AN AGROECOLOGICAL ZONATION FOR UGANDA:
Methodology and Spatial Information

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PREFFACE

Complementing its mandate for bean research, CIAT is committed to undertaking and supporting research on processes that offer prospects for enhancing the relevance and the cost-effectiveness of formal sector research and development. Efficient planning and implementation of activities likely to contribute to rural development require good understanding of variation in agricultural systems. The causes of variation include climatic, soil and land use characteristics, farmers' preferences and traditions, and the interactions among these factors. This publication, taken together with *Uganda's agroecological zones: a guide for planners and policy makers* by the same authors, uses a geographic information system to draw upon numerous local sources, personal observations and subsequent analyses in updating, collating and facilitating future use of Uganda's agricultural information. We have attempted to make sensible use of old as well as new sources, but realise that our interpretations are subject to the quality of those sources. This and other data is available on CD-ROM: Bean database for Africa/Uganda's agroecological zones and other data - CIAT, Version 1.0, September 1999. We welcome comments on the approach and methods used, and suggestions for improvement.

The Network on Bean Research in Africa serves to stimulate, focus and coordinate research efforts on common bean, the systems within which it is produced and the people who consume it. The network is organized by CIAT in collaboration with two interdependent sub-regional networks of national programs: the Eastern and Central Africa Bean Research Network (ECABREN) and the SADC Bean Research Network (SABRN) for southern Africa.

Financial support for regional bean projects comes from the Canadian International Development Agency (CIDA), the Swiss Agency for Development and Cooperation (SDC) and the United States Agency for International Development (USAID).

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Since 1987 the Government of Uganda has generously provided CIAT with an important base for its regional operations, at the Kawanda Agricultural Research Institute (KARI). Continuing collaboration with the management and staff of both KARI and Namulonge Agricultural Research Institute (NARI) contributed greatly to our activities, and we hope that this publication will go some way to returning to Uganda what we have learned together.

We also recognize those organizations from which data was sought. Special mention is due to: Ministry of Agriculture, Animal Industry and Fisheries (MAAIF); National Biomass Study, Forest Department – Ministry of Lands, Water and Environment; Statistics Department – Ministry of Finance, Planning; and Economic Development and the International Center for Research in Agroforestry (ICRAF) for digitizing the soils map.

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INTRODUCTION

Agriculture is economically and socially very important in Uganda. The agricultural systems of Uganda are diverse and a product of the fusion of various factors governing land use. Climate varies with altitude which ranges from 610 m in the Rift Valley to 4324 m above sea level on Mt. Elgon, and with mean annual rainfall which ranges from 510 mm in the northeast to 2160 mm in the Ssese Islands. Soil productivity and land use are related to soil depth, texture, acidity and organic matter levels. Climatic, soil and land use characteristics interact with farmer preferences and traditions resulting in varied agricultural systems. Good understanding of this variation in agricultural systems is needed for efficient planning and implementation of activities related to rural development. The zonation defined in this document presents differences and similarities among agro-ecological systems of Uganda.

A broad division of systems, categorizing them as being short grass and tall grass areas, has long been in general use (Parsons, 1970). In the short grass areas, rainfall is less with a pronounced dry season and cropping systems are based on annual crops established from seed. In the tall grass areas, rainfall is more and perennial crops are important. Much variation occurs within this broad characterization, and research and development efforts can benefit from better delineation and definition of agro-ecological zones according to agricultural, as well as climatic and soil characteristics.

Site selection and prioritization usually take into account spatial information but, this information is often not well synthesized and interactions between some important variables are often overlooked. Definition of agroecological zones, by analyzing and synthesizing information for diverse variables provides a framework within which to consider climatic, soils and farming systems aspects. The zonation gives a basis for relating research sites "to adjacent and more distant places, systems or communities" (Carter, 1997) and for extending technical options developed and verified at one location to other areas of probable adoption.

Two main steps are required to stratify agroecological systems. Important variables need to be identified and mapped, often in electronic form using a geographic information system. The map images are overlain to identify unique combinations of values. The second step is to sub-divide the geographic area into discrete spatial units or grids (e.g. square cells of 5 km x 5 km), extract the data on a grid basis from the overlying images, and conduct multi-variate analysis of the data (Jones *et al.*, 1992; Carter, 1997).

The objective of this work was to zone agroecological systems of Uganda and to describe the zones for impact-oriented agricultural research, technology diffusion, rural development and policy formulation. The zonation used a synthesis of a range of different types of spatial information, including population, biophysical and land use variables to determine and describe the agroecological zones.

MATERIALS AND METHODS

A database was generated for Uganda using information from the following sources (Table 2):

- Administrative boundaries map;
- Soil map for Uganda based on the Soil Reconnaissance Survey (Lands and Surveys, 1958) and digitized by ICRAF;
- Climatic database for Africa (Hutchinson, 1995)
- Population data (National Population and Housing Census, 1991), but excluding population of officially designated municipal areas;
- Crop production data at district level from the Ministry of Agriculture, Animal Industries and Fisheries for 1995; estimates were extended to county level based on estimates by District Agricultural Officers of the proportion of district production occurring in each county;
- Land use maps (The National Biomass Study, 1996) to estimate proportion of land area in grassland, woodland (includes bush and wooded savannas and forests), farmland, and protected or gazetted areas.

Agroecological zones (AEZs) were delineated and defined for Uganda considering 25 variables, including:

- three climatic variables (mean annual rainfall and temperature, and July rainfall as a percentage of annual rainfall (JAR));
- six soil variables (percent of land area with sand, pH, organic matter, available P, and exchangeable Ca and K above or below a critical level) (Table 1);
- two population variables (population density and male:female ratio where low values may indicate out-migration of males for employment);
- four land use types (farmland, woodland, grassland and wetland); and,
- ten food crops (intensity of production of banana, maize, cassava, sweet potato, Irish potato, finger millet, sorghum, bean, groundnut, and rice).

Determination of soil property values

Soil properties are expressed as percentages of land area with values above or below levels considered to be constraining to soil productivity: sand > 60%, pH < 5.5, available P < 10 ppm, exchangeable K < 0.3 meq/100 g, exchangeable Ca < 1.75 meq/100 g, exchangeable Mg < 0.80 meq/100 g, and soil organic carbon < 1.74%.

We assumed that soil fertility declined since the soils were sampled some 40 to 50 years ago, although empirical evidence to support this assumption is lacking. Therefore, mean values for each soil unit as determined from soil profile descriptions available in the memoirs were adjusted by -0.2, -1.0, -0.2, -0.1 and -0.1 for pH, P, Ca, Mg and K, respectively. Organic carbon was adjusted by –20%. Percent sand was not adjusted. Equations were determined from data of 6 to 43 samples collected for each of six soil groups to estimate the proportions of land area with values considered to be agronomically constraining for each soil property (Table 1).

Estimation of intensity of crop production

District estimates of hectares of production for principal food crops, a total of sole crop and intercrop production, were obtained from the Ministry of Agriculture, Animal Industries and Fisheries. The data were for 1995 and for the districts as defined in 1995; several new districts were created in 1997. The basis for these estimates may be the 1966 agricultural census (Jameson and Stephens, 1970), with regular adjustments since then. The crop production data were considered to be the least sound of all data used.

District agricultural officers were interviewed to estimate the proportion of the total area of a district's production for a commodity occurring in each county. County level area estimates were then calculated. Reference to land use maps enabled further refinement of the county-level estimates.

In some instances, personal observations were used to adjust official statistics. Estimates of banana production were judged to be extremely high in several districts relative to area planted to other crops. These were revised to equal the total of the nine other food crops considered for Kiboga (75,641 to 12,984), Luwero (38,167 to 26,772), Mpigi (61,759 to 40,000), and Mubende (50,426 to 20,000). Banana production was also adjusted for Rakai (118,027 to 70,000) and Masaka (153,975 to 100,000). Areas planted to crops were reduced by 35, 18, 11, 47 (banana, only) and 65% for the Kapchorwa Farm-woodland, Mt Elgon High Farmland, Jinja and Mbale Farmlands, Southwest Grass-farmlands and Ssese Islands, respectively, as the estimates were impossibly high given the farmland area in the AEZ. Some other doubtful, but unchanged estimates include: the high intensity of banana production in the Southwestern Medium-high Farmlands; the low intensity of bean production in Kisoro; the low intensity of sorghum production in Kabale; the high level of bean production in Southern and Eastern Lake Kyoga Basin; and the low level of crop production in the Central Buruli Farmlands, in the Lake Victoria Crescent and in the Western Mid-altitude Farmlands. Maximum levels of crop intensity were set: 80% of the land area for banana, bean and sweet potato, and 50% for other crops realizing that much land will produce two annual crops per year and that more than one crop may occupy a field with intercrop associations.

Creation of maps

Map images were created for 25 variables and overlain with the administrative boundary map. Maps were produced using county level data for population density, human male:female ratio, and production intensity for 10 major food crops. Soil property maps were based on the digitized version of the soil reconnaissance survey map and the soil units were the basic mapping polygons. Map images for climatic variables were taken from a database of interpolated climatic surfaces for Uganda, and land use images were derived from the maps of the National Biomass Study (1996).

Data analysis and delineation of agroecological zones

Data were extracted on a 5.05 x 5.05 km grid cell basis to create the data set. The data set was divided into five parts according to regions of the country to achieve better distinction of clusters. The southwestern region included Bushenyi, Kabale, Kabarole, Kasese, Kisoro, Mbarara, Ntungamo and Rukungiri districts. The central region included Kalagala, Kampala, Kiboga, Luwero, Masaka, Mpigi, Mubende, Mukono, Rakai and Sembabule. The eastern region included Bugiri, Busia, Iganga, Jinja, Kamuli, Kapchorwa, Kumi, Mbale, Pallisa and Tororo. The northcentral and northeastern regions included Apac, Katakwi, Kitgum, Kotido, Lira, Moroto and Soroti. The western and northwestern regions included Adjumani, Arua, Gulu, Kibaale, Hoima, Masindi, Moyo and Nebbi.

The variables were submitted to principal components analysis with varimax (variance maximizing) normalized rotation to reduce the constraint of correlation between factors. Variables with rotated loading factors greater than 0.70 were noted for the first five principal components generated for each region, as well as nationally.

Cluster analysis (SPSS, 1994) was used to group grid cells with similar attribute values. The analysis was done using only original variables, excluding the factors formed by principal component analyses. For each of the five regions of Uganda as defined above, K-means clustering analyses were done using different numbers of allowable clusters. The results of the different runs were judged considering efficiency in consolidation of grid cells, agro-ecological distinctiveness of clusters and agreement with other geographic information. An analysis of variance determined the variables which contributed most to the differentiation between clusters, and the five principal determining variables, as well as non-significant variables, were noted.

Isolated grid cells were converted to the value of the surrounding cells, or the most likely adjacent cells. The Kabale-Rukungiri Highlands and the Bushenyi-Northern Rukungiri Farmlands originally fell in the same cluster, but these non-contiguous areas were judged to be sufficiently different to be separate AEZs. The Kasese Transition Zone was formed from grid cells of several other clusters which were occurring as single cells or in very small groups of cells, often without a clear pattern. The Semliki Flats were separated from what was later called the Rwenzori Footslopes and Fort Portal Farmlands.

The five regions and their clusters were merged to form country maps. Similarities between cluster mean values for variables were considered; clusters that were very similar were aggregated to form one unit. From 45 clusters identified from the regional level analysis, 33 agroecological zones were delineated.

Description of the agroecological zones.

Description of the agroecological zones was based on the mean values for the 25 variables, as well as information from other sources. Information on landforms was taken from Ollier *et al* (1965). Information on soil erodibility and rainfall erosivity (by Modified Fournier Index;

FAO, 1977; $C_1 = \sum p_i^2/P$ (i = 1-12), where C_1 is the rainfall erosivity, p_i is the rainfall in month I and P is the annual rainfall) was taken from Yost and Eswaran (1990).

RESULTS AND DISCUSSION

The national analysis

Information for different variables is presented in a series of maps appended to this document. Often the information is of insufficient quality for quantitative uses.

Nationally, 80% of the variation was accounted for by six principle components (Table 3). The first accounted with 26.9% and found JAR, male:female ratio, and the intensities of several annual crops to be positively correlated. Annual rainfall was negatively related to proportion of land area in grassland. The main variables of the third principal component were percent of land areas with sandy soil and K deficient soils. The intensities of maize, banana and bean production were related in the fourth principal component.

The regional analyses

The first five principal components accounted for 70-80% of the variation between zones at the regional level (Table 4). In all regions, except the central region, and for Uganda nationally, JAR, the male:female ratio and several annual food crops were closely related and fell into the first principal component. This accounted for 21-39% of the variation. The annual crops, Irish potato, finger millet, groundnut and rice frequently had rotated loading factors greater than 0.70 for this principal component (Table 3 and 5). Most variables were statistically significant in the differentiation of zones at the regional level. Non-significant variables ranged from zero to six per region (Table 5).

In the southwest, annual rainfall, population density, proportions of land area in farmland and in grassland, and the intensity of banana production accounted for much of the variation between clusters. The male:female ratio, JAR and intensity of rice production did not significantly affect the formation of clusters; all other variables were significant. Grassland increased as rainfall decreased. Calcium deficiency was associated with acid soils. Eleven zones were initially identified and delineated.

In the northwest, annual rainfall, population density and soil properties (percent land area with sandy soil, and with calcium and potassium below critical levels) accounted for much of the variation between clusters. The male:female ratio, JAR, and intensities of production of Irish potato, finger millet, sorghum, and rice did not account for a significant amount of variation between clusters. Sandy soils were related to low soil organic matter. Grassland increased as rainfall decreased. Five zones were identified and delineated.

In eastern Uganda, clusters were largely differentiated due to variation in annual rainfall, population density, percent farmland, percent area with sandy soils, and intensity of banana production. The male:female ratio and JAR were not significant. Soils deficient in Ca were generally deficit in potassium as well. Intensities of cassava and groundnut production were spatially related in this region. Nine zones were identified in eastern Uganda.

In northcentral and northeastern Uganda, soil texture, annual rainfall, population density, and proportions of land area in farm and grass lands were the main determinants of the clusters. Deficiencies of Ca and K were associated with higher rainfall and sandy soils. Eight zones were identified.

In central Uganda, soil texture and K availability, temperature, and proportions of land in grassland and farmland accounted for much of the variation between clusters. Variation in annual rainfall did not contribute significantly to the determination of the clusters. Soil organic matter was less with sandy soils, and Ca and K deficiencies tended to occur together. Nine zones were delineated.

The agroecological zones

When the AEZ images for the regions were joined together, opportunities for aggregation were apparent. Eventually, 33 agroecological zones from the original 42 were delineated (Table 6). The results of this zonation are summarized in Table 7 and presented in detail in Wortmann and Eledu (1999).

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Table 1. Equations for the estimation of proportion of land area with soils above or below levels constraining to soil productivity.

Mean values for soil group	**Proportion of land area**
Proportion of land area with soil of more than 60 % sand (Sand%) based on mean sand content (Sand) for described profiles of soil group	
43% < Sand >75%	Sand% = -128.2 + 2.943 * sand
Sand < 43%	Sand% < 5%
Sand > 75%	Sand% > 90%
Proportion of land area with soil of less than 5.5 pH (pH%) based on mean pH level for described profiles of soil group	
4.7 < pH <6.4	pH% = 340.5 – 52.72*pH
pH ≥ 6.4	pH% < 10%
pH ≤ 4.7	pH% > 90%
Proportion of land area with exchangeable Ca < 1.75 meq $100g^{-1}$ (Ca%) based on mean Ca level for described profiles of soil group	
1.0 < Ca < 4.5	Ca% = 154.74 – 77.81 * Ca + 10.86 * Ca^2
Ca ≥ 4.5	Ca% < 10%
Ca ≤ 1.0	Ca% > 90
Proportion of land area with exchangeable Mg < 0.80 meq $100g^{-1}$ (Mg%) based on mean Mg level for described profiles of soil group	
0.38 < Mg < 1.25	Mg% = 123.83 – 90.19 * Mg
Mg ≥ 1.25	Mg% < 10%
Mg ≤ 0.38	Mg% < 90%
Proportion of land area with exchangeable K < 0.30 meq $100g^{-1}$ (K%) based on mean K level for described profiles of soil group	
0.07 < K < 0.90	K% = 451.16 – 165.24 * K – 614.06 * $K^{0.25}$
K ≥ 0.90	K% < 10%
K ≤ 0.07	K% > 80%
Proportion of land area with exchangeable P < 5 ppm (P%) based on mean P level for described profiles of soil group	
2.5 < P < 5.0	P% = 125 – 15 * P
5.0 ≤ P ≤ 17.0	P% = 92.9 – 4.32 * P
P > 17.0	P% < 15%
P ≤ 2.5	P% > 90%
Proportion of land area with exchangeable P < 10 ppm (P%) based on mean P level for described profiles of soil group	
3.2 ≤ P ≤ 17.8	P% = 106.53 – 5.15 * P
P > 17.8	P% < 15%
P < 3.2	P% > 90%
Proportion of land area with organic carbon < 1.74% (OC%) based on mean OC level for described profiles of soil group	
1.3 ≤ OC ≤ 2.0	OC% = 209.9 – 92.12 * OC
2.0 < OC < 3.2	OC% = 144.32 – 100.03 * $OC^{0.25}$
1.3 < OC	OC% > 90%
OC ≥ 3.2	OC% < 10%

Table 2. Sources of data used for stratification.

Data	Source	Notes
Soil: proportion of land area with sand > 60%. pH < 5.5, available P < 5 (10) ppm, organic carbon < 1.74%: and exchangeable < 1.75, Mg < 0.80, and K < 0.30 meq 100 g^{-1}.	Memoirs of the Research Division: Kawanda Research Station, Uganda (1960), Series 1, No. 2-5.	Estimated from soil profile descriptions; percent of land area.
Rainfall: annual mean; July rainfall as percent of annual rainfall to indicate of mode of rainfall distribution; and mean annual temperature.	Africa: A Topographic and Climatic Database. Version 1.0, 1995.	Mean values for 5.05 x 5.05 km grids
Population density and sex ratio by county	The 1991 Population and Housing Census Summaries, 1992.	Data county
Land use: percent land area in grassland, farmland, woodland, maize, sorghum, cassava. sweet potato, finger millet, banana, rice, Irish potato, bean and groundnuts.	National Biomass Study, 1996. MAAIF district crop production data, 1995. Interviews of DAOs.	Data by county

Table 3. Variables with rotated loading factors of greater than 0.70 for six principal components (PC) when data was analyzed on a countrywide basis.

Principal component	Variation explained (%)	Variables with rotated loading factors greater than 0.70.
PC1	26.9	July rainfall as a percent of total rainfall; male:female ratio: sorghum, Irish potato, finger millet and rice
PC2	10.7	Annual rainfall, grassland (-)
PC3	9.1	Sand, potassium
PC4	14.1	Maize, banana, bean
PC5	7.0	
PC6	6.1	Woodland(-)

Table 4. Percent of total variation within variables accounted for by the first five principal components derived for each region.

Region	PC1	PC2	PC3	PC4	PC5
Southwest	31.8	9.7	11.2	12.8	7.1
Northwest	38.6	15.5	9.1	8.7	6.2
Eastern	21.2	16.4	10.1	8.8	13.6
North	36.9	16.1	10.9	6.2	9.8
Central	35.9	13.0	14.2	8.2	5.4

Table 5. Level of significance[1] and membership of variables in principal components for each of five regions of Uganda.

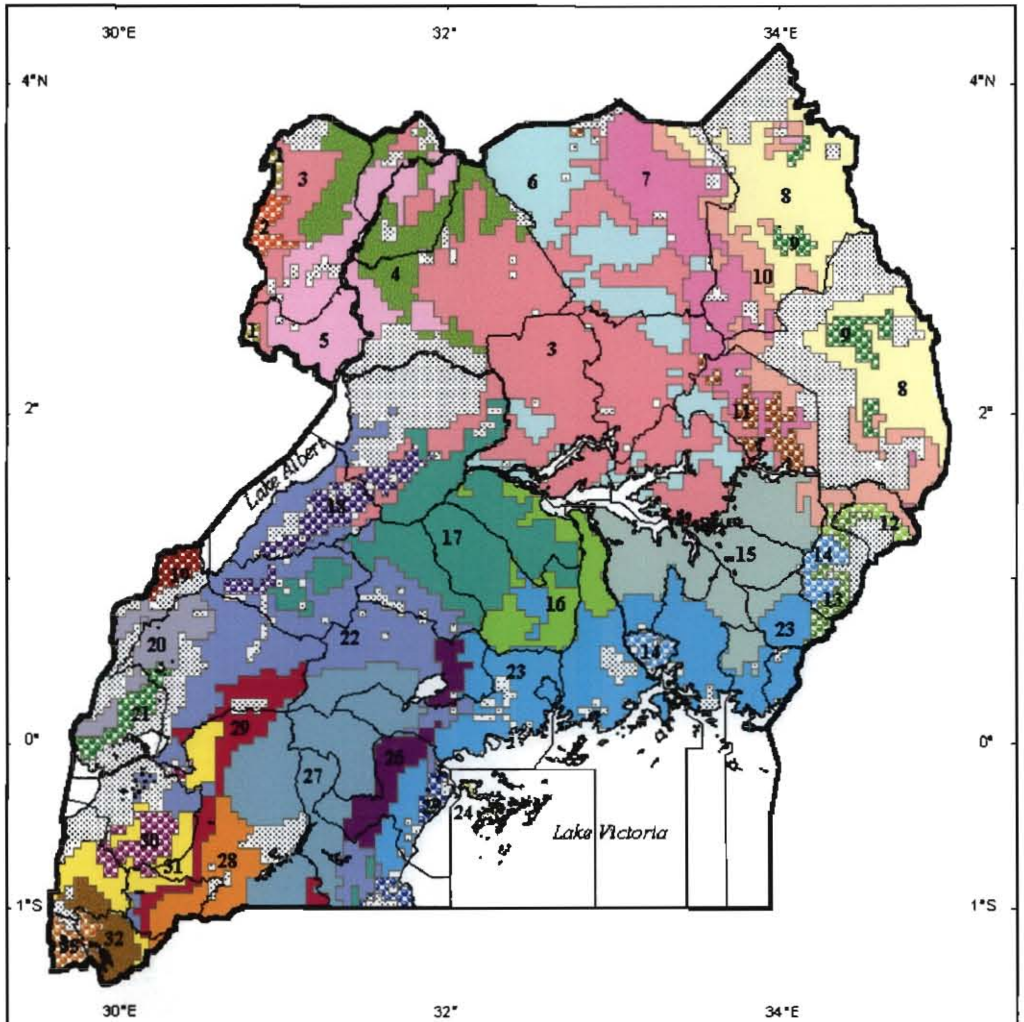
Variable	Southwest		Northwest		Eastern		North		Central	
	Sign.[1]	PC.	Sign.	PC	Sign.	PC	Sign.	PC	Sign.	PC
Sand			MV	3	MV		MV	3	MV	-2
Ca		5	MV	5		4		3		4
K			MV			4		3	MV	4
OC				3						-2
pH		5								
P										5
Rain	MV	2	MV	4	MV		MV	3	NS	1
July rain	NS	1	NS	1	NS	1		1		
Temperature						-2			MV	1
Pop. Density	MV		MV		MV		MV	5		
Male:female	NS	1	NS	1	NS	1		1		
Grass	MV	-2		-4		3	MV	-2	MV	-3
Farm	MV	-3,4		2	MV		MV	2	MV	3
Wood		3		-2		2		-4		1
Maize				1		2				1
Sorghum		1,4	NS	1		1				1
Cassava		1				5		1		
S. potato		4						1		1
I. potato		1	NS	1		1		1		1
F. millet		1	NS	1				1		
Banana	MV				MV					
Bean				1						1
Groundnut		1		1		5		1		1
Rice	NS	1	NS	1				1		

[1]MV indicates the variables that are among the five variables which accounted for the most variability in the stratification of regional level zones. NS means the variable was non-significant; all other variables were significant at P = 0.05. The numbers indicate which variables had rotational loading factors greater than 0.70 for principal components (PC) 1-5.

Table 6. Zones identified regionally which were aggregated to form the final agroecological zones.

Agroecological Zone	Regional level zones
Northern Moist Farmlands	Northwestern and Gulu Moist Farmlands; Northcentral Moist Farmlands; Northcentral Farmlands with Clay Soils
Northeastern Short Grass Plains with Clay Soil	Northeastern Short Grass Plains with Clay Soil; Sebei Farmlands
Jinja and Mbale Farmlands	Mbale Mid-altitude Farmlands; The Jinja Farmlands
Southern and Eastern Lake Kyoga Basin	Kumi Farmlands; Pallisa Farmlands; Eastern Buruli Farmlands
Lake Victoria Crescent	Central Farmlands; Lake Victoria Crescent
Southwestern Grasslands	Semi-arid Mbarara Grasslands; Semi-arid Central Grass-Farm lands
Western Mid-altitude Farmlands	Southwestern Mid-altitude Farm-Bush Lands; Mubende-Kiboga Farmlands

Map 01: Agroecological zones of Uganda



LEGEND

1. West Nile Loam Farmlands
2. Arua Farmlands
3. Northern Moist Farmlands
4. Northwestern Wooded Savanna
5. Northwestern Farmland - Wooded Savanna
6. Northcentral Farm-Bush Lands with Sandy Soils
7. Northern Grass-Farm-Bush Transition AEZ
8. Northeastern Short Grass Plains with Sandy Soils
9. Northeastern Semi-arid Farmlands
10. Northeasten Short Grass Plains with Clay Soils
11. Usuk Sandy Farm-Grasslands
12. Kapchorwa Farm-Forest AEZ
13. Mt. Elgon High Farmlands
14. Jinja and Mbale Farmlands
15. Southern and Eastern Lake Kyoga Basin
16. Central Buruli Farmlands
17. Central Wooded Savanna
18. Western Clay Loam Farmlands
19. Semliki Flats
20. Rwenzori Footslopes and Fort Portal
21. Kasese Transition Zone
22. Western Mid-Altitude Farmlands
23. Lake Victoria Crescent
24. Sese Islands
25. Sango Plains
26. Western Masaka and Mityana Farmlands
27. Southwestern Grasslands
28. Southwestern Grass-Farm Lands
29. Semi-arid Grass-Farmland Transition
30. Bushenyi-N.Rukungiri Farmlands
31. Southwestern Medium-High Farmlands
32. Kabale-Rukungiri Highlands
33. Kisoro-Kibale Highlands with Acid Soils

Gazetted (protected) areas

Map 02: An aggregation of Agroecological zones of Uganda

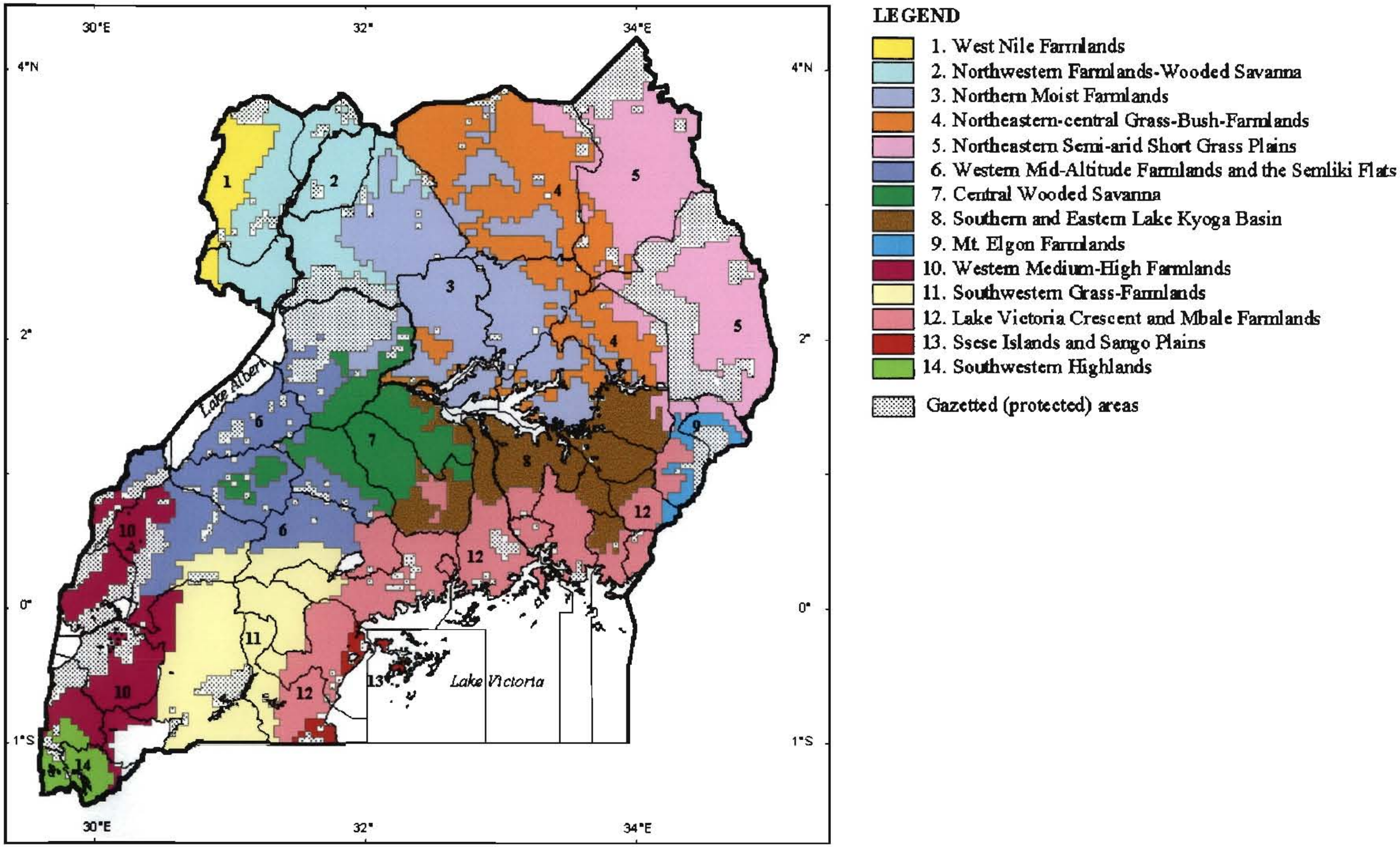


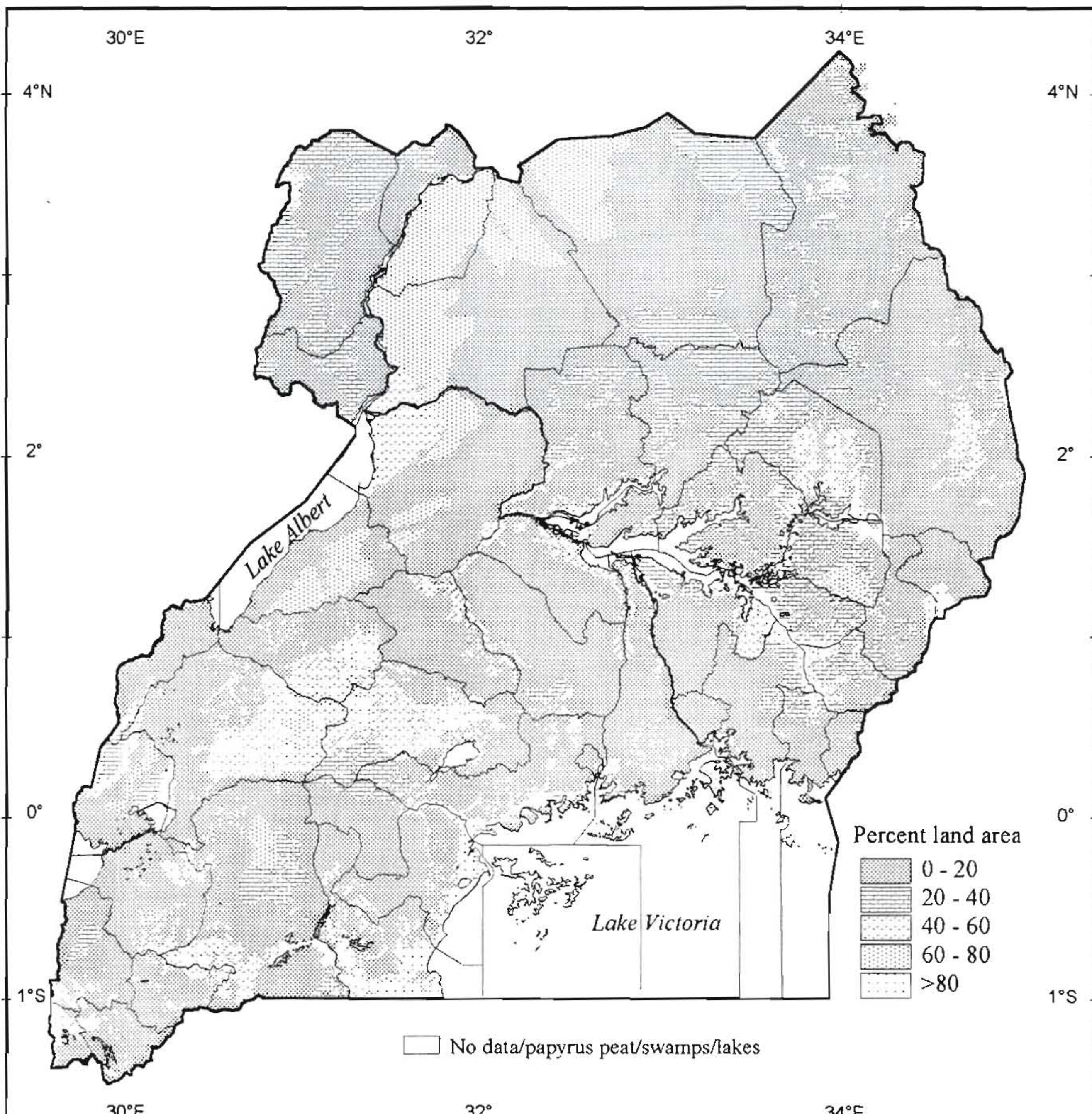
Table 7. Agroecological zones of Uganda—a summary

Uni-modal rainfall pattern	
Temperature ≤ 20°C and rainfall > 1200 mm yr^{-1}	
- 30-70% of the land has soil of >60% sand	- Mt. Elgon High Farmlands (969 km^2)
- <30% of the land has soil of > 60% sand	- Kapchorwa Farm-forest Lands (612 km^2)
Temperature > 20°C and rainfall > 1200 mm yr^{-1}	
- >70% of the land has soil of >60% sand	- Arua Farmlands (816 km^2), Northwestern Wooded Savanna (6505 km^2), Northcentral Farm-bush Lands with Sandy Soil (10791 km^2)
- 30-70% of the land has soil of > 60% sand	- West Nile Loam Farmlands(408 km^2), Northern Moist Farmlands (27527 km^2)
Temperature > 20°C and rainfall of 1000-1200 mm yr^{-1}	
- >70% of the land has soil of >60% sand	- Northwestern Farmland Wooded Savannah (7449 km^2), Usuk Sandy Farm-grasslands (1403 km^2)
- 30-70% of the land has soil of > 60% sand	- Northern Grass-farm-bush Transition (7755 km^2)
Temperature > 20°C and rainfall < 1000 mm yr^{-1}	
- 30-70% of the land has soil of > 60% sand	- Northeastern Short GrassPlains with Sandy Soil (11786 km^2)
- <30% of the land has soil of >60% sand	- Northeastern Semi-arid Farmlands (1684 km^2), Northeastern Short Grass Plains with Clay Soil (6608 km^2)
Rainfall moderately reduced and unreliable in June to August	
Temperature ≤ 20°C and rainfall > 1200 mm yr^{-1}	
-	- Rwenzori Footslopes and Fort Portal (2515 km^2)
Temperature > 20°C and rainfall > 1200 mm yr^{-1}	
- 30-70% of the land has soil of >60% sand	- S.&E. Lake Kyoga Basin (10154 km^2), Jinja and Mbale Farmlands (1505 km^2), Lake Victoria Crescent (14797 km^2)
- <30% of the land has soil of > 60% sand	- Western Clay Loam Farmlands (2423 km^2)
Temperature > 20°C and rainfall of 1000-1200 mm yr^{-1}	
-	- Central Buruli Farmlands (4311 km^2), Central Wooded Savanna (10919 km^2), Semliki Flats (740 km^2), Kasese Transition Zone (1097 km^2), Western Mid-altitude Farmlands (15307 km^2)

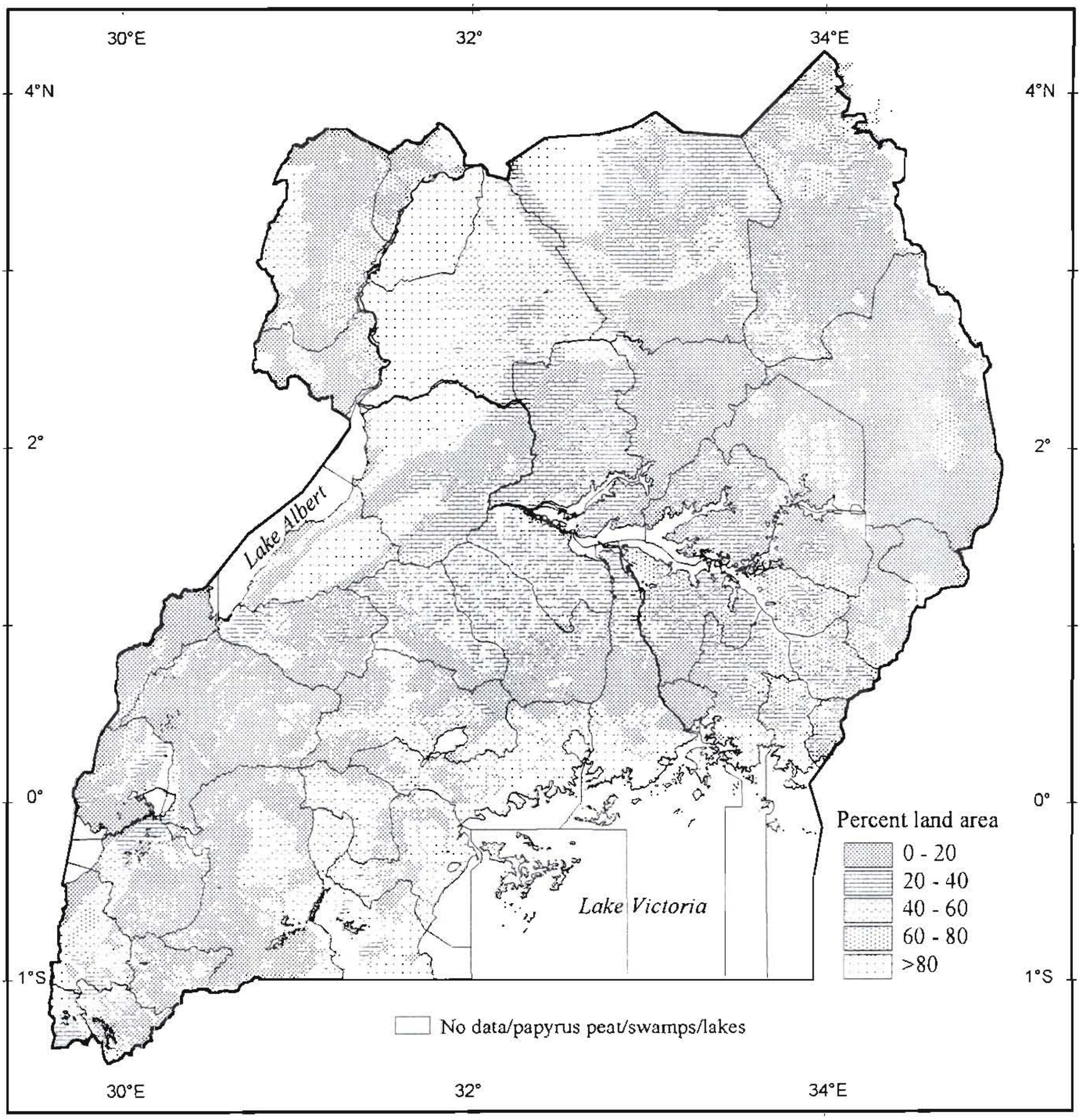
Table 7. Continued.

Bimodal rainfall with a distinct dry season during June to July	
Temperature ≤ 20°C and rainfall > 1200 mm yr^{-1} -	- Kisoro-Kabale Highlands with Acid Soils (89 km^2)
Temperature ≤ 20°C and rainfall of 1000-1200 mm yr^{-1} -	- Kabale-Rukungiri Highlands (1607 km^2), Bushenyi-Northern Rukungiri Highlands (1505 km^2), Southwestern Medium-high Farmlands (3546 km^2)
Temperature ≤ 20°C and rainfall < 1000 mm yr^{-1} -	- Southwestern Grass-farm Lands (2882 km^2)
Temperature > 20°C and rainfall > 1200 mm yr^{-1} -	- Ssese Islands (434 km^2), Sango Plains (842 km^2)
Temperature > 20°C and rainfall of 1000-1200 mm yr^{-1} -	- Western Masaka and Mityana Farmlands (2755 km^2)
Temperature > 20°C and rainfall > 1200 mm yr^{-1} -	- Southwestern Grasslands (11659 km^2), Southwestern Grass-farmlands (3342 km^2), Semi-arid Grass-farm Land Trans. (2882 km

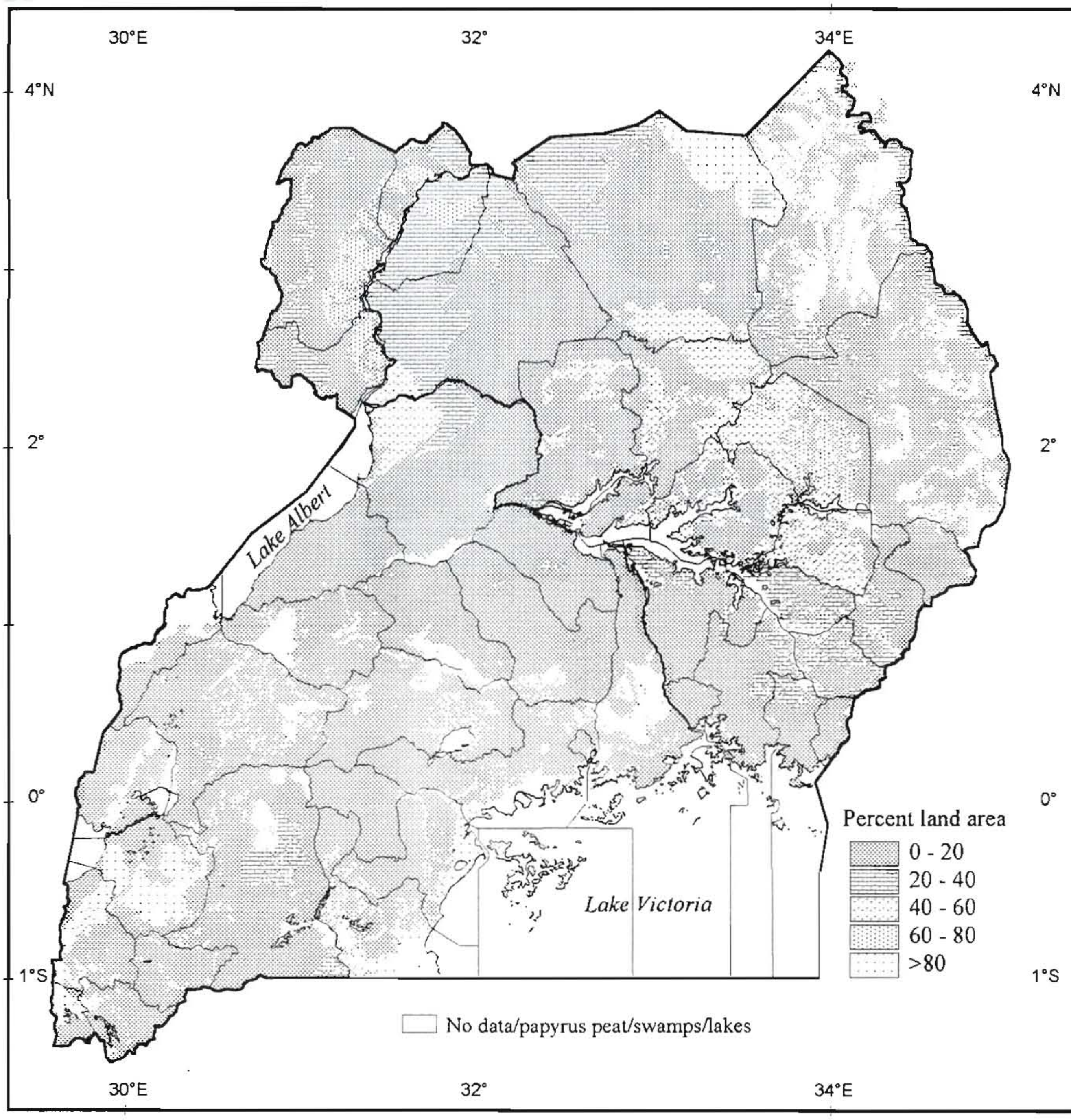
Map 03: Proportion of land area with low Calcium (exchangeable Ca <1.75 meq $100g^{-1}$)



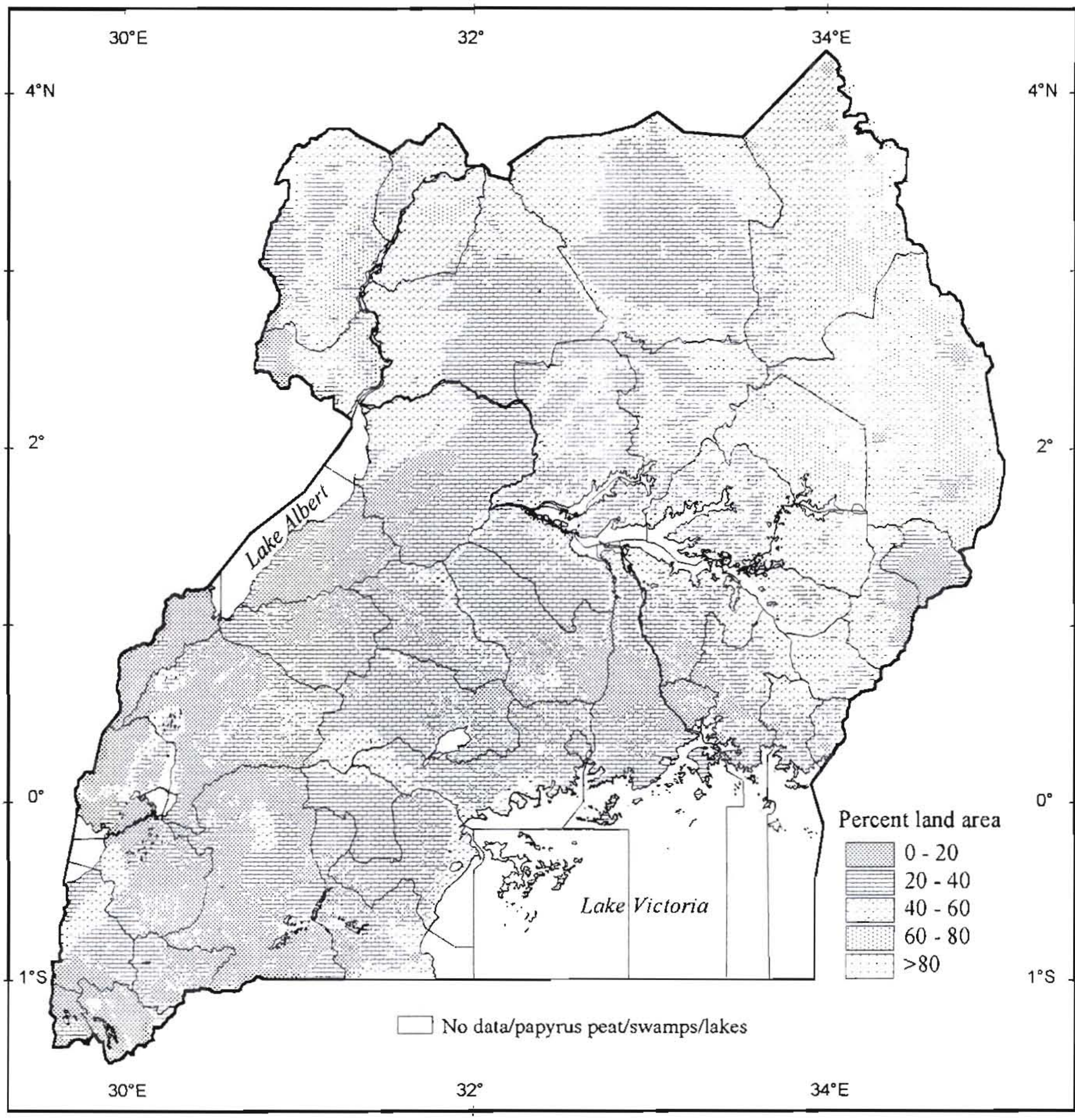
Map 04: Proportion of land area with low Potassium (available K <0.3 meq $100g^{-1}$)



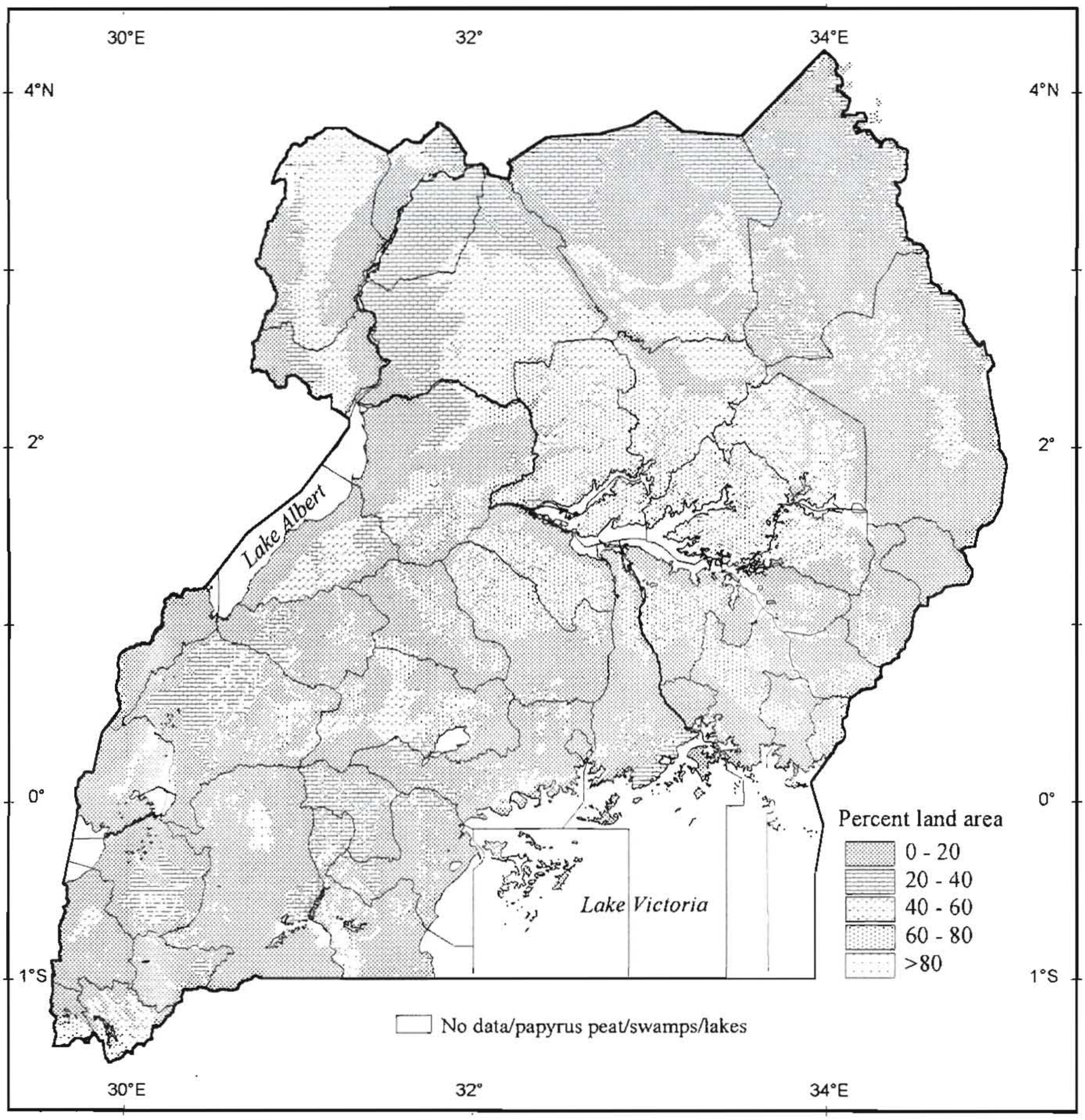
Map05: Proportion of land area with low Magnesium (exchangeable Mg <0.8 meq $100g^{-1}$)



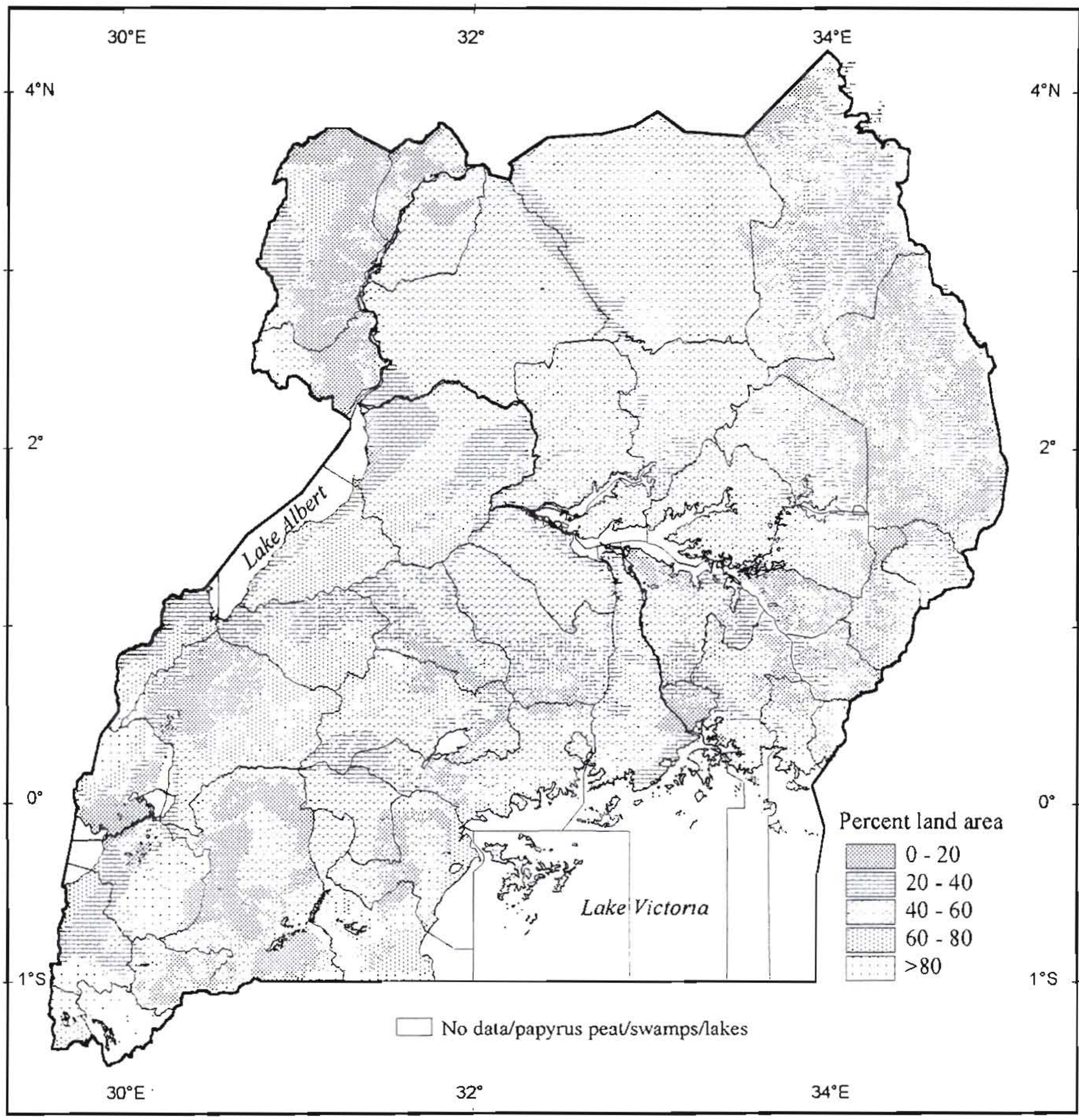
Map 06: Proportion of land area with low organic-matter (Organic carbon <1.74%)



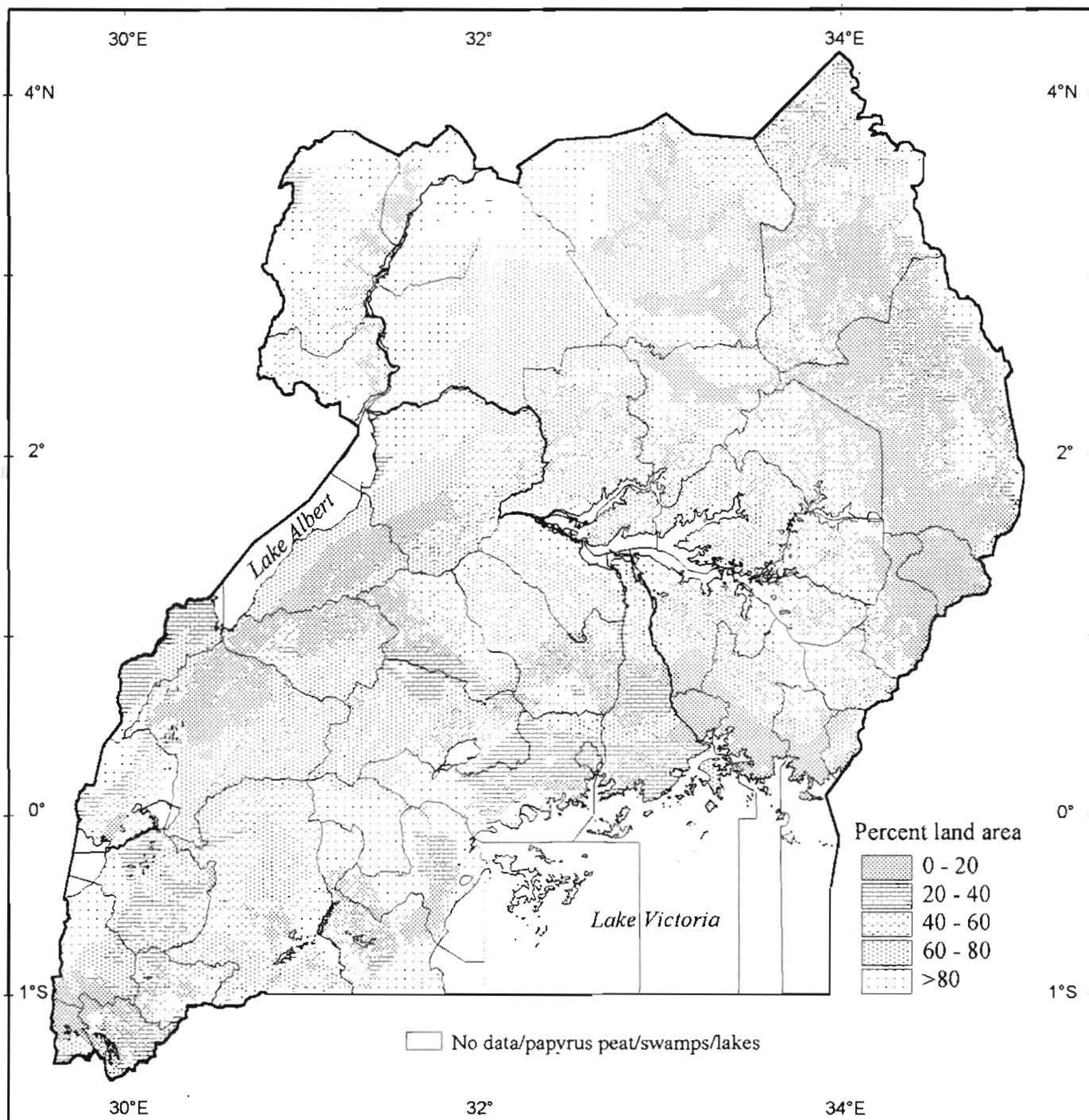
Map 07: Proportion of land area with low Phosphorus (available P <10 ppm)



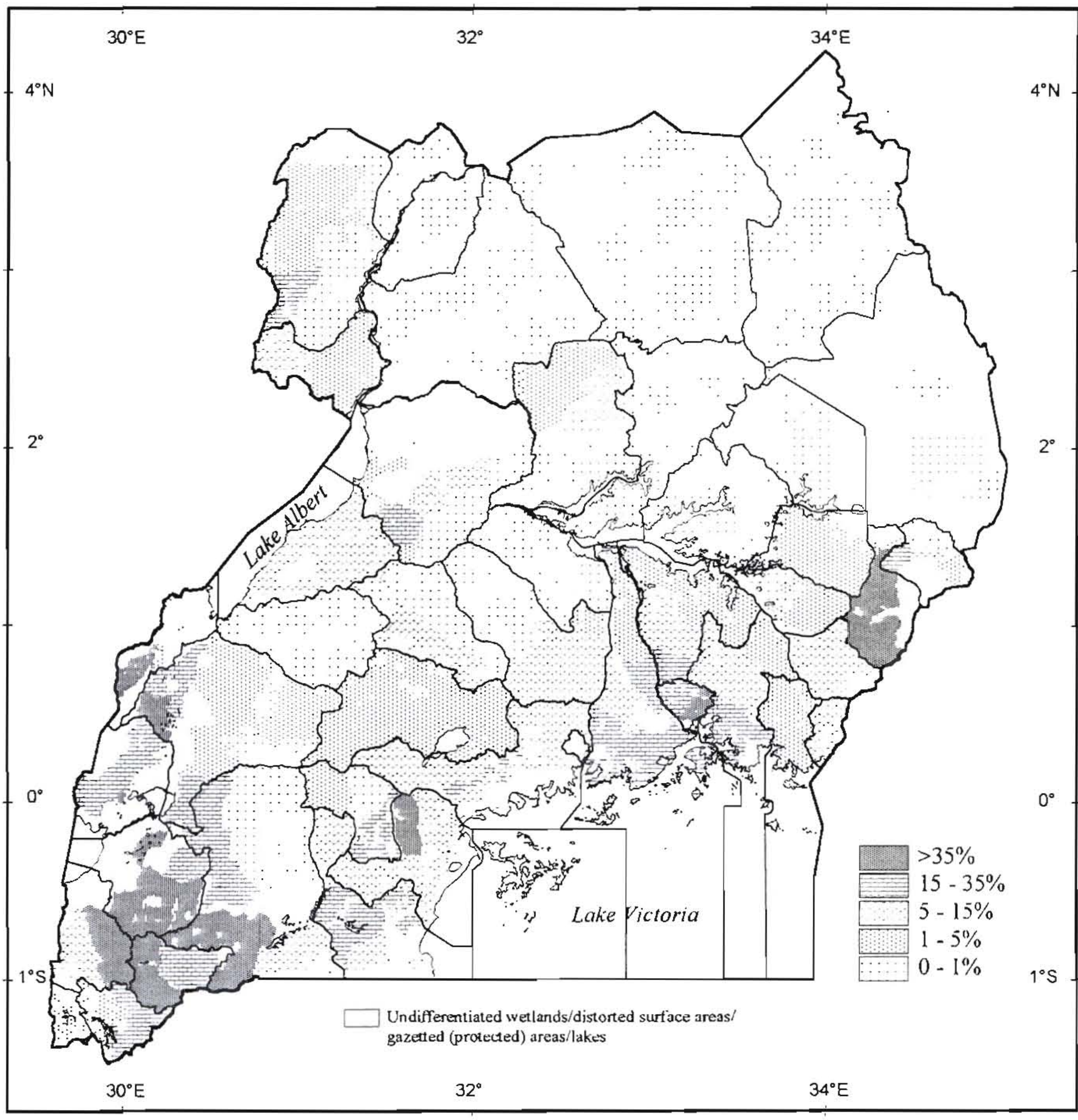
Map 08: Proportion of land area with acid soils (soil pH <5.5)



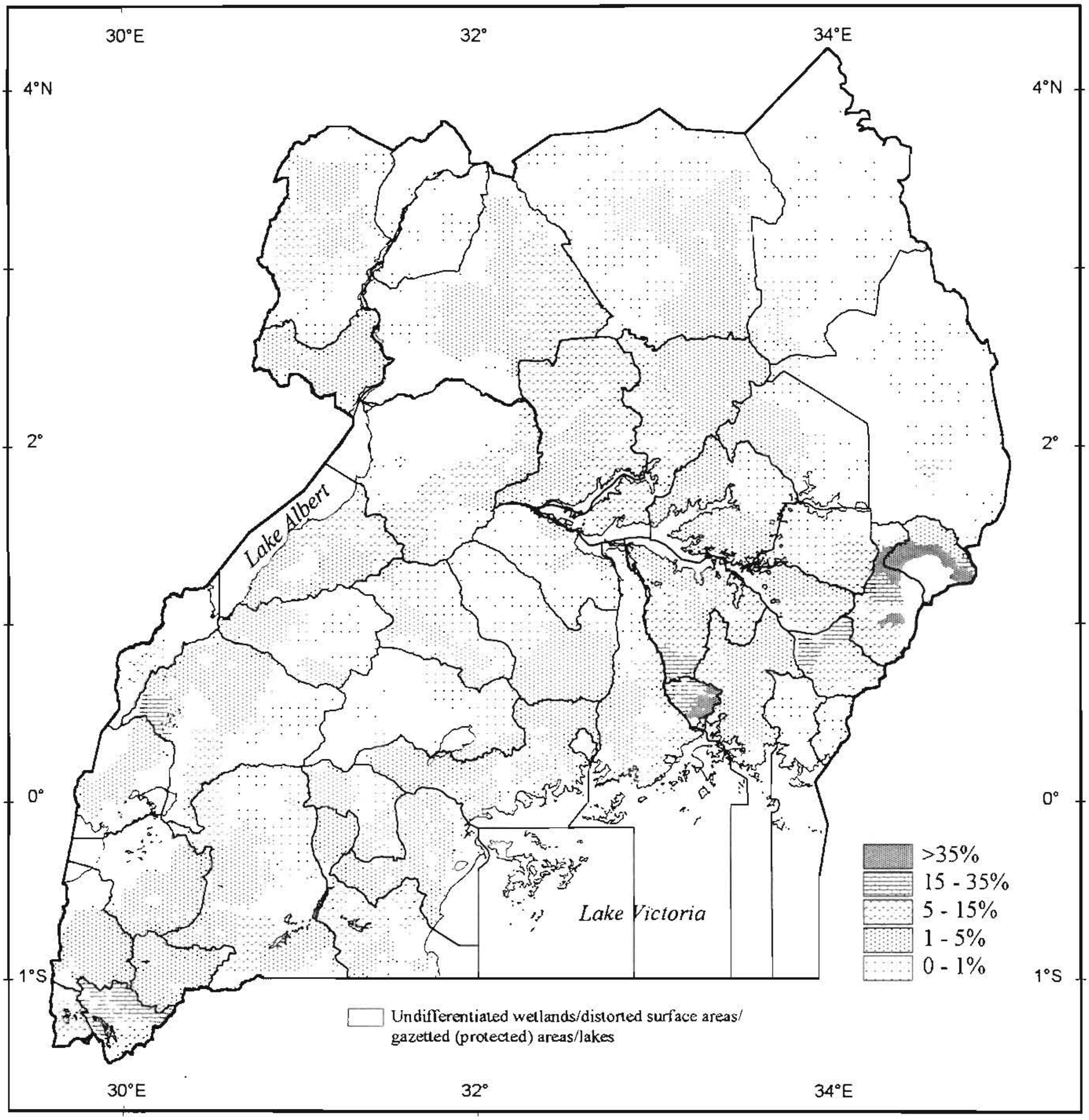
Map 09: Proportion of land area with sandy soils (sand >60%)



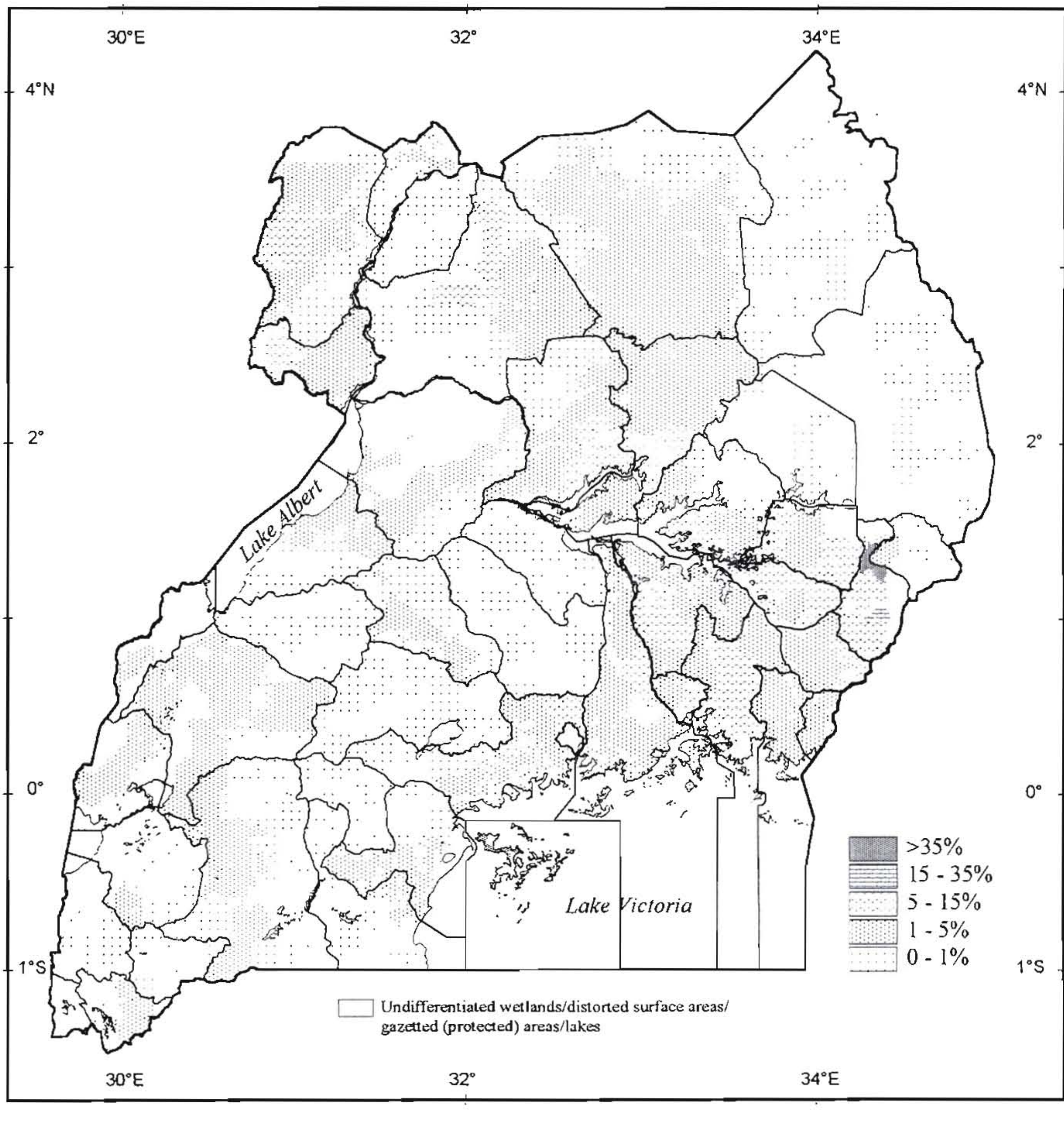
Map 10: Percent land area in banana



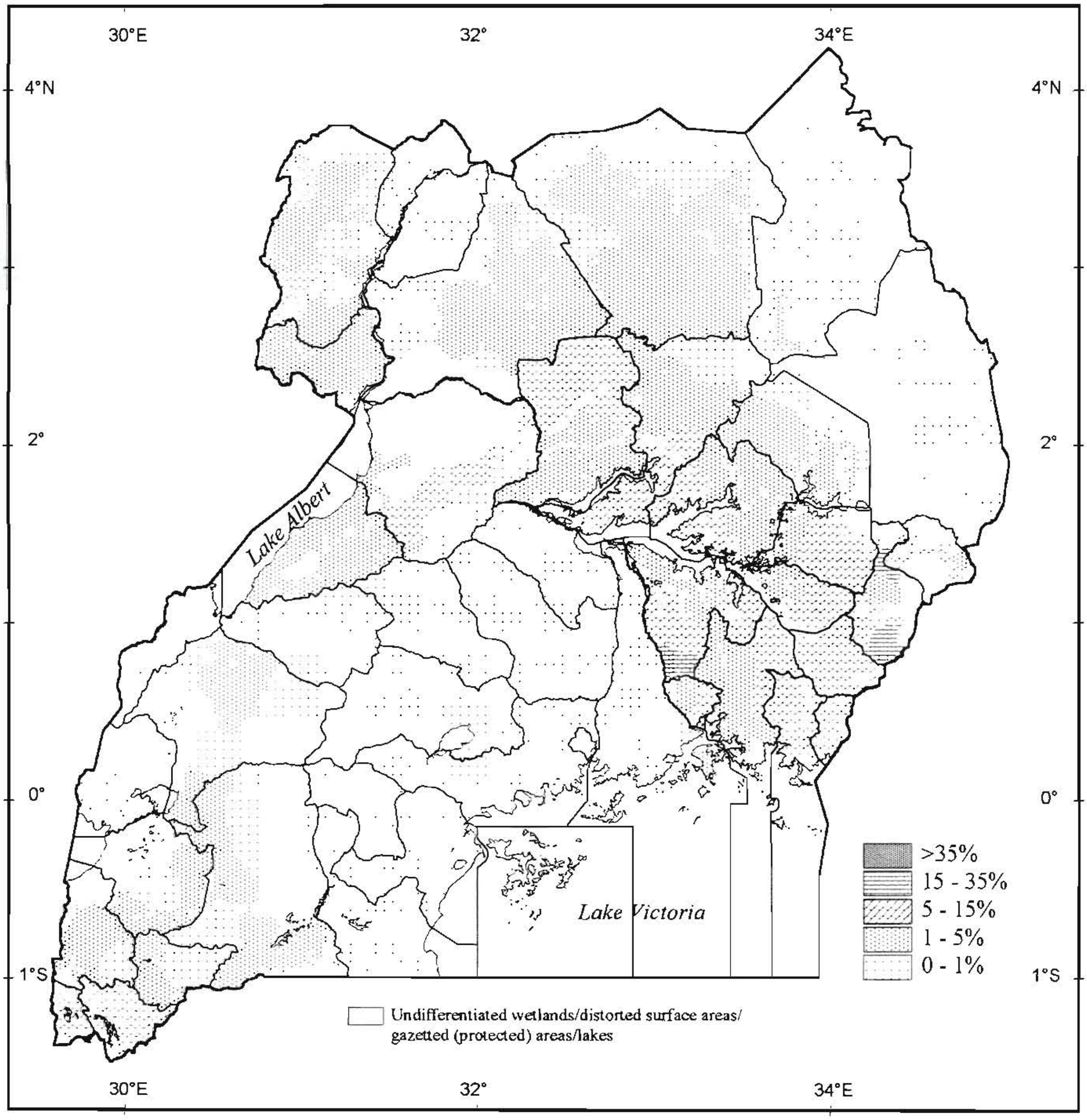
Map 11: Percent land area in bean



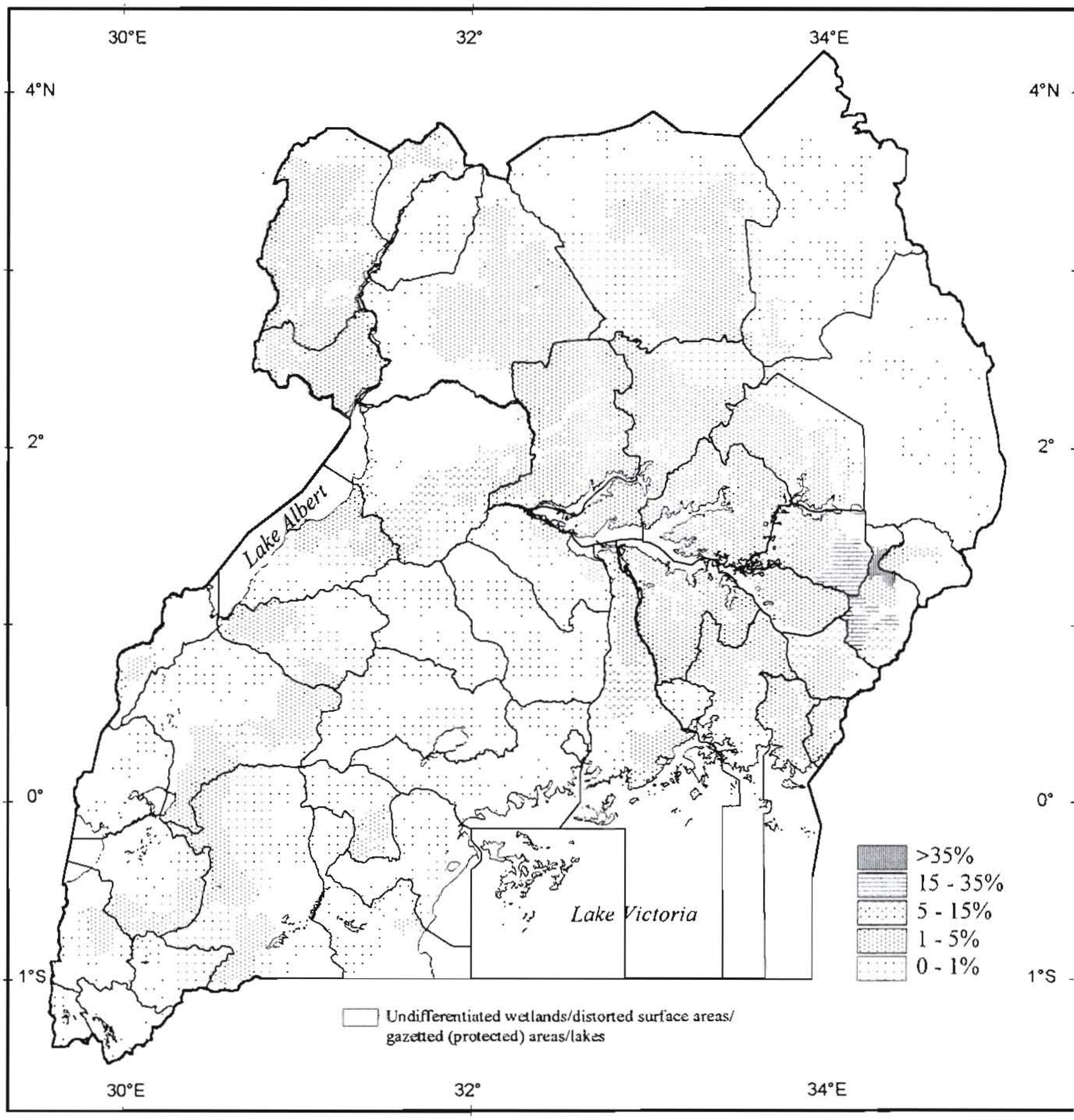
Map 12: Percent land area in cassava



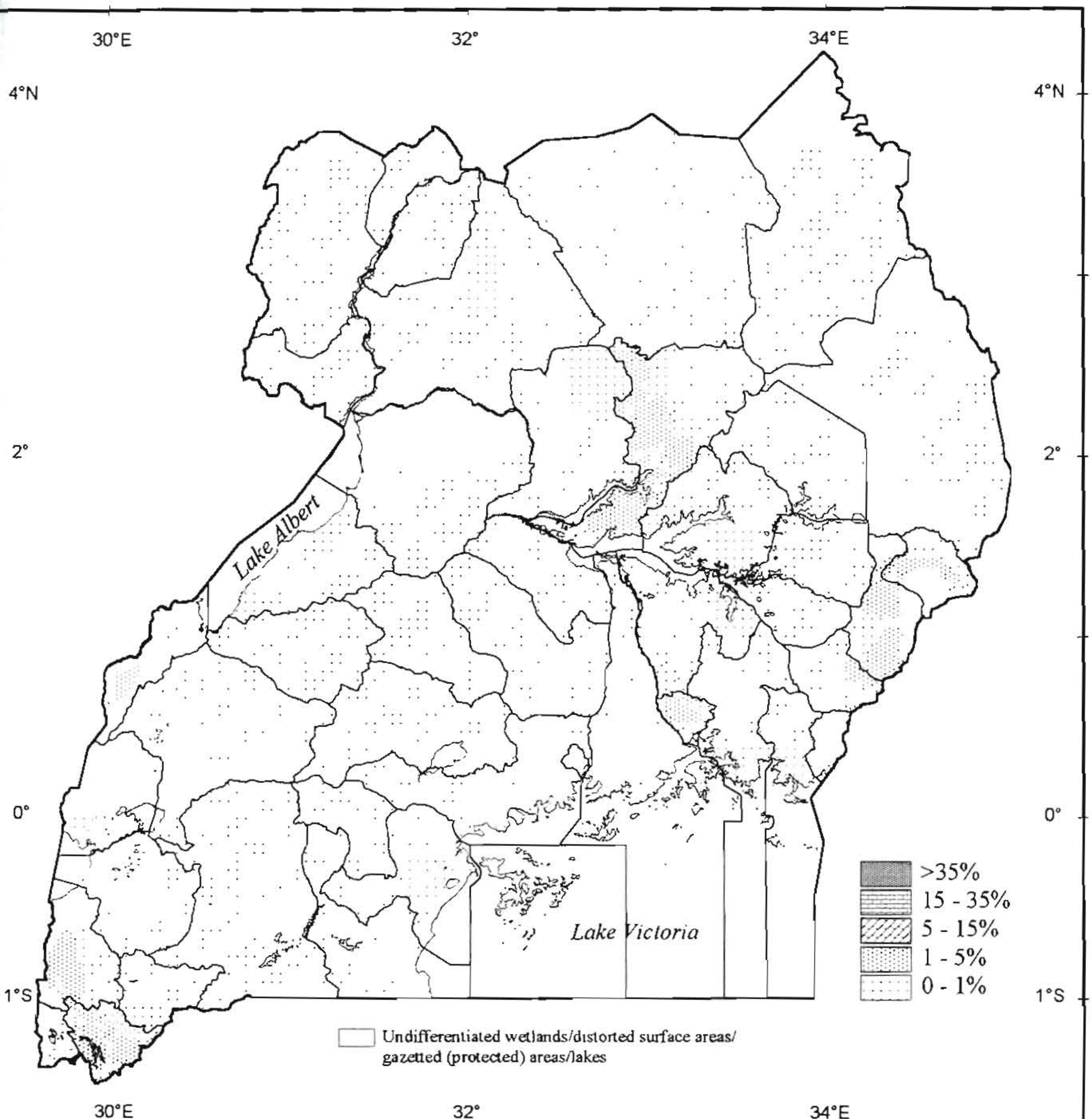
Map 13: Percent land area in finger millet



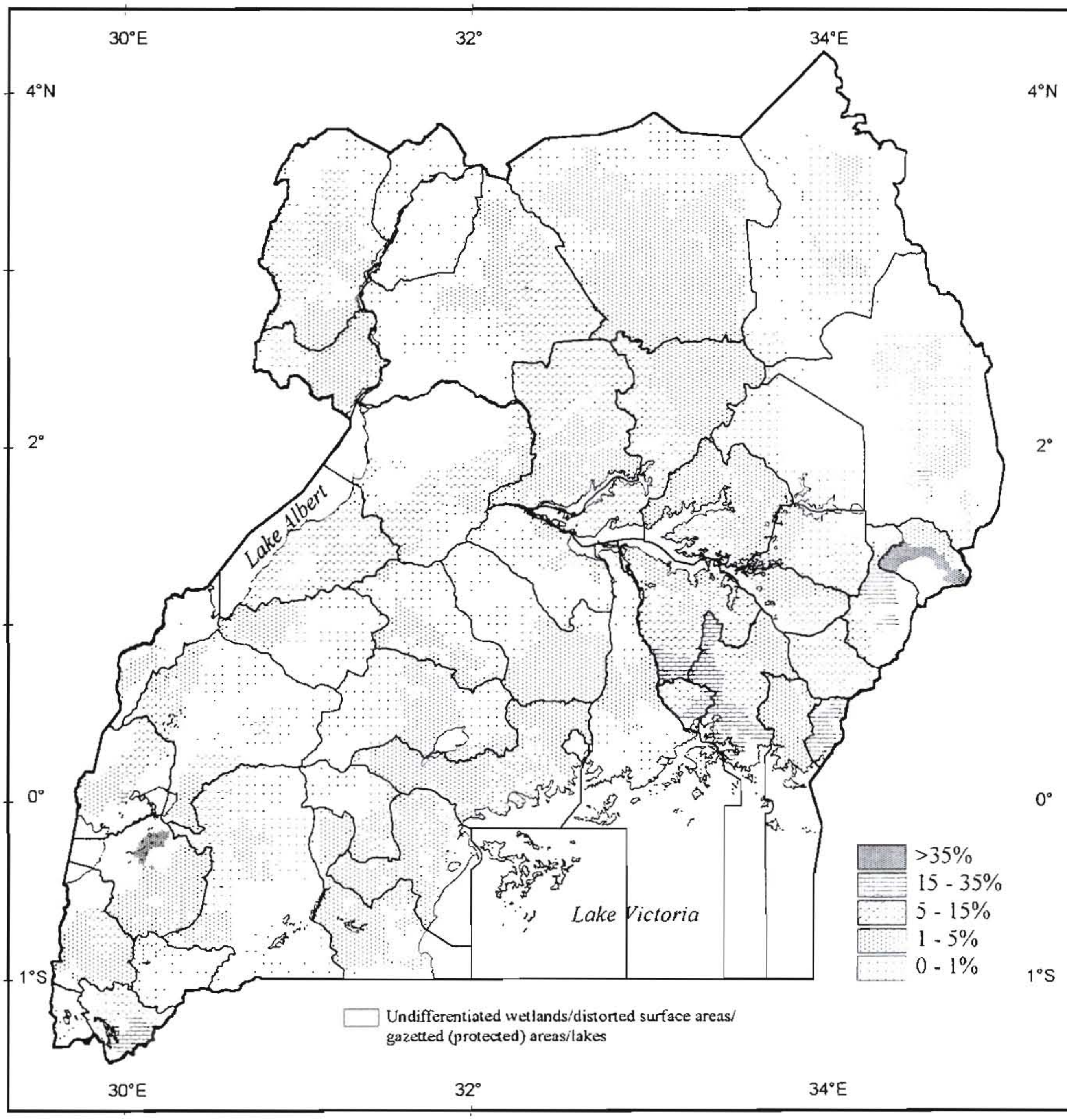
Map 14: Percent land area in groundnuts



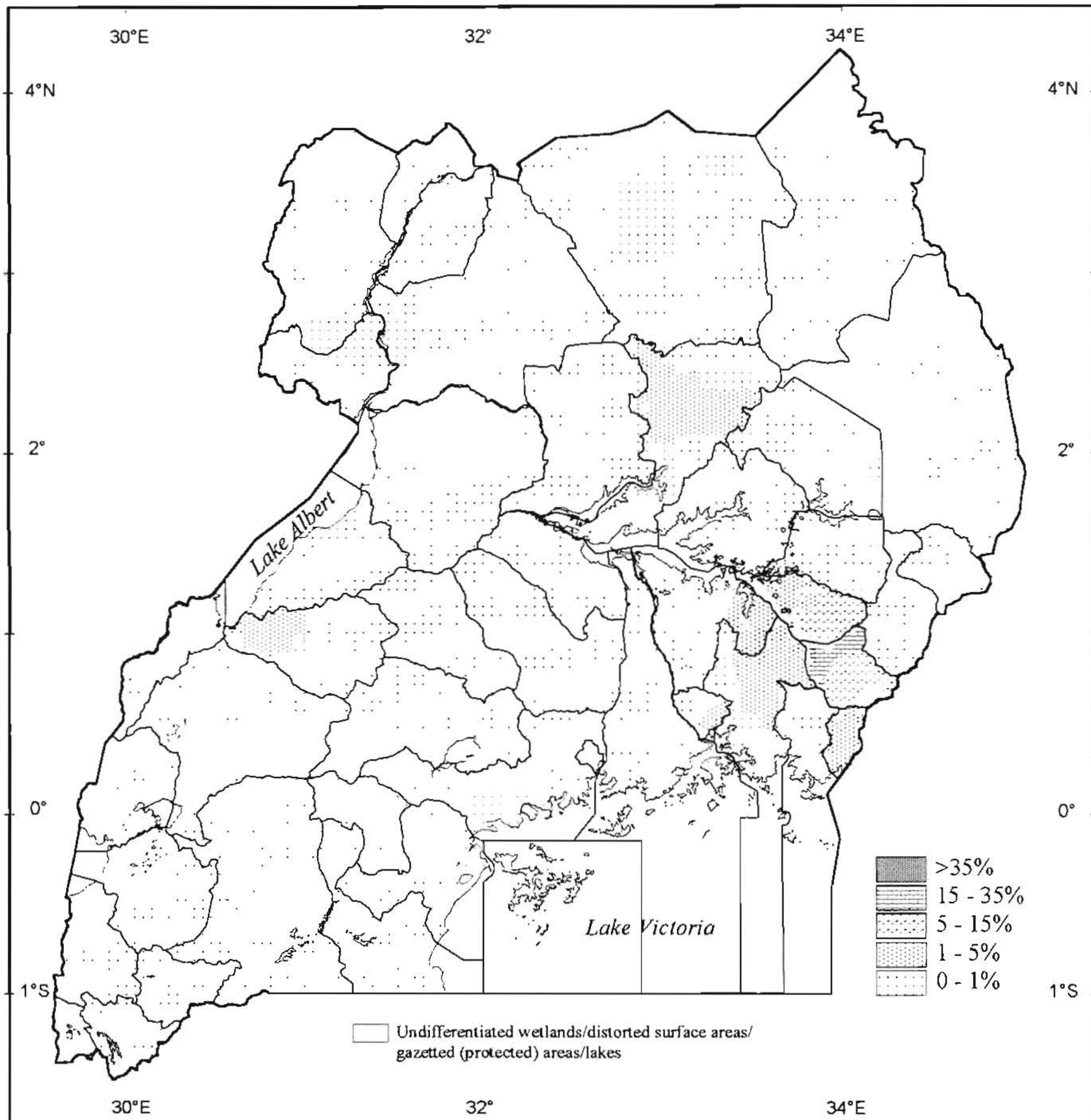
Map 15: Percent land area in Irish potatoes



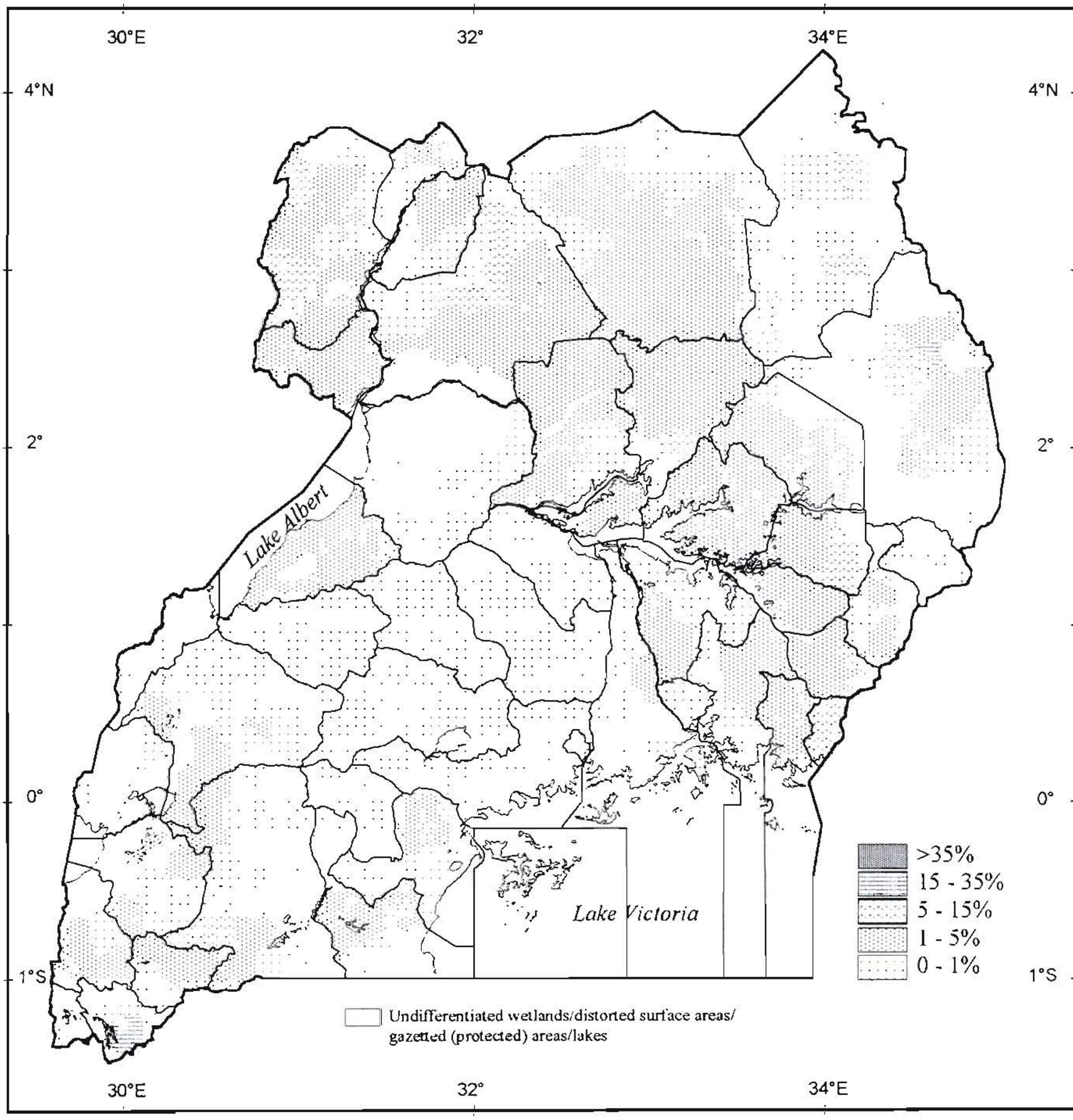
Map 16: Percent land area in maize



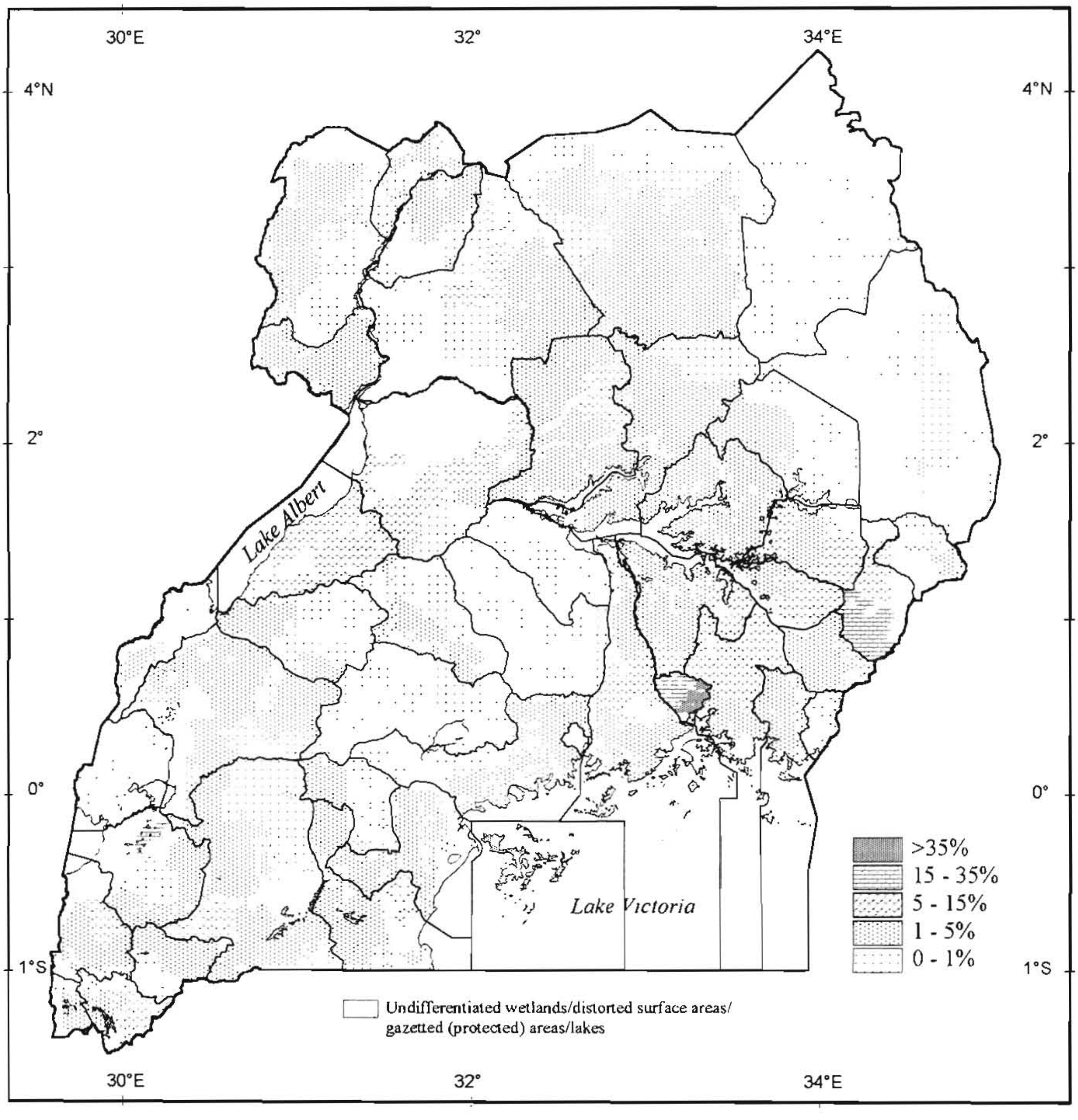
Map 17: Percent land area in rice



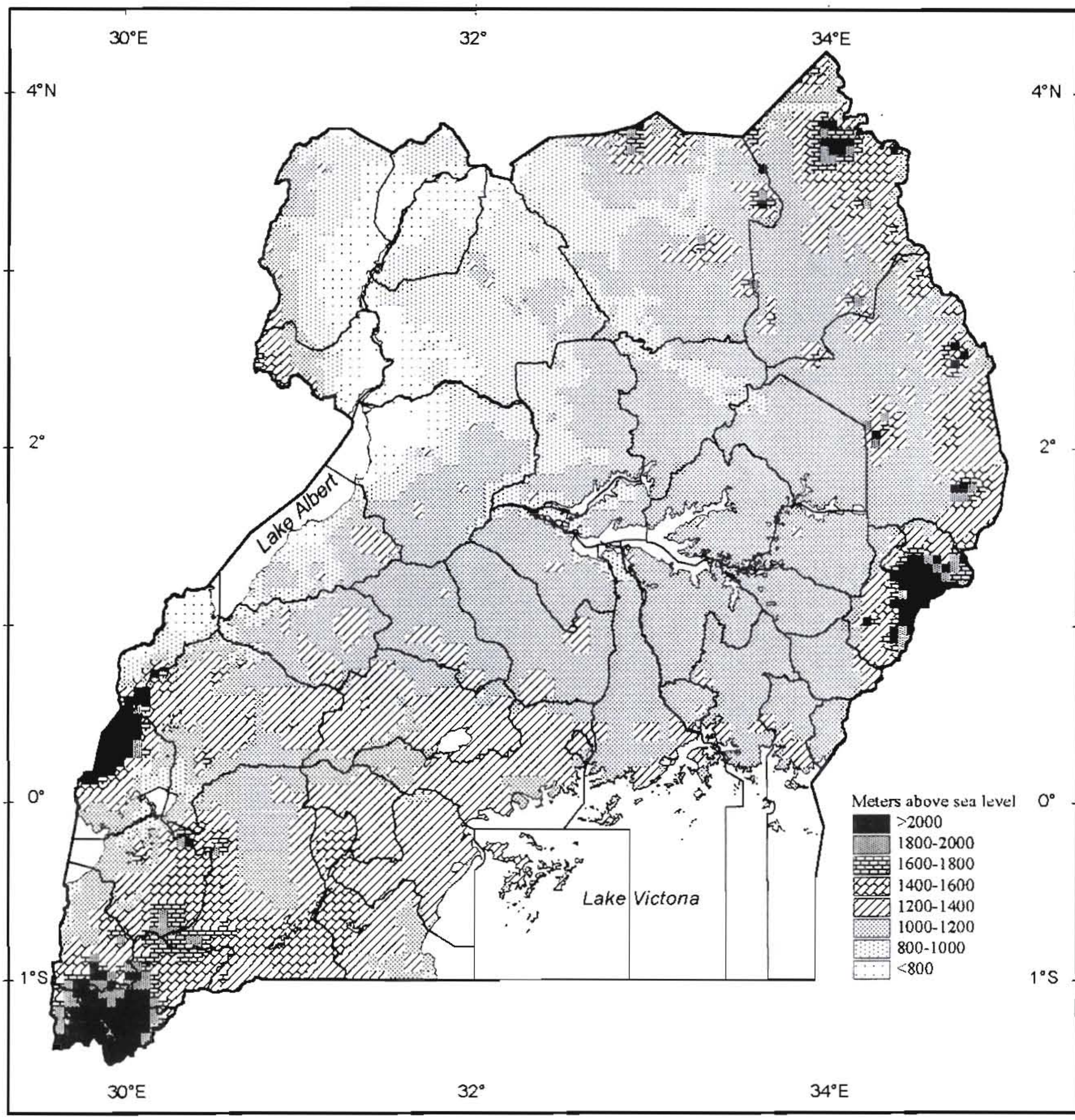
Map 18: Percent land area in sorghum



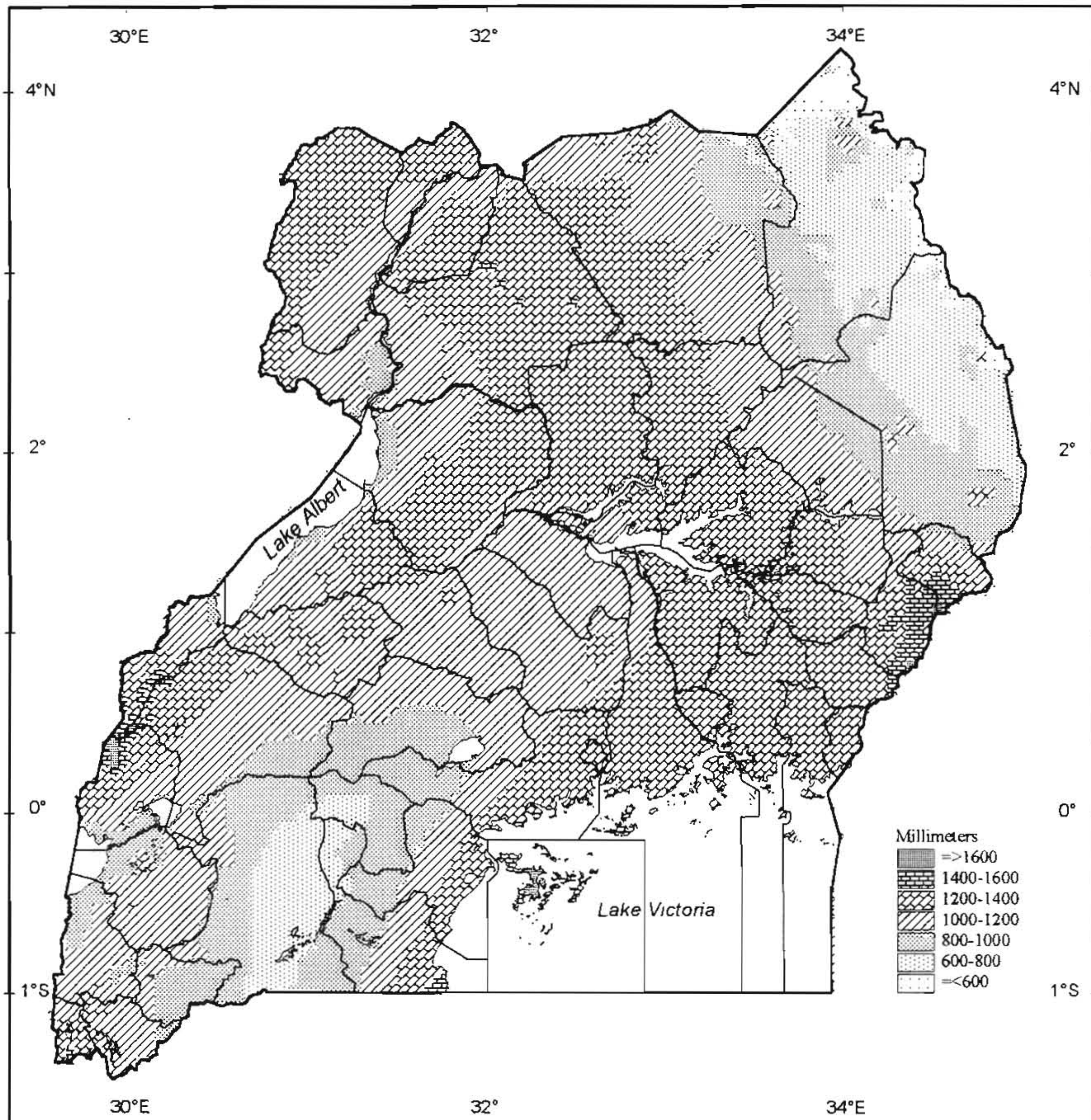
Map 19: Percent land area in sweet potatoes



Map 20: Elevation of Uganda



Map 21: Mean annual rainfall for Uganda



Map 22: Population density for rural areas of Uganda