Modeling factors that predict the distribution and density of ungulate species in the Queen Elizabeth National Park: Preliminary findings

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Introduction

Factors determining large mammal abundances

The ecological factors that determine animal densities in any particular area are many and varied. In general they can be grouped under the following categories:

a. Edaphic factors: soil, geology, water availability, fire etc
b. Food supply: availability of vegetation for herbivores and prey for carnivores
c. Disease: disease can play an important role in regulating populations
d. Human impacts: impacts of hunting or poisoning by man

There have been studies of large mammal abundances in many savanna protected areas in Africa over the years and their impacts on the vegetation coupled with the impacts of fire. However, not many savanna ecosystems have been studied in great detail to assess the factors that determine large mammal abundances. The main parks that have been studies intensively are Serengeti National Park in Tanzania and the Kruger National Park in South Africa.

There has been extensive work in the Serengeti National Park in Tanzania to assess the factors that drive the wildebeest and other antelope migration (Sinclair and Norton Griffiths, 1979; Sinclair and Arcese, 1995). This research over the years showed that rainfall and food availability, specifically mineral availability (particularly phosphorus) for reproduction were the main drivers of the migration. Research in Kruger National Park (Du Toit, Rogers and Biggs, 2003) showed that food availability, which was primarily affected by rainfall and fire were the main factors determining abundances of large ungulates although disease, particularly anthrax, also regulated population numbers.

Prior research in Queen Elizabeth National Park, Uganda

A lot of research was undertaken in Queen Elizabeth National Park in western Uganda in the 1960s and early 1970s. This research focused on the impacts of animals and fire on the vegetation and determined that grazing by elephants coupled with fire tended to open up the habitat and reduce woody vegetation cover (Lock, 1993). Conversely heavy grazing by hippopotamuses tended to reduce grass cover and encourage unpalatable woody shrubs (Lock, 1972). Experiments on the Mweya Peninsula in the late 1960s where the hippopotamus population was culled showed that the recovery of the vegetation allowed an increase in the abundance of other ungulates, particularly buffalos (Eltringham, 1974).

Some autecological studies have been undertaken on ungulate species: Waterbuck (Spinage, 1982), elephant (Field, 1971;Malpas, 1978), Hippopotamus (Klingel, 1991; Eltringham, 1999), Uganda Kob (Modha,1971; Balmford, 1992,; Balmford, Albon and Blakeman, 1992; Deutsch, 1994a,194b), buffalo (Grimsdell, 1969), Topi (Yoaciel, 1977; Yoaciel and Van Orsdol, 1981), bushbuck (Waser, 1975; Wronski *et al.*, 2006) and warthogs (Clough, 1969; Clough and Hassan, 1970). However none of these have estimated what factors determine their respective densities throughout the park.

Queen Elizabeth National Park

Queen Elizabeth National Park occurs within the Greater Virunga Landscape (Plumptre *et al*. 2007a), the most species rich landscape for vertebrates in Africa (figure 1). Contiguous with the Virunga Park in the Democratic Republic of Congo (DR Congo) these two parks contain more bird species than any other on the continent and the landscape as a whole contains more mammals than anywhere else in Africa (Plumptre *et al*. 2007a). In the 1960s the savanna areas of this landscape contained the highest biomass of large mammals per square kilometre ever recorded in the World.

Civil war in Uganda during the mid to late 1970s and early 1980s and then war in DR Congo from 1996 to 2006 decimated the large mammal populations. However, the transboundary nature of the Greater Virunga Landscape buffered the decline in ungulate numbers by allowing some individuals to see refuge over the international border when poaching was high (Plumptre *et al*. 2007b). As a result the populations in Queen Elizabeth National Park have recovered relatively quickly. Elephant numbers and most large ungulate densities are at levels similar to those estimated in the 1960s because of in migration from DR Congo.

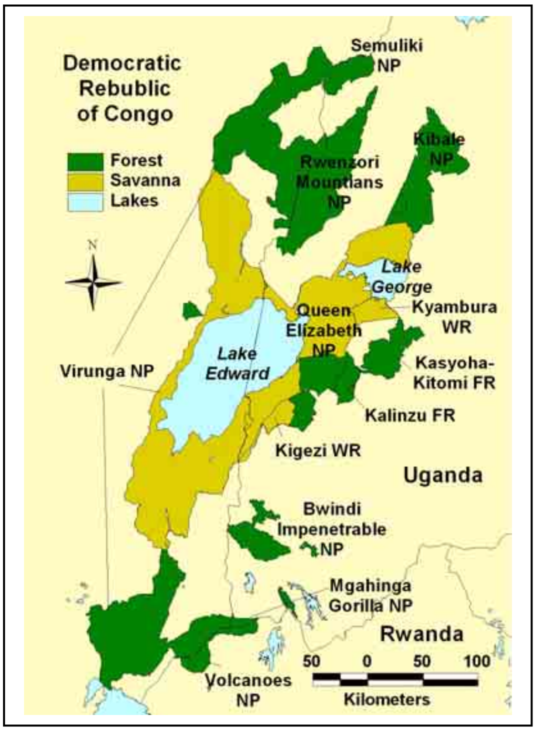

Figure 1. The Greater Virunga Landscape showing the location of Queen Elizabeth Park within the landscape, areas of savanna and forest cover and the international border separating this park from Virunga Park.

As a result of this in-migration it is likely that most ungulate populations are at or near carrying capacity in Queen Elizabeth Park while in Virunga Park they are very low because of rampant poaching by armed groups. In order to assess the factors that might affect population density in these ungulates there is a need to have populations at carrying capacity, otherwise they may not be constrained by any factors.

This study starts to assess how ungulates respond to habitat types and fire within the Queen Elizabeth National Park with the longer term aim of being able to predict animal densities for Virunga park when populations rebuild after the war.

Methods used

Vegetation mapping

In June 2006 an aerial mapping survey was undertaken using Enso Mosaic over Queen Elizabeth and the savanna portions of Virunga National Park. Enso Mosaic comprises a digital camera linked to a GPS and computer which can be programmed to take photos at regular intervals to allow an aerial photo coverage to be obtained. The images are then orthorectified and compiled into one mosaiced image in a computer which is georeferenced and can be imported into a GIS package (figure 2).

A 250 x 250 metre grid of cells was overlaid over this imagery in a Arcview 3.3 and then each cell assigned a vegetation type based upon visual interpretation by one observer (T. Akuguzibwe). The vegetation types assigned are given in table 1.

Table 1. Vegetation types, their codes and definitions assigned to aerial photo mosaics.

Code	Landcover Type	Description
PS	Papyrus Swamp	Dense Papyrus - more than 50% cover
OS	Other Swamp	Seasonally waterlogged areas with different vegetation - not papyrus
SF	Swamp Forest	Forest North of lake George that is permanently flooded
GL	Grassland	At least 20 m radius of grassland with no trees/shrubs
WG	Wooded Grassland	Between 10-50% woody cover - grassland under and between trees
WD	Woodland	More than 50% woody cover - grassland between trees
LF	Low Stature Forest	Trees and shrubs -at least 30% tree cover - trees generally less than 15 metres tall
HF	Tropical High Forest	Trees only and most canopy trees greater than 15 m
RF	Riverine Forest	Narrow strips of trees along streams and rivers
EU	Euphorbs	Euphorbia candelabra with at least 30% cover
SC	Bush / Scrub	Low stature bushes with little grass between - at least 50% cover
AB	Banana	Banana trees form at least 50% cover
AT	Tea	Tea forms at least 50% cover
AC	Coffee	Coffee/low stature tree crops form 50% cover
AP	Tree Plantation	Trees planted in rows - eucalyptus or pine
PG	Pastoralists grassland	Grassland used for grazing cattle, goats and sheep
AO	Other Agriculture	Any other short stature crops - cassava, potatoes etc
BE	Bare Earth	Less than 20% vegetation cover
SE	Settlement	Human habitation and bare earth/roadscovers at least 30% of land
SW	Salt Water	Crater lakes
WT	Water	Lakes

Figure 2. Example of Enso Mosaic product for Mweya Peninsula.

A vegetation map was produced for Queen Elizabeth and Virunga National Parks (figure 3) which was then used to assess associations by ungulates with different habitat types.

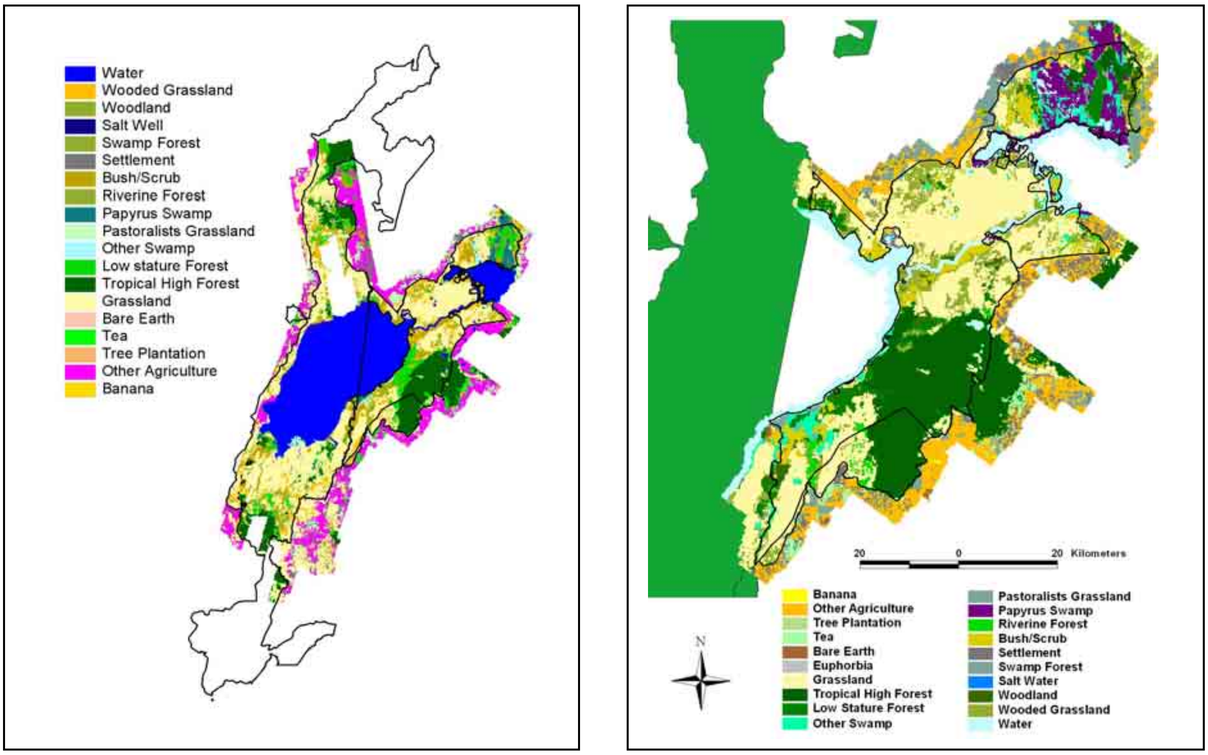

Figure 3. Vegetation map produced for the savanna and surrounding areas of the Greater Virunga Landscape (left) and a close up of Queen Elizabeth Park (right).

Animal densities

Since 1995 the Uganda Wildlife Authority has been undertaking aerial sample counts of wildlife in Queen Elizabeth National Park using a standardized grid flight system over the savanna areas of the park. The grid cell sizes are 2.5 x 2.5 km and the observers record all wildlife seen within each cell. During the processing of the aerial census data densities of different species are assigned to each grid cell as well as estimates for sectors of the park and the whole park.

Aerial sample counts have been undertaken in 1995, 1999, 2000, 2004, and 2006 using the same grid cells and it was therefore possible to calculate a mean density of each species per cell for these five censuses and also a mean was calculated for only animal densities from the three censuses from 2000-2006. Mean animal density was then plotted for these grid cells over the vegetation map to allow a visual assessment of relative abundance of the different species across the park (figure 4).

The vegetation map was created using 250 x 250 metre cells but the animal surveys use 2.5 x2.5 km cells. There are therefore 100 vegetation cells per animal survey cell. The number of cells of each vegetation type (equivalent to percentage) were then calculated for each animal survey cell using ArcView 3.3. This produced a file of percentage of each vegetation type per animal survey cell. The mean density of each animal species surveyed between 2000-2006 was then joined to this file, matching the filed by Cell ID to produce one file with vegetation data and animal density data.

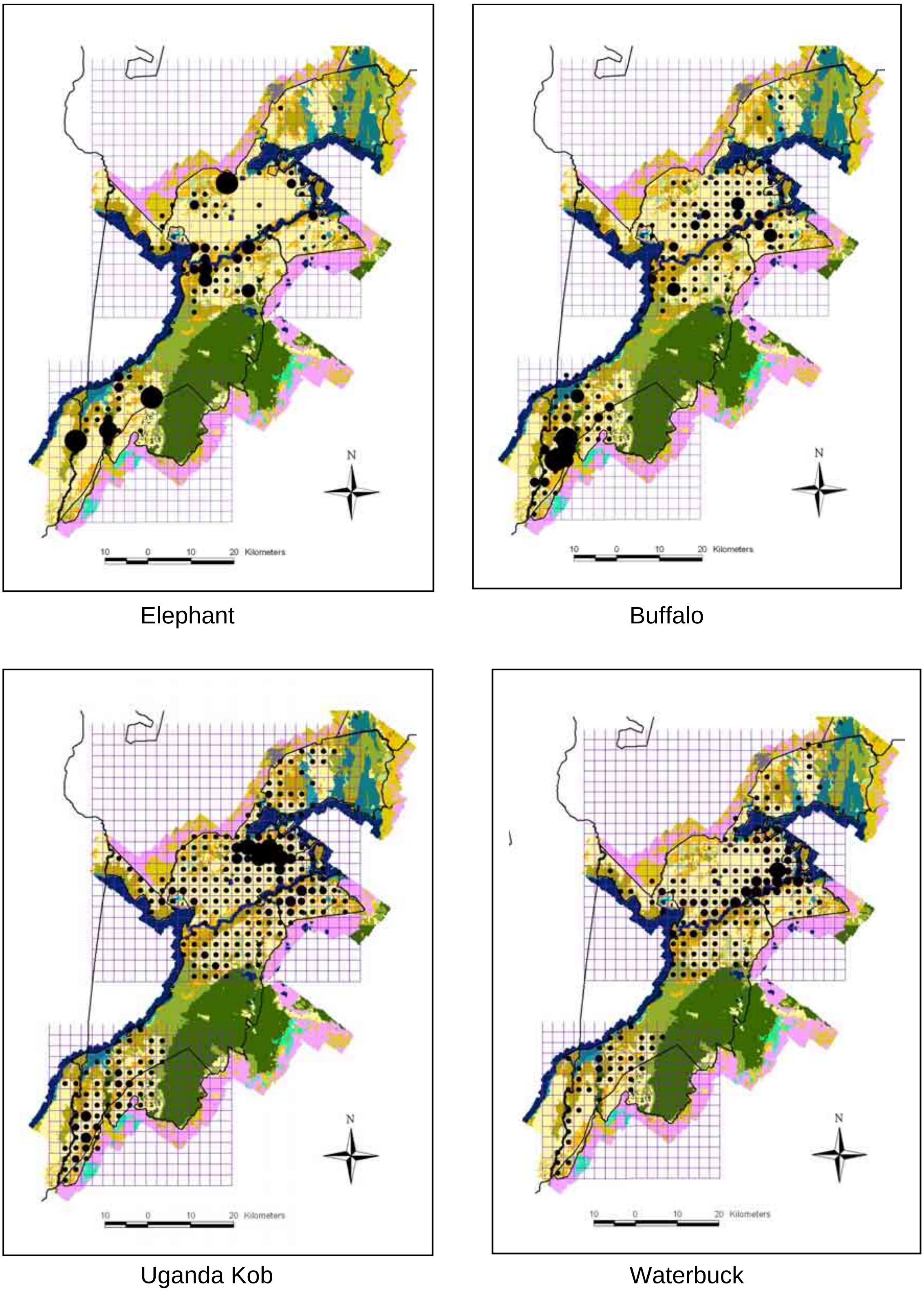

Figure 4. Relative abundances of four ungulate species in the Queen Elizabeth National Park, averaged over six aerial sample counts from 1995-2006.

Fire mapping
Woods Hole Research Centre (WHRC) digitized all fire scars at the end of dry seasons (Dec-Feb and Jun-Aug) from the early 1970s to the present day from Landsat quick look imagery. There are not many images available for the 1970s and early 1980s but in the 1990s there are more and WHRC were able to compile data for the whole of 2001-2007 (appendix 1).

The number of times an area burned was then mapped for the period 2001-2007 (figure 5).

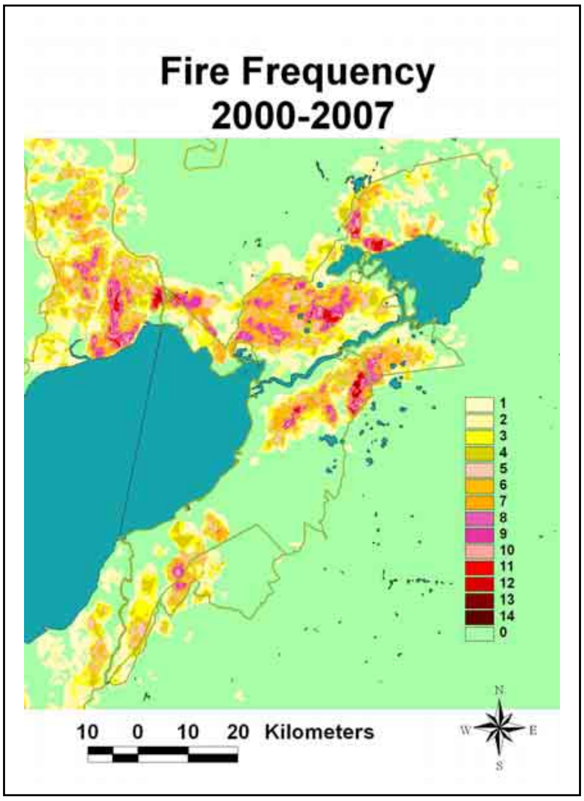

Figure 5. The frequency an area of the park has burned based on the compiled data from 2001-2007.

The frequency of burning per 2.5 x 2.5 km grid cell was then calculated as follows. Only data from within the park was used by clipping the fire layer to the boundary of the park. Raster data sets were then created for each season's burning at a 30 x 30 m resolution (because this was the original image resolution for Landsat imagery) and assigned a 1 if burnt or 0 if not burnt. These were then summed for the 2001-2007 period to calculate a burn frequency over this time period. The mean number of times a 30 x 30 metre cell burned was then calculated for cells within each 2.5 x 2.5 animal survey cell to produce a mean number of times burned. This value was then joined with the vegetation and animal census data.

Statistical analyses
The combined data for vegetation, mean animal density and mean burn frequency for the 2.5 x 2.5 km grid cells was analysed in SPSS 9.0 in two ways:

1. A multiple regression model was created and all available predictive variables (vegetation and burn frequency) were entered to develop a model that would predict each species density
2. A stepwise multiple regression model was calculated that selected those variables that best predicted the density of a species of animal and eliminated those variables that were redundant. A 5% entry/exit level was used.

All data were normalized where necessary using a natural log transformation.

Results

The results of the two regression models are summarized for each species and model in table 2. These show that the two regression models did not differ greatly except for Topi where the full entry of all variables was not significant. Topi only occur in the southern half of the park and only data from this region was used and the number of cells was therefore considerably fewer.

Table 2. Results of the regression models for each animal species. The R^2_{adj} value is equivalent to the proportion of the variation in density explained by the model.

Species	Model	R2 adj	F value	df	P
Elephant	1	0.080	3.03	15,337	<0.001
	2	0.099	10.64	4,348	<0.001
Buffalo	1	0.154	5.23	15,337	<0.001
	2	0.144	12.89	5,347	<0.001
Uganda Kob	1	0.421	18.07	15,337	<0.001
	2	0.416	36.76	7,345	<0.001
Topi	1	0.014	1.09	15,75	ns
	2	0.062	6.86	1,89	<0.01
Waterbuck	1	0.148	5.09	15,337	<0.001
	2	0.143	20.56	3,349	<0.001
Warthog	1	0.188	6.416	15,337	<0.001
	2	0.188	17.27	5,347	<0.001

Table 3. The variables selected in the stepwise regression model as being most strongly associated (positively or negatively) with the density of the animal species.

Species	Variables selected in regression model	
	Positively associated	*Negatively associated*
Elephant	Riverine Forest Bush/Scrub Wooded Grassland Woodland	
Buffalo	Grassland	Grassland with pastoralists Tropical High Forest Papyrus swamp Bush/Scrub
Uganda Kob	Burn frequency Grassland Settlement	Grassland with pastoralists Low stature forest Papyrus swamp
Topi	Wooded grassland	
Waterbuck	Wooded Grassland Grassland	Burn frequency
Warthog	Wooded grassland	Grassland with pastoralists Low stature forest Riverine Forest Burn frequency

The stepwise regression models selected a subset of variables that best predicted species densities (table 3). Those that were positively associated (selected), and those negatively associated (avoided) with species density. For Uganda Kob, Waterbuck and warthog burn frequency was an important predictor variable together with vegetation types but topi, buffalo and elephant did not appear to be distributed in relation to burn frequency.

Discussion

The models developed here predicted between 6-42 % of the variation in animal densities of the individual species. Uganda Kob had the best model with 42% of the variation predicted followed by warthog (18%), buffalo (15%) and warthog (14%). There is a need to identify other variables that may be important in predicting species distributions to better refine these models. One variable we plan to use is distance to water which could be important for some species.

The frequency with which the park burns does deem to be important for some species and was selected in three of the stepwise regression models. Uganda Kob are found in the areas that burn most frequently while warthogs and waterbuck tend to be at higher density in areas that burn least frequently. This is probably linked to the vegetation composition of these areas. WCS field staff will be visiting areas that have been burnt at different frequencies over the past 7 years to assess whether plant species differ greatly in these areas in relation to the burn frequency in the near future.

This report is a summary of preliminary findings and will be improved over the coming year as more data and variables are incorporated.

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Appendix 1. Summary of imagery used to derive statistics of fire extent in Elizabeth National Park.

Landsat Image Tile 173_60
Statistics for entire tile (not just within Queen Elizabeth NP boundary)

Burn Season 1 = December (y-1) – April
Burn Season 2 = May - November

1970s

Burn Season	# of Burns	Min. Burn Area (km^2)	Max. Burn Area (km^2)	Avg. Area (km^2)	Total Area Burnt (km^2)	# of Images Used	Image Date(s) - dd/mm/yyyy
Season 1 - 1973	61	0.34	45.72	6.63	404.20	1	2/4/1973
Season 1 - 1975	50	0.30	152.96	9.87	493.29	1	3/12/1975

1980s

Burn Season	# of Burns	Min. Burn Area (km^2)	Max. Burn Area (km^2)	Avg. Area (km^2)	Total Area Burnt (km^2)	# of Images Used	Image Date(s) - dd/mm/yyyy
Season 1 - 1984	25	1.09	208.24	28.78	719.59	1	2/12/1984
Season 2 - 1984	18	0.45	8.32	3.64	65.54	1	5/26/1984
Season 1 - 1986	10	1.35	46.85	13.93	139.25	1	1/8/1986
Season 2 - 1986	65	0.15	141.77	9.14	594.04	3	6/1/1986, 7/19/1986, 8/4/1986
Season 1 - 1987	42	0.03	61.68	14.98	629.23	3	1/27/1987, 2/28/1987, 3/16/1987
Season 2 - 1987	97	0.22	57.15	8.87	860.41	6	5/3/1987, 5/19/1987, 6/7/1987, 8/7/1987, 9/8/1987, 10/2/1987
Season 2 - 1988	7	0.72	23.74	6.00	41.99	1	5/29/1988
Season 2 - 1989	120	0.47	34.98	5.37	644.88	4	7/3/1989, 8/4/1989, 8/20/1989, 9/21/1989

1990s

Burn Season	# of Burns	Min. Burn Area (km^2)	Max. Burn Area (km^2)	Avg. Area (km^2)	Total Area Burnt (km^2)	# of Images Used	Image Date(s) - dd/mm/yyyy
Season 1 - 1990	24	0.44	17.23	3.88	93.17	1	4/17/1990
Season 2 - 1990	33	0.56	12.47	3.34	110.26	1	6/4/1990
Season 2 - 1994	24	1.45	27.63	6.74	161.76	1	8/10/1994
Season 1 - 1995	92	0.40	52.62	6.36	585.15	3	1/17/1995, 2/2/1995, 2/18/1995

Season 1 - 1999	32	1.75	78.73	17.14	548.58	1	2/13/1999

2000s

Burn Season	**# of Burns**	**Min. Burn Area (km^2)**	**Max. Burn Area (km^2)**	**Avg. Area (km^2)**	**Total Area Burnt (km^2)**	**# of Images Used**	**Image Date(s) - dd/mm/yyyy**
Season 1 - 2001	36	0.72	66.19	15.84	570.39	2	3/14/2001, 1/9/2001
Season 1 - 2002	6	1.14	12.37	3.54	21.22	1	12/11/2001
Season 2 - 2002	19	0.55	26.86	5.86	111.30	2	7/23/2002, 10/11/2002
Season 1 - 2003	65	0.60	220.64	13.90	903.46	4	12/30/2002, 1/15/2003, 1/31/2003, 3/4/2003
Season 2 - 2003	4	11.26	92.56	40.38	161.51	1	10/14/2003
Season 1 - 2004	58	0.86	62.29	13.18	764.62	5	12/17/2003, 2/19/2004, 3/6/2004, 3/22/2004, 4/7/2004
Season 2 - 2004	23	1.17	38.49	12.20	280.67	2	10/6/2004, 12/7/2004
Season 1 - 2005	115	0.26	127.78	11.02	1266.74	4	1/4/2005, 1/20/2005, 2/5/2005, 2/21/2005
Season 2 - 2005	64	0.51	64.46	9.88	632.21	5	6/13/2005, 6/29/2005, 7/15/2005, 9/1/2005, 9/17/2005
Season 1 - 2006	76	0.85	97.32	10.87	825.79	3	12/22/2005, 1/23/2006, 2/8/2006
Season 2 - 2006	73	0.64	39.69	7.64	557.46	5	7/2/2006, 8/19/2006, 9/4/2006, 9/20/2006, 10/6/2006
Season 1 - 2007	33	0.82	59.98	13.25	437.18	3	1/26/2007, 2/27/2007, 3/15/2007
Season 2 - 2007	33	0.08	36.00	4.06	133.89	3	7/21/2007, 8/6/2007, 11/26/2007