Interactions between fire and flooding in a southern African floodplain system (Okavango Delta, Botswana)

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Abstract

A series of 98 satellite images was analysed to reconstruct the fire and flood history of a floodplain system in southern Africa (Okavango Delta, Botswana). The data was used to investigate interactions between fire and flooding, and to determine the relevance of rainfall and flood-events for fire occurrences on floodplains and on drylands. The aims of the study are (1) to analyse and compare the fire frequency on floodplains and on adjacent drylands, (2) to investigate the influence of rainfall and flooding on the fire occurrence and (3) to determine correlations between fire frequency and flood frequency. The analyses show higher fire frequencies on floodplains than on drylands because of higher biomass production and fuel loads. The fire occurrence on drylands shows a correlation with annual rainfall events, while the fire frequency on floodplains is in principle determined by the flood frequency. Between floodplain types, clear differences in the susceptibility to fire where shown by analysing flood frequency vs. fire frequency. Here, the highest potential to burn was found for floodplains that get flooded about every second year. By calculating mean fire return intervals, the potential to burn could be specified for the different floodplain types.

Introduction

Vegetation fires are important ecological factors in many parts of the world and can, in principle, occur under most climate regimes (Bond and van Wilgen 1996). But global observations have shown that most biomass burning occurs in the tropics and subtropics, especially in savannas (van de Vijver 1999). Typical for this biome are a hot wet season of four to eight months and a warm dry season for the rest of the year (Nix 1983). These climatic conditions are often responsible for extensive and regular fires common to savannas (Scholes 1997; van Wilgen 1997). During the rainy season, vegetation grows rapidly and accumulates fuel loads that are susceptible to burning during the dry season.

While the dry season in savanna regions is simply the period of potential burning, the amount of water available during the wet growing season strongly determines the biomass accumulation and therefore affects the chance of fire. Direct dependencies between rainfall, as prerequisite for fuel accumulation, and fire was found by van Wilgen and Scholes (1997), who describe a positive relationship between rainfall, biomass production and fire frequency. Similar trends are described by Du Plessis (1997); van Wilgen et al. (2003) and van Wilgen et al. (2004). Also for Bond (1997), fire frequency in southern Africa follows a productivity gradient, which is determined by a rainfall gradient.

However, all these studies use rainfall just as a surrogate for fuel accumulation. Despite the accepted applicability of this approach for most savanna regions, other factors or even other sources of moisture, besides rainfall, have to be considered for fuel accumulation where relevant. Following the approach of using water availability for fuel load estimations, especially seasonal floodplain systems deserve special consideration. They usually show a clear difference to adjacent non-flooded areas in terms of the amount of water available, the season of water availability and soil properties. In addition, the associated floodplain vegetation differs clearly from non-flooded areas and often consists of unpalatable sedges. This reduces biomass off-take by herbivores and leads combined with the usually higher rates of biomass production on floodplains to higher fuel loads, which in turn should lead to higher fire frequencies and different fire regimes compared to non-flooded areas.

The aims of the present study are therefore to

(1) compare the fire frequency on floodplains and on adjacent drylands. It is hypothesised, that the fire frequency on floodplains is significantly different to the fire frequency on adjacent drylands despite the same amount of rainfall;
(2) investigate the influence of rainfall and flooding on the fire occurrence on floodplains and drylands, hypothesising that on drylands fire occurrences are positively correlated with the amount of rainfall, and on floodplains fire occurrences are positively correlated with the extent of the flooding;
(3) determine correlations between fire frequency and flood frequency independent of rainfall.

These analyses should lead towards refining the present approach on estimating fire frequencies – but also towards improving the knowledge about biomass burning, especially for wetlands. Although floodplain systems or temporal wetlands in general might be a minority in savanna areas, they are of significant importance for the ecology of arid or semi-arid environments (e.g. Okavango Delta (Botswana), Kafue Flats (Zambia), Kakadu National Park (Australia)). They therefore deserve attention and a separate consideration in burning assessments. Scholes et al. (1996) have already indicated the differences of fire regimes on wetlands and drylands, but only single studies (e.g. Russell-Smith et al. 1997) are available on fire regimes, specific to floodplains or temporal wetlands. With a more detailed understanding of specific fire regimes, not only certain wetlands can be protected and managed more effectively, but also global estimations on biomass burning might be more precise, as wetlands contribute a significant part to the total biomass consumed by fire (Scholes et al. 1996).

For the present study, the Okavango Delta in Botswana was chosen as the study area. This large wetland in southern Africa experiences many fires every year and provides a mosaic of seasonal floodplains that allow comparative studies of areas with different flood and fire frequencies. Besides its suitability for the aims of the study, the Okavango Delta itself acts as own important study object. Ecological research in the Okavango Delta has mainly focused on the hydrology of the wetland system (e.g. McCarthy et al. 1998; Ellery et al. 1993) and scientific knowledge about frequency and distribution of vegetation fires are currently not available. The present study therefore provides initial insights into the relationship between the fire frequency and the flood regime, so that mean fire return intervals for the floodplains of the Okavango Delta can be derived. This should lead to a better understanding of the driving ecological forces in the Okavango Delta and help to manage and protect this unique wetland system in times of rising anthropogenic pressure.

Study area

The Okavango Delta is situated in northern Botswana (Ngamiland District) in southern Africa approximately between E22.0°–E24.0° and

S18.5°–S20.5° (Figure 1). The vast tropical wetland in the central Kalahari is supplied by the Okavango River, which has its catchment in central Angola. The mean annual rainfall is 490 mm, and the season of rainfall is typically from November to March (McCarthy et al. 2000).

The Okavango Delta is an alluvial fan with a very low elevation gradient (app. 1:3300; (McCarthy et al. 2000)) over the whole extension of roughly 15,000 km^2, forming a wetland composed of an intricate system of channels, lakes, floodplains and elevated dry islands. The water inflow into the Okavango Delta system through the Okavango River as well as the annual amount of rainfall is highly variable. As a consequence, there are strong annual shifts in the water distribution, with dry areas becoming inundated and swamps being desiccated regularly. At the distal reaches of the permanently flooded areas the intensity and duration of the flooding decreases and the permanent swamps change to seasonal swamps and irregularly inundated floodplains (Ellery et al. 2003). These floodplains in the southern, drier section of the Okavango Delta are primarily the focus area of the present study (Figure 1). The habitats range from small permanently flooded swamps and channels, dominated by *Phragmites* ssp. and aquatic herbs (e.g. *Nymphaea* ssp., *Potamogeton thunbergii*) to regularly inundated floodplains, dominated by sedges (e.g. *Cyperus articulatus*, *Schoenoplectus corymbosus*) and old floodplains that have not been flooded for years, dominated by grasses (e.g. *Eragrostis* ssp., *Panicum* spp., *Stipagrostis uniplumis*) with scattered shrubs and trees (e.g. *Pechuel-loeschea leubnitziae, Acacia* spp.). Besides these Okavango floodplains, a large portion of the study area is covered by typical savanna vegetation, with *Acacia* spp. or *Colophospermum mopane*, unaffected by the floodwaters from the Okavango River.

Fires are common phenomena throughout the entire study area. Main fire season is from the middle to the end of the dry season, i.e. roughly from June to September. The fires are almost exclusively surface fires, supported by grasses and small shrubs and trees. Natural ignition is rare and most fires are of anthropogenic origin, as access to natural resources in this area is often dependent on burning, e.g. fishing, hunting, etc. (Cassidy 2003; Heinl et al. 2006). Burning is usually just applied to small areas and the fires then spread uncontrolled where they are supported by accumulated biomass. Due to a general burning prohibition, fires are usually considered as accidental.

The study area in the Okavango Delta provides a regime of infrequent flooding and uncontrolled

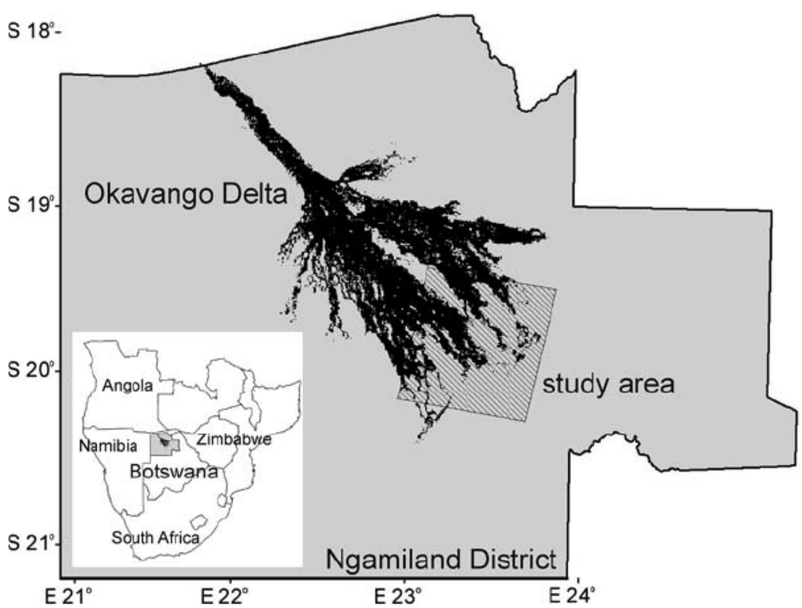

Figure 1. Location of the study area. The central quadrate indicates the study area in the southern part of the Okavango Delta fan in northern Botswana (Ngamiland District), southern Africa.

burning, which leads to a fine-scaled mosaic of areas with different flood and fire frequencies and therefore offers excellent opportunities to investigate the relationships between burning and flooding.

Material and methods

The analysis of the temporal and spatial distribution of fires as well as the calculation of fire and flood frequencies require a detailed knowledge about the fire and flood history of the study area. Since no comprehensive documentation is available for fires in the Okavango Delta region, the fire and flood history was reconstructed using remotely sensed data.

A series of 98 satellite images (91 Landsat Thematic Mapper (TM, ETM+) and 7 EO-1 Advanced Land Imager (ALI) scenes) with a spatial resolution (pixel size) of 30×30 m were used to determine flooded and burned areas for a 15-year period from 1989 through 2003. The study area is represented by the upper left quarter of the Landsat scene 174/074 with an extent of approximately 6141.1 km^2. Limited by cloud cover and technical availability, at least five images evenly distributed over the year could be used for each year. A minimum frequency of images of about 2 months would be required, as preliminary studies have shown that fire scars in this area are difficult to detect after an 8 weeks period both on the ground and in the imagery. However, both fire activity and especially the flooding in the southern Okavango Delta is most extensive during the dry season, for which most images were available, so that an adequate temporal cover of images for the detection of fires and the inundated areas could be achieved.

Detection of burned and flooded areas was extracted from a 40-class unsupervised classification (ISODATA) of the georeferenced satellite images. Three bands, representing the mid-, near- and thermal infrared wavelengths (Landsat TM bands 4, 7 and 6, respectively) were included into the classifier, which showed the best approximation on preliminary assessments of burned and flooded areas in 2001. Annual fire and flood distribution maps were generated from the image analyses using ArcView 3.2 software. The fire distribution maps contain information about the spatial extent and the date of each fire, while the flood distribution maps show all areas inundated for the particular year. Fire frequency and flood frequency maps were generated by summarizing recoded annual fire and flood distribution maps, using ENVI 3.4 software. Areas (pixels) identified with similar fire or flood frequency were grouped into frequency classes. The number of the class represents the number of burns or floods during the 15-year period. Hence, areas burned/flooded for example seven times in the 15-year period are named as fire/flood frequency class 7. Rainfall data were provided by the Harry Oppenheimer Okavango Research Centre in Maun, Botswana. Mean annual rainfall over the study area was approximated by the average of the Maun and Shakawe records as suggested by McCarthy et al. (2000). For statistical analyses, SPSS 11.0 software was used.

Results and discussion

Distribution of fire and flood frequencies

The analyses of the distribution of the flood frequency classes over the study area showed that areas never flooded (flood frequency class 0) during the 15-year period account for 75.4%. Flood frequency class 1 accounts for 7.5%, while the areas flooded 2 times or more (classes 2–15) show almost similar cover values between 2.7 and 0.6% of the study area (Figure 2). Responsible for the higher values of class 1 is one extensive flood-event in 1989, which inundated areas that were never recorded as flooded again until 2003. Flood frequency class 15 covers basically permanent channels and lakes, but also regularly inundated floodplains.

The flood frequency was used to divide the study area into two basic landscape units, that is drylands and floodplains. Drylands were defined as areas that were never flooded during the 15-year study period (flood frequency class 0; 75.4%), while as floodplains all areas with at least one flood-event were considered (flood frequency class 1–15; 24.6%).

Analysing the distribution of the fire frequency classes revealed no fire activity for almost half of the study area (Figure 3). The maximum number of burns for a single area during the 15-year study period was 10. The fire frequency classes 5–10 account for less than 5.0% of the study area, with

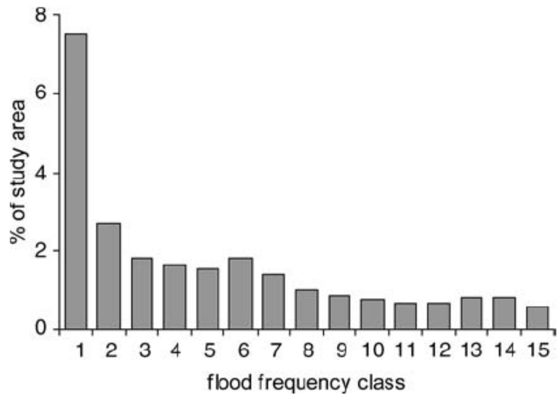

Figure 2. Distribution of the flood frequency classes within the study area. The flood frequency classes represent the number of floods during the 15-year study period.

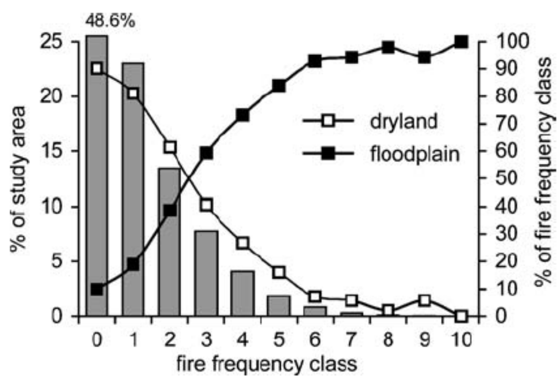

Figure 3. The distribution of the fire frequency classes within the study area (grey bars on primary axis). The lines with markers, corresponding to the secondary axis, show the portion of floodplains and drylands within each fire frequency class. The fire frequency classes represent the number of burns during the 15-year study period.

the fire frequency classes 7–10 even covering less than 1.0%. However, with a study area of more than 6000 km^2 these classes still constitute more than 60 km^2 and are therefore still considerable. The distribution of floodplains and drylands within each fire frequency class differed significantly (Figure 3; secondary axis). The fire frequency classes 0 and 1 show a clear trend of being represented by drylands, which account for more than 80% (90.1 and 81.2%, respectively) of each of the fire frequency classes. In contrast, floodplains dominate the fire frequency classes 5–10, accounting also for more than 80% of each class (83.9, 92.8, 94.3, 97.9, 94.2 and 100%, respectively). Areas with the maximum frequency of 10 fire records during the study period were solely found on floodplains.

This analysis shows that areas with a low fire frequency are mainly covered by drylands and areas with a high fire frequency are basically located within floodplains. Therefore, as hypothesised, a significant difference in the fire frequency of floodplains and drylands exist and a trend towards higher fire frequency on floodplains can be derived, despite the same amount of rainfall on both floodplains and drylands.

Fire frequency vs. rainfall and flooding

The preceding analysis showed the differences of floodplains and drylands in terms of fire frequency, despite a similar rainfall. However it cannot be concluded, that rainfall has no effects on the fire occurrence and that flooding is automatically the determining factor for the fire frequency. Therefore, to investigate the influence of rainfall and the extent of flooding directly on the fire occurrence on floodplains and on drylands, the burned area is set into relation to the extent of flooding and rainfall on a yearly basis. Rainfall over the preceding wet season shows a significant positive correlation to the area burned on drylands ($r_S = 0.55$; $p = 0.03$; Figure 4) and no correlation to the burned area on floodplains. No significant correlation was found between the extent of the flooding and the area burned on floodplains or on drylands.

Hence, as hypothesised, a direct effect of rainfall on the extent of the annual burns on drylands can be observed, whereas on floodplains, the extent of the fire is not directly dependent on the rainfall. But, for floodplains, also the extent of the flooding showed no correlation to the annual extent of burned areas. The formerly stated relation of high fire frequencies on floodplains, indicating a general trend towards wetter areas burning more often, was therefore not observed on a yearly basis. Areas, that get flooded during a particular year, do not necessarily show a high probability to burn in this particular year.

Comparing fire on drylands and floodplains

The comparison of drylands and floodplains, as defined for the present study, revealed clear

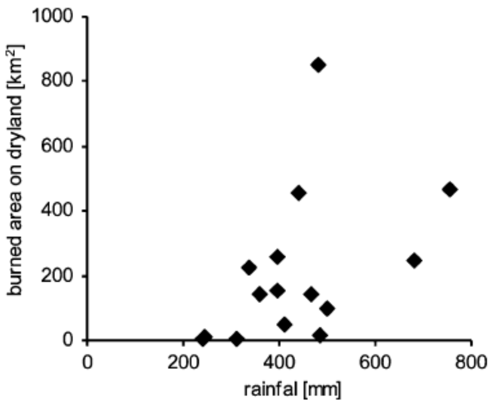

Figure 4. Relationship between the extent of the burned area on drylands and the amount of rainfall over the preceding rainy season for 1989–2003.

differences in their susceptibility to burning, and this susceptibility seems to be dependent on the time-scale considered.

On drylands, burning seems to be directly affected by the amount of rainfall over the preceding rainy season (Figure 4). The amount of rainfall, falling typically at the beginning of the year, affects immediately the biomass production, so that high fuel loads are present after the growing season, supporting fires during the dry fire season. Responsible for the immediate effects on the fire occurrences are probably fast growing and productive grass species (e.g. *Urochloa mosambicensis*), which are able to grow and seed quickly after rainy periods. In 2004, a year with exceptionally high rainfall and several separated wet periods during the rainy season, even the development of several plant generations, which multiplied fuel loads, could be observed (pers. obs. MH).

For floodplains, no such direct dependence of the extent of the burned area on the amount of rainfall was observed. Also the extent of the flooded area did not correspond with the burned area for the particular years. Nevertheless, higher fire frequencies were observed on floodplains than on drylands. Therefore, it is expected that burning on floodplains does not immediately respond to a sudden availability of fuel loads (as it was observed for drylands), but is rather following a trend dependent on mean fuel loads in the long run. In contrast to the drylands, most floodplains of the Okavango Delta do not experience a distinctive dry period and hence, large fluctuations in water availability throughout the years are small. Thus, there are no significant changes in standing biomass for particular floodplains observed over the years. However, the variety of floodplain types is high. The broad class of floodplains, as defined for this study, ranges from irregularly inundated grasslands with scattered shrubs to annually flooded wetlands, dominated by tall sedges or reeds. And these differences are not due to the annual flood or rainfall events, but are determined by the long-term water supply of these habitats. The fire frequency on floodplains should therefore be dependent on the flood frequency, as water availability is the factor that, in principle, determines the vegetation on floodplains and that is also responsible for the variety in the amount of fuel load.

Comparing drylands and floodplains showed a trend of higher fire frequencies on the floodplains. But do the floodplains themselves follow this trend of the wetter areas burning more often, that is, is there a linear positive correlation between the flood frequency and the fire frequency on floodplains? Theoretically, permanently flooded areas should then show the highest fire frequencies – but this is unlikely. To investigate this correlation between flooding and burning, the floodplains are analysed more detailed and subdivided according to their flood frequency.

Interdependence between flood frequency and fire frequency

For comparative analyses of flood and fire frequency, the study area was divided into regions with different flood frequencies. For each of these flood frequency classes, the mean number of burns was calculated to show how often an area with a certain flood frequency burned on average (Figure 5a). The fire frequency shows an obvious correlation to the flood frequency. The results indicate a trend towards lower fire frequencies for the lowest and highest flood frequency classes, with the highest fire frequencies occurring at intermediate flood frequencies, i.e. areas that are flooded about every second year. Therefore, there is no linear correlation between the fire and flood frequency, and hence the general trend of wetter areas burning more often is not supported. However, the drier sections (flood frequency classes 0–7) show a steady rise of the fire frequency with the

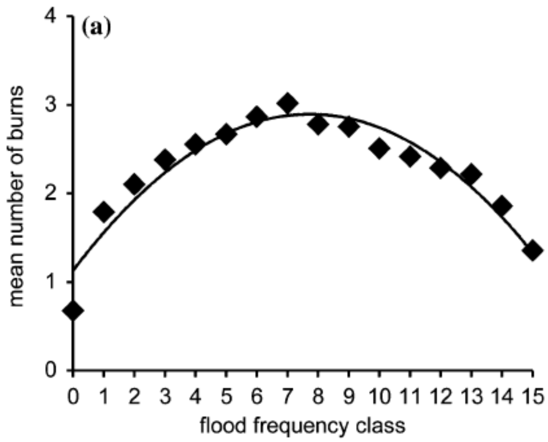

Figure 5. The calculated mean number of burns for each flood frequency class (a) and the calculated mean number of floods for each fire frequency class (b). 30×30 m pixels were used as sample units (N=9498560). The black line shows the regression curve (r^2_A = 0.913, r^2_B = 0.964).

wetness of the classes. There, flooding supports burning, most likely since more fuel load is available in areas with higher flood frequencies. In contrast, for the areas that get flooded more than every second year (flood frequency classes 8–15), the flooding already seems to suppress the fires. As a decline in biomass production on these sites cannot be expected, the areas are simply to wet to burn regularly, as the inter-flood intervals get shorter.

Similar to the flood frequency classes, the fire frequency classes were analysed to show how often an area with a certain fire frequency was flooded on average (Figure 5b). Fire frequency and mean flood frequency show an almost linear relation (r^2 = 0.989) for the areas 0–6 times burned (fire frequency classes 0–6), with the more often an area was burned, the higher the mean number of floods. Since these fire frequency classes account for more than 99% of the study area, they reflect a clear trend towards areas with higher fire frequencies being represented by high flood frequency classes. Nevertheless, the fire frequency classes 7–10 should not be neglected. Interestingly, for all these classes, about the same mean number of floods between 5.3 and 5.8 were calculated, not following the just described trend of rising flood frequency with fire frequency. Moreover, these fire frequencies seem to be independent of the flood frequency and thus, other factors than the accumulated biomass, which is dependent on the flooding, have to be made responsible for these high fire frequencies. It can only be hypothesised, that these areas that were burned seven times or more are the centres of anthropogenic ignition sources and the points from which most of the fires spread.

An estimate on the general burning capacity of the floodplains can be drawn by summarizing these findings: The areas flooded about every second year (flood frequency class7) show the potential to support the most fires, while the maximum number of fires that is supported by this vegetation type is six. Hence, areas that burned more often than six times during the 15-year study period were most likely forced to burn.

To specify these findings, a matrix was generated, that describes the distribution of the fire frequency classes within each flood frequency class. Following these analyses, the fire frequency classes can be grouped into three categories (low, mid and high fire frequency), with each category showing a typical distribution over the flood frequency classes (Figure 6). Low fire frequencies, i.e. the fire frequency classes 0 and 1 (Figure 6a), are basically located in the "extremes" of the flood frequency, that is the dry section (classes 0 and 1) and the wet section (classes 12–15). These two fire frequency classes summarized (classes 0 and 1), account for more than 40% of each of these "extreme" flood frequencies. In contrast, for the intermediate flood frequency classes 6–8, the portion of the fire frequency classes 0 and 1 are lowest. Hence, simplified, in the extremely dry and wet parts of the study area, fire is rare whereas in

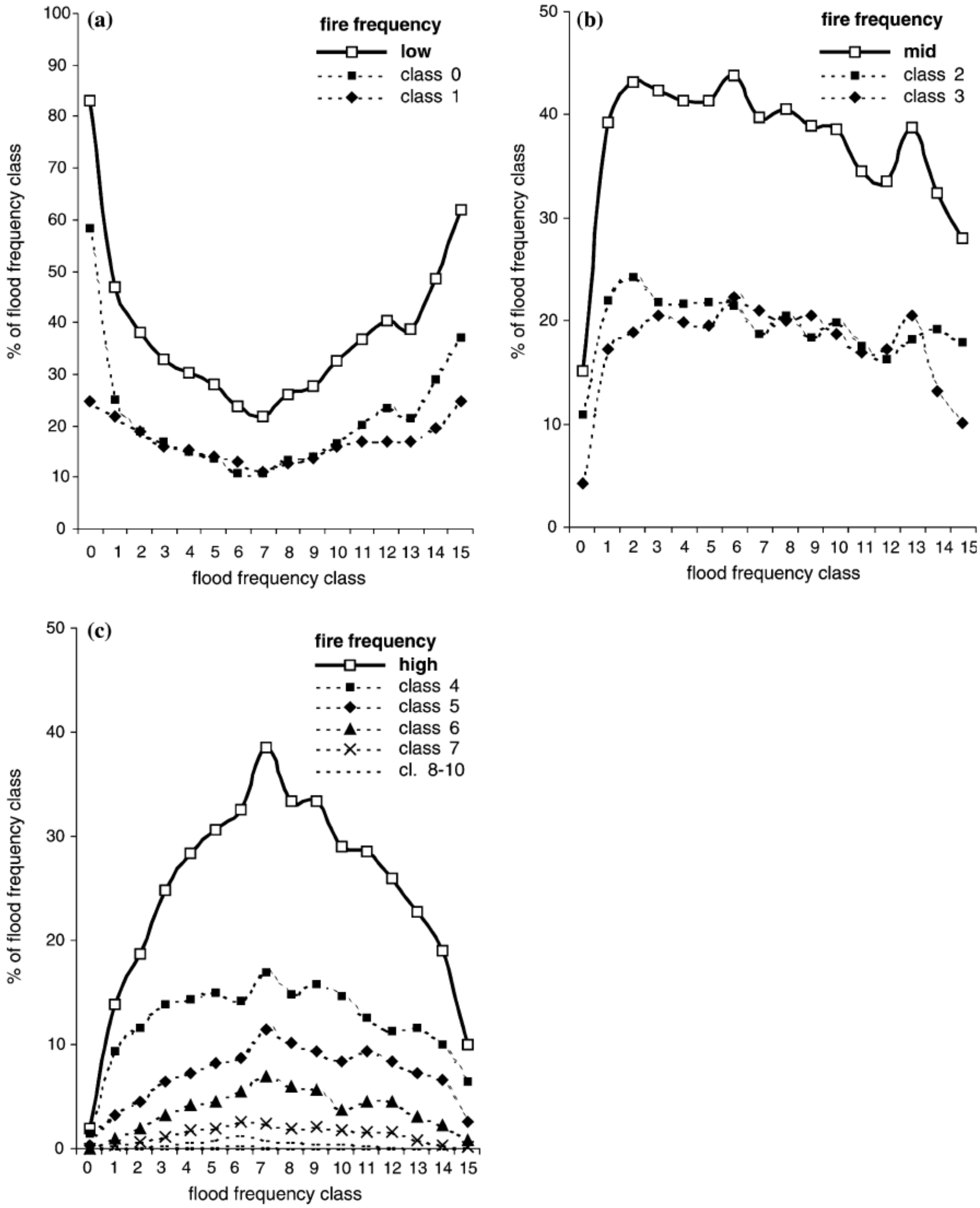

Figure 6. The distribution of fire frequency classes (number of burns) within each flood frequency class (number of floods). The fire frequency classes are summarised into the fire frequency categories low (fire frequency classes 0 and 1) (a), mid (fire frequency classes 2 and 3) (b) and high (fire frequency classes 4 to 10) (c).

intermediately flooded parts, a low fire frequency is the most unlikely.

Medium fire frequencies, i.e. fire frequency classes 2 and 3 (Figure 6b) are almost equally distributed over the different flood frequency classes, together covering about 40% of each of the flood frequency classes. In this case, fire shows no clear relation to the flooding and areas with medium fire frequencies are likely to be found over the entire study area. Exceptions are the extremely high and low flood frequency classes (classes 0, 14 and 15). They clearly have a lower portion of the mid fire frequencies, basically because of the already high portion of areas unburned or burned just once (fire frequency classes 0 and 1) as described above (Figure 6a).

The high fire frequencies, i.e. the fire frequency classes 4–10 (Figure 6c), show a totally different distribution over the flood frequency classes, compared to the low and mid fire frequencies. Although these high fire frequency classes are comparatively rare in the study area (Figure 3), they still account for more than 25% of each of the flood frequency classes 4–12. High fire frequencies are therefore basically found on the intermediately flooded areas, with the highest fire frequency in the flood frequency class 7. The drier and wetter areas show, as expected after the previous results, just minor areas with a high fire frequency.

Summarised, low fire frequencies have their maximum in the "extremes", i.e. in the driest and the wettest parts and their minimum in the intermediate flood frequencies. High fire frequencies are in contrast basically found in the intermediate flood frequencies and are rare in the "extremes" of the flooding. Mid fire frequencies are found about equally in all flood frequency classes.

Mean fire return intervals

By determining the proportion of the fire frequencies within each flood frequency class, a mean fire-return-interval (MFRI) can be calculated. For each flood frequency class, the MFRI was calculated by dividing the length of the study period (15 years) by the mean number of burns (MNB). MNB was determined as the sum of the portions of each fire frequency class within the flood frequency class, weighted by the number of burns, using the equation

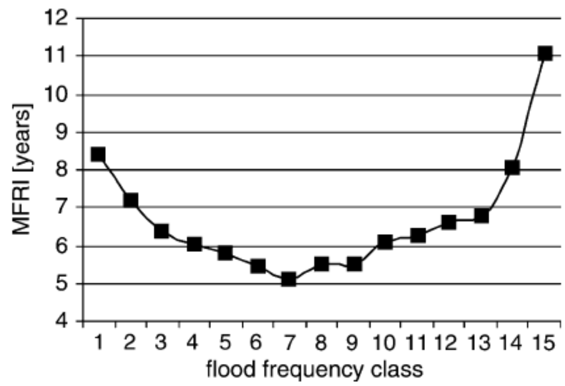

Figure 7. Mean fire return interval (MFRI) in years for the flood frequency classes. Flood frequency class 0 is not considered.

$$\text{MNB} = \sum[(A\,\text{fc}_i/A_t^* \text{NB}_i]$$

Here, MNB is the mean number of burns during the 15-year period, A_t is the total extent of the flood frequency class, A_{fc} is the extent of a single fire frequency class within A_t, and NB is the number of burns. As expected, the intermediate flood frequency classes (classes 5–9) show the lowest MFRI, all with values below 6 years and the absolute minimum for class 7 with 5.1 years (Figure 7). The highest MFRI were recorded for the flood frequency classes 15, 1 and 14, all with a MFRI over 8 years, with values of 11.1, 8.4 and 8.1 years, respectively. For the flood frequency class 0, a theoretical MFRI of 22.2 years was calculated, but this value was not considered as reasonable due to the study period of only 15 years.

These data now allow, in combination with the previously gained results, an estimation of fire return intervals and fire frequencies for specific floodplains. And these estimations are, as intended, not based on rainfall data, which proved to be inadequate to estimate fire frequencies on floodplains, but rather based on the flood frequencies.

Conclusion

Relevance of the results

For the analyses of the fire frequency classes, mean values were used to describe the relation between fire and flooding (Figure 5). Sound trends and significant regression curves could be derived. However, each flood frequency class shows a high range of fire frequencies. For almost every flood frequency class, fire frequency shows the maximum possible range from 0 to 10, so that for all floodplain types all kind of fire frequencies were recorded. Drylands were recorded as burned up to nine times and floodplains were recorded as unburned during the 15-year study period. Although these areas are small, no significant cause-and-effect relation between flooding and burning can be derived from the results and fire-events or fire recurrences for specific floodplains cannot be predicted accurately. Although areas with the highest fire frequencies had their principle distribution on floodplains that were flooded about every second year, not all of these floodplains show necessarily high fire frequencies. In fact, only 40% of the flood frequency class 7 show high fire frequencies and still about 25% show low fire frequencies (Figure 6). But the point is that flood frequency class 7 shows the highest portion of high fire frequencies and that these floodplains therefore show the highest potential to burn. The results of this study can therefore be used to estimate the main distribution of fires and the probability of an area to support a fire.

This estimate of the potential of an area to burn is considered as largely unaffected by the indicated anthropogenic origin of many floodplain fires (Heinl et al. 2005). Although people might set the time of ignition, which is often accidental, burning is usually just applied to small areas. Large fires rather spread uncontrolled into areas where biomass is available and which are susceptible to fire. An important factor affecting fuel accumulation, and hence the probability of a fire, is grazing by herbivores. This phenomenon can often be observed on floodplains, which are largely situated in Wildlife Management Areas. However, it is a rather local phenomenon and should not affect the described overall trends in the study area.

Interpretation and application of the results

Comparable studies on fire frequencies in floodplain systems are rarely published. Available data on fire occurrences are often just describing the results of an applied fire management (Du Plessis 1997; van Wilgen et al. 2000) and documentations of natural or uncontrolled burning regimes are extremely rare (Russel-Smith et al. 1997). Studies considering fire regimes specifically on wetlands were not found at all. Fire frequency estimations for wetlands are therefore mostly just anecdotal or based on subjective ground observations. Scholes et al. (1996) argue, that these kind of observations usually overestimate the fire frequency for a specific landscape type, as they focus only on the burned areas, eventually with high fire frequencies, and ignore unburned sections of the same landscape type. The estimation is therefore only applicable to specific investigated areas. Also for the present study, the calculated fire frequencies for floodplains are much lower than estimated frequencies by local scientists, who expected floodplains to burn at least every second year. The fire frequencies are in contrast much more in line with studies following similar remote sensing techniques, which show mean fire return intervals for floodplains of roughly about 4 to 10 years (Scholes et al. 1996; Du Plessis 1997; Russel-Smith et al. 1997). On the other hand, the anecdotes about high fire frequencies from on the ground observations should not be neglected, as they are also in line with the presented results. The analyses of the distribution of the fire frequency classes revealed areas with seven to ten burns during the 15-year study period. Hence, there are areas that show the observed fire frequencies, although they might be small and can be considered as not representative for a specific floodplain type.

Showing this existence of a representative fire frequency for certain floodplain types, which are definable by flood frequencies, is the major finding of the present study. Although the overall fire frequency of the floodplains might be in line with other studies, the detailed investigations showed clear variations of the mean fire return interval (MFRI) within the floodplains. These calculated mean fire return intervals specify the potential to burn for each flood frequency class, and the absolute values provide the possibility to evaluate fire frequency in relation to the MFRI. Hence, areas with fire frequencies above average can be determined and causes and ecological consequences can be analysed, as it is in progress for the presented study area.

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