Every year, the tropics experience more fire than any other region in the world (Fig. 1). Tropical grassland (savannah) fires are the dominant source of carbon from biomass burning and provide more than 60% of the global total (Mouillot and Field, 2005). However, much of what is known about tropical fire ecology is based on monitoring programs started within the last decade, with highly fragmentary historical data extending only to the early 20th century. These data do not allow us to assess whether recent trends in fire frequency and magnitude are unusual in the context of natural long-term ecosystem dynamics (Gillson and Willis, 2004).

Natural or anthropogenic fire regime?
Seventy percent of tropical and subtropical areas worldwide are considered to have ecologically degraded fire regimes (Shlisky et al., 2007). In Africa, the recent increase in fire frequency is attributed to human ecosystem disturbance associated with agricultural and tourism development around the Mediterranean Sea. Understanding them will help us to better manage and preserve one of the most fire-prone regions of the world, characterized by extraordinary plant diversity.

Data
The data are submitted to the Global Paleofire Working Group Database (http://www.gpwg.org) and are available by contacting B. Vannière (boris.vanniere@univ-fcomte.fr).

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Tropical fire ecology across the African continent: A paleoecological perspective

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High-resolution charcoal records from African lake sediments provide new insights for longstanding research questions on fire-climate-human interactions in tropical and subtropical ecosystems.
with intensifying agriculture (Fig. 2; Davidson et al., 2003). For instance, in the lowland rainforests of West Africa and in moist montane forests at higher elevations in East Africa, natural fire is uncommon (Goldammer, 1990). Yet widespread clearance of natural vegetation has converted large, formerly forested areas into highly flammable grasslands (Roberts, 2000; Goldewijk, 2001). Studies of global-scale patterns in historical land use (e.g., Archibald et al., 2005) tend to assume that human impact on tropical African ecosystems was limited before 1700 AD because population densities of indigenous people were low (Goldewijk, 2001; Ramankutty and Foley, 1999). This perspective contrasts with archeological and paleoecological evidence that indicates that anthropogenic forest clearance in parts of East Africa started at least 2.5 ka ago, in association with the introduction of iron smelting technology (Robertshaw and Taylor, 2000). Other authors suggest that humans have altered African forest ecosystems over a longer time (Willis et al., 2004). If increasing fire activity during the Holocene was indeed related to intensifying human impact (Leju et al., 2005; Rymer et al., 2008), the timing and extent to which humans altered local ecosystems varied regionally and among ecosystems. For instance, recent studies indicate that deforestation associated with sedentary agriculture started only ~0.35 ka ago in the moist highlands of central Kenya (Lamb et al., 2003) but at least ~0.8–1 ka ago in sub-humid western Uganda (Ssemmanda et al., 2005; Russell et al., 2009). In drier environments, agricultural activity often began ~0.12 ka ago, during colonial times, yet landscapes may have been significantly modified by pastoralist cultures well before then. Detailed charcoal studies with adequate spatial coverage are needed to determine whether current fire regimes are within the range of historic variability (Willis and Birks, 2006), or whether fire frequency has increased in response to the different types and intensities of human impact associated with pastoralist and agriculturalist societies.

**Fire regime response & feedback to past climate variability**

High-resolution charcoal studies have shown how fire can be a “catalyst” for climate-change effects on vegetation. For instance, moist conditions limit fire to spread in present tropical forests, but during drier periods in the past wildfire was likely more common, causing changes in ecosystem structure and degradation (e.g., Willis and Birks, 2006; Bush et al., 2008; Fig. 2). Climate-proxy information from the sediments of East African lakes document major variations in moisture balance. For example, in the late 18th century, an episode of severe drought completely desiccated all but one lake in the Eastern Rift Valley of Kenya, south of Lake Turkana (Vershuren, 2004; Bessems et al., 2008). In the last few millennia, century-long periods of both significantly drier and wetter conditions than today have occurred over most of equatorial East Africa. There have also been periods (e.g., from ~1500 to 1750 AD) when climate was unusually dry in the normally sub-humid western parts of the region while remaining unusually wet in semi-arid regions further east (Vershuren et al., 2000; Russell and Johnson, 2007). Research documenting the response of terrestrial ecosystems to this climate variability reveals the high sensitivity of vegetation transition zones, such as the forest/savannah ecotone, to even modest decadal-scale variations in rainfall (Lamb et al., 2003; Ngomanda et al., 2007). Additional charcoal records of high temporal resolution are needed to show how fire regimes have responded to contrasting climate trends at the regional scale (Fig. 1b).

**Tropical ecosystems resilience to fire**

In the seasonally dry climate regime prevailing throughout most of East Africa, fire is the dominant direct control on vegetation distribution (Bond et al., 2005; Gillson and Duffin, 2007) but natural fire frequency decreases from semi-arid central and eastern Kenya to sub-humid western Uganda. How does fire control the landscape-scale ecotone between savannah and forest? Recent studies postulate that tropical rainforests and grass savannah may exist as “stable states” in which a grass-dominated ecosystem is maintained by frequent fires while a tree-dominated ecosystem helps create a wet microclimate and low ground cover/fuel load that limits fire (Sankaran et al., 2005; Gillson and Duffin, 2007; Gillson, 2008). A shift from small patchy fires set by indigenous peoples to the larger fires characteristic of European land management has strongly altered the savannah-forest ecotone, by favoring highly flammable annual grasses. Thus, by increasing the flammability of grass communities, this historical change in fire management may have caused a positive feedback with fire (Cochrane, 2009). This hypothesis needs to be rigorously tested.
on long timescales and in multiple regions to determine whether this feedback is characteristic of presently highly disturbed conditions, or whether it also occurred during natural cycles of long-term hydrological change. Paleoinformation on the resilience of tropical moist forests to occasional fire and, specifically, the rate at which rainforests recover from destructive fire would also be highly instructive for future conservation (Cochrane, 2003). New reconstructions of past fire regimes based on fossil charcoal analysis that quantify the local frequency of fire (e.g., Whitlock and Larsen, 2001; Gavin et al., 2006; Higuera et al., 2008), combined with modern calibration studies (Duffin et al., 2008), should reveal how African ecosystems respond to fire variability at decadal to century timescales.

Research outlook
Coupled atmosphere/ocean/biosphere climate models project future temperatures across tropical Africa to increase from 0.2 to 0.5°C per decade, and precipitation in East Africa to increase during the short rainy season (Northern Hemisphere winter) and decrease during the main rainy season (Northern Hemisphere spring) (Hulme et al., 2001; IPCC, 2007). In addition, changes in the teleconnected El Niño/Southern Oscillation (ENSO) are projected to cause pronounced drought in some regions and increased risk of flooding in others (Wara et al., 2005). If mean annual precipitation over East Africa does increase (IPCC, 2007), its beneficial effect on forest ecosystems will likely be lost in areas with frequent anthropogenic fires and increasing demographic pressure. Insights into how Africa’s forest and savannah ecosystems will respond to the multiple stressors of future global climate change requires an understanding of past ecosystem responses to large-magnitude environmental changes. Currently still very rare in Africa and elsewhere in the tropics, high-resolution paleoecological records of (pre-)historical human impact, fire and vegetation can provide such holistic information.

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