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Ecology of Edible Indigenous Mushrooms of the Lake Victoria Basin (Uganda)

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Abstract: The present study was conducted between (October, 2004) and (June, 2005) in two parishes of Kyebe Sub County in Rakai District located in the Lake Victoria Basin, Southwest of Uganda and west of Lake Victoria. The objective of the study was to assess the relationship between mushroom species occurrence, environmental factors and different vegetation types. Ten 1000 m^2 plots were established in each of three vegetation types (grassland, forest and garden) from where mushroom species and trees were assessed. Physical and chemical soil properties as well as canopy were determined in the sample plots. A total of 4.077 individual mushrooms belonging to 5 genera and 10 species were recorded in the plots. Three individuals that could not be identified were assigned to morpho species. Mushroom diversity and evenness were highest in the grassland while dominance was highest in the forest. *Pluteus* sp was found occurring only in the grassland, *Agaricus* sp 2 and K/K/04/N1 were found in the garden while three species (*Termitomyces* sp 1, *Podabrella microcarpa* and *Agaricus* sp 1) were found in all vegetation types. *Termitomyces* sp 1 and *Pluteus* sp were significantly correlated with some of the measured environmental factors. Indigenous edible mushrooms are an important aspect of ecology. The integrity of the grasslands should be protected to promote mushroom conservation. Field studies on mushroom species in this area in the future should target the rain season between September and December.

Key words: Mushroom ecology, mushroom diversity, mushroom distribution

INTRODUCTION

Mushrooms are fleshy conspicuous macrofungi that have provided food for millennia and are in many societies associated with potentates and royalty because of their pleasant taste and flavour (Iga, 1978; Chang and Miles, 1989; Chang and Mshingeni, 2001; Sadler, 2003; DaSilva, 2005). Many societies have passed down knowledge on mushrooms from one generation to another. In China this knowledge has been the focus of research and constitutes what today is known as traditional Chinese medicine (Sadler, 2003; DaSilva, 2005).

The ecology of plants and animals is crucial in utilisation of resources. The ecology of fungi has not been extensively studied compared to their vascular plant counterparts though some studies have been carried out such as Bergemann and Largent (2000) as well as Bergius and Danell (2000). In Europe there is evidence showing that fungi are disappearing at distressing levels (Jerome, 1992; Eef, 1995). This has prompted increased research efforts and development of conservation action plans for selected fungi (Newton *et al*., 2003). Among the fungi, scientific research has mainly focused on mycorrhizae (Bergemann and Largent, 2000; Dahlberg, 2001; Kernaghan *et al*., 2003). There have been a few studies on community ecology (Packham *et al*., 2002) and relationships with environmental variables (Zamora and Cecilia, 1995) of macrofungi. Studies have also been done on polypores at a community level (Urcelay and Robledo, 2004).

Since many biologists (Stamets, 2000) view mushrooms as indicator species, the first to fall leading to the failure of forest life support systems, data on their diversity in different vegetation types is important for planning and managing ecosystem biodiversity. In Uganda biodiversity has been documented for many

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localities including the Sango bay and Albertine rift (Pomeroy, 1993; Fuller *et al*., 1995; Bakamwesiga, 1998; Eilu *et al*., 2003; 2004 a and 2004 b). In the Sango bay for example, species lists do not include the fungi but cover flowering plants, insects, fish, amphibians, reptiles, birds and mammals (Fuller *et al*., 1995). Information on species richness and diversity of mushrooms is limited or is lacking in Uganda. Several questions are unanswered: for example, are the mushrooms occurring in specific vegetation types? Are the mushrooms influenced by environmental factors such as canopy cover and soil properties? Such information is required to design conservation strategies for indigenous mushroom species.

MATERIALS AND METHODS

Description of study area: The study was conducted in Rakai district (Fig. 1) in the southwestern region of Uganda, west of Lake Victoria between 31° 28[1] to 32° 43[1]E and 0° 47[1] to 1° 00[1]S. It is bordered by Masaka district in the north and northeast, Kalangala district in the southeast, Mbarara district in the west and northwest, and the Republic of Tanzania in the south. The area is about 4,989 km² out of which, 1,089 Km² consists of water bodies (NEMA, 1998). This study was carried out in Kakuuto County, Kyebe Sub County (Fig.2).

Climate: Kyebe sub-county lies in a modified equatorial climatic zone with high temperatures and heavy rainfall almost all year round. A relatively dry season occurs in January and February and another in June, July and August. A principal rainfall peak occurs in March, April and May, with the minor peak occurring in October and November. The mean annual recordings for maximum temperatures and rainfall are 25°C and a variation of 1.350 to 2.125 mm, respectively with a mean annual minimum temperature of 17.5° C (NEMA, 1998).

Geology and soils: Over 75 % of the soils are ferralitic with little or no mineral reserves left. Some heavy clay varieties have moderate fertility but sandy varieties are poor. Other types include lithosols, alluvial and lacustrine sands, and alluvial clays. Lithosols and loams are the dominant upland components while the gray sandy soils (derived from hill wash or river alluvium), gray clays of the valley bottoms and lacustrine sands dominate the lowland components. The soils are classified into four soil catenas and four soil series. The Sango series covers the whole of Kyebe (NEMA, 1998).

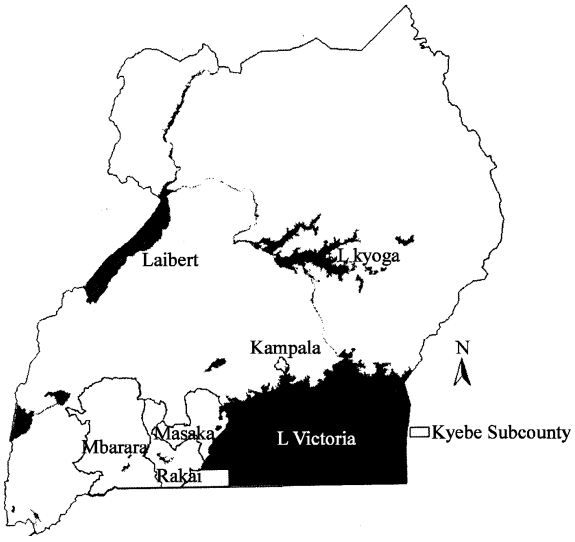

Fig. 1: The location of Rakai district in Uganda showing the demarcation of Kyebe sub county within the district, the districts bordering it and Kampala. (Source: Makerere University Institute of Environment and Natural Resources-MUIENR)

Flora: The vegetation of Rakai district varies from the medium altitude forests on the shores of Lake Victoria, through swamps, to savanna grasslands. The forests are mainly found in the Sango Bay area in the southern part of the district at the mouth of the Kagera river floodplain. They occupy part of the Kagera river floodplain, and are surrounded by swamp and seasonally flooded grassland communities. The canopy is generally lower than that of medium altitude mixed evergreen forests, although many of the component species are the same. Two tree species (*Cordia millenii* Bak. and *Irvingia gabonensis* (Aubry-Lecomte O'Rorke) Baill.), in these forests are listed on the International Union For Conservation of Nature (IUCN) Red lists as endangered (NEMA, 1998).

Study sites: Ecological studies were carried out in Kanabulemu parish of Kyebe sub county because it was more representative of the vegetation characteristics the study intended to incorporate. Ten plots of 50×20 m (0.1 ha) were established in grasslands and gardens while in the forest ten 5×200 m (0.1 ha) strip plots were used in order to facilitate the search for mushrooms. In total each of the vegetation types had an area of 1-ha. Wetlands were not sampled because edible mushrooms are not known to grow in such habitats (Hobbs, 1995).

The grasslands are dotted with many termite mounds and *Phoenix reclinata* Jacq. palms. The most common grass is *Loudetia kagerensis* although *Themeda* sp. and

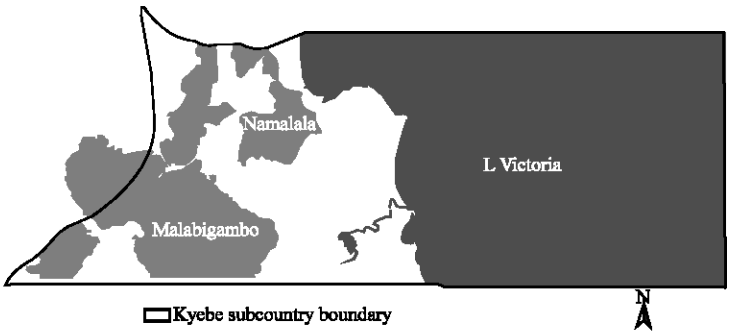

Fig. 2: A map of Kyebe Sub County showing its forest reserves. Plots for sampling edible mushrooms were established in Malabigambo and Namalala forest reserves (Source Muienr)

Cymbopogon sp. also occur. The gardens are tilled using traditional agricultural techniques and family labour in smallholder farms. The most common crops are *Phaseolus vulgaris*, *Musa* sp., *Ipomoea batatus*, *Zea mays* and *Mannihot esculentum*. The forests have been encroached upon and degraded for timber especially, resulting in many forest gaps. Encroachment for agriculture is mainly around the forest edges. Trails also exist within the forests leading to sites where swamp forest fishery is done. Twenty five percent of the canopy cover is formed by *Baktaea* sp. (NEMA, 1998; Rodgers *et al*., 2002).

Ecological studies

Assessment of edible mushrooms: Mushrooms were assessed for 2 weeks a month for a period of eight months. Edible fruit bodies were identified by the local people in the field using local names, collected (as in Härkönen *et al*., 1995) and counted by species. The total number of mushrooms in each plot were used for calculating alpha diversity. Gregarious mushrooms were counted in plots of $1m^2$ and extrapolated to obtain values for the 0.1ha plot. Growth habits of mushrooms were recorded as solitary (all by themselves), scattered (grouped, 30 cm to 60 cm apart), gregarious (growing close together in groups not clusters), or cespitose (growing in aggregated tufts, but tufts not growing together). Smith and Weber (1980) and Menser (1996).

Taxonomic identification was done in the Department of Botany Makerere University. Morphological characteristics (Härkönen *et al*., 1995) and spore print (using a white and black background cardboard. Fischer and Brown (1992) was determined for each mushroom species to aid identification. Mushrooms that could not be identified were assigned to morphor species.

Trees: Trees with diameter at breast height (DBH or 1.3 m high) greater than 10 cm (Tuxill and Nabhan, 2001) were enumerated. Diameter was determined using a diameter tape. Specimens were collected and identified in the Botany Department Herbarium at Makerere University.

Environmental factors: The canopy cover in the plots was estimated by eye as described by Kent and Coker (1996) and categorised as: open (0-25%), slightly open (26-50%), slightly closed (51-75%) and closed (76-100%). One kilogram soil samples were collected at a depth of between 0 and 20 cm from each vegetation type in duplicates and analysed for pH, organic matter, exchangeable cations (sodium (Na), potassium (K), Calcium (Ca), Magnesium (Mg)), and texture. Soil analyses were done in the Faculty of Agriculture Soil Science Department of Makerere University using methods similar to Bergemann and Largent (2000). Total nitrogen and phosphorus were determined using the Kjeldhal method. The reaction involved total oxidation of organic matter after addition of H_2SO_4 acid to allow digestion. This was followed by distillation and titration (Okalebo *et al*., 1993). Exchangeable bases were extracted using NH_4OAC at neutral pH and exchangeable extracts determined using flame photometry (Na and K) and atomic absorption (Ca and Mg). Organic matter was estimated from organic carbon, which was determined, by a mixture of H_2SO_4 acid and $K_2cr_2O_{7\ (aq)}$. After heating, residual Cr_2O_7 was titrated against $Fe(NH_4)_2SO_4$ and the difference between the added and the residual $K_2cr_2O_7$ gave the amount of organic carbon (Okalebo *et al*., 1993). Consequent multiplication of the organic carbon with a calculated constant gave the organic matter content. The Bouyoucos/Hydrometer method was used for analysing texture (Okalebo *et al*., 1993) of air-dried soil samples based on the proportion of different particle sizes. pH was measured using a pH meter in which the soil was mixed with deionised water in the ratio of 2.5:1 (Okalebo *et al*., 1993).

Data analysis

Diversity and ecology of mushrooms: The Fisher's alpha, Simpson's and Shannon's (H^1) diversity indices (Ludwig and Reynolds, 1988; Magurran, 1988) and Evenness or Equitability (E), were calculated to determine mushroom species evenness and diversity in the different vegetation types. Total species richness was also estimated using

Table 1: Mushroom species richness and diversity in three 1-ha plots of three vegetation types in Kyebe sub-county

Vegetation	Density	Species	Jack 1	Chao 1	H^1	Fisher'	E	Ds
Grassland	1441*	8*	12*	10*	1.674*	1.095	0.726*	3.951*
Garden	1387	8*	10	8	1.540	1.106*	0.669	3.871
Forest	1249	4	5	4	0.179	0.533	0.077	1.072*

Indicates the highest value; Jack 1 and Chao 1 are estimators of total species richness; H^1, Fisher's alpha, and Ds are Shannon's, Fisher's alpha and Simpson's diversity indices; E represents pielou's evenness

Table 2: Abundance and distribution of mushroom species occurrence, growth habits and substrates in the different vegetation types

Species	Grassland	Garden	Forest	Species density	Growth habit	Substrate
Agaricus sp1	+	+	+	31	Solitary/Scattered	Soil
Agaricus sp2	-	+	-	35	Solitary/Scattered in lines	Soil
K/K/04/E1	+	+	-	33	Scattered	Soil
K/K/04/N1	-	+	-	3*	Solitary/Scattered	Soil/Decomposing wood
K/K/04/N2	+	+	-	174	Gregarious	Soil
Pluteus sp	+	-	-	17	Solitary/Scattered	Soil
Podabrella microcarpa	+	+	+	622*	Gregarious	Soil
Termitomyces sp1	+	+	+	103	Solitary/Scattered	Soil, decomposing wood
Termitomyces sp 2	+	+	-	323	Cespitose	Soil
Volvariella speciosa	+	-	+	17	Solitary/Cespitose	Soil, decomposing wood

(+) Indicates presence; (-) indicates absence; (*) indicates the highest and lowest density

the Jackknife estimate 1 and Chao 1 estimate. These calculations were done using the computer program Species Richness and Diversity (SDR) version 3.02 (Henderson and Seaby, 2002). The first order jackknife estimator of species richness, Jack 1 was calculated based on 0.1-hectare (0.1-ha) subunits of the 1-ha vegetation types.

Ordination: Detrended Correspondence Analysis (DCA) was carried out using the computer program CANOCO version 4.0 (Ter Braak and Šmilauer, 1998) to determine species distribution in the sample plot (Jongman *et al*., 1987), and infer indirectly about how the species data can best be explained (based on 0.1-ha subunits of the 1-ha vegetation categories). Detrending was done by segments and the mushroom abundance data were log transformed after adding a constant of one to all the values because the logarithm of zero is undefined (Jongman *et al*., 1987). Species' points were taken as the optimum of its unimodal response using Hill's scaling. There were 25 active samples (5 samples had zero abundance and were eliminated) and 10 species.

Correlation analysis using the SPSS computer program version 8.0 ($p<0.05$) was used to determine correlation between mushroom species and tree species abundance in the plots. While Partial correlation was used to assess the correlation between measured environmental factors and the abundance of mushroom species.

RESULTS

Ecology of indigenous mushroom species

Species richness and diversity: A total of 4077 individual mushrooms were recorded comprising 10 species in six genera. The genera *Termitomyces* and *Agaricus* were represented by two species. The species *Podabrella microcarpa* had the highest density and K/K/04/N1 the lowest. The highest density of mushroom species was recorded in the grasslands (Table 1). The number of species ranged between 4 and 8/ha in the three vegetation types (Forest, Grassland and Garden).

There was a general reduction in species richness and diversity from the first to the second rain season. The density of mushrooms recorded in the first rains was 3.568 and 509 for the second. The total number of species, Jackknife richness estimate and Shannon diversity index for the first and second rain seasons were 10, 13, 1.53 and 3, 5, 0.416 respectively. *Podabrella microcarpa* was most abundant during both the first and second rain seasons while K/K/04/N1 and *Pluteus* sp were least abundant during the two rain seasons, respectively.

The highest density, Jackknife and Chao estimates, Shannon's and Simpson's diversity indices, and evenness of mushroom species occurred in the grassland (Table 1). The garden had the highest Fisher's alpha and the forest had the lowest values for all the species diversity and richness measures.

Three species (*Termitomyces* sp.1, *Podabrella microcarpa* and *Agaricus* sp1) occurred in all the vegetation types while another three (*Agaricus* sp2, K/K/04/N1 and *Pluteus* sp.) occurred in only one vegetation type (Table 2).

Factors influencing mushroom species distribution: DCA - biplot of species and sites (Fig. 3) show a distinct separation of sites between the different vegetation characteristics along the first axis (eigenvalue of 0.617 and length of 4.332 SD). Grassland plots occur at the left, garden plots at the center and forest plots at the right of the ordination diagram. The first four DCA axes explained 39% of the cumulative variance in the species data (Table 3). The third and fourth axes with eigenvalues less than 0.1 were less important in ecological terms and not considered further.

Table 3: Eigenvalues of the first four axes of Detrended Correspondence Analysis (DCA) of all plots and the amount of variance explained of the species data by the DCA axes

Axes	1	2	3	4	Total inertia
Eigenvalues (DCA)	0.617	0.276	0.1	0.064	2.709
Lengths of gradient (DCA)	4.332	2.627	1.943	1.972	-
Cumulative percentage variance of species data (DCA)	22.8	33	36.7	39	-
Sum of all unconstrained eigenvalues (DCA)	-	-	-	-	2.709

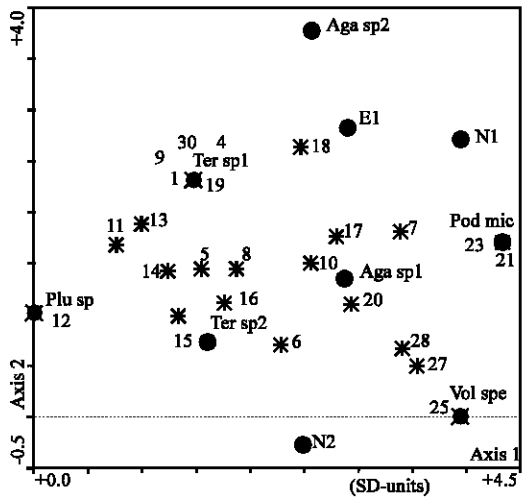

Fig. 3: DCA ordination diagram of mushroom species data with species shown as black circles and plots represented by stars and labeled by their number

Plu sp-*Pluteus* sp; Ter sp1-*Termitomyces* sp1; Ter sp2-*Termitomyces* sp2; Aga sp2-*Agaricus* sp2; E1-K/K/04/E1; Aga sp1-*Agaricus* sp1; N1-K/K/04/N1; Pod mic-*Podabrella microcarpa*; Vol spe-*Volvariella speciosa*; N2-K/K/04/N2.

Pluteus sp occurs at the left of the DCA ordination diagram while K/K/04/N1, *Podabrella microcarpa* and *Volvariella speciosa* occur on the right. From the ordination diagram rank orders for different species can be predicted as follows; The rank order for *Termitomyces* sp.1 is plots 1, 19, 9, 30 and 4. *Termitomyces* sp2 is plots 15, 16 and 6. *Agaricus* sp 1 is plots 20, 10 and 17. *Podabrella microcarpa* is plots 26, 23 and 21. *Volvariella speciosa* is plots 25, 27 and 28. It can be predicted that plot 12 and plots 20, 23 and 25 hardly have any species in common while sites closer to each other such as plots 23, 26 and 21 have one or more species in common.

The soils were generally acidic soil (pH ranging from 3.8 to 4.5 in the garden and grassland, respectively). Calcium (6.12 cmol kg^{-1}) and Magnesium (2.6 cmol kg^{-1}) were highest in the forest while Sodium (0.08 cmol kg^{-1}) and Organic Matter (5.67%) were highest in the grassland. Available Phosphorus (28.43 mg kg^{-1}) and Potassium (0.56 cmol kg^{-1}) were highest in the garden. The soils in this study can be classified according to the United States Department of Agriculture as Sandy clay loam soil in the garden, Sandy loam in the grassland and Clay loam in the forest.

Termitomyces sp.1 was significantly correlated with pH (-0.4623), phosphorus (0.4943), canopy cover (-0.4117) while *Pluteus* sp. was significantly correlated with organic matter (0.4807), potassium (-0.4073), sodium (0.4895), sand (-0.025), magnesium (-0.4005) and clay (-0.4855). The rest of the other mushroom species did not show any significant relationship with the measured environmental variables.

Six hundred and seventy-five individual trees were sampled in the plots (10 in the garden, 11 in the grassland and 654 in the forest). They belonged to 28 families, 43 genera and 46 species. Euphorbiaceae and *Syszygium guineense* (Wild.) DC. were the most common family and species respectively. The grassland was represented by three species, the garden six species and the forest 40 species. *Phoenix reclinata* Jacq, (Palmae) occurred most in the grassland while *Beilschmedia ugandensis* Rendle, (Lauraceae) *S. guineense*, (Myrtaceae) and *Spondianthus preusii* Engl. (Euphorbiaceae) were the most frequent in the forest.

Five forest trees were found in all the plots with mushrooms. These were *B. ugandensis*; *Spondianthus preusii*; *Syszygium guineense*, *Whitfieldia elongata* (Beauv.) De willd, α Th. Dur (Acanthaceae) and *Pseudospondias microcarpa* (A. Rich.) Engl. (Anacardiaceae).

Shannon's, Simpson's and Fisher's alpha diversities, Jackknife species richness estimate and Evenness for tree species were calculated and compared with the alpha diversities of mushroom species in the plots. The species diversity and evenness was higher for the tree species compared to the mushroom species. The respective indices for the tree and mushroom species were H^1 (2.884 and 1.552); D_s (10.92 and 3.444); α (11.18 and 1.28); Jack 1 (60 and 12) and Evenness (0.7532 and 0.674). There was no correlational relationship (r = 0.06) between the mushroom species and tree species occurrence within the plots.

DISCUSSION

Mushroom species diversity recorded by this study are lower than what was observed in other studies that

have been carried out in Tasmania (Packham *et al*., 2002), Scotland (Newton *et al*., 2003) and Mexico (Zamora and Cecilia, 1995). In Mexico for example, 29 edible mushrooms were recorded in an area smaller than what was sampled by the present study.

The DCA-biplot did not easily separate the grassland plots (11-20) from the garden plots (1-10) because they had species in common. *Pluteus* sp. is more commonly found in grasslands as shown in the DCA diagram whereas *Podabrella microcarpa* is mainly in the forest vegetation type. Species such as *Agaricus* sp. 2 that lie at the edge of an ordination diagram have been described by Jongman *et al*., (1987) to be rare or have a preference of extreme environments. However, it could be that this species falls at the edge of its natural range in the environment therefore its occurrence is more unpredictable.

In the present study pH, phosphorus, canopy cover, organic matter, potassium, sodium, magnesium, sand and clay were significantly correlated with abundance of mushroom species. Zamora and Cecilia (1995) noted that sandy loam texture, low soil bulk density, high organic matter and pH were properties that stimulated the development of fungi. The importance of organic matter is due to its water holding capacity and nutrient availability (Bergemann and Largent, 2000).

Zamora and Cecilia (1995) noted that acid soils and high organic matter stimulated decomposition function of fungi over other micro-organisms such as bacteria and actinomycetes. The soils in the present study were generally acidic which is consistent with findings of Ahn (1993), as well as Syers and Rimmer (1994) for tropical regions.

Härkönen *et al*., (1995) and Packham *et al*., (2002) reported mushroom seasonality in Tanzania and Tasmania, respectively. This is consistent with the findings of the present study. Different species were recorded at different times of the year. Packham *et al*., (2002) suggested that the total number of species present in an area might not be found until after 5 years of sampling. Seasonality in the present study was between the first and the second rains. During the second rain season (March-may) some plots were flooded particularly in the forest. This probably explains the low diversity recorded during the second rain season. Zamora and Cecilia (1995) noted that variation in rainfall affected fungal production. Maximum fungal production generally coincided with a slight decrease in rainfall during months with the heaviest rains.

Mushroom distribution in other studies has been found to be influenced by moisture, inundation, geology, temperature, duff depth, humus and relative humidity (Packham *et al*., 2002; Zamora and Cecilia, 1995; Bergemann and Largent, 2000).

CONCLUSION

Ecological studies recorded ten edible species in five genera and showed that mushroom species diversity was highest in the grassland. Some mushroom species were most commonly found in certain habitats for example, *Pluteus* sp. was found in the grassland. The most important environmental factors related to mushroom species abundance were pH, phosphorus, canopy cover, organic matter, potassium, sodium, magnesium and clay. Mushroom species are more abundant during the first rain season and the occurrence of mushrooms was not related to occurrence of tree species.

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