

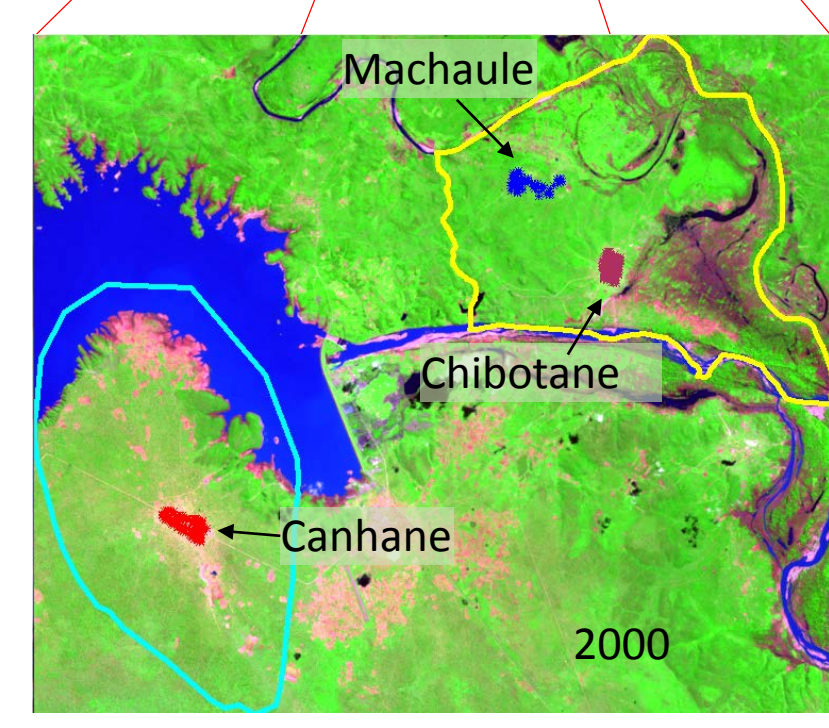
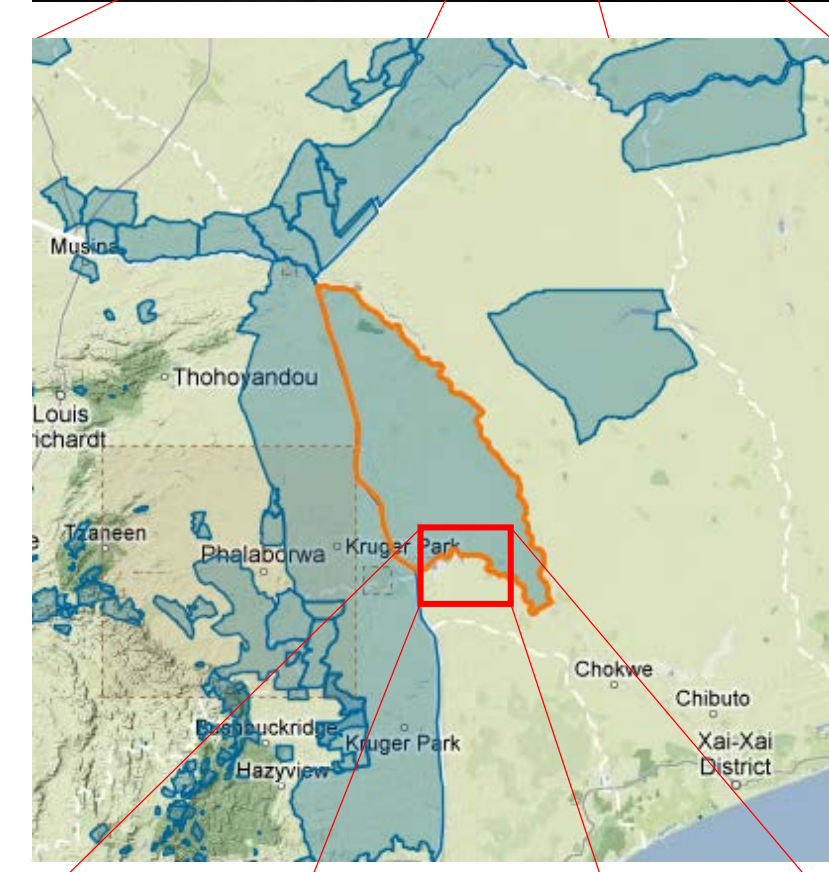
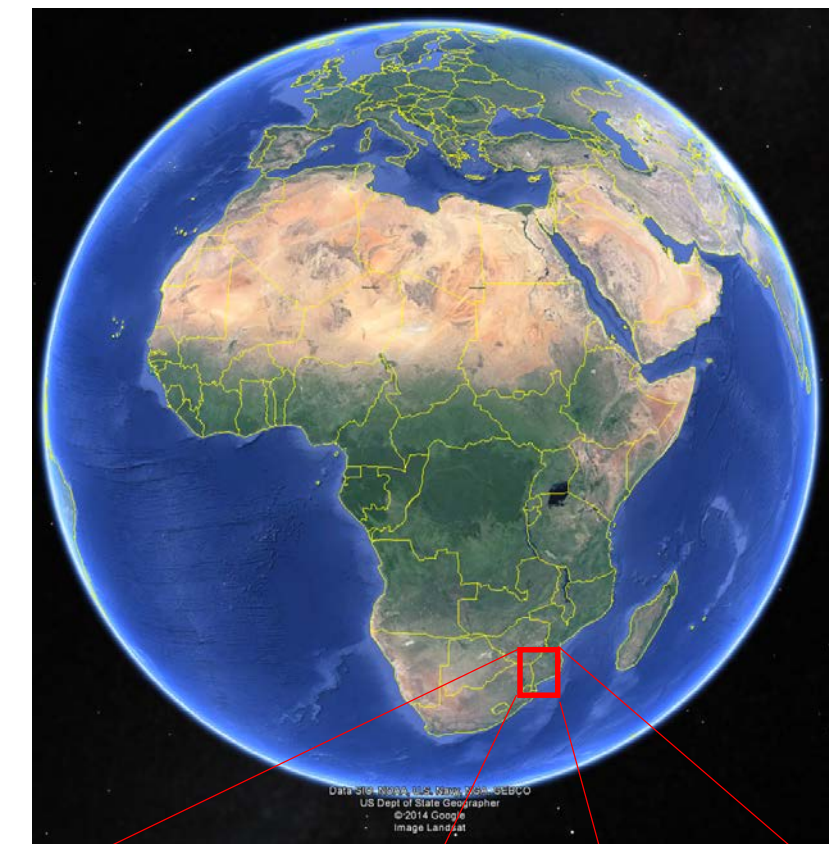
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Introduction

Economically underdeveloped regions in Africa have become a key focus of environmental conservation, in large part because high levels of biodiversity still exist in these areas. Transboundary natural resource management (TBNRM) approaches have been increasingly used in Africa to promote both conservation and economic development goals. Specifically, they are expected to 1) reduce dependence on subsistence agriculture in high biodiversity areas, 2) increase alternative formal employment opportunities within the park and in supporting industries, 3) facilitate community development projects and improved transportation infrastructure, 4) advance conservation goals in expanding the wildlife habitat and preserving existing biodiversity. However, the success of the Peace Parks approach relies largely on the ability of economic incentives to induce local residents to participate in land use practices consistent with tourism. These incentives would include preserving wild game species for tourist viewing and refraining from using certain land—such as wildlife corridors—for livestock grazing or agriculture.

The Great Limpopo Transfrontier Park (GLTP) was established in November 2000 to develop a contiguous wildlife corridor linking protected areas across Mozambique (outlined in orange), South Africa, and Zimbabwe. South African and Zimbabwean components of the GLTP have functioned as protected areas prior to the GLTP establishment. In contrast, the Mozambican section of the GLTP still has ~26,500 residents within its borders distributed among ~50 villages ranging in size from 150 to 2000 people and ~5,000 heads of cattle (Spenceley 2006). In this study we compare spatial patterns of land use with local residents' evaluations of the benefits associated with tourism-based development in three communities at the border of the GLTP. Two of the communities (Chibotane and Machaule) are based within the GLTP boundaries and one (Canhane) outside. Our research findings, based on a socioeconomic census of 358 households and in-depth interviews with 136 residents living in and near the GLTP, indicate that people associate tourism with decreased food security.

We conducted a change detection analysis using a dense stack of Landsat imagery for the period between 1990 and 2010 to examine patterns of land cover change within and just outside the park. During this period this area recovered from civil war, was designated as a national park, and then was re-classified as part of the GLTP. We harmonize the results from the remote sensing analysis with qualitative findings to link resident perceptions of well-being with spatial patterns of deforestation in and around the park. We find strong evidence of significant deforestation within the park but not in surrounding areas. Our study findings suggest that residents' fear of being forcibly relocated to areas outside the park and human-wildlife conflict may encourage land clearing within the park boundaries.



Community socio-economic development background

Standard measures of socio-economic standing among the three communities (Fig. a - below) show broad-scale similarities (Canhane – outside GLTP, Machaule & Chibotane – inside GLTP):

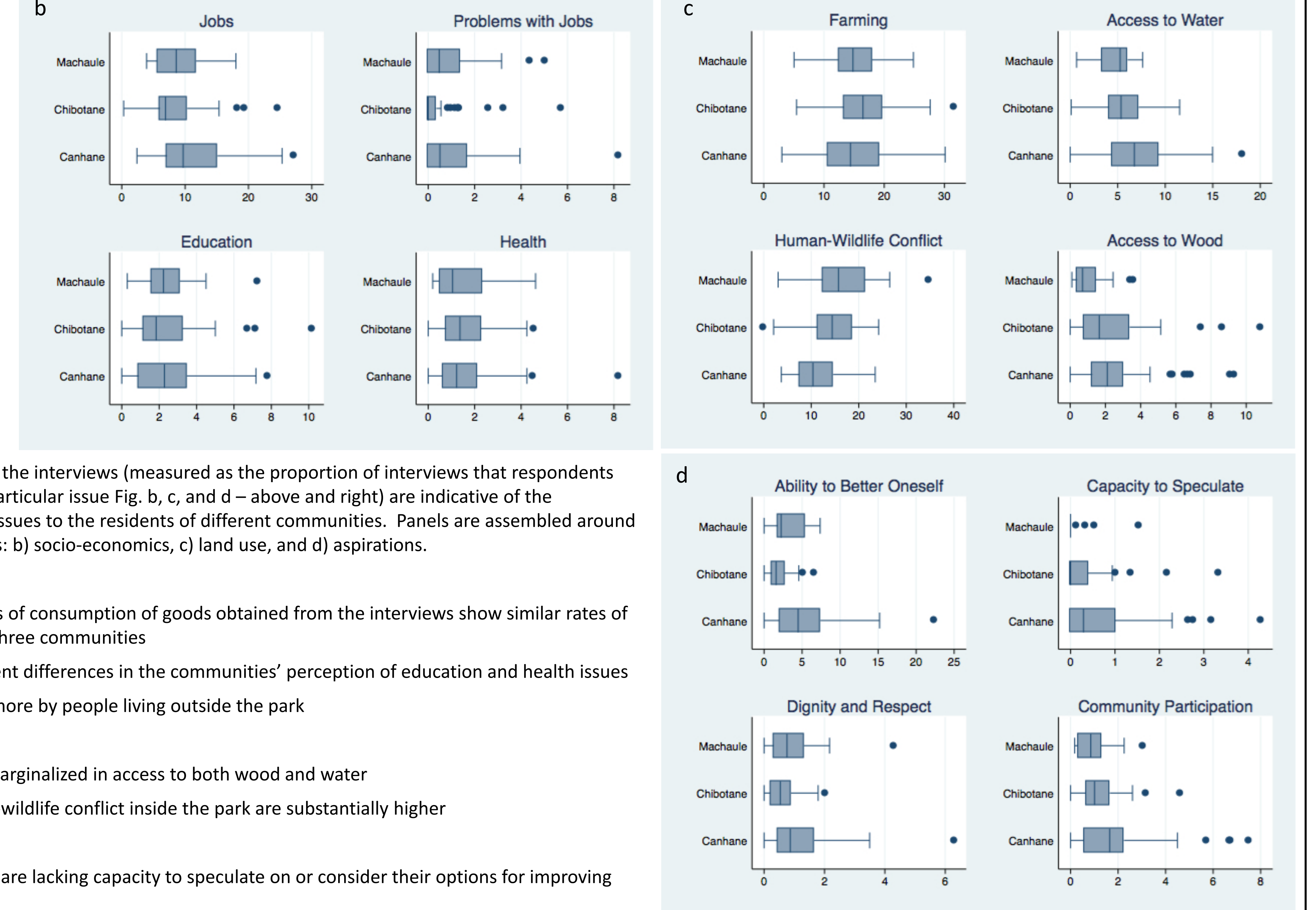
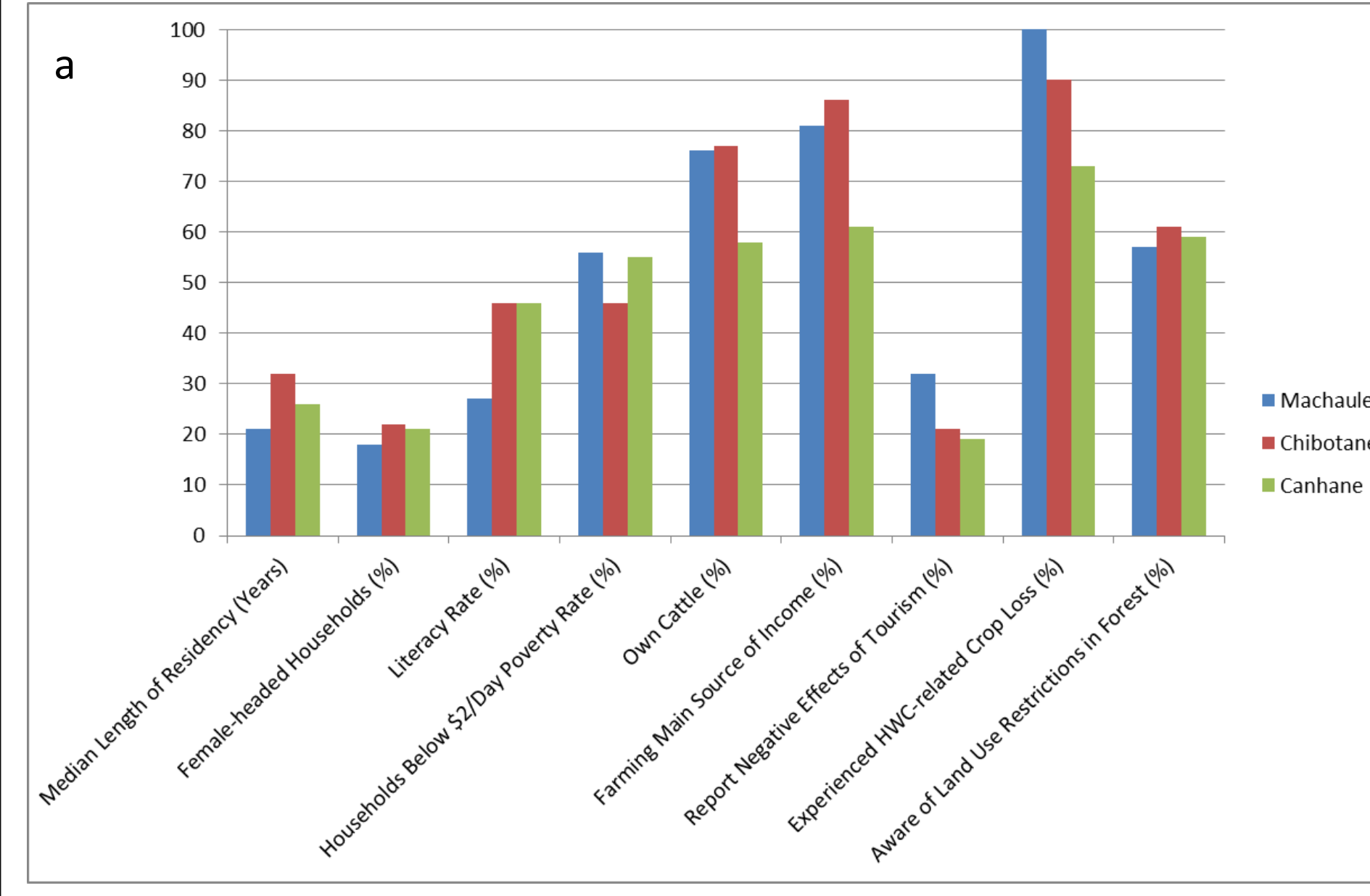
- 45-55% of population lives at the extreme poverty rate (\$2/Day)
- All are equally aware of land use restrictions (forest conversion is prohibited) inside the park

Major differences between settlements inside and outside the park include:

- Farming and cattle ownership are ~20% more prevalent for the communities inside the park boundary
- Human-wildlife conflict and resultant loss of crops is more prevalent inside the park

Machaule community inside the park boundary appears slightly more vulnerable:

- A more recently established community than Canhane or Chibotane
- Substantially lower literacy rate compared to others
- Largest rate of reported negative effects of tourism
- 100% of population experiences crop loss from human-wildlife conflict



Detailed assessment of the interviews (measured as the proportion of interviews that respondents spent talking about a particular issue Fig. b, c, and d – above and right) are indicative of the importance of various issues to the residents of different communities. Panels are assembled around three dominant themes: b) socio-economics, c) land use, and d) aspirations.

Socio-economics:

- Additional measures of consumption of goods obtained from the interviews show similar rates of poverty across the three communities
- There are no apparent differences in the communities' perception of education and health issues
- Jobs are discussed more by people living outside the park

Land use:

- Machaule is most marginalized in access to both wood and water
- The rates of human-wildlife conflict inside the park are substantially higher

Aspirations:

- Machaule residents are lacking capacity to speculate on or consider their options for improving their life

Land cover change detection methods

Extreme (drought vs flood) inter-annual variability of surface conditions

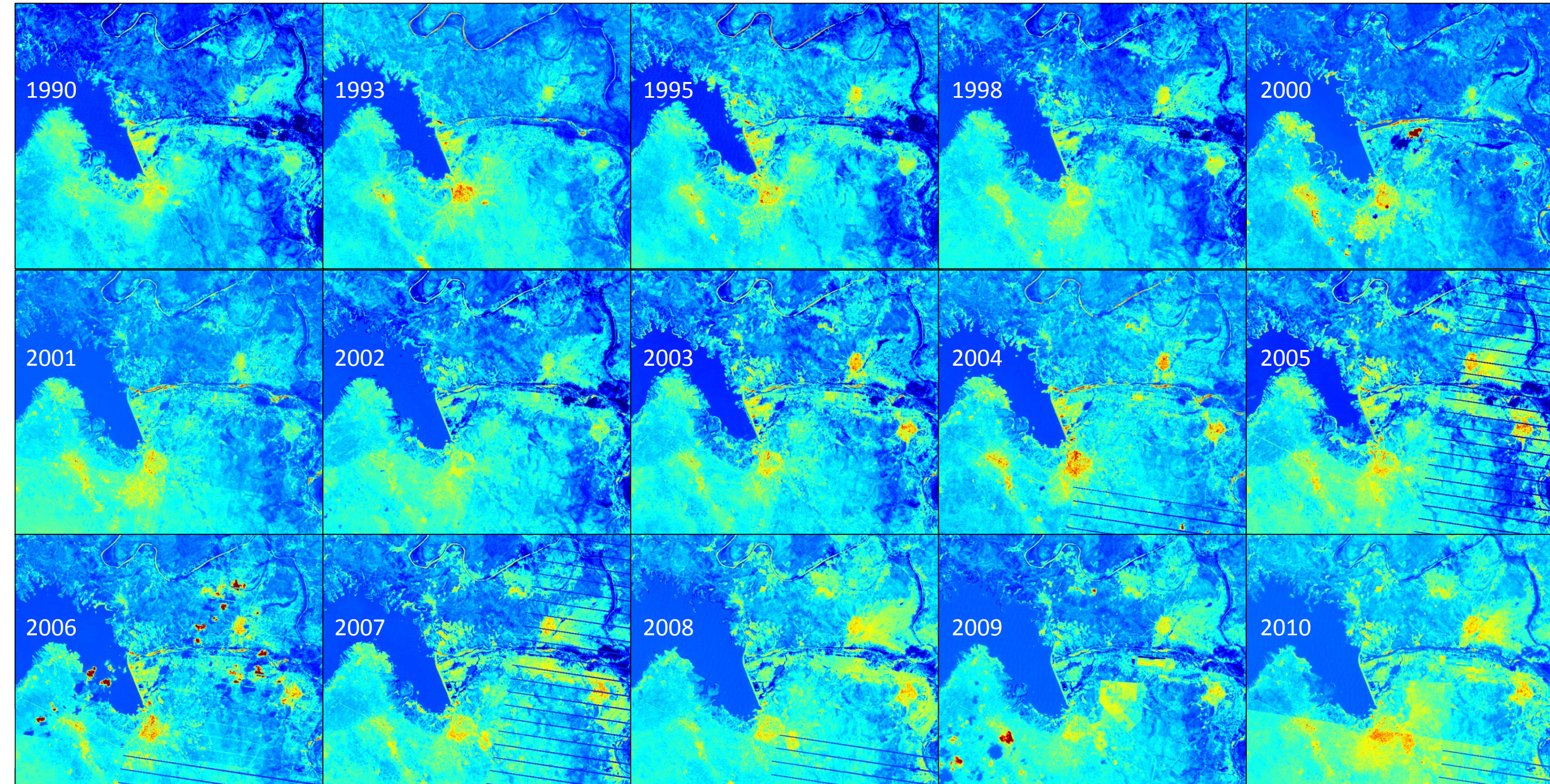
Variation in date of clear surface image acquisition
Crop rotation practices and variation on planting dates

Required normalization of forest signatures over time

Disturbance Index (Healy et al., 2005) in dense imagery cube

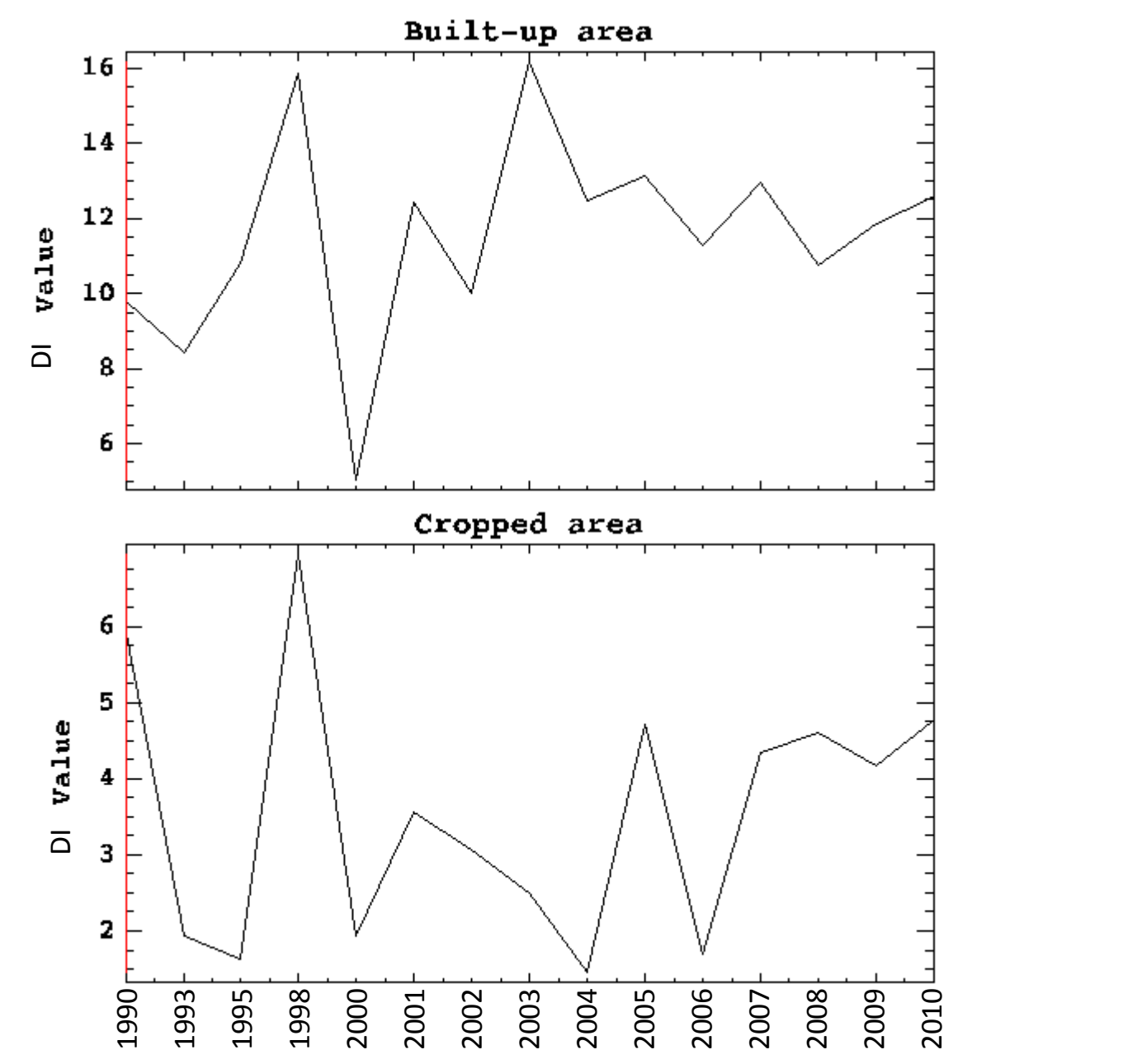
where B_t , G_t , and W_t are z-score of Tassled Cap Brightness, Greenness, and Wetness within mature forests, respectively.

Disturbance Index
 $DI > 3 \rightarrow \sim$ disturbance



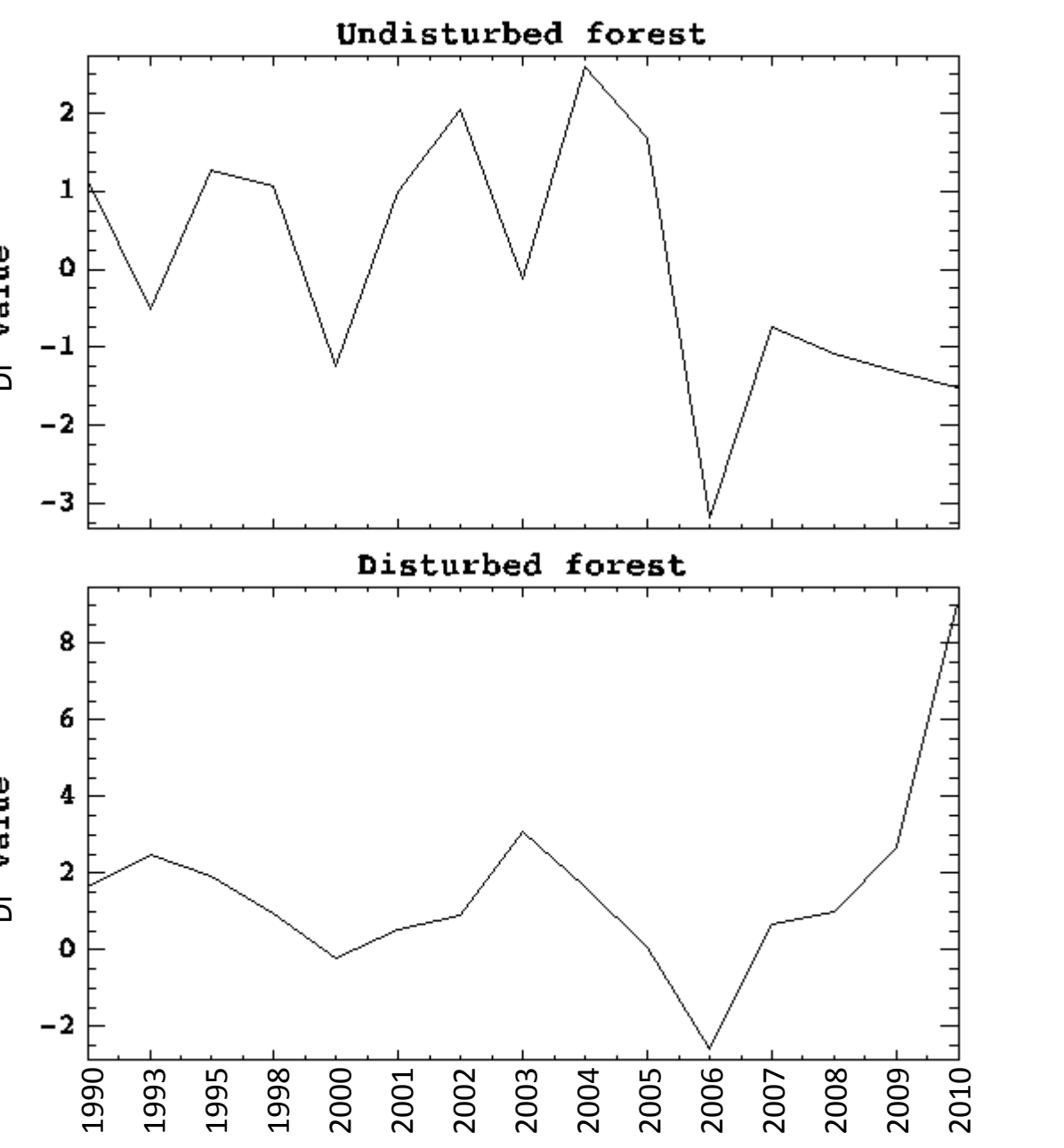
Mapping land use using multi-temporal DI

- DI of dense built-up areas is consistently > 3
- DI of cropped areas varies based on the crop rotation practices but exceeds 3 multiple times during the mapping period



Separating disturbance from phenology

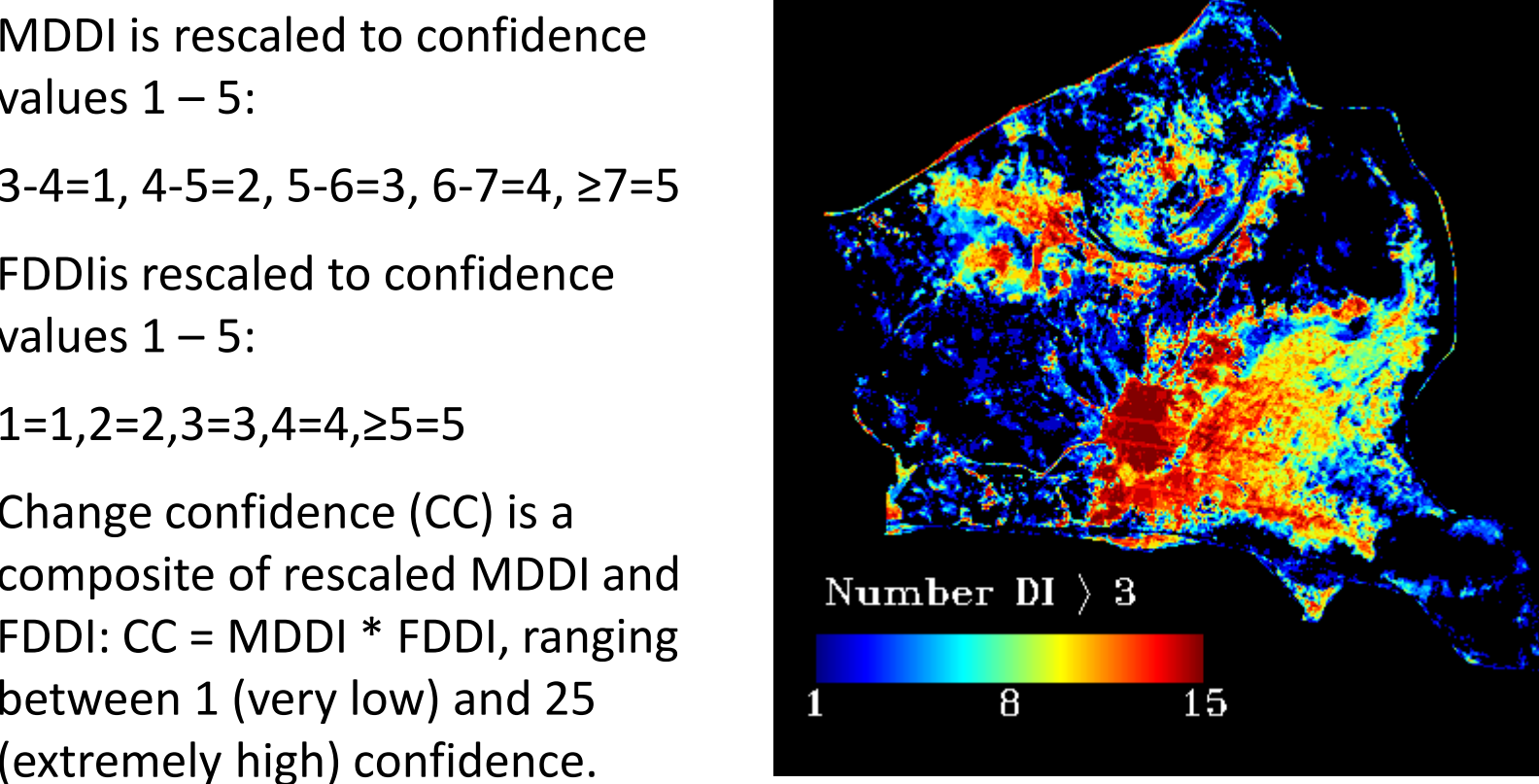
- Phenology within undisturbed forest causes DI to near or slightly exceed 3 but will stay below on average
- True disturbance causes a sharp increase in DI but if occurs in 2010 will be recorded only once



DI stack metrics

Two new metrics are identified to map disturbance:

- Mean disturbance DI (MDDI - left) computed as a mean value of all DI values in the stack exceeding DI of 3
- Frequency of disturbance DI (FDDI - below) computed as the number of times DI exceeds 3 in the mapping record

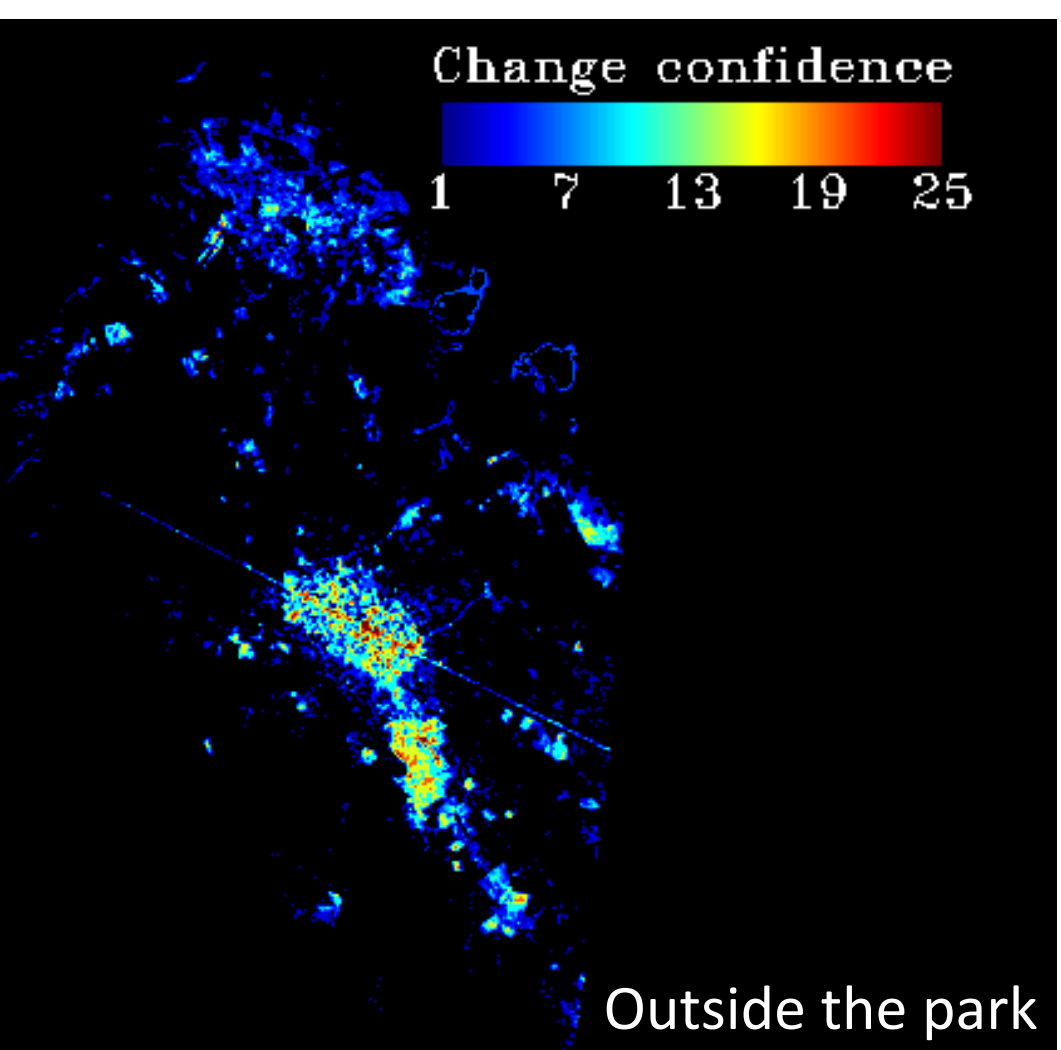


Land cover and land use change in selected GLTP communities within and outside the GLTP

Mapping areas without forest cover in and around GLTP

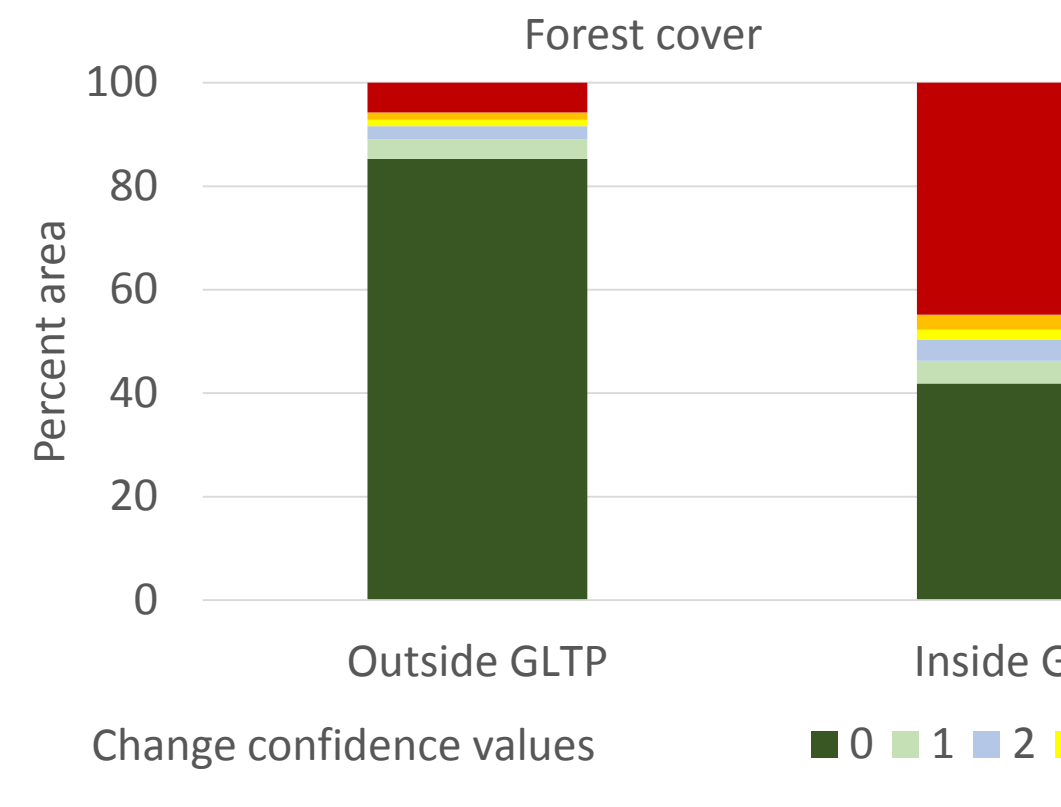
Chibotane and Machaule (right) are characterized by a high proportion of disturbed forest concentrated along:

- The built-up areas of the villages
- Extensive agricultural areas to the right of Chibotane village
- Considerable contiguous agricultural zone south and east of Machaule
- A set of individual fields along the rivers and deeper in the mountainous regions



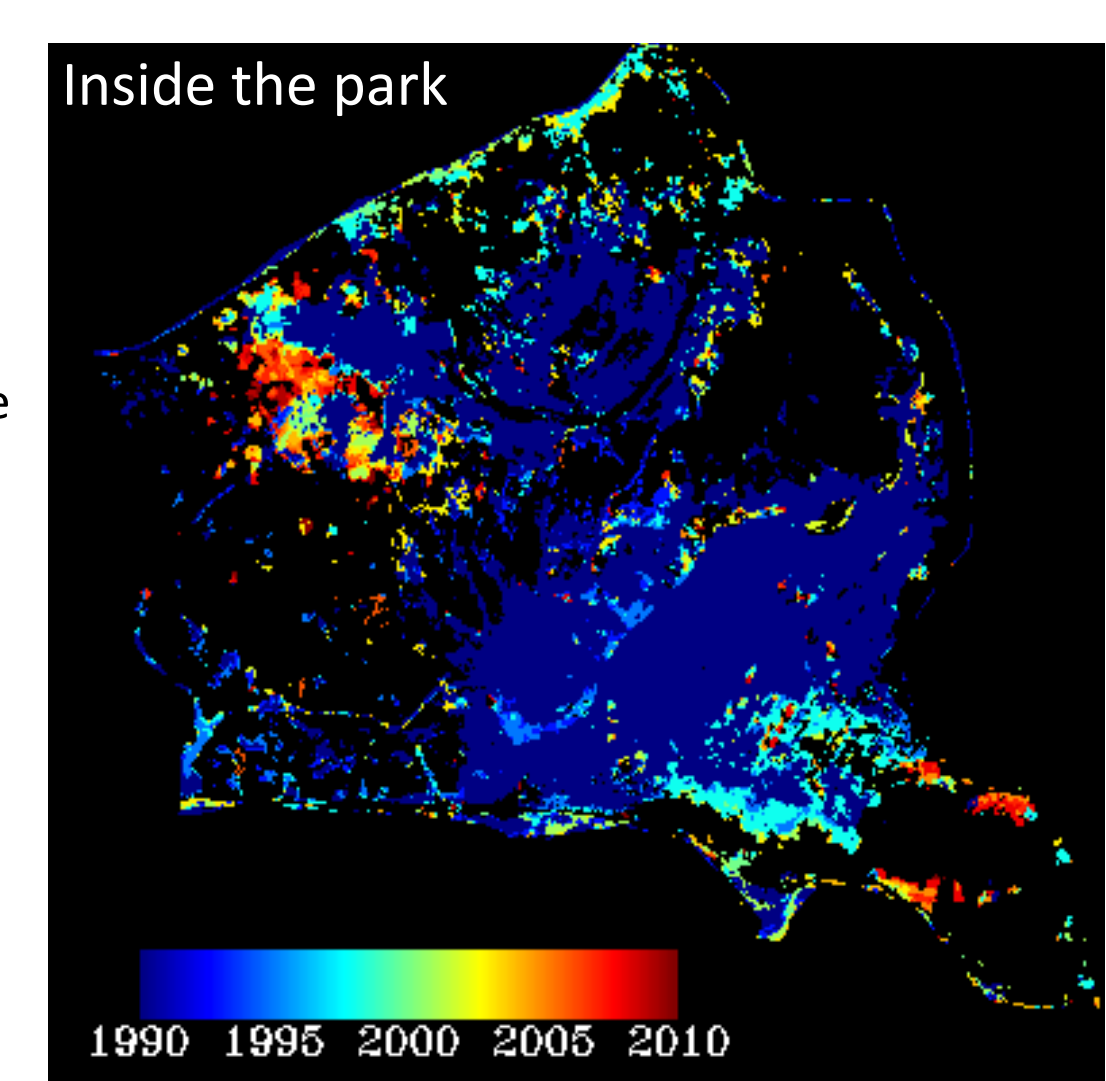
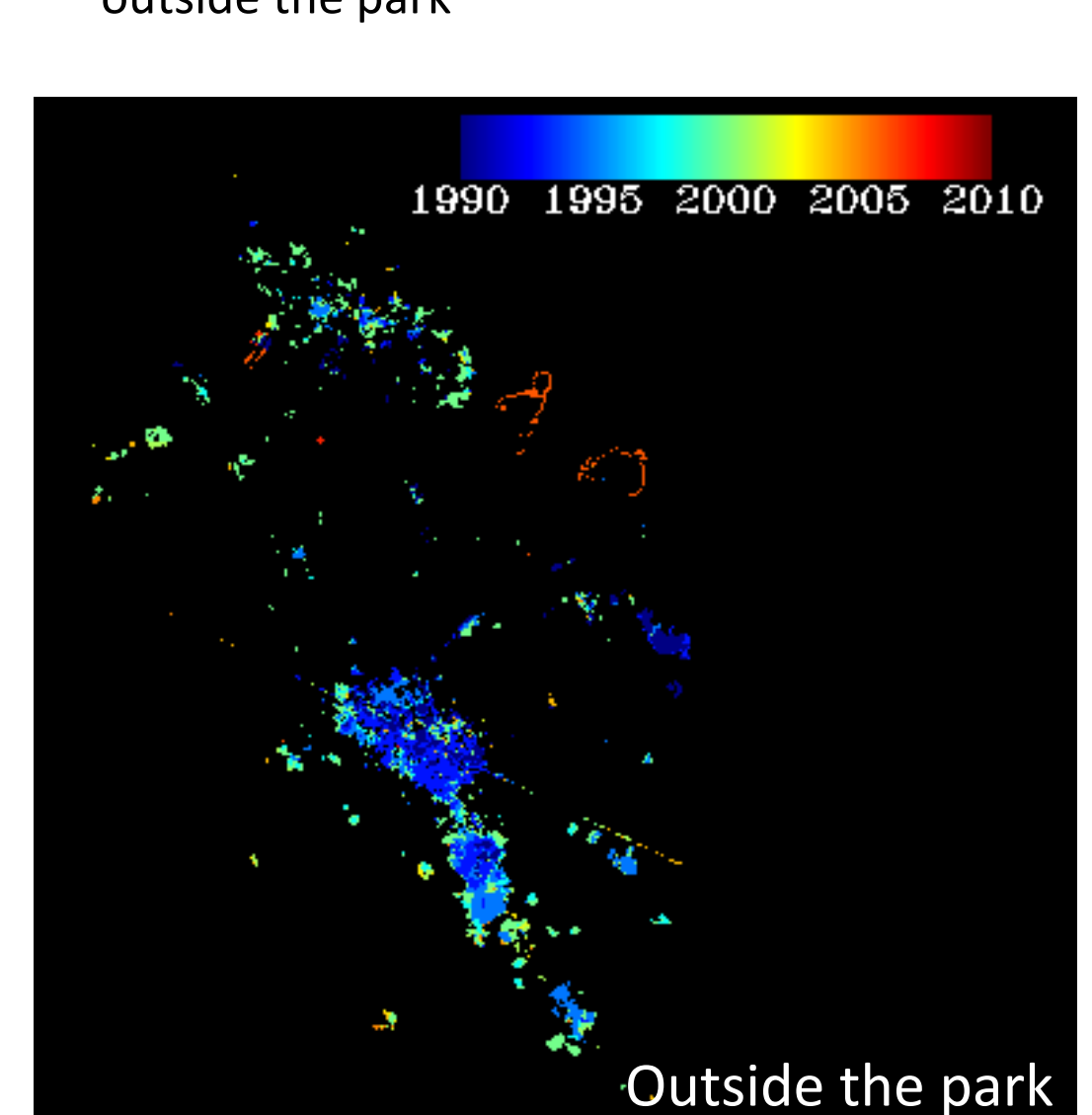
Canhane area (left) has experienced relatively little disturbance which has been concentrated along:

- The built-up area of the village (center),
- Along a stream bed south-east of the village
- North-west along the shoreline of the Massingir Dam where a lodge supporting the tourism to the park was built



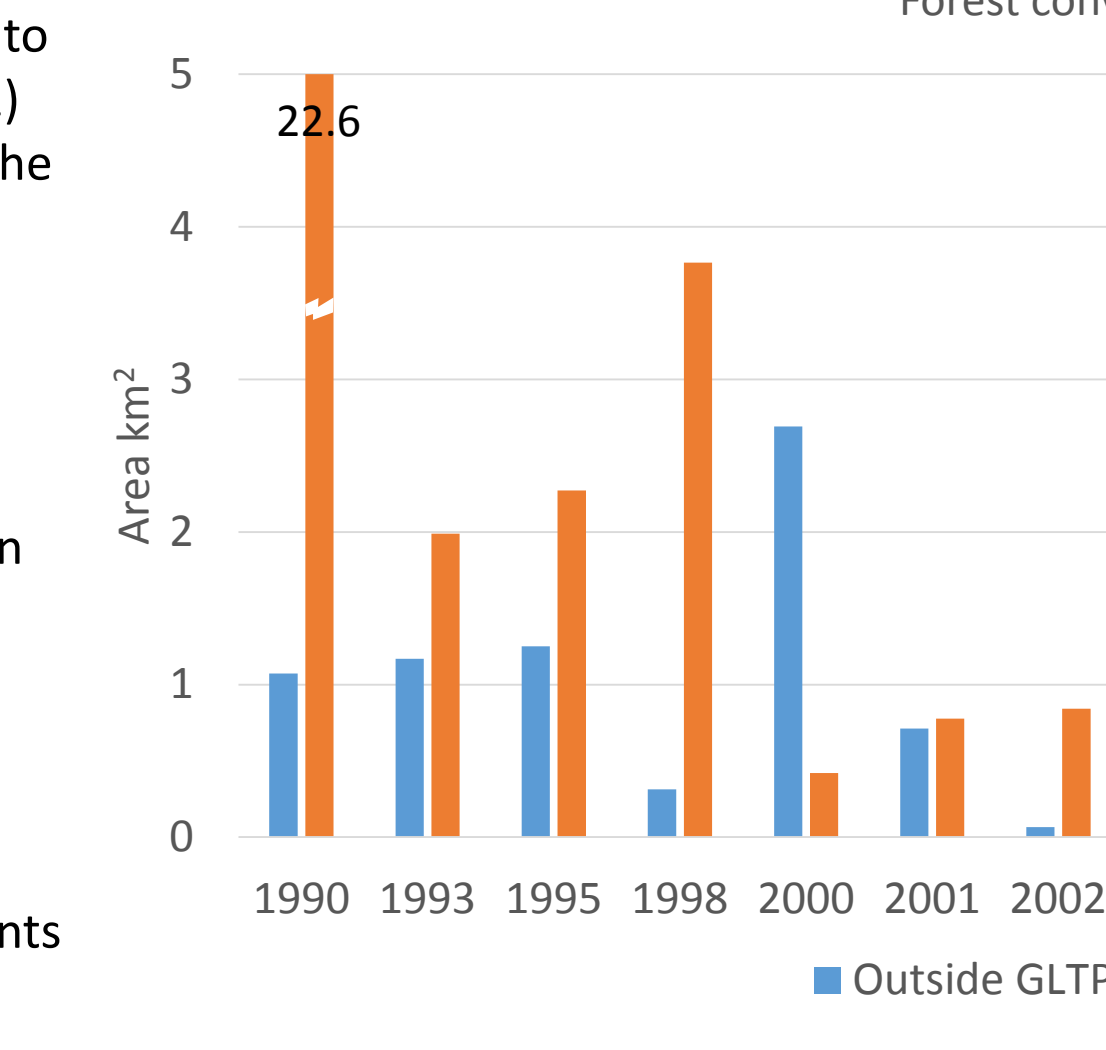
Defining date of disturbance

- Date of disturbance is mapped for areas of moderate and above disturbance confidence levels (CC of ≥ 3)
- Date is defined as the first image with $DI > 3$
- Dark blue color (date 1990) defines areas which have been disturbed prior to the change detection window \rightarrow These represent old areas of settlement and agriculture within and outside the park



- In the area as a whole the majority of forest conversion occurred prior to 2001 (GLTP designation) as the area was recovering from the civil war.
- Outside the park major development in mid-late 2000s is associated with the nature tourism lodge construction in the north-western section
- Inside the park, a large expansion of agricultural lands in mid-late 2000s is evident south of Machaule and east of Chibotane

Forest conversion rate



Perceptions of well-being as a driver of land cover change

- Our analysis shows no statistically significant relationship between the rate of deforestation and the standard socio-economic metrics used in the development literature.
- All three communities are at very similar levels of economic well-being with similar access to education (primary schools are available in all 3 communities).
- A detailed analysis of interviews has highlighted a potential underlying driver of land cover and land use change which is not related to objective measures of socio-economic standing: a limited ability to aspire (i.e., articulate or imagine what they would like to see change in the future).
- This is largely a function of exposure to new/different things, quality of (rather than access to) education, and other potential contributors
- Field observations have shown that Machaule schools are of particularly low quality compared to other villages (according to 2009 census no teachers lived in the village of Machaule and overall literacy level in the village is 50% below the other sites).

In qualitative interviews, the Canhane (outside GLTP) residents demonstrate a much stronger capacity to aspire. They discuss the ability to better themselves more frequently than those villages inside the park. They also devote more time to speculation, discuss community relations more frequently, and describe the need for dignity and respect with more words. "For a person to have a good life it must be that the person works. And that is how change happens... When a person works this is what gives him ideas to change his life." Male, truck driver, 34 years old, Canhane (QNO 061061).

Similarly, residents of Chibotane (the larger village inside GLTP) are more willing to speculate about the ways to better their livelihoods which are different from following the traditional patterns of development: "Our ideas nowadays lead to more development, but our grandparents were even afraid of building a house... We are now clever." Male, farmer, 39 years old, Chibotane. (QNO 051051)

In contrast, Machaule residents seem to have very limited ability to aspire and express a lack of awareness on how to improve their situation. Here is an illustrative quote from a 41 year old male farmer/temporary park employee in Machaule. "What I would like to say, it is that we should have good and profitable ideas. If hunger comes, we should know what to do, apart from stealing to get food. It is what I want God to give me. I just pray God to give me these ideas." (QNO 052039).

People in all sites say that farming is becoming less viable as a livelihood strategy as food security becomes increasingly income dependent (due to human-wildlife conflict, extreme weather, etc.). But households in Machaule seem to have fewer notions of what to do about it, and this could lead to them intensifying the one thing they have experience with (e.g., farming) and could conceivably lead to more forest clearance.

Next steps

- Our research has uncovered a potential new theoretical underpinning of human drivers of land cover and land use change in poor rural African communities. In our next steps we intend to undertake more field surveys with two major aims:
 1. Re-interview previously sampled communities of Canhane, Chibotane, and Machaule to confirm the satellite-detected patterns of land cover and land use change and discuss the residents' perception of drivers of those changes.
 2. Use satellite imagery to find similar patterns of land cover and land use change across other populated areas within and outside the park and interview residents within a subset of those areas to determine a broader applicability of these findings.

References and acknowledgements

Healy SP, Cohen WB, Zhiqiang Y, Krankina O, 2005. Comparison of Tassled Cap-based Landsat data structures for use in forest disturbance detection. *Remote Sensing of Environment*, 97: 301-310.
Spenceley A, 2006. Tourism in the Great Limpopo Transfrontier Park. *Development Southern Africa*, 23(5): 649-667.
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