

POTENTIAL NATURAL VEGETATION OF SOUTH- WESTERN KENYA FOR SELECTION OF INDIGENOUS TREE SPECIES

DESCRIPTION OF POTENTIAL NATURAL VEGETATION TYPES,
VEGETATION-SPECIFIC INDIGENOUS TREE SPECIES LISTS AND
METHODOLOGIES USED

SUMMARY

R Kindt, JPB Lillesø and P van Breugel

World Agroforestry Centre (ICRAF),
Nairobi, Kenya

2007

1. Introduction

Trapnell and his co-workers (Trapnell et al. 1966, 1969, 1976, 1986; Trapnell and Brunt 1987) produced four sheets of a vegetation map for south-western Kenya. We believe that the map may still be useful today despite the fact that the main fieldwork for the map was completed in the early 1960s, as we used the original map to derive a map of potential natural vegetation (Kindt et al. 2005). Potential natural vegetation can be defined as the vegetation structure that would become established if all successional sequences were completed under the present climatic and edaphic conditions, including those created by man (Mueller-Dombois and Ellenberg 1974). We see the principle value for the new vegetation map in providing a basis for selection of indigenous species by its conceptual linkage to the ecological definition of agroforestry in “mimicking natural ecosystems”, which we interpret here to the detail of establishing the similar tree species and thus similar vegetation types of those that were occurring under natural conditions. Since many agricultural systems are vast simplifications of natural ecosystems, a move in the direction of the species composition of the natural system will result in an increase of biodiversity. Increments in tree diversity may have beneficial effects on the functioning of the agro-ecosystem, and could also result in an increase of suitable habitat for associated native biota, although both effects are conditional on other factors than an increase of biodiversity *per se*.

Several authors have observed that there is a good correspondence between geographic patterns of vegetation and those of climate (e.g. Prentice et al. 1992, Box and Fujiwara 2005). Since vegetation types, climate and taxonomic composition all correspond to each other, it is possible to predict climate from information on taxonomic composition of plants (e.g. Jolly et al. 1998, Elenga et al. 2000). As a result of the correspondence between climate, vegetation and species, the vegetation map of Africa developed by Frank White turned out to provide boundaries of floristic regions (phytochoria) that showed continental patterns of plant endemism, although there was no *a priori* information on species distribution that was used to delineate the boundaries (White 1983, p. 41). Vegetation maps therefore often portray the distribution of species and of climates, although vegetation maps are not necessarily correct for all species (Olson et al. 2001).

Although Trapnell and his co-authors were aware of possible limitations of their approach as they acknowledged that vegetation is changing, they did see the purpose of their maps in being an ecological or species suitability map:

“The use of ecological zones for agricultural development planning rested on the concept that climax vegetation communities develop in response to local limitations of climate and soil. In the absence of detailed soil survey and a complete network of climatic stations, mapping climax vegetation is therefore an indirect means of establishing the limits of different eco-climatic zones, each suitable for a specific range of crops” (Trapnell and Brunt 1987, p. 1)

“Vegetation (...) is constantly changing under the several influences of fire, grazing, cultivation and timber extraction. This applies particularly to the climax forest areas (...). This fact, however, in no way invalidates the concept of using vegetation as an index of land potential” (Trapnell and Brunt 1987, p. 4)

Although we are confident that the new potential natural vegetation map and associated vegetation-specific species lists provide a powerful decision-support tool for extension workers that seek to diversify landscapes in western and central Kenya, we also want to make it clear to any user that we expect there to be several limitations to the use of the new potential natural vegetation maps. One of the limitations is that site conditions may have changed so much in some places that it is not possible to grow a particular species in a place at present, although the species was growing there before. This may have to do with changes in climatic conditions (the climate of Africa has undergone several cycles, see for example Olago [2001] or Nicholson [2001]), soil degradation or the disappearance of animals that are necessary to transfer pollen or seeds. Not all species are pioneer species and some require a closed canopy or rehabilitated soil ecosystem to be able to regenerate. That the present conditions do not favour the regeneration of a particular species does not mean that the species – and therefore the vegetation type – may never come back to a certain area. We recommend that closer attention is paid to the ecosystem restoration literature in finding out how vegetation can be brought closer to original types.

Another limitation is conceptual: the range where a species occurs may only in part overlap with the range where a certain vegetation type occurs. We tried to test for these assumptions, but given the limited data that were available on the distribution of indigenous species we were not able to statistically test this assumption at this point (see also Guisan et al. 2006). The fact that distribution data are not readily available was actually the reason that we turned to the vegetation maps – where details are provided on the spatial distribution – to provide some information on where we expect that species can grow. The assumption that the distribution of species and of vegetation types are linked is not that farfetched, however. Beentje (1994) for example provides the vegetation type as one of the descriptors for Kenyan species. Trapnell (1997) also provided typical species for some of the vegetation types. Ecosystems and communities (assemblages of species that grow together) are similar concepts and it does therefore make sense to provide species lists for vegetation types. Several of the general caveats about the use of biogeographic maps apply, however: that no single biogeographic framework is optimal for all taxa but is a compromise for as many taxa as possible, and that ecoregions contain some habitats that differ from the assigned biome (Olson et al. 2001). For example, the criterion of 50% of endemism used as a criterion for African phytochoria (White 1983) explicitly acknowledges that it is not possible to construct useful biogeographical maps that apply to 100% of species.

Although many species occur in several vegetation types, we warn against transferring seeds or other planting materials from one vegetation type to another. We warn against such transfers because many species have different populations that have evolved for particular situations (Kindt 2006). When you transfer seeds from a moist forest type to a dry forest type for the same species, it may not be guaranteed that the resulting trees may survive or grow well. In some situations, there may be no problems with such transfers. Without having tested such transfers, we simply do not know. Since we do not know the results of seed transfers, it is better to adhere to the safety principal. In as far as possible, we recommend expanding our knowledge about the results of transferring seeds between vegetation types. The description of the vegetation of Africa mentioned that it is difficult to distinguish between various forest parts due to the large environmental tolerance of species (White 1983). We expect that several species with large environmental tolerances may actually be composed of several populations (“provenances”) that each have different environmental tolerances. Mixing of these populations may result in outbreeding depression

(Young and Boyle 2000). Without prior knowledge on the performance of populations outside their native range (as provided by provenance trials) it is therefore best to adhere to the precautionary principle and not to transfer seeds to new locations.

The third limitation is closely related to the second one: by classifying vegetation in a number of distinctive types, some information on the natural variation in vegetation is lost. Not all boundaries between vegetation types are abrupt and in many situations do ecotones exist between the vegetation types. Some authors have interpreted ecotones as areas where the different species that constitute an ecological community (here: vegetation type) reach their ecological limits in individualistic ways (van der Maarel 2005). There may also not be abrupt boundaries in species suitability maps between the places where a particular species is able to grow and where it is not able to grow as more gradual changes in suitability may exist, which may further contribute to the formation of ecotones. For example, those that are investigating where a species should be conserved should also make a distinction between source and sink populations of the species, and only consider the areas of higher suitability where species are able to maintain viable populations (Guisan and Thuiller 2005). One should therefore not interpret the map as being completely homogeneous within vegetation types. One could for instance be cautious for places that are very close to a boundary – it may mean that species that are listed for the vegetation type could not grow under these marginal conditions. The fact that vegetation maps make abstraction of reality by providing actual boundaries has been recognised for a long time. For example, in describing their new global map of terrestrial ecosystems, WWF included a warning that “ecoregion boundaries rarely form abrupt edges, but are bound by ecotones and mosaic habitats” (Olson et al. 2001). Being limited in the number of classes that can be portrayed is actually an inherent feature of a map (Farina [2000] mentions that homogeneity or heterogeneity are two different ways of seeing the same environment) – and being a meaningful summary of reality can also be a useful feature for a tool that has primarily been designed as a decision support tool for extension activities.

2. Description of the map of the natural vegetation types for western and central Kenya

The reclassification of the original vegetation types resulted in 17 potential natural vegetation types (Table 1; consult the methods section below to find out how the vegetation types were determined from maps of vegetation observed on aerial photographs and field surveys in the late 1950s and early 1960s) (note that in the rest of the document, ‘vegetation types’ will refer to these potential natural vegetation types). Although the authors of the original vegetation map did not provide a detailed description of the various types (and especially not a set of criteria that can be used to differentiate between the various types), it was possible to obtain some criteria from the literature to distinguish between the types.

The main classification scheme that is used is based on the physiognomy or structure of the vegetation, with categories of forest (characterised by touching or intermingling crowns often with lianas, height > 8 [10] m), woodland (cover > [40] 50 %, height > 8 m), bushland (cover > [40] 50%, height 3-7 m), thickets (as bushland, but impenetrable except along animal tracks), savanna or wooded grassland (cover 10 – [40] 50 %, height 6 – 12 m), grassland (cover < 10 %). Some differences in the threshold levels were a result from

differences in classification criteria (Trapnell and Langdale-Brown 1972, Greenway 1973, Lind and Morrison 1974, White 1983, Beentje 1994), where we used Trapnell and Langdale-Brown (1972) as the key reference (as the principal author was the same as for the original vegetation maps). Distinguishing the bamboo and other high mountain vegetation types as different vegetation types, rather than including them in the physiognomic classification scheme provided above, allows for a better discrimination for these distinctive vegetation types (White 1983).

Not only a physiognomic classification scheme is used, however, since floristic differences must explain differences among potential natural vegetation types of the same physiognomic category, such as between moist montane and dry intermediate forest types, or between the moist *Combretum-Terminalia*, dry *Combretum*, upland *Acacia* and *Acacia* on soils with impeded drainage savanna types. Some of these floristic differences are highlighted by the names of the vegetation types, and by differences in the species that are listed of the various types (section 3). Trapnell and his coworkers tried to relate the floristic differences of the vegetation types to climatic and soil characteristics by using descriptions of moist, dry, upland, lowland or impeded drainage for some of the vegetation types, although the climate map was derived from the vegetation map, and climatic or soil criteria were therefore not used to distinguish between vegetation types of the same physiognomic category. The fact that it was not possible for example to differentiate between moist montane and moist intermediate forest in the western part of the map as heavy cultivation prevented distinction between the two types provides clear evidence for the floristic differentiation (Trapnell and Brunt 1987). The names of various forest vegetation subtypes in the original map that refer to characteristic species or genera (such as *Albizia-Polyscias*, *Lovoa snynnertonii*, *Neoboutonia*, *Podocarpus milanjanus* or *Prunus-Cordia-Albizia* forest subclasses) serve as additional evidence for the use of a floristic rather than climatic classification scheme.

Although the vegetation was mapped on the basis of physiognomic and floristic criteria, there are some obvious differences in the biophysical conditions of the various vegetation types. For example, the vegetation types on soils with impeded drainage (*Papyrus* and swamp, open grassland areas on clay plains, and *Acacia* and allied vegetation on soils with impeded drainage) are vegetation types that only occur under certain soil conditions. As another example, upland *Acacia* woodland, savanna and bushland occurs on altitudes that are generally in between 1290 and 1850 m, whereas Lowland *Acacia-Commiphora* woodland, bushland and thicket generally occurs in between 734 and 1299 m (Table 1). Moist *Combretum-Terminalia* savanna has most of its rainfall in between 1084 – 1521 mm, whereas dry *Combretum* savanna has rainfall from 741 to 1004 mm (Table 1). The altitude and rainfall for the four forest vegetation types show a general correspondence to the name of the forest vegetation type, although there is a range of overlap between the typical conditions. For example, a forest area that has 1200 mm of rainfall and occurs at an altitude of 1950 m could belong to any of the four forest types (Table 1).

Table 1. Description of the 17 potential natural vegetation types available from the literature and by an analysis of spatial datasets

Potential natural vegetation type	Summary of description of vegetation types available from the literature on African vegetation	Biophysical limits obtained from GIS analysis ‡
1. Afro-alpine	Vegetation of the highest mountains of tropical Africa (3800 – 6000 m) that is characterised by giant senecios, giant lobelias, shrubby alchemillas and other plants of remarkable lifeform (White 1978).	Altitude: 4029, (3737) 3777 - 4292 (4341) Rainfall: 1587, (1354) 1476 - 1680 (1722)
2. Mountain scrubland and moorland	An Ericaceous belt of bushland, shrubland or thicket (0.5 – 8 m) dominated by species of <i>Philippia</i> and with species of <i>Erica</i> playing an important role in the lower parts (White 1978).	Altitude: 3306, (1817) 3029 - 3645 (4104) Rainfall: 1414, (710) 1209 - 1600 (1722)
3. Bamboo woodland and thicket	Dense thickets of bamboo with a height of 10 – 15 m and above sometimes mixed with some trees, between 2400 – 3000 m. Bamboo dies out in blocks and trees establish in the interval before regeneration (Trapnell and Langdale-Brown 1972).	Altitude: 2686, (2197) 2363 - 3099 (3471) Rainfall: 1226, (534) 1024 - 1408 (1621)
4. Moist montane forest	Wetter montane forest that is generally above 1800 m with rainfall of 1400 – 2000 mm (Trapnell and Langdale-Brown 1972).	Altitude: 2015, (1414) 1791 - 2289 (2757) Rainfall: 1334, (688) 1055 - 1608 (1801)
5. Dry montane forest	Drier montane forest that is generally above 1800 m with rainfall of (650) 750 – 1400 mm (Trapnell and Langdale-Brown 1972). Undifferentiated afro-montane forest replaces afro-montane rain forest at higher altitudes (and sometimes lower altitudes) on the wetter slopes and at comparable altitudes on the drier slopes of afro-montane forests. It usually but not always receives a lower rainfall (White 1983).	Altitude: 2325, (1636) 1987 - 2709 (3329) Rainfall: 982, (534) 711 - 1238 (1562)
6. Moist intermediate forest	Wetter intermediate forest is generally below 1800 m and receives a rainfall of 1000 – 1900 mm (Trapnell and Langdale-Brown 1972).	Altitude: 1580, (733) 1246 - 1952 (2161) Rainfall: 1419, (602) 1102 - 1639 (1864)
7. Dry intermediate forest	Drier intermediate forest is generally below 1800 m and receives a rainfall of 900 – 1000 mm (Trapnell and Langdale-Brown 1972). Only small fragments remain with some well-preserved examples near Nairobi (1650 – 1800 m, 800 mm) (White 1983)	Altitude: 1745, (1284) 1485 - 2005 (2249) Rainfall: 1190, (688) 902 - 1447 (1595)
8. Upland <i>Acacia</i> woodland, savanna and bushland	Higher-level <i>Acacia</i> savanna types are possible exceptions to <i>Acacia</i> types that occur on special soil and drainage conditions or to <i>Acacias</i> that are of secondary character. They have a grass layer of the <i>Themeda</i> order (Trapnell and Langdale-Brown 1972).	Altitude: 1575, (860) 1290 - 1850 (2117) Rainfall: 834, (502) 627 - 1025 (1316)
9. Broad-leaved savanna-evergreen bushland mixtures	No description is available from the literature, but the name suggests that it is a mixture of <i>Combretum</i> savanna and evergreen and semi-evergreen bushland.	Altitude: 1776, (1130) 1362 - 2017 (2252) Rainfall: 868, (562) 649 - 1059 (1257)
10. Lowland <i>Acacia-Commiphora</i> woodland, bushland and thicket	Somalia-Masai <i>Acacia-Commiphora</i> deciduous bushland and thicket is the climax vegetation over the greater part of the Somalia-Masai regional centre of endemism and is characterised by dense bushland (3-5 m) with scattered emergent trees (9 m). Locally it is impenetrable and forms thickets. Only a few species have well-defined trunks and most species are branched near the base (White 1983). Some woodland types occur in lower regions where <i>Acacia polyacantha</i> ssp. <i>campylantha</i> , <i>A. xanthophloea</i> and <i>A. tortilis</i> ssp. <i>spirocarpa</i> form closed stands (Trapnell and Langdale-Brown 1972). In higher rainfall areas, especially on rocky hills, the emergent trees occur closer together and are a little taller though scarcely ever more than 10 m (White 1983).	Altitude: 1066, (489) 734 - 1299 (1651) Rainfall: 754, (541) 600 - 869 (1223)

Potential natural vegetation type	Summary of description of vegetation types available from the literature on African vegetation	Biophysical limits obtained from GIS analysis ‡
11. Moist <i>Combretum-Terminalia</i> savanna	A small tree savanna with <i>Combretum</i> species and large-leaved species of <i>Terminalia</i> (Trapnell and Langdale-Brown 1972). Information that became available after the maps were published suggests that moist <i>Combretum-Terminalia</i> savanna is secondary to forest (east of Bungoma) or to semi-evergreen thicket (west of Bungoma) (Trapnell and Brunt 1987). Much of the rainforest has been destroyed by cultivation and fire and occurs in a mosaic with small (usually degraded) patches of the original forest. The grassland is often 2 m or taller and contains an admixture of fire-hardy trees (White 1983). Increase in effective rainfall favours this vegetation type to <i>Acacia-Themeda</i> savanna (= upland <i>Acacia</i>). Two genera of the Combretaceae family, <i>Combretum</i> and <i>Terminalia</i> , are common (Lind and Morrison 1974).	Altitude: 1526, (1128) 1280 - 1853 (2065) Rainfall: 1325, (1001) 1084 - 1521 (1696)
12. Dry <i>Combretum</i> savanna	A small tree savanna with <i>Combretum</i> species and smaller-leaved species of <i>Terminalia</i> that becomes woodland locally (Trapnell and Langdale-Brown 1972)	Altitude: 1306, (611) 1055 - 1674 (2120) Rainfall: 863, (544) 741 - 1004 (1243)
13. Evergreen and semi-evergreen bushland	Evergreen and mixed evergreen and deciduous vegetation that were once extensive in drier parts of the Kenya highlands and in some parts of the Lake Victoria basin (Trapnell and Langdale-Brown 1972). East African evergreen and semi-evergreen bushland and thickets occur on the drier slopes of mountains and upland areas. It often forms an ecotone between montane forest (<i>Juniperus</i>) and <i>Acacia-Commiphora</i> bushland and thicket (White 1983).	Altitude: 1876, (1176) 1698 - 2066 (2335) Rainfall: 822, (516) 587 - 1124 (1482)
14. Semi-evergreen thicket	The climax vegetation of large parts of the Lake Victoria regional mosaic. Today only small islands remain and most of the landscape is of lightly wooded <i>Acacia</i> grassland. The thickets are established because lianes that smother the crowns of <i>Acacia</i> trees suppress the regeneration of <i>Acacia</i> and the vigour of the grass layer (White 1983). (See also descriptions for the evergreen and semi-evergreen bushland above)	Altitude: 1250, (712) 1103 - 1455 (1981) Rainfall: 1134, (562) 788 - 1369 (1728)
15. <i>Papyrus</i> and swamp	Swamp vegetation of permanently wet or flooded areas that are dominated by <i>Cyperus papyrus</i> and other Cyperaceae (Trapnell and Langdale-Brown 1972).	Altitude: 1570, (955) 1140 - 2089 (2705) Rainfall: 1230, (532) 811 - 1561 (1801)
16. Open grassland areas on clay plains	Pure natural grassland areas exist in the absence of fire under confined conditions of impeded drainage, such as vleis, mbuga, dambo, flood plains and certain black clay plains (Trapnell and Langdale-Brown 1972).	Altitude: 1418, (978) 1151 - 1765 (1786) Rainfall: 1013, (619) 694 - 1122 (1262)
17. <i>Acacia</i> and allied vegetation on soils with impeded drainage	<i>Acacia</i> savanna on flood-plain, black clay, seasonally waterlogged and hardpan is vegetation that is associated with special soil and drainage conditions (Trapnell and Langdale-Brown 1972).	Altitude: 1670, (729) 1149 - 2354 (3580) Rainfall: 1086, (508) 740 - 1408 (1801)

‡ Altitude was measured in m and rainfall in mm. The statistics refer to the mean, (minimum observed value) 10% quantile value - 90% quantile value (maximum observed value). Quantiles are those values for which x% of values are smaller, for example the 10% quantile for altitude indicates the value of altitude for which 10% values were larger. For example, the 10% quantile of 811 mm for rainfall of *Papyrus* and swamp means that 10% of observations within this vegetation type had rainfall smaller or equal than 811 mm.

Even if the correspondence between the occurrence of a particular vegetation type and biophysical range may only partially be correct, the map can also be interpreted as a summary of environmental conditions. For example, the area that was mapped as ‘moist montane forest’ can simply be interpreted as an area where annual rainfall generally ranges from 1055 – 1608 mm, whereas areas that were mapped as ‘dry montane forest’ as areas where annual rainfall ranges from 711 – 1238 mm. In this sense, the map can be used as a summary map of environmental conditions, which relates to the original purpose of Trapnell and co-workers of developing an ecological map.

More comprehensive descriptions on the various vegetation types, including a listing and description of their subtypes and their correspondence with other vegetation mapping systems, are provided elsewhere (Kindt et al. 2007a and references therein).

Table 2. Number of indigenous tree species for 12 potential natural vegetation types

Potential natural vegetation type	Total number of species	Total number of endemic species‡	Total number of species with documented uses	Total number of endemic species with documented uses ‡
3. Bamboo woodland and thicket	22	2	13	1
4. Moist montane forest	99	35	54	7
5. Dry montane forest	91	15	60	2
6. Moist intermediate forest	105	30	72	13
7. Dry intermediate forest	74	20	55	9
8. Upland <i>Acacia</i> woodland, savanna and bushland	22	1	22	1
10. Lowland <i>Acacia-Commiphora</i> woodland, bushland and thicket	92	61	53	27
11. Moist <i>Combretum-Terminalia</i> savanna	44	18	36	13
12. Dry <i>Combretum</i> savanna	24	2	23	2
13. Evergreen and semi-evergreen bushland	44	9	33	3
14. Semi-evergreen thicket	29	8	22	3
17. <i>Acacia</i> and allied vegetation on soils with impeded drainage	28	5	25	3
All types	362	206	203	84

‡ Endemic species were defined here as those that uniquely occurred in one potential natural vegetation type

3. Species lists for the potential natural vegetation types

Species lists were compiled from literature information (including information from herbarium vouchers) for the various potential natural vegetation types. Of the total number of 362 species that were recorded, information was available on their uses for a subset of 203 species (Table 2; see methods for a description of how the species lists were obtained). Five vegetation types were not listed as they were not listed in the literature (broad-leaved savanna and evergreen bushland mixtures), or since no (*Papyrus* and swamp, open grassland areas on clay plains) or only specialised (afro-alpine vegetation, montane scrubland and moorland; these types also occur in protected mountain areas) woody species were listed for those types. The vegetation types with the smallest number of tabulated species were the bamboo and upland *Acacia* vegetation types (22 species), whereas the vegetation type with the highest number of species was the moist intermediate forest (105 species). The three other forest types were among the vegetation types with highest numbers of species (moist montane forest: 99 species, dry montane forest: 91 species, dry intermediate forest: 74 species). The non-forest vegetation type with highest number of species was the lowland *Acacia-Commiphora* woodland, bushland and thicket (92 species). Each vegetation type had some unique species, whereas a minimum of 13 species had documented uses for each type. Species lists for each vegetation type and the recorded uses of each species are available from the more extensive documentation for the maps (Kindt et al. 2007b) and from an Excel sheet (*SpeciesSelector.xls*).

4. Suggested method for selecting indigenous tree species for a particular area

We propose a two-step approach to select indigenous tree species. In the first step, determine the potential natural vegetation type from one of the printed or electronic versions of the four sheets of the map (Kindt et al. 2005). Although we tried to use distinctive colours for each of the 17 potential natural vegetation types, it may be a good idea to confirm the identified vegetation type from its small-scale distribution map (Appendix III in Kindt et al. 2007a). In the second step, you can select indigenous tree species from a special-purpose Excel sheet (*SpeciesSelector.xls*; check the guidelines for using the *AutoFilter* options) or from the vegetation-specific tables (provided in the Appendix to Kindt et al. 2007b). Always keep in mind that there are several limitations to this selection approach and try to consult other sources of information (including local informants) to verify the final shortlist of species.

5. Methods used to develop the natural potential vegetation map and species lists

5.1. Development of the natural potential vegetation map

Vegetation boundaries of the original maps were determined by aerial photographs (1:30,000 photographs for 1945 – 1950; 1:50,000 photographs for 1957 – 1963; some photographs for 1967 and 1969) and by field work (main field work from 1959 – 1961 and some further fieldwork in 1962, 1972, 1976 and 1980). The main field work was carried out by driving along all the tracks in less accessible areas and by following a dense network of traverses (one mile apart or less) in the other areas. During the main field work, vegetation was observed along the tracks (including field glass observations on either side), transferred to 1:50,000 field maps and subsequently to aerial photographs. The additional field work was used to revise the field maps and reinterpret the aerial photographs. The final maps were prepared at the scale of 1:250,000 by stereoscopic studies of the air photographs.

The attempt of the original maps was to plot vegetation boundaries as they were in 1960, including an interpretation of the potential natural vegetation. Trapnell and Brunt (1987) mention that identification of the potential vegetation type (they actually use the term ‘climax vegetation’) was possible for most of the secondary vegetation types on the basis of fragments that contain typical species for the potential vegetation type. These species include remnants of the climax species, understorey species that are associated with the climax species or pioneer species. Some of the residual and secondary species after selective felling of forests are provided by Trapnell (1997), together with provisional lists for each forest type that are partially based on field notes from the 1960s. A detailed list of indicator species for each vegetation type and an investigation of the accuracy of the correspondence between indicator species and vegetation type would have increased the value of the original and new maps.

It is unfortunate that the original vegetation maps and their documentation provide little information on the criteria that were used to distinguish between the different vegetation types. Although the boundaries between the vegetation types are provided on the map, no information was provided on the actual criteria that were used to distinguish between the types on aerial photographs and during fieldwork. The reclassification of the vegetation types of the map was therefore primarily based on information from the legend of the maps and on the information from climatic maps that were derived from the vegetation maps by Trapnell and co-workers.

The legend for the four original vegetation map sheets provides a hierarchical classification of vegetation types in 18 groups, 23 subgroups, 55 classes and 217 subclasses. Polygons were digitized for all the classes. Polygons could not be digitized for subclasses since the maps only provide labels and not a polygon for the area that is covered by the subclass. Areas with water or bare rock were classified as areas that are not under vegetation. The original vegetation types were reclassified into 17 natural potential vegetation types as several of the original types were secondary vegetation types. The name of the secondary vegetation type often enabled identification of the potential natural vegetation. For example, vegetation class 22 of the original map was named “upland *Acacia* (vegetation types) from evergreen and semi-deciduous bushland” and was reclassified under the “evergreen and semi-evergreen bushland” potential natural vegetation type. As another example, vegetation class 26 “clearings and cultivation communities from upper moist montane forest” was classified as

the “moist montane forest” potential natural vegetation type. The other primary source of information that allowed reclassifying secondary vegetation types was provided by the climatic maps that accompanied each vegetation sheet, since these climatic maps reflect the potential natural vegetation, except for potential natural vegetation types that occurred under special soil conditions (*Papyrus* and swamp; open grassland areas on clay plains; and *Acacia* and allied vegetation on soils with impeded drainage). For the western part of the map, where no distinction is made between moist montane and moist intermediate forest (climate type Western Moist forests, for which Trapnell and Brunt [1987] mention that heavy cultivation prevented distinction between both types), we studied the distribution of other vegetation types. In case of doubt, we used the boundary of 1830 m (6000 feet) to distinguish between these two types.

Since the original vegetation maps did not provide criteria for the vegetation types, we used two methods of finding criteria that could help to distinguish between the different potential natural vegetation types that we distinguished: (i) literature information from other sources; and (ii) spatial datasets to describe the range of environmental values for each type.

For the literature information, we only consulted some common references that provided a description of vegetation types for East Africa or Africa. We did not consult literature that describes the vegetation type for a particular area of Kenya, such as a particular forest or national park. We expect that our approach will have resulted in a more general description of the various vegetation types that were encountered, and not on exceptional features of vegetation of areas of limited extend. Of the various literature references used, we expect that the vegetation types of the map correspond best with the descriptions of Trapnell and Langdale-Brown (1972), since the original maps and this reference share the same principal author.

The spatial datasets that were utilised were common GIS datasets that were available, such as the ACT 1995 and SOTER databases, including information on annual precipitation (5 km² resolution), mean minimum temperature of the coldest month (5 km² resolution), altitude (92 m² resolution), or rootable depth (derived from 1:1,000,000 map with frequencies and characteristics of soil types). Details of the results of more sophisticated analyses of the relationship between environmental characteristics and the distribution of vegetation types involving statistical methods such as linear discriminant analysis or environmental niche factor analysis are reported elsewhere; in general, these confirm that vegetation boundaries delineate areas with different environmental characteristics, although the correspondence is different between the various vegetation types, no vegetation type is predicted correctly everywhere and the analysis suffered from the lower resolution of the environmental datasets (van Breugel 2006, Kindt et al. 2007a). The correspondence of the new map with other vegetation maps (such as the vegetation of Africa by White [1983] or the terrestrial ecoregions map developed by WWF [Olson et al. 2001]) are also provided elsewhere (Kindt et al. 2007a).

5.2. Compilation of the species lists

As information on occurrences was limited for most species, whereas modelling of the distribution of a species requires considerable occurrence data (Guisan et al. 2006, Kindt et al. 2007b), we used four types of inferences about the species for a certain vegetation type: (i) information from the legend of the map; (ii) information from Trapnell (1997) on typical species for forest and bamboo vegetation types; (iii) information from other sources of literature on vegetation types; and (iv) information from herbarium vouchers available from the East Africa Herbarium (based at the National Museums of Kenya). Because we expect a progressively worse correspondence of these four types of information with the vegetation types of the map, we distinguished 5 levels of correspondence between a vegetation type and a species. In the table, we only provide the highest correspondence rank.

The highest correspondence (rank 1) is for species that were listed as part of names of vegetation types of the original map. Although there may be floristic or ecological reasons that a species may not be able grow everywhere within the potential vegetation types (since the potential vegetation types often cluster vegetation classes and subclasses of the original map that do not occur everywhere in the map), we think that this information provides the best correspondence between the mapped vegetation and a species, as both species and vegetation distribution were available from the same source of information.

Correspondence rank 2 is for those species that were listed by Trapnell (1997) for the different forest and bamboo vegetation types, referring to the original fieldwork for the vegetation map as source of information of the species lists.

Correspondence rank 3 is for species that were listed by other sources of literature than the legend of the map or the species lists of Trapnell (1997), since there was only a partial overlap between the vegetation classification scheme of the map and the classification schemes of the references. We ignored species inventories for particular places (such as particular forests or national parks) in the literature references to obtain a more widely applicable species list for the vegetation types.

Correspondence rank 4 and 5 are for species for which herbarium positions were obtained from the East Africa Herbarium based at the National Museums of Kenya. We attribute lower correspondence since information on herbarium positions were only obtained from a limited number of species (positions were retrieved for 114 of the 125 species that were listed both in the Agroforestree database [Simons et al. 2005] and useful trees of Kenya books [ICRAF 1992, Maundu and Tengnas 2005]), which may not necessarily be typical species for the listed vegetation types. The lower correspondence was also expected as the number of positions was small for the majority of species, especially if only vouchers with original coordinates were considered and not those of the *gazetteer*, i.e. the coordinates of the position name listed on the herbarium voucher (only two species had more than 20 positions with original coordinates), or if only vouchers were considered that had some meaningful description of the vegetation type in the habitat description. Species with correspondence rank 4 were those where the position (including gazetteer position) of the herbarium voucher (investigated by an analysis in ArcView GIS) and habitat description of the voucher indicated a particular vegetation type. The lowest correspondence rank (rank 5) was for species that were not listed with rank 4, but for which there was some information in Beentje (1994), inventory lists by Lind and Morrison (which were not used for rank 3 for reasons explained above) or in the habitat description of the herbarium on the vegetation type.

A subset of species is presented in this paper for those species for which information on uses was available in the Agroforestree database (Simons et al. 2005) or useful trees of Kenya books (ICRAF 1992, Maundu and Tengnas 2005). The comprehensive species lists, with details from the various literature references and an analysis of how the various sources confirm each other are provided elsewhere (Kindt et al. 2007b).

6. Acknowledgments

We are very grateful to the Flemish Association for Development Cooperation and Technical Assistance (VVOB) that provided funding for the development of the potential natural vegetation map and vegetation-specific species lists through the Testing Options and Training Partners in Participatory Tree Domestication and Marketing in East Africa (TOTDOMEA) project, and the Danish International Development Assistance (DANIDA) through its support to the Improved Seed Systems for Agroforestry in African Countries (ISSAAC) project at ICRAF (Kenya) and Forest and Landscape (Denmark). We thank all that provided support to the development of the map, especially Tony Simons (head of the Trees and Markets thematic program at the World Agroforestry Centre [ICRAF]) and Siro Masinde (head of East Africa Herbarium at the National Museums of Kenya).

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