Perspectives on the pastoral landscape: Combining remote sensing observations and pastoralist perceptions in southern Tamil Nadu, India

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This article explores how land cover change studies could be advanced through a methodology that integrates remote sensing (RS) observations and perceptions from the ground. This is done through a case study in southern Tamil Nadu, India where changes in the pastoral landscape are investigated from two perspectives: from space through satellite images and from the ground through interviews and participatory mapping. RS results provide valuable insights about large-scale changes in the landscape, which could not have been captured through interviews. Grasslands, an important source of livestock feed, have decreased while agricultural land and built-up land has increased between the years 1992 and 2014. The qualitative data generated a deeper understanding of land cover change dynamics and revealed the complexity of pastoralist livelihoods where shrinking pastures is perceived as one of many challenges. Combining the two data types and analysing the gaps between them indicates that pastoralists are referring to the loss of relatively small but significant grazing lands. Such changes are not within the domain of detectable changes, which indicates that policy intended to improve pastoralist conditions based entirely on RS would most likely fail. This risk could be minimized by integrating qualitative data to the RS analysis.

Keywords: Land cover change, pastoralism, India, mixed methods, remote sensing

A drastic decline of grasslands and common property grazing lands have been observed in parts of India (Chaudhry, Bohra, & Choudhary, 2011; Tsarouchi, Mijic, Moulds, & Buytaert, 2014). This has had serious consequences for Indian pastoralists whose traditional livelihoods are largely dependent on these natural resources (Ghotge & Kishore, 2016; Sharma, Köhler-Rollefson, & Morton, 2003). The social and political marginalisation of pastoralism have resulted in policies and laws that do not attend to pastoralists' needs and major difficulties with finding their place in modern economies (IUCN, 2017). Monitoring and preventing the loss of grazing lands is therefore critical for the survival of this age-old livelihood and for the well-being of pastoralists.

Remote sensing (RS) is arguably the most useful and well-known tool for studying land cover changes. However, significant inconsistencies may occur between RS observations and perceptions from the ground (Herrmann, Sall, & Sy, 2014). This is because RS and qualitative interviews tell different parts of the same story about land cover change (Jiang, 2003), and also because of the different epistemological traditions these methods come from (Nightingale, 2003). Subjectivity and human interpretation is an often-underrated component within RS. Although many geographers and other RS practitioners today acknowledge the importance of human factors in aerial image analysis (Gardin et al., 2011), they have historically often been neglected as the researcher's task has been seen as to "correctly" interpret the land cover (Nightingale, 2003). This is an approach that does not align with the worldview of most qualitative researchers who rather see objective knowledge creation as impossible and non-desirable (Aitken & Kwan, 2010).

In this article, I combine RS data with pastoralist perceptions of land cover change with the aim to contribute to the development of an improved methodology for studying landscape dynamics. Integrating and comparing quantitative and qualitative data about land cover change could generate a deeper understanding of the pastoral landscape, which is better suited to informing policy. I illustrate this through a mixed methods case study in Tirunelveli and Thoothukudi districts of southern Tamil Nadu, a densely populated agricultural area where semi-nomadic sheep pastoralist have roamed for many generations.

A qualitative approach to GIS

RS provides important sources of data for GIS analysis. Land cover change detection is critical for understanding the dynamics of social-natural processes that shape the surface of the earth. Numerous technological approaches and methods have been developed for performing change detection on remotely sensed data, however, no single approach has been found to be optimal and applicable to all cases (Lu, Mausel, Brondizio, & Moran, 2004). RS is a relatively new and evolving scientific field, which has seen much technological improvement in recent years, and further progress can be assumed in the near future. Most studies on land cover change have in common that they are quantitative and focused on technological solutions for improving the detection of land cover change (e.g. Bakr, Weindorf, Bahnassy, Marei, & El-Badawi, 2010; Güler, Yomralıoğlu, & Reis, 2007; Lu et al., 2004; Young et al., 2017). Conventional GIS have been criticised for being socially exclusive and for producing incomplete analyses and out of this critique a new field has developed, sometimes referred to as qualitative GIS, participatory GIS or community integrated GIS (Dunn, 2007). This field works towards a more socially integrated GIS where people are involved in the process of obtaining and analysing geographical data.

Combining RS with qualitative data has highlighted the 'situatedness' and incompleteness of RS data on its own (Nightingale, 2003). This partiality is by no means unique to RS data, however, discussions on situated knowledge and partiality might be even more relevant within this field since human perception and interpretation has only quite recently been acknowledged to affect RS results and remains an undervalued component (Gardin et al., 2011). Analysing the discrepancies between the results of the different methods can help us understand new dimensions of the research topic while at the same time highlighting the limitations of the chosen methodologies. Local knowledge is a valuable source for improving our understanding of land cover change dynamics, and qualitative and quantitative methods can be used to complement and validate each other (Mialhe et al., 2015). A particularly suitable social group to involve in studies on land cover change is pastoralists because of their familiarity with large geographical areas due to the spatial scale of transhumance pastoralism (Herrmann et al., 2014). In addition to being large in scale, pastoralists tend to possess rich and detailed information about their environment and its ecological conditions (Jiang, 2003).

A look at pastoralism in India

One of the most critical livelihood threats faced by Indian pastoralists today is the dwindling pastoral lands. This development has been driven by factors like non-supportive government policies, expanding irrigated agricultural land, the enclosure of forests and protected areas, and the deterioration of pasture lands because of invasive species (Sharma et al., 2003). Several studies have confirmed that the shrinking and degradation of grasslands is a problem in the arid zones of northern India (e.g. Chaudhry et al., 2011; Jodha, 1985; Tsarouchi et al., 2014). Less attention has been given to the complex and densely populated agricultural landscapes of the south of the country. In fact, literature on pastoralism in southern India is remarkably scarce.

Indian pastoralists belong to a caste that specialises in animal husbandry, often within a society alongside people of other castes and occupations. This is in stark contrast to pastoral communities in areas more frequently associated with pastoral livelihoods, e.g. in Africa and the Middle East, where the pastoralists often inhabit vast remote territories practically by themselves (Sharma et al., 2003). Indian pastoral groups are not at the bottom of the social hierarchy and generally have more assets (i.e. livestock) than the poorest social groups. There are even rare examples of very socially mobile pastoral castes, for instance the Yadavs who are dominating politics in large areas of northern India (Jaffrelot, 2003). However, pastoral livelihoods undoubtedly face negative attitudes and misconceptions, which often lead to social and political exclusion (Ghotge &

Kishore, 2016).

Pastoralists are frequently blamed for degrading the environment through overgrazing which has resulted in hostile government attitudes and policies (Sharma et al., 2003). It is only recently that some states have decided to ease their restrictions on pastoralists and allow them to enter certain forests and protected areas that used to be their traditional grazing grounds (Ghotge & Kishore, 2016). Today the Government of Tamil Nadu officially recognises the vital role of animal husbandry for rural livelihoods and for the economy of the state (Government of Tamil Nadu, 2016). However, protecting existing grazing lands does not seem to be an incentive for this change; focus is rather on increasing the production capacity of existing cultivable lands for fodder (Government of Tamil Nadu, 2016). Nevertheless, improved government attitudes could be a result of a rather newfound international interest in pastoralism as a sustainable food production system which does not degrade the environment, but provides ecosystem services by maintaining soil quality, regulating water, and contributing to biodiversity conservation (McGahey, Davies, Hagelberg, & Ouedraogo, 2014). Furthermore, pastoralists play a key role in the sustainability of agricultural activities in India through the fertilization of soils that their livestock contributes to (Ramdas, Yakshi, & Deepika, 2001).

Remote sensing methods and data

The RS methodology followed a four-step process that involved 1) pre-processing, 2) classification, 3) accuracy assessment, and 4) post-classification change detection. All RS steps were performed in the software program ArcGIS 10.2. Three Landsat images were used for the analysis; one Landsat 5 TM image from 1992, one Landsat 7 ETM+ image from 2000, and one Landsat 8 OLI/TIRS image from 2014. The Landsat program's near continuous record of the earth's surface since the early 1970s makes it particularly useful for monitoring land cover change (Tsarouchi et al., 2014; Young et al., 2017). The study area was delimited into four 12 x 12 kilometre study sites with a total area of 576 km^2 (Figure 1). These four study sites (Ambasamudram, Tirunelveli, Srivaikuntam and Peikulam) were identified with the help of local pastoralists as particularly important areas for grazing.

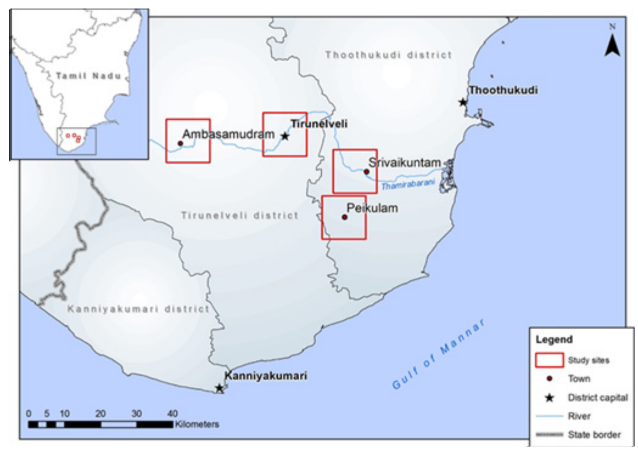

Figure 1: Map of the study area in southern Tamil Nadu (Wennström, 2017).

First, the satellite images were pre-processed through geometric correction and image enhancement (Young et al., 2017). Excessive information in the images were also removed through a principal component analysis (PCA) in order to facilitate interpretation and comparison (Abdi & Williams, 2010). A supervised classification was then performed which means that 'training samples' of predetermined land cover classes were manually classified. For this study, five classes were used; water, built-up land, agricultural land, scrubland and grassland. The training samples were then used by the classification algorithm to classify all pixels in the images into these five classes (Lillesand, Kiefer, & Chipman, 2004). Four types of accuracy were calculated; overall, user, producer, and kappa statistics. 260 reference points were used per classified image, which were compared to 126 ground truth points collected through fieldwork as well as high-resolution reference data. Finally, land cover changes between the years were calculated using a post-classification change detection technique where the images were compared on a pixel-to-pixel basis (Güler et al., 2007).

Qualitative methods and data

Qualitative data were collected through participatory mapping (PM) with local pastoralists and separate personal semi-structured interviews. Various forms of mapping have long been established as part of Participatory Rural Appraisal (PRA) techniques in rural development as a way of understanding existing resources and social arrangements in particular locations (Chambers, 1994). For this study scale mapping was used which is a method that generates data that is easily integrated into a GIS because the participants draw landscape features directly on a printed map or an aerial image (Corbett et al., 2006). The venue for the PM workshop, a small temple in the village of Peikulam, was chosen in consultation with a key informant. Twelve herders between the ages of 32 and 55 were present at the workshop; they were selected through snowball sampling which is a useful method for reaching social networks and marginalised populations (Tracy, 2012). The reference maps were used both as a tool for stimulating discussion on environmental and livelihood changes, and for drawing migratory routes and identifying key locations for grazing and diminished pastures.

Separate personal interviews with pastoralists were conducted to further explore and analyse in what way the changing environment affects their livelihoods. A total of 17 pastoralists were interviewed for this study and the participants were found, approached, and interviewed in the field. For the purpose of this study it was important that the sample participants had several years of experience of herding in southern Tamil Nadu so that information about the environmental and social change could be generated. This sort of purposeful convenience sampling is suitable when information could be generated from anyone within the particular social network (Tracy, 2012). Finally, the interviews were transcribed, coded and analysed.

Remote sensing observations

The classified images from the years 1992, 2000 and 2014 are shown in Figure 2. Figure 3 shows that the most noteworthy changes that have occurred between the years 1992 and 2014 are an increase in agricultural land (+7.3%) and a decrease in grassland (-7.1%). The remaining land cover classes had not changed significantly; built-up land (+0.9%) and water (+1%) had increased marginally while there had been a slight decrease in scrubland (-2.1%). Most of these changes appear to have occurred between the years 1992 and 2000. The results of the accuracy assessments are showed in Table 1. The two images from 1992 and 2014, which were used for the change detection analysis, scored above the commonly suggested benchmark of 85% for overall accuracy (Tsarouchi et al., 2014). The kappa statistics for the 1992 classified image was 0.83, which according to Landis and Koch (1977) should be considered 'almost perfect', while the classifications of the 2000 and 2014 images scored 0.73 and 0.77 respectively, which falls into the category 'substantial strength of agreement' (Landis & Koch, 1977).

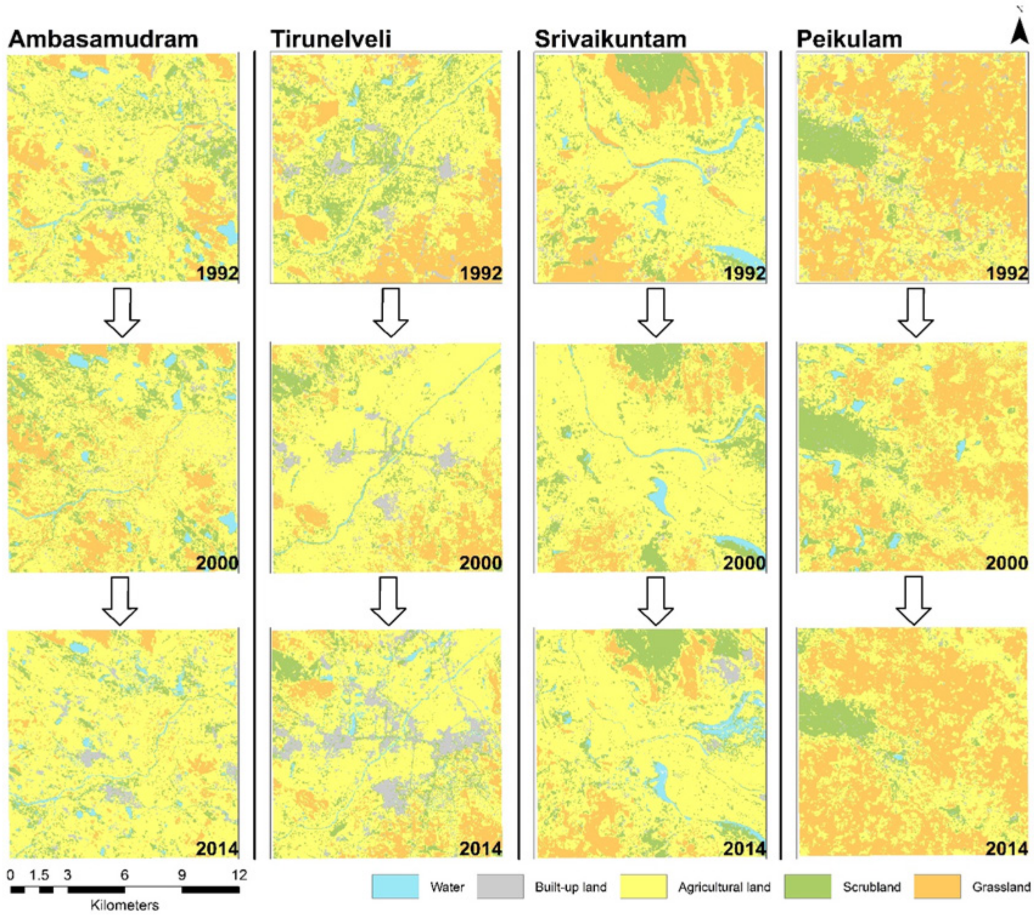

Figure 2: Classified images of the four study sites for the years 1992, 2000 and 2014 (Wennström, 2017).

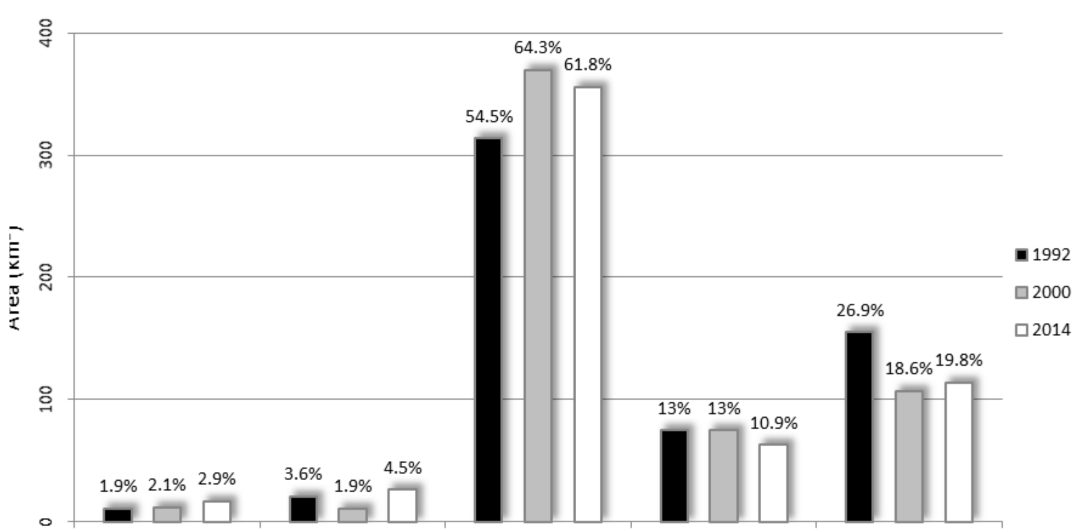

Figure 3: Area of land cover classes in the classified images from 1992, 2000 and 2014.

1992 Landsat 5 TM	Water	Built-up land	Agricultural land	Scrubland	Grassland	Classified total	User accuracy (%)
Water	**7**	1				8	87.5
Built-up land		**2**	3			5	40.0
Agricultural land		3	**127**	11	2	143	88.8
Scrubland			3	**27**		30	90.0
Grassland		1	3		**70**	74	94.6
Reference total	7	6	137	38	72	260	
Producer accuracy (%)	100.0	33.3	92.7	71.0	97.2	Overall accuracy: 89.6%	
2000 Landsat 7 ETM+	Water	Built-up land	Agricultural land	Scrubland	Grassland	Classified total	User accuracy (%)
Water	**11**		1	1		13	84.6
Built-up land		**4**	3			7	57.1
Agricultural land		3	**130**	9	2	144	90.3
Scrubland		3	11	**24**		38	63.1
Grassland			9		**49**	58	84.5
Reference total	11	10	154	34	51	260	
Producer accuracy (%)	100.0	40.0	84.4	70.6	96.1	Overall accuracy: 83.8%	
2014 Landsat 8 OLI/TIRS	Water	Built-up land	Agricultural land	Scrubland	Grassland	Classified total	User accuracy (%)
Water	**7**			1		8	87.5
Built-up land	1	**10**	2	3		16	62.5
Agricultural land	2		**147**	7	3	159	92.4
Scrubland			7	**16**	1	24	66.6
Grassland			7		**46**	53	86.8
Reference total	10	10	163	27	50	260	
Producer accuracy (%)	70.0	100.0	90.0	59.2	92.0	Overall accuracy: 86.9%	

Table 1: Results of the accuracy assessment of the classified images from 1992, 2000 and 2014.

The post-classification change detection analysis (Figure 4) showed that by far the most significant change that has occurred between the years 1992 and 2014 was grassland that has become agricultural land, which stands for 66.78% of the land cover changes. Surprisingly and rather contradictorily, the second largest change that can be observed through RS was agricultural land that has become grassland which accounted for 27.56% of the changes. This could indicate that grassland and agricultural land have been mixed up in the classification. The accuracy assessment (Table 1) is to some extent supporting this assumption since some grassland has been incorrectly classified as agricultural land and vice versa. Although RS images are often seen as neutral and analysts aim to interpret changes objectively, the results of RS image analyses are inevitably affected by human performance variability and individual interpretations (Gardin et al., 2011). The selection of training samples, ground control points and land cover classes are examples of where analysts makes choices and interpretations which influence the results. This subjectivity needs to be highlighted and discussed also within a technical field such as RS. However, it does not reduce its usefulness for providing valuable information on large-scale changes in the landscape as RS generates information that cannot be revealed through qualitative interviews alone (Jiang, 2003). When combined with qualitative data, the somewhat shallow understanding of land cover change that RS provides can be deepened. Additionally, a seemingly contradictory result of simultaneously diminishing and expanding pastoral lands and cultivated areas does not necessarily need to be results from a "failed" classification. It could also indicate that land cover change dynamics are more complex than they might appear at first.

Pastoralist perceptions

Interactions with pastoralists revealed six issues that were perceived as impediments to pastoralist livelihoods in southern Tamil Nadu. These are (in a random order) proliferation of invasive species, animal diseases, physical obstacles on the migratory routes, changing land use patterns, deterioration of village institutions, and stigmatisation of pastoralism. All are perceived as problems that affect land cover dynamics in the area, either by directly altering the landscape or through social processes which have more indirect effects on land use.

Pastoralists in southern Tamil Nadu perceive the main changes that have occurred to be a transformation of grasslands into agricultural land and, to a lesser extent, built-up land near villages and towns. Disappearing commons due to the privatization of land and deterioration of the village institutions that used to protect the commons are other perceived changes that have transformed the landscape for the worse for them. Village commons have been sold and/or converted to housing lots or reduced due to agricultural encroachments. Perceptions of environmental change also need be understood in a wider context where climatic fluctuations may impact local knowledge (Jiang, 2003). The field work for this study was done in early 2016, immediately after an exceptionally wet northeast monsoon which resulted in the 2015 South Indian floods (Burke, 2015). This might have subconsciously influenced participants' perceptions of land cover change, with them possibly overemphasizing issues related to floods and excessive rain. Indeed, the rains were mentioned rather frequently as a problem; during unusually wet years, animal diseases are reported to escalate, and non-irrigated lands are often cropped as well, which might have led to exaggerations of the issue of agricultural encroachment on grasslands.

Proliferation of the fast growing invasive tree Prosopis juliflora is also perceived as a significant change, which has severe consequences for pastoral livelihoods. This is because the tree is seen as a key cause for the aggravating problem with animal diseases as its fruits are believed to poison their sheep. The toxicity of Prosopis juliflora and its constituent species Lantena camera has some support in the academic literature and the latter is believed to be causing thousands of livestock deaths every year (Robbins, 2001; Sharma et al., 2003). Physical obstacles due to infrastructural development and fencing are also seen as critical changes that are increasing. Congested roads mean direct danger to the livestock and obstacles like fences are fragmenting the landscape, which forces pastoralists to choose alternate routes, often along roads. Another issue that is forcing the herders to change their migratory routes is the enduring problem of the stigmatisation of pastoralists. Some previously important grazing grounds are avoided because of local villagers' hostility towards herders. Negative stereotypes and harassment seem to have created a feeling of hopelessness regarding the future of their profession. The absolute majority of the herders interviewed for this study no longer viewed pastoralism as a viable livelihood option and were determined that their children should not follow in their footsteps. from the ground because of the different stories these methods tell about environmental change. Local knowledge about the environment is very limited on a landscape-scale since land cover changes often occur slowly and over large geographical areas which makes them difficult to understand from a ground perspective. The unique contribution of RS to studies on land cover change thus lies in its large (temporal and spatial) scale perspective (Jiang, 2003). A purely qualitative study might have exaggerated the extent of grassland loss since such changes might be perceived as more

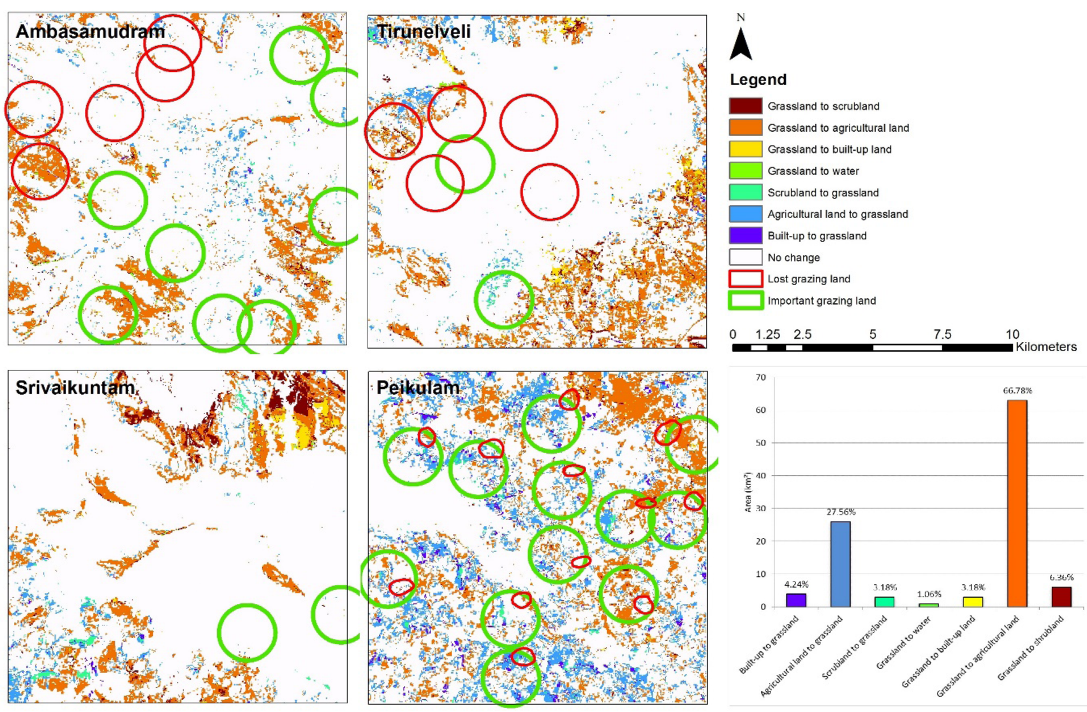

Figure 4: Remote sensing observations of land cover change within the four study sites between the years 1992 and 2014. Only changes that involves the class 'grassland' are shown. The red circles marks locations where pastoralists perceive grazing lands have disappeared and the green circles represents particularly important grazing lands (Wennström, 2017).

Comparative analysis of observed and perceived changes

The findings from the quantitative and qualitative parts of this study illustrate the value of combining RS observations with perceptions extensive than they are according to RS observations. However, a conventional RS study on the pastoral landscape of southern Tamil Nadu would have missed important perspectives on landscape dynamics and obstacles faced by pastoralists. Mixing methods in this way produces data that complement and authenticate one another since information about the environment that cannot be observed from space can be provided through local knowledge which brings an additional dimension to land cover change studies (Mialhe et al., 2015). Both perspectives are valuable and important for understanding social-natural processes in the landscape (Herrmann et al., 2014).

Any discrepancies that might appear between the results can also provide useful clues about the changing landscape (Nightingale, 2003). Both the RS observations and the pastoralists' perceptions about the land cover indicated that grasslands have been transformed into agricultural land. However, there is no obvious correlation between the two information sources regarding the exact location that these changes have occurred (figure 4). One possible explanation for this discrepancy could be that the pastoralists talked about land cover changes that were in fact restricted to relatively small but important pastures. The disappearance of small patches of grasslands cannot be detected by the RS analysis of coarse resolution satellite imagery. Resource users may in fact perceive a certain land cover change as more extensive than it is because of the location's significance (Nightingale, 2003). Another possible explanation for the discrepancies between RS observations and pastoralist perceptions could be that the perceived decrease of pastoral lands is not mainly caused by conversion of grasslands into agricultural and built-up land. The interviews revealed that physical obstacles on the landscape, such as fences and roads, are making certain routes and grazing grounds inaccessible to the pastoralists. Such changes could not be detected through RS since the actual land cover has not changed. Nevertheless, to the pastoralists, their traditional pastures have been lost which might partly explain why they marked some areas as diminishing pastures during the PM workshop although no significant changes in land cover could be detected at the same location using RS.

Conclusion

Combining RS observations and pastoralist perceptions has helped gain a wider perspective and a deeper understanding of land cover change dynamics than each method would have been capable of achieving on their own. The qualitative and quantitative methods worked not only to emphasize the different aspects of land cover change, but also to tell completely different stories about the pastoral landscape in southern Tamil Nadu. Thus, mixing methods has demonstrated how land cover change studies can be advanced through a methodology that integrates data from different epistemological traditions.

Large-scale changes in the pastoral landscape were captured through RS observations, which indicated that a decrease in grassland and increase in agricultural land and built-up land had occurred between 1992 and 2014. However, it also showed complex and obscure land cover change patterns that were difficult to interpret. The qualitative data gave further insights to this by providing perceptions from the ground. Pastoralists confirmed that agricultural expansion into grasslands were a major threat to their livelihood, however, to them this was just one out of a series of perceived livelihood impediments. Comparing the results highlighted the gap between the quantitative and qualitative data; the perceived drastic decline of grasslands was not detected by the RS analysis. Interviews indicated that physical obstacles such as fences and roads are fragmenting the landscape making important pastures inaccessible. Hence, the pastoralists are understood to be refering to the loss of rather small but significant locations and the perception of shrinking grasslands might be further reinforced by the fragmentation of the landscape. This result indicates that a policy to improve pastoralist conditions based on RS observation alone would most likely fail since most obstacles that were found through this study are not in the domain of detectable changes.

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