



Watershed Management Cross-Cutting Activity

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Objectives

1. Support natural resource management at a watershed and policy analysis scale by documenting landscape condition, quantifying natural resources, and defining land cover and land use change using geospatial imagery and analysis.
2. Assess the impacts of climate variation and land use practices on agricultural sustainability and natural resource management at a watershed scale.
3. Evaluate the accuracy and value of low-cost community-based monitoring of watershed hydrology.

Approach...

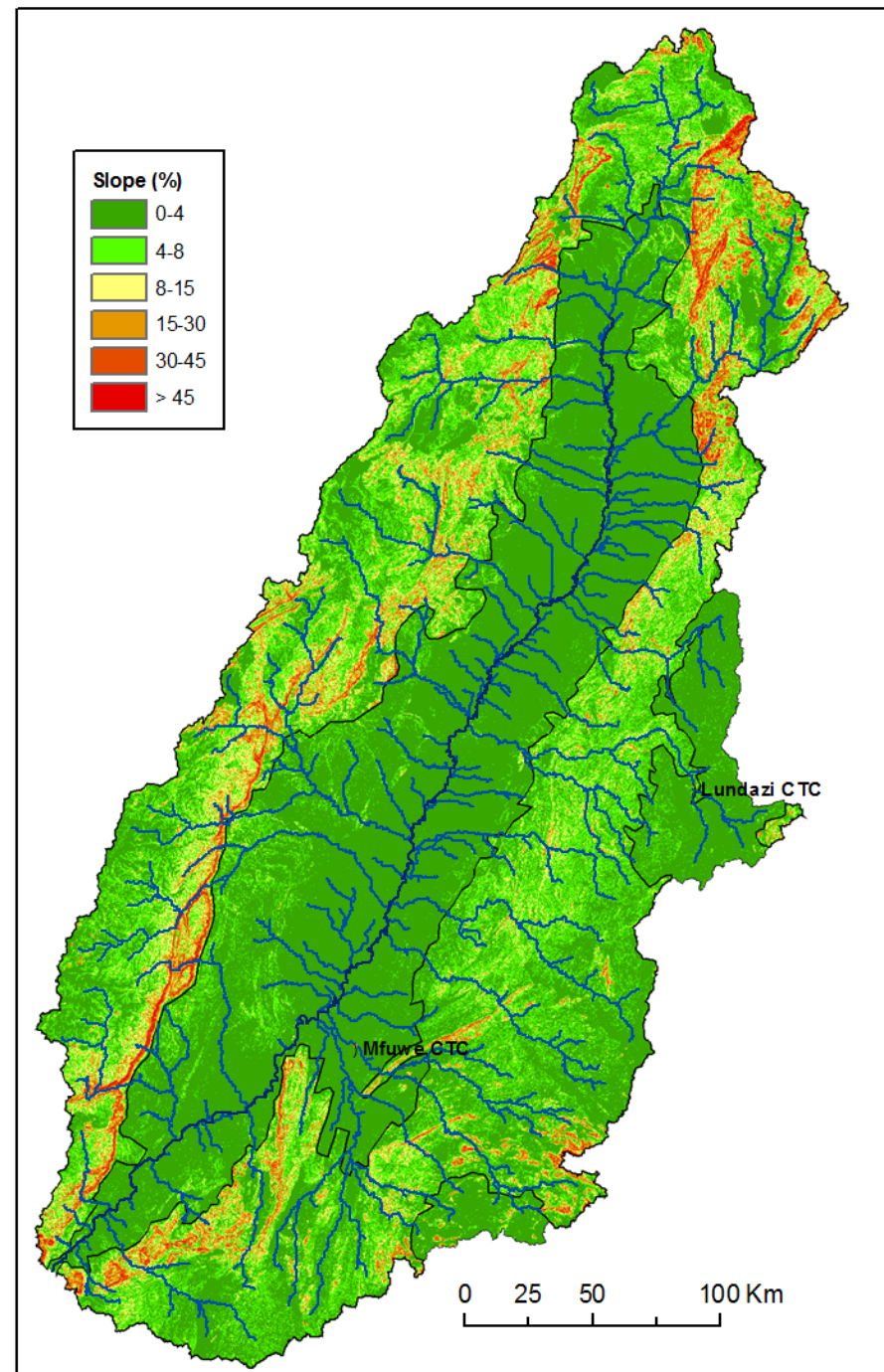
- Assist and support current LTRAs in achieving and enhancing their project objectives, specifically in the use of high resolution imagery and modeling for watershed management
 - support, enhance, and extend LTRA project impacts
 - Will not duplicate assessment, imagery analysis or modeling presently planned by the LTRA
 - synthesize results across projects
 - Work within the overall SANREM mission of collaborative research, capacity building, gender equity

Collaboration with LTRA-2



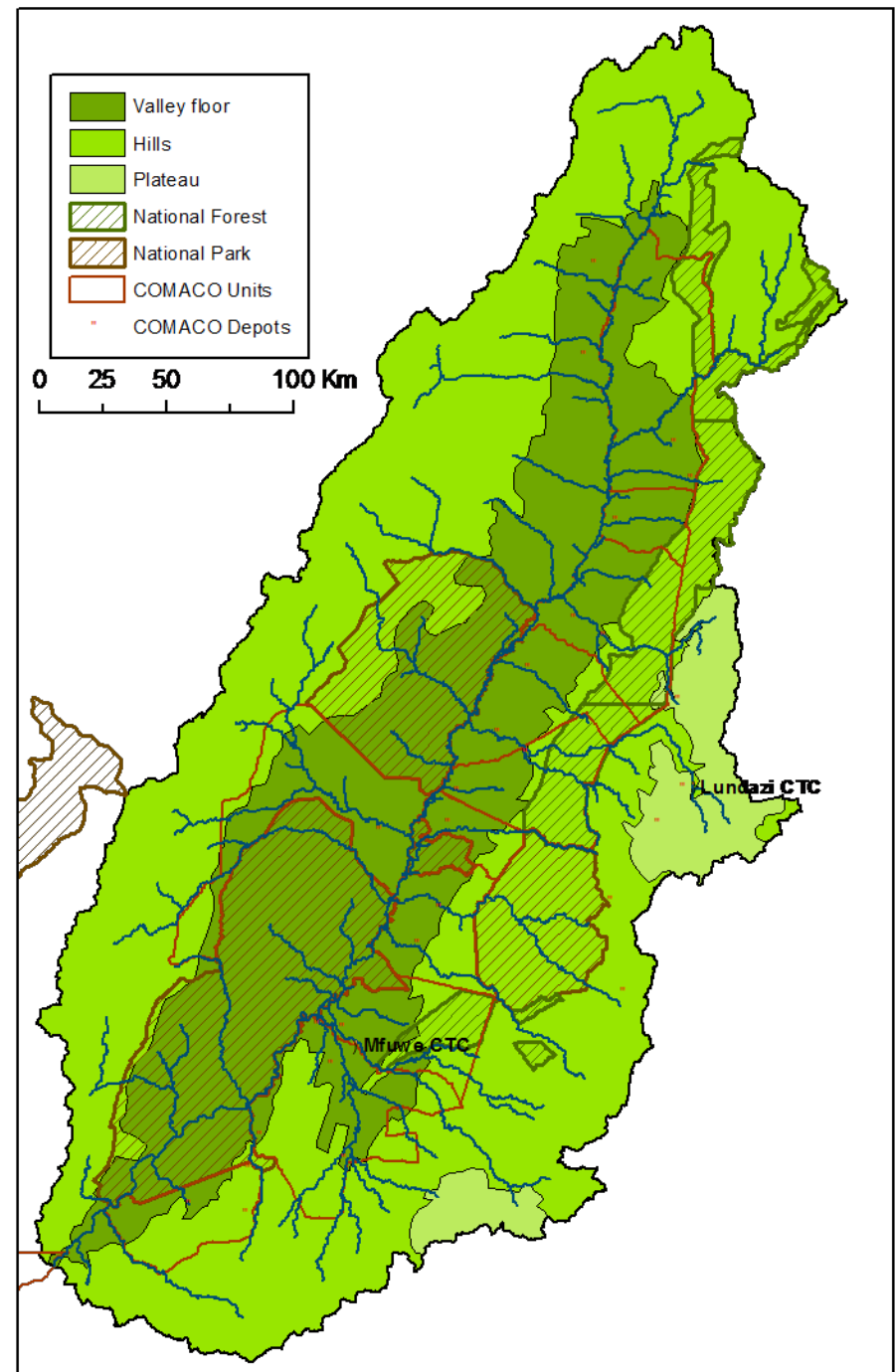
Luangwa River Valley Physiographic Regions

- Three regions ...
 - Valley floor
 - Hills /escarpment
 - Plateau / upland area



Luangwa River Valley Physiographic Regions

- National Parks
 - On the valley floor, with the river and floodplains
 - Elephants, lions, hippos, giraffes, water buffalo, etc..
- National Forest
 - Hill region
 - Not protected, subject to active settlements and clearing
- COMACO units & depots
 - Main population and agriculture





Plateau agriculture

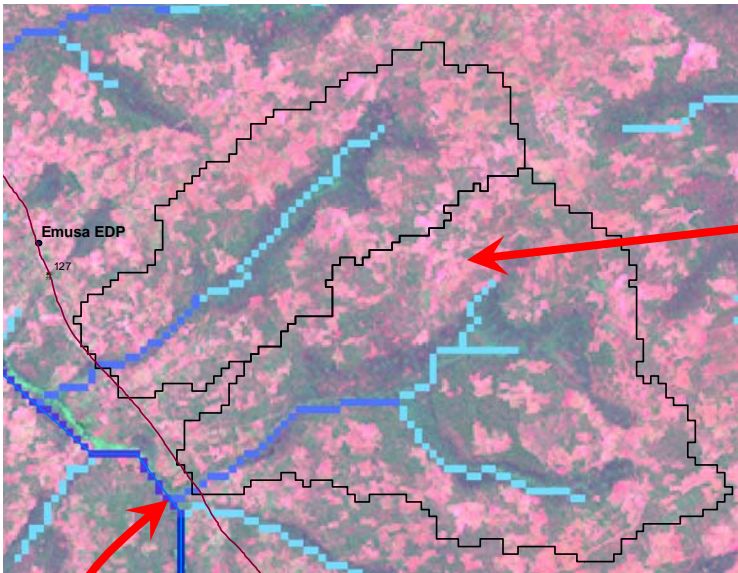


Plateau runoff and erosion

- Limited runoff from fields
 - Low slopes
 - High infiltration
 - High roughness in tillage
- Runoff and erosion is largely from paths and roads



Dambos in the plateau landscape



Cropland

– maize, groundnuts, cotton



Dambo – grassy wetland
drainageways

Hill region



Hill region – typical land uses

- Crops:
 - maize, cotton, groundnuts
- Soils, slopes, and farming practices contribute to greater runoff and erosion
 - Less permeable soils
 - Moderate slopes
- Erosion in fields and roads
 - Gullies developing
- No dambos !



Plateau Productivity



- Potential productivity is high
- Productivity related to:
 - Soil fertility (seasonal requirement)
 - Soil quality
 - Crop rotation / fallow period
 - Rainfall amount and timing
 - Weeds and pests
 - Improved varieties
- Reasons for poor yields:
 - Lack of knowledge (inputs, methods, economics)
 - Limited capital
 - Limited availability of inputs
 - Other factors??

(All photos taken March 2007 near Emusa)

Result of poor land management...



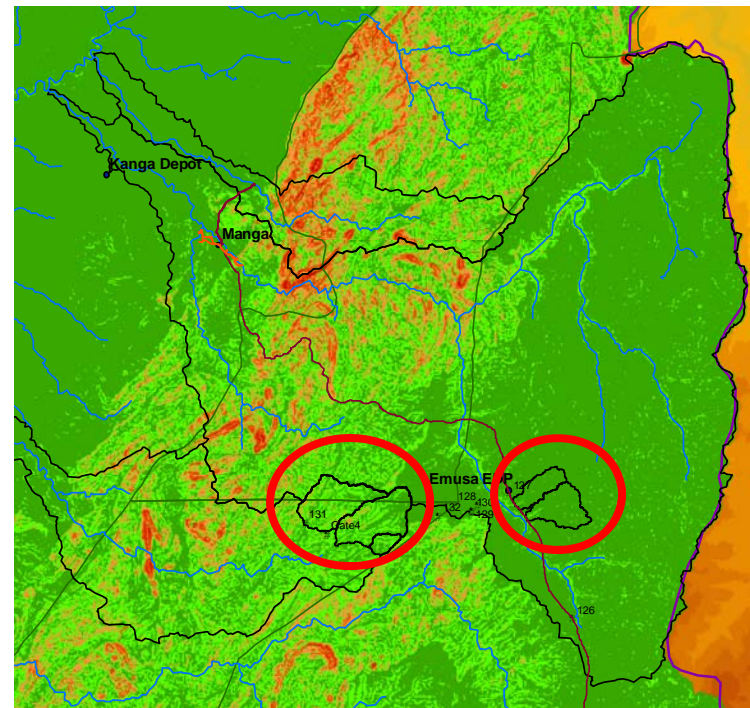
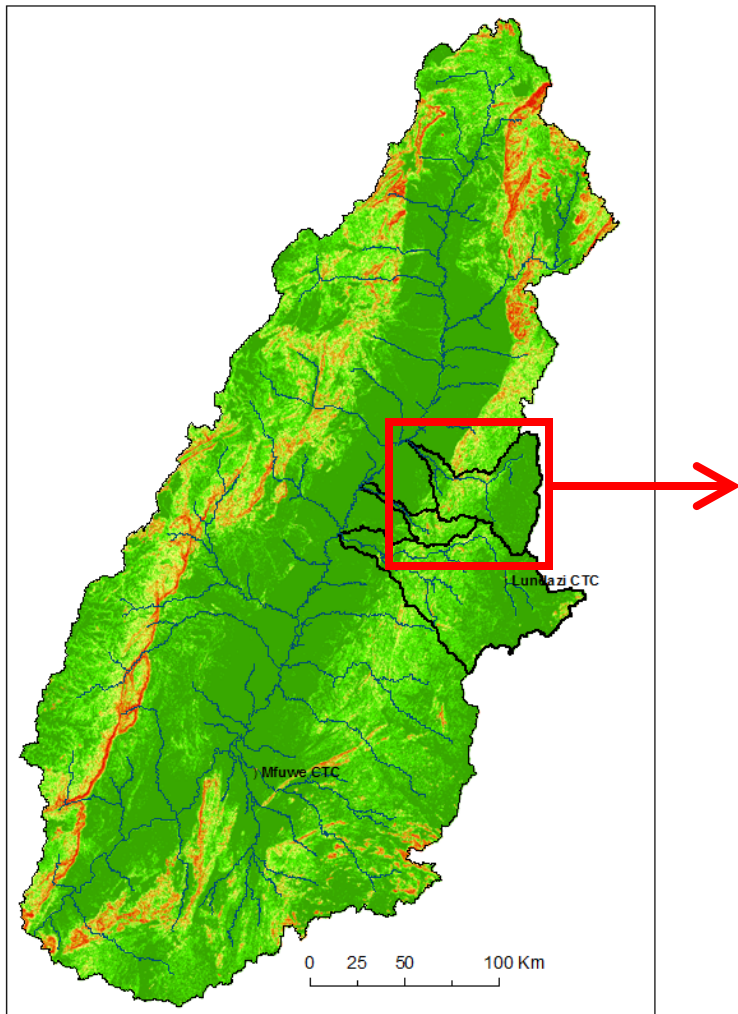
Objectives with LTRA-2

- Overall goal – provide guidance to land use policy regarding the expansion of settlements into the forested region
 - Quantify the impact of present land use practices on land and water resources
 - Determine acceptable land use (agricultural) practices that will ensure protection of natural resources and provide for sustainable livelihoods

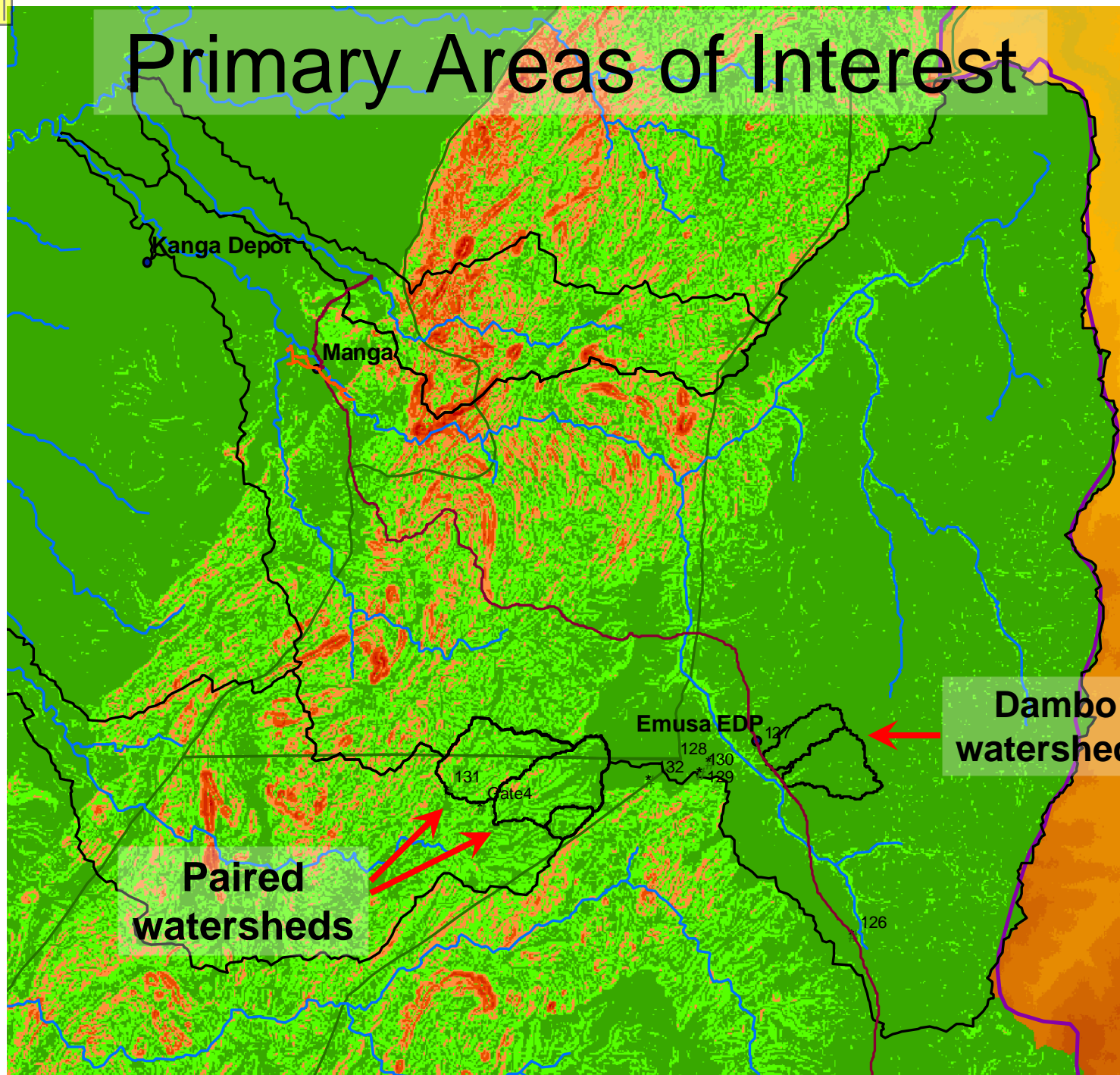
Focus of current activities

1. Document and map the expansion of settlements into the National Forest
2. Quantify hydrology of the primary landscape systems in Eastern Zambia
3. Provide preliminary analysis (through modeling studies) regarding the impact of increased clearing on runoff and sediment

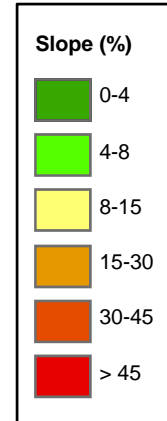
Area of focus



Primary Areas of Interest



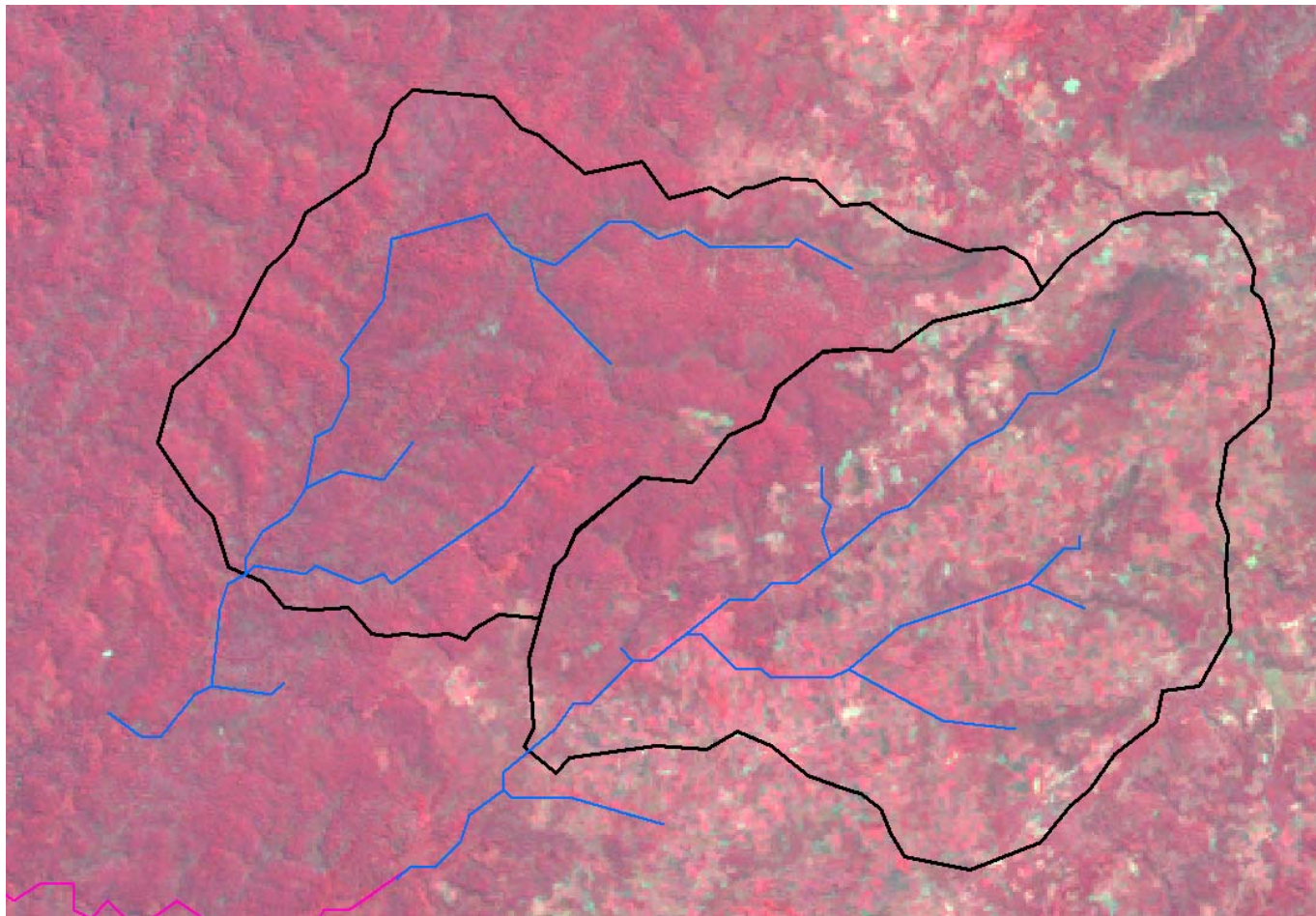
Slope





Cropland expansion 1989-2007

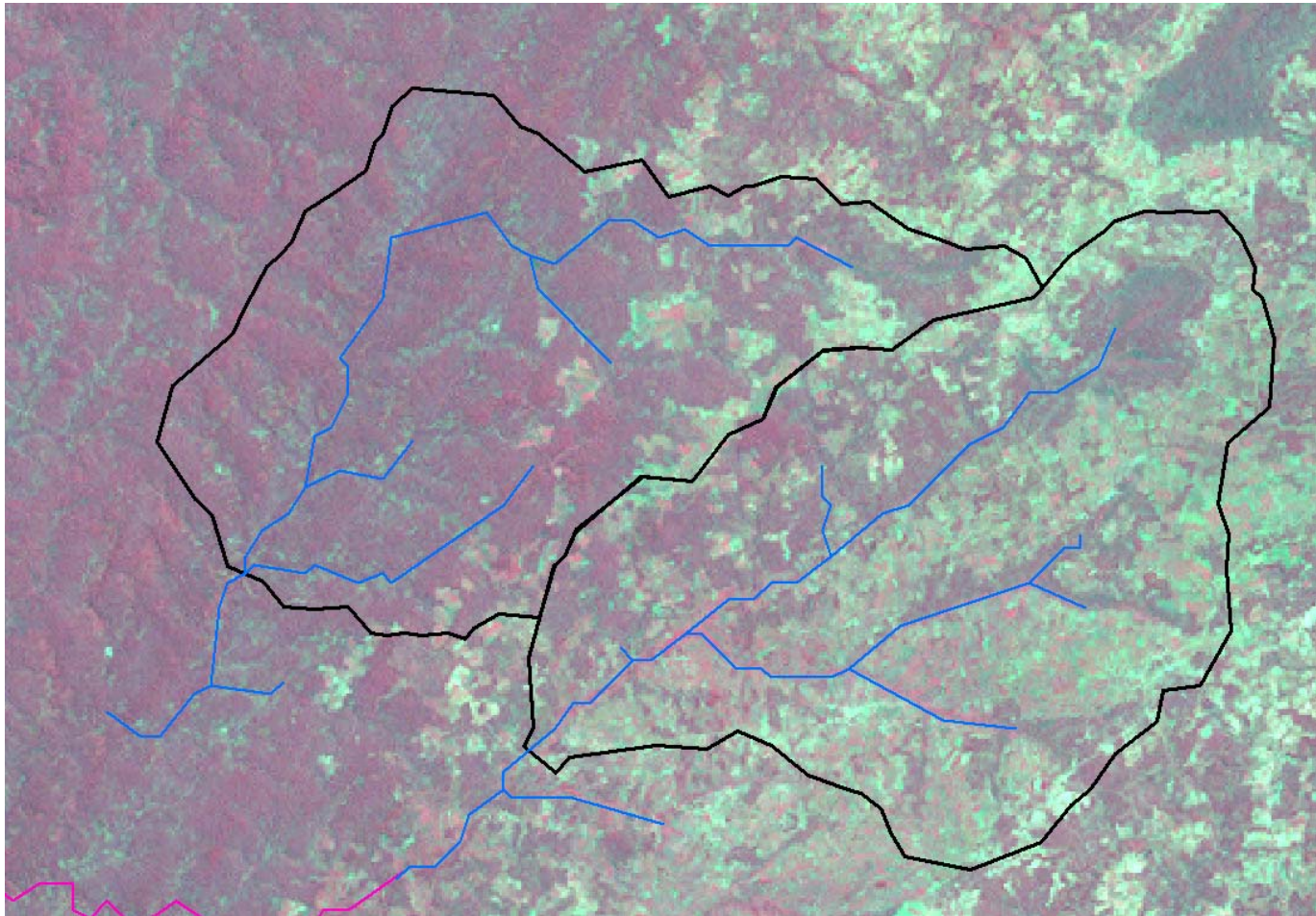
1989
Landsat





Cropland expansion 1989-2007

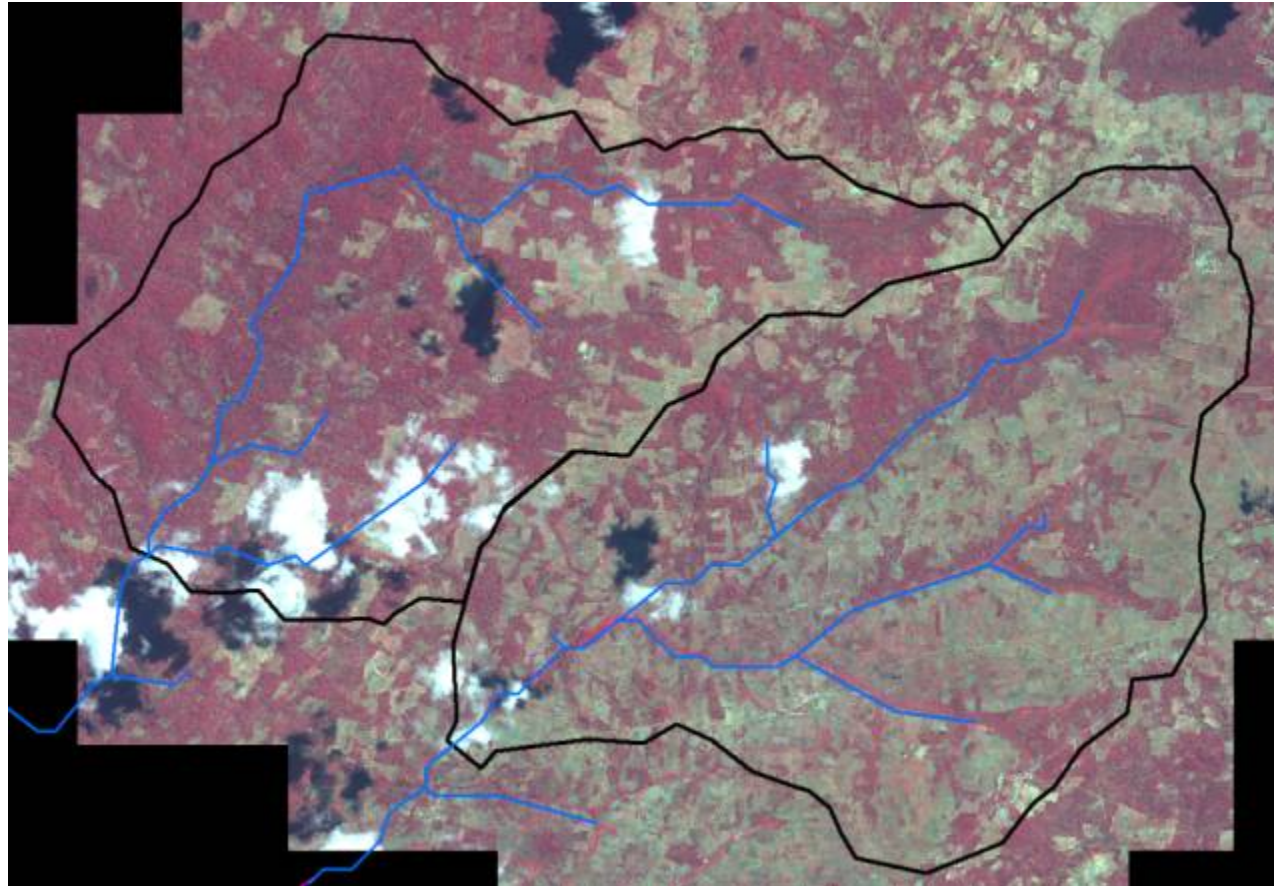
2002
Landsat





Cropland expansion 1989-2007

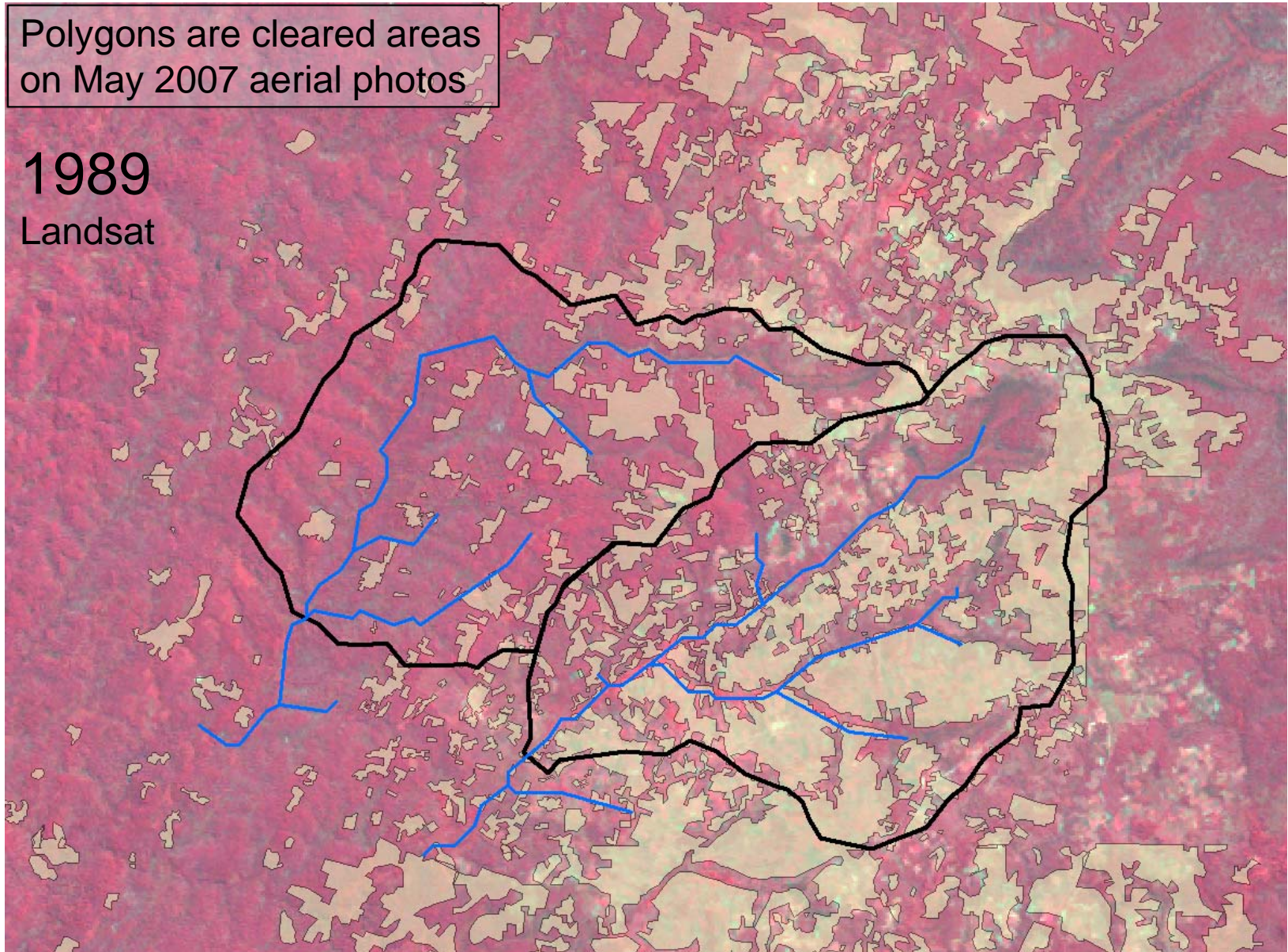
2007
Ikonos



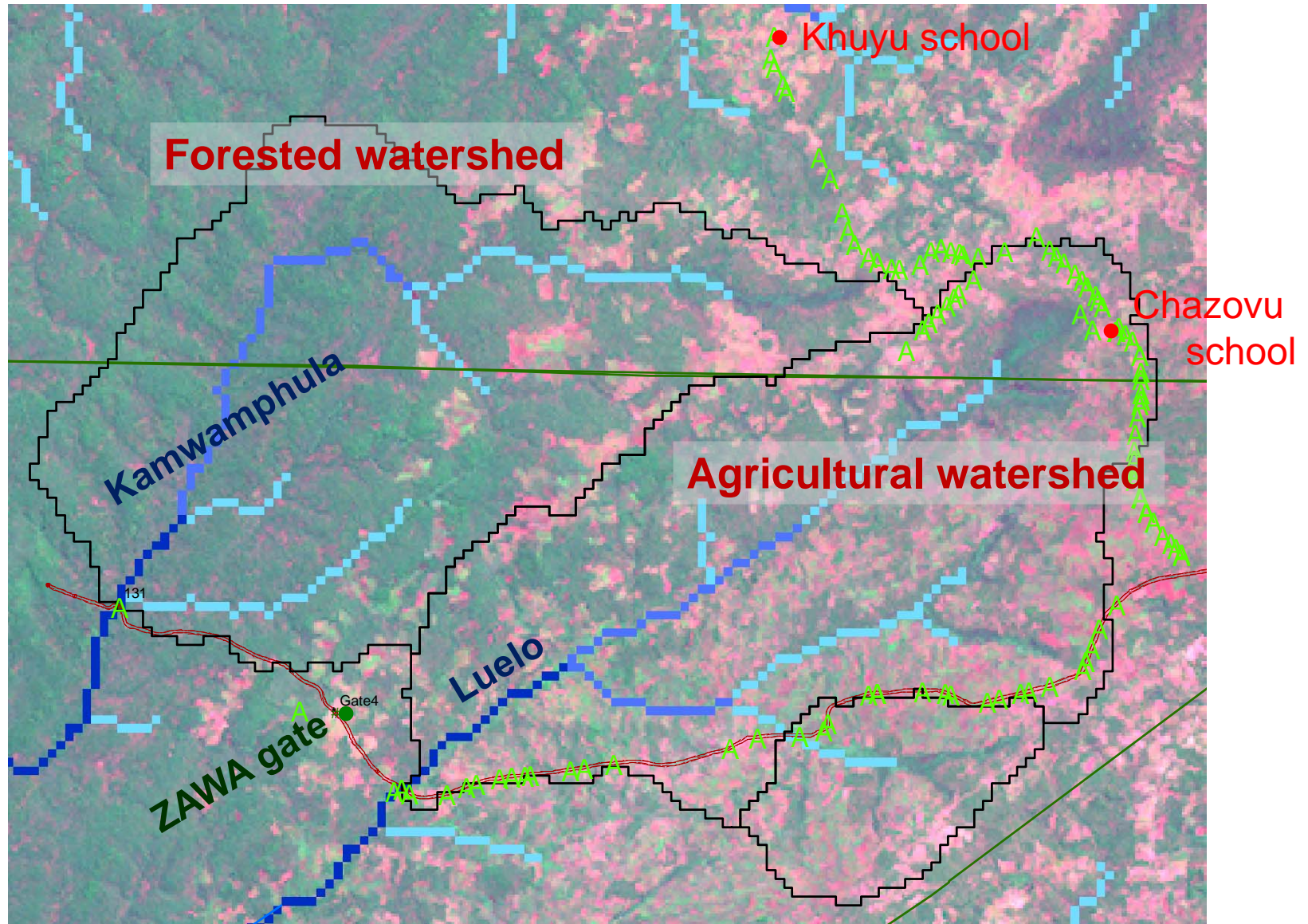
Cropland expansion 1989-2007

Polygons are cleared areas
on May 2007 aerial photos

1989
Landsat






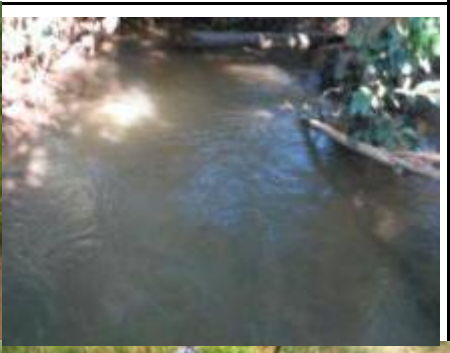




Paired Forest/Ag. Watersheds



Comparison of flow for 9-20 Mar 2007

Kamwamphula – forested watershed

Luelo – agricultural watershed

	9 Mar	10 Mar	14 Mar	20 Mar
	<p>Heavy flow w/ high sediment load: Luelo mainly clay; Kamwampula has fine sand</p>	<p>Luelo– flow is deeper & turbid. Kam.- flow is decreasing and is clearer</p>	<p>Luelo flowing in culverts but still turbid. Kamwamphula is almost clear..</p>	<p>Flow continues to decrease. Kam.- water clear, while Luelo is still turbid</p>
Luelo				
Kamwamphula				

Luberezi Dambo – 9-10 Mar 07



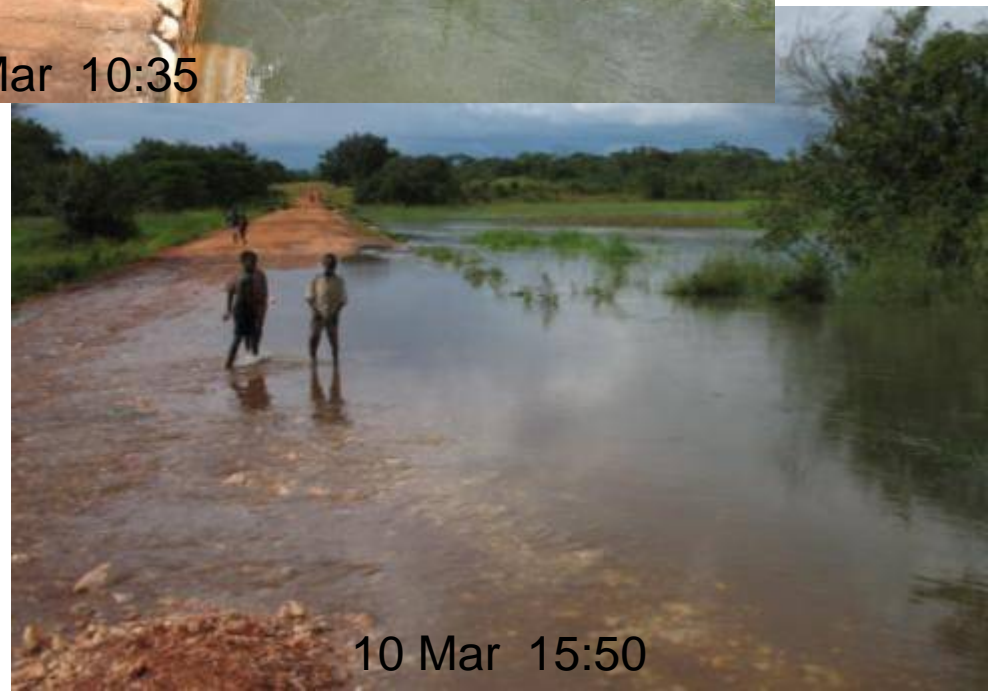
9 Mar 11:10



10 Mar 10:35

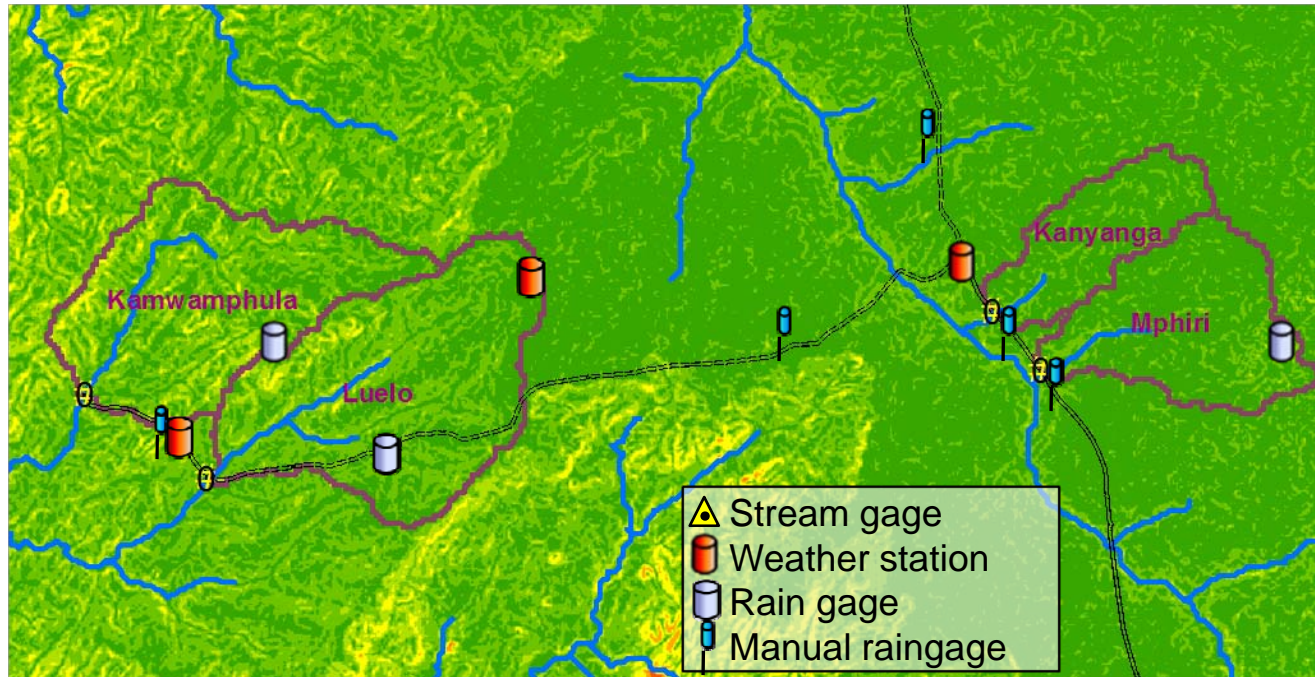
Luberezi River at Chama road

- Catchment in plateau region
 - intact dambo landscape
- Major storm event
 - Significant runoff
 - Low sediment/turbidity
- Compare to paired watersheds



10 Mar 15:50

Study watersheds – Magodi



Paired watersheds (Kamwamphula, Luelo) in Hill region

- similar size, slopes and landscape position
- side-by-side,
- predominantly forested vs. cleared land use

Dambo watersheds (Kanyanga, Mphiri)

- comparison of plateau hydrology

Expected impact of forest clearing:

- Lower infiltration
- Increased surface runoff
- Increased erosion and sediment delivery
 - Degrades local stream condition
 - Fills reservoirs
 - Downstream impacts of sedimentation
- Lower groundwater recharge and decreased dry season base flow

Hydrologic monitoring program

- Data is being collected help us understand the water dynamics in the Eastern Luangwa Valley landscape and support better modeling analysis
 - Weather data / rainfall
 - 3 weather stations: rainfall, temp, solar radiation, etc.
 - 3 automatic recording raingages
 - Community observers for rainfall
 - Stream flow – 4 study watersheds
 - Community observers record water depth daily
 - Pressure sensors – depth every 15 minutes
 - Flow data – velocity and cross-section for rating curve
- Monitoring began Dec 2007

Weather and Rainfall

- Rainfall is spatially variable (convective storms) so a dense raingage network is needed
- Combination of data logging raingages and manual observations
- Four schools in the district are cooperators



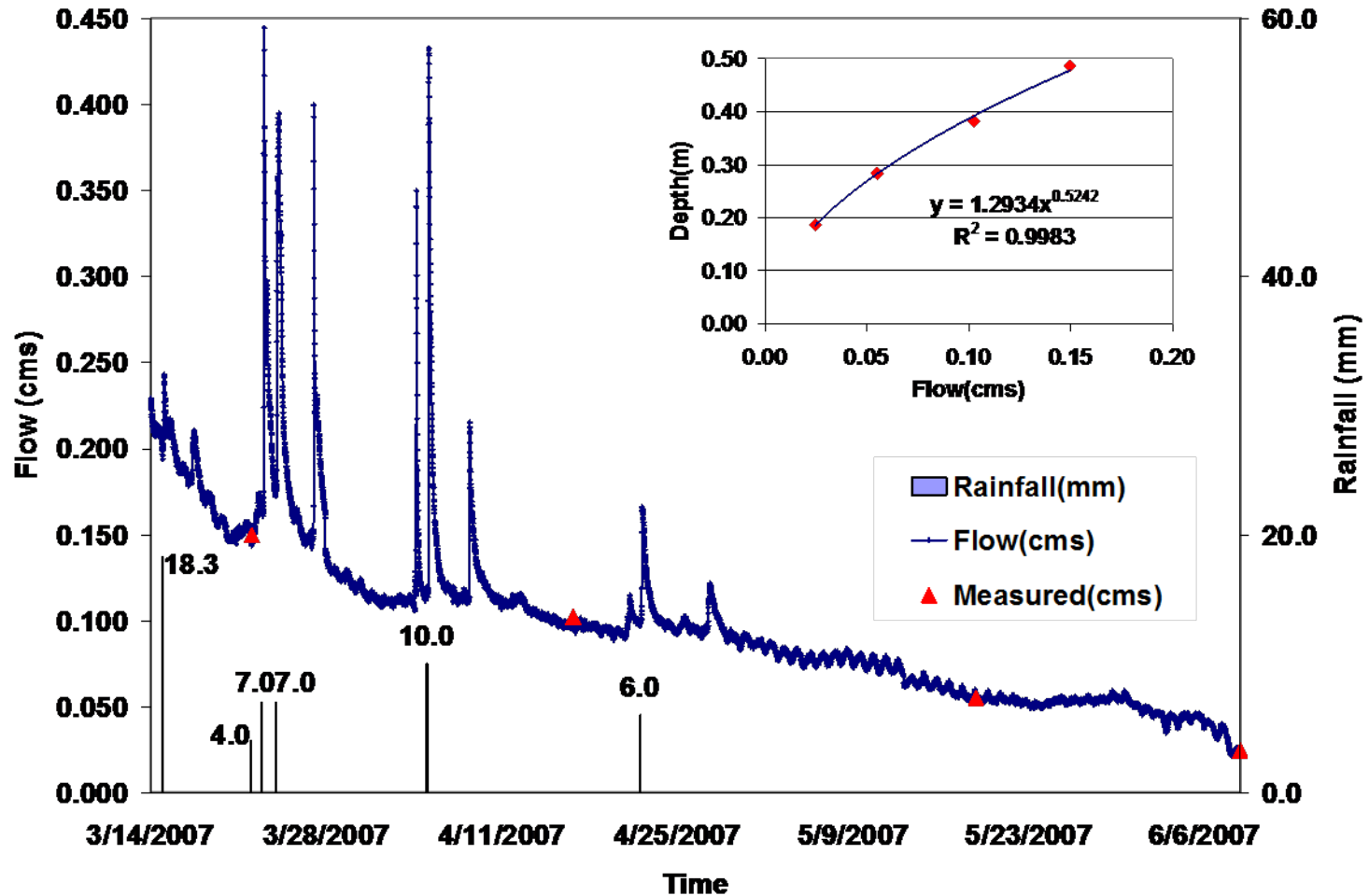
Stream Flow Measurement

- Water depth
 - Staff gage readings (daily) by local observer
 - Pressure sensor records depth every 15 min
- Flow rate for stage/discharge relationship
 - Cross-section and velocity using flow meter
 - Velocity using float and stopwatch



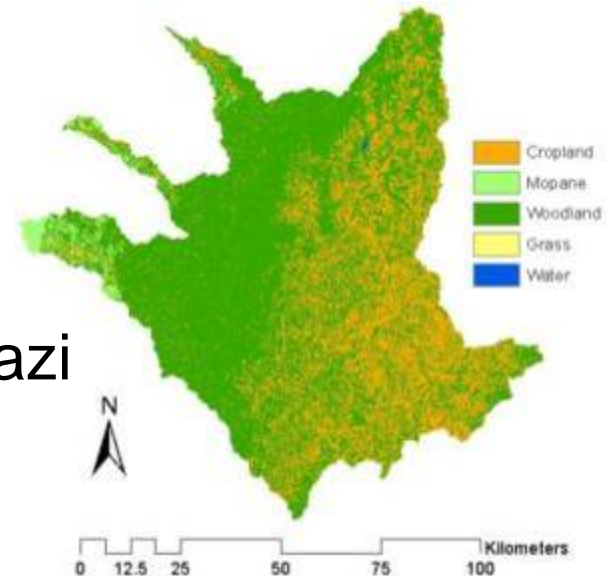
Kamwamphula River

(preliminary data)



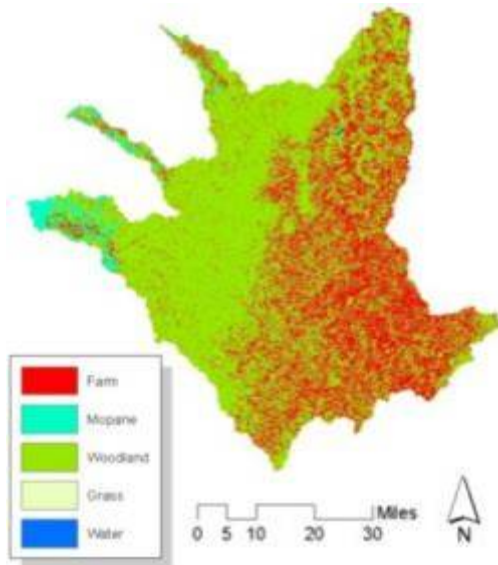
Modeling analysis of land use impacts

- Want to use model of watershed hydrology to compare different scenarios
- Data required:
 - Land use → from satellite imagery
 - Soils → from FAO data
 - Topography (elevation and slope)
 - Climate → historical data from Lundazi
- Modeling approach
 - Use the SWAT watershed model
 - Results are tentative – observed data is limited

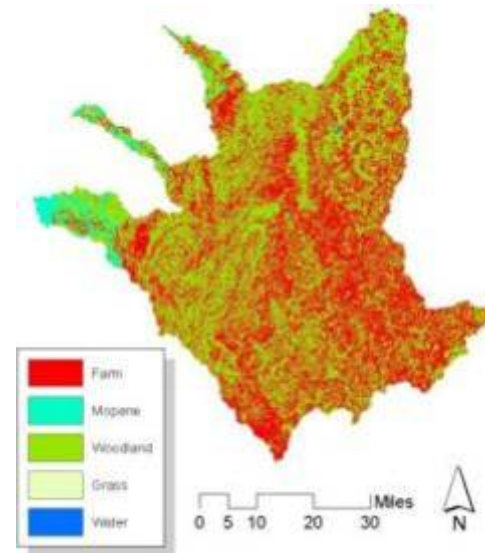


Modeling Analysis – 3 Scenarios

- Current (2002) land use
- Scenario1 – “Native” – all forest (no cropland)
- Scenario2 – Expanded cropland in forest area
 - Assumes hill region with slopes $< 4\%$ are cleared for crops

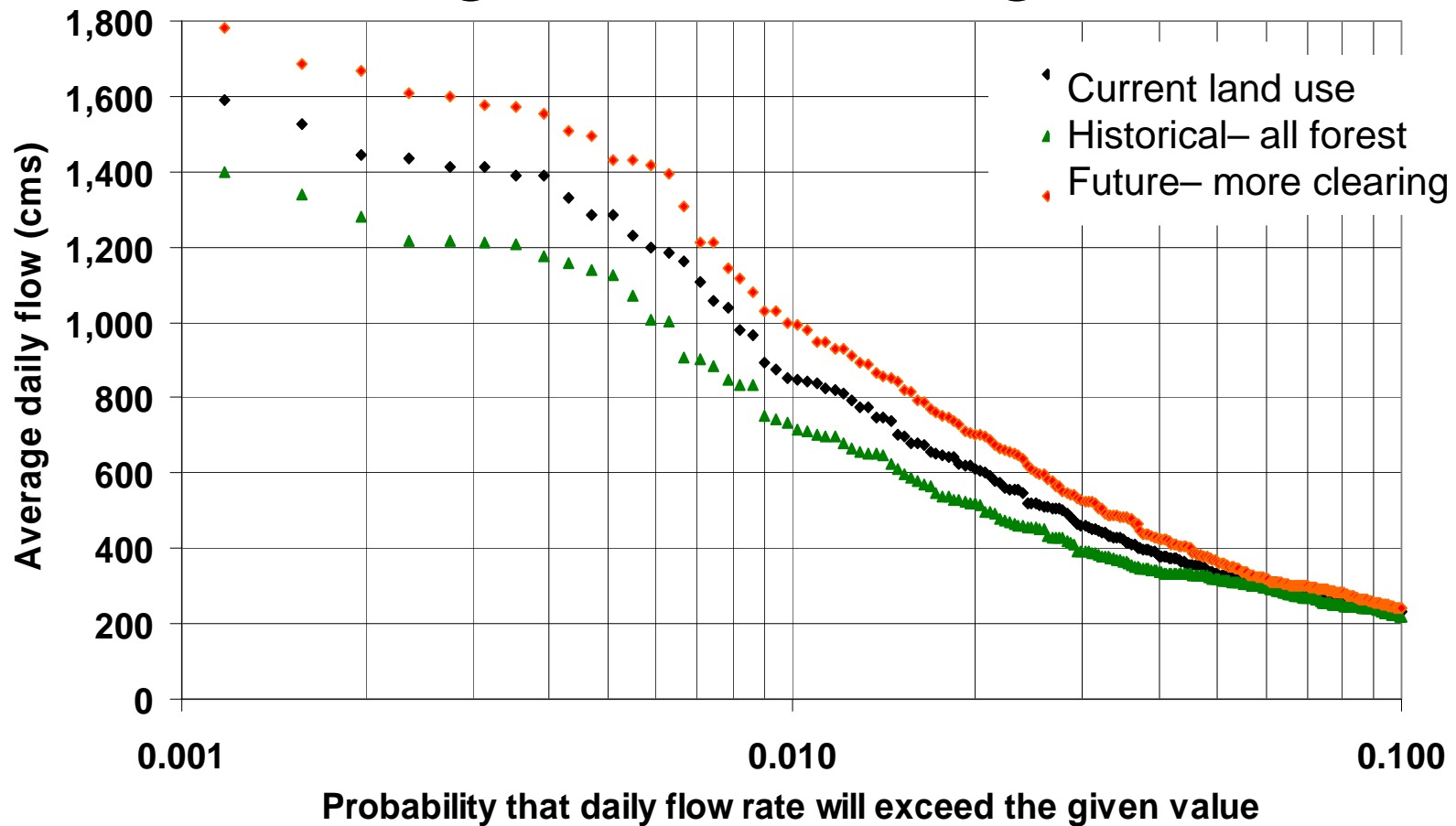


Current (2002)



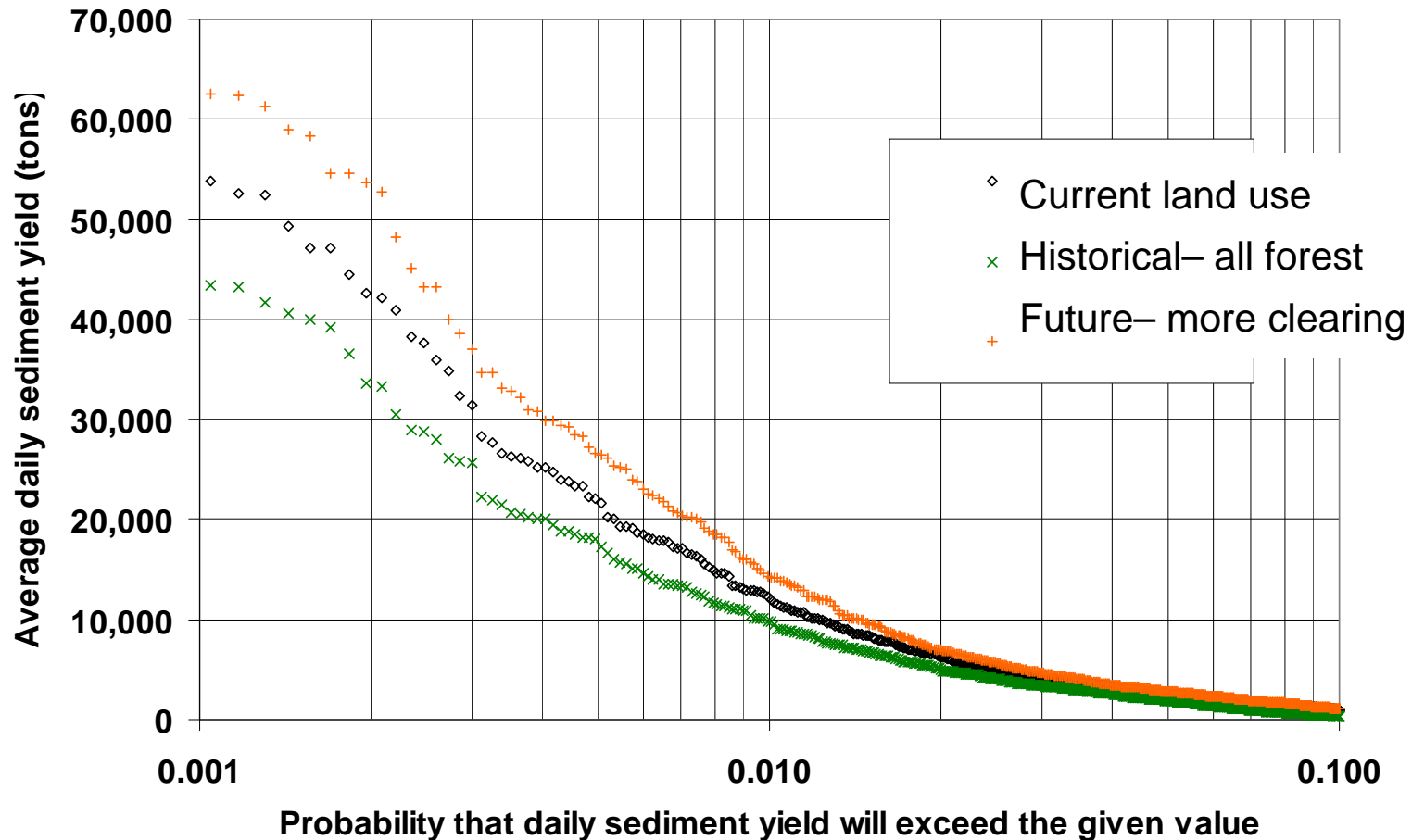
Future (Scenario 2)

Modeling Results – High Flows



- *Key points....*
 - *High flows (flooding) occurs for any land use, but*
 - *Flooding is more frequent and higher with increased clearing of forest*

Modeling Analysis - Sediment



- *Key point....As with high flows, sediment loads will be higher and occur more frequently as clearing of forest increases.*

Preliminary conclusions from a general assessment of Eastern Luangwa Valley

1. Crop production is best in the plateau
 - Good soils, low slopes, low runoff
 - Dambos provide natural filtering and flow attenuation functions
2. Dambos should be managed carefully to preserve their function in the landscape
3. The hill region has higher runoff and erosion and requires careful management if used for cropping
 - steeper slopes
 - shallow less-permeable soils



Preliminary conclusions...

4. The expansion of cropland into the hill region (and National Forest) has long-term detrimental impacts on local forest, soil, and water resources as well as on downstream flooding, water availability, and sedimentation, and should be minimized.
5. Landscapes of the Eastern Luangwa Valley can be very productive, and proper management of these systems to improve productivity is a key to improving livelihoods and sustaining ecosystems across the Luangwa Valley.

Improving the productivity and sustainability of plateau cultivation benefits all valley ecosystems

Living in the National Forest

Kamatete Basic School – Chazovu District



Policy decisions - settlements → schools → expansion

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Back to the bigger picture...

Activities with other projects...

- LTRA-3 - Bolivia – Toralapa watershed
 - Plot studies; watershed monitoring – 6 sub-watersheds to examine LU change
 - Watershed modeling – management and policy
- LTRA-3 - Ecuador – 2 watersheds
 - Monitoring in support of modeling
- LTRA-4 - Bolivia (& Peru)
 - land use change analysis
 - Monitoring in Ancoraimes watershed
 - water balance analysis
 - Modeling to assess impacts of climate change
- LTRA-5 - Philippines
 - Monitoring of flow and sediment at 3 points;
 - Modeling analysis of land use impacts

Philippines – Alanib watershed



Summary of activities

Working in 9 watersheds:

Bolivia, Ecuador, Zambia, Philippines

- Base satellite imagery acquired for 8 project areas
- 22 stream gauging stations (pressure sensors and staff gauge) installed
- 8 weather stations installed and operating
- 17 recording rain gauges (tipping bucket) installed
- initial data on flow rates at each station
- training on flow monitoring using the salinity tracer method and flow meter for project teams
- Workshop for LTRA-3 partners at Virginia Tech

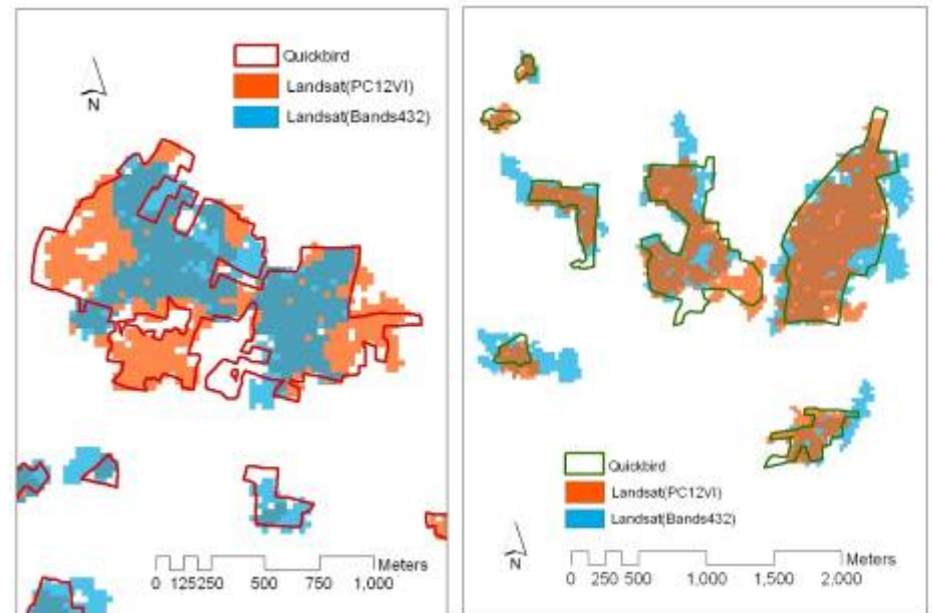
Research Outputs

- Support research of LTRA objectives
- Watershed monitoring
 - Paired watershed study; water balance; plot study
 - Data to support modeling studies
- Modeling applications and analysis
- Imagery analysis
- Cross-project synthesis
- Affiliated research – methods development

Imagery analysis

Objective: Determine the best techniques for defining classification targets and best classification methods in using Quickbird (0.6m) and Landsat (30m) imagery

Her, Younggu, and C. Heatwole. 2007. *Land use classification in Zambia using Quickbird and Landsat imagery*. ASABE Paper No. 072017. St. Joseph, Mich: ASABE.



Training data for crop fields and forests

Cross-Cutting Research

- Identify uses of high-resolution imagery for SA/NRM and develop needed techniques to support that use
 - *Are there uses beyond aerial imagery ?*
 - *What are efficient techniques for classification?*
- Can low-cost monitoring techniques provide useful (appropriate quality) hydrologic and water quality data and also benefit community education and participation in SA/NRM
- How can the SWAT model provide useful information for SA/NRM in tropical and developing countries (small plots, steep lands, soils, climate)
 - *What are possible applications?*
 - *What changes and improvements are needed?*

Low cost monitoring – will it work?



Partnerships and Training

Project partners are the key... !!!

- Mirco Peñaranda (LTRA-4, Bolivia)
 - MS degree on hydrologic budget
- Ana Karina Saavedra (LTRA-3, Bolivia)
 - Possible PhD through Virginia Tech
- Carlos Montufar (LTRA-3, Ecuador)
 - Possible MS at Virginia Tech
- Nathaniel Alibuyog (LTRA-5, Philippines)
 - Post-doc in collaboration with Victor Ella

Next steps...

- Analyze data from this first year
- Revise and refine research plans
- Prepare for next rainy season - maintain and update monitoring installations
- Data analysis, modeling, publications

Looking ahead ...

Monitoring beyond 2009 ??

- Move assessment and modeling into project
- Develop cross-cutting project from the outset

