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DISTRIBUTION OF FIRE ACTIVITY IN AFRICA, CRITICISM OF PREVIOUS EXPLANATIONS BASED ON A DATA BASE FROM 2001 TO 2021

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Abstract:
Africa is the continent most exposed to fires, accounting for over half of the burned areas and pyrogenic greenhouse gas emissions globally. Fire seasonality in Africa follows the dry seasons, primarily from October to March for the Northern Hemisphere, with a peak in December–January, and from April to October for the Southern Hemisphere, with a peak in August. In 2001, we monitored active fires monthly, observing significant changes based on the seasons. The equatorial and southern regions of Africa showed a higher concentration of fires, less in the north. This variation has been consistent for 21 years, up to 2021. A strong correlation exists between the latitude of African regions and fire abundance. Equatorial countries experience more fires during the period between December and March, while southern countries see more during the other time of year period. Key factors include the accumulation of biomass, which fuels fires during the rainy season, and increasing human pressure, especially due to the need to warm up.

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Key words: fires, Africa, seasonality, biomass, climate change.

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INTRODUCTION

Africa is the continent most exposed to fires, responsible for more than half of the burned areas in the world and more than half of the emissions of pyrogenic greenhouse gases globally (Andela *et al.*, 2017). According to estimates derived from satellite data, more than 80% of burned areas in Africa are in savannas, with the remainder in forests and croplands (Giglio *et al.*, 2018). Fire seasonality in Africa follows the respective dry seasons, occurring primarily from October to March with a seasonal peak in December–January in the Northern Hemisphere, and from April to October with a peak in August in the Southern Hemisphere (Boschetti and Roy, 2008). Savanna fires in Africa are generally surface fires, burning as frequently as every 1–6 years (Archibald *et al.*, 2010). The long dry season of African savannas and the high rate of fuel accumulation have been identified as the main factors contributing to such a large number of fires (Archibald *et al.*, 2010). Grasses can grow back quickly after fire, making the ecosystem prone to frequent fires (Gillespie *et al.*, 2024). Fire seasonality and behavior have also been linked to biogeographical factors, as shown in Australian ecosystems where fire regimes reflect local climate and vegetation (Bradstock, 2010).

Three elements must be present for fire to start: sufficient biomass to burn, flammability of the fuel, and an ignition source. Both climate and humans can modify the abundance of biomass, the number of ignitions, and the potential spread of fires. It is difficult to disentangle the effect of these factors, particularly in Africa. Africa is a continent where humans have shaped fire regimes for millennia, with up to 90% of savanna fires being caused by human activities rather than natural ignitions (Laris and Jacobs, 2021). Although several studies have reported a recent decline in burned areas in Africa, the causes of this decline are not yet well understood. It was found that between 2002 and 2016, the area burned in Africa decreased by 18.5%, with the largest decline (80% of area) occurring in the Northern Hemisphere. One-third of the reduction in area burned occurred in cropland, suggesting that changes in agricultural practices (including cropland expansion) are not the predominant driver of recent changes in extent.

Linear models taking into account the interannual variability of climatic factors directly linked to biomass productivity and aridity explain approximately 70% of the extent of fires. Aridity explains about 70% of the decrease in area burned in natural land cover. Despite the fact that most fires are human-caused in Africa (Zubkova *et al.*, 2019), the increase in terrestrial humidity between 2002 and 2016 facilitated the decline of wildfires. During the period 2002–2016, a decline in fire activity in Africa was observed (Zubkova *et al.*, 2019). The last 20 years of satellite observations indicate a decrease in burned area globally, but this decrease is not uniformly distributed geographically. Africa, the continent most affected by fires, saw the most pronounced decrease in burned areas. The causes are still poorly understood: the reduction in fire activity could be due to both climate change and human factors. Interannual variability of burned areas in natural lands (forest and non-forest) has been linked to climatic variables related to moisture availability (Zubkova *et al.*, 2019). Approximately 70% of the reduction in area burned in natural lands can be explained by the observed increase in plant-available moisture and increased effective precipitation, which inhibits flammability, ignition, and spread of fires, especially in humid savannas (Zubkova *et al.*, 2019). Similarly, changes in fire intensity and frequency have been linked to rainfall patterns and management practices in southern African savannas (Govender *et al.*, 2006).

AFRICA FIRE DATA OBTAINED BY NASA AND BIBLIOGRAPHIC STUDIES

NASA provides continuous access to images detecting active fires around our planet. This monitoring is made possible by the Moderate Resolution Imaging Spectroradiometer (MODIS), which delivers data across 36 spectral channels with global coverage every 1 to 2 days. The wide spectral range of MODIS data allows for its use in various disciplines, including plant health, land cover and land use changes, oceans and marine biology, as well as sea surface temperature and cloud analysis. Additionally, MODIS is extensively used for monitoring fires, natural hazards, and oil spills. MODIS fire products are regularly validated and improved to increase accuracy (Ying *et al.*, 2019). An important feature of MODIS data is its real-time and near-real-time availability. Direct reception stations around the world download raw MODIS data directly from the satellite in real-time, while NASA's LANCE (Land, Atmosphere Near Real-time Capability for EOS) system provides several MODIS products within three hours of satellite observation (Giglio *et al.*, 2018). The Moderate Resolution Imaging Spectroradiometer has played a critical role in global environmental monitoring, including fire detection, land surface temperature, and aerosol studies (Justice *et al.*, 2002; Kaufman *et al.*, 1997; Justice *et al.*, 1998; Pereira *et al.*, 2017).

For an in-depth study of fires and their spatial and temporal variations in Africa, a reliable database covering the period from 2001 to 2021 was selected. Although this period is sufficient for comparison with previous studies on this topic, a detailed literature review was conducted to interpret and analyze the collected data. The bibliographic references used cover a range of research from the impacts of fires on vegetation and carbon emissions to remote sensing tools for fire monitoring and interactions with climate change. They offer a global perspective while integrating specific studies on fire regimes in Africa and elsewhere.

Our critical analysis synthesizes key contributions and evaluates the strengths and limitations of existing studies, highlighting advancements and gaps in understanding fires in African savannas and their management. Gillespie *et al.* (2024) provide a detailed analysis of fire regimes in the semi-arid savannas of the Kalahari region in southern Africa, emphasizing vegetation dynamics, rapid grass regrowth, and frequent fire cycles that influence the carbon balance, while also considering the roles of climate, vegetation, and human activities. Archibald and Bond (2003), Archibald and Scholes (2007), as well as Archibaled *et al.* (2009), delve into the relationship between precipitation, fire dynamics, and their impact on vegetation structure and carbon dynamics. The 2010 studies by Archibald *et al.* (2010) provide analyses of fire regimes and decadal trends using remote sensing data, offering valuable insights into long-term changes.

Chidumayo *et al.* (2011) address the impacts of fires on African forests and woodlands, often less studied compared to savannas. Williams and Abatzoglou (2016) examine the complex interactions between fire activity and climate change, highlighting recent scientific advances as well as the major uncertainties associated with future projections. References such as Giglio *et al.* (2018) and the MODIS product guides by Justice *et al.* (2002) focus on remote sensing tools for fire monitoring, emphasizing the importance of advanced detection technologies in fire management. Scheiter and Higgins (2009) use coupled models to simulate vegetation and fire dynamics in Africa. Recent global studies emphasize the importance of considering alternative biome states between savanna and forest, as described by Staver *et al.* (2011), and the critical role of adaptive ecosystem management in large protected savanna areas (Van Wilgen and Biggs, 2011). Fire history has been linked to vegetation structure and landscape patterns in African savannas (Mouillot and Field, 2005), while fire regimes in other regions such as the Amazon Basin highlight the influence of climate oscillations like ENSO on fire activity (Pereira *et al.*, 2017). The biogeographic context of fire regimes, as explored in Australia by Bradstock (2010), provides comparative insights useful for Africa.

DATA ANALYSIS AND DISCUSSION

We carried out monthly monitoring of active fires for the year 2001, observing notable variation in the concentration of fire points from one month to the next, influenced by seasons, particularly in the equatorial and southern regions of Africa. This trend is less marked in the north of the continent. In Figure 1, in January fires show a significant peak near the equator; in February and March, their concentration gradually decreases towards the south, reaching Madagascar. This distribution continues from April to June, with a gradual accumulation towards southern Africa. During the summer, from July to September, fires die out near the equator and increase significantly in the south of the continent. Returning to the period from October to December, we again observe a concentration near the equator and a decrease to the south. In conclusion, fires mainly affect equatorial regions during cold seasons and southern regions during warm seasons.

These observations are based on a study covering the period 2001–2021. We specifically analyzed the months of July and December. Figure 2 confirms a significant correlation between latitude and fire activity: in December, fires are concentrated near the equator, while in July, they become significant in southern Africa. This correlation highlights the impact of latitude on the distribution of fires.

Revisiting previous studies on the causes of increasing or decreasing fires in Africa, the researchers identified

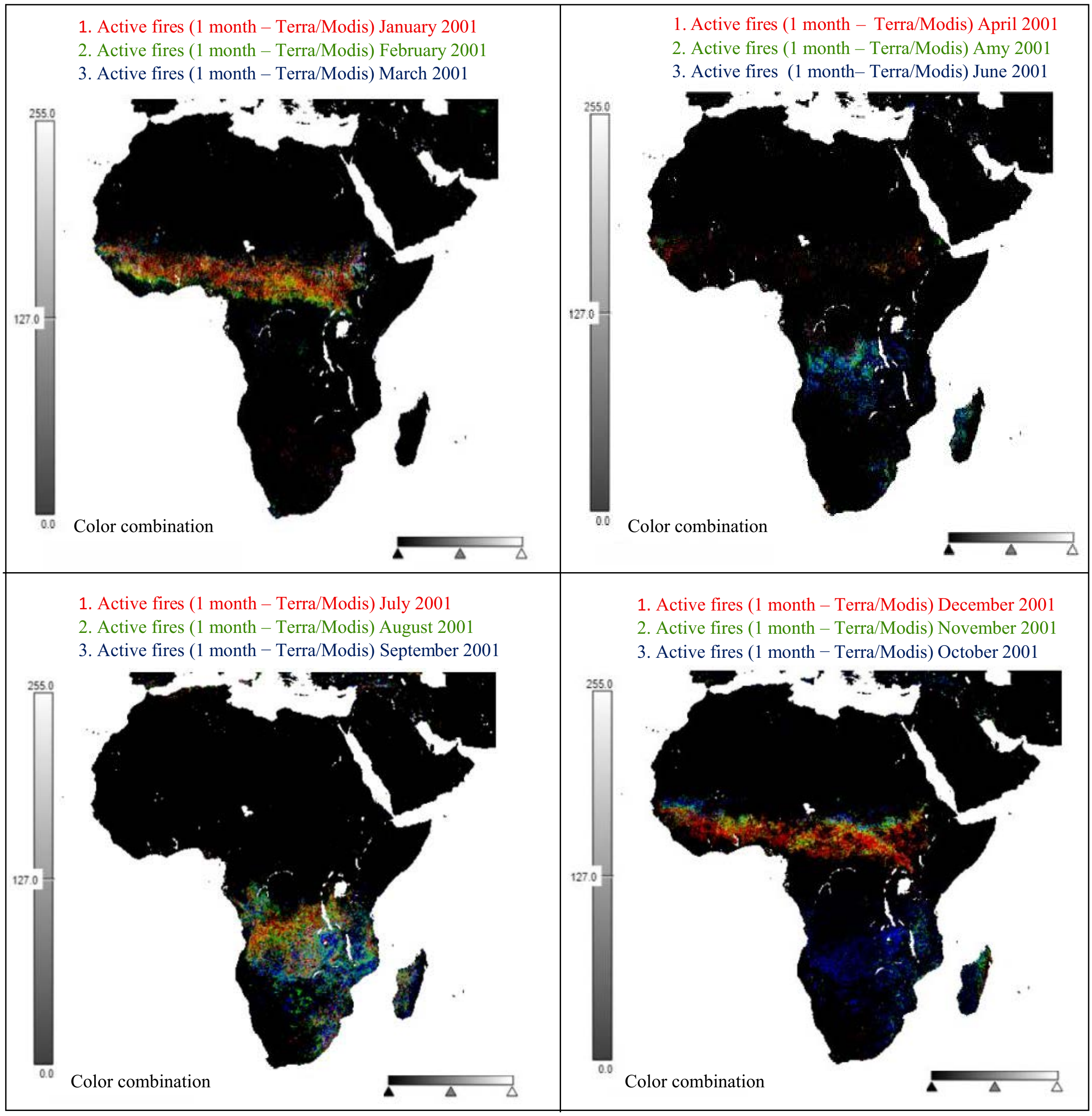

Fig. 1. Monitoring of the monthly change in the distribution of fires in Africa (example of the year 2001).

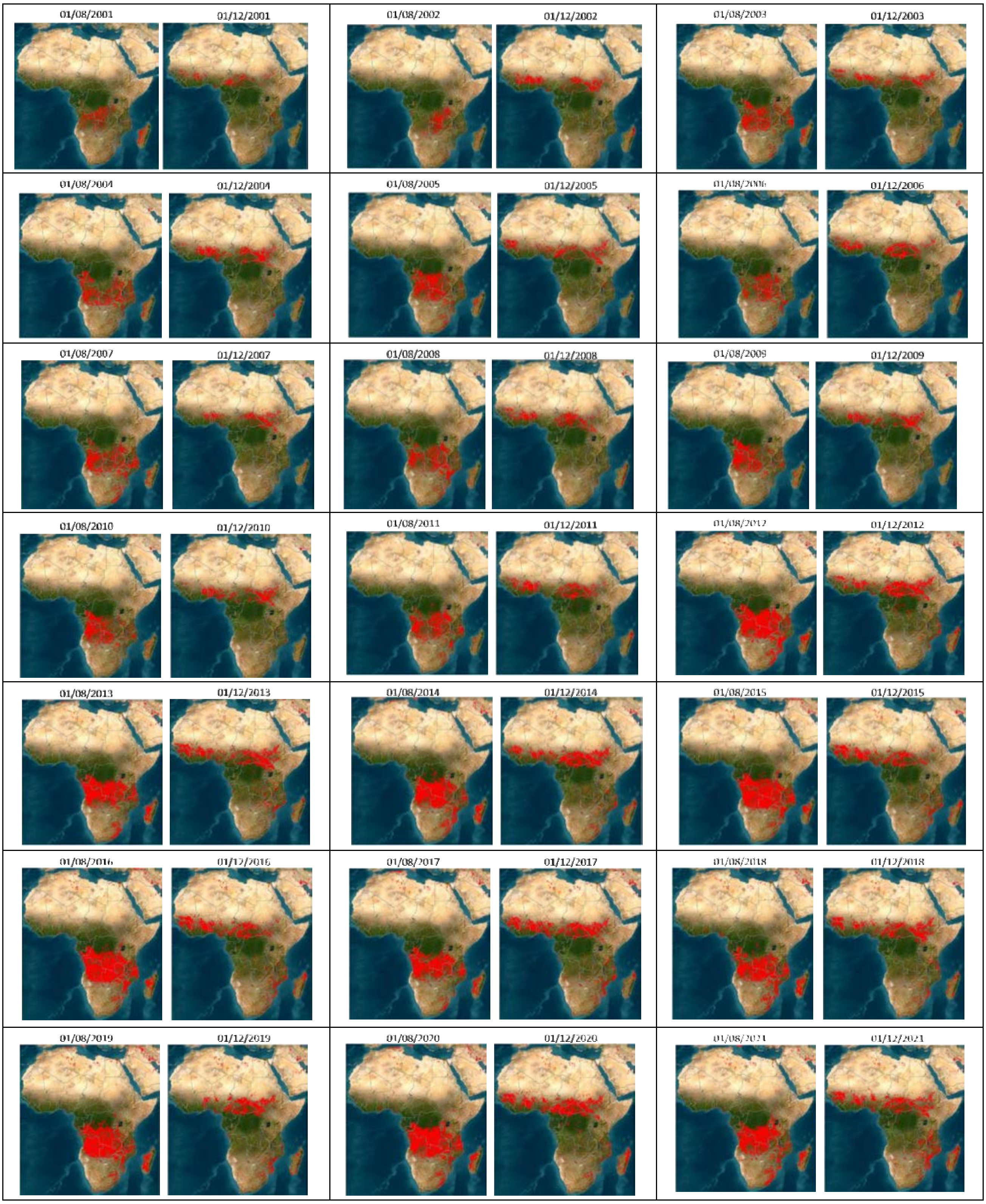

Fig. 2. Monitoring of fires in Africa from 2001 to 2021 using MODIS data; the red color represents active fires.

several key factors, including the complex interplay between fire, climate, and humans. Growing human pressure and climate change have both influenced recent fire dynamics in Africa. Human pressures such as farming, slash-and-burn practices, deforestation, and fuel wood collection contribute significantly to the increase in fire frequency and intensity. These activities often dry out vegetation, reduce forest resilience, and create conditions that make ecosystems more vulnerable to uncontrolled fires (Andela *et al.*, 2017; Earl and Simmonds, 2018; Zubkova *et al.*, 2019). Savanna fires, common in Africa, are largely surface fires, often recurring every 1 to 6 years due to the prolonged dry season and the rapid accumulation of fine fuels (Archibald et al., 2010). These factors make African ecosystems particularly vulnerable to frequent fires (Archibald *et al.*, 2010).

Traditional surface fire practices are an ancient method in Africa, traditionally used by local populations for purposes such as slash-and-burn agriculture and pastoral land management. These periodic fires are essential for maintaining biodiversity and regenerating soils in ecosystems like savannas and tropical woodlands (Archibald *et al.*, 2010). Natural fire cycles in African savannas involve burns every 1 to 6 years, influenced by alternating wet and dry seasons. This fire regime is crucial for maintaining ecosystem structure and function, promoting the regrowth of fire-adapted plant species (Archibald and Scholes, 2007).

Climatic changes increasingly impact fires in Africa by altering precipitation and temperature patterns. Prolonged droughts and elevated temperatures raise fire frequency and intensity in some regions (Andela *et al.*, 2017; Earl and Simmonds, 2018). Furthermore, fire intensity and patterns are influenced by seasonal rainfall and management practices, as demonstrated in South African savannas (Govender *et al.*, 2006).

Anthropic pressure remains a major driver of fires: up to 90% of fires in Africa are of anthropogenic origin, often triggered by slash-and-burn agriculture and expanding settlements. This human pressure leads to ecosystem degradation and biodiversity loss (Andela *et al.*, 2017; Archibald *et al.*, 2009).

Additional research suggests that the frequency of fires in Africa is influenced by several interrelated factors. Water availability plays a critical role by affecting dry season severity and, thus, fire likelihood. Vegetation composition is also decisive: African savannas, with prolonged dry periods and abundant flammable biomass, are particularly fire-prone (Archibald *et al.*, 2009). Fire history and vegetation structure are tightly linked (Mouillot an Field, 2005), and coupled vegetation-fire models help simulate these dynamics (Scheiter and Higgins, 2009). Globally, large-scale studies emphasize the complex interactions of fire regimes with climate, vegetation, and human activity (Williams and Abatzoglou, 2016).

CONCLUSIONS

The analysis and interpretation of the databases collected and organized in this work, from MODIS products provided by NASA agency which we thank very much, make it possible to strengthen previous studies on changes in fire activity in Africa. This collection covers the period from 2001 to 2021, revealing a remarkably stable distribution throughout this period. The researchers' previous results on the factors triggering fires and their correlation with climate change allows us to better understand the impact of the positioning of African regions in relation to the equator. In addition, our study contributes to the explanations of researchers and fire specialists working on the African continent, based on a bibliographic study of essentially recent research, even if it is quite few in number. We have tried to collect sufficient data in order to discuss the most influential factors and limit the most vulnerable areas in Africa, highlighting the increased impact of factors such as sufficient accumulation of fuel biomass during the cold period, rainy climatic conditions, as well as the increase in human intervention which burns these combustible materials during this period. We hope that these results will be taken into consideration by those responsible and environmental defenders to react effectively, while continuing to monitor the phenomenon by this relevant means of spatial detection, in conjunction with other means and methods of study, in situ.

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