What is Early and what is Late?: The West African fire experiments and what they can (and can't) tell us about savanna fires

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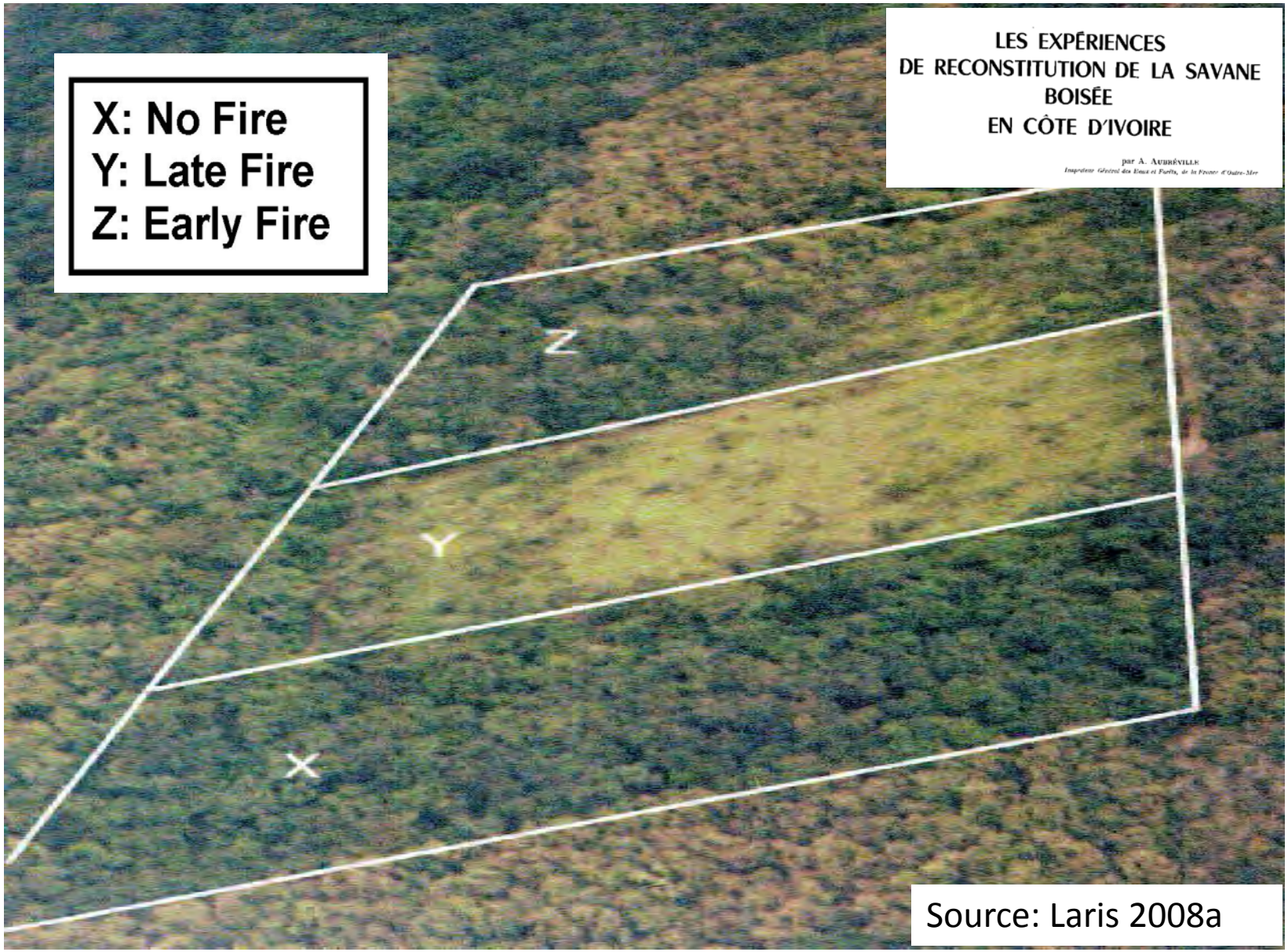
Aubréville's long-term burning experiment



Source: Laris 2008a

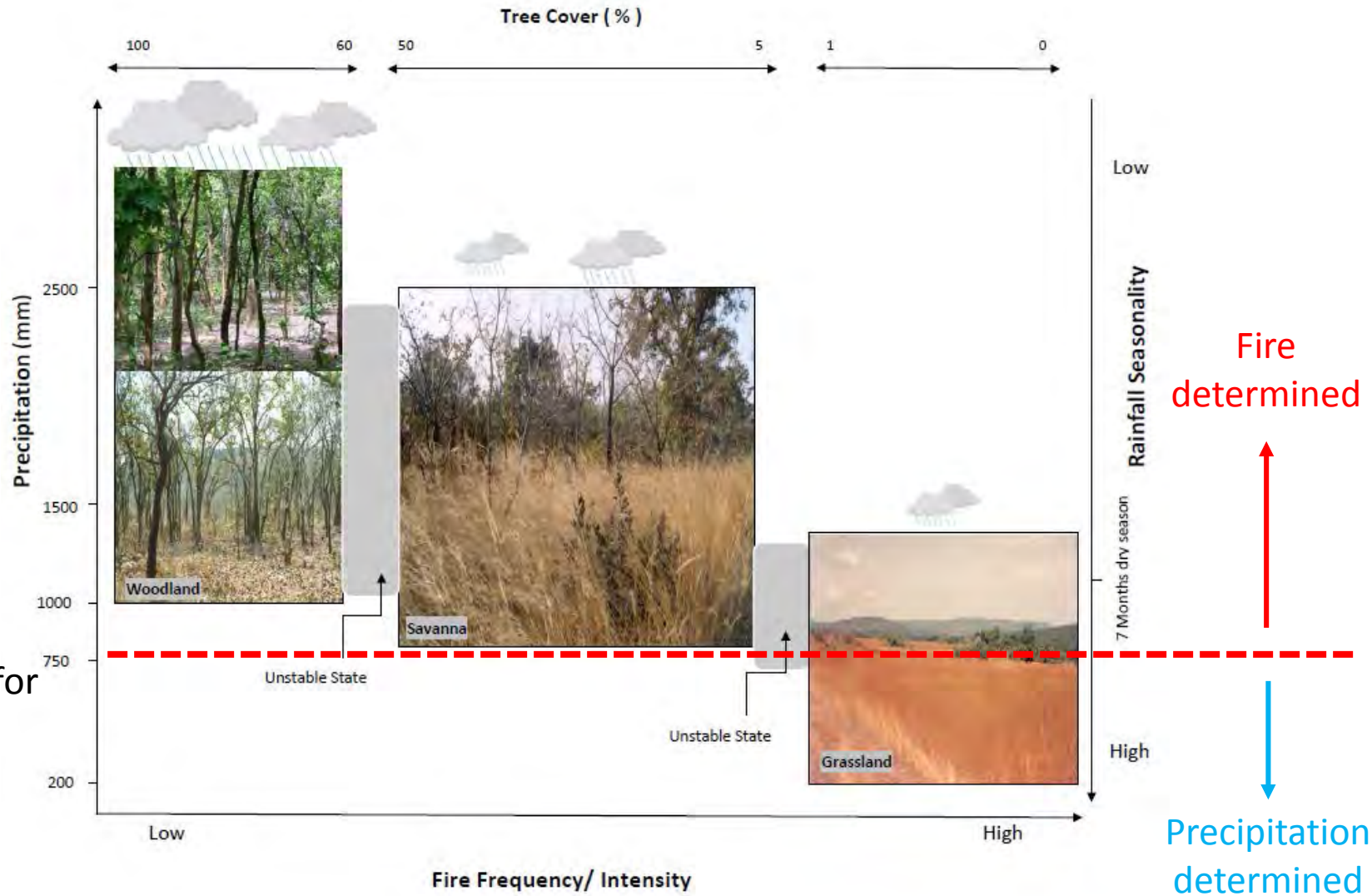
Second Law of Savanna Fire Ecology

Late fires are more intense than early fires and thus more damaging to trees (especially juveniles).

Timing of fire => fire intensity, severity& ecosystem response

Fire-Driven Savanna Ecology Models

"Fire, which prevents trees from establishing, differentiates high and low tree cover, especially in areas with rainfall between 1000 mm and 2000 mm" (Staver et al 2011).



Sankaran 750 mm for Africa

Study Results Mapped on to Science as Well as Policy in West Africa

The Geographical Journal, Vol. **172**, No. 4, December 2006, pp. 271–290

Good, bad or 'necessary evil'? Reinterpreting the colonial burning experiments in the savanna landscapes of West Africa

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Early fires are a goal in themselves when it comes to assure minor damage to the forest . . . Early fires are primarily a means to protect agriculture lands and fallow against big blazes by constitution of a barrier distant from combustible materials

Ortoli 1955, 7–11

Aubréville 1953:5

"We must remember that these experiments are meant not only to support our own conception of forestry policy **but also to convince others of our conclusions, especially administrative and political authorities**. **They must be like propaganda** and not remain secret …. I remind the reader that the principle of these demonstrations, **being conducted to prove the effects of brush fires and conversely the effects of their suppression**, is to delimit several plots in the woody savannah, of which one is the control plot, completely protected from brushfires while, in the others, various types of treatments are experimented with: **early fires, late fires**, extreme cutting following the passage of fire **or protection from fire** altogether, etc.

Aubréville 1953

"Given the regular and **excessive degradation of these forests and of their soils** due to clearings, agricultural abuse of depleted soil, and, **above all, annual bush fires** during the dry season, our forestry policy in the woody savannah of Guinea and Sudan is established on the double conviction that, in order to stop the depletion of the soils and, consequently, that of the water reserves, it is in the best interest of agriculture and forests to have a wood covering as dense as the area will permit, and that restoration is **possible only when the passing fires can successfully be stopped during a certain time, variable according to the climatic conditions, the state of the soil, and the woody vegetation.**

Aubréville's Legacy

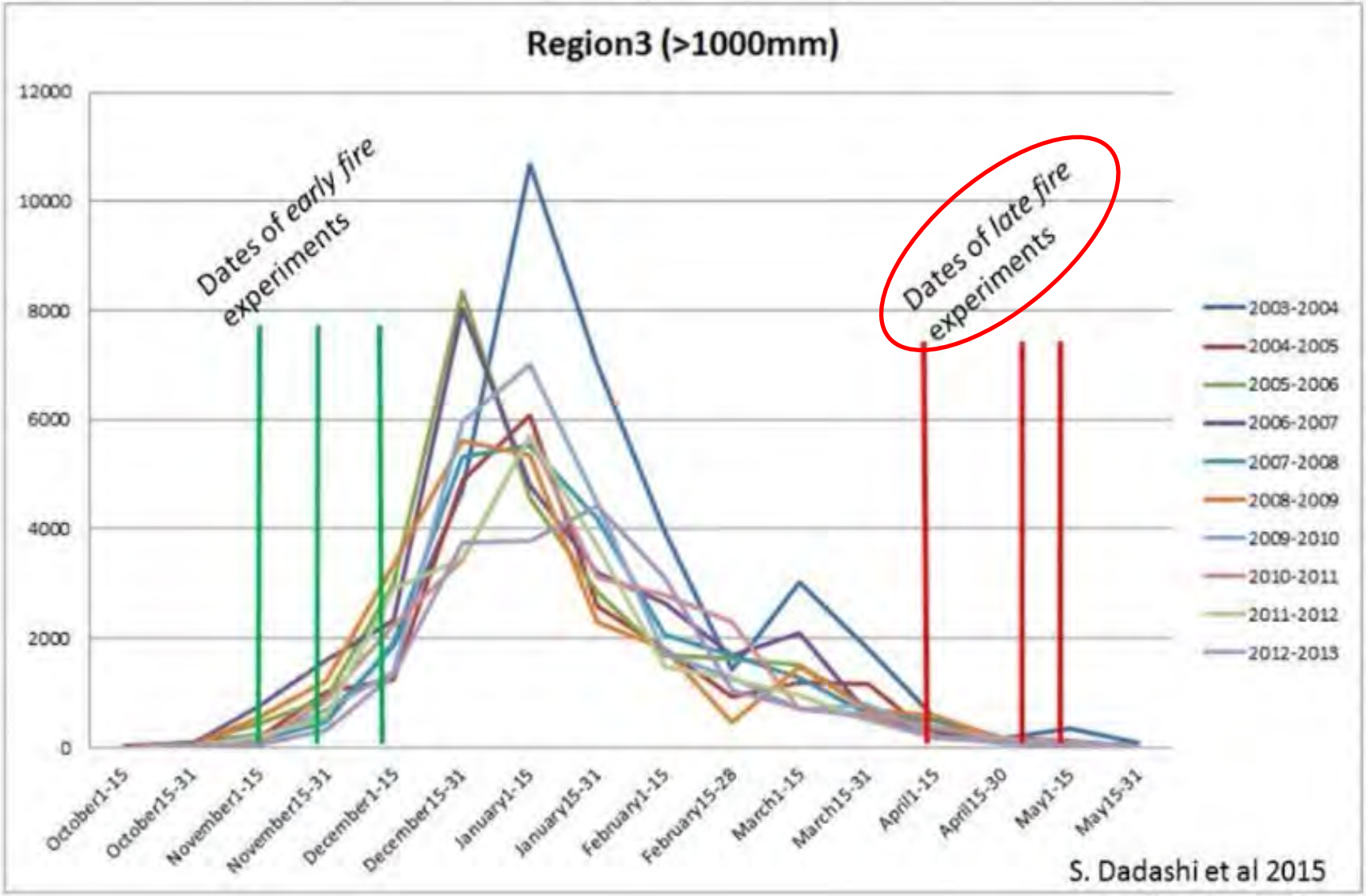
Author	Site	Precip (mm)	Dates	Additional Findings	Impact of Soils	History	Burn dates
Aubreville /Louppe	Kokondero Ivory Coast	1200-1250	1953 1995		Soil fertility is decisive on early burn plots, poor soils akin to late fire	6 year Fallow	Dec. 15 May 1-15
Ramsay & Rose-Innes	Olokomeji Nigeria		1973	Androgon gayanus a key perennial prefers early burning	Late fires severely damaged woody vegetation on poor soils	?	Early Nov. April
Brookman -Amissah	Navrongo, Ghana	1100 mm	1980	Grass biomass (Androgon gayanus) is highest on early burn		Felled plots	Mid-Nov. April
Afolayan and Ajayi	Nigeria		1979	Focus on grasses: early burning produces perennials		?	**Early and Late**
Ramsay & Rose-Innes	Bamako, Mali	1000	1973		Soil conditions determine seedlings and suckers growth	?	**Early and Late**
Chidu-mayo	Zambia (Miombo)		1988 1997	Early fire and no fire were similar		Felled plots	**Early and Late**

There were many limitations or flaws:

1. **The experiments do not take into account the heterogeneity of different savanna** which are partly a function of soils and vegetation types and other factors which are known to influence tree and grass cover. Recent research has demonstrated that these factors play a critical role in determining the impacts of different types of fires on savanna trees.
2. **Experimental controls and documentation of the initial conditions of the plots were often far from ideal** (Furley et al 2008). Important information such as whether the study sites were formerly cultivated or clear cut were often not disclosed and even the specific burn dates were not often recorded or published.
3. **The a-spatial nature of the experiments limits their application** to what is a highly heterogeneous environment where fire regimes frequently have a patch-mosaic pattern and where fire timing is not random, but often correlates with grass type (Laris 2011).
4. Finally, the **experiments failed to correlate the timing of experimental fires with those of the burning practices of local people**. Indeed, Moss (1982) raised this issue over 30 years ago arguing that the experiments do not reflect the reality of burning practices in Africa because the dates of experimental burning do not coincide with the actual burn timing in the areas studied.


What is the human burning regime?
Photo by C. Strawn 2005

Mid-Fire Season Peak* and Experiment Dates



* Based on analysis of 10 years of MODIS active fire data

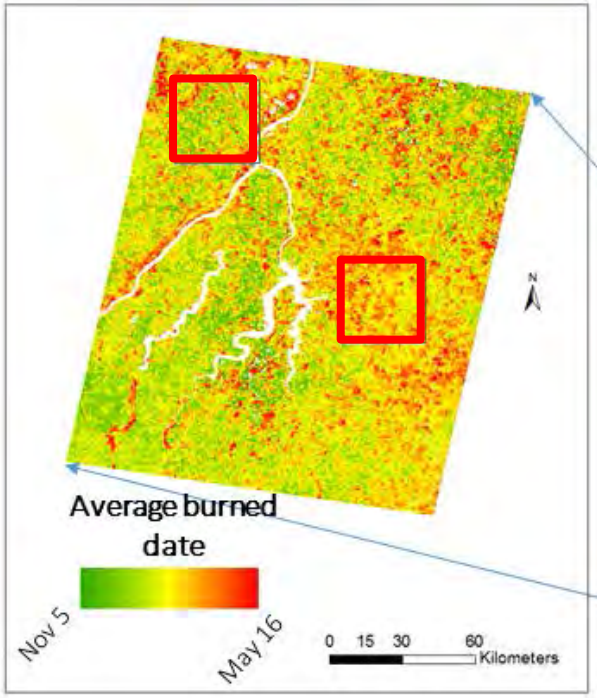
Objectives

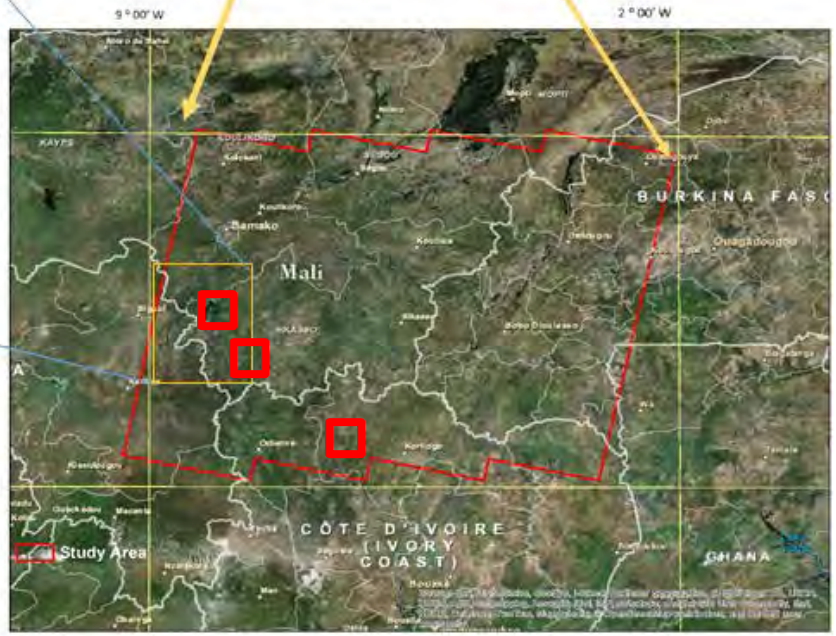
(i) to critically review the results of the burning experiments;

(ii) to evaluate their limitations based on actual human burning practices; and

(iii) to test the alternative hypothesis that time of day, fire direction and grass species—more so than fire timing—determine the impacts of savanna fires on tree regeneration and growth based on field evidence

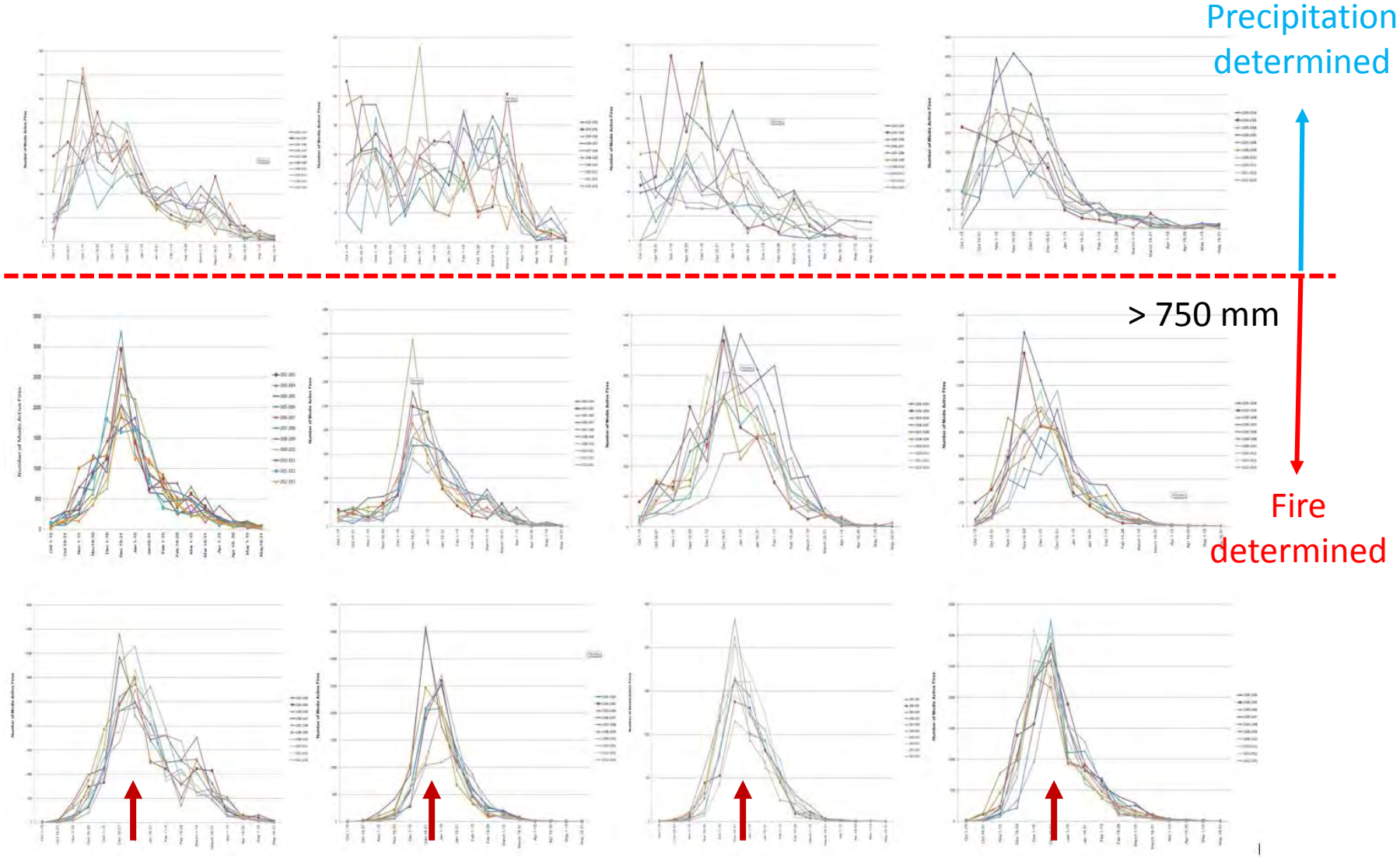
Study areas at multiple scales: MODIS and Landsat Data





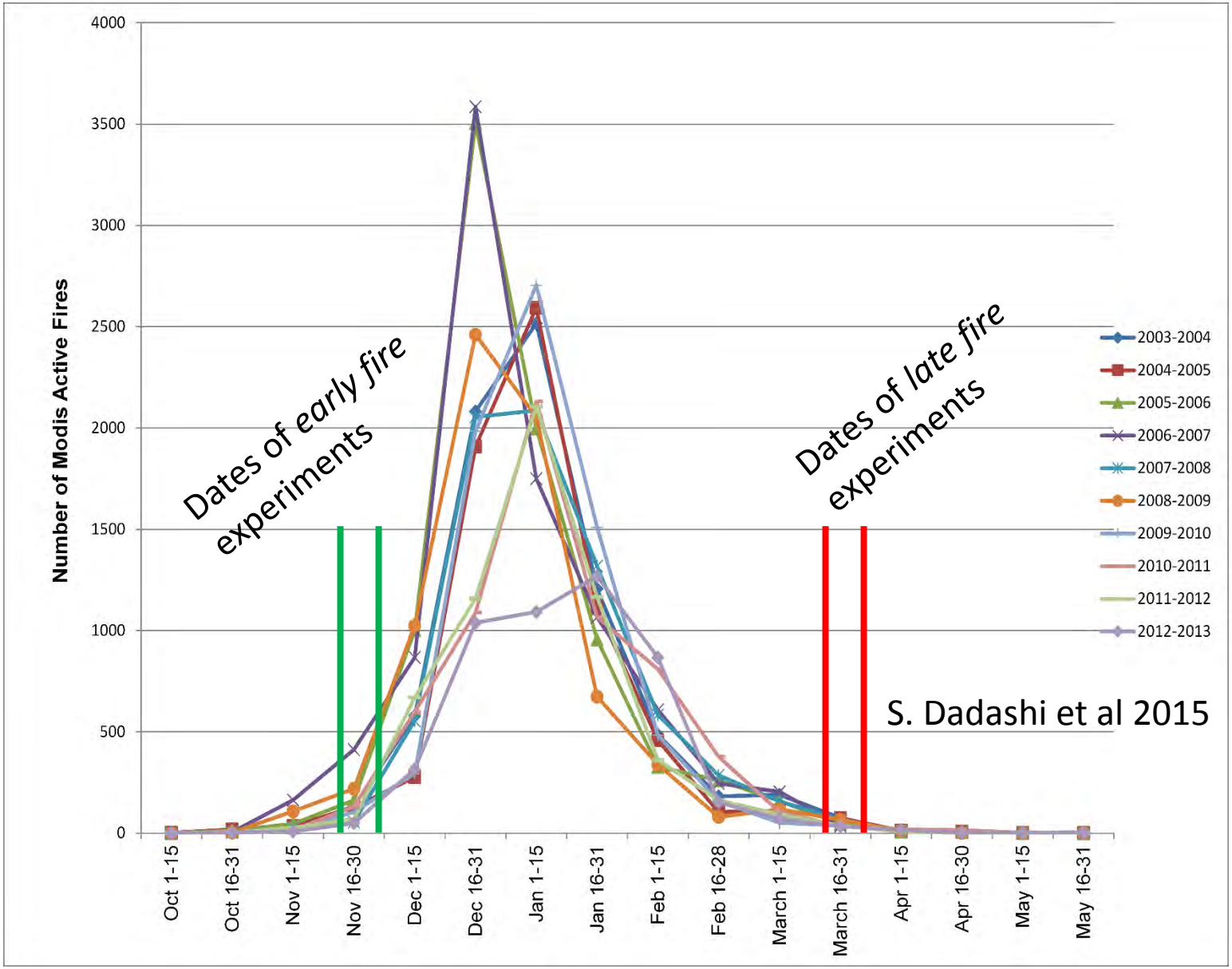
Sub areas for interviews and fire experiments

Regular annual timing of fire

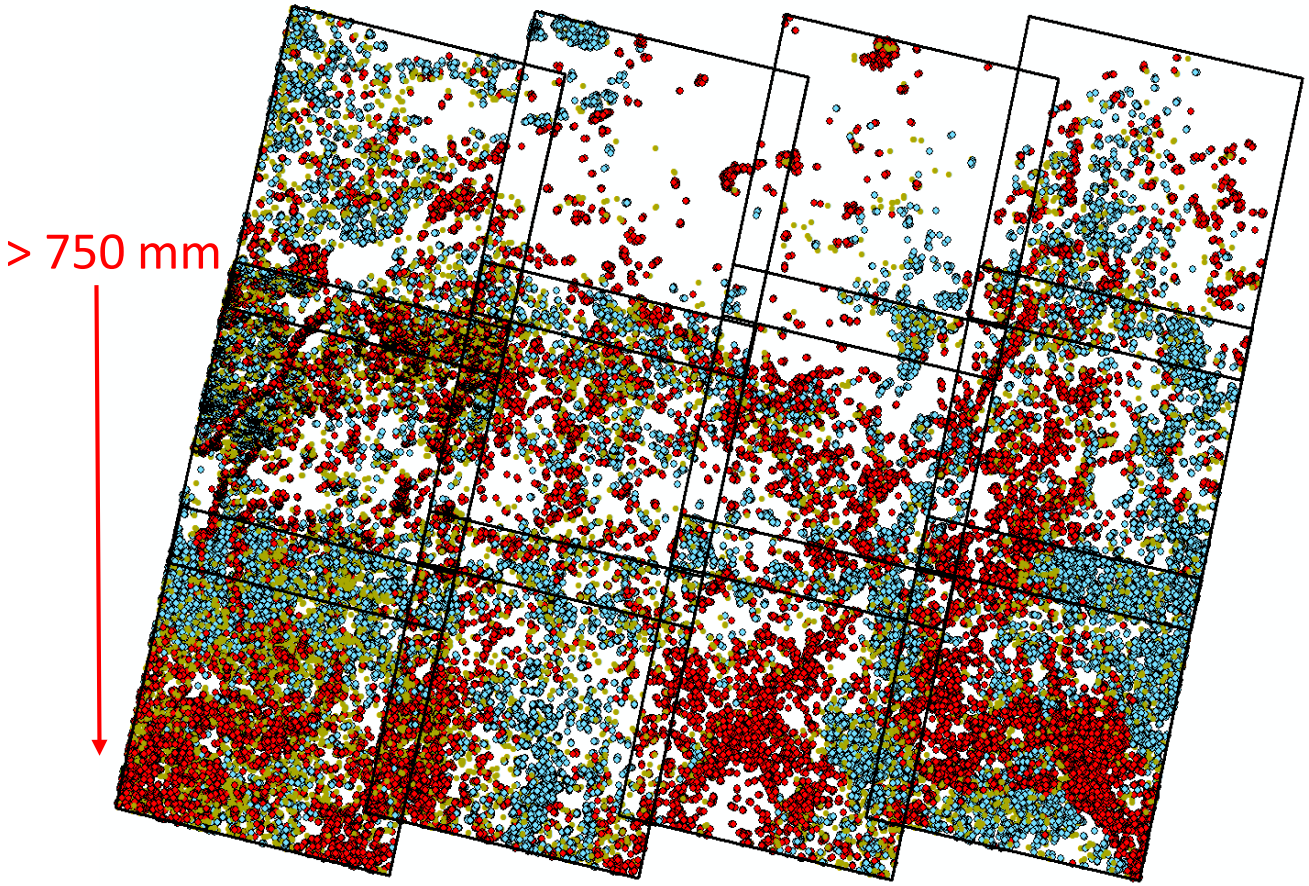


S. Dadashi et al 2015

Note consistency of burn peak in the southern zone



Regular annual *spatiotemporal patterns* of fire (linked to vegetation) Precip > 750mm



LISA: Blue areas regularly burn *early*, red areas regularly burn *late*

Late-Late		LL
Early-Early		EE
No Pattern		

S. Dadashi et al 2015

Relationship between timing and vegetation type and burning purpose.

Land Cover Type	Average burn date based on image analysis	Burn timing based on survey	Rural calendar	Common reasons for burning*
Short Grass Savanna	December 8	96% of cover type burned by December 31st	Peanut Harvest	To separate areas, clear paths, create fire breaks, prepare pasture and hunting grounds, eliminate pests and danger of late fires
Short Fallow/Ag	December 12	67% of cover type burned by December 31st	Millet and Cotton Harvest	
Long Fallow	December 22			
All Other Savanna	January 1st	NA	Harvest End	
Forest/Woodland	January 8	36% of cover type burned December 31st	Cool Season	Hunt, clear grasses and pests to promote gathering, accidents, unknown
All Cover Types	Dec 24 (69% by Dec. 31st)	71% of cover type burned by December 31st		

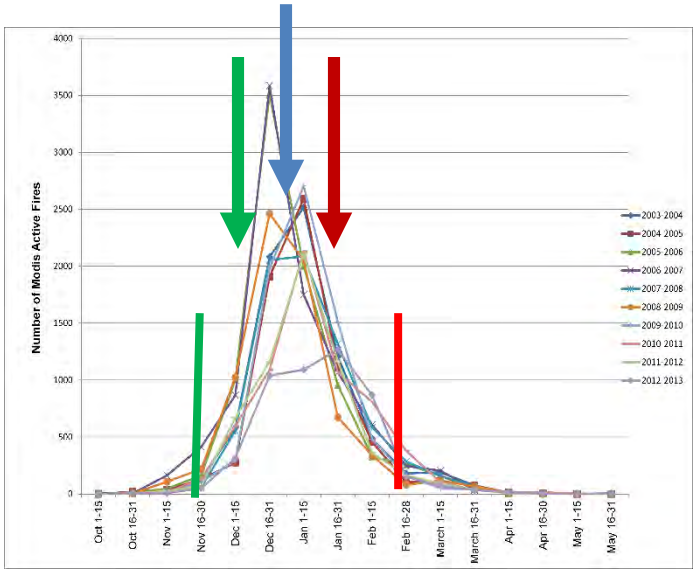
* From Laris 2002, 2006

What do we know about West African savanna fire regimes (in mesic environments)

- Fire regime has a very regular spatiotemporal pattern (often little variation between years)
- Fires begin early in the dry season and continue for several months with the peak of burning occurring in mid-dry season prior to the peak in vegetation drying or senescence.
- Generally there is high fire frequency
- Spatiotemporal pattern of burning closely aligns with vegetation cover.

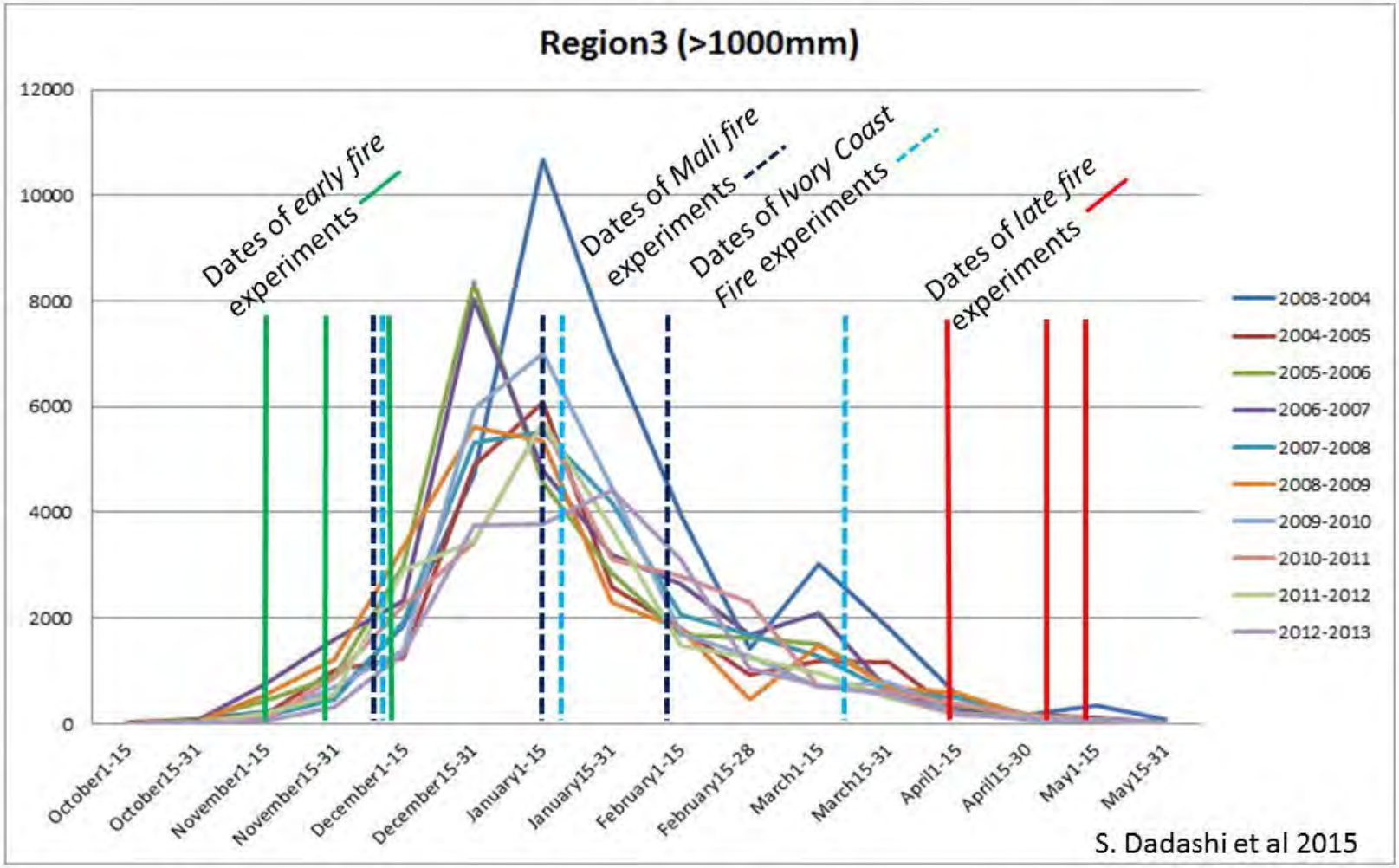
Mesic savanna theory is based on the "fire trap"

But what fire regime is sufficient to "trap" juvenile trees under what conditions?




What do field observations tell us?

Dates of our fire experiments and annual fire timing and frequency, historical burning experiment dates shown for comparison



Fire temperature (°F) measured in experimental plots for early, middle and late dry season (Katiali, Ivory Coast)

Burning periods	**Minimum (°F)**	**Maximum (°F)**	**Mean (°F)**
Early dry season	76	602	302.16
Middle dry season	**85**	**1009**	**329.18**
Late dry season	83	624	291.4
Entire dry season	76	1009	309.03

Mean values of fire temperature (°F) for different vegetation types and burning seasons*

Vegetation type	Early dry season	Middle dry season	Late dry season
Fallow field	283.61	284.42	303.79
Grass savanna	349.65	459.99	325.72
Shrub savanna	339.84	256.36	331.41
Savanna woodland	239.78	333.46	259.67
Dry forest	225.17	288.31	294.58

**Varies by cover type and season*

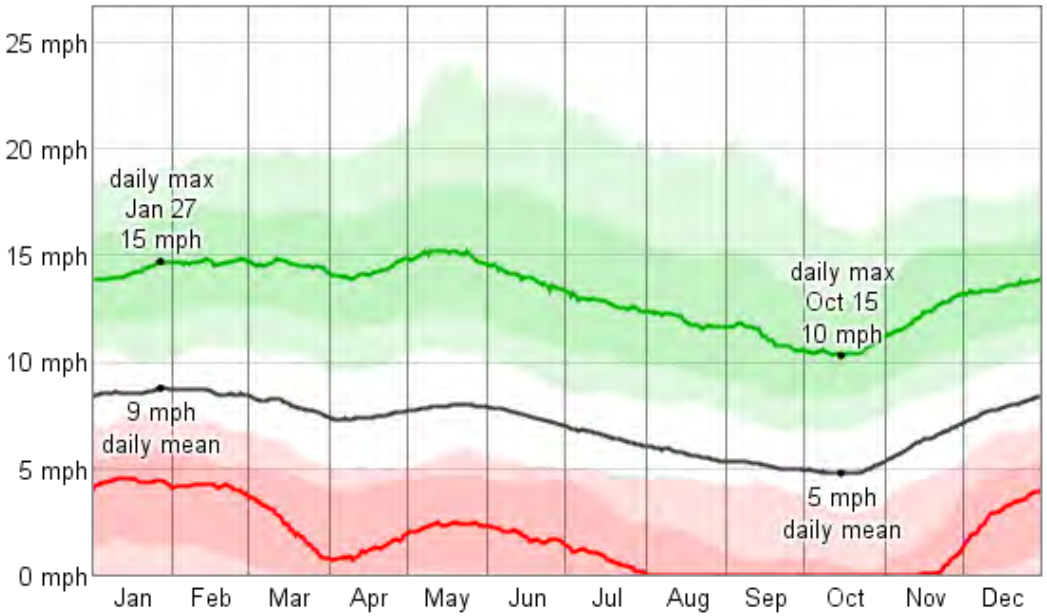
Burning efficiency by dry season period

Burning periods	Minimum (%)	Maximum (%)	Mean (%)
Early dry season	20	99	66.61
Middle dry season	10	99	71.71
Late dry season	40	99	70.62
Entire dry season	10	99	70.62

Mean values of burning efficiency by vegetation type and by burning period

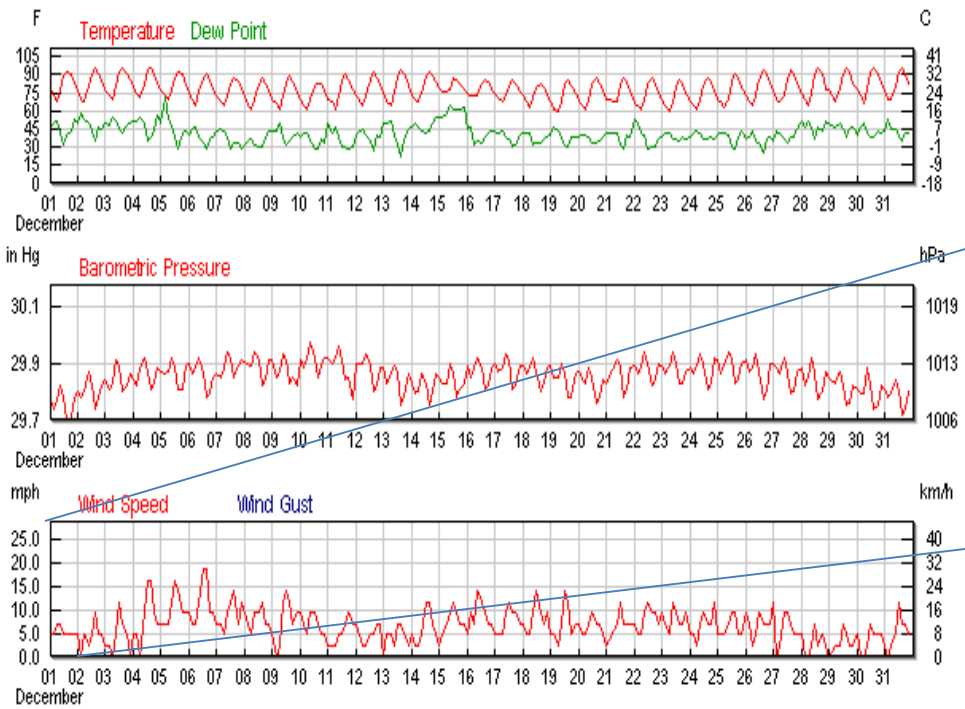
Vegetation type	Early dry season	Middle dry season	Late dry season
Fallow field	31.14	55.57	56.81
Grass savanna	99	99	99
Shrub savanna	71.04	88.42	64.42
Savanna woodland	56.9	77.41	66.54
Dry forest	55.12	82.78	80

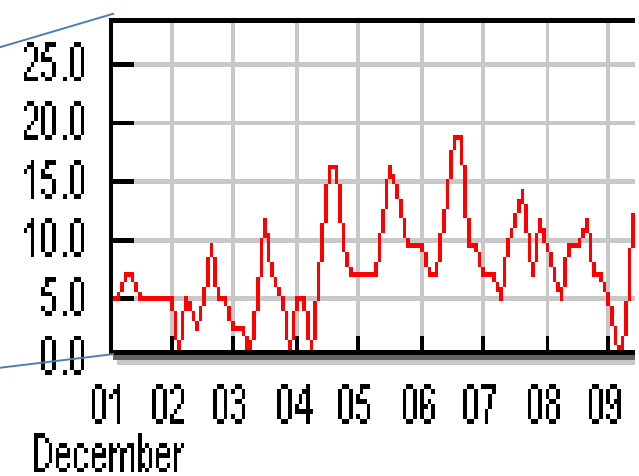

Leaves remaining on small juvenile trees
indicate a low intensity,, low severity fire
for a February--late season--burn, Mali)



Wind Speed peaks during late fires (Feb.)

But as is the case with humidity and temp, *time of day* is critical





People set fires most in afternoon when temp and wind are falling and humidity rising

MODIS data finds that 70% of the fires burn in the afternoon and evening—353,507 compared to 161,921 detected in the morning hours.

Interviews also indicate that afternoon is the preferred time for setting fires because winds are dropping and humidity rising and thus *fires are easier to control and tend to burn themselves out*.

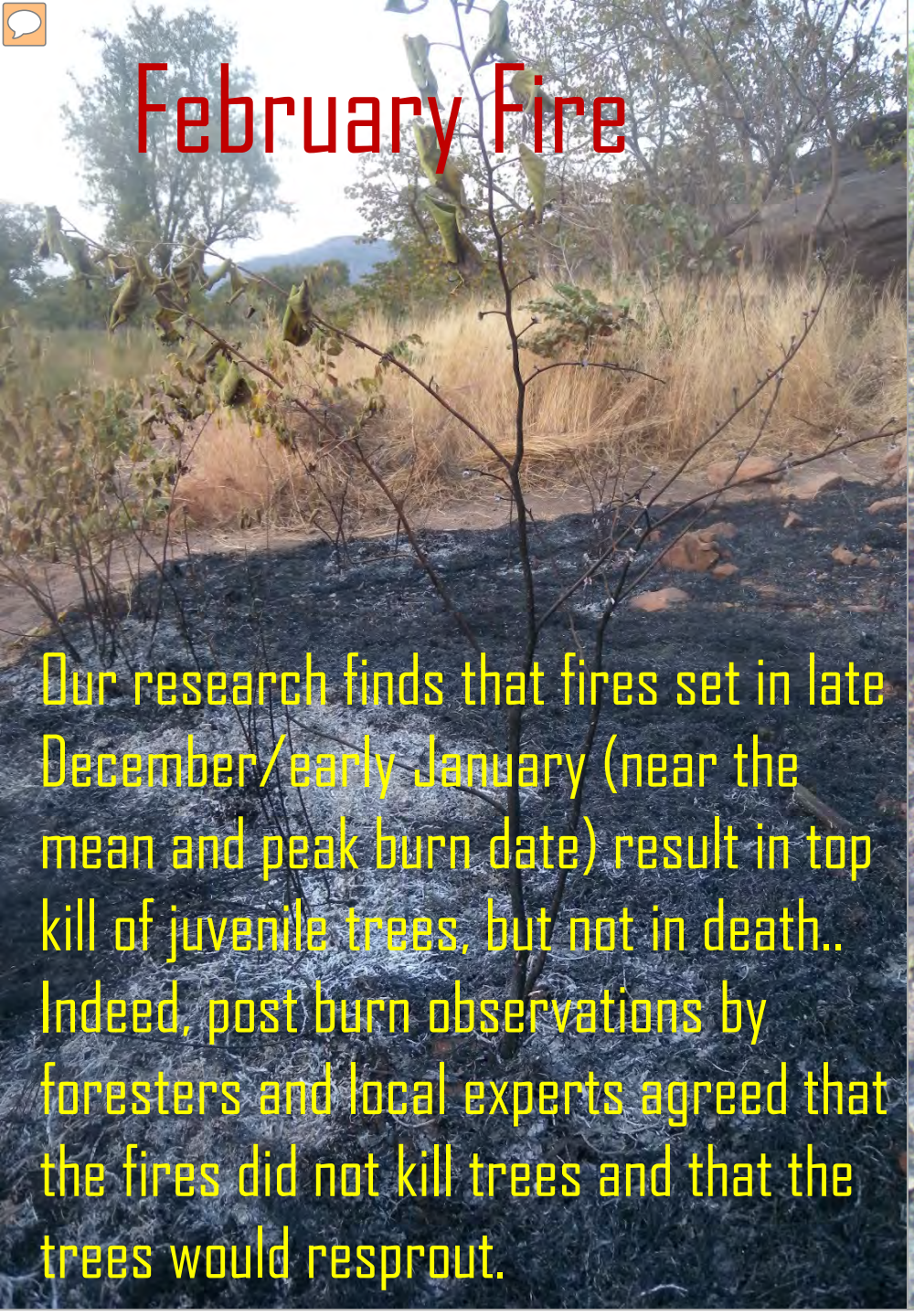
Fire Type/Wind Direction

There was a significant relationship between fire direction and flame height for both mid-season and late-season fires. **Head fires burned more intensely with higher average flame heights** (2.0m compared to 1.2m for mid-season and 2.1m compared to 1.4m for late season). These finding suggests that **fire direction is a critical determinant** of intensity especially when annual fire timing is linked to grass type.

Conclusions

Our analysis finds four general characteristics describe the West African fire regime:

- 1) there is a regular annual spatiotemporal pattern of burning;
- 2) this pattern is linked to veg/soil types and specifically grass types;
- 3) the peak in burning is annually at the "mid fire season" prior to the peak dryness by vegetation type; and
- 4) fires are generally set in the afternoon when wind speed is falling and humidity rising.
- Although most people we interviewed who set fires indicate they prefer to set back fires, it is clear that winds and terrain result in a mix of head and back burns.


February Fire
Our research finds that fires set in late December/early January (near the mean and peak burn date) result in top kill of juvenile trees, but not in death.. Indeed, post burn observations by foresters and local experts agreed that the fires did not kill trees and that the trees would resprout.


Re-spouting after January fire
Fire Trapped?

What is Early and what is Late?: The West African fire experiments and what they can (and can't) tell us

- Mid season fires *may* be severe enough to prevent tree growth, but do not cause death but, again, this depends upon grass type…
- …because fire timing and grass species are correlated
- Finally, we partially accept our alternative hypothesis that *time of day and fire direction as well as grass species are more important factors than seasonality* in determining the impacts of savanna fires on tree regeneration and growth.
- Is it fuel load or tree stress that impacts juvenile trees most?
- Wind and fire direction are major unknowns.

First and Second law of Savanna Fire Ecology

The **first law** of savanna fire ecology—*fire regime determines vegetation cover in a savanna*—cannot be confirmed for actual burning practices—we need more research. The findings support a different rule—*vegetation (especially grass type) determines fire regime.*

In terms of the **second law** that—*late fires are more intense than early fires and thus more damaging to trees*—the data only partially support this rule. Results from Ivory Coast indicate that fire intensity is highest during the mid-dry season for all vegetation types, results from Mali find there is **no significant difference between fire intensity and severity because fire timing is a function of vegetation type.**

Thanks to all of those people in Mali and elsewhere who made the research possible

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