River dry, river high, elephants nigh: transformation of the Greefswald Forest 1990-2007

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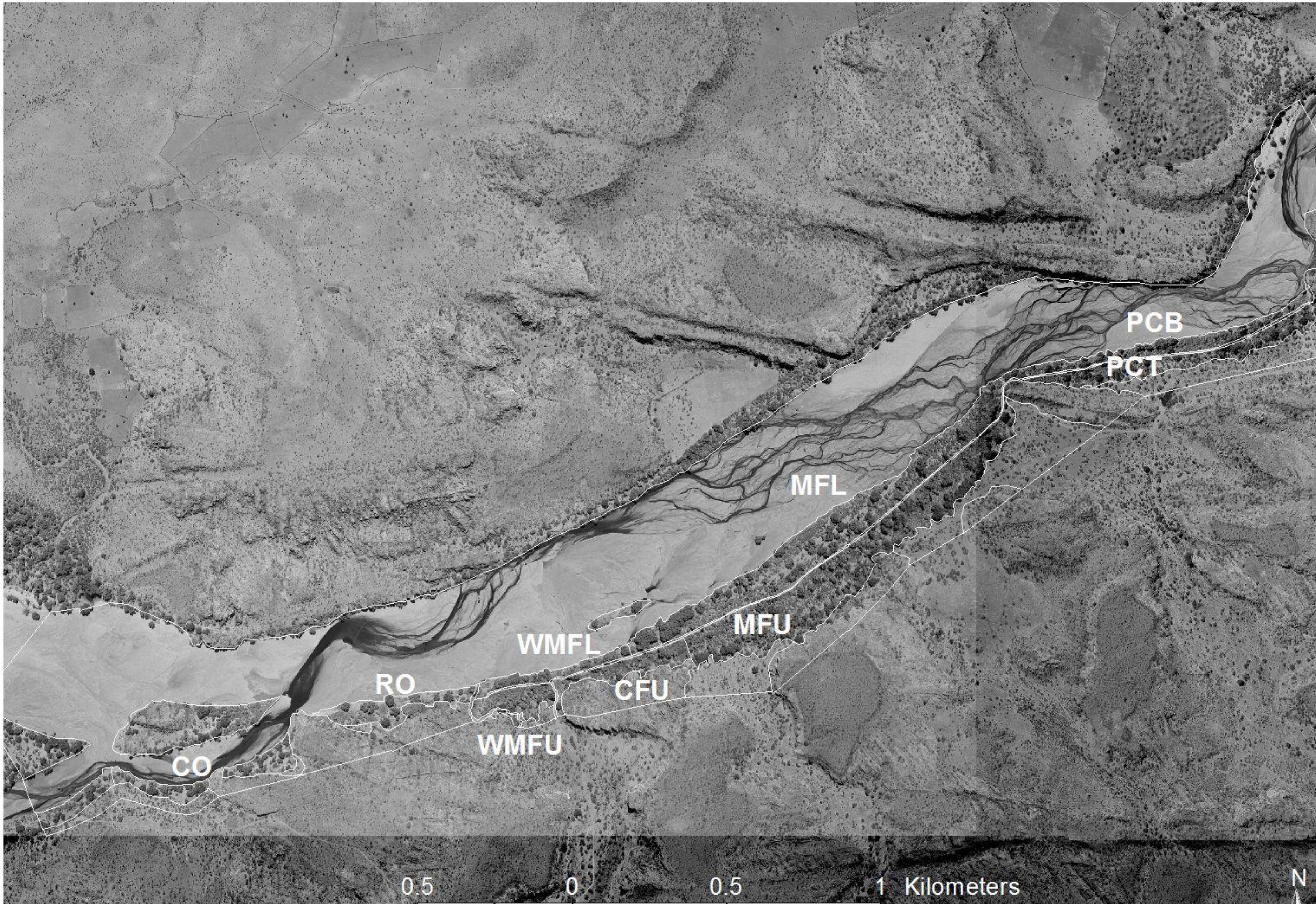
Aim of talk

- Illustrate a case history of forest change
- Use it to identify some principles for long-term observation of dynamics of this nature

Study site: Shashe-Limpopo confluence to 4 km downstream



Left: Thin riparian strip below confluence.
Right: Central forest area with Shashe in background, *Salvadora* flats, and Cave sandstone hills (Jan 2007)

Study site

- Fed by large Limpopo (catchment: NE Botswana, northern SA, southern Zimbabwe) and smaller Shahshe (old Zambezi)
- Semi-arid region (350 mm pa) – site water inputs are minimal
- 54 ha forest 2-4 km below confluence – Lowveld Riverine Forest (FOa1)
- Forest aquifer recharged directly from river
- 15 well points established along upper levee for 0.7 km in 1991 – 4.2 million m^3 extracted per annum
- State land with low wildlife densities for past few decades.
- Resident elephant population in Botswana but absent from site for decades.
- Elephants appeared within Greefswald since 2000 and numbers have increased since then.

Background

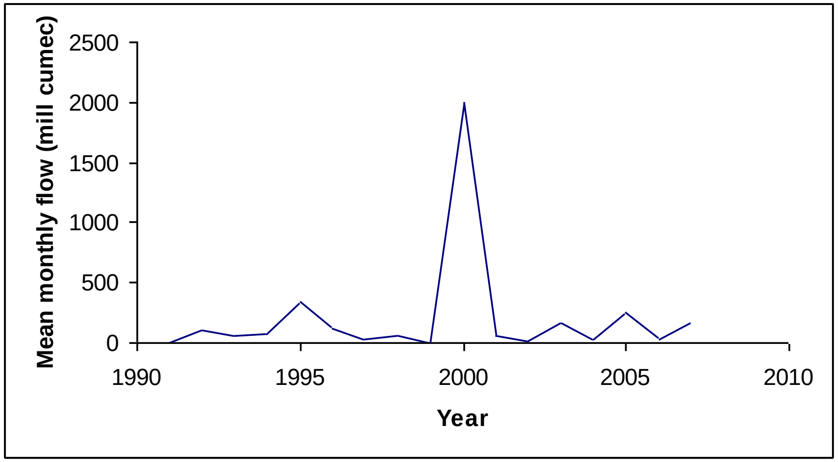
1. Water abstraction from a wellfield within the forest commenced in 1991 in order to supply mining requirements
2. Concern about effects on riparian vegetation, hence a scoping study for impact assessment.
3. This study was for description of vegetation.
4. An alternative monitoring approach was used for water management.

Impacts on riparian vegetation

1. Need to consider all potential impacts on forest
2. Riparian systems depend on hydrological regime. Change this, and can change the system. Therefore concern about water abstraction.
3. But there are also natural agents of forest change:

- Droughts
- Ingress of saline water (Western and van Praet 1963)
- Floods
- Elephants (ringbarking, uprooting, stem pollarding)
- Porcupine ringbarking (Thomson 1974)
- Lightning (Spinage & Guiness 1971), shear by high winds
- Creepers (Amazon)
- Long-term forest decline in response to long-term climatic variation

Limpopo hydrograph



- 0 for 1991: flow ceased midwinter 1991 through summer to midwinter 1992 – first time no summer flow recorded
- Followed by some poor years
- Mega-flood of February 2000 unprecedented – > 1:100 years

Lesson 1. Flow monitoring failed when needed most.

Lesson 2. Mandated flow monitoring was poorly maintained.

Sampling and methods

1. **Impact assessment:** BACI design desired
2. BUT monitoring only initiated at outset, and
3. No controls were available, therefore monitored from well upstream to well downstream of wellfield
4. Delimit physiographic regions that would reflect different amounts of available water (ie distance from and elevation above river)

Sampling

- 1990 – baseline assessment of forest composition, size and condition of canopy trees (mapped individual trees)
- 2005 – repeat
- 2007 – additional mortality resulting from elephants' impact

Measures

Tree morphometry, creeper infestation, elephant ringbarking, biomass loss to wind, elephants, and drought.

Note: **Had to infer causes of death from evidence. Can do with adult forest trees but otherwise can be difficult. More frequent sampling would have reduced potential error.**

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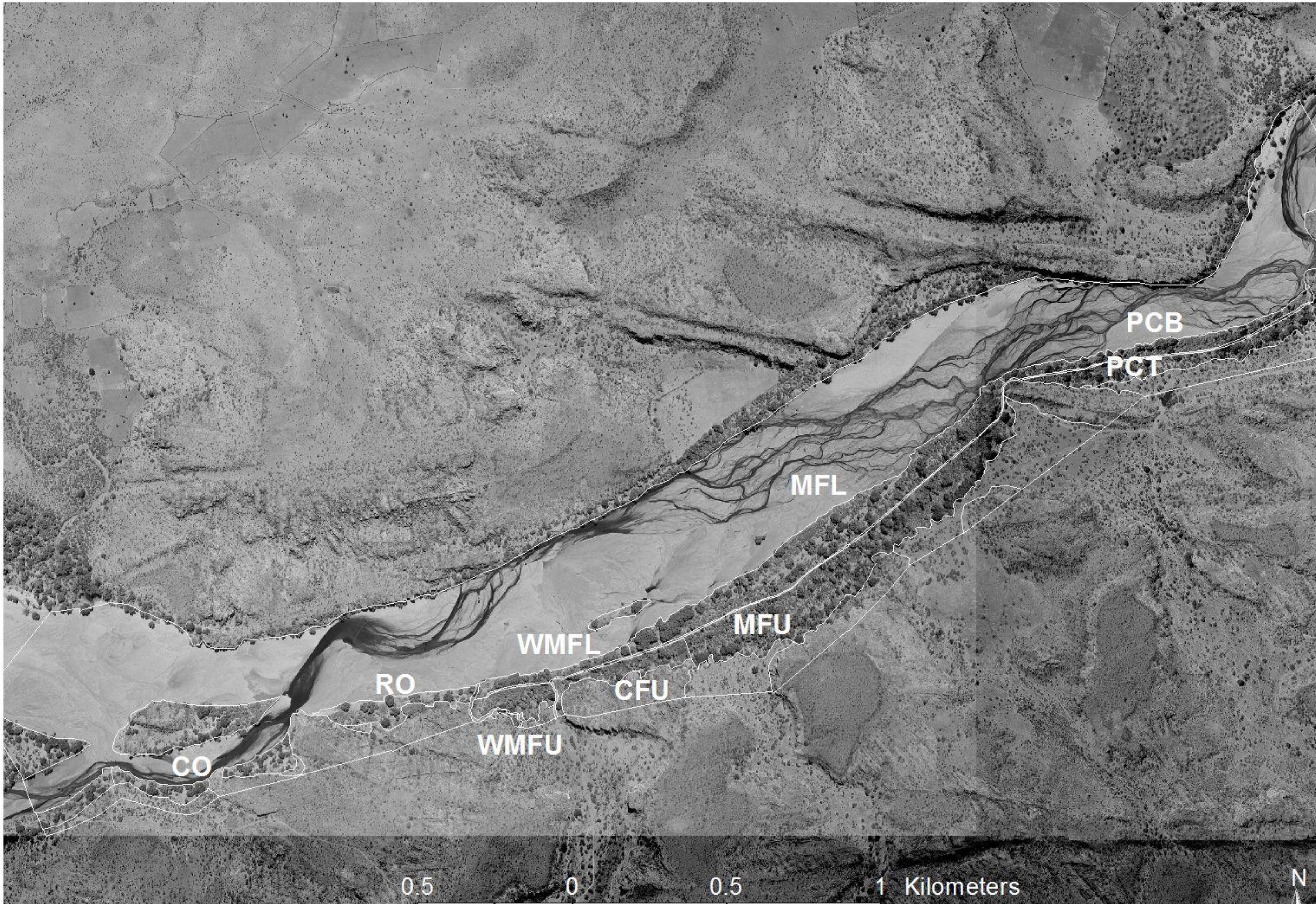

Impact of flood

Intact bank

Bank eroded by 2000 flood –
Up to 60 m lost

Lesson 1. 1:100 event - right place at the right time
Lesson 2. Sampling should have followed event

Mortality of adult trees: 1990-2005

Species (*n*)	Mortality (%)	Drought (%)	Drought/ Creeper (%)	Flood (%)
Acacia xanthophloea (59)	56	70	30	-
Faidherbia albida (60)	37	32	50	18
Ficus sycamorus (89)	25	18	9	73
Philonoptera violacea (63)	11	57	43	-
Schotia brachypetala (56)	13	71	29	-
Sclerocarrya birrea (18)	6	-	100	-
Xanthocercis zambesiaca (47)	6	33	-	67
All species (428)	25	47	30	21

Lesson. Drought event should have been sampled.

Impact of abstraction

- Compared mortality from drought stress (& loss of basal area) of physiographic regions containing well-field versus those without
- Greater proportion of trees died from drought stress in wellfield (24.4 %) than in non-well-field areas (18.6 %) (Gadj=3.5; 1 df; $P<0.065$)

Lesson. Fine-scaled monitoring of mortality in relation to distance from well point would have improved inference, but was in pre-GPS days

Creepers and tree mortality

Tree type	Number dead	Number alive
Microphyllous		
Faidherbia albida	9	2
Acacia tortilis	2	0
Acacia xanthophloea	9	0
Sub-total	20	2
Broad-leaved		
Ficus sycamorus	1	4
Philonoptera violacea	1	1
Schotia brachypetala	1	4
Sclerocarrya birrea	1	4
Xanthocercis zambesiaca	0	1
Sub-total	4	14

Lesson. Biological intuition can pay

Other impacts on survivors

Species	Dieback 05	Creepers (% trees)	Wind shear (% trees)
Acacia xanthophloea	31	19	12
Faidherbia albida	42	58	16
Ficus sycamorus	37	31	5
Philonoptera violacea	16	21	20
Schotia brachypetala	18	16	20
Sclerocarrya birrea	12	29	6
Xanthocercis zambesiaca	5	16	14

Rank order of drought tolerance

1. *Ficus sycamorus*
2. *Acacia xanthophloea*
3. *Faidherbia albida*
4. *Xanthocercis zambesiaca*
5. *Schotia brachypetala*
6. *Philonoptera violacea*
7. *Sclerocarrya birrea*

(shown by distance from, and elevation above, river)

Impact of elephants

Species	% debarked 2005	% debarked 2007
Acacia xanthophloea	92 (26)	100 (45)
Faidherbia albida	18 (3)	22 (4)
Ficus sycamorus	94 (22)	97 (33)
Philonoptera violacea	0	0
Schotia brachypetala	20 (4)	27 (6)
Sclerocarrya birrea	82 (45)	86 (50)
Xanthocercis zambesiaca	18 (<1)	19 (1)

First maroela recorded to die from elephant ringbarking Jan 2007

Value in parentheses – median % of circ debarked

Lesson. Appropriate measures for well understood impacts

Compositional change: % basal area

Species	1990	2005
Acacia nigrescens	0.58	0.70
Acacia tortilis	0.54	0.43
Acacia xanthophloea	7.17	4.96
Croton megalobotrys	0.52	0.65
Faidherbia albida	13.04	11.04
Ficus sycamorus	55.75	55.47
Philonoptera violacea	4.64	5.64
Schotia brachypetala	7.26	3.41
Sclerocarrya birrea	2.95	3.41
Xanthocercis zambesiaca	20.54	24.58

Lesson. Community-level monitoring would have been weak for revealing impact

Long-term climatic response?

- GIS mapping of forest extent using aerial photographs: 1955; 1964; 1970; 1977; 1987; 1999; 2004
- No meaningful change in spatial extent of forest
- Air photo analysis showed 1.6 km of bank eroded by up to 60 m – accounts for substantial loss of *Ficus sycamorus*

Lesson: air photography an exceptional (underutilised??) resource for detecting historical change

Forest to woodland: 1990-2007

Closed canopy

Open woodland

Ecological conclusions

1. Water abstraction had an impact, but eclipsed by that of drought, flood and elephants
2. Composition tending toward ‘drought-tolerant’ species
3. Elephants minor to date, but their impact is set to increase over time

Observation conclusions

1. Observation ‘capture’ of a concatenation of rare events was serendipitous
2. Change was stark (mortality) rather than subtle (growth rates)
3. Identification of agents of mortality only as good as pre-considered agents – but at least others than abstraction recognised from the outset
4. Should monitor directly in relation to key events (drought, flood)
5. Offset in part because evidence remains for some time with long-standing (or prostrate) tree skeletons
6. Study of ecological history not the same as of ecology