

Natural and human impact on land use change of the Eastern Himalayan piedmont, India

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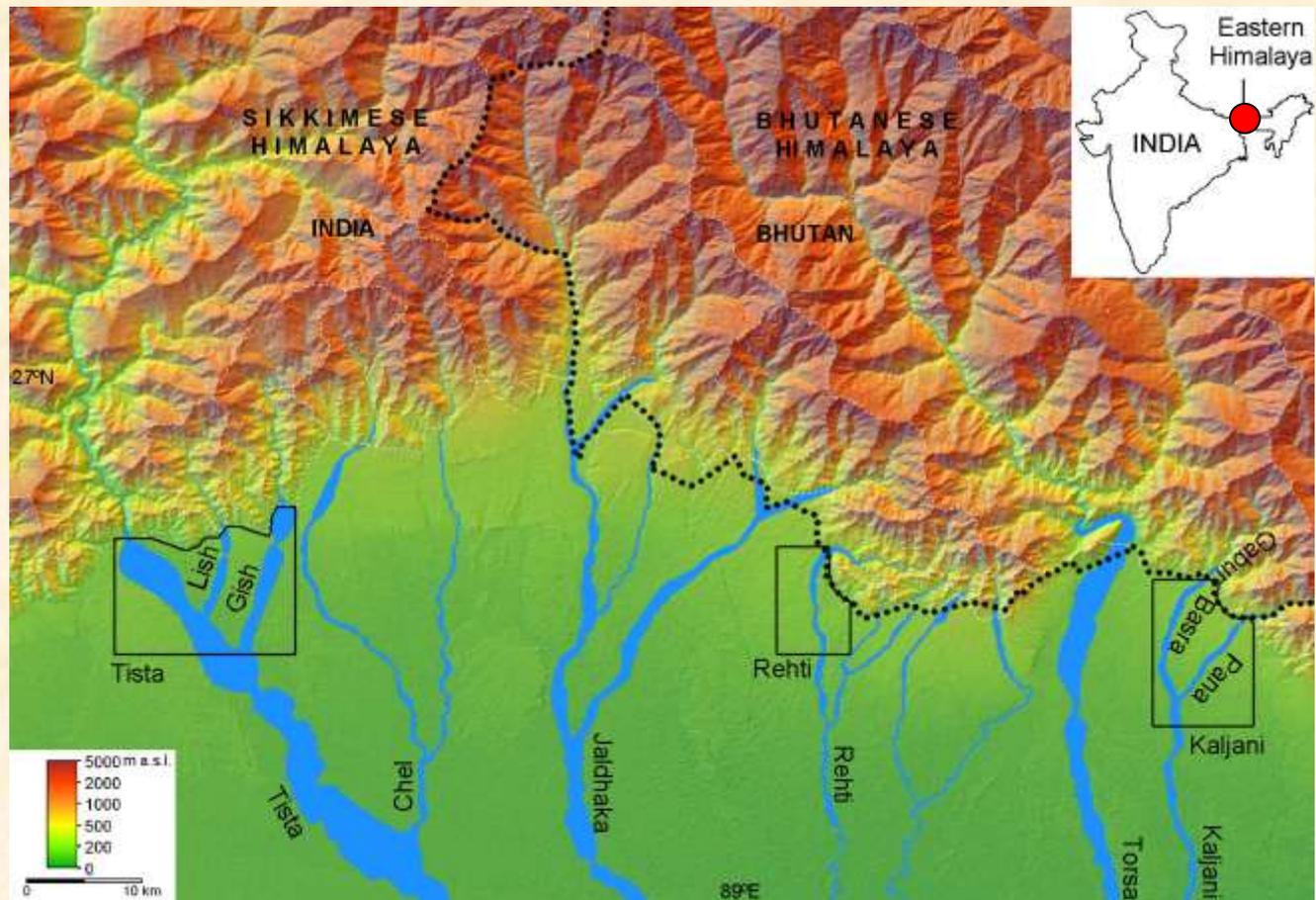
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Study area

The piedmont of the Eastern Himalaya forms a system of fans dissected by dense braided river network



- High rainfall reaching 4000-6000 mm annually cause frequent floods
- The present-day economy of piedmont depends on tea, trees and tourism
- Population density reach 800 person/km² and 80-95% lives in tea gardens
- A hydrologic and geomorphic approach was employed to delineate three key areas (about 300 km²) along river courses on alluvial fans stretching 10 km from the mountain front

Aim

Analysis of natural and anthropogenic causes of land use/land cover (LULC) development of the Himalayan piedmont with special emphasis on period 1930–2010

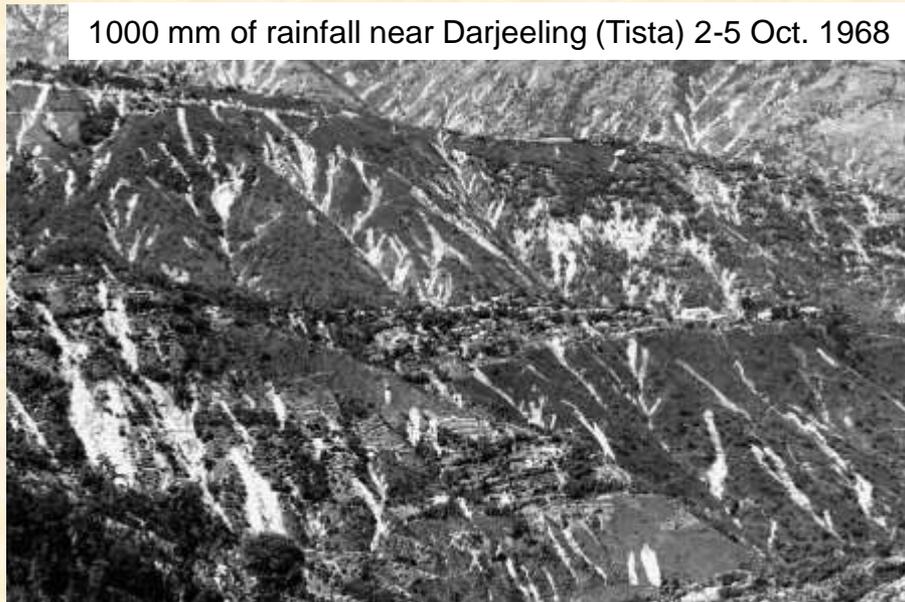
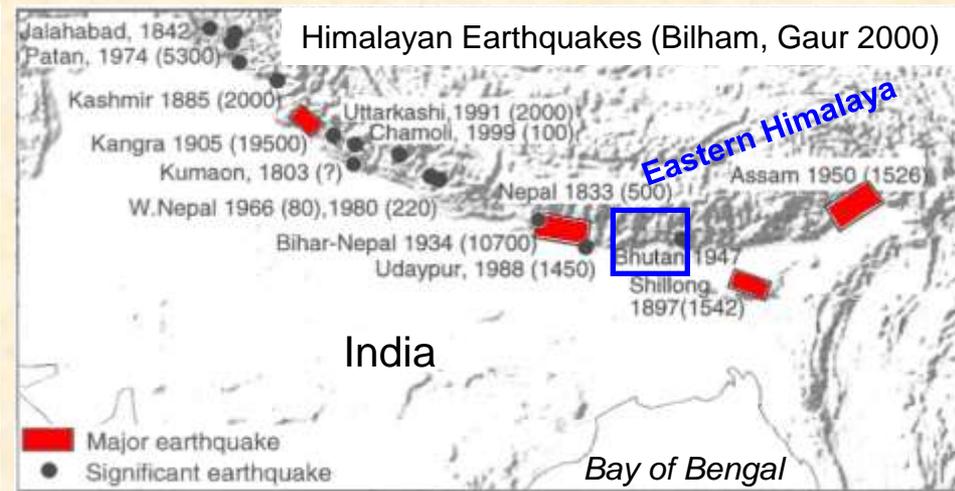
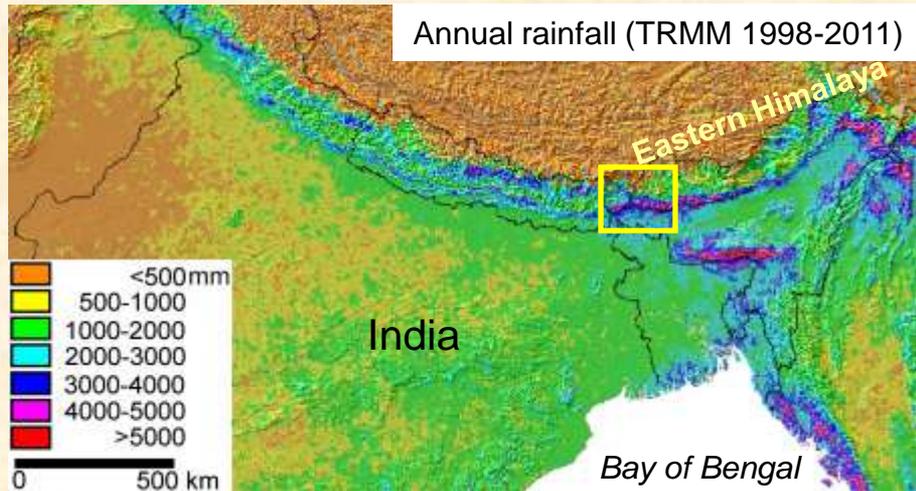
Materials

- Historical reports, maps and census data for the 19th century
- Topographical maps at scale 1:50 000 for the year 1930
- American Corona panchromatic photo images for the year 1970
- Google Earth satellite images for the year 2010

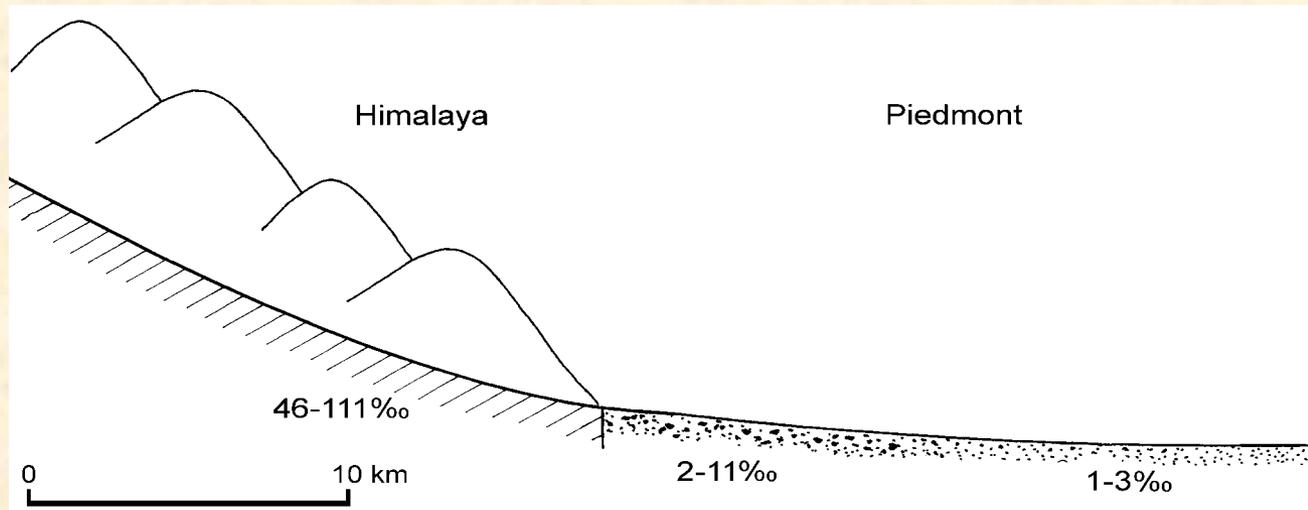
Methods

- Visual interpretation technique combined with several field surveys was used for LULC mapping. Six LULC categories were defined: forest, grassland, tea cultivation, crop cultivation, built-up area and river bed.
- Stability land use maps for the period 1930-2010 with delimited:
 - stable areas – the same land use class in each time period
 - stepped change – one point of change between two land use classes: forest – forest – tea
 - cycle change – frequent change has occurred between two classes: forest – river – forest
 - dynamic change – high turnover between many different classes

Natural impact on land use change of the Eastern Himalayan piedmont



Effects of Himalayan impact on LULC of piedmont



The decrease in river gradients at the outlet from the mountains causes extensive deposition of material eroded from the mountains, increase the flood risk, river bank erosion and shifting their braided courses leading to direct changes LULC system of piedmont.



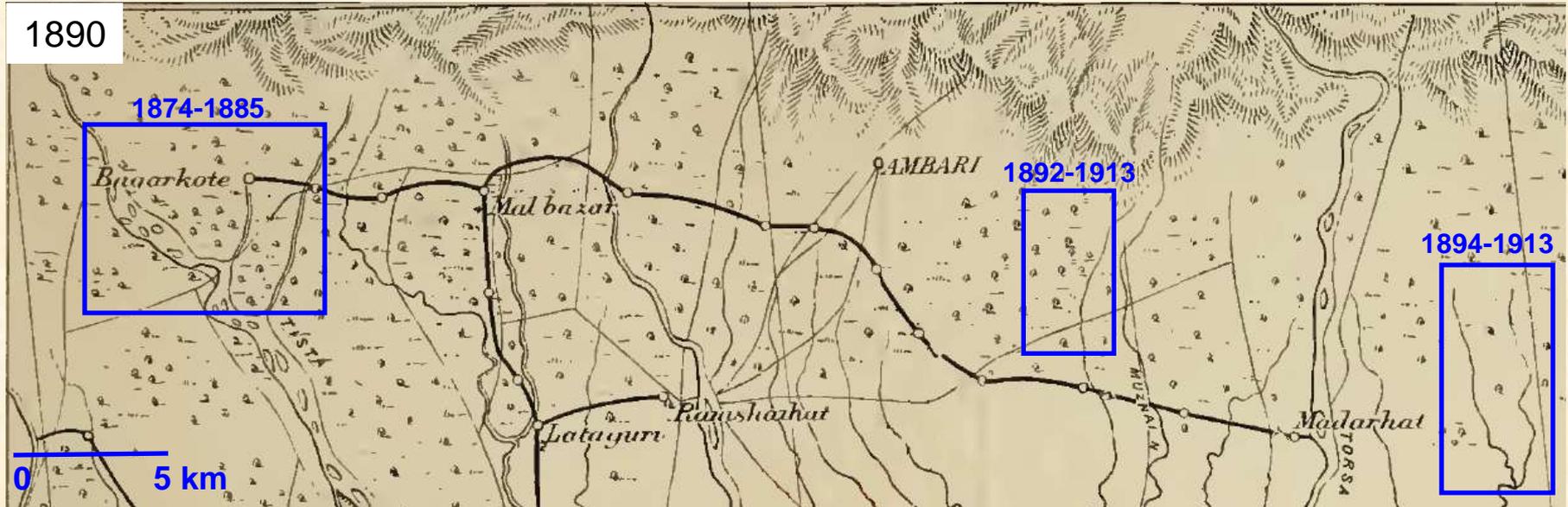
LULC in the 19th century

The piedmont zone was under natural forest before the incorporation into the possessions of the British East India Company in 1865.

The lack of water infiltrating into alluvia in the dry winter caused that area was only seasonally settled and population density did not exceed 5-10 inhabitants km⁻².



Foundation of tea plantations and laborers migration caused rapid deforestation. Simultaneously forestry was developed on the basis of commercially valuable trees.



Examples of LULC classes



Prepared elephants to the tourist safari in the natural forest near Kaljani



Tea plantation at the high terrace of Rehti river

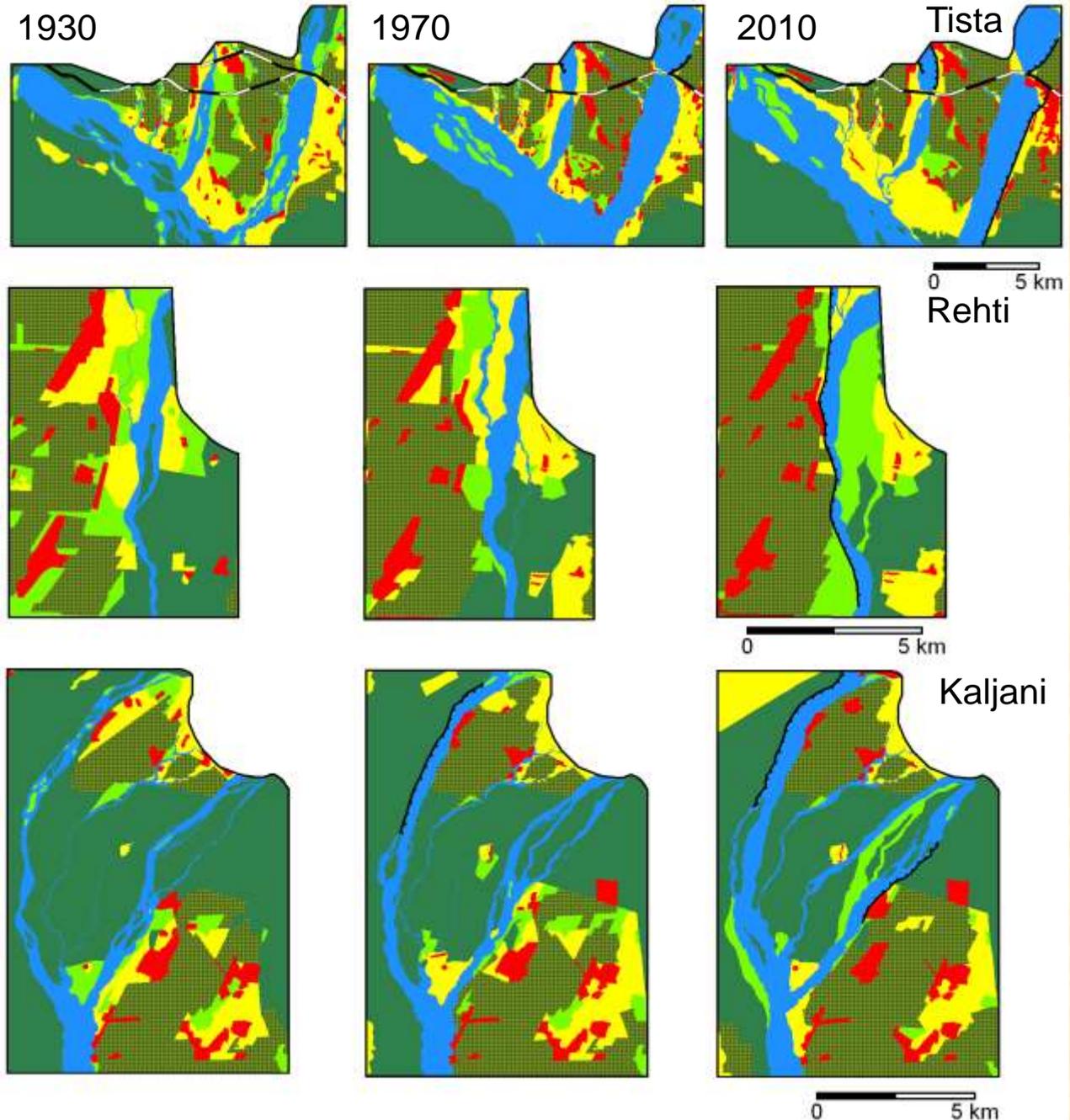


Rice fields at the Gish floodplain

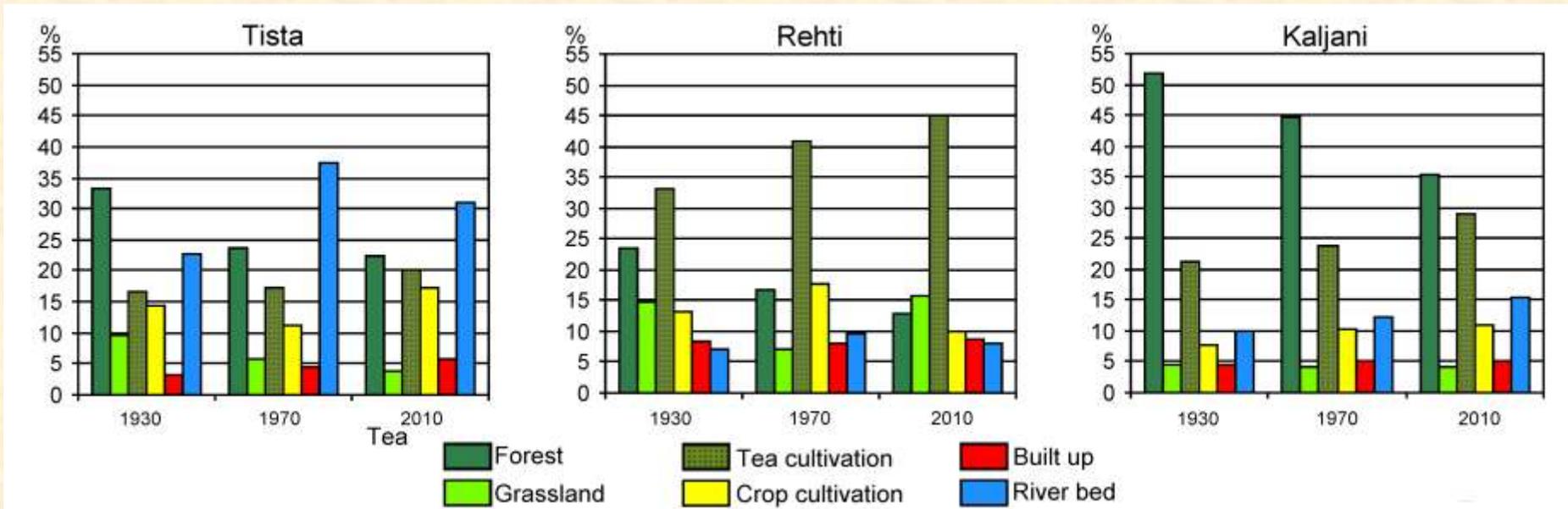


Dry braided channel of Rehti river

Spatial distribution of LULC in the study sites



Percentage contribution of LULC categories in the selected study sites



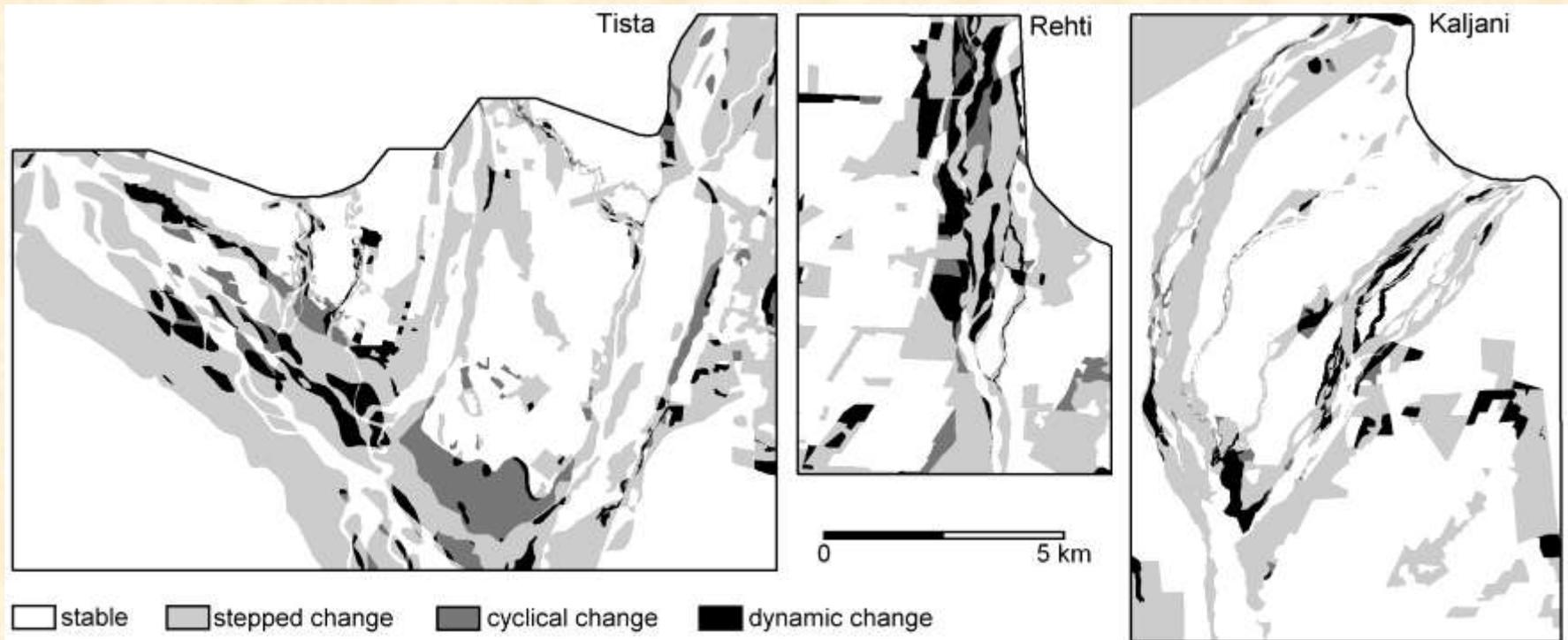
General tendencies of LULC change 1930-2010:

- forest area decreased
- tea plantation area increased
- no changes in grassland, crop cultivation and river bed area – but visible effects of floods
- stable built up areas

Predominant types of LULC changes (claiming over 1% of the total area)

Type LULC change	Tista		Rehti		Kaljani	
	1930-1970	1970-2010	1930-1970	1970-2010	1930-1970	1970-2010
No change	72.1	75.0	66.1	74.3	82.2	79.6
Forest to grassland	1.6			3.5	1.9	
Forest to crop cultivation			4.9		2.9	2.7
Forest to river bed	7.2	3.2	2.2		4.5	5.2
Grassland to tea cultivation			5.7	1.9		1.7
Grassland to crop cultivation	1.3		6.3		1.1	
Grassland to river bed	4.3	1.4		1.3		
Crop cultivation to grassland			5.5	3.2		
Crop cultivation to tea cultivation		1.5	1.5	2.8	1.6	2.2
Crop cultivation to built up	1.4	2.2				
Crop cultivation to river bed	5.1			2.7		
Built up to crop cultivation			1.3			
River bed to forest		1.1			2.4	
River bed to grassland	1.2	1.7		5.9		2.1
River bed to crop cultivation		9.3				

LULC stability between 1930 and 2010



Stable: occupy 54 to 67% area of each site – core area of tea cultivation, forest complex and built up

Stepped change: occupy 1/3 of each site – extension of tea cultivation, changes of river beds

Cyclical change: occupy 6% of Tista, 4% of Rehti – distal parts of the large floodplains such Tista, Gish

Dynamic change: 4% of Tista and Kaljani, 10% of Rehti – changes within river beds – degradation and built up of sand bars by flowing water of Tista and Pana, Rehti river bed migration

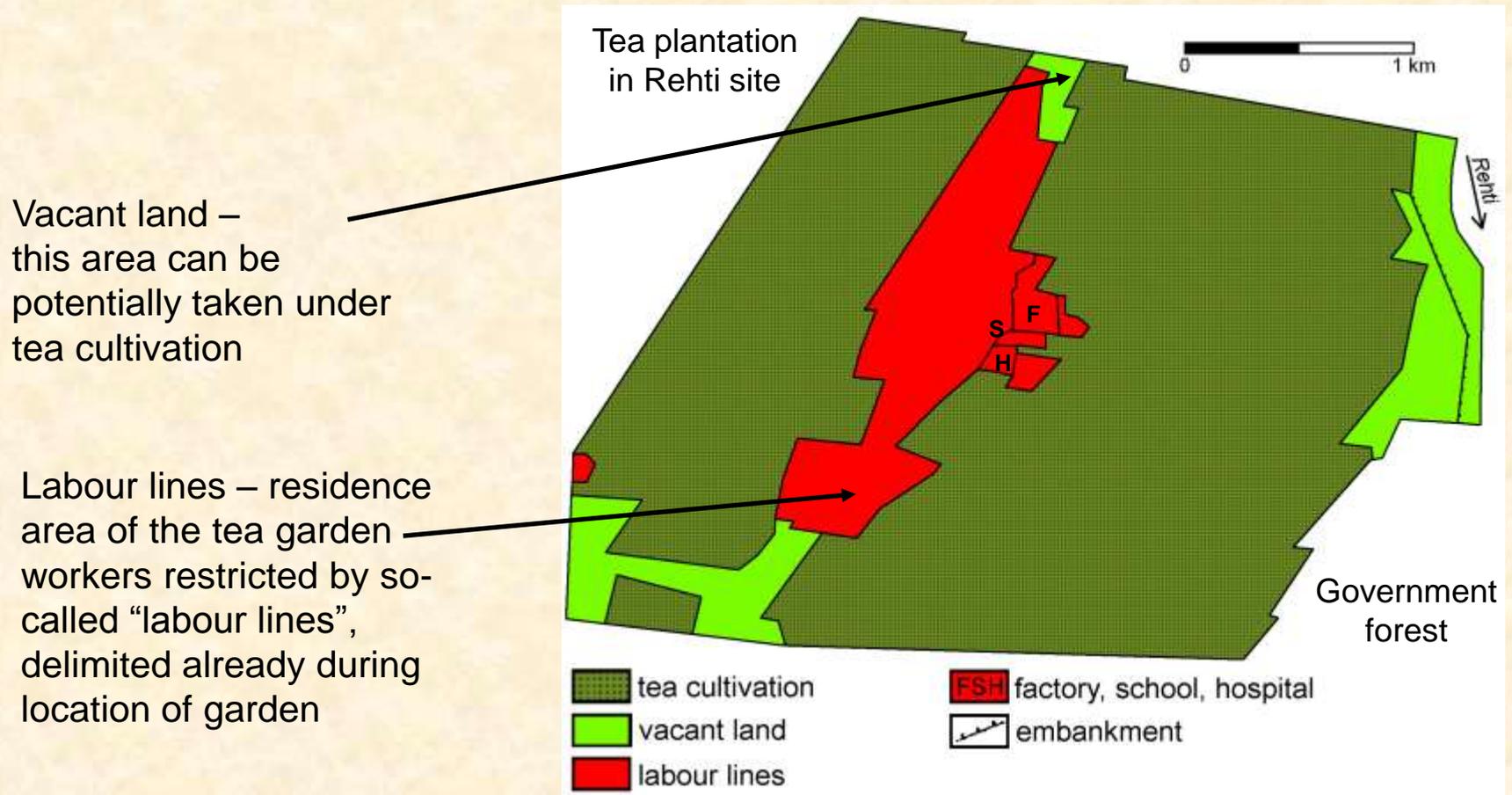
Discussion

1. Why extension of tea cultivation increases LULC stability?

- **legal causes** – the land for the plantations belongs to Government and is given in lease to the employers. Each lease has to be renewed after 30 years, and is subject to the condition that the land will be used for tea production alone
- **environmental causes** – the tea cultivation is long term monoculture and bushes can survive more than 100 years
- **economical causes** – the highest yield tea bushes have between 10-20 years, but lack of money cause that about 43% of tea bushes are more than 50 years
- **historical causes** – inherited and strictly specified internal LULC structure within tea plantation

Discussion

2. Why the built-up areas are stable despite the population growth



Discussion

3. Why we do not observe considerable deforestation as a result of the human activity?

- **legal causes** (Forest Act of 1865):

- ownership system – forest belongs to the Government
- development of tree plantations
- implementation of ban on illegal timber extraction
- flood and fire protection

- **economical causes** (Plantation Labour Act of 1951):

- women in the labour force constitute more than half of workers
- the employment of child labour aged below 14 years
- the children of a plantation worker who has retired has to be hired in the place of their parent
- subsidized food as a part of payment: 4.5 kg of rice and wheat per week for each worker and his children
- free of charge education and health care

Conclusions

- The piedmont of the Eastern Himalayas is characterized by a shift from natural towards human-dominated landscape over the last 150 years
- The LULC transformation marked three distinct periods:
 - forest prevailed up to annexation piedmont into British East India Company in 1865
 - new LULC structure was formed through rapid deforestation connected with the location of tea plantations and taking floodplains under crop cultivation up to 1930
 - increase of LULC stability through gradual extension of tea gardens and crop cultivation as well as development of forestry up to 2010
- Intensive human activity is important but secondary driving force of LULC change and the fluvial activity again staying a main deforestation agent
- Floods, river bank erosion or channel avulsion are not new phenomena for this region and only changing LULC pattern, increase vulnerability of region to such hazards
- Observations seems to be indicative of land use trends in Eastern Himalayan piedmont generally, particularly as tea plantations and floodplain crop cultivation expand to the east into neighboring Assam

Thank you

