able to depict with remarkable statistical accuracy the distribution of virtually all tsetse species in Africa. These studies produced predictions of environmental suitability for tsetse that are capable of supporting an informed selection of priority areas for intervention. Nonetheless, the instruments and methods used to study tsetse distribution at low resolution cannot be directly applied at larger scales. This is as a result of the intrinsic trade-off between spatial and temporal resolution of available earth-observation satellites; higher resolution sensors are characterized by a much lower revisit frequency.

When moving on from the selection of priority areas for intervention to the actual planning and implementation of tsetse control projects over specific areas, the available continental and regional tsetse distribution maps are no longer sufficient (Hendrickx *et al.*, 2001a) and there is a need to produce or collect baseline datasets, among which high resolution maps of land cover are of prime importance.

There is an increasing volume of literature regarding the application of high resolution satellite images in relation to various aspects of the T&T problem (Kitron *et al.*, 1996; Wilson *et al.*, 1997; Reid *et al.*, 1997; Reid *et al.*, 2000; de la Rocque *et al.*, 2001; Hendrickx *et al.*, 2001b; Bourn, 2003; De Deken *et al.*, 2005; Bouyer *et al.*, 2006). In most researches, remotely sensed data have been used to depict the vegetation cover of potential tsetse habitats and to study land cover/land-use dynamics and how they relate to trypanosomiasis intervention. In these studies, land cover maps cover a limited area within the affected country and they are produced using ad hoc classification systems. This makes it difficult to compare the analyses from different locations and to extrapolate the outcomes over wider areas. The lack of standardization in the land cover mapping exercises carried out in the context of T&T intervention also hinders the use of existing and future multipurpose land cover databases that are being produced in the framework of different international initiatives (i.e. GLCN and GLOBCOVER).

The aim of this paper (which expands on the study by Cecchi *et al.*, in press) is to promote the application of the FAO/UNEP LCCS within T&T management activities and to demonstrate the potential of high resolution, multipurpose land cover databases in support of the fight against African trypanosomiasis

Chapter 1
Tsetse fly habitat and land cover: an analysis at continental level

TSETSE HABITATS

A habitat is the place where a particular species lives and grows. It is essentially the biophysical environment that surrounds, influences and is utilized by a species population. Tsetse flies are found in a number of habitats in sub-Saharan Africa, ranging from the rain forest to savannahs. Their presence is usually related to the characteristics of land cover (i.e. vegetation), which is affected primarily by climate and human activities. The presence of a suitable source of food is also essential for tsetse. Like many other arthropods, tsetse flies are particularly sensitive to temperature and humidity and at the northern edge of their distribution high temperature and dryness limit the spread of the flies. This is also true for the southern limit of the distribution, even though in some areas seasonal low temperatures can be more important.

The three groups of tsetse flies (*morsitans, palpalis* and *fusca*) prefer different types of habitat. With one exception (*G. longipennis*), the species of the *fusca* group (corresponding to the subgenus *Austenina*) are forest flies inhabiting either rain forest or isolated patches of forest, along with riverine forest in the savannah zones. Flies of the *palpalis* group (subgenus *Nemorhina*) are found mainly in gallery forests, swamps and in watersides with closed canopy. The typical habitat of the *morsitans* group (subgenus *Glossina* s.s.) is open woodland and woodland savannah, but they are found also in forest edges, scattered thickets or even open country.

In addition to the typical habitats mentioned above, *Glossina* species can be found in less usual habitats, among which the man-made ones are the most important. Tsetse are found in and around villages, especially in the rain forest belt of West Africa, where the original vegetation has been cut down to create farms and plantations (mango, oil palm, bananas, cola nuts, cocoa, coffee).

Along with the macrohabitat, it is also important to know which are the microhabitats of tsetse flies. Microhabitats are suitable places for a species that can be depicted at a finer resolution. They can significantly differ from the surrounding areas in many ways, including the climate. Suitable microhabitats for tsetse are able to provide cooler or more humid conditions, especially in particularly harsh seasons or times of the day. The fly's behaviour can bring it into these places where it can survive better than if it had to suffer the general climatic conditions of the area.

LAND COVER CLASSIFICATION SYSTEMS: CONCEPTS AND DEFINITIONS

Land cover is the observed (bio)physical cover on the earth's surface. It describes vegetation and man-made features, whereas **land use** is characterized by the arrangements, activities and inputs people undertake in a certain land cover type to produce, change or

maintain it (FAO, 2005). Land use establishes a direct link between land cover and the actions of people in their environment.

Classification is an abstract representation of the situation in the field using well-defined diagnostic criteria, i.e. the classifiers. Classification can be defined as the ordering or arrangement of objects into groups or sets on the basis of their relationships (Sokal, 1974). A classification describes the systematic framework with the names of the classes and the criteria used to distinguish them, and the relationship between classes. Classification thus requires the definition of class boundaries, which should be clear, precise, possibly quantitative, and based upon objective criteria.

A classification should therefore be:

- source independent, implying that it is independent of the means used to collect information (satellite imagery, aerial photography, field survey or a combination of sources); and
- scale independent, meaning that the classes should be applicable at any scale or level of detail.

A **legend** is the application of a classification in a specific area using a defined mapping scale and specific dataset. Therefore a legend may contain only a proportion, or subset, of all possible classes of the classification. Thus, a legend is:

- data and mapping methodology dependent; and
- scale and cartographic representation dependent.

A critical factor in the production of reliable and comparable land cover and land-use data is the availability of common, harmonized classification systems that provide a reliable basis for interaction among the increasing number of national, regional and global mapping and monitoring activities. While the creation of a standard land-use classification system is still in its infancy[1], the definition of a standard of the International Organization for Standardization (ISO) for land cover classification is close to being achieved.

The Land Cover Classification System has been developed by FAO and UNEP to meet the need for improved access to reliable and standardized information on land cover and land cover changes. The Land Cover Classification System enables comparison of land cover classes regardless of mapping scale, land cover type, data collection method or geographic location. Currently, LCCS is the only universally applicable classification system in operational use. The inherent flexibility of LCCS, its applicability in all climatic zones and environmental conditions, and the built-in compatibility with other classification systems have given it the potential to be accepted as the international standard. For these reasons, LCCS is currently in the approval process by ISO.

The advantages of the classifier, or parametric, approach are manifold. The system created is a highly flexible *a priori* land cover classification in which each land cover class is clearly and systematically defined, thus providing internal consistency. The system is truly hierarchical and applicable at a variety of scales. Rearrangement of the

[1] http://www.glcn.org/news/downs/pub/res/GLCN-Bulletin4-JanFeb06.pdf

BOX 1
Land Cover Classification System design criteria

In LCCS, land cover classes are defined by a combination of a set of independent diagnostic criteria, the 'classifiers', which are hierarchically arranged to assure a high degree of geographical accuracy. The classification has two main phases:

- an initial dichotomous phase, where eight major land cover types are distinguished; and
- a subsequent modular-hierarchical phase, where the set of classifiers and their hierarchical arrangement are tailored to the major land cover type.

Further definition of the land cover class can be achieved by adding attributes. Two types of attributes, which form separate levels in the classification, are distinguished:

- environmental attributes (e.g. climate, landform, altitude, soil, lithology and erosion), which influence land cover but are not inherent features of it, and which should not be mixed with 'pure' land cover classifiers; and
- specific technical attributes, which are associated with specific technical disciplines (e.g. for (semi)natural vegetation, the floristic aspect can be added; for cultivated areas, the crop type; and for bare soil, the soil type).

classes based on regrouping of the classifiers used facilitates extensive use of the outputs by a wide variety of end users. All land covers can be accommodated in this highly flexible system.

The Land Cover Classification System is already an important tool in global mapping, being used in initiatives such as the GLC2000 project and the next global assessment, GLOBCOVER, that aims to produce a land cover map of the world for the year 2005. Developed initially through the practical experience of the FAO Africover project, LCCS has been widely adopted at the national level throughout Africa, Asia, Near East and Latin America.

MATCHING TSETSE HABITAT AND LAND COVER: POSSIBLE APPROACHES

The availability of multipurpose land cover datasets at different resolutions released into the public domain makes the prospect of matching standardized land cover classes and tsetse habitat very promising. It is expected that T&T research and control activities will greatly benefit from the use of existing and future land cover maps produced in compliance with the standard FAO/UNEP LCCS.

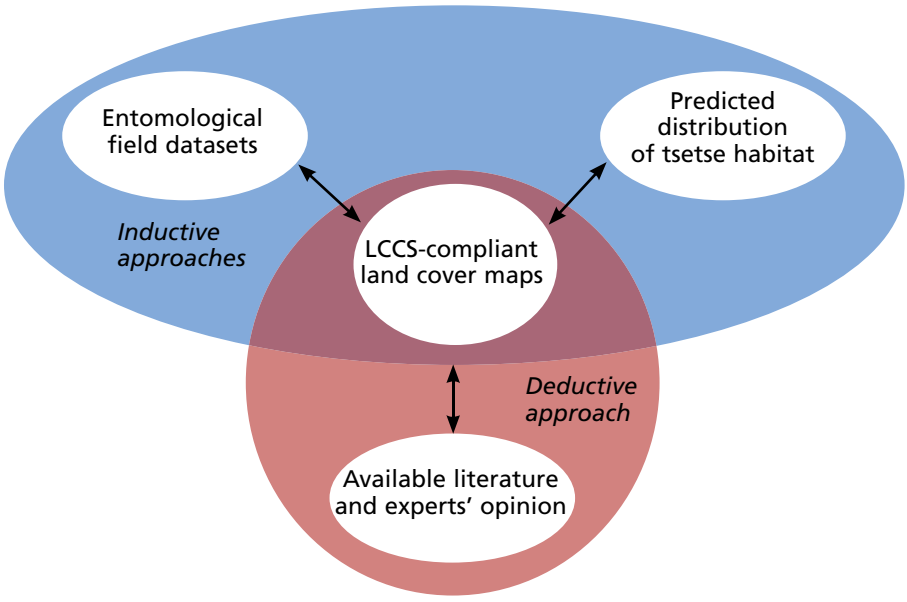
It is well known that among the factors influencing the suitability of habitats for tsetse flies, land cover is one of the most relevant. Vegetation is affected by and affects temperature and humidity, the two major abiotic determinants of tsetse distribution; trees in particular provide shade for developing pupae and resting sites for adults. The analysis of the vegetation cover has often played a major role in the estimates of the tsetse distribution and in the description of their habitat (Ford and Katondo, 1975; Ford and Katondo, 1977a,b; FAO, 1982; Katondo, 1984), but recent developments in remote sensing techniques provided global, regional and national datasets that can be

used to bridge the gap in our knowledge on the relationship between tsetse habitat and standardized land cover classes in Africa.

Three methods can be used to assess the suitability of land cover classes for tsetse: analysis of land cover maps and entomological field datasets (traps catches), analysis of land cover maps and predictions of tsetse distribution (e.g. based on remote sensing), review of available literature and experts' opinion (Figure 1). The two former methods belong to the category of inductive approaches, where the relationship between the variables is not assumed *a priori*, the latter can be defined instead as a deductive approach, which uses the species' known ecological requirements to extrapolate suitable land cover classes (Corsi *et al.*, 2000).

The first method is thought to be capable of providing the most accurate results, but as a result of the lack of updated and consistent field datasets for the whole continent, its application can only be envisaged over single countries or smaller areas. The second method is the one used in this chapter to estimate the land cover suitability for tsetse in sub-Saharan Africa; its major drawback is the use of predictions of tsetse habitat that have not yet undergone a full field validation. Therefore, this approach can only provide qualitative results. The third method is used in Chapters 2 and 3 to estimate the land cover suitability for tsetse flies, respectively in sub-Saharan Africa and in Uganda. The main problem in the application of this method lies in the fact that the scientific community studying tsetse habitat and ecology has not adopted LCCS yet, therefore the comparison of ad hoc defined classes and standard ones can be troublesome.

FIGURE 1
Possible approaches for estimating the suitability of standardized land cover classes for tsetse



TSETSE HABITAT AND LAND COVER IN SUB-SAHARAN AFRICA: AN INDUCTIVE APPROACH

In this chapter, the land cover of tsetse habitat in sub-Saharan Africa is described by means of the GLC2000 of Africa, and the FAO predicted distribution of tsetse habitat, produced in 1999. Both datasets, in their respective category, represent the best available information to date for the whole continent. The results are in substantial agreement with the literature related to tsetse habitats and they demonstrate that general-purpose land cover maps can be effective in supporting strategic decision-making in the field of T&T intervention.

Materials

Global Land Cover 2000

The Global Land Cover database for the year 2000 was produced by an international partnership of about 30 research groups coordinated by the European Commission's Joint Research Centre (JRC). The database contains regional land cover maps with detailed, regionally relevant legends and a global product that combines all regional classes into one consistent legend.

The land cover maps are based on daily data acquired between 1 November 1999 and 31 December 2000, from the VEGETATION sensor on board the fourth Satellite Pour l'Observation de la Terre (SPOT) satellite, SPOT 4. In addition, data from other sensors (the Along Track Scanning Radiometer [ATSR], the Japanese Earth Resources Satellite [JERS], the European Remote Sensing Satellite [ERS] and the Defense Meteorological Satellites Program [DMSP]) were used to solve specific problems, in particular in regions with persistent cloud cover, especially in equatorial regions, and for identification of urban areas. Each partner used the LCCS, which ensured that a standard legend was used over the globe. This hierarchical classification system allowed each partner to choose the most appropriate land cover classes to describe their region, whilst also providing the possibility of translating regional classes to a more generalized global legend. Data and information update may be found on the GLC2000 web pages[2].

In the present study, the regional product over Africa was used (Mayaux *et al.*, 2003; Mayaux *et al.*, 2004). The relevant legend (Global Land Cover 2000 of Africa) is given in Table 1 (p. 6).

Tsetse distribution maps

The predicted absence or presence of the three tsetse fly groups across Africa was derived from the FAO–PAAT predicted distribution of tsetse habitat (1999). All of the distributions were produced by modelling the 'known' presence and absence of the flies (usually the 1977 Ford and Katondo maps modified with more recent information collected from national and international agencies and researchers). The modelling process relied on logistic regression of fly presence against a wide range of predictor variables for a large number of regularly spaced sample points for each area. The predictor variables include remotely sensed (satellite image) surrogates of climate, vegetation, temperature and moisture, which were subjected to Fourier processing to provide an additional set of

[2] http://www-gem.jrc.it/glc2000/

TABLE 1
Legend of the Land Cover of Africa for the year 2000

	English name	Nom français
	Forests	**Forêts**
	Closed evergreen lowland forest	Forêt dense humide
	Degraded evergreen lowland forest	Forêt dense dégradée
	Submontane forest (900–1500 m)	Forêt submontagnarde (>900 m)
	Montane forest (>1500 m)	Forêt de montagne (>1500 m)
	Swamp forest	Forêt marécageuse
	Mangrove	Mangrove
	Mosaic forest / croplands	Mosaïque agriculture / forêt
	Mosaic forest / savanna	Mosaïque forêt / savane
	Closed deciduous forest (Miombo)	Forêt décidue dense (Miombo)
	Woodlands, shrublands and grasslands	**Savanes**
	Deciduous woodland	Savane boisée décidue
	Deciduous shrubland with sparse trees	Savane arborée à arbustive décidue
	Open deciduous shrubland	Savane arbustive décidue
	Closed grassland	Savane herbacée dense
	Open grassland with sparse shrubs	Savane herbacée ouverte à faible strate arbustive
	Open grassland	Savane herbacée ouverte
	Sparse grassland	Pseudo-steppe
	Swamp bushland and grassland	Savane herbacée et arbustive inondée
	Agriculture	**Agriculture**
	Croplands (>50%)	Agriculture (>50 %)
	Croplands with open woody vegetation	Mosaïque agriculture / végétation sèche
	Irrigated croplands	Agriculture irriguée
	Tree crops	Vergers
	Bare soil	**Autres occupations du sol**
	Sandy desert and dunes	Roche nue
	Stony desert	Désert rocheux
	Bare rock	Désert sableux et dunes
	Salt hardpans	Dépôts salins
	Other land cover classes	**Autres occupations du sol**
	Waterbodies	Eau
	Cities	Villes

season- and timing-related measures for each parameter. Demographic, topographic and agro-ecological predictors were also used. These models were then applied to the predictor imagery to determine the probability of fly distributions. Data are at 5 km resolution for the whole sub-Saharan Africa. The 5 km continental maps were produced for the FAO Animal Health and Production Division and the Department for International Development (DFID) Animal Health Programme by the Environmental Research Group Oxford (ERGO) Ltd in collaboration with the Trypanosomosis and Land-use in Africa (TALA) research group at the Department of Zoology, University of Oxford.

Method

The predicted distributions of tsetse habitat define habitat suitability in probabilistic terms; for the present study, the threshold of 50 percent was used to discriminate suitable from unsuitable areas. The mask of suitable areas was overlaid onto the Global

TABLE 2
Thresholds for the tsetse suitability classes

	Suitability of land cover for tsetse *(0–3)*	Criterion: proportion of suitable habitat within the class *(%)*
3	High	> 50
2	Moderate	> 25 and ≤ 50
1	Low	> 5 and ≤ 25
0	Unsuitable	≤ 5

Land Cover of Africa to calculate the proportion of each land cover class within the potential fly distribution. The results of the analysis were used to define for each fly group and land cover class a degree of suitability for tsetse. For each land cover class, the suitability value was assigned as a function of the percentage of tsetse infestation area within the total area covered by the class (fifth column in Table 3, Table 4 and Table 5). The thresholds used are given in Table 2.
The chi-square test was used to measure the relative magnitude of the statistical relationship between land cover and tsetse presence.

Results

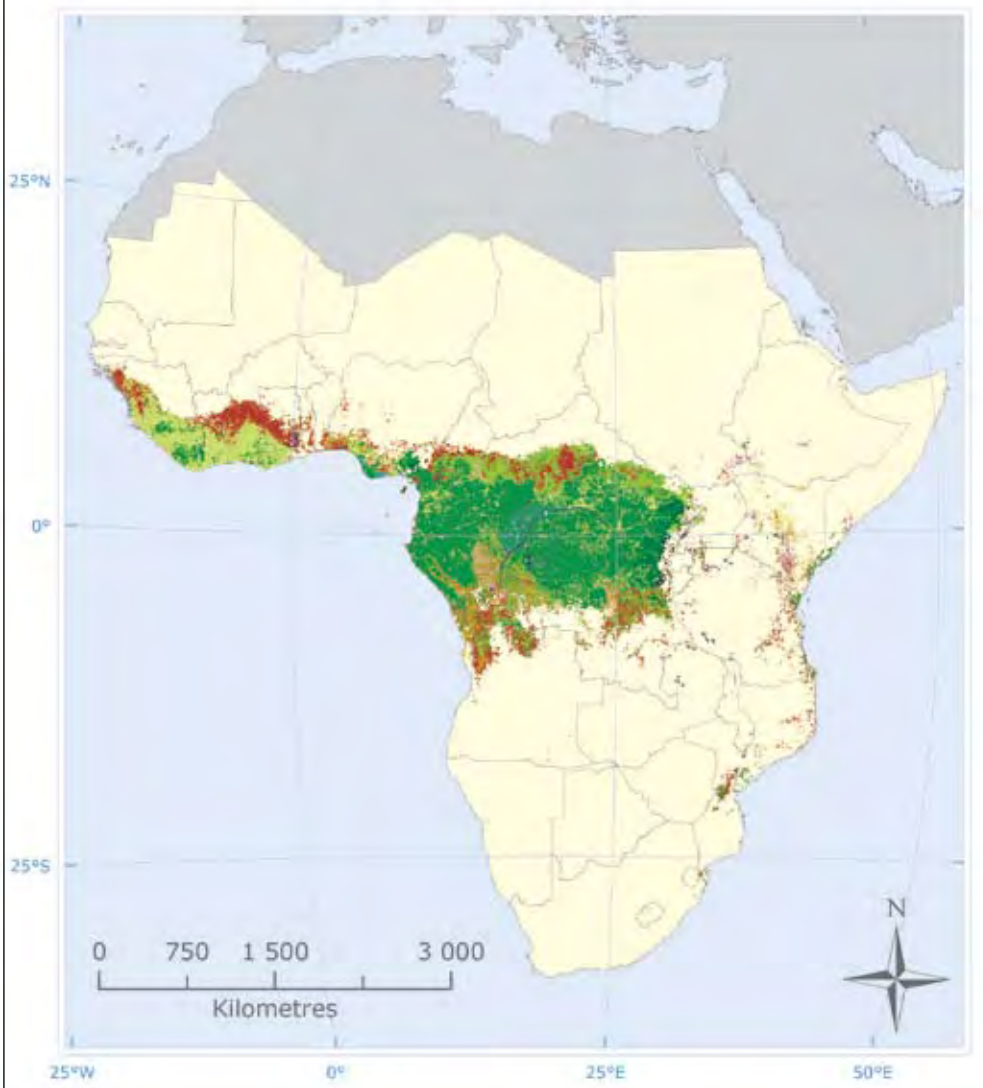
The results of the analysis are summarized in Figures 2, 3 and 4 and in Tables 3, 4 and 5, and charted in Figure 5.

'Closed evergreen lowland forest' is the most important land cover class for the *fusca* group, covering almost 40 percent of its distribution. The principal habitat of these forest flies is clearly confirmed by the analysis; a forest or woodland component is present in the first five classes ranked in Table 3. Similarly, for the *palpalis* group (Figure 3 and Table 4), the single most relevant land cover class is 'Closed evergreen lowland forest', which accounts for more than 25 percent of the distribution. More generally, most of the classes with a forest component appear to be highly suitable for flies of the *palpalis* group, meaning that more than 80 percent of their distribution falls within the tsetse infestation area e.g. 'Mosaic forest/croplands', 'Mosaic forest/savannah (Gallery-forests)', 'Swamp forest', 'Submontane forest (900–1500 m)', 'Degraded evergreen lowland forest'.

For the *morsitans* group (Figure 4 and Table 5), the marked preference for savannah habitats is clearly described. 'Deciduous woodland' and 'Deciduous shrubland with sparse trees' account for more than 50 percent of the distribution and include such habitats as tree savannah, woodland savannah and shrub savannah. 'Closed deciduous forest', more commonly known as Miombo woodland, accounts for an additional 10 percent of the distribution. Also important are landscapes with an agricultural component – 'Croplands (>50 percent)', 'Mosaic forest/croplands', 'Croplands with open woody vegetation' – which add up to around 18 percent of the distribution[3].

[3] The detection of agriculture in Africa from remote sensing data at 1 km spatial resolution is quite problematic because of the characteristics of prevailing farming systems and the spatial pattern of croplands. The fields are small and mixed with savannahs and fallows, which preclude a reliable mapping. On the other hand, the low intensification level of agricultural techniques induces spectral or temporal properties of agriculture close to the surrounding natural vegetation.

FIGURE 2
Land cover of tsetse habitat, *fusca* group, in sub-Saharan Africa



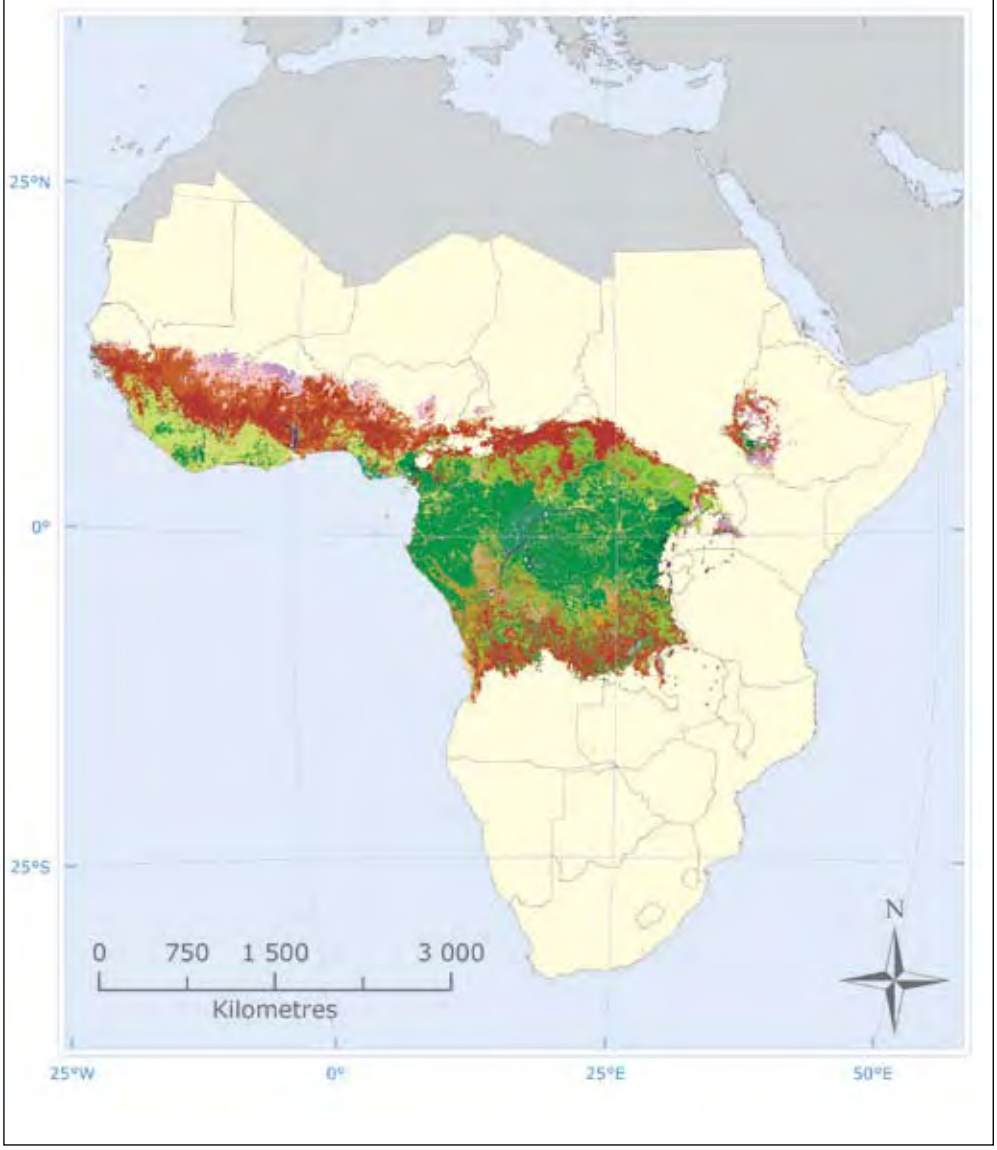
The last class worth noting is the 'Mosaic forest/savannah' that contains vegetation formations including forest elements and savannah elements; in this class of the GLC2000 fall the gallery-forests, tree formations developed along the riverbanks in the middle of shrub or grass vegetation. Gallery-forest is a typical habitat of riverine flies (*palpalis* group) but used by *morsitans* group too, in particular during the drier periods of the year.

TABLE 3

Land cover and tsetse habitat, *fusca* group, in sub-Saharan Africa. For the definition of the suitability index the thresholds in Table 2 (p. 7) were used

	Land cover class name	Tsetse habitat (km^2)	Tsetse habitat (%)	Proportion of the land cover class in sub-Saharan Africa (%)	Suitable habitat within the class (%)	Suitability index for tsetse (0–3)
	Closed evergreen lowland forest	1 638 800	39.7	7.3	95.5	3
	Mosaic forest / Croplands	628 100	15.2	3.2	82.9	3
	Deciduous woodland	458 200	11.1	12.3	15.9	1
	Mosaic forest / Savanna (Gallery-forests)	422 100	10.2	2.9	61.5	3
	Closed deciduous forest (Miombo)	175 300	4.2	5.1	14.8	1
	Open deciduous shrubland	167 900	4.1	4.4	16.4	1
	Swamp forest	133 600	3.2	0.6	100.0	3
	Submontane forest (900–1500 m)	107 400	2.6	0.6	80.4	3
	Deciduous shrubland with sparse trees	107 200	2.6	7.2	6.4	1
	Closed grassland	95 200	2.3	3.7	11.1	1
	Croplands (>50 percent)	51 400	1.2	9.4	2.3	0
	Open grassland with sparse shrubs	38 600	0.9	6.8	2.4	0
	Degraded evergreen lowland forest	32 800	0.8	0.2	94.9	3
	Open grassland	19 100	0.5	4.8	1.7	0
	Montane forest (>1500 m)	14 700	0.4	0.3	21.8	1
	Mangrove	13 200	0.3	0.1	46.4	2
	Sparse grassland	10 200	0.3	6.2	0.7	0
	Swamp bushland and grassland	7 900	0.2	0.5	7.5	1
	Croplands with open woody vegetation	5 000	0.1	4.1	0.5	0
	Cities	2 800	0.1	0.1	16.4	1
	Irrigated croplands	1 400	0.0	0.1	4.1	0
	Bare rock	1 100	0.0	3.8	0.1	0
	Stony desert	400	0.0	8.4	0.0	0
	Sandy desert and dunes	200	0.0	7.9	0.0	0
	Salt hardpans	200	0.0	0.1	1.2	0
	TOTAL	4 132 800	100.0	100.0		

FIGURE 3
Land cover of tsetse habitat, *palpalis* group, in sub-Saharan Africa



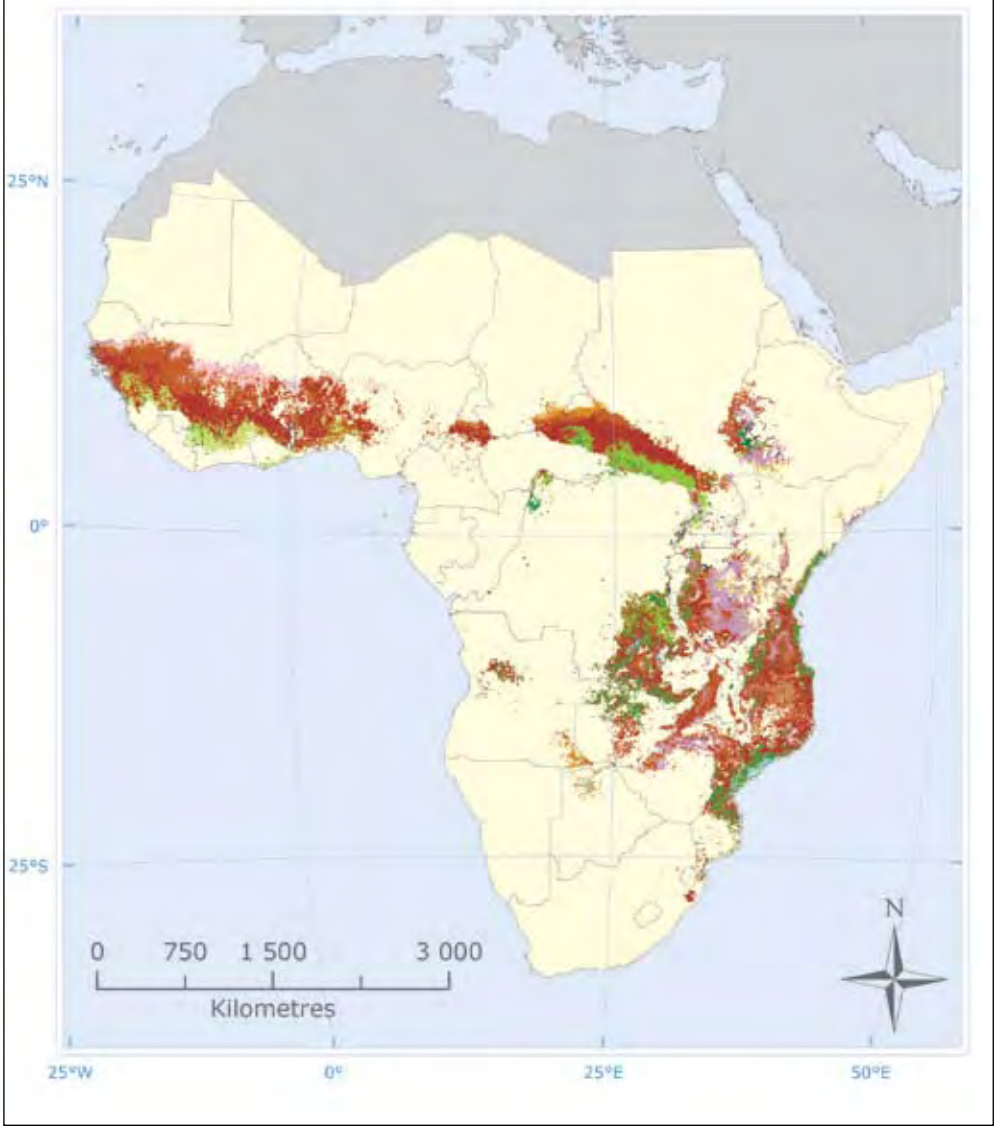
The difference in resolution between the two input layers (1 km for the GLC2000 and 5 km for the tsetse habitat maps) and more importantly the inherent inaccuracies of the two datasets, in particular the tsetse flies predictions, must be taken into account when interpreting the results. Particular care must be taken when reading the figures related to the least represented classes (e.g. 'Cities', accounting for only 0.06 percent in the GLC2000 of sub-Saharan Africa) because of the limited statistical representativeness of the sample.

TABLE 4

Land cover and tsetse habitat, *palpalis* group, in sub-Saharan Africa. For the definition of the suitability index the thresholds in Table 2 (p. 7) were used

	Land cover class name	Tsetse habitat *(km²)*	Tsetse habitat *(%)*	Proportion of the land cover class in sub-Saharan Africa *(%)*	Suitable habitat within the class *(%)*	Suitability index for tsetse *(0–3)*
	Closed evergreen lowland forest	1 674 700	26.1	7.3	97.5	3
	Deciduous woodland	1 282 900	20.0	12.3	44.6	2
	Mosaic forest / Croplands	708 300	11.0	3.2	93.4	3
	Deciduous shrubland with sparse trees	702 400	11.0	7.2	41.9	2
	Mosaic forest / Savanna (Gallery-forests)	643 800	10.0	2.9	93.8	3
	Closed deciduous forest	319 800	5.0	5.1	26.9	2
	Croplands with open woody vegetation	265 900	4.2	4.1	28.0	2
	Open deciduous shrubland	218 900	3.4	4.4	21.3	1
	Croplands (>50 percent)	158 300	2.5	9.4	7.2	1
	Swamp forest	133 600	2.1	0.6	100.0	3
	Submontane forest (900–1500 m)	113 000	1.8	0.6	84.6	3
	Closed grassland	95 500	1.5	3.7	11.2	1
	Degraded evergreen lowland forest	33 800	0.5	0.2	97.9	3
	Mangrove	12 900	0.2	0.1	45.1	2
	Montane forest (>1500 m)	12 100	0.2	0.3	18.0	1
	Swamp bushland and grassland	12 000	0.2	0.5	11.4	1
	Open grassland with sparse shrubs	10 300	0.2	6.8	0.7	0
	Open grassland	5 200	0.1	4.8	0.5	0
	Irrigated croplands	4 200	0.1	0.1	12.5	1
	Cities	3 600	0.1	0.1	21.2	1
	Bare rock	1 300	0.0	3.8	0.2	0
	Sparse grassland	1 000	0.0	6.2	0.1	0
	Sandy desert and dunes	700	0.0	7.9	0.0	0
	Stony desert	700	0.0	8.4	0.0	0
	Salt hardpans	100	0.0	0.1	0.7	0
	TOTAL	6 415 000	100.0	100.0		

FIGURE 4
Land cover of tsetse habitat, *morsitans* group, in sub-Saharan Africa



More accurate results could be obtained in the future through the GLOBCOVER 2005 project that will provide a land cover map of the world at 300 m resolution. Nonetheless, the main limitation in this type of analysis is represented by the resolution and the accuracy of the tsetse distribution maps, whose update and upgrade at continental level would call for long-term studies and investments.

Further studies might concentrate on smaller geographical areas, for example at country level, and take advantage of datasets at a higher spatial resolution. Africover maps, for

TABLE 5

Land cover and tsetse habitat, *morsitans* group, in sub-Saharan Africa. For the definition of the suitability index the thresholds in Table 2 (p. 7) were used

Land cover class name	Tsetse habitat *(km²)*	Tsetse habitat *(%)*	Proportion of the land cover class in sub-Saharan Africa *(%)*	Suitable habitat within the class *(%)*	Suitability index for tsetse *(0–3)*
Deciduous woodland	1 297 100	32.0	12.3	45.1	2
Deciduous shrubland with sparse trees	922 900	22.8	7.2	55.1	3
Closed deciduous forest (Miombo)	407 200	10.1	5.1	34.3	2
Croplands (>50 percent)	371 200	9.2	9.4	16.8	1
Mosaic forest / Savanna (Gallery-forests)	204 700	5.1	2.9	29.8	2
Mosaic forest / Croplands	202 700	5.0	3.2	26.7	2
Croplands with open woody vegetation	191 600	4.7	4.1	20.1	1
Open deciduous shrubland	124 100	3.1	4.4	12.1	1
Closed grassland	102 100	2.5	3.7	11.9	1
Closed evergreen lowland forest	65 100	1.6	7.3	3.8	0
Open grassland with sparse shrubs	64 300	1.6	6.8	4.0	0
Swamp bushland and grassland	34 000	0.8	0.5	32.3	2
Submontane forest (900–1500 m)	19 000	0.5	0.6	14.2	1
Montane forest (>1500 m)	10 000	0.3	0.3	14.8	1
Open grassland	9 100	0.2	4.8	0.8	0
Mangrove	8 400	0.2	0.1	29.4	2
Irrigated croplands	5 900	0.2	0.1	17.8	1
Swamp forest	4 000	0.1	0.6	3.0	0
Degraded evergreen lowland forest	2 900	0.1	0.2	8.3	1
Sparse grassland	2 700	0.1	6.2	0.2	0
Cities	1 000	0.0	0.1	5.8	1
Bare rock	1 000	0.0	3.8	0.1	0
Stony desert	800	0.0	8.4	0.0	0
Salt hardpans	500	0.0	0.1	3.5	0
Sandy desert and dunes	500	0.0	7.9	0.0	0
TOTAL	4 052 800	100.0	100.0		

FIGURE 5
Synthetic view of the land cover of tsetse habitat by group

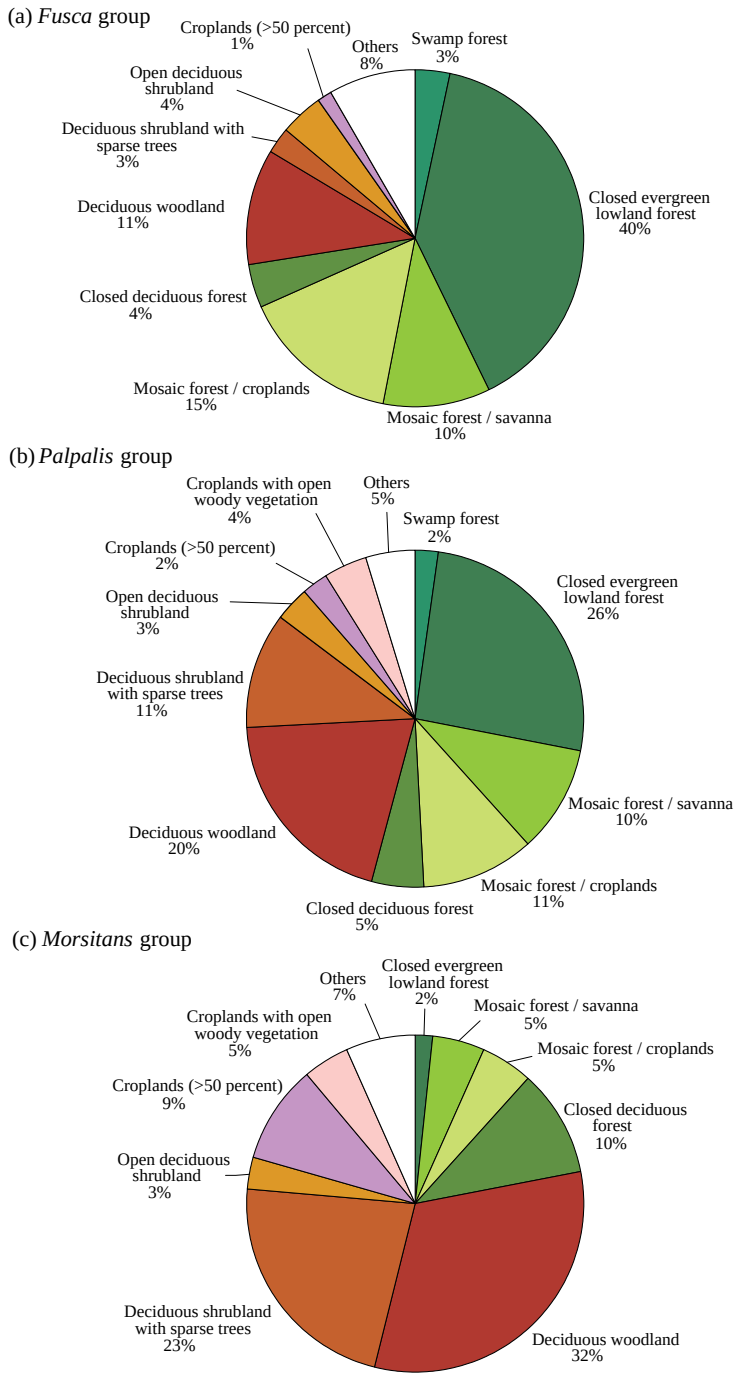


TABLE 6

Shared variance between tsetse habitat and land cover classes (χ^2 test)

Tsetse group	r^2 (shared variance)
Fusca	0.56
Palpalis	0.47
Morsitans	0.19

instance, are produced by means of 15 m resolution Landsat images, which are able to describe potential tsetse habitats with much greater detail. Such high-resolution vector maps could be matched with point entomological datasets on tsetse presence and abundance with a view to studying in more depth the effects of landscape features and patterns on fly populations. It is also possible to interpret the work presented in Chapters 2 and 3 in this framework.

For this exercise we used the threshold of 50 percent to discriminate suitable from unsuitable habitat, using the predicted areas of suitability by PAAT-IS as input dataset. In order to examine the impact of this assumption, for each land cover class we compared two indexes: the 'suitable habitat within the class (percent)' (based on the threshold of 50 percent and reported in Tables 3, 4 and 5) and an 'average suitability'. The latter was calculated averaging the percentage values of the predicted areas of suitability for tsetse. For the purpose of our study, the two indexes can be considered equivalent, to the extent that using the latter to estimate the class of suitability in the last column in Tables 3, 4 and 5 would not alter the outcome for any land cover class (in the linear regression between the two indexes the coefficient of determination [R^2] is equal to 1, 0.9999 and 0.9962, respectively for the *fusca*, *palpalis* and *morsitans* groups).

Chi-square test

Chi-square (χ^2) is a simple non-parametric test of statistical significance for bivariate tabular analysis. Used in this context, i.e. to check the hypothesis that the different land cover classes help us to predict the presence or absence of tsetse flies, the test gave an easily predictable positive result for all three fly groups. More interestingly, symmetric measures based on the chi-square statistic are capable of measuring the strength of the relationship between the dependent and independent variable. In particular, the measure called shared variance[4] is the portion of the total distribution of the variables measured in the sample data that is accounted for by the relationship detected with the chi-square test. The values of the shared variance (land cover–tsetse presence/absence) for the three tsetse groups are shown in Table 6.

It is apparent that for the *fusca* and *palpalis* groups the land cover suitability plays a bigger role in the definition of the environmental suitability than it does for the *morsitans* group. The figure 0.56 for *fusca* means that 56 percent of the tsetse habitat can be predicted by land cover. The p*alpalis* group displays a slightly weaker relationship with the predictor (47 percent), while the *morsitans* group absence/presence can be explained by land cover only to a limited extent (19 percent).

[4] $r^2 = \chi^2 / N(k - 1)$, where χ^2 is chi-square, N is the total number of observations and k is the smaller of the number of rows or columns in the cross tabulation. In this exercise the tables contain 26 rows (land cover classes), and 2 columns (tsetse absence/presence).

Chapter 2
Standardized land cover for T&T decision-making

In Chapter 1 the land cover of tsetse habitat was studied at continental scale by means of the GLC2000 of Africa. Global Land Cover 2000 is a multipurpose dataset, meaning that it was not created for a specific use but rather for a wide variety of applications. For the purpose of studying tsetse habitat and supporting T&T intervention the legend used in GLC2000 is not the ideal one; in the present chapter we try to define a more appropriate legend, using as a basis the datasets produced by the FAO Africover project. Even though the legend was created by aggregating some hundreds of land cover classes available in the Africover maps of east African countries, the legend is general enough to become a standard for T&T, valid for the whole continent. As is the case for GLC2000 and Africover, the proposed standard land cover for T&T is also based on the LCCS. Some general information about Africover and ensuing initiatives is given below.

HIGH RESOLUTION LAND COVER MAPS: AFRICOVER AND GLOBAL LAND COVER NETWORK

The purpose of the Africover project was to establish a digital georeferenced database on land cover and a geographic reference for the whole of Africa. The eastern Africa module was the first operational component of the Africover project and it was part of FAO assistance to countries involved in the Nile Basin initiative. The project was operational from 1995 to 2002 and the main output was the production of standardized land cover maps for ten countries[5]. From the methodological standpoint, Africover promoted the development of the LCCS, adopted by FAO and UNEP as the international standard for land cover classification and currently on its way to becoming an ISO standard.

The Global Land Cover Network initiative stemmed from the Africover Project; GLCN is a global alliance for the production of standardized, multipurpose land cover data worldwide; GLCN is now envisaging the production of land cover maps of several African countries[6] (Figure 6). The map of Senegal should be completed by the end of 2007.

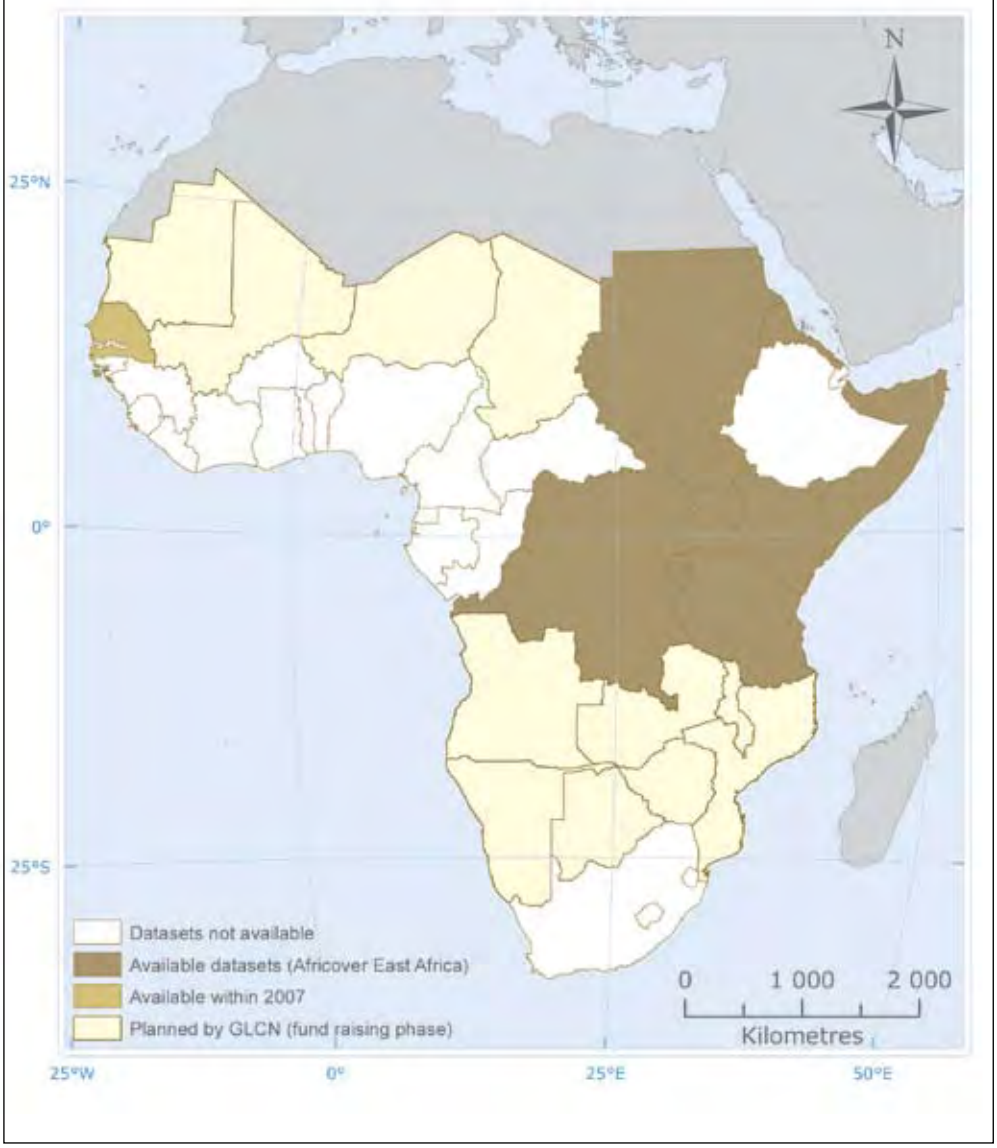
Africover products

For each project country, the most detailed land cover map produced by Africover is the 'Full resolution multipurpose land cover database'. The maps are on a scale of 1:200 000 or 1:100 000, respectively for large or small countries (or specific areas of

[5] Burundi, Democratic Republic of the Congo, Egypt, Eritrea, Kenya, Rwanda, Somalia, Sudan, United Republic of Tanzania and Uganda.

[6] Angola, Botswana, Chad, Malawi, Mali, Mauritania, Mozambique, Namibia, Niger, Zambia and Zimbabwe.

FIGURE 6
Availability of LCCS-compliant, high resolution land cover datasets in sub-Saharan Africa



interest in a country, e.g. the Nile river delta). The geodetic datum is the World Geodetic System 1984 (WGS84), the cartographic projection is Universal Transverse Mercator (UTM), and the planimetric accuracy of land cover polygons is 100 m. The land cover was produced from visual interpretation of digitally enhanced LANDSAT TM images (Bands 4, 3, 2). The land cover classes were developed using LCCS. In the 'Full resolution multipurpose land cover database' no minimum mapping unit (the smallest

area that can be shown on the map) was set; therefore very small polygons measuring a few hectares are also present.

FAO Africover distributes a public domain, spatially aggregated version of the full resolution land cover dataset. The thematic content of the spatially aggregated dataset is very similar to the original one; the aggregation is performed at a spatial level, setting a threshold under which the polygons are dissolved into adjacent polygons.

On the Africover website[7], three predefined thematic aggregations (agriculture, grassland, woody), all based on the original 'Full resolution multipurpose database', are also available. In general terms, thematic aggregation is the procedure for customizing the Africover database to fulfil specific requirements. The Africover database gives equal levels of detail to agriculture as well as to natural vegetation or bare areas etc. A single user normally does not need a high level of detail for each class type; therefore they will enhance the information of one land cover type and will generalize or erase the information related to other land cover aspects.

Dissemination policy

The national databases developed by Africover are the property of each country; the NFPIs are responsible for the maintenance, update and distribution of the national databases. Specific data access policies have been developed in agreement with the NFPIs for the different types of datasets. The 'Full resolution multipurpose land cover database' is deposited in the NFPIs; FAO Africover also acts as a repository of the full resolution dataset and can access it for specific purposes. The authorization to access the full resolution database must be granted by the NFPIs. On the base of an agreement with the participating countries, FAO Africover distributes free of charge the spatially aggregated version of the full resolution database. Starting from the public domain Africover database, users can develop their own aggregations to satisfy specific information needs.

Thematic aggregation: basic concepts

Either the 'Full resolution multipurpose database' or the 'Spatial aggregation' can be used to perform customized thematic aggregations to better meet the requirements of the final user. Thematic aggregation is the process through which the original richness of the database is reduced in order to highlight the features that are relevant for the user and to drop all unnecessary information. The production of land cover maps for tsetse habitat mapping presented in this chapter was carried out through thematic aggregation of the 'Full resolution multipurpose databases' of eight T&T affected countries.

The most powerful way to conduct an aggregation is to use the classifiers as basic elements of the exercise. This gives the user the maximum flexibility on the use of data. The aggregation procedure follows three main conceptual phases:

1. Identification of the classifiers needed for the data customization.
2. Identification of the thematic classes containing the selected classifiers.
3. Creation of the aggregated classes taking into account the Africover cartographic standards.

[7] www.africover.org

In the Africover database, because of the Minimum Mappable Area (MMA) chosen, the concept of mixed unit and the inherent characteristics of the study area, land cover class 'A' can be spatially represented in different ways:

- As a single map unit: A
- As a mixed map unit where 'A' is the dominant feature (more than 50 percent of polygon area): A/B;
- As a mixed map unit where 'A' is not the dominant feature (from 20 to 49 percent of polygon area): B/A; and
- As a mixed map unit were 'A' is not the dominant feature (from 10 to 20 percent of polygon area): B/A (this is valid only for 'isolated agricultural fields').

Owing to the fact that in Africover a mixed unit can have up to three classes A/B/C an aggregation class (called 1) can be represented in four (five for agriculture) different ways:

- 1 (were 100 percent of polygon area represents the aggregation class);
- 1a (60 percent approximately);
- 1b (40 percent approximately);
- 1c (20–30 percent approximately); and
- 1d (15 percent approximately. Only for agriculture).

In the aggregated map of Uganda presented in Chapter 3, the above possible combinations of mixed units were used to weight the contributions of different classes within mixed units in the assessment of tsetse suitability (see Figure 27, p. 57).

DEFINING A STANDARDIZED LEGEND FOR LAND COVER MAPPING IN T&T DECISION-MAKING

The standard legend proposed in this chapter was defined through the customization of eight out of ten national Africover databases currently available over East Africa[8] (i.e. the eight T&T affected countries). In the proposed methodology, based on thematic aggregation, one single legend is used to describe the land cover of all countries; the legend is composed of 26 classes (Table 7) that summarize more than 500 classes of the original databases. The aggregated classes have been defined with a view to depicting tsetse habitat across several countries in a harmonized and coherent manner.

One guiding principle for the definition of the legend has been the detailed description of natural vegetation, which is of prime importance in studies of tsetse habitat; 17 out of the 26 classes describe natural primarily vegetated areas, either terrestrial or aquatic. Two major LCCS classifiers have been used to define the natural vegetation: 'life form'[9]

[8] Burundi, Democratic Republic of the Congo, Kenya, Rwanda, Somalia, Sudan, United Republic of Tanzania, Uganda.

[9] *Life form* of a plant is defined by its physiognomic aspect: 'woody' life forms are distinguished from 'herbaceous' life forms. The woody life form is subdivided into 'trees' and 'shrubs'. A condition of height is applied to separate trees and shrubs. Plants higher than 5 m are classified as trees. In contrast, plants lower than 5 m are classified as shrubs (these general rules are subjected to the following exception: a plant with a clear physiognomic aspect of tree can be classified as tree even if the height is lower than 5 m but more than 3 m). A special class, called 'woody', has been created for plants included into the 2–7 m range, when no further

TABLE 7
Legend of the land cover map of East Africa for T&T (derived from Africover maps)

	MapCode	Class name (User Defined Description)	LCC User Defined Label
	1	Forest plantations and tree plantations	T
	2	Shrub crop	S
	3	Herbaceous crops	H
	4	Vegetated urban areas	5UV
	5	Forest	2TC
	6	Woodland	2TP
	7	Closed woody vegetation	2WC
	8	Open woody vegetation	2WP
	9	Thicket	2SC
	10	Shrubland	2SP
	13	Tree savannah	2H7
	12	Shrub savannah	2H8
	11	Grassland	2H(CP)
	14	Sparse trees	2TR
	15	Sparse shrubs	2SR
	16	Sparse herbaceous vegetation	2HR
	17	Fields rice	GZ-r
	18	Closed swamp	4TC
	19	Open swamp	4TP
	20	Woody vegetation on flooded land	4W
	21	Shrubs on flooded land	4S
	22	Herbaceous vegetation on flooded land	4H
	23	Artificial surfaces	5
	24	Bare soil	6
	25	Water bodies	W
	26	Snow	8SP

and 'cover'[10]. These two classifiers are considered to be the most relevant in determining the suitability for tsetse of different vegetation types because they describe the height and structure of the individual plants (life form, i.e. physiognomy) and the density of the vegetation (cover).

With respect to cultivated areas, the only distinction is made between tree, shrub or herbaceous crops. In the original databases detailed information is available on field size, cultural practices (e.g. rainfed, irrigated, etc.) and crop species; if need be, this information could be retrieved from the original databases to arrange a different type of

definition into tree or shrub is specified. The 'woody' class can be applied basically in two cases: the vegetation is an intricate mixture of both trees and shrubs which cannot be distinguished and with height included in the 2–7 m range; the user is not interested in further subdivision into trees or shrubs or has no information about it.

[10] Cover can be considered as the presence of a particular area of the ground, substrate or water surface covered by a layer of plants considered at the greatest horizontal perimeter level of each plant in the layer (according to Eiten, 1968). A distinction is made between 'closed' (>60–70 percent), 'open' (between 60–70 and 10–20 percent) and 'sparse' (<10–20 percent but >1 percent). As herbaceous plants are seasonal in character, cover is always assessed in terms of fullest development.

aggregation. Further information on the land cover classes listed in Table 7, such as the standard definition of classes according to LCCS and the LCCS classifiers used, can be found in Annexes 1 and 2.

Figure 7(d) shows the Africover land cover customized for T&T decision-making over a small area 35 km west of Kampala, Uganda. The map legend reports only the land cover classes relevant to the area depicted. In the map, polygons are coloured on the basis of the main land cover, while a slash symbol, '/', separates the codes of mixed polygons in the labels. In Figure 7(a), (b), and (c) the satellite imagery upon which the maps is based is presented. The panchromatic band (15 m resolution) is displayed in greyscale, 7(a), in true colours, 7(b), is the Red–Green–Blue (RGB) composite of bands 3, 2 and 1 (30 m resolution), in false colours 7(c) is the RGB composite of bands 4, 3 and 2. (Band 4 of Landsat 7 satellite is sensitive to the near infrared band of the electromagnetic spectrum and is particularly useful for vegetation monitoring.)

Given that the proposed legend derives from the thematic aggregation of the land cover classes of the Africover maps (see table of class aggregation in Annex 3), it is straightforward to derive the standardized maps for T&T decision-making for the eight countries available in the Africover dataset (Figure 8). For the sake of clarity, in these graphic representations each land cover polygon was given the colour of its main class only (i.e. in these maps, patches characterized by mixed cover cannot be distinguished from pure polygons).

Figures 9 to 15 are the national maps used to create the seamless regional mosaic in Figure 8.

The proposed legend has tsetse habitat mapping and T&T intervention as its major targets. For studies of a different nature it might be more useful to define other aggregations. If mapping trypanosomiasis risk were the final goal, the interface between natural and managed areas could be analysed in more detail; for instance, in the Africover datasets it is possible to highlight the presence of scattered or isolated cropped areas in a matrix of natural vegetation. More in general, Africover datasets are capable of depicting varying degrees of intermixing between cropped areas and natural vegetation. These zones of transition between natural and managed areas are the ones were risk of contact between vectors and cattle or men is at its highest (de la Rocque *et al.*, 2001) and they should be the target of more intense T&T control actions. A closer look at the spatial pattern of natural and managed areas could also be used to study tsetse habitat fragmentation due to human encroachment.

The proposed classification is not only aimed at the customization of existing Africover datasets, but it can be used also within ad hoc land cover mapping exercises carried out in the framework of T&T research and control activities. It could also be applied to upcoming datasets produced within the framework of the GLCN, possibly with minor adaptations.

It is very important to stress that the use of the legend in Table 7 is not sufficient for a land cover map to be compliant with the LCCS. The definition of each class in LCCS must be fully understood. Some details on the classes definition can be found in Annexes 1 and 2, while for further specific information the reference text is 'Land Cover Classification System – Classification concepts and user manual – Software version 2' (FAO, 2005).

FIGURE 7
(a), (b), (c) Satellite imagery acquired by Landsat 7 and (d) Africover land cover map derived from it

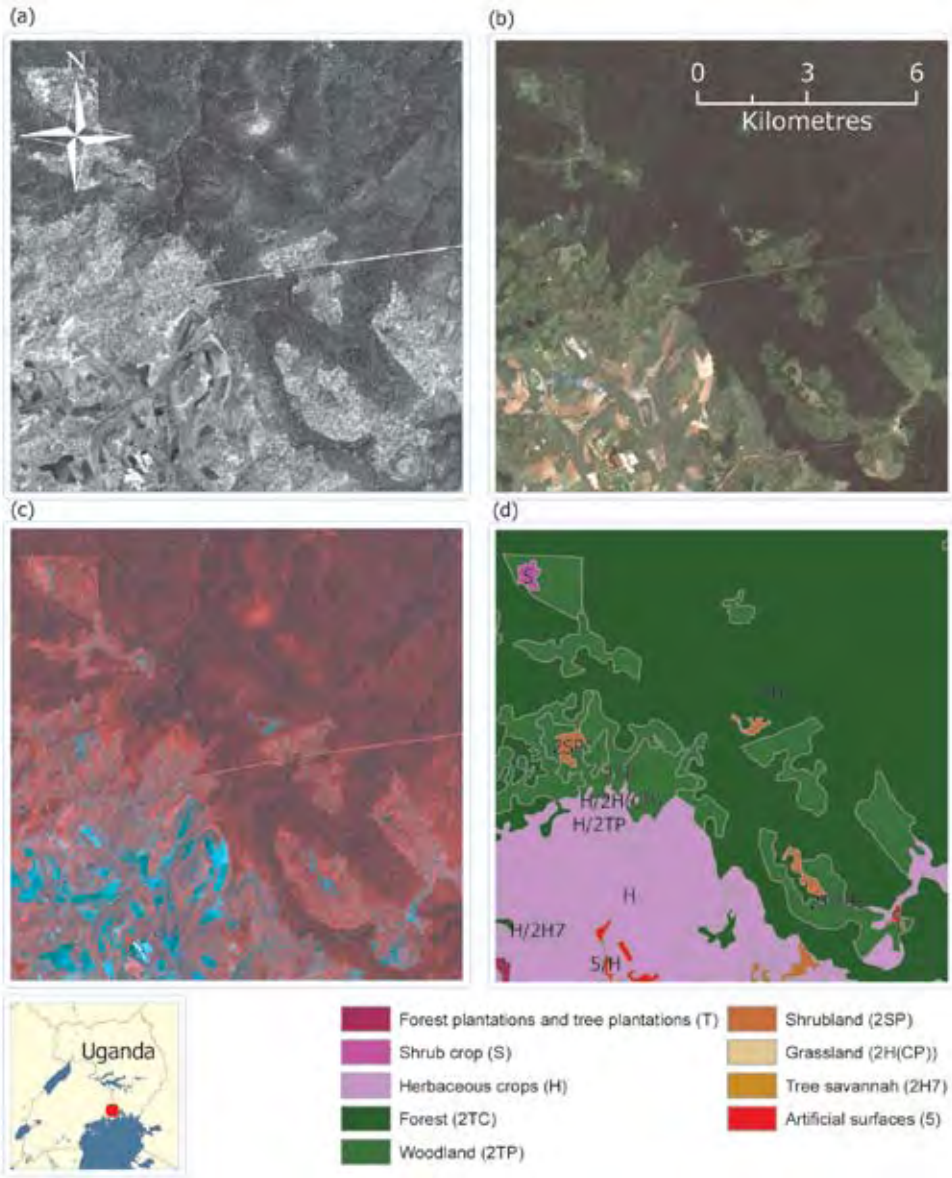
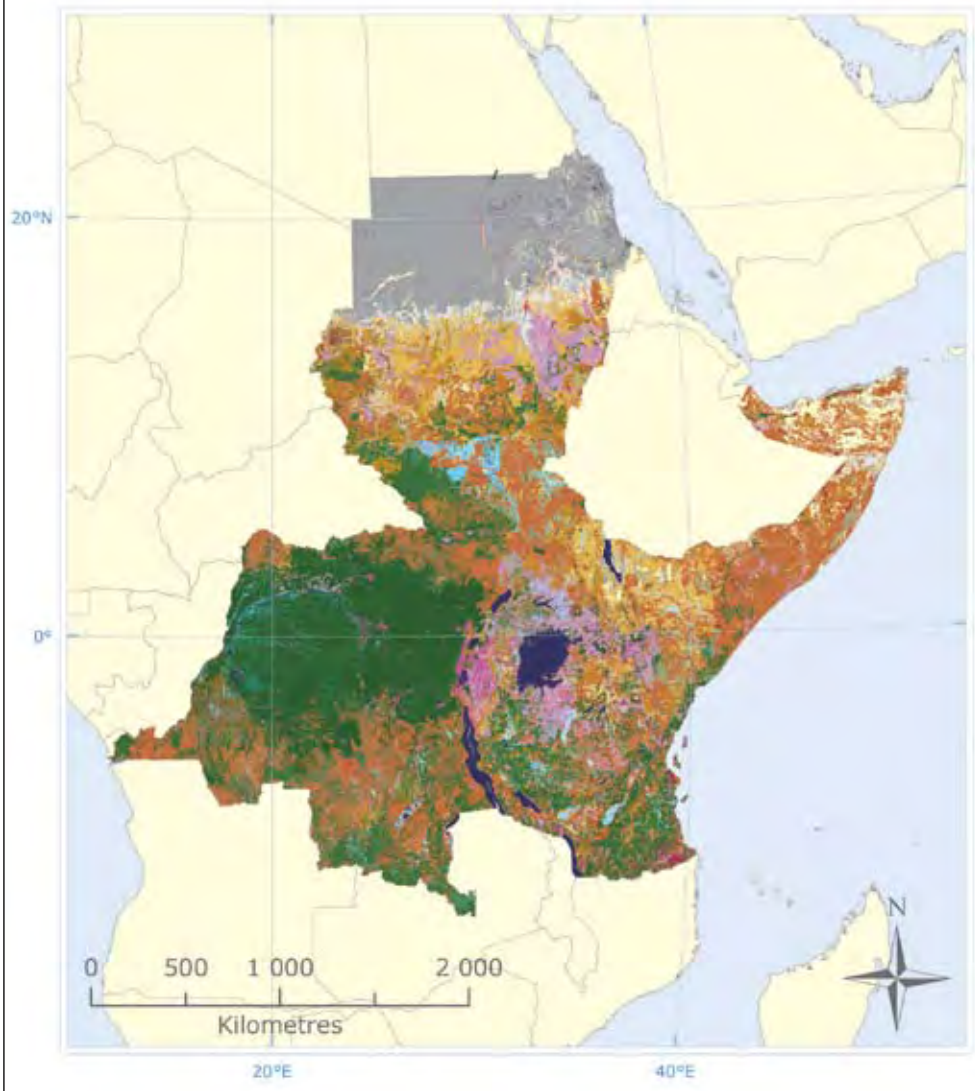
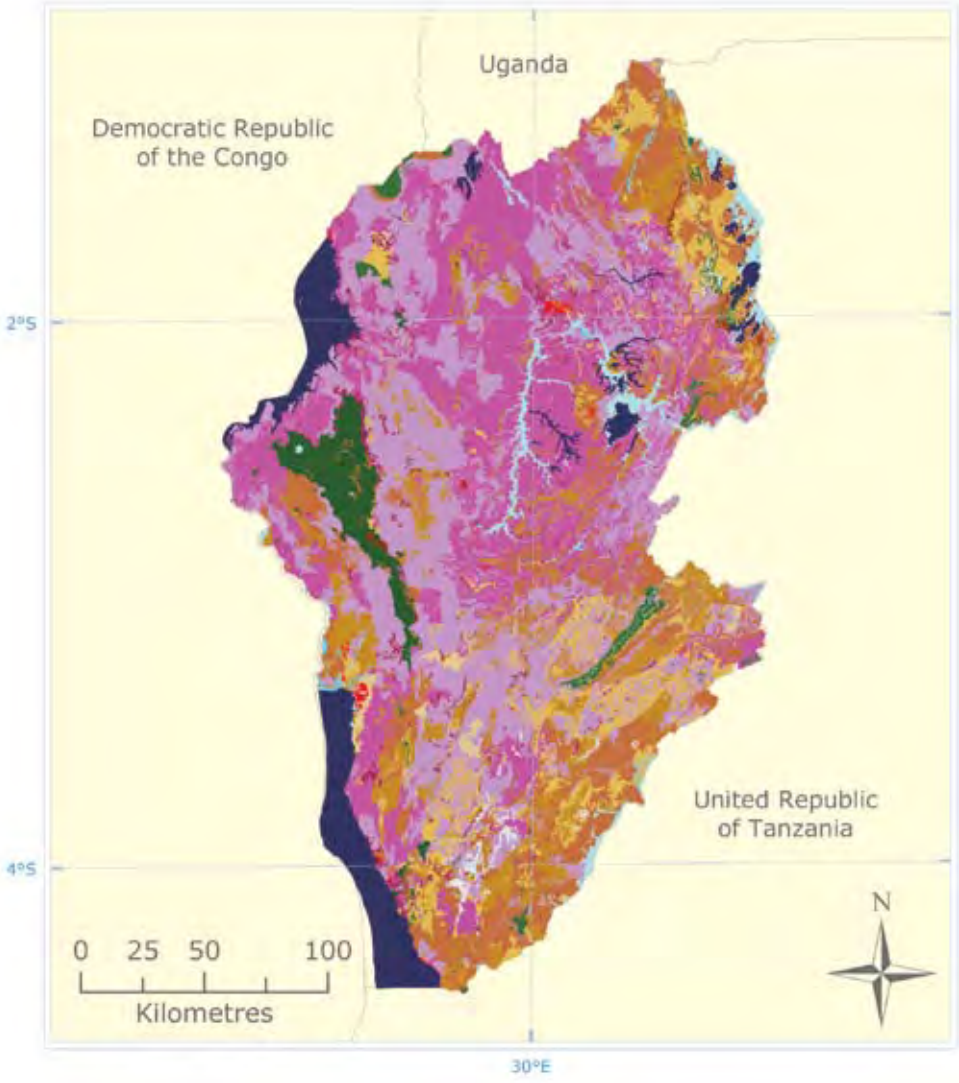


FIGURE 8
Africover land cover maps for tsetse and trypanosomiasis decision-making (the eight T&T affected countries mapped by the Africover project)



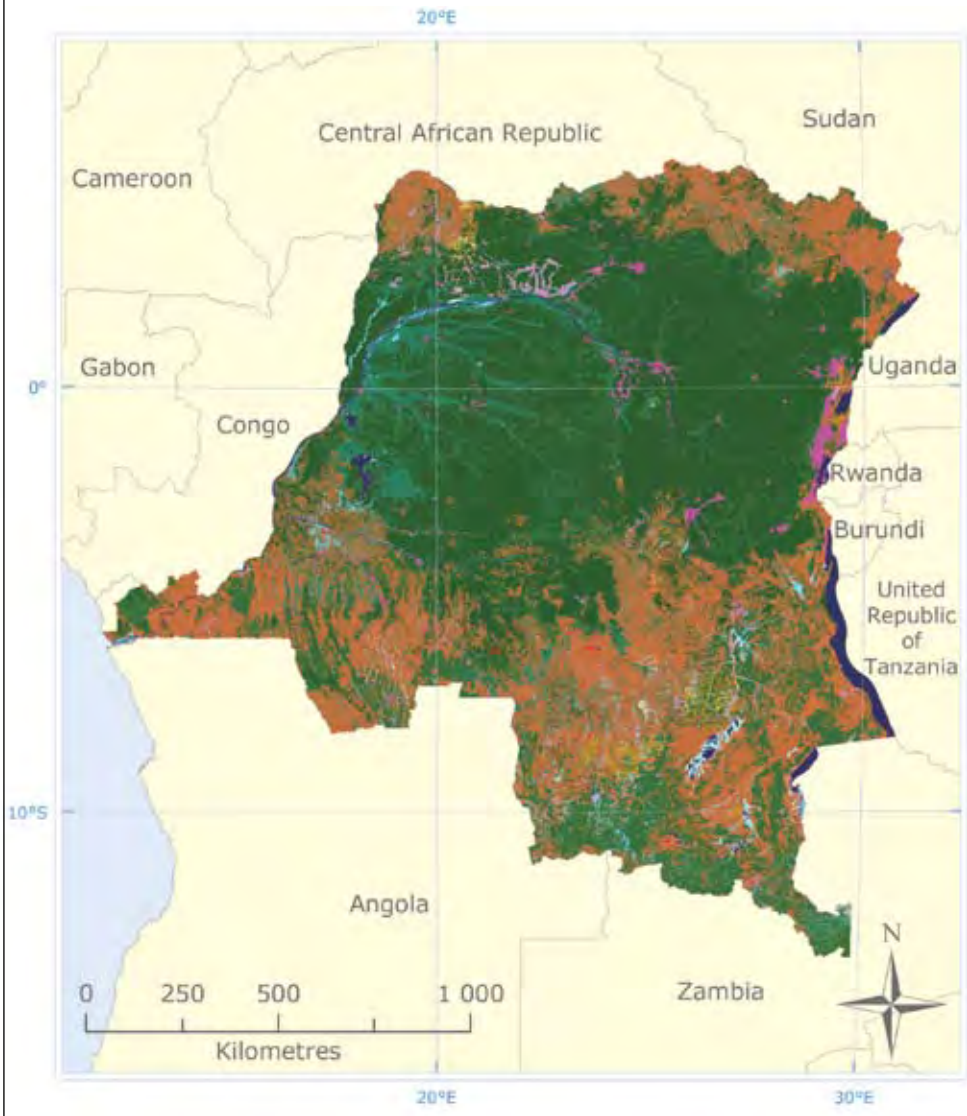
Note: The legend is in Table 7 (p. 21). The maps are available through FAO GeoNetwork (www.fao.org/geonetwork)

FIGURE 9
Land cover of Burundi and Rwanda for tsetse and trypanosomiasis decision-making



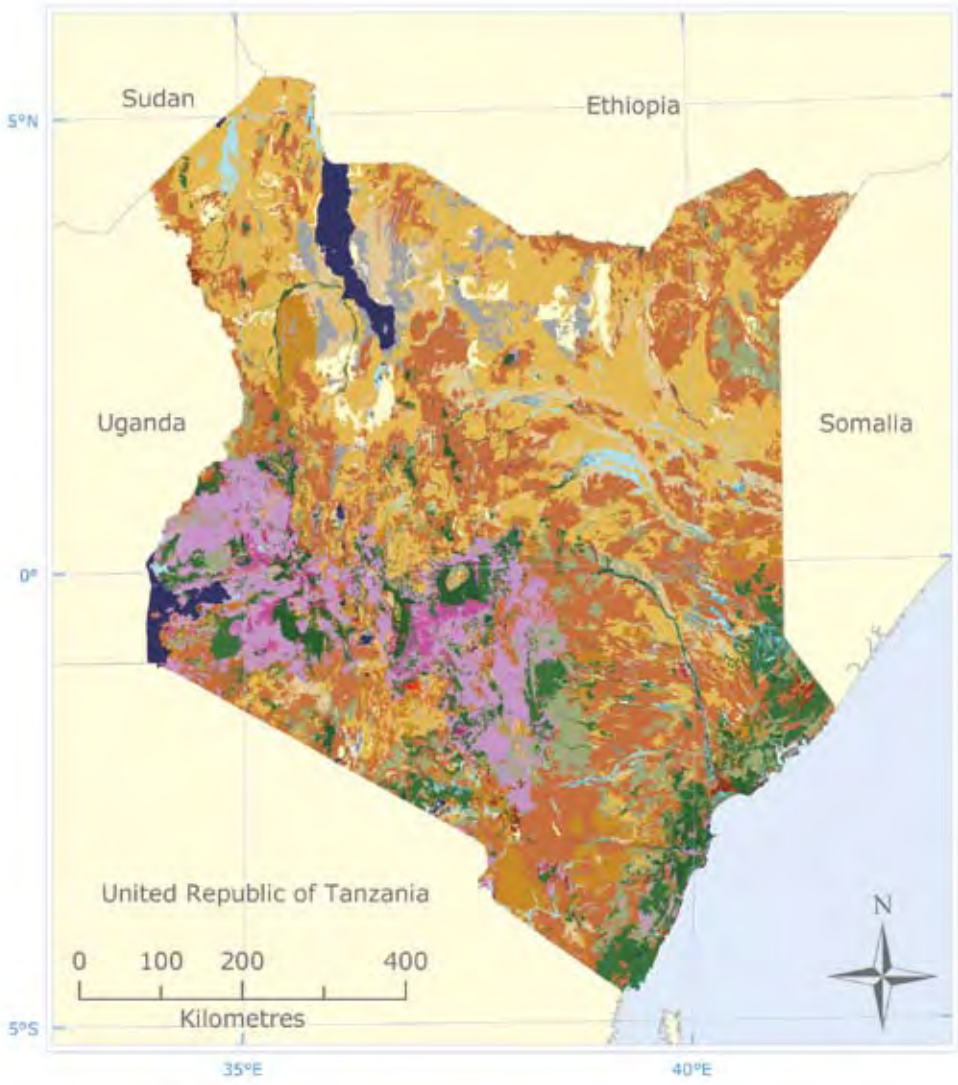
Note: The legend is in Table 7 (p. 21). The maps are available through FAO GeoNetwork (www.fao.org/geonetwork)

FIGURE 10
Land cover of Democratic Republic of the Congo for tsetse and trypanosomiasis decision-making



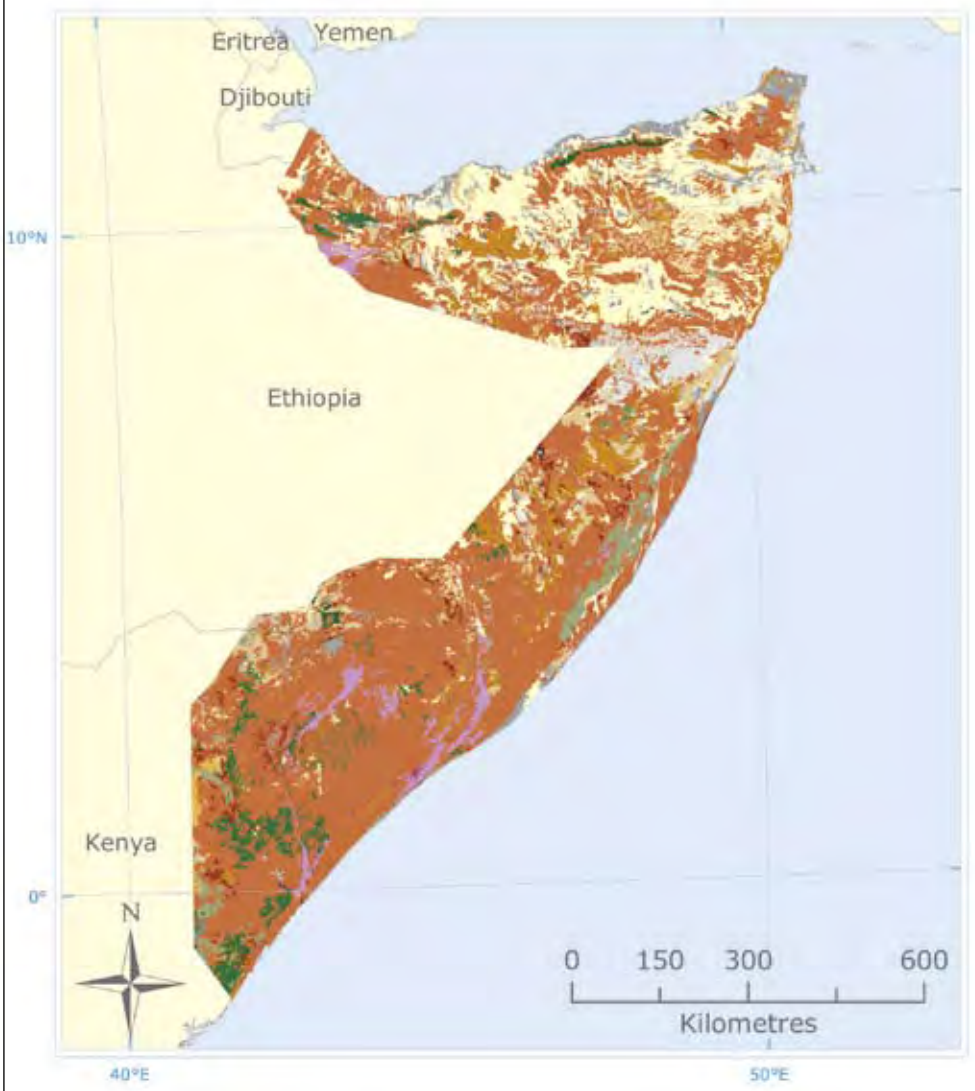
Note: The legend is in Table 7 (p. 21). The map is available through FAO GeoNetwork (www.fao.org/geonetwork)

FIGURE 11
Land cover of Kenya for tsetse and trypanosomiasis decision-making



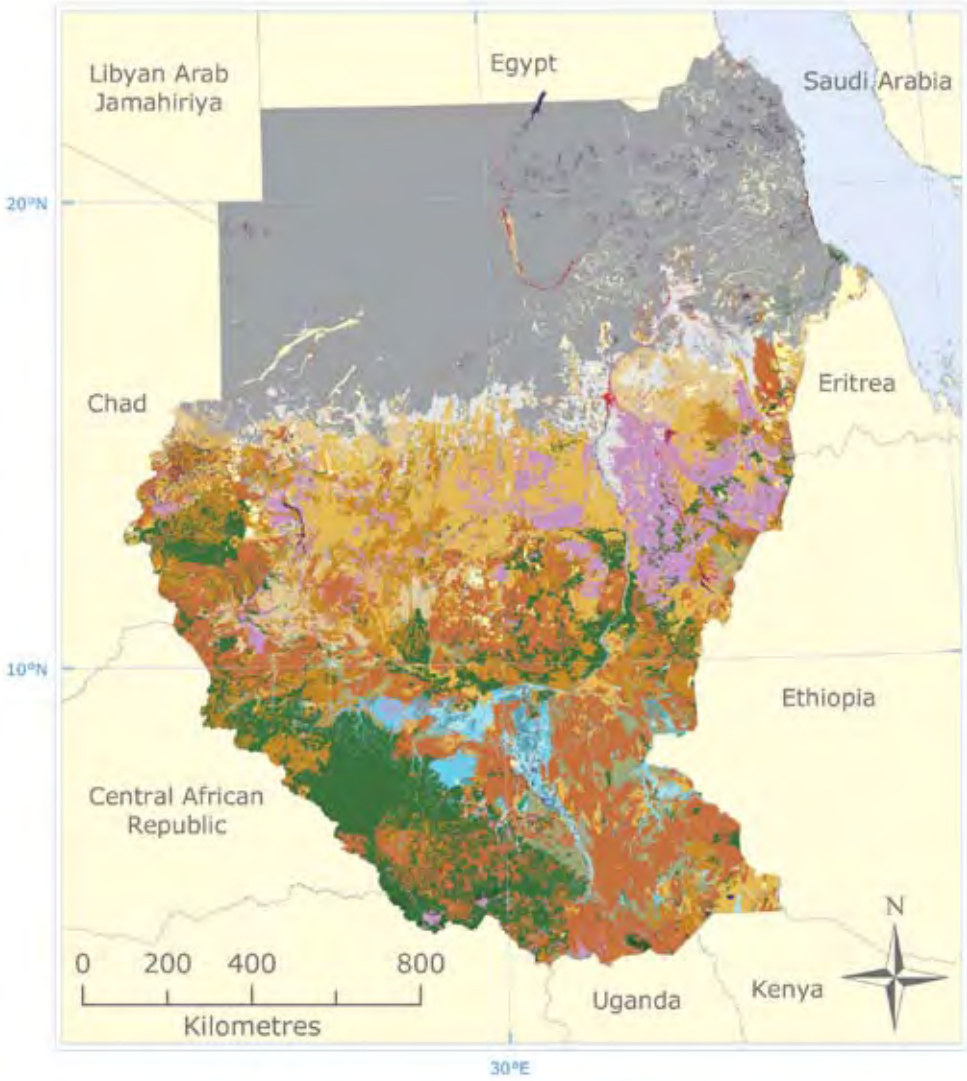
Note: The legend is in Table 7 (p. 21). The map is available through FAO GeoNetwork (www.fao.org/geonetwork)

FIGURE 12
Land cover of Somalia for tsetse and trypanosomiasis decision-making



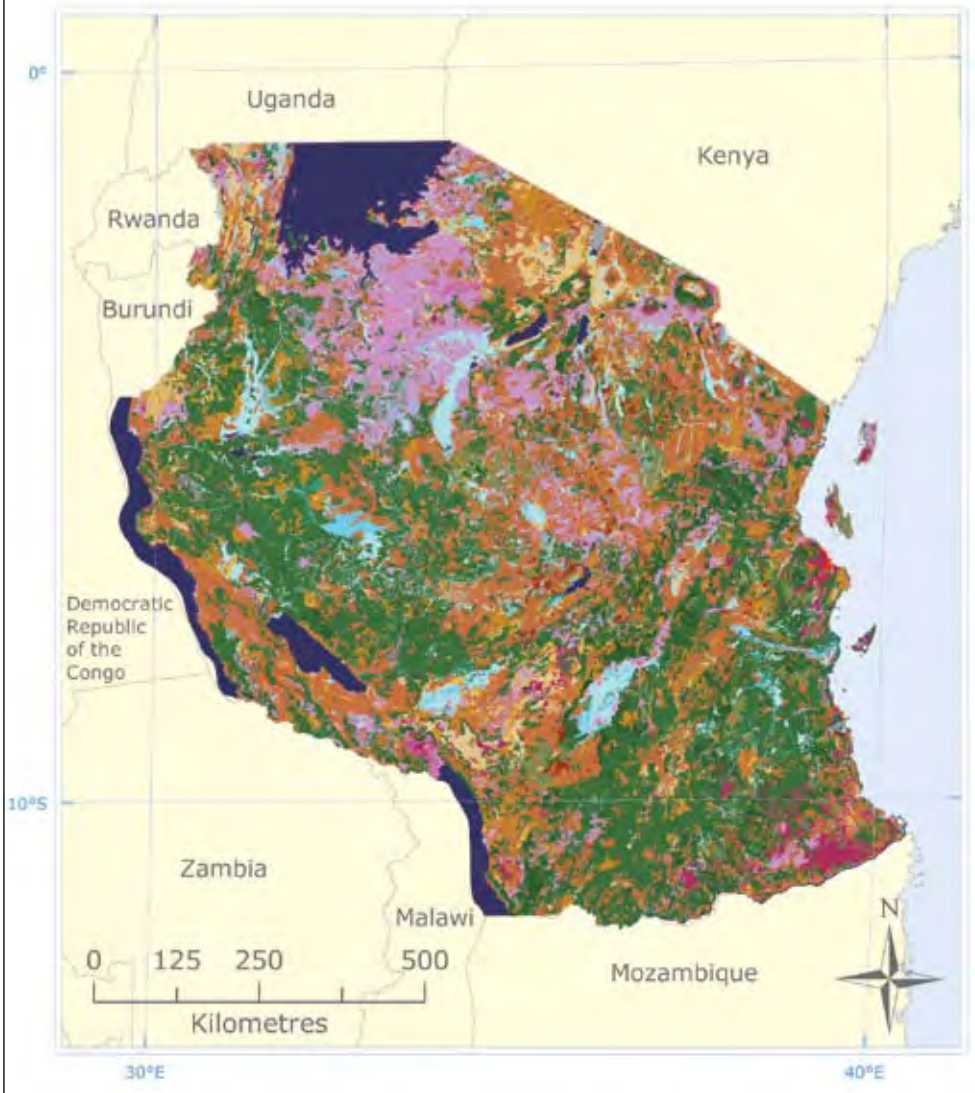
Note: The legend is in Table 7 (p. 21). The map is available through FAO GeoNetwork (www.fao.org/geonetwork)

FIGURE 13
Land cover of Sudan for tsetse and trypanosomiasis decision-making



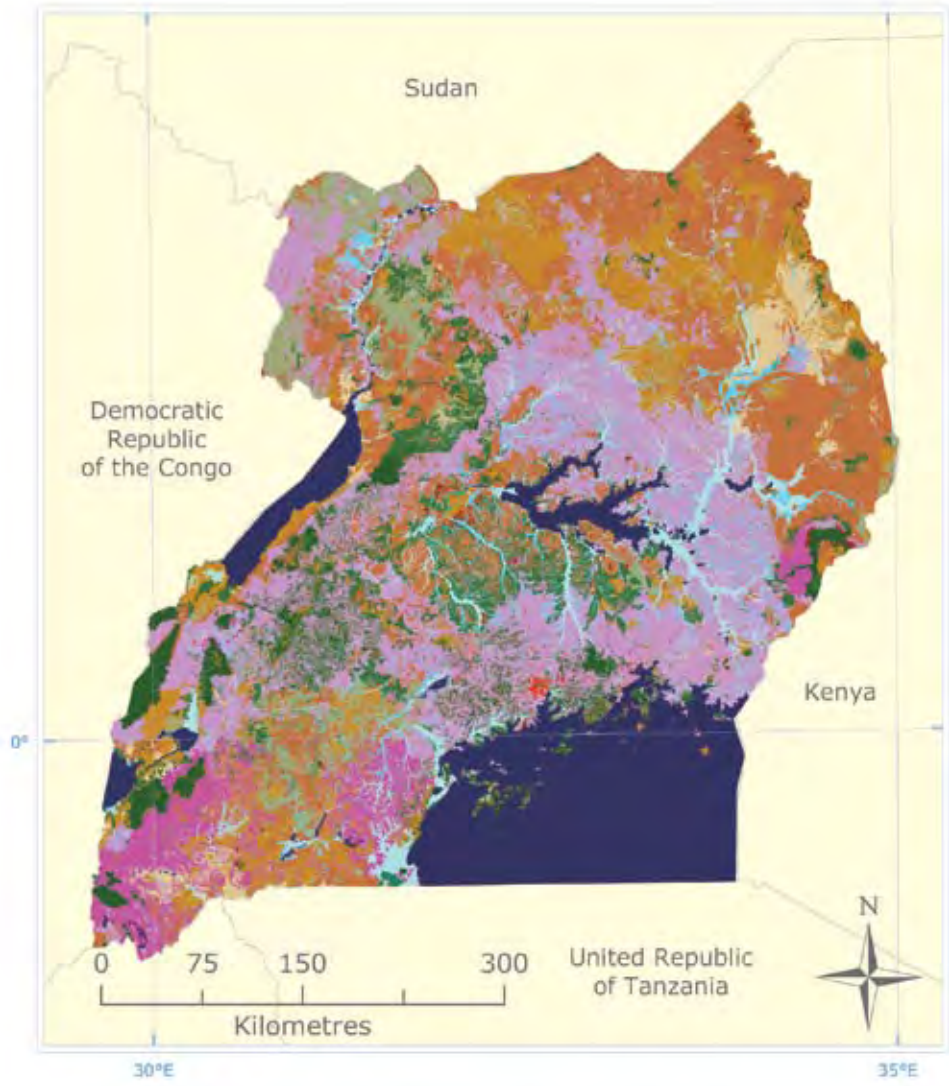
Note: The legend is in Table 7 (p. 21). The map is available through FAO GeoNetwork (www.fao.org/geonetwork)

FIGURE 14
Land cover of the United Republic of Tanzania for tsetse and trypanosomiasis decision-making



Note: The legend is in Table 7 (p. 21). The map is available through FAO GeoNetwork (www.fao.org/geonetwork)

FIGURE 15
Land cover of Uganda for tsetse and trypanosomiasis decision-making



Note: The legend is in Table 7 (p. 21). The map is available through FAO GeoNetwork (www.fao.org/geonetwork)

LAND COVER SUITABILITY FOR TSETSE FLIES: A DEDUCTIVE APPROACH

For the land cover classes defined in Table 7 (p. 21), it is possible to define a degree of suitability for the three tsetse groups. Because the goal of this exercise is to define a methodology applicable to all sub-Saharan countries, the ranking of the classes does not take into account the national or regional specificities. Even though it is derived from the aggregation of the land cover classes of the East African module of the Africover project, the proposed legend is general enough to encompass practically all possible land covers in the continent, at least as far as the vegetated areas are concerned. Furthermore, the definition of the classes is independent of the mapping scale, therefore the suitability classes were assigned without reference to the spatial resolution of the Africover maps from which they are derived.

The suitability for tsetse fly was assigned as a function of intrinsic features of the land cover class only, without *a priori* assumptions on the association or mosaic of various land cover patches. The underlying hypothesis was to consider an indefinite expanse of one single land cover type and to estimate its capability to support a fly population. The tsetse suitability for each land cover class is summarized in Table 8.

A complete account of the features of the land cover classes in Table 8 is beyond the scope of this paper; a full explanation of the LCCS methodology can be found in FAO (2005). However, it seems useful to clarify a few aspects that are probably not intuitive but which have important implications in the analysis of tsetse habitat requirements. One such aspect is the possible presence, in certain classes, of additional vegetation layers, which, not being always present and being, if present, always sparser that the main layer, have not been explicitly included in the name of the class. One example is the class 'Thicket'. 'Thicket' as defined in Table 8 and with more details in Annex 1, does not always include a second layer of trees. At the same time, there is not a separate class named 'thicket with emergent trees', meaning that such a potential class has been aggregated with the general 'Thicket' (this is also apparent in the table of class aggregation for the Africover maps in Annex 3). Given this background, the suitability of the class 'Thicket' for tsetse flies was assigned considering that such additional vegetation layers could be present. Similar considerations apply to the classes 'Closed' and 'Open woody vegetation', 'Shrubland' (Figure 16, p. 34), 'Woody vegetation on flooded land', 'Shrubs on flooded land' and 'Herbaceous vegetation on flooded land'.

In the case of terrestrial herbaceous vegetation it was decided not to discard all the information related to multiple layers and three distinct classes were defined: 'Grassland', 'Shrub savannah' and 'Tree savannah' (Figure 17, p. 34). In all three classes the main layer is herbaceous vegetation.

The fact that 'Grassland' as defined in our aggregation excludes the presence of additional vegetation layers (which are accounted for in the two savannahs) led to the estimated unsuitability of the class for tsetse flies.

Validation

Rigorous validation of the estimated suitability for tsetse of the land cover classes defined in Table 8 is hindered by a range of practical and conceptual difficulties. Foremost among the conceptual problems is the fact that land cover vegetation is only one component

TABLE 8
Land cover and tsetse suitability

LCC User Defined Label	Class name (User Defined Description)	Suitability for tsetse groups		
		fusca	*palpalis*	*morsitans*
T	Forest plantations and tree plantations	1	2	1
S	Shrub crop	1	1	1
H	Herbaceous crops	0	1	0
5UV	Vegetated urban areas	1	2	1
2TC	Forest	3	3	2
2TP	Woodland	1	2	3
2WC	Closed woody vegetation	1	2	2
2WP	Open woody vegetation	1	1	2
2SC	Thicket	1	1	2
2SP	Shrubland	0	1	2
2H7	Tree savannah	0	1	2
2H8	Shrub savannah	0	1	1
2H(CP)	Grassland	0	0	0
2TR	Sparse trees	0	0	1
2SR	Sparse shrubs	0	0	0
2HR	Sparse herbaceous vegetation	0	0	0
GZ-r	Fields Rice	0	0	0
4TC	Closed swamp	3	3	1
4TP	Open swamp	2	2	2
4W	Woody vegetation on flooded land	1	2	1
4S	Shrubs on flooded land	1	2	1
4H	Herbaceous vegetation on flooded land	0	1	0
5	Artificial surfaces	0	0	0
6	Bare soil	0	0	0
W	Water bodies	0	0	0
8SP	Snow	0	0	0

Tsetse suitability

3 - High
2 - Moderate
1 - Low
0 - Unsuitable

of potential tsetse habitat; favourable environmental conditions must include, *inter alia*, availability of hosts on which to feed and convenient climatic conditions. As a consequence, suitable vegetation can still represent an unsuitable habitat because of the lack of either of the above environmental conditions. A second difficulty is related to the challenge of defining classes of suitability valid for all sub-Saharan tsetse-infested countries; validation should be based on a number of sites capable of encompassing the enormous environmental heterogeneities in Africa. Another problem is related to the

FIGURE 16
Two possible structural configurations of the class 'Shrubland'

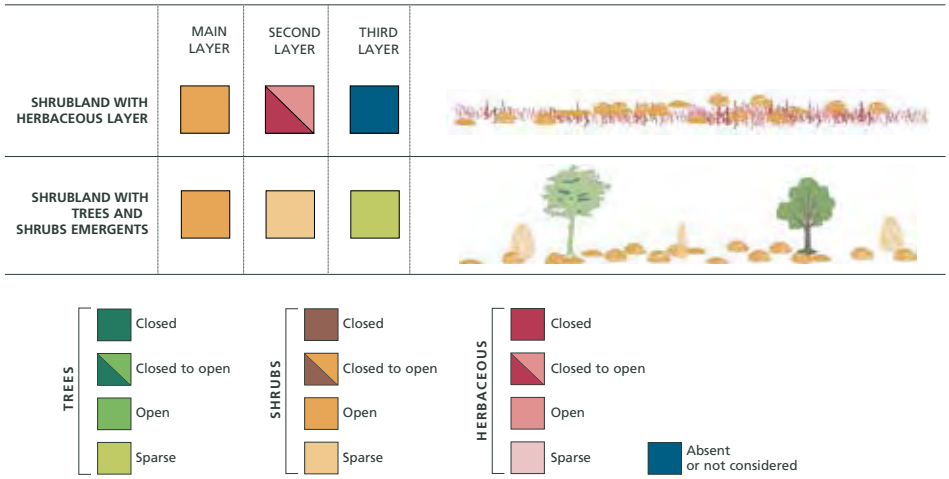
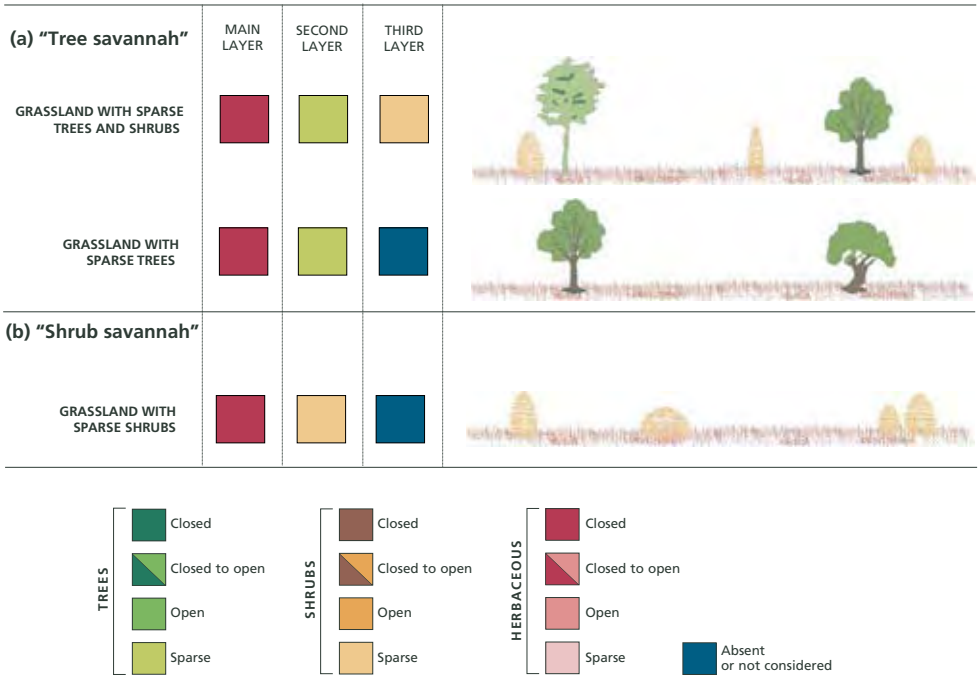


FIGURE 17
(a) 'Tree savannah' (with or without a third layer of shrubs) and (b) 'Shrub savannah' in the Land Cover Classification System



intra-group differences in habitat requirements; if the definitions of forest, riverine and savannah flies for the three groups *fusca*, *palpalis* and *morsitans* are commonly accepted, it is also true that the ecology and spatial distribution of the species within each group vary considerably (e.g. *G. longipennis*, belonging to the *fusca* group, and *G. tachinoides*, of the *palpalis* group, are found in more arid environments than the other species in the same groups). Another complicating factor is the dispersal of flies, some of which can easily travel hundreds of metres away from their resting and breeding sites for feeding; this implies that it is troublesome to link trap catches (i.e. apparent densities) to the vegetation in the immediate surroundings of the trap; trap catches are influenced by the vegetation mosaic at landscape level. In other words, it is almost impossible to define experimental conditions that comply with the hypothesis of 'indefinite expanse of one homogeneous land cover' on which the present evaluation is based. Furthermore, the opportunity to move in less shaded and less protected environments is heavily influenced by thermal and humidity gradients linked to seasonality.

The above considerations explain why very broad and qualitative suitability classes were used in the present paper. If updated and consistent entomological datasets were available, at least for one country or for a sufficiently large area, it would be possible to verify to what extent the suitability classes are capable of describing the situation on the ground.

Comparison between the inductive and deductive approaches at two spatial scales

In the previous section we discussed the reasons why it is difficult to envisage a rigorous validation of the estimated classes of suitability for tsetse (see Table 8, p. 33). Nevertheless it seems interesting to try to link the results of the study on a continental scale (described in Chapter 1) with the higher resolution land cover datasets presented in this chapter and available for some East African countries. The comparison helps to verify the validity of the estimates and demonstrate the limitations inherent in the overall approach.

In Chapter 1, the 26 classes of land cover defined in GLC2000 of Africa were ranked with respect to their suitability for tsetse on the basis of the percentages of suitable habitat within the land cover class; unfortunately these suitability values cannot be directly linked to the land cover classes used in the Africover maps, which in all comprise more than 500 classes. The issue is further compounded by the presence of Africover polygons with mixed encoding, characterized by up to three land cover classes. Even though the two datasets apply the same classification system, LCCS, the legends are different and the relationship between the classes in the two legends is not univocal.

An attempt was made to overcome the existing discrepancies in the legends through a statistical correlation between the classes of the two datasets. The original Africover maps were first thematically aggregated (see also the lookup table in Annex 3) to match the standardized legend for T&T and thus reduce the number of classes to 26, then the datasets were transformed from a vector into a grid format (grid spacing 0.00111 decimal degrees, about 120 metres at the equator) and overlaid with the GLC2000 of Africa (about 1.1 km resolution at the equator). For each class of Africover it was possible to determine the statistical relationship with the GCL2000 classes. As an example, in

Table 9 the results of the calculation for two Africover classes, i.e. 'Shrubland' and 'Shrubs on flooded land', are displayed. For the sake of clarity, only classes accounting for at least 1 percent were reported.

Table 9 gives a good picture of the degree of correspondence between GLC2000 and Africover. The case of 'Shrubland' is particularly relevant because it is the most widespread class in the eight T&T affected countries mapped by Africover, accounting for more than 20 percent of the total area. Overall, we can argue that for this class Africover and GLC2000 are sufficiently coherent, especially if we consider that 'Shrubland' in Africover for T&T encompasses a number of subclasses characterized by a second layer of emergent trees (see also Figure 16, p. 34).

TABLE 9
Correspondence between the classes 'Shrubland' and 'Shrubs on flooded land' of Africover and GLC2000

Africover for T&T Class name (User Defined Description)		Global land cover 2000 for Africa		
		(%)	*Class name*	
	Shrubland	12.5	Deciduous woodland	
		9.6	Deciduous shrubland with sparse trees	
		9.5	Open grassland with sparse shrubs	
		9.1	Croplands (>50 percent)	
		8.9	Sparse grassland	
		8.1	Mosaic forest / Savanna	
		7.8	Open deciduous shrubland	
		7.7	Closed deciduous forest (Miombo)	
		6.7	Closed grassland	
		6.2	Open grassland	
		5.5	Croplands with open 0 vegetation	
		2.1	Stony desert	
		2.1	Closed evergreen lowland forest	
		1.9	Bare rock	
		1.2	Mosaic forest / Croplands	
	Shrubs on flooded land	24.8	Deciduous shrubland with sparse trees	
		14.6	Deciduous woodland	
		12.5	Croplands (>50 percent)	
		9.2	Closed deciduous forest (Miombo)	
		8.1	Swamp bushland and grassland	
		8.1	Open deciduous shrubland	
		3.4	Mosaic forest / Savanna	
		3.3	Closed grassland	
		3.3	Closed evergreen lowland forest	
		3.0	Croplands with open woody vegetation	
		2.9	Mosaic forest / Croplands	
		2.8	Swamp forest	
		2.5	Open grassland with sparse shrubs	

An exhaustive discussion of the results of the comparison between Africover and GLC2000 is beyond the scope of this paper because it would call for a careful review of several technical issues related to the creation of the two land cover datasets. For our purposes it is sufficient to mention that, as for the two classes in the example, the analysis shows globally an acceptable match between the Africover maps for T&T decision-making and the GLC2000. More information on this point can be found in Torbick *et al.* (2005). It seems reasonable then to calculate the suitability for tsetse of the Africover classes as a function (weighted average) of the suitability of the GLC2000 classes that are statistically associated with them. For ease of comparison, the results of the calculation and the literature-based estimates are summarized in Table 10, Table 11 and Table 12.

Table 10 shows coherent and easy to interpret results for the *fusca* group. The two classes that are expected to provide the ideal habitat for flies of the *fusca* group on the basis of the available literature and expert opinion (estimated suitability) also got the top

TABLE 10
***Fusca* group: calculated and estimated suitability of standardized land cover classes**

LCC User Defined Label	Class name (User Defined Description)	Calculated suitability (%)	Estimated suitability (0–3)
2TC	Forest	82.0	3
4TC	Closed swamp	67.5	3
S	Shrub crop	40.2	1
4TP	Open swamp	16.8	2
2TP	Woodland	16.1	1
4S	Shrubs on flooded land	15.1	1
T	Forest plantations and tree plantations	13.0	1
5	Artificial surfaces	12.1	0
H	Herbaceous crops	11.0	0
5UV	Vegetated urban areas	9.5	1
4H	Herbaceous vegetation on flooded land	9.4	0
2WC	Closed woody vegetation	8.6	1
2SP	Shrubland	8.6	0
4W	Woody vegetation on flooded land	6.5	1
2WP	Open woody vegetation	6.2	1
2H7	Tree savannah	5.7	0
2SC	Thicket	5.4	1
GZ-r	Fields rice	5.0	0
W	Water bodies	3.4	0
2H8	Shrub savannah	2.6	0
2H(CP)	Grassland	2.1	0
2TR	Sparse trees	1.4	0
8SP	Snow	0.8	0
2SR	Sparse shrubs	0.5	0
2HR	Sparse herbaceous vegetation	0.3	0
6	Bare soil	0.1	0

TABLE 11
***Palpalis* group: calculated and estimated suitability of standardized land cover classes**

LCC User Defined Label	Class name (User Defined Description)	Calculated suitability (%)	Estimated suitability (0–3)
2TC	Forest	86.0	3
4TC	Closed swamp	72.2	3
S	Shrub crop	48.6	1
2TP	Woodland	34.6	2
4S	Shrubs on flooded land	33.0	2
T	Forest plantations and tree plantations	30.9	2
4TP	Open swamp	30.4	2
2WC	Closed woody vegetation	27.7	2
4H	Herbaceous vegetation on flooded land	21.7	1
H	Herbaceous crops	20.2	1
5	Artificial surfaces	20.2	0
2SP	Shrubland	19.9	1
4W	Woody vegetation on flooded land	19.1	2
2WP	Open woody vegetation	18.8	1
2H7	Tree savannah	17.6	1
5UV	Vegetated urban areas	16.0	2
GZ-r	Fields rice	12.3	0
2SC	Thicket	10.7	1
2TR	Sparse trees	6.3	0
2H8	Shrub savannah	5.7	1
2H(CP)	Grassland	4.7	0
W	Water bodies	4.2	0
2SR	Sparse shrubs	0.8	0
2HR	Sparse herbaceous vegetation	0.2	0
6	Bare soil	0.2	0
8SP	Snow	0.1	0

scores in the calculation. The thresholds for the ranking of the calculated suitability are the same used in Chapter 1 for GLC2000 classes (see Table 2, p. 7): 5 percent, 25 percent and 50 percent. For 73 percent of the classes the calculation confirms the literature-based estimates and the seven non-matching classes only differ by one class. Nevertheless, a closer look at the figures reveals why the calculations proposed in this section, cannot be used to validate, or in the place of, the estimated suitability. For the class 'Artificial surfaces' the indicator provides a non-null value higher than 5 percent that we interpret as 'low suitability' for tsetse flies of the *fusca* group. Yet we know that non-vegetated areas are not capable of sustaining fly populations. The reason for this discrepancy can be traced back to the resolution of the tsetse habitat maps used to assess the suitability of the GLC2000; the 5 km resolution of these maps is too coarse to depict the presence of most artificial areas in Africa (among which are many urban areas). As a consequence the 'Cities' of GLC2000 are often wrongly considered a suitable habitat for tsetse. This

TABLE 12
***Morsitans* group: calculated and estimated suitability of standardized land cover classes**

LCC User Defined Label	Class name (User Defined Description)	Calculated suitability (%)	Estimated suitability (0–3)
4W	Woody vegetation on flooded land	30.4	1
4S	Shrubs on flooded land	28.0	1
2TP	Woodland	23.4	3
4H	Herbaceous vegetation on flooded land	23.3	0
2WC	Closed woody vegetation	20.8	2
2WP	Open woody vegetation	20.8	2
T	Forest plantations and tree plantations	19.0	1
4TP	Open swamp	18.5	2
2H7	Tree savannah	18.3	2
5UV	Vegetated urban areas	16.6	1
2SP	Shrubland	16.4	2
H	Herbaceous crops	16.1	0
S	Shrub crop	15.8	1
GZ-r	Fields rice	15.2	0
5	Artificial surfaces	13.2	0
2SC	Thicket	8.2	2
2TR	Sparse trees	7.4	1
2TC	Forest	7.4	2
2H8	Shrub savannah	6.6	1
4TC	Closed swamp	6.5	1
2H(CP)	Grassland	5.6	0
W	Water bodies	1.7	0
2SR	Sparse shrubs	1.2	0
8SP	Snow	0.5	0
2HR	Sparse herbaceous vegetation	0.3	0
6	Bare soil	0.2	0

kind of drawback is particularly evident in less represented classes, but it also affects the overall accuracy of the calculations.

Substantial agreement between calculated and estimated suitability was also demonstrated for the *palpalis* group (Table 11). In this case, a slightly lower number of classes (namely six) differ, but still by no more than one class of suitability. Nevertheless, a different type of bias becomes clearer in Table 11. If we consider the class 'Fields rice' we discover that it has no direct equivalent in the GLC2000 legend; almost half of the 'Fields rice' of the Africover maps are classified in GLC2000 as a more general 'Cropland' and the calculated suitability reflects this association. This case exemplifies the nature and magnitude of the errors induced by the different legends of Africover and GLC2000.

We already discussed the fuzzier relationship between the habitat of the *morsitans* group and land cover; Table 12 confirms the more complex interpretation of the results

related to the subgenus *morsitans*. For more than half of the classes the two indices differ; for the Africover class 'Woodland', considered the most suitable habitat for this group of flies, the difference is of two classes of suitability. Furthermore the two classes that score the highest values of the calculated suitability all belong to the group of 'Aquatic or regularly flooded vegetation', strictly linked to hydrological network (see also Figure 23, p. 51). If it is true that during the dry seasons the riparian vegetation is a very favourable environment for flies of the *morsitans* group, it is not traditionally considered their typical habitat, being largely surpassed by open woodland and woodland savannah. The rather homogeneous figures of the calculated suitability in Table 12 seem to confirm that *morsitans* group flies are indeed more versatile, dispersive and invasive than those flies that remain in the forest and riparian vegetation.

Chapter 3
Case study: land cover of Uganda for T&T decision-making

Uganda is one of the six African countries that were identified as priority countries for T&T intervention in the framework of the African Union-led PATTEC (Pan African Tsetse and Trypanosomiasis Eradication Campaign) initiative, which aims at the creation and subsequent expansion of tsetse-free zones. Baseline data collection is one of the key activities carried out during the preliminary phase of implementation of the national projects. Land cover maps rank high in the list of necessary data and they are considered essential for planning the baseline entomological surveys, for implementing control actions and for monitoring environmental impacts on reclaimed areas. The Programme Against African Trypanosomiasis and the Coordinating Office for Control of Trypanosomiasis in Uganda (COCTU) identified the Africover database as the best available land cover record for the country. This chapter describes the process of customization of the original land cover database with a view to producing a map capable of depicting habitats in relation to their suitability for tsetse.

The number of classes was reduced from 67 of the original database to 18, through a process of class aggregation compliant with LCCS rules. For each class a value of suitability for the three tsetse groups was assigned, mainly by means of a review of the available literature but also by considering the outcomes of the analysis at continental level described in Chapter 1. When assigning the suitability classes, the specific situation in Uganda was taken into account; for instance, FAO Statistical Database (FAOSTAT) data on crop production were used to estimate the relative abundance of different crops grown in the country (FAOSTAT, 2005). Because of such specificities, direct application of the suitability classes in different countries should be avoided. Future entomological datasets collected in Uganda for the implementation of the PATTEC initiative could be used to validate the assumption of tsetse suitability based on the literature and the analysis at continental level.

It is worth noting that by the end of 2007, the National Forestry Authority of Uganda should complete the production of an updated land cover map of the country for the reference year 2005, which will also be characterized by a higher spatial accuracy (scale 1:50 000). Africover products are available for nine sub-Saharan countries and ongoing projects are addressing the production of land cover maps for several more countries (see Figure 6, p. 18). By virtue of the standardization, it will be easy to take advantage of such future products as they become available and it will be possible to harmonize the activities of neighbouring countries.

THEMATIC AGGREGATION OF THE AFRICOVER DATABASE OF UGANDA FOR TSETSE HABITAT MAPPING

As already mentioned in the introduction to this chapter, the aggregation of the land cover classes of the original Africover map has the objective of simplifying the

map interpretation, discarding unessential information and highlighting all features relevant for tsetse habitat description. The proposed map provides a consistent and accurate description of important tsetse habitats: 'Woodland', 'Forest', 'Savannah', etc. Nonetheless, for some specific applications the full richness of information of the original database or different types of aggregation might prove more useful.

Even though the proposed legend is similar to the general one defined in Chapter 2 (see Table 7, p. 21), fewer classes were needed to describe the land cover in the country (see Table 13). In was also possible to define categories with a higher degree of specificity (i.e. containing more detailed information). The greater specificity is also demonstrated by the higher number of classifiers used for Uganda, 47, as compared with those used for the general legend, 36 (see Annexes 6 and 2).

For each aggregated class the authors defined a class name (user defined description) and a label (LCC user defined label). The abbreviations in the column 'LCC user defined label' were defined by the Africover project in East Africa and their meaning can be found in Annex 4. In the following paragraphs, the standard LCC label for each class is given (see also Annexes 5 and 7). An 'Additional description' gives further details on the class and provides some information on the specific characteristics of that class in Uganda. Last, 'Tsetse suitability' describes what can be inferred from the land cover about tsetse habitat suitability (information summarized in Table 14). For some classes a graphic representation of the land cover is provided. The images were extracted from 'LCCS – Classification concepts and user manual – Software version 2'

TABLE 13
Legend of the land cover map of Uganda for T&T decision-making (derived from the Africover map of Uganda)

	Class name (user defined description)	LCC user defined label
	Forest plantations and tree plantations	T47PL
	Rainfed shrub crop	S47V
	Herbaceous crops	H
	Vegetated urban areas	5UV
	Forest	2TC
	Woodland	2TP
	Woody vegetation	2W
	Thicket	2SCJ
	Shrubland with herbaceous	2SP6
	Grassland	2G(CP)
	Savannah	2G(CP)78
	Fields rice	GZ-r
	Freshwater swamp	4T(CP)
	Shrubs on flooded land	4S(CP)
	Herbaceous vegetation on flooded land (fresh water)	4H(CP)
	Urban areas, airports	5
	Bare soil	6S
	Lakes and rivers	8WP

(FAO, 2005). The footnotes in the following pages provide the definitions of the basic nomenclature used in the LCCS. Further information on the aggregated classes, such as standard definition, LCCS classifiers used and table of classes aggregation, can be found in Annexes 5, 6 and 7. The main reference for the definition of tsetse suitability of land cover was the FAO 'Training Manual for Tsetse Control Personnel, Volume 2: Ecology and behaviour of tsetse' (FAO, 1982). Additional main references were 'Trypanosomiasis Control and African Rural Development' (Jordan, 1986) and 'Tsetse Distribution', in 'The Trypanosomiases'. (Rogers and Robinson, 2004).

1. Forest plantations and tree plantations

LCC Label

Permanently[11] cropped area with rainfed[12] tree[13] crop(s). Crop cover: plantation(s).

Additional description

The class includes fruit trees (e.g. citrus, mango, palm, etc.), conifers (e.g. *pinus* spp., *cupressus* spp.) and hedging and shade plants.

Tsetse suitability

Among the less typical habitats of tsetse flies, man-made ones are particularly important from the point of view of disease transmission, in particular for Human African Trypanosomiasis (HAT). Tree plantations are arguably the most suitable man-created habitat for some tsetse species. Plantations of mango are breeding sites for some species of the *palpalis* group (e.g. *G. tachinoides* and *G. palpalis*); many mango plantations are grown along riversides, which provide tsetse flies with suitable shelter, particularly so in the case of old trees with low branches. Examples of other semi-artificial habitats of this class are plantations of oil palms and cola nuts and tree hedges. Untrimmed hedges and tree crops can also provide a suitable habitat for *G. pallidipes* (*morsitans* group).

2. Rainfed shrub crop

LCC Label

Permanently cropped area with rainfed shrub[14] crop(s). Crop cover: orchard(s).

Additional description

The class includes shrub crops such as plantains, coffee, cotton, bananas, tea, cocoa and pineapple. In Uganda, the largest portion of this class consists of permanently cropped

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[11] This applies to the growing of crops that are not replanted for several years after each harvest (e.g. trees and shrubs). The crop should cover the land for at least two years. The first harvest takes usually place after one year or later. Under this cultivation system the land is cultivated for more than 66 percent of the years (Ruthenberg *et al.*, 1980).

[12] Crop establishment and development is completely determined by rainfall.

[13] Woody plants higher than 5 m are classified as trees (a woody plant with a clear physiognomic aspect of tree can be classified as a tree even if the height is lower than 5 m but more than 3 m)

[14] A shrub is a woody perennial plant with persistent and woody stems and without any defined main stem (Ford-Robertson, 1971).

continuous[15] small size[16] fields. In terms of harvested area (see Annex 8), the most widespread crops of this class in Uganda are plantains, coffee, cotton and bananas (FAO, 2005).

Tsetse suitability
Semi-artificial habitats consisting of various kinds of orchards or other type of plantations (such as bananas, cacao, coffee) can be atypical habitats for some species of the *palpalis* group (e.g. *G. tachinoides*). On the contrary, other crops of this class are unsuitable for all tsetse species (e.g. cotton fields).

3. Herbaceous crops
LCC Label
Herbaceous[17] crops.

Additional description
Among the crops of this class are cereals, roots and tubers, sugar cane, pulses and vegetables.

In Uganda, the staple crops of these classes are beans, maize, sweet potatoes, millet, cassava and sorghum. Most of the areas in this class consist of permanently cropped, continuous, rainfed small fields (smaller than 2 ha) with one additional herbaceous crop growing in sequence in the same field within one growing season and sparse (between 1 percent and 10–20 percent) tree crops.

Tsetse suitability
Herbaceous crops are unsuitable for tsetse flies. Locally, intercropping with sparse tree crops can provide a limited suitability for species of the *palpalis* group.

4. Vegetated urban areas
LCC Label
Vegetated urban areas.

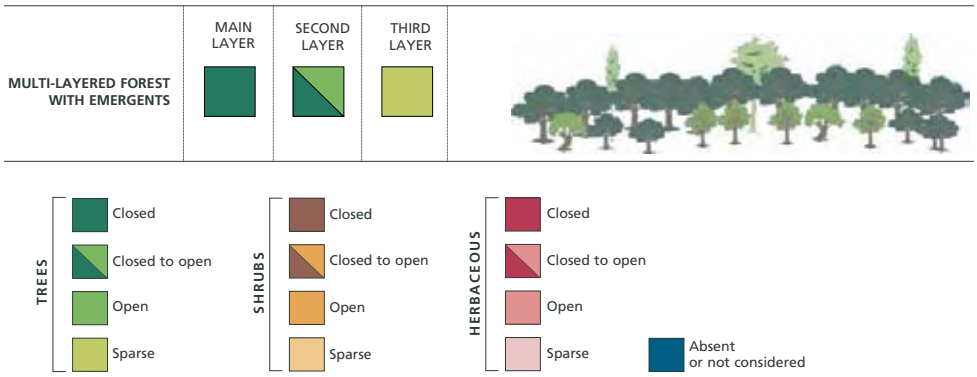
Additional description
Vegetated urban areas are dominated by clumps of trees and/or shrubs.

Tsetse suitability
Peri-domestic habitats with tree and shrub vegetation can be suitable for species of the *palpalis* group and, to a lesser extent, of the *morsitans* group.

5. Forest
LCC Label
Continuous closed[18] trees.

[15] Inside the MMA, the class covers more than 80 percent of the area.
[16] Smaller than 2 ha.
[17] Plants without persistent stem or shoots above ground and lacking definite firm structure.
[18] Within the class, one 'Life form' (in this case 'Trees') covers more than 60–70 percent of the defined area.

FIGURE 18
'Multilayered forest with emergents' in the Land Cover Classification System



Source: 'LCCS – Classification concepts and user manual – Software version 2' (FAO, 2005)

Additional description

The main layer consists of closed trees (crown cover is more than 60–70 percent). The height is in the range of 3–30 m or more. The vegetation is spread over the area without intervals or breaks. In Uganda, most of the areas in this class are covered by broad-leaved evergreen trees with a second layer of trees that form a different stratum due to a difference in height and a third layer of emergent trees higher than the main stratum (Figure 18).

Tsetse suitability

Forests provide favourable habitats to several tsetse fly species of the *fusca* and *palpalis* groups and, to a lesser extent, of *morsitans* group. With one exception (*G. longipennis*), the species of the *fusca* group are forest flies inhabiting either rain forest or isolated patches of forest, along with riverine forest in the savannah zones. Gallery forests are the typical habitat for the flies of the *palpalis* group. Species of the *morsitans* group can be found in forest edges, forest islands and in riverine forests. (Vegetation areas not used by *G. morsitans* include very high rainfall areas such as rain forests.)

6. Woodland

LCC Label

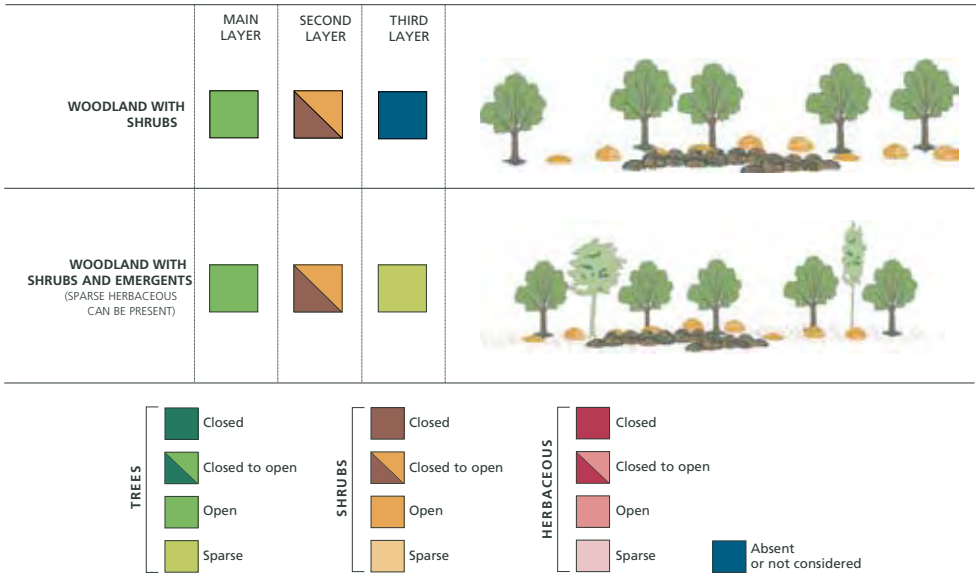
Continuous open[19] trees (Woodland).

Additional description

The main layer consists of open trees (crown cover between 10–20 and 60–70 percent). The height is in the range of 3–30 m or more. The vegetation is spread over the area without intervals or breaks. In Uganda, in most of the areas of this class there is a second

[19] Between 10–20 and 60–70 percent of a defined area is covered by one' Life form' (in this case 'Trees').

FIGURE 19
'Woodland with shrubs' in the Land Cover Classification System



Source: 'LCCS – Classification concepts and user manual – Software version 2' (FAO, 2005)

layer of closed to open shrubs; this subclass can be defined as 'Woodland with shrubs' (Figure 19) and it covers an area of around 14 000 km² (6 percent of the total surface of the country)[20]. In a less abundant subclass (1 percent of the total surface of the country), the second layer consists of emergent trees higher than the main stratum and there is a third layer of sparse shrubs ('Woodland with shrubs and emergents') (Figure 19).

Tsetse suitability

Woodlands are typical habitats of tsetse flies. Open woodland and woodland savannah are favourite habitats of the *morsitans* group; woodlands are also suitable for the *palpalis* and, to a lesser extent, for the *fusca* group, but those two groups tend to prefer somewhat thicker vegetation.

7. Woody vegetation

LCC Label

Continuous closed to open woody vegetation.

Additional description

The main layer consists of woody vegetation and the height is in the range of 2–7 m. In Uganda, most of the areas of this class have an open cover (between 10–20 and

[20] FAO, Reports on Uganda Africover, 'Mosaic codes (Area)'.

60–70 percent), a second layer of closed to open herbaceous vegetation and a third layer of emergent trees; this subclass is defined by LCCS as 'Open woody vegetation with medium to tall herbaceous layer with emergents' and it covers an area of around 9 500 km² (4 percent of the total surface of the country).

Tsetse suitability

This type of land cover class is rarely described as such in the literature related to tsetse flies. We can assume that it is alternatively included in other classes such as 'Shrubland', 'Thicket' and 'Woodland savannah'. On these grounds, we can affirm that it is moderately suitable for the species of the *morsitans* and *palpalis* groups and less so for the *fusca* group.

8. Thicket

LCC Label

Continuous closed medium to high shrubland (thicket).

Additional description

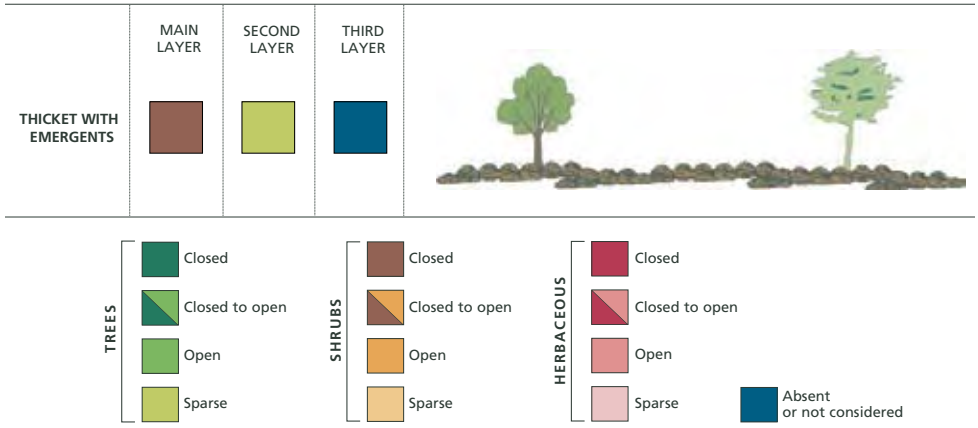
The main layer consists of closed shrubland (crown cover more than 60–70 percent); the height is in the range of 0.5–5 m. The vegetation is spread over the area without intervals or breaks. In Uganda, most of the areas of this class have a second layer of emergent trees (Figure 20); which covers an area of around 550 km² (0.23 percent of the total surface of the country).

Tsetse suitability

This class represents an extremely suitable habitat for tsetse species of the *morsitans* group and, to a lesser extent, of the *palpalis* and *fusca* groups.

FIGURE 20

'Medium to high thicket with emergents' in the Land Cover Classification System



Source: 'LCCS – Classification concepts and user manual – Software version 2' (FAO, 2005)

9. Shrubland with herbaceous

LCC Label

Closed to open shrubs.

Additional description

The main layer consists of shrubs (crown cover is between 15 and 100 percent). The height is in the range of 0.3–5 m. In Uganda, most of the areas of this class have an open cover (between 10–20 and 60–70 percent), a second layer of closed to open herbaceous vegetation and a third layer of emergent trees; this subclass is defined by LCCS as 'Open shrubland with herbaceous and emergents' (Figure 21) and it covers an area of around 35 000 km^2 (16 percent of the total surface of the country).

Tsetse suitability

This habitat differs from the classic savannah only for the presence of the main shrub layer. Thus, we can assume that it is moderately suitable for the *morsitans* group and less so for the *palpalis* group. This class is deemed unsuitable for the *fusca* group.

10. Grassland

LCC Label

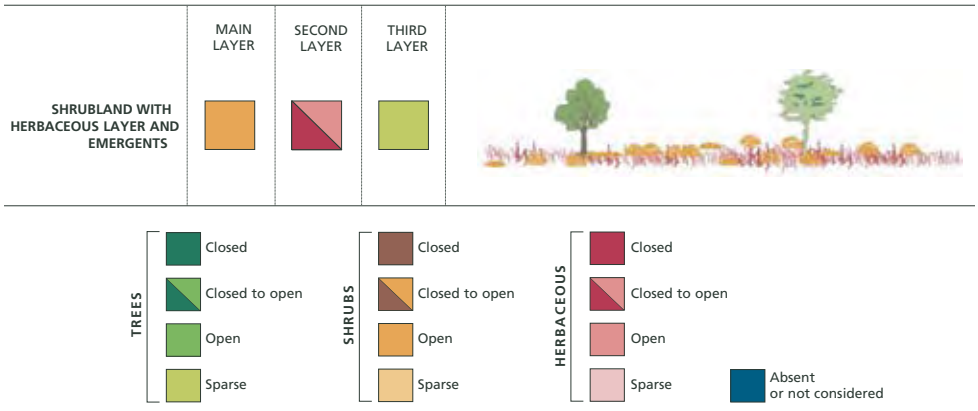
Continuous closed to open grassland.

Additional description

The main layer consists of grassland (crown cover is more than 15–100 percent); the height is in the range of 0.03–3 m, the vegetation is spread over the area without intervals or breaks. In Uganda this class covers around 6 000 km^2 (2.5 percent of the total surface of the country).

FIGURE 21

'Shrubland with herbaceous and emergents' in the Land Cover Classification System



Source: 'LCCS – Classification concepts and user manual – Software version 2' (FAO, 2005)

Tsetse suitability
This land cover is unsuitable for tsetse flies.

11. Savannah

LCC Label
Closed to open grassland with trees and shrubs.

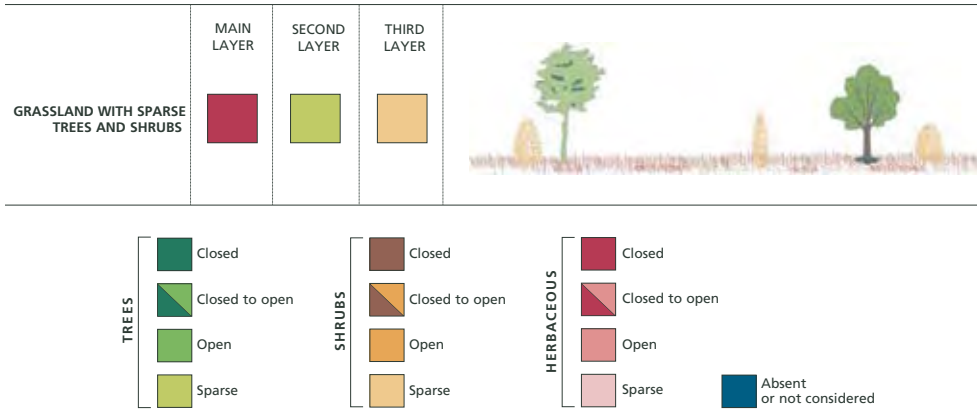
Additional description
The main layer consists of grassland (crown cover is between 15 and 100 percent); the height is in the range of 0.03–3 m. The vegetation is spread over the area without intervals or breaks. The second layer consists of sparse trees. The third layer consists of sparse shrubs (Figure 22). In Uganda this class covers more than 20 000 km² (8.5 percent of the total surface of the country).

Tsetse suitability
Savannah offers moderately suitable habitats for species of the *morsitans* group and for some of the *palpalis* group, much less so for the *fusca* group. The limited tree and shrub cover of this class can be sufficient for many species during the wet season, but it is usually unable to support flies populations during the dry season.

12. Fields rice

LCC Label
Continuous field(s) of graminoid crops on permanently flooded land. Dominant crop: cereals – rice (*Oryza* spp.).

FIGURE 22
'Savannah' in the Land Cover Classification System



Source: 'LCCS – Classification concepts and user manual – Software version 2' (FAO, 2005)

Additional description
Field(s) are covered with graminoid crops. The crops are growing on permanently flooded land.

Tsetse suitability
This land cover is not suitable for tsetse flies.

13. Freshwater swamp
LCC Label
Closed to open trees. Water quality: fresh water.

Additional description
The main layer consists of tree vegetation on permanently or temporarily[21] flooded land (crown cover is between 15 and 100 percent); the height is in the range of 3–30 m or more. There is a second layer of shrubs or herbaceous vegetation. In Uganda this class occupies less than 2 000 km^2 (less than 1 percent of the total surface of the country) and it is mainly represented by open trees (crown cover is between 15 percent and 60–70 percent) on seasonally flooded land. This type of class, and others belonging to the group 'Natural and semi-natural aquatic or regularly flooded vegetation (A24)', are strictly related to the hydrological network, as it is shown clearly in Figure 23.

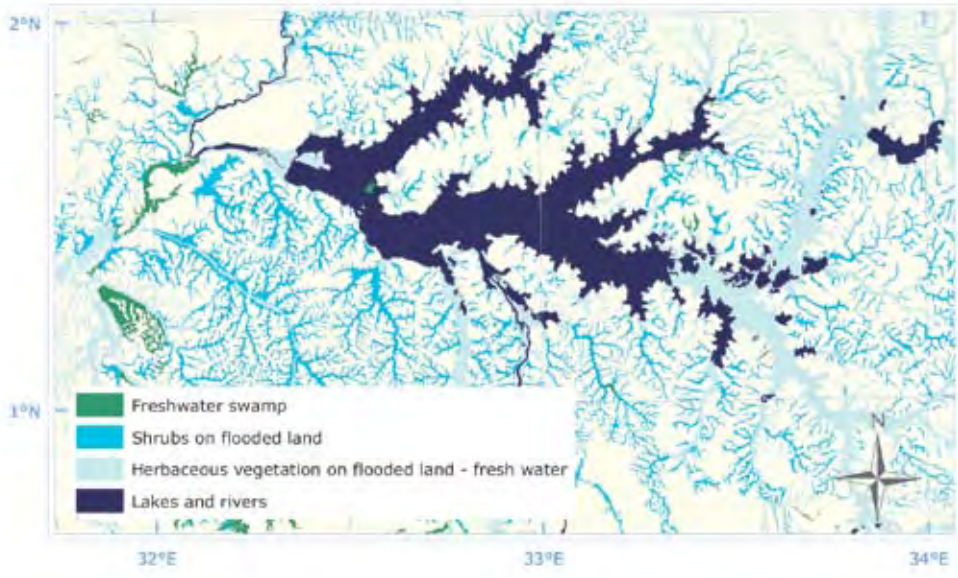
Tsetse suitability
This class describes the vegetation of riverine forests and woodlands, which are among the most suitable habitats for a wide range of tsetse species, first and foremost for the *palpalis* group (riverine flies). Forest swamps areas are also extremely suitable for the *fusca* group and, seasonally, for the *morsitans* group.

14 Shrubs on flooded land
LCC Label
Closed to open shrubs.

Additional description
The main layer consists of shrub vegetation on permanently or temporarily flooded land (crown cover between 15 and 100 percent); the height is in the range of 0.3 – 5m.

[21] For 'aquatic or regularly flooded natural and semi-natural vegetation (A24)', one classifier consists of water seasonality. This classifier type can be described as the persistence of the water at or near the surface. There are three subdivisions:
- (Semi-)Permanent (three months a year or more than a specific season): in this class, areas are considered to be covered by water for a substantial period, which is not directly linked to a specific season).
- Temporary or Seasonal (less than three months a year or during a specific season): this class covers areas that are regularly flooded, but where the water cover does not remain for a substantial period of time or other than in a particular season.
- Waterlogged: the water table is very high and at or near the surface; these areas could be occasionally flooded, but the main characteristic is the high level of the water table (e.g. bogs).

FIGURE 23
'Natural and semi-natural aquatic or regularly flooded vegetation' in the area of the Lake Kyoga in Uganda



In Uganda, this class occupies over 10 000 km² (more than 4 percent of the total surface of the country); almost all of this area consists of open shrubs (crown cover between 10–20 and 60–70 percent) on temporarily flooded land with a second layer consisting of herbaceous vegetation.

Tsetse suitability
The humid environment and the shading provided by the shrub vegetation can provide a suitable habitat for many tsetse species, especially of the *palpalis* group. Nonetheless, the lack of tree vegetation is such that this class cannot be considered a primary habitat.

15. Herbaceous vegetation on flooded land (fresh water)

LCC Label
Closed to open herbaceous vegetation.

Additional description
The main layer consists of herbaceous vegetation on permanently or temporarily flooded land (cover is between 15 and 100 percent, the height is in the range of 0.03–3 m).

In Uganda, this class covers approximately 12 000 km² (more than 5 percent of the total surface of the country); on around half of this area a second layer of sparse shrubs is present.

Tsetse suitability
Though it is by definition associated with humid environments, this class cannot be considered a major habitat for tsetse flies because of the very limited presence of woody (shrub or tree) vegetation. Sparse shrubs occasionally present in these areas can provide atypical habitats to some species, particularly of the *palpalis* group.

16. Urban areas, airports
LCC Label
Non-linear built-up area(s).

Additional description
Built-up areas are characterized by the substitution of the original (semi-)natural cover or water surface with an artificial, often impervious, cover. This artificial cover is usually of long duration. In the Africover map of Uganda, this class occupies 300 km² only and consist of urban areas and airports.

Tsetse suitability
This land cover is not suitable for tsetse flies.

17. Bare soil
LCC Label
Bare soil and/or other unconsolidated material(s).

Additional description
The surface aspect of bare areas describes the land rather than the land cover, because the land is not covered by (semi-)natural or artificial cover. In the Africover map of Uganda, this class occupies 4 km² only. The surface can be stony (5–40 percent) or very stony (40–80 percent).

Tsetse suitability
This land cover is not suitable for tsetse flies.

18. Lakes and rivers
LCC Label
Perennial natural water bodies. Salinity: fresh (<1 000 parts per million [ppm] of total dissolved solids [TDS]).

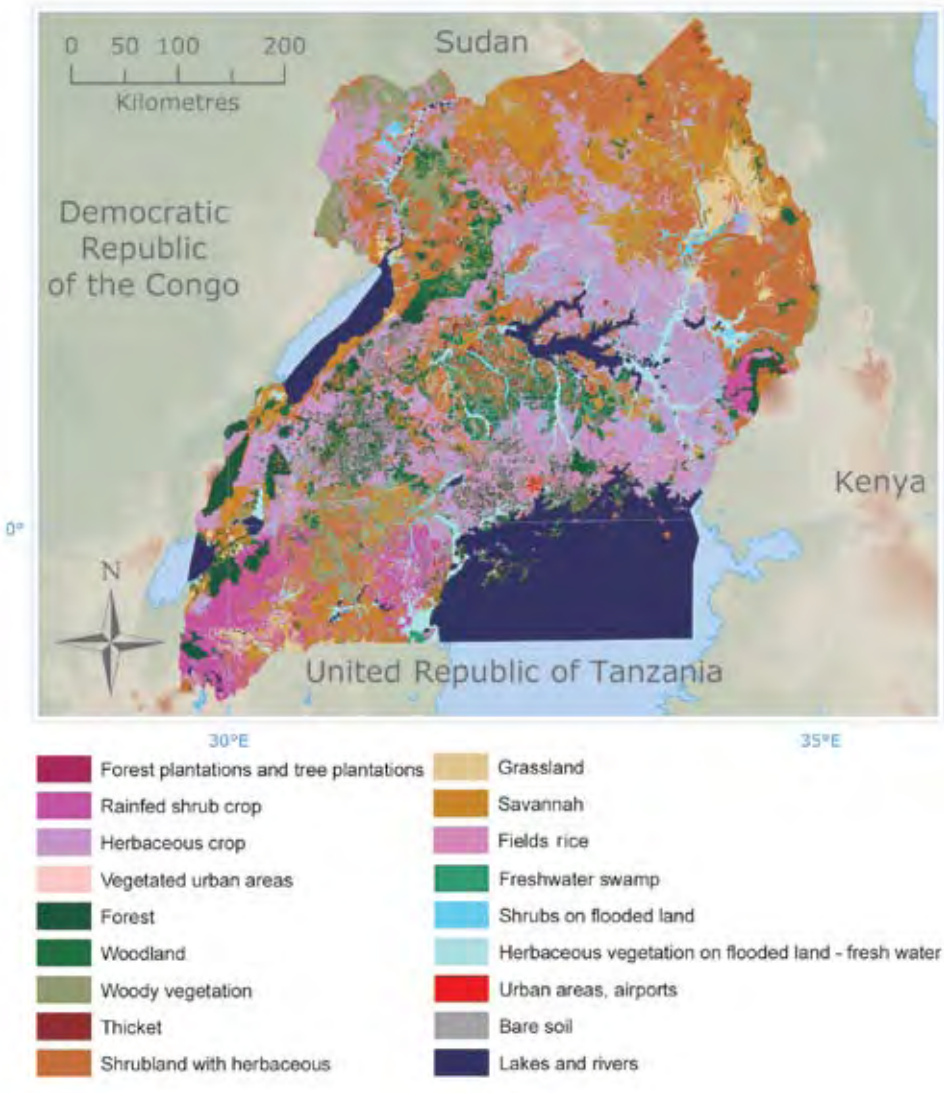
Additional description
The land cover consists of perennial natural water bodies (including flowing or standing water). In the Africover map of Uganda, this class occupies 36 000 km² (more than 15 percent of the total surface of the country), including the vast expanses of lakes Victoria, Albert and Kyoga.

Tsetse suitability
This land cover is not suitable for tsetse flies.

LAND COVER MAP OF UGANDA FOR T&T

The 18 classes described in the previous section and the aggregation table in Annex 7 were used to reclassify the Africover map of Uganda and the result is displayed in Figure 24. For the sake of clarity, in this graphic representation each polygon was given the colour of the main class only (i.e. in this map, areas characterized by mixed codes cannot be distinguished from pure polygons). In contrast, in the underlying database the information related to mixed polygons was retained and it was duly weighed to estimate the degree of tsetse suitability of each area (e.g. Figure 26).

FIGURE 24
Land cover of Uganda for tsetse and trypanosomiasis decision-making



LAND COVER SUITABILITY FOR TSETSE FLIES IN UGANDA

The tsetse suitability for each one of the aggregated land cover classes identified for Uganda is described in the section 'Thematic aggregation of the Africover database of Uganda for tsetse habitat mapping' (p. 41) and the information is summarized in Table 14. It is worth noting that the degree of suitability was assigned according to the inherent features of the land cover class only. No assumption is made on host availability, climatic conditions, size and distribution of habitat patches, vicinity of water bodies, etc. It is also important to mention that the peculiarities of a given land cover class as it occurs in Uganda were taken into account. For instance, most of the areas belonging to the class 'Shrubland with herbaceous' in Uganda are in fact 'Shrubs with herbaceous and sparse trees'. The presence of trees has some relevance for tsetse suitability that has not been neglected. Therefore, the values in Table 14 should be exported to other countries with care. One limitation of the method consists in the analysis of tsetse suitability at group (*subgenus*) level. At this stage of investigation, existing differences in the habitat preferences of various fly species within the same group have been averaged.

TABLE 14
Tsetse suitability for land cover classes in Uganda

User defined label	User defined description	Suitability for tsetse groups		
		fusca	*palpalis*	*morsitans*
T47PL	Forest plantations and tree plantations	1	2	1
S47V	Rainfed shrub crop	1	2	1
H	Herbaceous crop	0	1	0
5UV	Vegetated urban areas	1	2	1
2TC	Forest	3	3	2
2TP	Woodland	1	2	3
2W	Woody vegetation	1	1	2
2SCJ	Thicket	1	2	3
2SP6	Shrubland with herbaceous	0	1	2
2G(CP)	Grassland	0	0	0
2G(CP)78	Savannah	0	1	2
GZ-r	Fields rice	0	0	0
4T(CP)	Freshwater swamp	3	3	2
4S(CP)	Shrubs on flooded land	1	2	1
4H(CP)	Herbaceous vegetation on flooded land - fresh water	0	1	0
5	Urban areas, airports	0	0	0
6S	Bare soil	0	0	0
8WP	Lakes and rivers	0	0	0

Tsetse suitability

3 - High
2 - Moderate
1 - Low
0 - Unsuitable

The considerations on which the estimate is made are similar to the ones described in Chapter 2 for the general classes. Some of the minor differences are caused by:

- difference in the definition of the classes (e.g. for Uganda one single 'Woody vegetation' was defined, while the general legend makes a distinction between 'Closed' and 'Open' woody vegetation); and
- specific features of the class in Uganda (e.g. most of the class 'Thicket' in Uganda is characterized by a second layer of emergent trees that are expected to provide a better habitat for flies of the *morsitans* group; in the general legend no assumption can be made on the presence or absence of emergent trees in the class 'Thicket', therefore the suitability was estimated 'moderate' and not 'high').

Figure 25 shows the land cover for the area around Kampala, and Figure 26 represents one possible graphic representation of land cover suitability for the *palpalis* group.

For the sake of simplicity, the maps in Figure 25 and Figure 26 are both drawn using the main land cover class of each polygon of the Africover dataset. We have to remember that LCCS, on which Africover maps are based, allows spatially mixed coding to be defined (i.e. polygons characterized by a maximum of three separate land cover classes). In Figure 25 the mixed classes pose an imaging problem only. In contrast, in Figure 26 and Figure 27, it is interesting to measure the influence of secondary and tertiary land cover classes on suitability.

FIGURE 25
Land cover of the area around Kampala (Uganda) for tsetse and trypanosomiasis decision-making

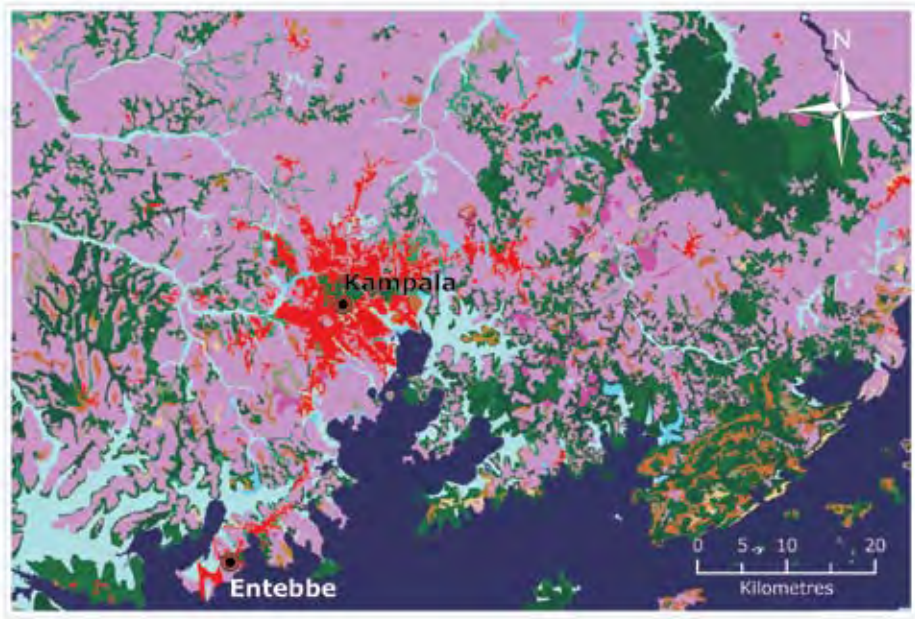
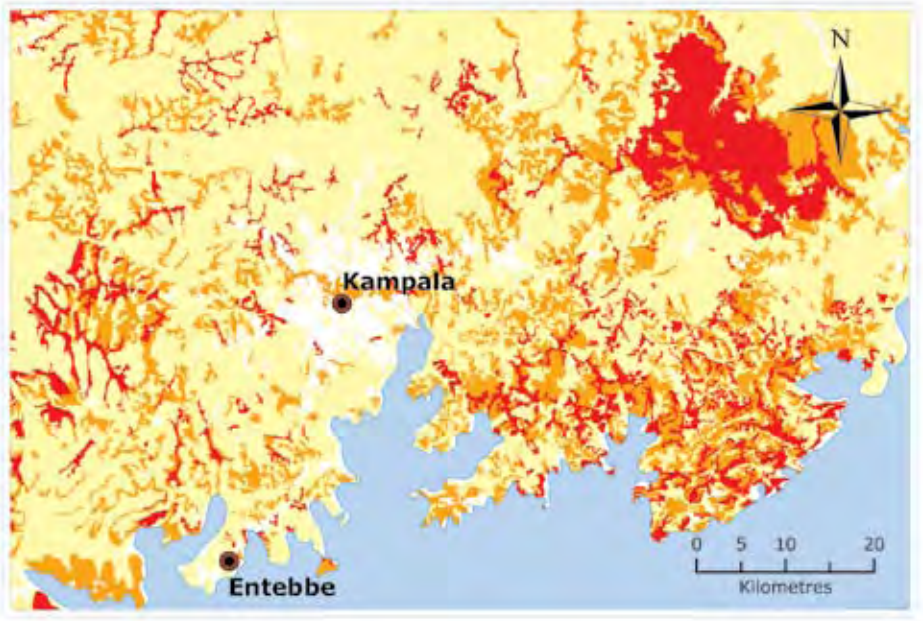


FIGURE 26
Land cover suitability for tsetse flies of the *palpalis* (riverine) group in the area around Kampala (Uganda), based for each polygon on the main land cover class of the Africover map



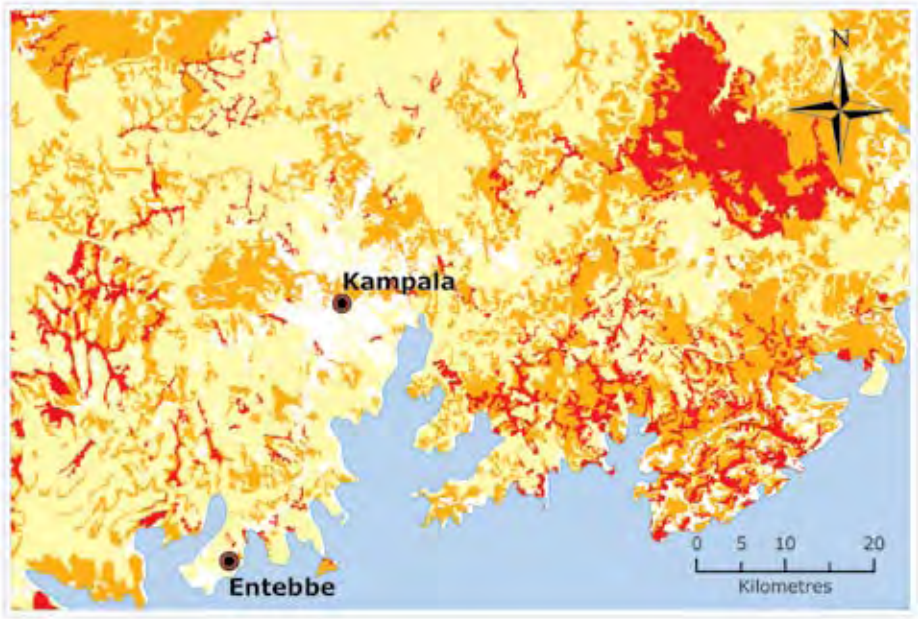
An analysis for the whole Uganda was carried out to confirm the hypothesis that considering or not considering mixed coding (i.e. for each polygon either using only the main land cover class or using the full encoding) leads to comparable results. If the full encoding is considered in the evaluation of suitability for tsetse (*palpalis* group in this case), only 4 percent of the polygons will fall in a different class when compared with the suitability of the main land cover[22]. Given the qualitative nature of the suitability estimates, this kind of error can be considered negligible.

[22] According to LCCS, spatially mixed coding can be characterized by a maximum of three separate land cover classes. The general criterion is that each class must be more than 20 percent of the mapping unit. On average, it is assumed that in a mixed class the like of A/B, A accounts for 60 percent of the area within the unit while B accounts for 40 percent, whereas in a mixed class the like of A/B/C, A accounts for 40 percent while B and C for 30 percent each. Tsetse suitability of mixed mapping units was weighted accordingly.

Figure 27 depicts the land cover suitability for the *palpalis* group of the area around Kampala, as it results from the analysis of the full encoding of the Africover map (i.e. including for each polygon the contribution of secondary and tertiary land cover classes). Comparison of Figure 26 and Figure 27 confirms that the main land cover class represents the global suitability of each patch well. This sensitivity analysis is important because it allows us to further simplify the complexity inherent in the Africover datasets, at least as far as this type of application is concerned.

FIGURE 27

Land cover suitability for tsetse flies of the *palpalis* (riverine) group in the area around Kampala (Uganda), based on the analysis of the full encoding of the Africover map



Conclusions

Land cover maps can be used in several stages of T&T intervention: mapping vector habitat, planning baseline entomological surveys, monitoring the efficacy of tsetse suppression, land-use planning of reclaimed areas and monitoring the environmental impacts of intervention strategies.

This paper highlights the availability of several land cover datasets produced by international organizations and research institutes, which can prove useful in supporting T&T decision-making. A growing number of land cover datasets are being produced in compliance with the FAO/UNEP LCCS and the time has come to adopt this classification system within T&T research and control activities. The Land Cover Classification System is a powerful and flexible system designed to map any type of land cover in the world, no matter which mapping technique is used (direct field survey, classification of remotely sensed images, etc.). In this paper the authors showed how to use existing land cover datasets (e.g. Africover maps) to create informative baseline layers for area-wide integrated pest management programmes. The transboundary nature of the trypanosomiasis problem calls for a multinational approach that will greatly benefit from the use of standardized methodologies and high quality baseline datasets. This methodological approach can potentially be used for vectors and vector-borne diseases other than tsetse and trypanosomiasis.

The Programme Against African Trypanosomiasis is presently focusing part of its efforts in support of the six countries that are implementing the first phase of the PATTEC initiative, which aims at the creation and subsequent expansion of tsetse-free areas in sub-Saharan Africa. Among these countries, Africover land cover databases are presently available for Uganda and Kenya, while Burkina Faso, Ghana and Mali should be mapped within an ongoing project (GLCN West Africa). Discussions with authorized Ethiopian institutions are still in progress. Work is underway within PATTEC to start project implementation in several countries (Angola, Benin, Botswana, Cameroon, The Central African Republic, Chad, Guinea, Namibia, Niger, Nigeria, Rwanda, Senegal, Sudan, United Republic of Tanzania, Togo, Zambia) in 2007 to 2008. The final chapter of the paper proposes a common customization of all existing land cover databases of the Africover project that provide valuable harmonized layers at regional level. The proposed customization can also be applied to land cover datasets that will progressively become available (e.g. the GLCN initiative).

Further research in the field of land cover and tsetse habitat should address the problems of landscape dynamics as related to anthropogenic factors, such as habitat fragmentation and agriculture and urban encroachment of natural areas.

This paper was produced in accordance with PAAT's strategy and mandate to enhance and facilitate policy and technical dialogue, and coordination and harmonization among T&T stakeholders, aiming at the development of common standardized strategies and approaches to improve health, animal production and income derived from livestock-agricultural activities.

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Annex 1
Land cover for T&T decision-making: standard description

The table below was created with the software Land Cover Classification System 2 (version 2.4.5 - 12/11/2004) developed by FAO - Environment and natural resources service. The authors of this paper defined the land cover classes for T&T and the software automatically assigned the standardised codes. The two 'user defined' fields ('User Defined Description' and 'LCC User Defined Label') are not filled in automatically by the software but they can be customized by the user. The 'LCC User Defined Label' was defined by the authors using the abbreviations list developed for the Africover project - East Africa module (see Annex 4 - LCCS user defined labels (abbreviation list), page 79).

MapCode	LCC Code	LCC Label	LCC Level	LCC User Defined Label
User Defined Description			**Standard Description**	
Cultivated and Managed Terrestrial Area(s) (A11)				
1	10001	Tree Crop(s)	A1	T
Forest plantations and tree plantations			Tree crops cover a defined area. The leaf type and leaf phenology can be further specified optionally.	
2	10013	Shrub Crop(s)	A2	S
Shrub crop			Shrub crops cover a defined area. The leaf type and leaf phenology can be further specified optionally.	
3	10025	Herbaceous Crop(s)	A3	H
Herbaceous crops			A defined area is covered by herbaceous crops.	
4	11176	Vegetated Urban Area(s)	A6	5UV
Vegetated urban areas			A defined area is covered by urban vegetation. This vegetation is dominated by clumps of trees and/or shrubs.	
Natural and Semi-Natural Primarily Terrestrial Vegetation (A12)				
5	20005	Closed Trees	A3A10	2TC
Forest			The main layer consists of closed trees. The crown cover is more than (70-60)%.	
6	20013	Open Trees (Woodland)	A3A11	2TP
Woodland			The main layer consists of open trees. The crown cover is between (70-60) and (20-10)%. The openness of the vegetation may be further specified.	

(cont.)

MapCode	LCC Code	LCC Label	LCC Level	LCC User Defined Label
User Defined Description			**Standard Description**	
7	20001	Closed Woody Vegetation	A1A10	2WC
Closed Woody vegetation			The main layer consists of closed woody vegetation. The crown cover is more than (70-60)%.	
8	20009	Open Woody Vegetation	A1A11	2WP
Open Woody vegetation			The main layer consists of open woody vegetation. The crown cover is between (70-60) and (20-10)%. The openness of the vegetation may be further specified.	
9	20017	Closed Shrubland (Thicket)	A4A10	2SC
Thicket			The main layer consists of closed shrubland. The crown cover is more than (70-60)%.	
10	20021	Open Shrubs (Shrubland)	A4A11	2SP
Shrubland			The main layer consists of open shrubland. The crown cover is between (70-60) and (20-10)%. The openness of the vegetation may be further specified.	
11	21453	Herbaceous Closed to Open Vegetation	A2A20	2H(CP)
Grassland			The main layer consists of closed to open herbaceous vegetation. The crown cover is between 100 and 15% (a further sub range can be defined – Closed to Open 100–40%).	
12	21643	Closed to Open Herbaceous Vegetation with Shrubs	A2A20B4XXXXXXF2F6F10G3	2H8
Shrub savannah			The main layer consists of closed to open herbaceous vegetation. The crown cover is between 100 and 15% (a further sub range can be defined – Closed to Open 100–40%). The height is in the range of 3 - 0.03m but may be further defined into a smaller range. The second layer consists of sparse shrubs.	
13	21640	Closed to Open Herbaceous Vegetation with Trees	A2A20B4XXXXXXF2F5F10G2	2H7
Tree savannah			The main layer consists of closed to open herbaceous vegetation. The crown cover is between 100 and 15% (a further sub range can be defined – Closed to Open 100–40%). The height is in the range of 3 - 0.03m but may be further defined into a smaller range. The second layer consists of sparse trees.	
14	20052	Sparse Trees	A3A14	2TR
Sparse trees			The main layer consists of sparse trees. The crown cover is between (20-10) and 1%. The sparseness of the vegetation may be further specified.	
15	20055	Sparse Shrubs	A4A14	2SR
Sparse shrubs			The main layer consists of sparse shrubs. The crown cover is between (20-10) and 1%. The sparseness of the vegetation may be further specified.	

(cont.)

MapCode	LCC Code	LCC Label	LCC Level	LCC User Defined Label
User Defined Description			**Standard Description**	
16	20058	Herbaceous Sparse Vegetation	A2A14	2HR
Sparse herbaceous vegetation			The main layer consists of sparse herbaceous vegetation. The crown cover is between (20-10) and 1%. The sparseness of the vegetation may be further specified.	
Cultivated Aquatic or Regularly Flooded Area(s) (A23)				
17	3025-S0308	Continuous Field(s) Of Graminoid Crops On Permanently Flooded Land. Dominant Crop: Cereals - Rice (Oryza spp.)	A1XXB5C1-S0308	GZ-r
Fields Rice			Continuous field(s) are covered with graminoid crops. The crops are growing on permanently flooded land.	
Natural and Semi-Natural Aquatic or Regularly Flooded Vegetation (A24)				
18	40003	Trees.	A3A12	4TC
Closed swamp			The main layer consists of closed trees. The crown cover is more than (70-60)%.	
19	40007	Woodland.	A3A13	4TP
Open swamp			The main layer consists of woodland. The crown cover is between (70-60) and (20-10)%. The openness of the vegetation may be further specified.	
20	41519	Closed to Open Woody Vegetation	A1A20	4W
Woody vegetation on flooded land			The main layer consists of closed to open woody vegetation. The crown cover is between 100 and 15% (a further sub range can be defined – Closed to Open 100–40%). The openness of the vegetation may be further specified.	
21	41895	Closed to Open Shrubs.	A4A20	4S
Shrubs on flooded land			The main layer consists of closed to open shrubs. The crown cover is between 100 and 15% (a further sub range can be defined – Closed to Open 100–40%). The openness of the vegetation may be further specified.	
22	42155//40031	Closed to Open Herbaceous Vegetation. // Sparse Herbaceous Vegetation.	A2A20 // A2A16	4H
Herbaceous vegetation on flooded land			The main layer consists of closed to open herbaceous vegetation. The crown cover is between 100 and 15% (a further sub range can be defined – Closed to Open 100–40%). The openness of the vegetation may be further specified. // The main layer consists of sparse herbaceous vegetation. The crown cover is between (20-10) and 1%. The sparseness of the vegetation may be further specified.	

(cont.)

MapCode	LCC Code	LCC Label	LCC Level	LCC User Defined Label
User Defined Description			**Standard Description**	
Artificial Surfaces and Associated Area(s) (B15)				
23	0010	Artificial Surfaces and Associated Area(s)	B15	5
Artificial surfaces			This class describes areas that have an artificial cover as a result of human activities such as construction (cities, towns, transportation), extraction (open mines and quarries) or waste disposal.	
Bare Area(s) (B16)				
24	0011	Bare Area(s)	B16	6
Bare soil			This class describes areas that do not have an artificial cover as a result of human activities. These areas include areas with less than 4% vegetative cover. Included are bare rock areas, sands and deserts.	
Aquatic or Regularly Flooded Primarily Non-Vegetated Areas (B2)				
25	0012	Primarily Non-Vegetated Aquatic or Regularly Flooded Area(s)	B2	W
Water bodies			The environment is significantly influenced by the presence of water over an extensive period of time each year.	
Natural Waterbodies, Snow and Ice (B28)				
26	8006	Perennial Snow	A2B1	8SP
Snow			The environment is significantly influenced by the presence of water over an extensive period of time each year.	

Annex 2
Land Cover for T&T decision-making: classifiers used

The LCCS applies a classifier, or parametric, approach in which land cover classes are defined by a combination of a set of independent diagnostic criteria. The classifiers are hierarchically arranged to assure a high degree of geographical accuracy.

The table below was created with the software Land Cover Classification System 2 (version 2.4.5 - 12/11/2004) developed by FAO - Environment and natural resources service. The authors of this paper defined the classifiers of land cover classes for T&T and the software automatically assigned the standardised codes and labels.

List of Land Cover Classifiers Used		
	Classifier	**Classifier Label**
Dichotomous Phase		
1	B15	Artificial Surfaces and Associated Area(s)
2	B16	Bare Area(s)
3	B2	Primarily Non-Vegetated Aquatic or Regularly Flooded Area(s)
Cultivated and Managed Terrestrial Area(s)		
4	A1	Tree Crops
5	A2	Shrub Crops
6	A3	Herbaceous Crops
7	A6	Urban Vegetated Area(s)
Natural and Semi-Natural Primarily Terrestrial Vegetation		
8	A1	Woody Vegetation (Main Layer)
9	A10	Closed > (70-60)% (Main Layer)
10	A11	Open General (70-60) - (20-10)% (Main Layer)
11	A14	Sparse (20-10) - 5% (Main Layer)
12	A2	Herbaceous Vegetation (Main Layer)
13	A20	Closed to Open (100-15)%
14	A3	Trees (Main Layer)
15	A4	Shrubs (Main Layer)
16	B4	3 - 0.03m (Herbaceous Height Main Layer)
17	F10	Sparse (20-10) - 5%

(cont.)

List of Land Cover Classifiers Used		
	Classifier	**Classifier Label**
18	F2	Second and/or Third Layer Present
19	F5	Trees (Second or Third Layer)
20	F6	Shrubs (Second or Third Layer)
21	G2	> 30 - 3m (Trees Height Second or Third Layer)
22	G3	5 - 0.3m (Shrubs Height Second or Third Layer)
Cultivated Aquatic or Regularly Flooded Area(s)		
23	A1	Graminoid Crops
24	B5	Continuous (Field Distribution)
25	C1	On Permanently Flooded Land
26	S0308	Rice (Oryza spp.)
Natural and Semi-Natural Aquatic or Regularly Flooded Vegetation		
27	A1	Woody Vegetation (Main Layer)
28	A12	Closed > (70-60)% (Main Layer)
29	A13	Open General (70-60) - (20-10)% (Main Layer)
30	A16	Sparse (20-10) - 1% (Main Layer)
31	A2	Herbaceous Vegetation (Main Layer)
32	A20	Closed to Open (100-15)%
33	A3	Trees (Main Layer)
34	A4	Shrubs (Main Layer)
Natural Waterbodies, Snow and Ice		
35	A2	Snow
36	B1	Perennial

Annex 3
Land Cover of East Africa for T&T: table of class aggregation

This table allows to aggregate the land cover classes of the Africover databases (Original Database Classes) into the 26 classes (LCC User Defined Label) defined for tsetse and trypanosomiasis intervention.

The meaning of the abbreviations in columns 'Original Database Classes' and 'LCC User Defined Label' can be found in Annex 4 - LCCS user defined labels (abbreviation list) (p. 79).

LCC user defined label	Original database classes
LCCS Category: Cultivated and Managed Terrestrial Area(s) (A11)	
Forest plantations and tree plantations (T)	
T	TR57V
T	TR57
T	TR47V-pc,oe
T	TR47V-oe,fc
T	TR47V
T	TR47
T	TR3S47V
T	TR3S47
T	TR3H57V
T	TR3H57
T	TR3H47V
T	TR3H47
T	TR347-pc,oe
T	TR347-oe,fc
T	TR247V
T	TR247
T	TR23H47V
T	TR23H47
T	TR147V
T	TR147
T	TR13S47V
T	TR13S47
T	TR13H57V
T	TR13H57
T	TR13H47V
T	TR13H47
T	TNEL47PL-pi,cu
T	TNE47PL-pi,cu
T	TNE47PL-pi
T	TNE47PL
T	TM57WV-ap,fc
T	TM57V
T	TM57
T	TM47V
T	TM47PL-op
T	TM47-op
T	TM47
T	TM3H47V-cw
T	TM3H47V
T	TM3H47-cw
T	TM3H47
T	TM357W-ap,fc
T	TM357
T	TM147V
T	TM147
T	TM13H47V
T	TM13H47
T	TM1357V
T	TM1357
T	TL47W
T	TL47PL
T	TL3S47V

LCC user defined label	Original database classes
T	TL3S47
T	TD3V-d
T	TD3-d
T	TBR247PL
T	TBR147PL
T	TBL47PL
T	TBER57WV-oe
T	TBER57W-oe
T	TBER57V-oe
T	TBER57V-d
T	TBER57V-cc
T	TBER57-oe
T	TBER57-d
T	TBER57-cc
T	TBER47V-d
T	TBER47-d
T	TBER147V
T	TBER247V-d
T	TBER247-d
T	TBER157V-d
T	TBER157-d
T	TBEM47V
T	TBEL57V-cc,m
T	TBEL57V-cc
T	TBEL57-cc,m
T	TBEL57-cc
T	TBEL47W
T	TBED57WV-oe
T	TBED57WV-cc
T	TBED57W-oe
T	TBED57W-cc
T	TBED57V-pw
T	TBED57V-m
T	TBED57V-d
T	TBED57V-cc
T	TBED57-pw
T	TBED57-m
T	TBED57-d
T	TBED57-cc
T	TBED47V
T	TBED47PL-e
T	TBE57PL-e
T	TBE47PL-e
T	TBE47PL-a
T	TBE47PL
T	TBE147PL-e
T	TBDYPL-an
T	TBDL47W
T	TBD47PL-tg
T	TBD47PL-as
T	TBD47PL-an
T	T47PL
T	T247PL
T	T147PL
Shrub crop (S)	
S	SR47V-t
S	SR47V-c
S	SR47V-b
S	SR47V
S	SR47-t
S	SR47-c
S	SR47-b
S	SR47
S	SR3S47V-c,b
S	SR3S47-c,b+2TO28
S	SR3S47-c,b+2TO268
S	SR3H47V
S	SR3H47
S	SR247V-t
S	SR247V-b
S	SR247V
S	SR247-t
S	SR247-b
S	SR247
S	SR23H47V
S	SR23H47
S	SR147V-t
S	SR147V-c
S	SR147V
S	SR147-t
S	SR147-c
S	SR147
S	SR13H47V
S	SR13H47
S	SM47V-t
S	SM47V
S	SM47-t
S	SM47

LCC user defined label	Original database classes
S	SL47V-t
S	SL47V-p
S	SL47V-c
S	SL47V
S	SL47-t
S	SL47-p
S	SL47-c
S	SL47
S	SD47V-t
S	SD47V-c
S	SD47V
S	SD47-t
S	SD47-c
S	SD47
S	SBED47W
S	SBE57V-b
S	SBE57-b
S	SBE157V-b
S	SBE157-b
S	SBDR57V-g
S	SBDR57-g
Herbaceous crops (H)	
H	NR57-pv
H	NR157-pv
H	ND57-pv
H	HRY
H	HR57-s
H	HR57-C
H	HR57
H	HR4-mz
H	HR4-C
H	HR47
H	HR4///GRZ-r
H	HR4
H	HR3T4-as
H	HR3S47
H	HR3HQY
H	HR3HQ57-mz,cl
H	HR3HQ57-ct,w
H	HR3HQ57
H	HR3HQ47-x/SR3H47
H	HR3HQ47-x/SR3H47V
H	HR3HQ47-x/SR23H47
H	HR3HQ47-x/SR23H47V

LCC user defined label	Original database classes
H	HR3HQ47-x
H	HR3H47
H	HR33H4
H	HR2Y
H	HR24-mz
H	HR24-C
H	HR247
H	HR24
H	HR23S47
H	HR23Q5
H	HR23HQ57
H	HR23HQ47-x
H	HR233H4
H	HR1Y
H	HR157-C
H	HR14-mz
H	HR14-C
H	HR147
H	HR14
H	HR13T4-as
H	HR13S47
H	HR13HQ57
H	HR13HQ47-x
H	HR133H4
H	HMY
H	HM57-s
H	HM57
H	HM4-w
H	HM4-mz
H	HM4
H	HM3HQ57
H	HM3HQ4
H	HM3H47
H	HM33H4
H	HM24-mz
H	HM24
H	HM1Y
H	HM14-mz
H	HM14
H	HL57-s
H	HL57-ct
H	HL57
H	HL4-z
H	HL4-w

LCC user defined label	Original database classes
H	HL4-s
H	HL4
H	HL3HQ57
H	HL3HQ4
H	HL3H47
H	HL14
H	HD-s
H	HD57-s
H	HD57-C
H	HD57
H	HD4-z
H	HD4-w
H	HD4-s
H	HD4-mz
H	HD4-C
H	HD4
H	HD3HQ57W-pv
H	HD3HQ57-mz,cl
H	HD3HQ57K
H	HD3HQ57-ct,w
H	HD3HQ57
H	HD157-C
H	HD14-w
H	HD14-C
H	HD14
H	HD13HQ57
Vegetated urban areas (5UV)	
5UV	5UV
LCCS Category: Natural and Semi-Natural Primarily Terrestrial Vegetation (A12)	
Forest (2TC)	
2TC	2TCM-B
2TC	2TCM8-B
2TC	2TCM28
2TC	2TCL8
2TC	2TCL1-pc
2TC	2TCL
2TC	2TCI8
2TC	2TCI28
2TC	2TCI218
2TC	2TCI217
2TC	2TCI187
2TC	2TCI177
2TC	2TCI128
2TC	2TC-B
2TC	2TC8
2TC	2TC3-j
2TC	2TC328
2TC	2TC3
2TC	2TC28
2TC	2TC128
Woodland (2TP)	
2TP	2TVM26
2TP	2TVM28
2TP	2TVL268
2TP	2TVL1-pc
2TP	2TVI
2TP	2TV-B
2TP	2TV8
2TP	2TV28
2TP	2TV268
2TP	2TPM86
2TP	2TPM8
2TP	2TPM28
2TP	2TPM218
2TP	2TPM18
2TP	2TPM128
2TP	2TP8
2TP	2TP68
2TP	2TP3-j
2TP	2TP28
2TP	2TP268
2TP	2TOM28
2TP	2TOM26
2TP	2TOL268
2TP	2TOI178
2TP	2TO8
2TP	2TO28
2TP	2TO268
Closed Woody vegetation (2WC)	
2WC	2WCZ
2WC	2WC7
2WC	2WC27Y
2WC	2WC27
2WC	2WC
Open Woody vegetation (2WP)	
2WP	2WP6Z

LCC user defined label	Original database classes
2WP	2WP67
2WP	2WP6
2WP	2WP26
2WP	2WP236
Thicket (2SC)	
2SC	2SCMZ
2SC	2SCM2-FE
2SC	2SCL
2SC	2SCJZ
2SC	2SCJ-cts
2SC	2SCJ7
2SC	2SCJ27
2SC	2SCJ2
2SC	2SCJ
Shrubland (2SP)	
2SP	2SVLZ
2SP	2SVL6
2SP	2SVJ67
2SP	2SVJ6//2HC
2SP	2SVJ6//2GC
2SP	2SVJ6
2SP	2SV6/2H(CP)
2SP	2SV6//2HC
2SP	2SV6//2H(CP)
2SP	2SV6//2GC
2SP	2SV6//2G(CP)
2SP	2SV6
2SP	2SPM58
2SP	2SPJ6-cts
2SP	2SPJ67
2SP	2SPJ6
2SP	2SPJ267
2SP	2SP6
2SP	2SOL6
2SP	2SOJ67
2SP	2SOJ6
2SP	2SO6
Grassland (2H(CP))	
2H(CP)	2HVJ
2H(CP)	2HV//2HR
2H(CP)	2HV
2H(CP)	2HP
2H(CP)	2HOJ
2H(CP)	2HCJ
2H(CP)	2HC
2H(CP)	2H(CP)
2H(CP)	2GC
2H(CP)	2G(CP)
Shrub savannah (2H8)	
2H8	2HVJ8//6S
2H8	2HVJ8
2H8	2HP8
2H8	2HOJ8
2H8	2HCJ8
2H8	2HC8
2H8	2H(CP)8//6S
2H8	2H(CP)8
2H8	2G(CP)8
Tree savannah (2H7)	
2H7	2HPJ78
2H7	2HP78
2H7	2HOJ78
2H7	2HCJ78
2H7	2HC78
2H7	2H(CP)78
2H7	2GPJ78
2H7	2GC78
2H7	2G(CP)78
Sparse trees (2TR)	
2TR	2TRL2
2TR	2TR6
2TR	2TR28
Sparse shrubs (2SR)	
2SR	2SRM6//6ST2
2SR	2SRM6//6ST1
2SR	2SRM6
2SR	2SRL6
2SR	2SRL
2SR	2SRJ6
2SR	2SR6//6ST2
2SR	2SR6//6ST1
2SR	2SR6
Sparse herbaceous vegetation (2HR)	
2HR	2HRJ//6ST1
2HR	2HRJ//6S
2HR	2HRJ//6L

LCC user defined label	Original database classes
2HR	2HRJ
2HR	2HR//6ST1
2HR	2HR//6S
2HR	2HR//6L
2HR	2HR
LCCS Category: Cultivated Aquatic or Regularly Flooded Area(s) (A23)	
Fields Rice (GZ-r)	
GZ-r	GRZ-r
GZ-r	GMZ-r
GZ-r	GLZ-r
GZ-r	GDZ-r
LCCS Category: Natural and Semi-Natural Aquatic or Regularly Flooded Vegetation (A24)	
Closed swamp (4TC)	
4TC	4TCMFF1Y
4TC	4TCMF218
4TC	4TCIFF1Y
4TC	4TCIFF1-rh
4TC	4TCIFF18
4TC	4TCIFF1
4TC	4TCIF17
4TC	4TCIF1
4TC	4TCFF1Y
4TC	4TCFF
4TC	4TCF8
4TC	4TCF
Open swamp (4TP)	
4TP	4TVF8
4TP	4TVF6
4TP	4TPMF218
4TP	4TPF6
4TP	4TOF8
4TP	4TOF6
4TP	4TPMFF218
4TP	4TPMFF18
Woody vegetation on flooded land (4W)	
4W	4WPF6
4W	4WCFF1X
Shrubs on flooded land (4S)	
4S	4SVJFF6
4S	4SVF6
4S	4SPJFF6
4S	4SPJF6
4S	4SPFF6
4S	4SPF6
4S	4SOF6
4S	4SCJFF7
4S	4SCJFF1Y
4S	4SCJFF
4S	4SCJF
4S	4SCF
Herbaceous vegetation on flooded land (4H)	
4H	4HVMFY
4H	4HPJFF
4H	4HPJF8
4H	4HPJF
4H	4HPIFF
4H	4HPF8
4H	4HCMFFY
4H	4HCMFF
4H	4HCJFF
4H	4HCJF8
4H	4HCJF7
4H	4HCJF
4H	4HCIFF7
4H	4HCIFF
4H	4HCFF8
4H	4HCFF
4H	4HCF8
4H	4HCF
4H	4H(CP)FF
4H	4H(CP)F8
4H	4GCIFFX
4H	4GCFF7
4H	4FRMFY
4H	4FRLW-Z-RE
4H	4FRLW-Z
4H	4FPLFF
4H	4FCMFF
4H	4FCLFF-j
4H	4FCLFF
4H	4F(CP)LFF
4H	4F(CP)FF
LCCS Category: Artificial Surfaces and Associated Area(s) (B15)	
Artificial surfaces (5)	
5	5UR
5	5UC

LCC user defined label	Original database classes
5	5U
5	5Q
5	5P
5	5I
5	5A1
5	5A
LCCS Category: Bare Area(s) (B16)	
Bare soil (6)	
6	6SZ
6	6ST2D
6	6ST2
6	6ST1H
6	6ST1D-RE
6	6ST1D
6	6ST1//6L
6	6ST1
6	6S
6	6RL
6	6R
6	6LT1
6	6L-m
6	6LD4-RE
6	6LD4
6	6LD3
6	6L//2HRJ
6	6L//2HR
6	6L
6	6G
LCCS Category: Aquatic or Regularly Flooded Primarily Non-Vegetated Areas (B2)	
Water bodies (W)	
W	8WT6
W	8WT1
W	8WPH6
W	8WP6
W	8WP
W	8WN6
W	8WN2
W	8WN1V
W	8WN
W	8WFP
W	8WFN2
W	8WFN1
W	7WP-Y
W	7WP
W	7WNB
W	5W
LCCS Category: Natural Waterbodies, Snow and Ice (B28)	
Snow (8SP)	
8SP	8SP

Annex 4
LCCS user defined labels (abbreviation list)

The following abbreviations (grouped for the eight major land cover types) are utilized throughout this paper in the 'User Defined Label'. Please note that the abbreviations are listed in the same order in which they appear in the tables.

The tables and related abbreviations in the present annex were developed for the Africover project - East Africa module and subsequently used by the authors of this paper.

CULTIVATED TERRESTRIAL (A11)
(begins with 1 in LCC Code)

CULTIVATED AQUATIC OR REGULARLY FLOODED AREAS (A 23)
(begins with 3 in LCC Code)

T = Tree crop
S = Shrub crop
H = Herbaceous crop
G = Graminoid crop
N = Non-graminoid crop
D = Large to medium field
L = Large field
M = Medium field
R = Small field
1 = Clustered
2 = Isolated
3 = 1 Additional crop
33 = 2 Additional crops
Q = Sequential
O = Overlapping
4 = Rainfed
5 = Irrigated
6 = Water logged
7 = Permanent
8 = Fallow
9 = Shifting
B = Broadleaved
E = Evergreen
PL = Forest Plantation
V = Orchards and/or other type of plantation
D = Deciduous (even from large to medium)
N = Needleaved (even non Graminoids)
Z = Aquatic or regularly flooded (Water persistent for whole day during cult. Period)
Y = Post Flooding
K = Sprinkler
W = Drip
C = Cereals

Sub classes

pv= Pulses & Vegetables
r = Rice
an = Acacia nilotica
ap = Apple
as = Acacia senegal
cl = Clover
cn = Coconut
ct = Cotton
cu = Cupressus spp.
cv = Cloves
cw = cashew
e = Eucaliptus
fc = Fig
g = Grapes
gu = Guava
mh = Mohogan
oe = Olive
op = Oil Palm
pc = Peach
pi = Pinus spp.
tg = Tectonia grandis

to = Tobacco

pl = Palm trees (natural)

a = wattle (Acacia Mearsi)

b = banana

ba = barley

bn = bean

c = coffee

ca = casava

cc = citrus

cp = cowpea

d = date palm

f = flowers

m = mango

mi = millet

mz = maize

np = napier grass

o = coconut

p = pineapple

pa = pasture

pf = passionfruit

pp = pigeon pea

pt = potatoes

pw = pawpaw

s = sugarcane

sf = sun flower

si = sim sim

so = sorghum

t = tea

z = sisal

w = wheat

NATURAL AND SEMINATURAL TERRESTRIAL VEGETATION (A12)
(begins with 2 in LCC Code)

W = Woody

T = Trees

S = Shrubs

H = Herbaceous

G = Graminoids

F = Forbs

C = Closed

O = Open 65-40%

P = Open General 65-15%

V = Very Open 40-15%

(CP) = Closed to very open (100 – 15%)

R = Sparse

1 = Broad leaved evergreen

2 = Broad leaved deciduous

3 = Needleaf Evergreen

4 = Needleaf Deciduous

I = High

M = Medium Height

L = Low

5 = Aphyllous

J = Sub General Height for Shrubs (5-0.5m) and Herb. (3-0.3m)

6 = Herbaceous 2-3 Layer

7 = Trees 2-3 Layer

8 = Shrub 2-3 Layer

M = Mosses

Z = Fragmented or Striped

Sub classes

FE = Fern

j = Juniperous

pc = Prosopis chilensis

cts = sparse cactus

Y = Thorny

B = Bamboo

NATURAL/SEMINATURAL AQUATIC VEGETATION (A24)
(begins with 4 in LCC Code)

W = Woody

T = Trees

S = Shrubs

H = Herbaceous

G = Graminoids

F = Forbs

C = Closed

O = Open 65-40%

P = Open General 65-15%

V = Very Open 40-15%

(CP) = Closed to very open (100 – 15%)

R = Sparse

1 = Broad leaved evergreen

2 = Broad leaved deciduous

3 = Needleave Evergreen

4 = Needleave Deciduous

I = High

M = Medium Height

L = Low

5 = Aphyllous

J = Sub General Height for Shrubs (5-0.5m) and Herb. (3-0.3m)

6 = Herbaceous 2 Layer

7 = Trees 2 Layer

8 = Shrub 2 Layer

9 = Herbaceous 2nd Layer

FF = Water seasonality > 3 months/year

F = Water Seasonality < 3 months/year

W = Waterlogged

X = Saline

Y = Brackish

SO = Solonetz

RE = Under Reclamation

Z = Salt Crust

j = Jacintus

ARTIFICIAL SURFACES AND ASSOCIATED AREAS (B15)
(begins with 5 in LCC Code)

U = Urban area

R = Rural settlements

C = Refugee camp

I = Industrial

P = Port

A = Airport

Q = Quarry

W = Waste

A1 = Archaeological Site

D = High density

M = Medium density

L = Low density

V = Other : Vegetated Areas

Sub class

m = permanently moist

BARE AREAS (B16)
(begins with 6 in LCC Code)

R = Bare Rock

S = Bare Soil

G = Gravel, Stones and Boulders

L = Loose and shifting sand

T1 = Stony

T2 = Very stony

D = Deep Soil

D1 = Barcham dunes

D2 = Parabolic dunes

D3 = Longitudinal dunes

H = Shallow soil

Z = Salt Crust

D4 = Dunes

Sub class

RE = Under Reclamation

ARTIFICIAL WATERBODIES (B 27)
(begins with 7 in LCC Code)

INLAND WATER (B28)
(begins with 8 in LCC Code)

W = Water bodies

R = River

S = Snow

F = flowing water

P = Perennial

N = Non perennial

T = Tidal area

1 = Sand/Bare Sand

2 = Bare soil

3 = Bare Rock

H = Shallow

Z = Sediment

Y = Fish Ponds

4 = Slightly Saline

5 = Moderately Saline

6 = Very Saline

B = Brine

Y = Fish ponds

V = Scattered Vegetation

Annex 5
Land Cover of Uganda for T&T: standard description

The table below was created with the software Land Cover Classification System 2 (version 2.4.5 - 12/11/2004) developed by FAO - Environment and natural resources service. The authors of this paper defined for Uganda the land cover classes for T&T and the software automatically assigned the standardised codes. The two 'user defined' fields ('User Defined Description' and 'LCC User Defined Label') are not filled in automatically by the software but they can be customized by the user. The 'LCC User Defined Label' was defined by the authors using the abbreviations list developed for the Africover project - East Africa module (see Annex 4 - LCCS user defined labels (abbreviation list), p. 79).

MapCode	LCC Code	LCC Label	LCC Level	LCC User Defined Label
User Defined Description			**Standard Description**	
Cultivated and Managed Terrestrial Area(s) (A11)				
1	11492-W7	Permanently Cropped Area With Rainfed Tree Crop(s) Crop Cover: Plantation(s)	A1XXXXXXD1D9-W7	T47PL
Forest plantations and tree plantations			Field(s) are covered by irrigated tree crops. The leaf type and leaf phenology can be further specified optionally. The irrigation systems commonly used are surface, sprinkler and drip irrigation.	
2	11496-W8	Permanently Cropped Area With Rainfed Shrub Crop(s) Crop Cover: Orchard(s)	A2XXXXXXD1D9-W8	S47V
Rainfed shrub crop			Field(s) are covered by irrigated shrub crops. The leaf type and leaf phenology can be further specified optionally. The irrigation systems commonly used are surface, sprinkler and drip irrigation.	
3	10025	Herbaceous Crop(s)	A3	H
Herbaceous crop			A defined area is covered by herbaceous crops.	
4	11176	Vegetated Urban Area(s)	A6	5UV
Vegetated urban areas			A defined area is covered by urban vegetation. This vegetation is dominated by clumps of trees and/or shrubs.	

(cont.)

MapCode	LCC Code	LCC Label	LCC Level	LCC User Defined Label
User Defined Description			**Standard Description**	
Natural and Semi-Natural Primarily Terrestrial Vegetation (A12)				
5	20007	Continuous Closed Trees	A3A10B2C1	2TC
Forest			The main layer consists of closed trees. The crown cover is more than (70-60)%. The height is in the range of >30 - 3m but may be further defined into a smaller range. The vegetation is spread over the area without intervals or breaks.	
6	20015	Continuous Open Trees (Woodland)	A3A11B2C1	2TP
Woodland			The main layer consists of open trees. The crown cover is between (70-60) and (20-10)%. The openness of the vegetation may be further specified. The height is in the range of >30 - 3m but may be further defined into a smaller range. The vegetation is spread over the area without intervals or breaks.	
7	21443	Continuous Closed to Open Woody Vegetation	A1A20B1C1	2W
Woody vegetation			The main layer consists of closed to open woody vegetation. The crown cover is between 100 and 15% (a further sub range can be defined – Closed to Open 100–40%). The height is in the range of 7 - 2m and is not further defined. The vegetation is spread over the area without intervals or breaks.	
8	20019-12374	Continuous Closed Medium To High Shrubland (Thicket)	A4A10B3C1-B14	2SCJ
Thicket			The main layer consists of closed shrubland. The crown cover is more than (70-60)%. The height is in the range of 5 - 0.3m but may be further defined into a smaller range. The vegetation is spread over the area without intervals or breaks.	
9	20389	Shrubland with Herbaceous	A4A11B3C1XXXXF2F4F7G4	2SP6
Shrubland with herbaceous			The main layer consists of shrubland. The crown cover is between (70-60) and (20-10)%. The openness of the vegetation may be further specified. The height is in the range of 5 - 0.3m but may be further defined into a smaller range. The vegetation is spread over the area without intervals or breaks. The second layer consists of closed to open herbaceous vegetation.	
10	21463	Continuous Closed to Open Grassland	A6A20B4C1	2G(CP)
Grassland			The main layer consists of closed to open grassland. The crown cover is more than 15-100)%. The height is in the range of 3 - 0.03m but may be further defined into a smaller range. The vegetation is spread over the area without intervals or breaks.	
11	21677	Closed to Open Grassland with Trees and Shrubs	A6A20B4C1XXXXF2F5F10G2F2F 6F10G3	2G(CP)78
Savannah			The main layer consists of closed to open grassland. The crown cover is between 100 and 15% (a further sub range can be defined – Closed to Open 100–40%). The height is in the range of 3 - 0.03m but may be further defined into a smaller range. The vegetation is spread over the area without intervals or breaks. The second layer consists of sparse trees. The third layer consists of sparse shrubs.	

(cont.)

MapCode	LCC Code	LCC Label	LCC Level	LCC User Defined Label
User Defined Description			**Standard Description**	
Cultivated Aquatic or Regularly Flooded Area(s) (A23)				
12	3025-S0308	Continuous Field(s) Of Graminoid Crops On Permanently Flooded Land. Dominant Crop: Cereals - Rice (Oryza spp.)	A1XXB5C1-S0308	GZ-r
Fields Rice			Continuous field(s) are covered with graminoid crops. The crops are growing on permanently flooded land.	
Natural and Semi-Natural Aquatic or Regularly Flooded Vegetation (A24)				
13	41636-R1	Closed to Open Trees. Water Quality: Fresh Water	A3A20B2-R1	4T(CP)
Freshwater swamp			The main layer consists of closed to open woodland. The crown cover is between 100 and 15% (a further sub range can be defined – Closed to Open 100–40%). The openness of the vegetation may be further specified. The height is in the range of >30 - 3m but may be further defined into a smaller range.	
14	41896	Closed to Open Shrubs	A4A20B3	4S(CP)
Shrubs on flooded land			The main layer consists of closed to open shrubs. The crown cover is between 100 and 15% (a further sub range can be defined – Closed to Open 100–40%). The openness of the vegetation may be further specified. The height is in the range of 5 - 0.3m but may be further defined into a smaller range.	
15	42156-R1	Closed to Open Herbaceous Vegetation. Water Quality: Fresh Water	A2A20B4-R1	4H(CP)
Herbaceous vegetation on flooded land - fresh water			The main layer consists of closed to open herbaceous vegetation. The crown cover is between 100 and 15% (a further sub range can be defined – Closed to Open 100–40%). The openness of the vegetation may be further specified. The height is in the range of 3 - 0.03m but may be further defined into a smaller range.	
Artificial Surfaces and Associated Area(s) (B15)				
16	5003	Non-Linear Built Up Area(s)	A4	5
Urban areas, airports			The land cover consists of non-linear built up areas which can be further specified into industrial area(s) or urban area(s). The density of the impermeable surface(s) can be specified into high, medium, low or scattered.	
Bare Area(s) (B16)				
17	6005	Bare Soil And/Or Other Unconsolidated Material(s)	A5	6S
Bare soil			The land cover consists of bare soil and/or other unconsolidated material(s). The surface can be stony (5 - 40%) or very stony (40 - 80%).	

MapCode	LCC Code	LCC Label	LCC Level	LCC User Defined Label
User Defined Description			**Standard Description**	
Natural Waterbodies, Snow and Ice (B28)				
18	8002-V1	Perennial Natural Waterbodies. Salinity: Fresh, < 1.000 ppm of TDS	A1B1-V1	8WP
Lakes and rivers			Lakes and rivers	

Annex 6
Land Cover of Uganda for T&T: classifiers used

The LCCS applies a classifier, or parametric, approach in which land cover classes are defined by a combination of a set of independent diagnostic criteria – the so-called classifiers – that are hierarchically arranged to assure a high degree of geographical accuracy.

The table below was created with the software Land Cover Classification System 2 (version 2.4.5 - 12/11/2004) developed by FAO - Environment and natural resources service. For Uganda, the authors of this paper defined the classifiers of land cover classes for T&T and the software automatically assigned the standardised codes and labels.

List of Land Cover Classifiers Used

	Classifier	Classifier Label
Cultivated and Managed Terrestrial Area(s)		
2	A2	Shrub Crops
3	A3	Herbaceous Crops
4	A6	Urban Vegetated Area(s)
5	D1	Rainfed Cultivation
6	D9	Permanently Cropped Area
7	W7	Plantation(s)
8	W8	Orchard(s)
Natural and Semi-Natural Primarily Terrestrial Vegetation		
9	A1	Woody Vegetation (Main Layer)
10	A10	Closed > (70-60)% (Main Layer)
11	A11	Open General (70-60) - (20-10)% (Main Layer)
12	A20	Closed to Open (100-15)%
13	A3	Trees (Main Layer)
14	A4	Shrubs (Main Layer)
15	A6	Graminoids
16	B1	7 - 2m (Height for Woody Vegetation Main Layer)
17	B14	Medium To High 5-0.5m (Shrub Height main Layer)
18	B2	> 30 - 3m (Trees Height Main Layer)
19	B3	5 - 0.3m (Shrubs Height Main Layer)
20	B4	3 - 0.03m (Herbaceous Height Main Layer)

(cont.)

List of Land Cover Classifiers Used		
	Classifier	**Classifier Label**
21	C1	Continuous (Vegetation Main Pattern)
22	F10	Sparse (20-10) - 5%
23	F2	Second and/or Third Layer Present
24	F4	Herbaceous Vegetation (Second or Third Layer)
25	F5	Trees (Second or Third Layer)
26	F6	Shrubs (Second or Third Layer)
27	F7	Closed (> 70-60%) To Open (70-60) - (20-10)% (Second or Third Layer)
28	G2	> 30 - 3m (Trees Height Second or Third Layer)
29	G3	5 - 0.3m (Shrubs Height Second or Third Layer)
30	G4	3 - 0.03m (Herbaceous Height Second or Third Layer)
Cultivated Aquatic or Regularly Flooded Area(s)		
31	A1	Graminoid Crops
32	B5	Continuous (Field Distribution)
33	C1	On Permanently Flooded Land
34	S0308	Rice (Oryza spp.)
Natural and Semi-Natural Aquatic or Regularly Flooded Vegetation		
35	A2	Herbaceous Vegetation (Main Layer)
36	A20	Closed to Open (100-15)%
37	A3	Trees (Main Layer)
38	A4	Shrubs (Main Layer)
39	B2	> 30 - 3m (Trees Height Main Layer)
40	B3	5 - 0.3m (Shrubs Height Main Layer)
41	B4	3 - 0.03m (Herbaceous Height Main Layer)
Artificial Surfaces and Associated Area(s)		
42	A4	Non-Linear (Feature)
Bare Area(s)		
43	A5	Bare Soil And/Or Other Unconsolidated Material(s)
Natural Waterbodies, Snow and Ice		
44	A1	Inland Water
45	B1	Perennial
46	V1	Fresh
Environmental attributes		
47	R1	Fresh Water

Annex 7
Land Cover of Uganda for T&T: table of class aggregation

This table can be used to aggregate the land cover classes of the Africover databases of Uganda (Original Database Classes) into the 18 classes (LCC User Defined Label) defined for tsetse and trypanosomiasis intervention in Uganda.

The meaning of the abbreviations in columns 'Original Database Classes' and 'LCC User Defined Label' can be found in Annex 4 - LCCS user defined labels (abbreviation list) (p. 79).

LCCS Category	Name of the aggregated class (User Defined Description)	LCC User Defined Label	Original Database Classes	Names
A11	Forest plantations and tree plantations	T47PL	TBL47PL	Large Tree Plantations Rainfed
			TNEL47PL-pi,cu	Forest Plantation - Pinus spp., Cupressus spp.
			T147PL	Forest Plantation, Clustered
			TBR147PL	Clustered Small Tree Plantations Rainfed
			TBR247PL	Isolated Small Tree Plantations Rainfed
	Rainfed shrub crop	S47V	SD47V	Rainfed Shrub Crop, Large to Medium Fields
			SD47V-c	Rainfed Shrub Crop, Large to Medium Fields - Coffee
			SD47V-t	Rainfed Shrub Crop, Large to Medium Fields - Tea
			SR47V	Rainfed Shrub Crop, Small Fields
			SR47V-b	Rainfed Shrub Crop, Small Fields - Banana
			SR13H47V	n.a.
			SR23H47V	n.a.
			SR147V	Rainfed Shrub Crop, Clustered Small Fields
			SR247V	Rainfed Shrub Crop, Isolated Small Fields
			SR247V-b	Isolated Small Shrub Fields Rainfed - Banana
	Herbaceous crops	H	HR13HQ47-x	Clustered Small Herbaceous Fields With One Additional Crop and Sparse Tree Crops Rainfed
			HR3HQ47-x	Small Herbaceous Fields With One Additional Crop and Sparse Tree Crops - Rainfed
			HD4	Large to Medium Herbaceous Fields Rainfed
			HD14	Clustered Large to Medium Herbaceous Fields Rainfed
			HD-s	Sugar cane Large to Medium Fields
			HR23HQ47-x	Isolated Small Herbaceous Fields With One Additional Crop and Sparse Tree Crops Rainfed

(cont.)

LCCS Category	Name of the aggregated class (User Defined Description)	LCC User Defined Label	Original Database Classes	Names
			HRY	Small Herbaceous Fields - Post Flooding / Waterlogged
			HL57	Irrigated Herbaceous Crop, Large Fields
			HR1Y	Clustered Small Herbaceous Fields - Post Flooding / Waterlogged
			HR2Y	Isolated Small Herbaceous Fields - Post Flooding / Waterlogged
			HR13S47	n.a.
			HR147	n.a.
			HR23S47	n.a.
			HR24	n.a.
	Vegetated urban areas	5UV	5UV	Urban Areas Vegetated
A12	Forest	2TC	2TCI177	Closed multilayered trees (broadleaved evergreen)
			2TC8	Closed trees with open shrubs
			2TC-B	Closed Trees - Bamboo
	Woodland	2TP	2TV-B	Very open trees - Bamboo
			2TOI178	Open high trees with sparse trees and sparse shrubs
			2TO8	Open trees with open shrubs
			2TPM18	Open general medium trees with open shrubs
			2TPM86	n.a.
			2TV268	Very open trees (broadleaved deciduous) with herbaceous and shrubs
			2TV8	Very open trees with closed to open shrubs
	Woody Vegetation	2W	2WP236	n.a.
			2WP26	n.a.
			2WP67	Open general woody with closed to open herbaceous and sparse trees
			2WP6	Open general woody with closed to open herbaceous
			2WC7	Closed woody with sparse trees
	Thicket	2SCJ	2SCJ	Closed shrubs
			2SCJ7	Closed shrubs with sparse trees
	Shrubland with herbaceous	2SP6	2SVJ6	n.a.
			2SV6	Very open shrubs with closed to open herbaceous
			2SVJ67	Very open shrubs with closed to open herbaceous and sparse trees
			2SOJ67	Open shrubs with closed to open herbaceous and sparse trees

(cont.)

LCCS Category	Name of the aggregated class (User Defined Description)	LCC User Defined Label	Original Database Classes	Names
			2SP6	Open general shrubs with closed to open herbaceous
			2SPJ67	Open general shrubs with closed to open herbaceous and sparse trees
	Grassland	2G(CP)	2G(CP)	Closed to very open grassland
	Savannah	2G(CP)78	2G(CP)78	Closed to very open grassland with sparse trees and sparse shrubs
A23	Rice Fields	GZ-r	GDZ-r	Large to Medium Fields Rice
			GRZ-r	Small Fields Rice
A24	Herbaceous vegetation on flooded land - fresh water	4H(CP)	4H(CP)F8	Closed to very open herbaceous with sparse shrubs on temporarily flooded land - fresh water
			4GCFF7	Closed grassland with sparse trees on permanently flooded land - fresh water
			4H(CP)FF	Closed to Open Herbaceous On Permanently Flooded Land
			4F(CP)FF	Closed to Open Forbs On Permanently Flooded Land - Fresh Water
	Shrubs on flooded land	4S(CP)	4SPF6	Open general shrubs with closed to open herbaceous on temporarily flooded land
			4SVJFF6	Very open shrubs with closed to open herbaceous on permanently flooded land - fresh water
			4SCJFF7	Closed shrubs with sparse trees on permanently flooded land - fresh water
	Closed to Open Trees	4T(CP)	4TPF6	Open general trees with closed herbaceous on temporarily flooded land - fresh water
			4TCF8	Closed trees with closed to open shrubs on temporarily flooded land - fresh water
			4TVF8	Very open trees with closed to open shrubs on temporarily flooded land - fresh water
			4TCFF	Closed trees on permanently flooded land - fresh water
B15	Urban and associated areas	5	5U	Urban areas
			5A	Airport
B16	Bare areas	6S	6S	Bare soil
B28	Natural waterbodies	8WP	8WP	Natural lakes
			8WFN1	n.a.
			8WFP	River

n.a.= not available

Annex 8
Crop statistics in Uganda

The table below shows the harvested areas for major crops in Uganda. The data source for this table is the FAOSTAT web site (FAO, 2005). The national figures for crop harvested area provide more detailed information than Africover land cover on the species cultivated in the country. This type of information allowed a more accurate estimation of tsetse suitability for cultivated areas in Uganda.

	"Life form" for LCCS	Species	Harvested area *(ha)*	Proportion of country area *(%)*	Proportion of crop area *(%)*
	S	Plantains	1 670 000	6.930	24.496
	H	Beans Dry	812 000	3.370	11.911
	H	Maize	750 000	3.112	11.001
	H	Sweet Potatoes	602 000	2.498	8.830
	H	Millet	412 000	1.710	6.043
	H	Cassava	407 000	1.689	5.970
	H	Sorghum	285 000	1.183	4.180
	S	Coffee Green	264 000	1.096	3.872
	S	Seed Cotton	250 000	1.037	3.667
	H	Groundnuts in Shell	221 000	0.917	3.242
	H	Sesame Seed	211 000	0.876	3.095
	H	Soybeans	144 000	0.598	2.112
	S	Bananas	135 000	0.560	1.980
	H	Sugar Cane	125 000	0.519	1.834
	H-a	Rice Paddy	93 000	0.386	1.364
	H	Pigeon Peas	84 000	0.349	1.232
	H	Potatoes	83 000	0.344	1.217
	H	Cow Peas Dry	64 000	0.266	0.939
	H	Vegetables Fresh nes	54 000	0.224	0.792
	H	Onions Dry	37 000	0.154	0.543
	H	Peas Dry	25 000	0.104	0.367
	S	Tea	20 000	0.083	0.293
	H	Tobacco Leaves	15 000	0.062	0.220
	S	Cocoa Beans	14 200	0.059	0.208
	H	Wheat	9 000	0.037	0.132
	T	Fruit Fresh nes	7 400	0.031	0.109
	H	Chick-Peas	6 300	0.026	0.092
	H	Sunflower Seed	5 000	0.021	0.073
	H	Pimento (all spices)	4 200	0.017	0.062
	H	Castor Beans	3 000	0.012	0.044
	H	Pepper	2 900	0.012	0.043
	H	Tomatoes	2 100	0.009	0.031

"Life form" for LCCS

H	Herbaceous crop
S	Shrub crop
T	Tree crop
H-a	Herbaceous crop – aquatic

Land cover maps are useful tools for supporting several stages of tsetse and trypanosomiasis (T&T) intervention: mapping vector habitats, planning baseline entomological surveys, monitoring the environmental impact of intervention strategies at landscape level and planning land use of reclaimed areas. In this paper the Land Cover Classification System (LCCS), developed by the Food and Agriculture Organization of the United Nations and the United Nations Environment Programme, is proposed as a tool for harmonizing land cover mapping activities carried out in the context of T&T research and control.

At a continental scale, the LCCS-compliant Global Land Cover of Africa of the year 2000 and the predicted areas of suitability for tsetse of the Programme Against African Trypanosomiasis Information System are matched in order to understand the broad patterns of the association between land cover and the three groups of tsetse flies (i.e. *fusca, palpalis* and *morsitans*) in sub-Saharan Africa.

At a regional and national scale, a standardized legend of land cover for T&T decision-making is proposed. From the FAO-Africover datasets, the standardized legend allowed the derivation of high resolution harmonized land cover maps for eight T&T affected countries: Burundi, Democratic Republic of the Congo, Kenya, Rwanda, Somalia, Sudan, United Republic of Tanzania and Uganda. A review of the literature also permitted estimation of land cover suitability for the three tsetse groups.

By means of one case study, namely Uganda, the relationship between land cover, LCCS-compliant datasets and tsetse habitat is described in detail.

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