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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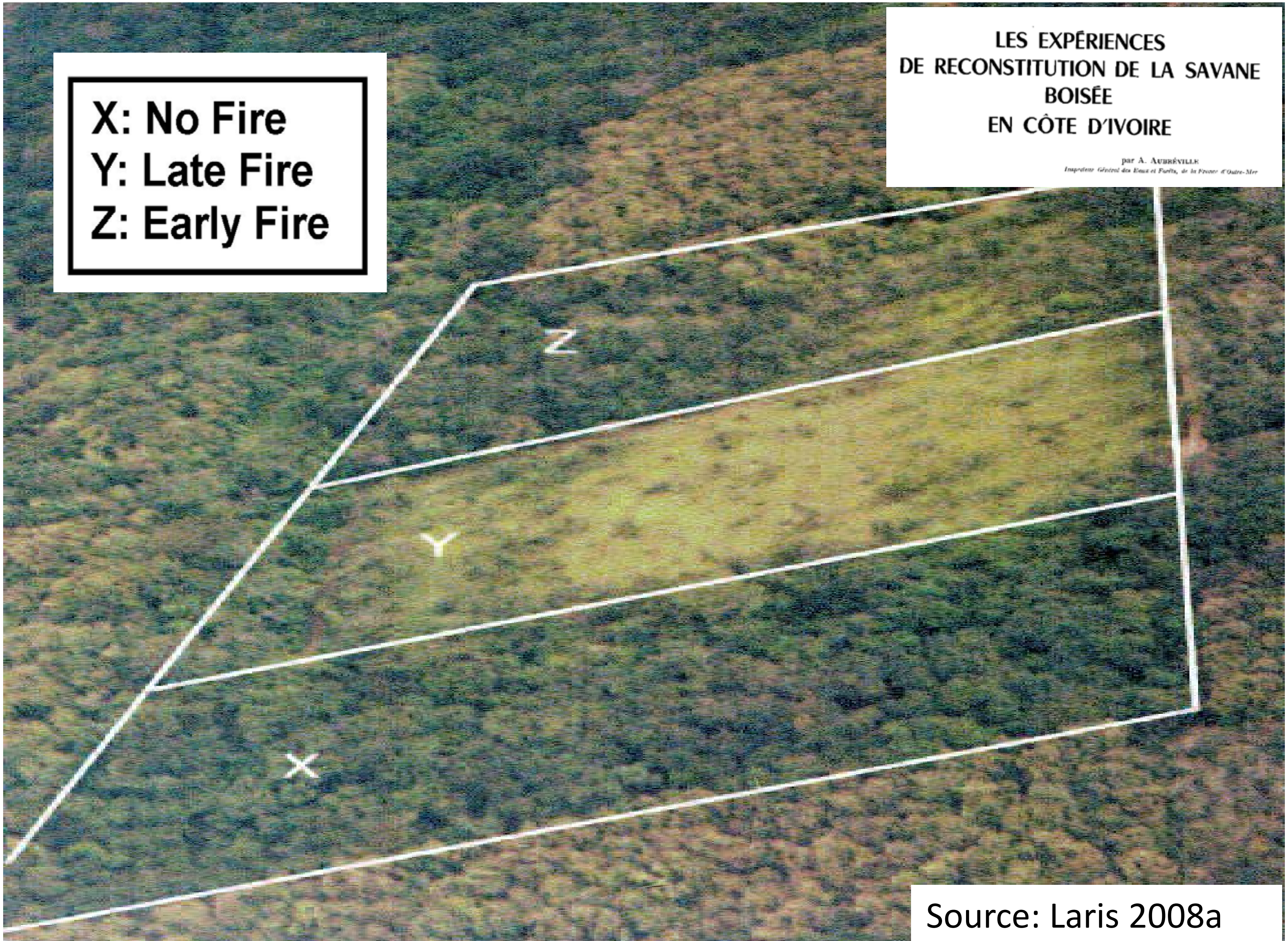
Aubréville's long-term burning experiment

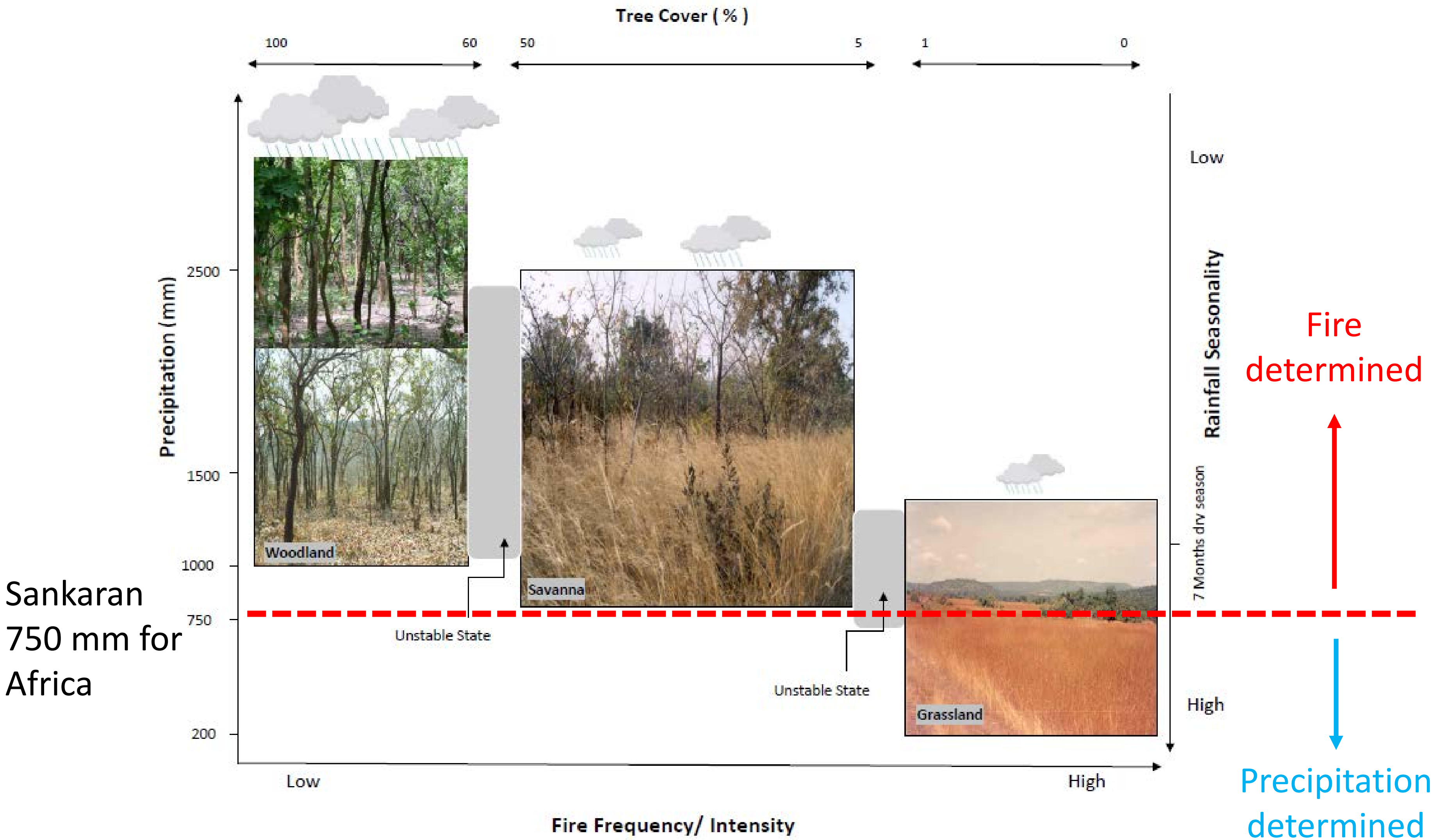


First Law of Savanna Fire Ecology

Fire regime determines vegetation cover in a savanna

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).



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

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

PAUL LARIS* AND DAVID ANDREW WARDELL†‡

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

IPCC and others note that methane emissions decrease by season

Influence of timing and spatial extent of savanna fires in southern Africa on atmospheric emissions

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Since the emission factor for CH_4 can decrease by 50–75% as the burning season progresses, it is strongly suggested that each inventory agency collect seasonal data on the fraction of savanna area burned, the aboveground biomass density, and the fraction of aboveground biomass burned in each savanna ecosystem from the early dry season to the late dry season.

IPCC 2000 (chap. 4, §A.1.1.3, p. 4.87)

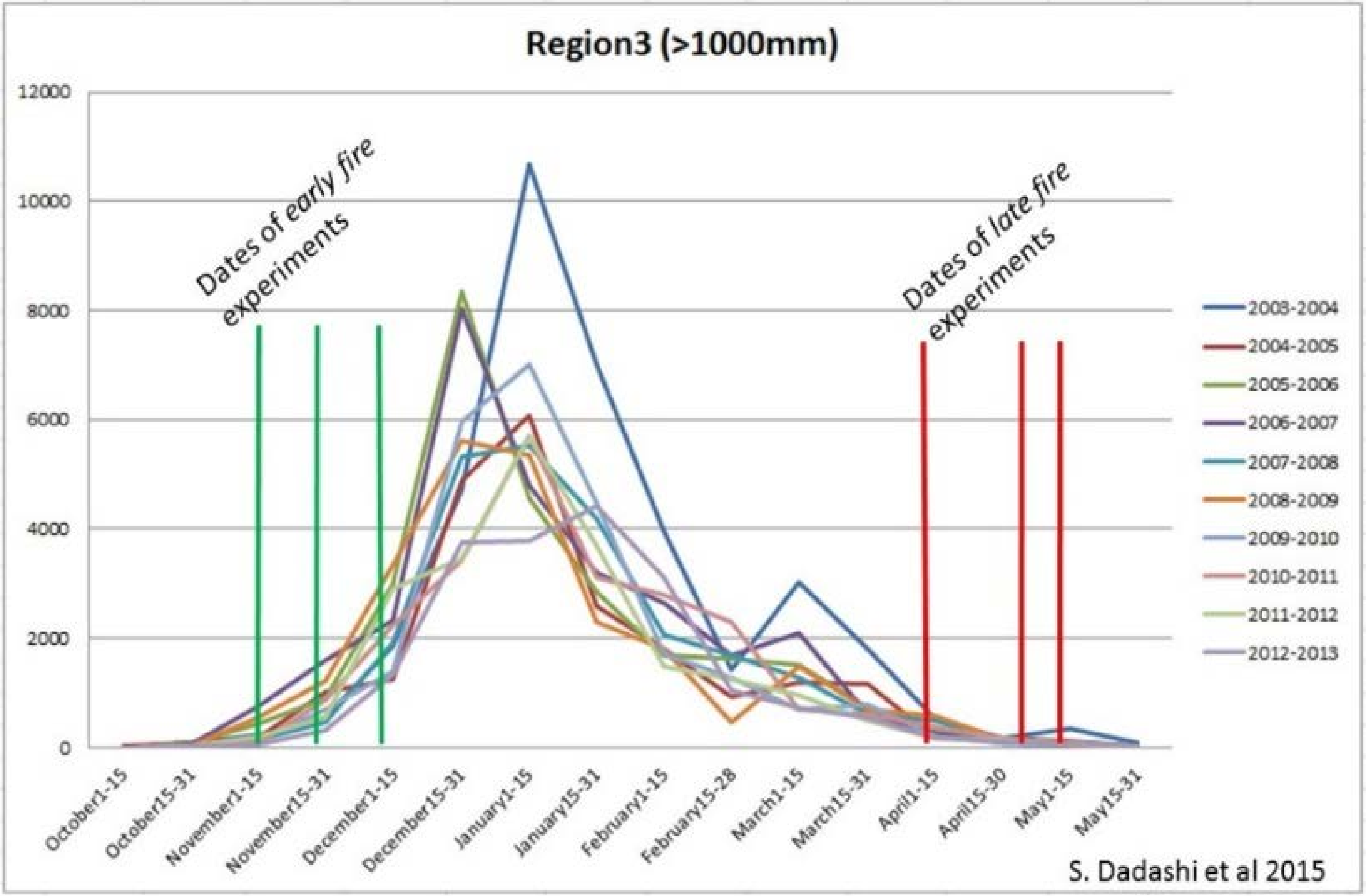
Early/Late: Aubréville's Legacy

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:

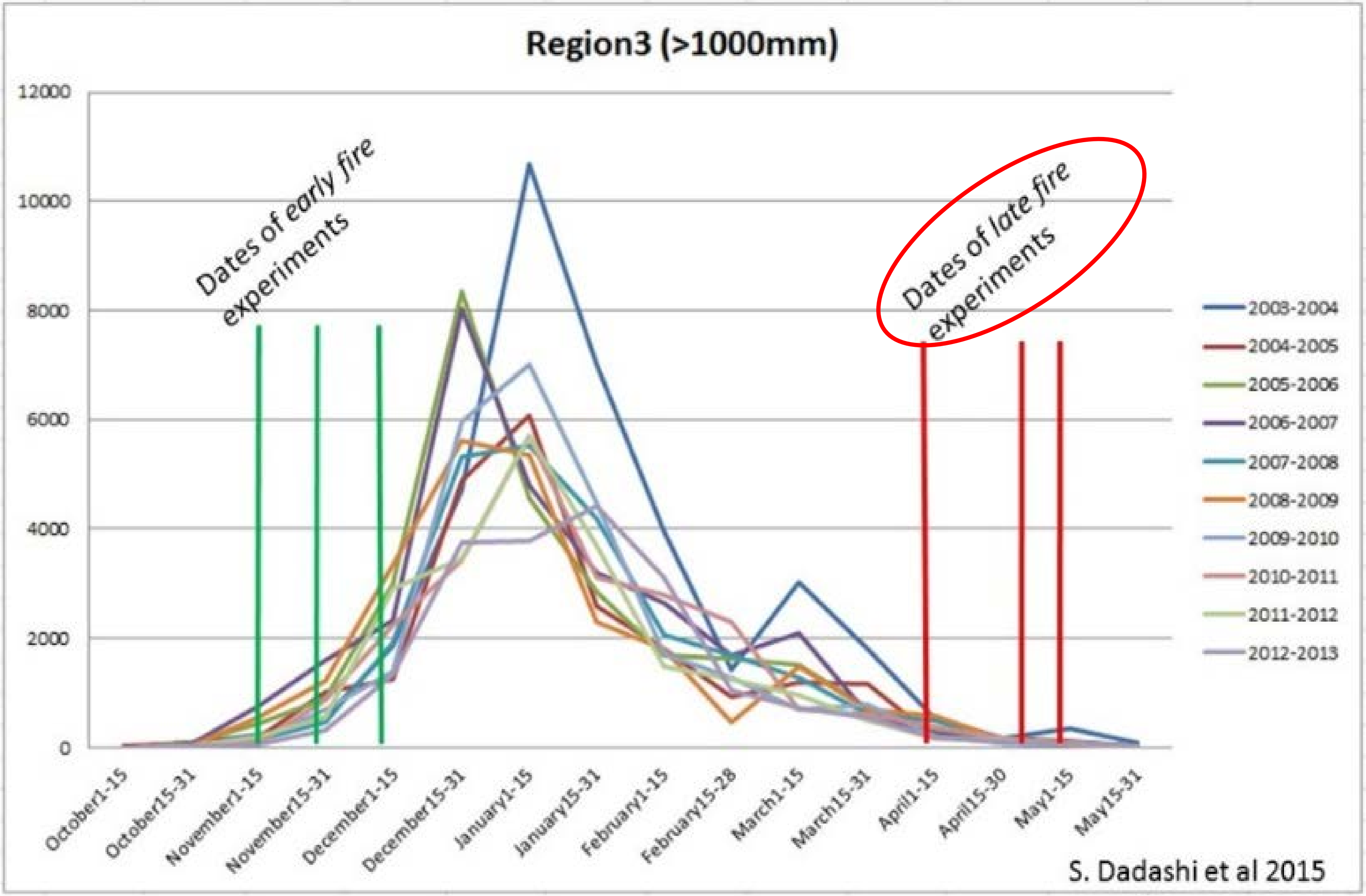
1. **The experiments do not take into account the heterogeneity of different savanna** which are partly a function of soils and vegetation types and other factors which are known to influence tree and grass cover. Recent research has demonstrated that these factors play a critical role in determining 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.

Fire Season Peak* and Experiment Dates



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

Fire Season Peak* and Experiment Dates



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


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

Objectives

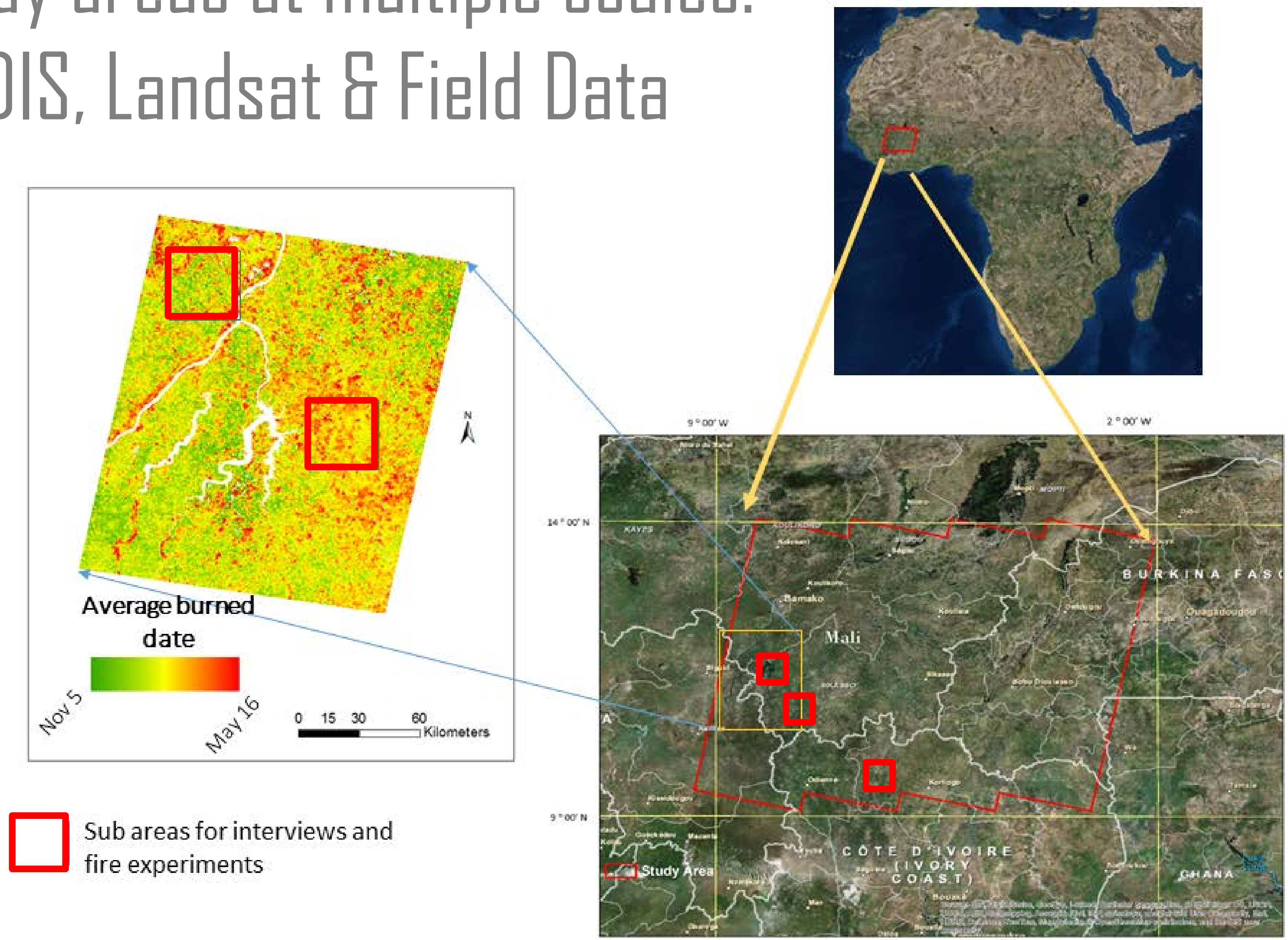
(i) to critically review the results of the burning experiments;

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

(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;

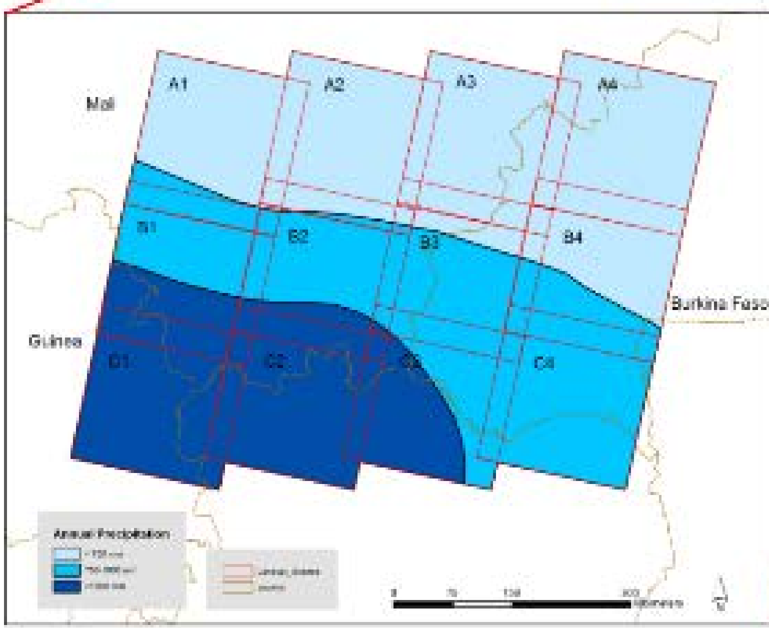
(iv) to suggest implications for GHG emissions research

Study areas at multiple scales: MODIS, Landsat & Field Data



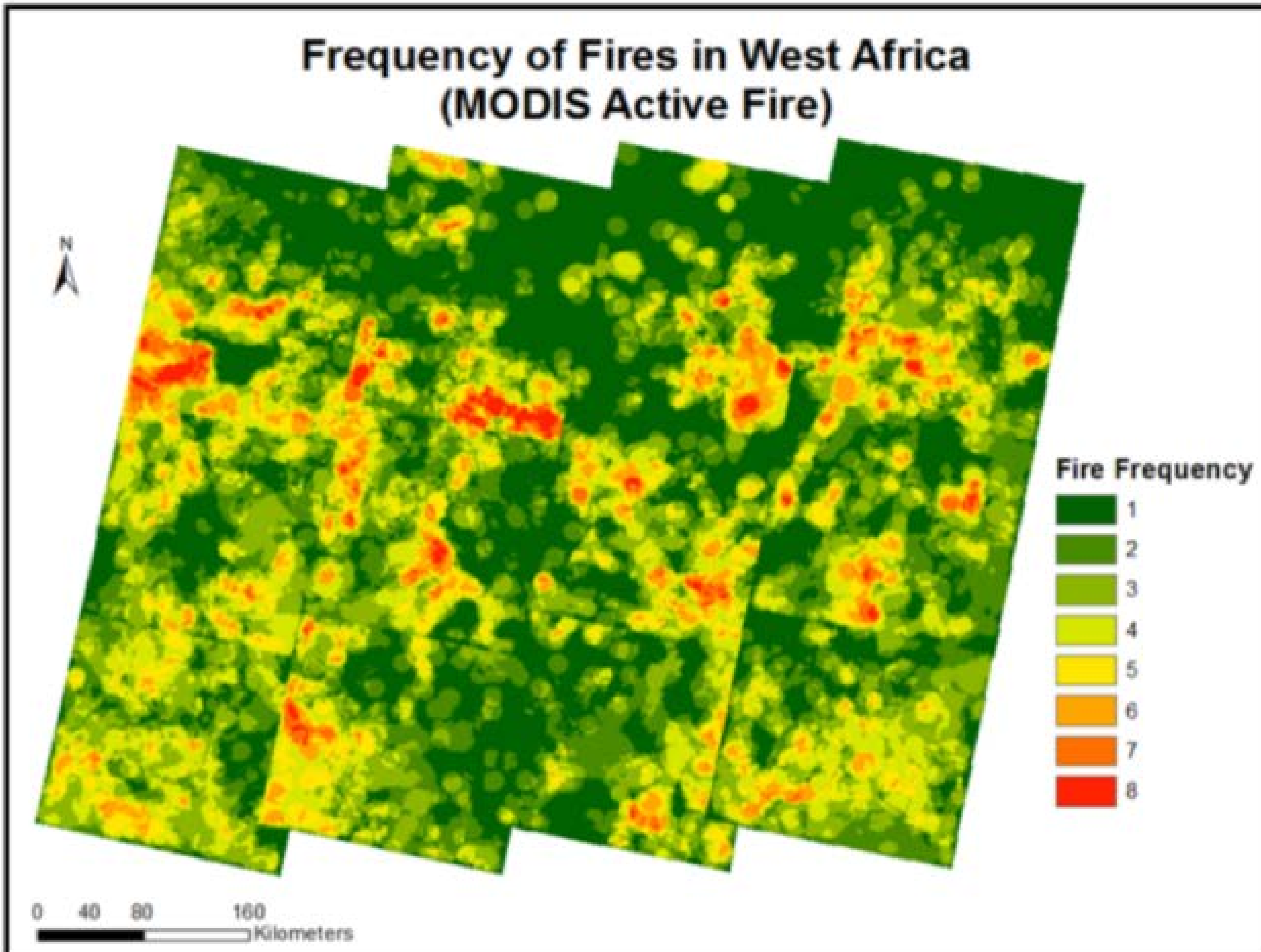
Dry (fire) season from November-May

Savanna Belts

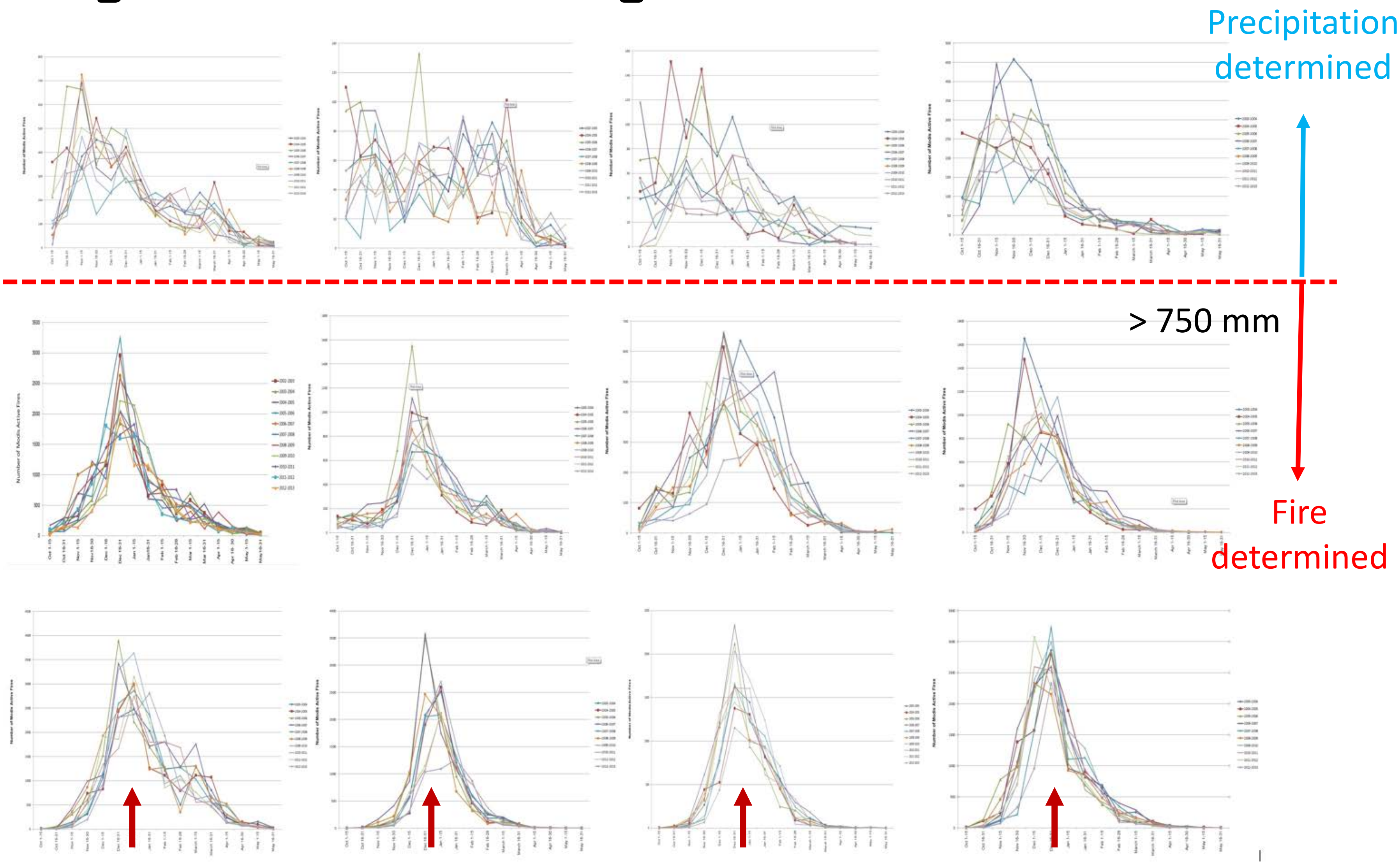


Landsat areas and MODIS Belts

No obvious *spatial* pattern at regional scale for fire frequency

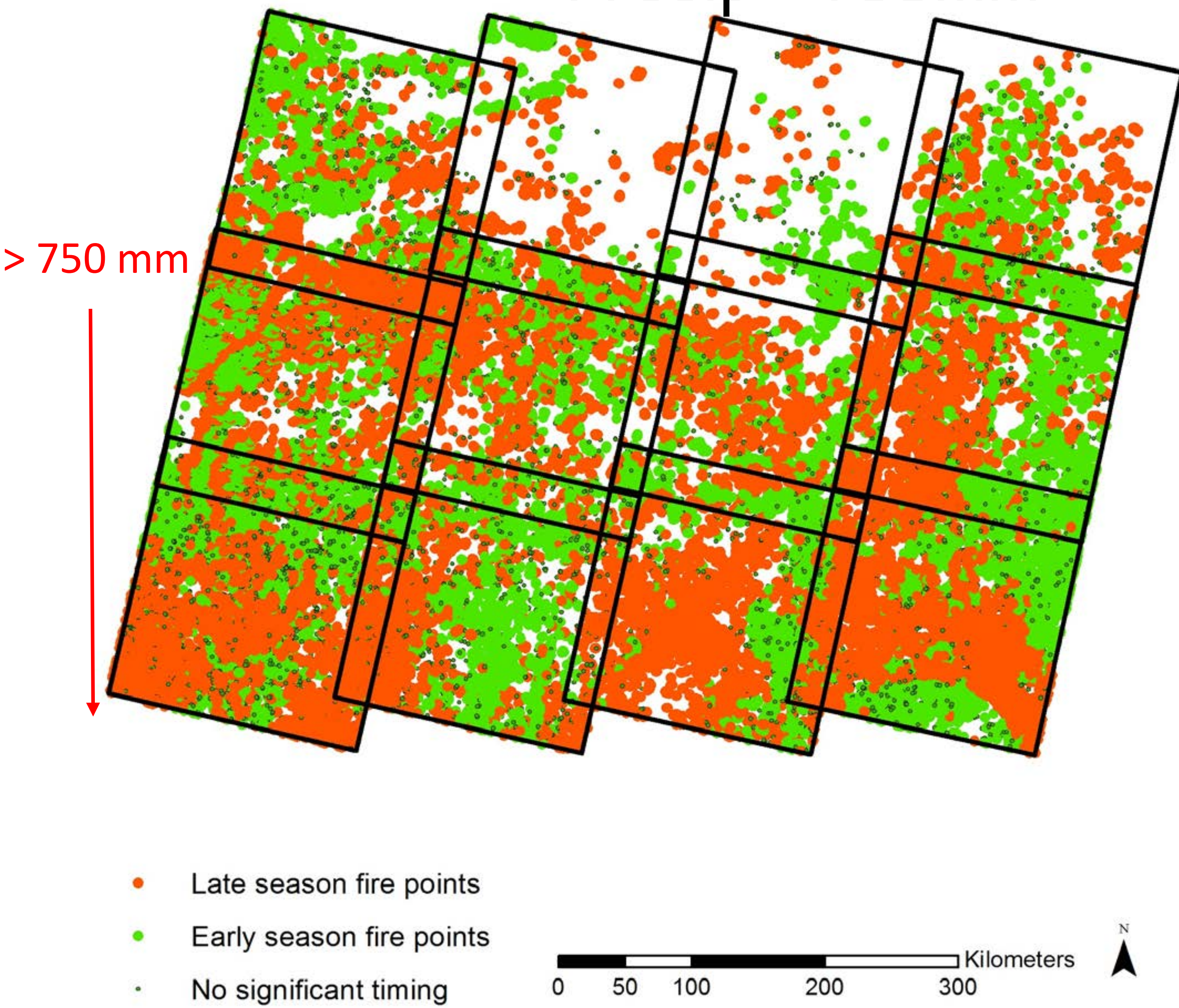


Regular annual timing of fire in mesic areas



Laris, Dadashi et al 2016

Regular annual *spatiotemporal patterns* of fire
Precip > 750mm

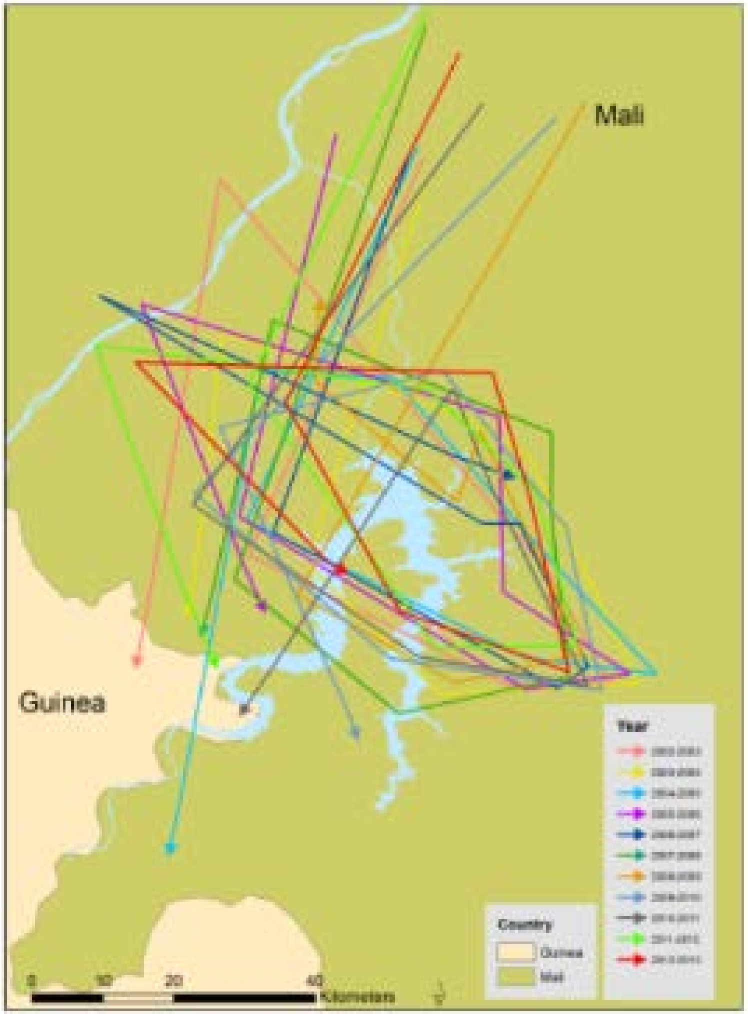


LISA: Blue areas regularly burn *early*, red areas regularly burn *late*

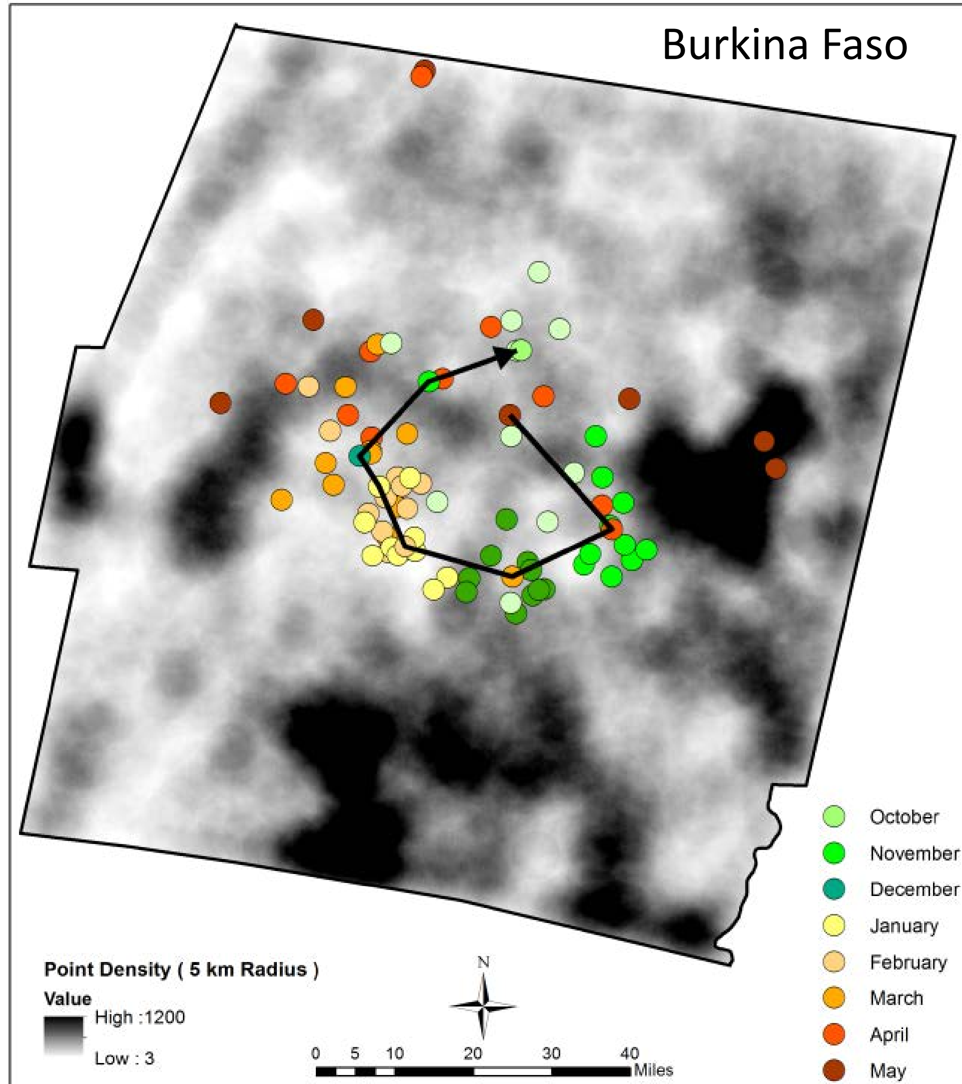
Laris, Dadashi et al 2016

Unique fire center of gravity "pathways" (not North-South)

B1

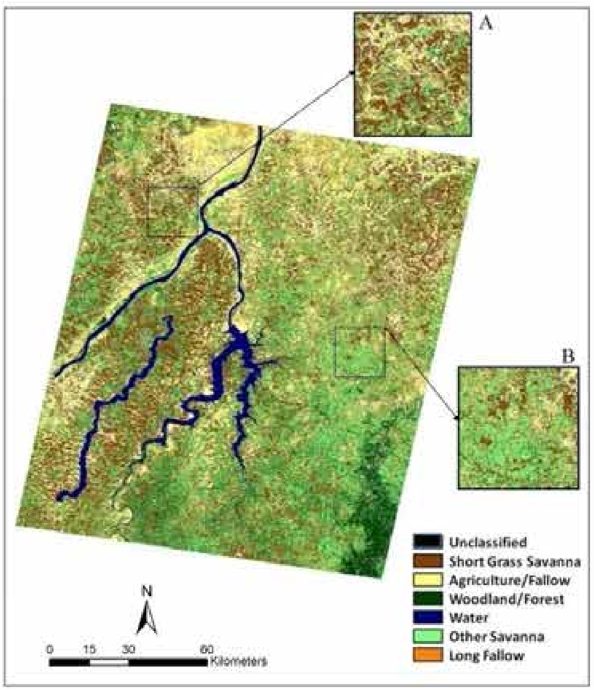


B4

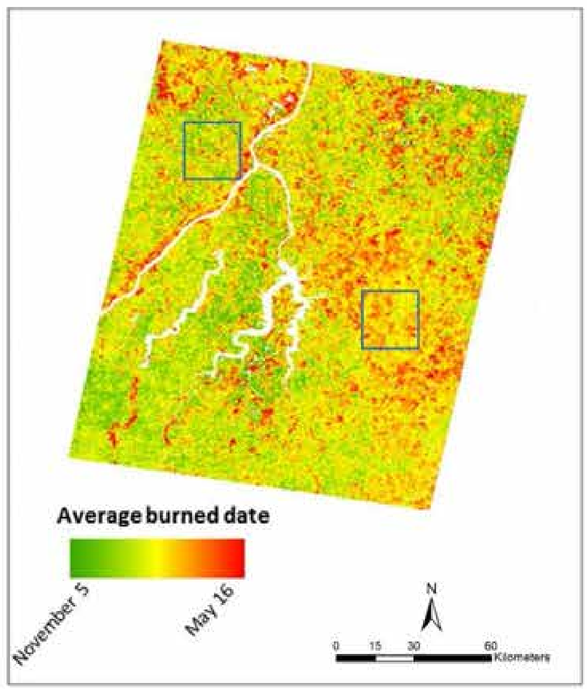


Laris, Caillault et al 2015

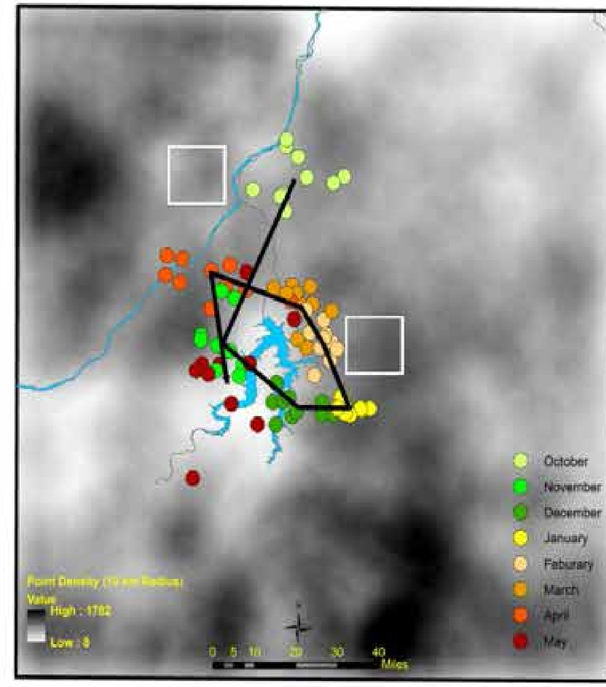
Vegetation, fire regime and spatio-temporal pattern are linked because people time fires to vegetation drying



Vegetation cover



Fire regime



Spatio-temporal pattern

Survey and Imagery Results link timing to vegetation as well

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		

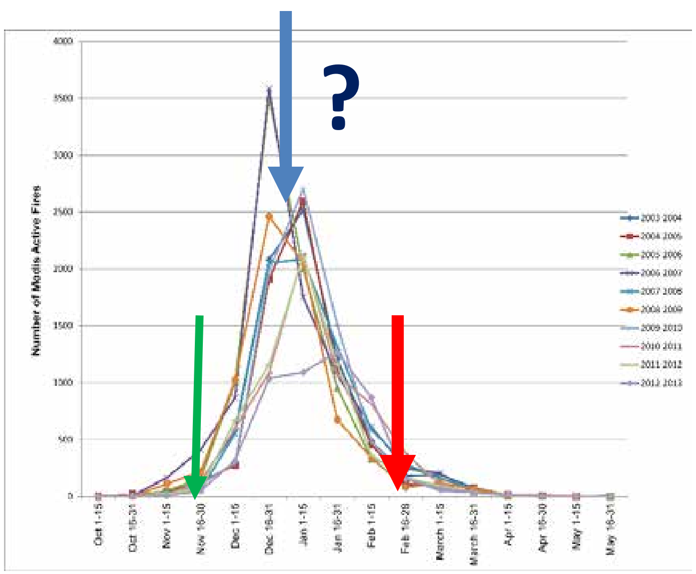
* From Laris 2002, 2006

Summary: What 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 (early January) prior to the peak in vegetation drying or senescence.
- Generally there is high fire frequency
- Spatiotemporal pattern of burning closely aligns with vegetation cover.

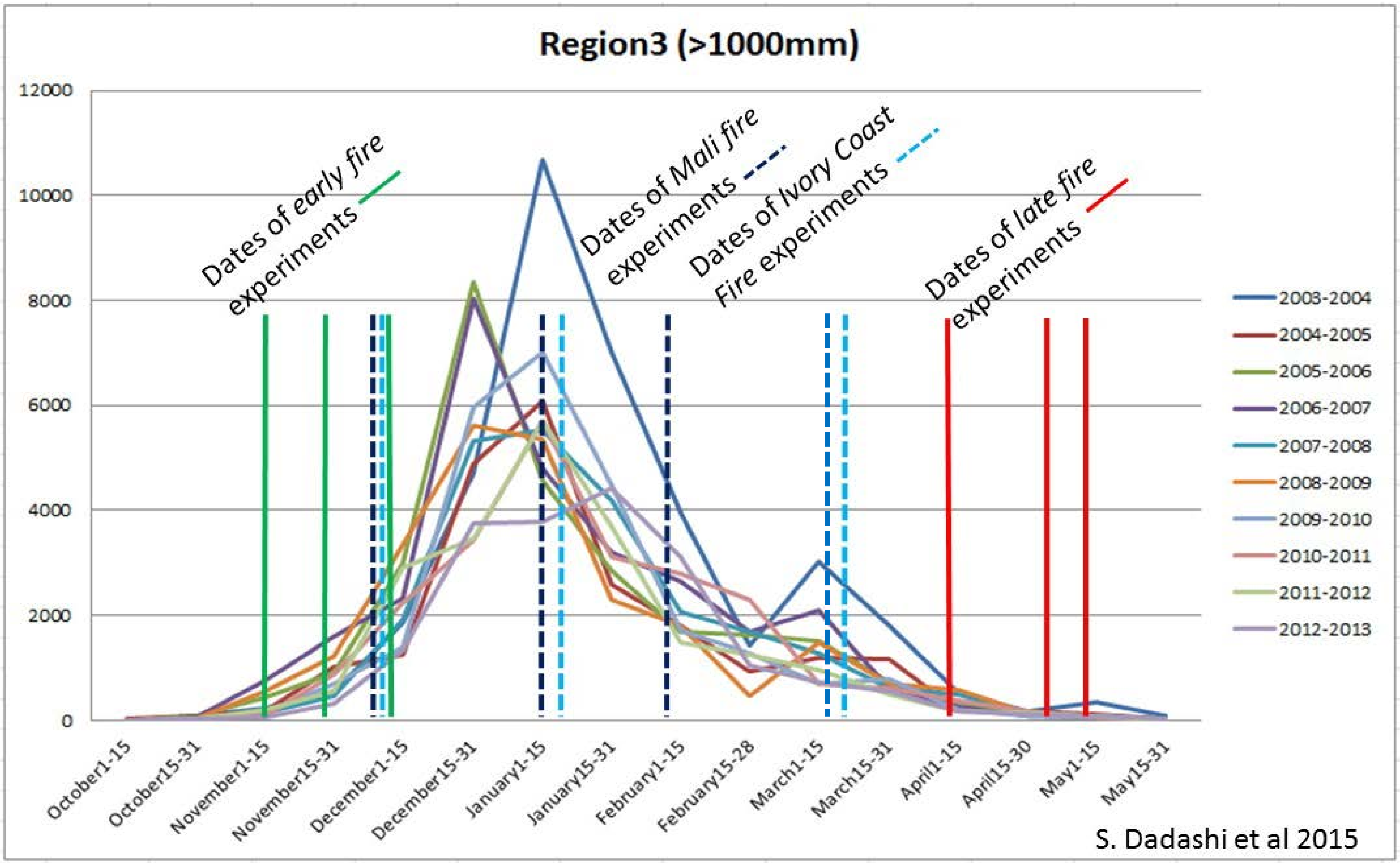
Implications for savanna theory based on the “fire trap”?

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 (ºF) measured in experimental plots for early, middle and late dry season (Katiali, **Ivory Coast**)

Higher temperatures are associated with more intense fires

Burning periods	**Minimum (ºF)**	**Maximum (ºF)**	**Mean (ºF)**
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

M.Kone

Burning efficiency by dry season period

Higher BE is associated with more severe fires

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

M.Kone

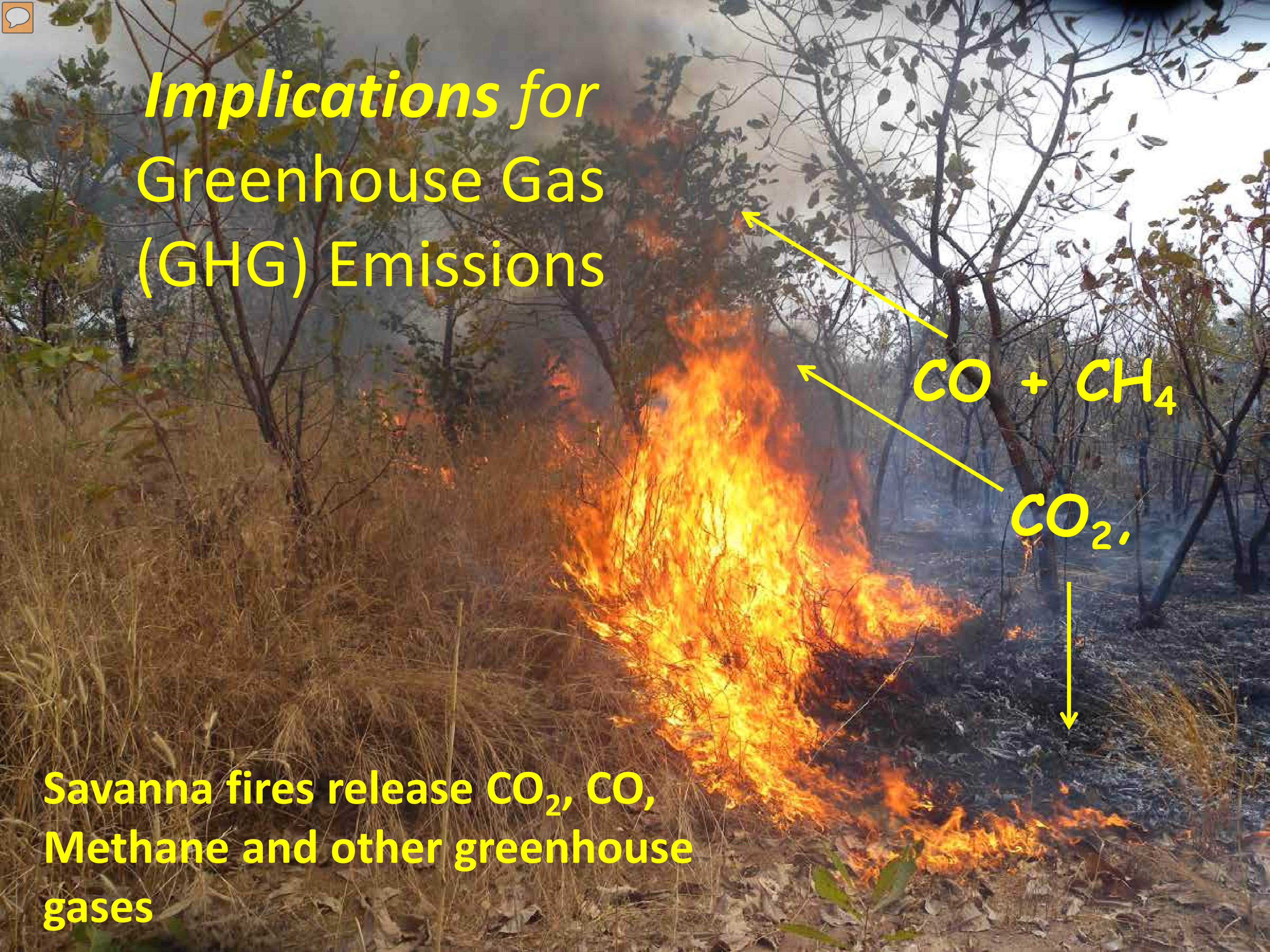
Mean values of burning efficiency by vegetation type and by burning period

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

M.Kone

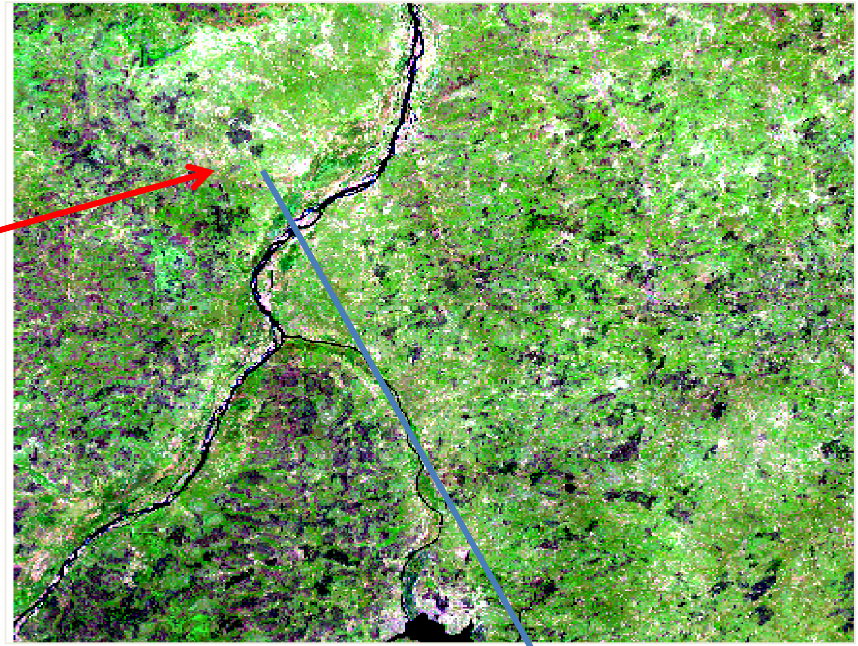

Leaves remaining on small juvenile trees
indicate a **low intensity,, low severity fire**
for a February--late season--burn, Mali)

Implications for Greenhouse Gas (GHG) Emissions



Savanna fires release CO_2, CO, Methane and other greenhouse gases

Building a model from the ground up



Fire timing, location and vegetation type determined from interview and long term data analysis

Area Burned determined from Landsat analysis of burn-scars and vegetation types

Biomass consumed and burn efficiency are determined the field

Burn Efficiency (Visual)

Higher in late season…

Means

Case Processing Summary

	Cases					
	Included		Excluded		Total	
	N	Percent	N	Percent	N	Percent
Eff_Visual (%) * Year/ Season	14549	100.0%	0	0.0%	14549	100.0%

Report

Eff_Visual (%)

Year/ Season	N	% of Total N	Minimum	Maximum	Mean	Variance	Std. Deviation	Std. Error of Mean
Early dry season	9640	66.3%	50.0	100.0	79.057	150.397	12.2637	.1249
Middle dry season	3466	23.8%	80.0	99.0	96.240	37.583	6.1305	.1041
Late dry season	1443	9.9%	100.0	100.0	100.000	.000	.0000	.0000
Total	14549	100.0%	50.0	100.0	85.228	184.368	13.5782	.1126

Biomass Consumed

Peaks in mid-season…

Means

Case Processing Summary

	Cases					
	Included		Excluded		Total	
	N	Percent	N	Percent	N	Percent
Biomass consumed (%) * Year/ Season	14549	100.0%	0	0.0%	14549	100.0%

Report

Biomass consumed (%)

Year/ Season	N	% of Total N	Minimum	Maximum	Mean	Variance	Std. Deviation	Std. Error of Mean
Early dry season	9640	66.3%	60.85	98.68	86.6584	73.490	8.57264	.08731
Middle dry season	3466	23.8%	79.26	96.43	92.7967	27.337	5.22850	.08881
Late dry season	1443	9.9%	92.11	92.11	92.1100	.000	.00000	.00000
Total	14549	100.0%	60.85	98.68	88.6614	63.115	7.94452	.06586

Methane by Season (Same Veg)

Means

Case Processing Summary

	Cases					
	Included		Excluded		Total	
	N	Percent	N	Percent	N	Percent
CH4_ppm * Year/ Season	14535	99.9%	14	0.1%	14549	100.0%

Report

CH4_ppm

Year/ Season	N	% of Total N	Minimum	Maximum	Mean	Variance	Std. Deviation	Std. Error of Mean
Early dry season	9633	66.3%	0	9196	494.85	762517.168	873.222	8.897
Middle dry season	3466	23.8%	0	4745	232.64	248122.597	498.119	8.461
Late dry season	1436	9.9%	0	5001	529.80	1216481.439	1102.942	29.106
Total	14535	100.0%	0	9196	435.78	697626.261	835.240	6.928

High methane => less complete combustion in the ***late*** fire season???

Combustion Efficiency (MCE)

Lowest in late season! Why?

Means

Case Processing Summary

	Cases					
	Included		Excluded		Total	
	N	Percent	N	Percent	N	Percent
MCE * Year/ Season	13576	93.3%	973	6.7%	14549	100.0%

Report

MCE

Year/ Season	N	% of Total N	Minimum	Maximum	Mean	Variance	Std. Deviation	Std. Error of Mean
Early dry season	8800	64.8%	.00	1.00	.8232	.136	.36881	.00393
Middle dry season	3363	24.8%	.00	1.00	.9074	.026	.16260	.00280
Late dry season	1413	10.4%	.00	1.00	.7562	.019	.13940	.00371
Total	13576	100.0%	.00	1.00	.8371	.099	.31427	.00270


Leaf Litter increases as
dry season progresses
Late January

Note that Hao and Ward found CE of 0.93 for Africa in general and a lower limit of 0.85 for a site with compact litter.

Summary

- There is a regular annual spatiotemporal pattern of burning; this pattern is linked to veg/soil types and specifically grass types;
- Grasses tend to burn just before they are completely desiccated
- Mid season fires *may* be severe enough to prevent tree growth, but do not cause death (fire trap) but, again, this depends upon grass type…because fire timing and grass species are correlated

- Wind and fire direction are major unknowns in the data.
- Future research: Is it fuel or tree stress that impacts juvenile trees most?

Conclusions: First and Second law of Savanna Fire Ecology and Emissions Implications

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**—*late fires are more intense than early fires and thus more damaging to trees*—the data only partially support this rule. Preliminary results indicate that fire intensity and severity are highest during the mid-dry season for all vegetation types.

In terms of emissions, the late fire season ***does not*** appear to have the most complete combustion and ***does not*** have lower values of CH_4 emissions, indeed, the values for emissions are higher than for the mid-dry season…in part due to increased leaf litter in late season.

Most fire is in mid-season = lower Methane than if shifted earlier or later.

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

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