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Developing land cover change methodology by combining remote sensing observations and pastoralist understandings

– A case study in southern Tamil Nadu, India

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Developing land cover change methodology by combining remote sensing observations and pastoralist understandings

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Abstract

Pastoralists in India are experiencing increased difficulties to sustain their livelihood, which is partly due to deterioration and diminishment of the pastoral lands that they depend on. Remote sensing (RS) is a powerful tool for investigating large-scale land cover change dynamics; however, a more complete and socially aware analysis of land cover change can be produced when incorporating qualitative data into the analysis. Through a case study in southern India, this study used interviews, participatory mapping, and RS to investigate how qualitative GIS methodology could be developed by comparing quantitative and qualitative data in order to highlight differences and similarities between them. RS findings showed that open land, which is an important source of livestock feed, has decreased while agricultural land and built-up land have increased. This result corresponded quite well with the qualitative data although the pastoralists experienced the decrease in open land to be more extensive than RS results indicated. The geographical locations where loss of pastures had occurred according to the pastoralists did not correspond with the RS analysis possibly since the respondents referred to small but significant areas of change which were not observable on satellite imagery. This result illustrates the partiality of both methodologies and of knowledge in general and also points to the value of mixing methods within land cover research, a field which usually has a strong preference for exclusively quantitative methods.

Keywords: Pastoralism, land cover change, remote sensing, participatory mapping, mixed methods

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Abbreviations

ATREE	Ashoka Trust for Research in Ecology and the Environment
CPR	Common Property Resources
GIS	Geographical Information Systems
KMTR	Kalakkad Mundanthurai Tiger Reserve
OP	Operation Flood
PCA	Principal Component Analysis
PM	Participatory Mapping
PRA	Participatory Rural Appraisal
RS	Remote Sensing

1 Introduction

Pastoralists in India are experiencing increased difficulties to sustain their livelihoods and it has been found that one cause behind this is that their pastoral lands are diminishing (Sharma et al., 2003). Remote sensing observations in northern India have shown a significant decrease in grasslands in recent years (Tsarouchi et al., 2014) and shrinking grazing lands is also a problem that has been observed in Tamil Nadu (Government of Tamil Nadu, 2016) which could have negative consequences for local smallholder pastoralists.

The idea for this thesis emerged out of an internship report about shrinking pastoral lands in southern Tamil Nadu that I produced in 2015 for the research institute the Ashoka Trust for Research in Ecology and the Environment (ATREE) in Bangalore. Through remote sensing (RS), the findings from this report gave a preliminary indication that the loss of grazing lands may not have been as extensive as was first anticipated based on communication with pastoralists in the area (Wennström, 2015). However, the reason for the alleged gap between remotely sensed environmental change and perceptions on the ground was not possible to further explore in this brief study. The relation between RS observed and perceived land cover change has been studied previously, and it has been shown that there might be significant inconsistencies between the two (Hermann et al., 2014). This is because RS and interviews as methods tell different, but often equally relevant, parts of the same story of land cover change (Jiang, 2003). One reason for the discrepancy might be that these two methods belong to different epistemological traditions (Nightingale, 2003). The view that RS images are inherently neutral and can be interpreted “correctly”, which seems to dominate spatial technology research (Nightingale, 2003) does not align with the worldview of most qualitative researchers, who see objective knowledge creation as impossible and non-desirable (Aitken & Kwan, 2010). RS is undoubtedly the most useful and well-known tool for studying land cover change, however this seemingly positivist worldview could potentially lead to inappropriate policies and development strategies in regards of pastoralism if these are to be founded solely on RS observations of land cover change.

While pastoralism as a food production system has gained recognition and increased interest internationally in recent years (McGahey et al., 2014), it is surprising that so little empirical research has been done on pastoralism and land cover change in India (Sharma et al., 2003). Especially since animal husbandry has historically played a vital role for the rural people of India at all times and also because the Indian livestock sector has prospered in recent years to become the largest milk producer in the world (Kurien, 2004). Moreover, research on the subject or related fields are primarily focusing on pastoralist groups in the semi-arid zones of the northern and western India (e.g. Sharma et al., 2003; Robbins, 2001; Jodha, 1985; Jodha, 1989; Chaudry et al., 2010). Very few studies have investigated land cover change dynamics in India (Tsarouchi et al., 2014), and as far as is known no previous research has explored the relationship between pastoralist livelihoods and large-scale land cover change in the country. Hence, a mixed methods study that combines these two subjects might lead to significant insights about the changing environment in southern Tamil Nadu as well as the changing conditions for pastoralist livelihoods in the region, while at the same time exploring and advancing existing RS methodology through incorporation of qualitative data.

2 Aims and research questions

2.1 Aims of the study

The aim of this thesis is to contribute to the development of qualitative GIS methodology by combining conventional remote sensing analysis with pastoralist perceptions of land cover change. This will be done via a case study on pasture land cover change in southern Tamil Nadu, India.

2.2 Research questions

The research questions consist of one overarching research question and three sub-questions which focus on different parts of the research problem:

In what ways can existing qualitative GIS methods be developed by combining remote sensing observations to pastoralist perceptions of land cover change in southern Tamil Nadu?

1) *How has land cover changed in the study area between the years 1992 and 2014 according to remote sensing observations?*
2) *How are land cover changes understood by pastoralists of southern Tamil Nadu?*
3) *What are the similarities and differences to land cover change based on remote sensing and pastoralist understandings?*

3 Literature review

This section will provide a review of what has been written and done on the subjects of qualitative GIS, pastoralism and land cover change in India. The two different research approaches will be treated as separate fields only to be analyzed jointly towards the end of this thesis. A set of theories are needed for the analysis however, and these are presented here.

3.1 A qualitative approach to GIS

Remote sensing (RS) provides important sources of data for GIS analysis. Two of the most commonly used applications of satellite imagery are land cover mapping through image classification and land cover change detection (Bakr et al., 2010). Land cover change detection is an extremely important tool for understanding the dynamics of social-natural processes that shapes the surface of the earth (Lu et al., 2004). Numerous technological approaches and methods have been developed for performing change detection on remotely sensed data, however, despite extensive research on the area no single approach has been found to be optimal and applicable to all cases (Lu et al., 2004). RS is a relatively new and evolving scientific field which has seen much technological improvements in recent years, and further progress can be assumed in the near future. Most studies on land cover changes today have in common that they are quantitative and focused on technological solutions for improving the detection of land cover change (e.g. Bakr et al., 2010; Lu et al., 2004; Güler et al., 2007; Campbell & Wynne, 2011). This might be because RS is rooted within an epistemology where the researcher's task is to "correctly" interpret the land cover (Nightingale, 2003). Most RS specialists view remotely sensed images as inherently neutral and subscribe to the notion that objective knowledge creation is desirable, not to mention at all conceivable (Aitken & Kwan, 2010; Nightingale, 2003). These are characteristics of a positivist worldview, sometimes referred to as the "scientific method", and indeed positivist assumptions are more strongly associated with quantitative than qualitative research (Creswell, 2014).

Qualitative researchers and critical geographers started to question the positivist worldview within GIS in the early 1990s (Aitken & Kwan, 2010). Conventional GIS were criticized for being socially exclusive and for producing incomplete analyses. Out of this critique a new field developed which works towards a more socially integrated GIS where people are involved in the process of obtaining and analyzing geographical data, sometimes referred to as qualitative GIS, participatory GIS, or community integrated GIS (Dunn, 2007).

Combining RS with social science has opened up for entirely new research areas, for example issues related to the relationship between social-natural processes (Hermann et al., 2014). It has also highlighted the situatedness and incompleteness of RS data on its own (Nightingale, 2003). This partiality is by no means unique to RS data, on the contrary it could be argued that all knowledge is situated which means that there is no single truth to be uncovered and that everything is contextual. However, discussions on situated knowledge and partiality might be even more relevant within this field because of the problematic claims of objectivity and neutrality that seem to permeate much of research within RS (Nightingale, 2003). Mixing methods, or triangulation, could be an efficient way to investigate the partiality of knowledge because when different types of data do not align we have to interpret the silences and incompatibilities between them (Nightingale, 2003) Analyzing 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 limitations of the chosen methodologies. For example Jiang (2003) showed in his study about land cover change in Inner Mongolia, China that interviews and RS as research methods tell us about different parts of the same story about land cover change. When combined, these two methods may lead to significant insights about the landscape and also about the aspects of partiality and human experience that characterize both methodologies (Jiang, 2003). Similarly, in their study on land cover changes in the Sahel region of Africa, Hermann et al. (2014) attempted to bridge the gap between qualitative and quantitative research methodology by applying a perception-based approach to investigating environmental change. The study showed that RS analysis of land cover changes could be deceptive without qualitative parameters such as perceptions on the ground, because these do not necessarily correspond with RS observations (Ibid.). Likewise, Mialhe et al. (2014) showed in their study of participatory GIS in the Philippines that qualitative methods and quantitative RS analyses can complement and validate each other. This is because certain information about the environment, e.g. plant species, presence of animals and historical land use, cannot easily be observed from space and therefore local knowledge is a valuable source for improving our understanding of land cover change dynamics (Mialhe et al., 2014). For these reasons, combining RS with local pastoralist knowledge in this study is believed to improve the understanding of land cover change.

A particularly suitable social group to involve in qualitative GIS studies on land cover change is pastoralists because of their familiarity with large areas due to the spatial scale of transhumance pastoralism (Hermann et al., 2014). Pastoralist knowledge about the landscape is not only larger in scale in comparison with many more sedentary social groups, but pastoralists also tend to possess rich and detailed information about their environment and its plant species and ecological conditions which provides valuable insights about land cover change (Jiang, 2003). The detailed spatial knowledge of pastoralists has also been demonstrated useful within natural resource management, because what non-users see as monotonous expansive rangelands are likely to consist of a myriad patches with different grazing characteristics to the pastoralists (Wario et al., 2015).

However useful it might be, mixing methods and combining qualitative and quantitative spatial data is not necessarily easy and some critics have even deemed the two incompatible due to the different epistemological foundations they rest upon (Dunn, 2007). It is also becoming politically controversial since a recently proposed law in India wants all use of geospatial information within the country to be approved by the government (Ministry of Home Affairs, 2016). The indirect, intuitive and geographically imprecise descriptions of the environment that qualitative data often consist of, is difficult to integrate with the factuality and preciseness of spatial information technology (Dunn, 2007). "Demanding precision where fuzziness might be more appropriate" (Corbett et al., 2006, p.18) and hence create misleading impressions of spatial accuracy is a risk when working with participatory approaches to GIS (Corbett et al., 2006). Another critique of qualitative GIS is its sometimes self-proclaimed social inclusiveness and democratization of spatial technology (Dunn, 2007).

Qualitative GIS can however help reduce the gap between influential and non-dominant knowledge by providing a platform for people whose voices are not often heard within policy-making and planning (Aitken & Kwan, 2010), although there is also a risk that only the elite in any one community are able to take part in participatory GIS activities since they have access to better education. A qualitative approach that promotes involvement does not necessarily lead to empowerment and democratization. Often it is ultimately the researcher who decides what information is relevant and what data do not fit in and hence presents a "cleaned up" version of the participants' knowledge (Dunn, 2007).

3.2 Pastoralism and land cover change in India

The potential of pastoralism as a sustainable food production system which provides ecosystem services by maintaining soil quality, regulating water, and contributing to biodiversity conservation, has recently started to gain attention worldwide (McGahey et al., 2014). Pastoralists also play a key role in the sustainability of agricultural activities in India through the fertilization of soils that their livestock contributes to (Ramdas et al., 2001). Literature on Indian pastoralism is remarkably scarce and yet there are certain fundamental differences in the spatial and social organization between pastoralism in India and elsewhere around the world. These differences are rooted in the caste system, meaning that Indian pastoralists belong to a caste which specializes in animal husbandry, often within a society and alongside people of other castes who traditionally have other occupations than animal husbandry. By contrast, in Africa and the Middle East, many pastoralists inhabit vast remote territories virtually all by themselves (Sharma et al., 2003). Indian pastoralists are ranked above the untouchable castes in the caste system and they also have more assets than the poorest social groups since their livestock can be readily transformed into cash (Sharma et al., 2003).There are also examples of very socially mobile pastoral castes like the Yadavs, who are dominating politics in large areas of northern India (Jaffrelot, 2003). Nevertheless, most Indian pastoralists are landless, financially poor, illiterate and often regarded as one of the most backward and conservative social groups in the Indian society (Sharma et al., 2003). Social stigmas around pastoralism seem to have created an almost collective low self-esteem among them, which Sharma et al. (2003) clearly illustrates in their study:

> […] they regard themselves as extremely marginalised [sic], almost succumbing to a collective psychology of being different and out of luck. Their almost complete illiteracy and consequent lack of knowledge of global developments may compound this feeling. Many of them are completely unaware that India is a nation state and that they as citizens have certain rights (Sharma et al., 2003, p.36).

It is clear that many Indian pastoralists experience social exclusion, and government attitudes towards pastoralism have generally been negative as well. For example, the Ministry of Environment and Forest has openly opposed pastoralism and made attempts to remove herders from their traditional grazing areas because of the incorrect idea that pastoral activities lead to environmental degradation through overgrazing and because the nomadic lifestyle is often seen as backwards and less civilized (Sharma et al., 2003). Fortunately, the Government of Tamil Nadu (2016) recognizes the vital role of animal husbandry today both in terms of sustaining rural livelihoods and for the economy of the state. Livestock rearing has increased rapidly the last three decades in Tamil Nadu and stands for a significant part of the growth in the agricultural sector (Government of Tamil Nadu, 2016). The increase in livestock is a result of the so called “white revolution”, which refers to the notable progress the Indian dairy industry went through in the latter part of the 20th century largely due to a national government program called Operation Flood (OF). OF focused on small rural producers and promoted creation of dairy cooperative networks, and the successful program led to a quadrupling of the produced milk in India between 1968 and 2002 (Kurien, 2004).

Pastoralists in India belong to a diverse group operating from the snow-clad mountains of Himalayas in the north to the tropical plains of the south, and practically everywhere in between. There are no reliable statistics on the total number of pastoralists in India, but a very rough estimate is that there are approximately 200 pastoral castes in India comprising around 6%, or about 78 million people, of the country’s total population (Khurana, 1999 in Sharma et al., 2003). Despite the diversity of Indian herding communities, studies have shown that there are surprisingly many similarities in terms of problems faced by Indian pastoralists (Sharma et al., 2003), although these studies are mostly focused on the western and northern parts of the country.

The major livelihood threat described by pastoralists in western India is shrinkage of pastoral lands and disappearance of the common property resources they depend upon (Sharma et al., 2003; Jodha, 1985). These changes are often driven by factors like non-supportive government policies, expanding irrigated agricultural land, enclosure of forests and protected areas, breakdown of village institutions, and deterioration of pasture lands due to increased grazing pressure and invasive species (Sharma et al., 2003). Shrinking and degrading pastoral lands in northwest India due to factors like privatized land, population growth and commercialization of community property resources has been shown to have negative impacts on livestock rearing in the region (Jodha, 1985). Loss of grazing lands in the same region has also led to an alarming decline in livestock over the last 20 years partly due to alternative land use, a trend that seems to be continuing (Chaudry et al., 2010). Tsarouchi et al. (2014) also concluded in their study of land cover changes in northern India that between the years 1984 and 2010 there had been a decrease in barren land (-9.5%), shrubland (-11.6%) and grasslands (-9%), while agricultural land (+1.3%), urban land (+5.8%) and forest (+4.7%) were increasing. It seems like the southernmost Indian state of Tamil Nadu has gone through a similar development. For example, Jodha (2000, in Sharma et al. 2003) showed in a study of seven villages in Tamil Nadu that common property resources (CPRs), commonly used for grazing had declined by 50% between 1950 and 1984. In the Policy Note on Animal Husbandry of 2015-16, the Government of Tamil Nadu is recognizing the importance of CPRs for grazing purposes and also mentions the problem with encroachments of urban areas and agricultural land. However, protecting common grazing lands are not among the nine aims that the Animal Husbandry Department has set up for 2015-2016. Instead, focus seems to be at increasing the production capacity of existing fodder cultivable lands (Government of Tamil Nadu, 2016).

Remaining pastoral lands have deteriorated as a consequence of increased grazing pressure and fast proliferation of invasive species (Sharma et al., 2003), particularly the aggressive tree *Prosopis juliflora* but also the constituent species *Lantana camera* which is poisonous and may be deadly to grazing animals (Robbins, 2001). The latter is reportedly causing thousands of livestock deaths every year (Sharma et al., 2003). Prosopis juliflora, more commonly referred to as prosopis, is native to the Americas and was first introduced to India in the early 1900s by the Maharajah of Jodhpur in Rajasthan, northwest India with the purely aesthetic purpose of 'greening' the desert. A few decades later, this fast growing tree gained recognition among international development organizations for its value as fuel wood, and among local foresters, who are often positive to any kind of increase of tree cover (Robbins, 2001).

Although it is sometimes implied that environmental change means transformation of a natural environment into an artificial one, land cover change needs to be understood as a continual process. Untouched nature, or wilderness, which has been a central principle within environmental conservation movements for decades, does not exist because the natural world has been manipulated by humans for as long as there are records of human activity (Cronon, 1996). Hence, we should not take off from assumptions of natural stability, meaning that the environment was once in a natural equilibrium that is now threatened by modern development and human interventions (Robbins, 2001). In order to understand land cover change dynamics, we need to abandon the dualism that sees certain environments as either pristine and natural or as artificial and unnatural (Cronon, 1996). This is perhaps especially important when discussing land cover change in rural areas, because the rural-urban dichotomy has falsely created the idea that the countryside is a more natural and original environment, as opposed to the unnatural city (Cronon, 1991). Cronon (1991) distinguishes between "first nature" and "second nature", where the former represents an original untouched landscape while the latter means an environment which is manipulated and shaped by humans. Rural environments are often incorrectly interpreted as first nature although it may well have been manipulated by human processes for centuries (Cronon, 1991). This is essential for understanding the land cover change dynamics of southern Tamil Nadu, which has been inhabited for thousands of years. As an example, the ancient irrigation system in the Thamirabarani river basin has developed over centuries into an extensive network of canals and thousands of irrigation dams in various sizes which have had a major impact on the landscape (Gomathinayagam, 2012). Hence, the land cover changes that may have occurred within the scope of this study need to be understood within a context of a continuously developing environment where no changes are seen as more natural than others.

4 Methodology and methods

In this section I will start with a short description of the study area before proceeding to describing the methodological approach of the thesis and the different methods that were used for understanding the research problem, i.e. remote sensing, participatory mapping and qualitative interviews.

4.1 Study area

Ashoka Trust for Research in Ecology and the Environment (ATREE) is an organization with unique interdisciplinary competences in India which is based in Bangalore and has several field stations across the country. One of these field stations, Agasthyamalai Community-based Conservation Centre (ACCC) is located in southern Tamil Nadu on the border of Kalakkad Mundanthurai Tiger Reserve (KMTR) in the Western Ghats. During my practical attachment at ATREE in 2015 I spent almost three months at this field station investigating the dwindling pastoral lands of the area through RS. The results of the report were rather surprising and showed that the pasture shrinkage had not been as extensive as first anticipated, and this motivated me to go deeper into the subject of comparing RS observations with perceptions of land cover change and therefore this particular location was chosen for this case study.

The study area spans the two districts Tirunelveli and Thoothukudi in southern Tamil Nadu at the tip of the Indian subcontinent. The population of Tirunelveli and Thoothukudi districts are 3 072 880 and 1 738 366 respectively according to the most recent censuses of 2011 (Tirunelveli District Administration, 2012; Department of Economics & Statistics, 2012). The climate of this region is semi-arid and unlike most other parts of India, southern Tamil Nadu receives the majority of its rainfall during the northeast monsoon between October and December instead of the summer southwest monsoon. The lifeline of this hot and dry area is the Thamirabarani River which originates in the Agasthyamalai Mountains of the Western Ghats and flows through the study area to its estuary some 15 kilometers south of Thoothukudi. Thamirabarani and other smaller perennial rivers feed a complex and ancient network of irrigation canals, tanks and wells which have made Tirunelveli and Thoothukudi districts the agricultural center of southern Tamil Nadu (Ganesh et al., 2014). Agriculture is therefore the by far most dominating sector in both districts in terms of occupation and land use. The cropped area in Tirunelveli district is 25% and in Thoothukudi district 38 % of the total land area and the dominant crops are rice and different millets like cholam, ragi, varagu and samai as well as commercial crops like banana, coconut, cotton, chili, sugarcane and groundnut (Tirunelveli District Administration, 2012; Department of Economics & Statistics, 2012). National highway 44, a.k.a. the North-South corridor highway, is the longest running highway in India and on its 3.745 km long route it passes Tirunelveli just before it reaches India's southernmost point Kanniyakumari (National Highways Authority of India, 2016).

The study area was further limited into four areas of particular interest due to their importance to the Peikulam herders. These areas are hereafter referred to as the study sites, which are Ambasamudram, Tirunelveli, Srivaikuntam and Peikulam. These study sites were identified through interviews with herders from Peikulam as particularly important sites for grazing. The decision to delimitate the study area from Tirunelveli and Thoothukudi districts to four 12 x 12 kilometer squares was done for two practical reasons. Firstly, for participatory mapping activities it is preferred to not work on scales larger than 1: 20 000 (IFAD, 2009), which forced me to drastically reduce the study area. Secondly, satisfactory land cover classifications were more likely to be produced on a considerably smaller study area within the limited timeframe of this study. The total area of the study sites used for remote sensing and participatory mapping are 576 km^2.

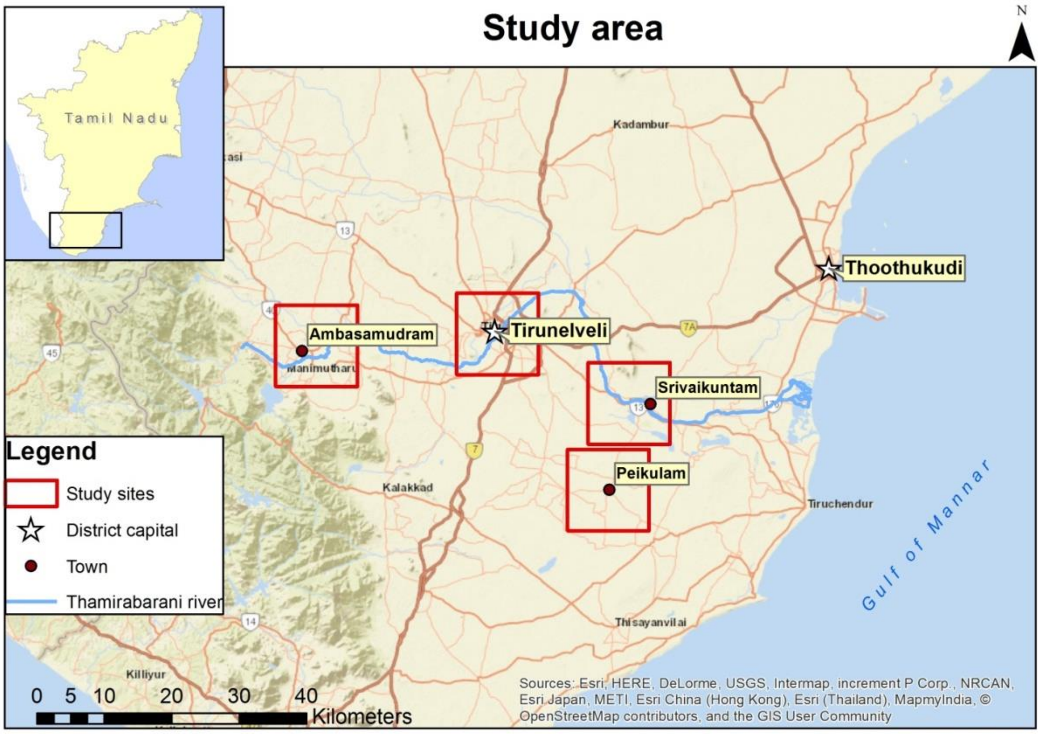

Figure 1. Map showing the study area and the four study sites that were used for the remote sensing.

4.2 Methodology and research design

A dichotomy between quantitative and qualitative research approaches is often experienced. These can however be thought of as different ends of a continuum where most studies can be placed closer to either the quantitative or the qualitative end. Research using mixed methods could then be placed in the middle of this continuum (Creswell, 2014). Mixed methods research refers to the process of collecting, connecting and integrating data (Tashakkori & Teddlie, 2010) which draws on entirely different philosophical approaches.

The philosophical worldview and academic training of the researcher is often influencing his or her preferred strand of methods. Where (post-) positivism is associated with quantitative approaches and constructivism is often linked to qualitative approaches, a pragmatic worldview could be ascribed to many mixed methods researchers (Creswell, 2014). Pragmatic researchers put emphasis on the research problem instead of the methods, and then choose what is considered to be the most suitable methods for understanding the problem. Diverse methods from different scientific traditions are used to gain knowledge about the problem (Creswell, 2014). Mixing methods which builds on different epistemological traditions is not necessarily an easy task but doing so in this case is believed to enrich the outcomes. Mixed methods research can highlight the subjectivity of knowledge through comparing quantitative and qualitative results that are equally valid on their own but tells different or contrasting stories (Nightingale, 2003). This means that relying solely on RS or exclusively on qualitative interviews for studying pasture land cover change would have been equally appropriate, but it would most likely have resulted in very different conclusions about land cover change.

Pragmatists generally agree on that research is not performed in a socio-political vacuum; history, politics and social factors need to be considered (Creswell, 2014). Coming from an interdisciplinary background, this worldview matches well with my own idea of how to approach a research problem. Mixed methods research emerged from the idea that combining quantitative and qualitative methods could help reduce bias in a study (Creswell, 2014); however, this is not the reason for why a mixed methods approach has been chosen for this thesis. Instead, I see it as a way to explore the problem from different angles and investigating different questions that are related to one another. Through this thesis I also wish to combine and explore ways to make use of the different skills I have acquired through my training in geographic information sciences and social sciences, disciplines which are not commonly integrated, with the aim to provide a social understanding of land cover changes. Using mixed methods to explore complex issues makes sense to me since the division between quantitative and qualitative methods is a construction made up in the academic world, while issues in the "real world" are complex and intertwined.

A disadvantage with the mixed methods approach is that it is more time consuming since both quantitative and qualitative data needs to be collected, interpreted and analyzed which requires both flexibility and structure (Creswell, 2014). Using methods which rests on different epistemologies also requires the researcher to be extra cautious about producing inconsistent results through incoherent analyses of the data. However, when used successfully this research design has potential of triangulating results through systematic convergence of quantitative and qualitative data and highlighting the meaning of contradictions between findings (Creswell, 2014).

Based on this understanding a choice has been made to use a convergent parallel mixed methods design for this thesis. Creswell (2014) refers to this research design as a merging of quantitative and qualitative data with the aim of providing a thorough analysis of a research problem. This model of mixed methods is characterized by parallel collection of quantitative and qualitative data that is integrated in the stage of interpretation and analysis of the overall results (see Creswell, 2014 for a more elaborate explanation of this research design). Consequently, the empirical findings of this thesis will be integrated and analyzed together but they will also be interpreted and analyzed separately. Considering that the different research questions are evaluated separately using different literature and methods, no unifying theoretical framework will be presented. Instead, results from the two approaches will be compared and analyzed in order to highlight contradictions and irregularities between the findings.

4.3 Remote sensing

Remote sensing in its broadest sense means the practice of obtaining information about an object or surface from a distance through a device which is not in contact with the studied object. By this definition, even reading can be called RS since our eyes act as sensors which respond to the reflected light of the paper or the screen, and the words that we read are interpreted by us in order to give it meaning (Lillesand et al., 2004). This analogy explains rather well how RS works, although RS more commonly refers to the scientific discipline of acquiring and interpreting information about the earth's surface from an aerial sensor attached to a satellite or an aircraft.

The following section will provide a step-by-step description of the process of transforming raw unprocessed satellite imagery into classified land cover maps in order to detect changes that may have occurred in the landscape. These steps involve downloading satellite images from NASA's Landsat program, preprocessing these images through enhancing certain elements in the image and removing excessive information, and classifying the images with the use of a software classification algorithm. Thereafter, the accuracy of the classifications is calculated and lastly, a post-classification change detection analysis is performed. All these technical operational aspects are explained in further detail below.

4.3.1 Software and datasets

The classification and change detection were performed in the software program ArcGIS 10.2. Three Landsat images were used for this study; one Landsat 5 TM image from 1992, one Landsat 7 ETM+ image from 2000, and one Landsat 8 OLI/TIRS image from 2014[1]. All images were acquired during the dry season in March and April when the cloud coverage was minimal. The spatial resolution of these Landsat images are 30 meters, which means that one pixel equals 30 x 30 meters

[1] The acronyms TM (Thematic Mapper), ETM+ (Enhanced Thematic Mapper Plus) and OLI/TIRS (Operational Land Imager/Thermal Infrared Sensor) refers to the different sensors on the Landsat satellites.

on the ground. However, some objects that are only a few meters wide, e.g. roads, bridges and canals, are still clearly visible as they are sharply contrasting from the surrounding land cover. The Landsat project was initiated by NASA and the U.S. Department of the Interior in 1967 and its first satellite, Landsat 1, was launched in 1972 (Lillesand et al., 2004). Since then, the Landsat project have obtained a virtually continuous record of the earth's surface which is available for anyone in the world to download at no charge via the USGS database Earth Explorer (Tsarouchi et al., 2014). Landsat data has opened up for seemingly unlimited areas of applications and analysis (Campbell & Wynne, 2011), for example within the fields of agriculture, botany, environmental monitoring, forestry, geography, geology, land use planning, and water- and land resource analysis (Lillesand et al., 2004). The wide application of Landsat imagery further motivates studies on how to improve existing RS methodology using coarse resolution satellite imagery.

4.3.2 Preprocessing

As a first step, the images were examined and an appropriate spectral band combination for the purpose of this study was selected. In multispectral imagery, different frequencies of the electromagnetic spectrum are separated into different bands, and hence the band combination affects what features in the landscape are detectable. For the Landsat 8 image the band combination that most clearly distinguished the land cover classes of interest were red-green-blue (RGB)-541, and for the Landsat 5 and Landsat 7 images the corresponding combination was RGB-431. In order to facilitate interpretation through enhancing differences, the images were also stretched using standard deviation stretch which means that the data between -2 and +2 standard deviations are distributed to the complete range of the values from the output image (Åhlén, 2015). All satellite images had been geometrically corrected and referenced to the projection UTM zone 43 and datum WGS84. The images were then preprocessed through atmospheric correction by converting the digital numbers (DN) to radiance, which according to Lu et al. (2004) is a requirement for all change detection analyses, although Bakr et al. (2010) claims that this procedure has little effect on classification accuracy. The cloud covers on the raw satellite images were between 8% and 21% and nearly all clouds were outside of the study sites. Nevertheless, remaining clouds were removed by performing an unsupervised classification on each of the images, deleting the class containing clouds, and then use the extract by mask-tool in ArcGIS 10.2. A principal component analysis (PCA) was also performed on all three images prior to the supervised classification. PCA is a frequently used multivariate statistical technique which removes redundancies and keeps the most important information in the image. This creates an image with fewer correlations that is smaller and easier to process through that new variables (principal components) are calculated and applied as linear combinations on the original data (Abdi & Williams, 2010).

After all Landsat images had been through the abovementioned steps, they were ready for the supervised classification.

4.3.3 Supervised classification

Classification within RS refers to the process of automatically grouping all pixels within an image into clusters which represents different land cover classes. Supervised classification means that an analyst specifies the spectral signatures of the desired land cover classes by classifying some pixels manually through creating polygons, referred to as training samples. The manually classified training samples are then used by the classification algorithm to classify all pixels in the image to the chosen classes. This is different from unsupervised classification where the analyst only decides how many classes to use, and then the image is automatically classified (Lillesand & Kiefer, 1994).

Maps are essentially rough simplifications of the earth's surface and as such, a single land cover class will inevitably contain multiple actual land covers and uses. Maps are displaying differences; if all land within a study area were uniform the map would be blank, but what is considered "difference" depends on the observer (Wario et al., 2015). Therefore, I had to make decisions regarding how to categorize the landscape into a few manageable, and yet useful classes. This was done through experimental unsupervised classifications of the satellite images using different number of classes in order to see how the software cluster algorithm would classify the images. The resulting classified images were then examined and compared with my own understanding of the landscape. The land cover classes that were ultimately decided upon were water, built-up land, agricultural land, shrubland, and open land. Due to the large spectral variability within the class 'agricultural land', it was divided into two classes during the classification; 'fallow agricultural land' and 'agricultural land'. These two classes were later merged into one class since this study is mainly concerned with changes related to pastoral lands, which is included in the class 'open land'. Moreover, fallow agricultural land is rotating between years and including this as a separate class for the change detection analysis would therefore produce an unreadable change detection map where most transformations of land covers detected would be between the less relevant classes ‘agricultural land’ and ‘fallow agricultural land’.

The spectral variability within a class determines how many training samples to use for each land cover class. Generally, many smaller training samples are preferred over a few big ones and it is also desirable to spread out the samples over the entire image (Lillesand & Kiefer, 1994). When the training samples had been taken for all land cover classes the images were classified using a maximum likelihood algorithm, which is a process where the means and variance of all pixels within the training samples are calculated for all bands. Each pixel will then be assigned to the land cover class which it most likely belongs to, which is a rather time consuming process but the main benefit is that all pixels in the image are classified (Lillesand & Kiefer, 1994).

4.3.4 Accuracy assessment

A critical part of remote sensing classification and change detection analyses is accuracy assessment. Estimating accuracy of historical land cover classifications is a complex procedure since ground truthing is out of question and reliable high-quality reference data might be difficult to obtain. Nevertheless, the error matrix-based accuracy assessment method is considered useful, and it is the most commonly used method for assessing accuracy (Lu et al., 2004) . Hence, this method was used for assessing accuracy of all three classified images. The number of reference points is essential for estimating the accuracy of a classification and 250 is usually considered to be the minimum number of reference points needed (Güler et al., 2007). For this study, 65 reference points were used per study site which means in total 260 reference points per classified image. The reference points were randomly placed across the study sites and the classified map were then compared with reference data from Google Earth, two high-resolution LISS IV-images, and 126 ground truth points that were collected during field work for my internship report in 2015.

The overall accuracy was calculated by taking the total number of pixels that have been classified as the same land cover class in the satellite image and on the ground and dividing this number by the total number of classified pixels. However, this measurement does not specify the accuracy of specific classes and therefore the user and producer accuracy were also calculated. The user accuracy refers to the probability that the pixels classified as one land cover class are correct on the ground, while producer accuracy means the probability that the total number of pixels on the ground of one land cover class were classified as such (The Yale Center for Earth Observation, 2003). Although there are no globally accepted minimum levels of accuracy for land cover classifications, 85% is often used as a benchmark (Tsarouchi et al., 2014).

Additionally, the kappa coefficient for each of the classifications were calculated which shows whether or not the classification was better than it would have been strictly by chance as well as how much better. Kappa statistics can be calculated using the following equation:

$$\frac{(Observed\ accuracy\ - Expected\ accuracy)}{(1 - Expected\ accuracy)}$$

Kappa statistics between 0.61-0.80 are often considered substantial and values >0.81 almost perfect, although these divisions are obviously arbitrary and should only be used as general guidance for discussion (Landis & Koch, 1977).

4.3.5 Change detection

There are numerous techniques for detecting land cover changes, one of the most common being post-classification change detection. This means that each of the images are classified separately into desired land cover classes, and then compared on a pixel-to-pixel basis (Güler et al., 2007). This method was applied in this study to detect land cover changes between the years 1992 and 2014. When detecting long-term land cover changes it would have been ideal to classify one image for each year since this would have made it possible to track the development of the landscape year by year. However, supervised classifications are very time consuming and therefore only three images could be classified within the timeframe of this study. Using three or less satellite images to detect land cover changes have been considered sufficient in many previous studies (e.g. Bakr et al., 2010; Güler et al., 2007; Robbins, 2001), and was thus considered enough for this study as well. A prerequisite for classifying three satellite images within the short timeframe of this thesis was also that two of the images, 2000 and 2014, had already been preprocessed during my internship at ATREE a year earlier. However, a much larger area was then classified which resulted in rather poor accuracy of the classified maps. For this study, the study area was therefore further delimited in order to improve accuracy and an additional satellite image from 1992 was also added to the change detection analysis.

The reclassify and combine-tools in ArcGIS 10.2 was used to perform the actual change detection where the classified map of the 1992 image was reclassified by multiplying the pixel values with 10. In this way, the reclassified image could be combined with the classified map of the 2014 image to produce an output map were the new pixel values were combinations of the older ones. Hence, the new pixel values 11, 22, 33, 44 and 55 meant that there had been no land cover changes while all other number combinations meant that there had been changes from one land cover to another between the years 1992 and 2014. The output image was then reclassified again so that all pixels that had not changed got the value 0.

The final results from the post-classification change detection was then interpreted and analyzed separately and together with the qualitative results.

4.4 Qualitative methods

This section will describe the qualitative methods used for this study and explain the course of action. First however, I will provide a brief elucidation of the ontological standpoint of this thesis which is necessary for understanding why I have chosen participatory mapping and interviews as qualitative methods for this study.

One of the research questions concerns how pastoralists from southern Tamil Nadu understands land cover change, and this question builds on some ontological assumptions. For example, it is assumed that it is possible to understand and reconstruct the worldview of the subjects and it is also assumed that pastoralists of southern Tamil Nadu as a group share this understanding since they are sharing culture. While I believe this to be largely true, I think it is important to stress that there are many ways of perceiving one's own surroundings and what I present as another individual's view is actually my own interpretation of their reality. The anthropological discussion on the so called "ontological turn" is highlighting these issues. Instead of viewing culture as different perspectives on the same reality, culture is increasingly seen as different realities on their own, meaning that there is no single truth about the world to be uncovered through social research (Paleček & Risjord, 2012). In a way, this could be seen as an ontological return to the long-established phenomenological concept of lifeworlds. Although lifeworlds are subjective, they are not necessarily individual since culture is shaping the lifeworlds of people (Inglis, 2012). This means that the subjects of this study might have very different spatial understandings and frames of references compared to my own, and the data presented and discussed in this thesis is my interpretation of their lifeworlds.

4.4.1 Participatory mapping

With the purpose to investigate perceptions among the herders of how land cover has changed in the study area, participatory mapping (PM) was used. This refers to the collaborative creation of maps in the field by local communities and practitioners. PM can range from basic methods of ground mapping where participants draw maps from memory on the ground, to advanced geographic information technology and internet-based mapping (IFAD, 2009). 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) but the increased use and affordability of GIS technologies has expanded the use to also include the production of high quality maps. As an established PRA method, PM has been used within numerous projects around the world even though cultural differences might affect how the tools and exercises are understood by the participants. For example, previous research has shown that mental representations of spatial information may differ greatly between different cultural groups (Wario et al., 2015). Since me and the participants in this study do not share the same culture or lifeworld, their reality is likely to be different from my own which is important to have in mind when interpreting the results from the PM activities.

The PM activities in this study roughly followed a model outlined in a practitioner's guide by the International Fund for Agricultural Development (IFAD, 2009). According to this guide, most PM activities contain the following elements; preparation of the mapping activity, determining the purpose of map construction, collection of information, creation of maps, analysis and evaluation of information, and usage/communication of results (IFAD, 2009). Three themes were explored during the participatory mapping session: 1) location of grazing grounds and important areas, which would be compared to the RS data, 2) perceived problems and obstacles, which was important since the herders' view on changes in the landscape might differ from our own, and 3) land cover changes.

A fieldwork support team of five people were present at the participatory mapping, including myself. The other four facilitators were Dr. Soubadra Devy, who is a senior researcher and was my supervisor in field; Mr. M. Mathivanan, who is the field station coordinator at ACCC and has many years' experience of qualitative field work in the area; Mr. Abhishek Samrat, who works as a GIS analyst; and Mr. Surya Narayanan, who works as a field station assistant. All four are employed by ATREE, and during the PM session all of us had responsibilities and roles of moderating and facilitating discussion, translating, taking notes, and document through video and audio recording and photographing. My own responsibility was to observe, take notes, and ask questions.

4.4.1.1 Preparations

Numerous tools for participatory mapping have been developed since the method became popular in the mid-1990s. The PM tool that were used for this study is called scale mapping, 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). These features are positioned in relation to landmarks that are recognizable to the participants. Scale mapping produces results that easily communicate local spatial knowledge through GIS. Illiteracy is common among the Peikulam herders and using aerial images is helpful when working with communities who have not gone through formal education systems since it is an intuitive and easy approach (IFAD, 2009). However, the participants' perceptions of the environment might greatly differ from my own since we categorize the landscape based on individual and cultural reference frames and parameters (Wario et al., 2015). It is therefore important to have reference maps that are adapted to the context and easy for the participants to understand. For this reason five reference maps were created; four showing the study sites and one overview map for mapping of their migratory routes. According to IFAD (2009) the connection between map and reality could be lost if the scale is too large and therefore their recommendation is to work with maps at 1:20 000 or smaller since this means that landscape features like villages, canals and roads can quite easily be identified (IFAD, 2009). However, a balance needs to be found between an appropriately large study area and printing very large and ungainly maps. The study site maps were printed on 61 x 61 cm plastic fabric and the scale was circa 1:20 833, while the overview map was printed on a 44 x 88 cm plastic fabric with a scale of circa 1: 100 000. The study site maps were created in ArcGIS 10.2 using a LISS-IV satellite image with spatial resolution of 5.8 meters as base, except for the overview map where an image from Google Maps was used as base. Some elements were emphasized in the images through manual digitization in order to facilitate interpretation by the participants; these were major roads, railways, villages, temples, rivers, canals, and large water bodies. All text in the reference maps was written in Tamil.

4.4.1.2 Sample selection

The sampling plan for this activity could be described as snowball sampling which is a useful method for reaching social networks and marginalized populations (Tracy, 2013). A key informant who had previously been interviewed by Dr. Devy and Mr. Mathivanan for another research project was used to get in contact with individuals within his social network to participate in the PM activity. The time and venue for the meeting was in the evening of February 27th 2015 in a temple in the village Peikulam. Since the key informant had contacted the other participants most of them were already acquainted with each other. According to Barbour & Kitzinger (1999) this is an ideal set-up since it is more likely to produce a setting where issues are discussed naturally and unhindered. During this time of the year the Peikulam herders are at their home grounds which made it possible to gather them all together. Obviously, there are also complications with this sampling method since it only captures the perceptions and ideas of a rather small group of individuals which increases the risk of skewed representation.

The size of groups for activities such as PM depends on the purpose of the study and the preferences of the researcher. Some would say that the ideal size is 8-12 participants while others prefer to work with considerably smaller groups (Barbour & Kitzinger, 1999). In this study, the participatory mapping involved 12 herders. In addition to these, four youths were present who mostly aided the participants in reading and writing on the maps. However, sometimes they were active in the discussion on their own.

The age range of the participants was approximately 32-55 years old and some had been herding in the region for over 40 years. Most of the participants had medium sized herds of 70-100 sheep although two of the participants had quit herding a few years back and currently did not own any sheep. Most of the participants had small-scale agriculture as additional income besides herding. For the purpose of the PM it was critical to include participants that had knowledge about historical land cover and therefore it was important to engage individuals who had been herding for many years while it was considered less important that two of the participants were not actively herding today. Using older individuals' wide-ranging knowledge about the community is often beneficial for PM activities (IFAD, 2010). All participants at the PM session were men, since herders in this region are exclusively male. Although women's understandings on land cover change might differ from men's, it is outside of the scope of this study to cover such differences. Also, since women in pastoralist households do not migrate, their environmental knowledge is limited to a more local scale compared to pastoralist men's large-scale knowledge. Nevertheless, gender roles and power relations affect groups of men as well and such relations were observed during the PM session, where for example some participants were more active and verbal than others although everyone got the chance to participate on equal terms. As facilitators, we did our best to bring forward all participants' views, but eliminating existing power relations completely are not possible for obvious reasons and therefore it is likely that the results of this study are somewhat affected by the group dynamics between the individuals at the PM session.

4.4.1.3 Implementation and analysis

The maps were placed on the ground in the temple and the participants and facilitators were sitting on the ground around the maps. The facilitators were introduced, the purpose of the activity was explained, and the participants were informed that the session was being recorded and what it would be used for. Thereafter, each of the participants got to introduce themselves. Transparent plastic sheets had been placed over the maps and the participants were then asked to draw features using marker pens in different colors. Some of the questions were only meant as discussion questions where the maps could be used as support and reference while other questions required the participants to first discuss and then draw features on the maps. For example the participants were asked to mark areas that are particularly important to them for grazing purposes. This method helped in identifying key locations that are particularly important to the herders. This is a useful method within natural resource management since it spatially represents the relative importance of different places and resources to the local people (Ramirez-Gomez & Martínez, 2013).

4.4.2 Interviews

Separate personal interviews with herders were done to explore and analyze in what way the changing environment is impacting on their livelihoods. A qualitative approach is especially beneficial when exploring a topic which has never been addressed before (Creswell, 2014). Qualitative interviews are also useful when the researcher is looking for an in-depth understanding of a social phenomenon (Esaiasson et al., 2012). Semi-structured interviews were the primary source of information about the livelihoods aspect. This interview method is suitable when the researcher has a clear focus that the questions are centered on, but it also gives the respondent room to bring up subjects or issues that might not have been expected but are still relevant for this study (Bryman, 2002). An interview guide (see Appendix III) with prepared questions and subjects were used for two reasons; as an aid for me to keep focus on the subject, and also so that the interpreter, in this case Mr. Mathivanan, can go through the questions beforehand. Conducting interviews with help of an interpreter is very different from interviewing where all participants share the same native language. Three languages were in translation during the interviews; English, Tamil and Swedish (since it is my mother tongue), and this also mean three critical points where meaning may be distorted or lost (Kapborg & Berterö, 2002). All interviews were recorded so that it was possible to return to the recordings in case any questions came up and to get a second opinion about particular statements. Reflexivity is a central feature within qualitative research (Tracy, 2013), and therefore my own impact on the interview process and the results must also be considered. It is perhaps especially relevant in regards of how I as a foreigner in a rural area that is rarely visited by outsiders might impact on the interview situations and how I as an outsider might interpret the answers of a social group I have very little previous knowledge about. The time for fieldwork is highly limited for a Master's thesis meaning that there was no possibility to stay for an extended period of time to learn about cultural codes and local ways of understanding. An advantage was that I had previously spent around three months in the area during my internship the year before, and for this study I spent an additional three months at the field station ACCC. The total time for the fieldwork for this thesis was six weeks during which time the majority of both the quantitative and the qualitative field work had to be done. The remaining time was used for processing, analyzing and writing.

4.4.2.1 Sample selection

It is important to purposefully generate a sample that correlates with the purpose, aims, and research questions of the study (Tracy, 2013). For this thesis, convenience sampling was used and like the name suggest, the main benefits of this sampling method is that it is a convenient, time efficient and inexpensive method (Tracy, 2013). Since I am mostly interested in information that could be generated from anyone within the social network of herders in Peikulam and because the time frame of this study is rather short, it would have been unproductive to invest a lot of time in finding perfect samples. The criteria for participating in this study were to be a herder from the village Peikulam and preferably to have been herding the region for many years so that information about environmental and social changes could be generated.

Four interviews were conducted during field work in 2015 and an additional five interviews were conducted in 2016. The interviewed pastoralists were all actively herding and between 35 and 75 years old. Most of them had additional income from agriculture and their herd sizes ranged between from 50 to 200 sheep. The interviewees were found through driving around the pastures surrounding the village Peikulam searching for pastoralists and these were then approached and asked if they wanted to participate. The interviews were thus conducted in field while the herders were working which was sometimes a distraction. The lengths of the interviews varied between 15 and 60 minutes, mostly depending on how much time they could offer us before having to move on with their sheep. Sometimes we walked along with the herders while interviewing. Due to the limited timeframe of the field work and because interviews were only one out of several methods used for this mixed methods study, saturation were not achieved if defined as the point where no new information is found through the interviews on the investigated issue (Mason, 2010). Ideally more qualitative interviews would have been conducted, and this is an opening for further research on this topic. However, the data gathered through interviews for this study is believed to be enough for discussing and answering the research questions and for comparing with the quantitative results. A limitation with mixing methods in this case, and with interdisciplinary research in general, is the tendency to scratch on the surface of the research problem rather than focusing on one aspect and exploring it in depth.

4.4.2.2 Secondary qualitative data

An additional source of information that was used for analysis was secondary interview data from eight interviews that were conducted in March and August 2015. Although I was not personally present during the collection of this data it is trusted because it was gathered by my supervisor in field and senior researcher at ATREE, Dr. Devy, and field station coordinator Mr.Mathivanan, who is a very experienced interviewer and has been present at all interviews used for this thesis. If any questions came up regarding the interview data I was therefore able to ask for clarifications, and the final text has been proof-read by both interviewers in order to minimize risk of misrepresentation.

Using pre-existing data, e.g. statistical data, is custom within quantitative research and secondary analysis has been an established and often used method for more than a century. Within qualitative research, re-using data from previous qualitative studies is a less acknowledged and more questioned method (Heaton, 2004). According to Heaton (2004), it is an approach which has recently gained interest among researchers and this new type of data requires a new methodology. However, Moore (2007) means that this view on secondary analysis relies on assumptions that data type and methodology is intrinsically linked while it is more relevant to link research questions with methodology. Furthermore, she claims that reuse of qualitative data is not something new and that the skepticism towards secondary qualitative data analysis is based on the hegemonic status of quantitative data within sociological research that makes it unaffected by situatedness and reflexivity while qualitative data is deemed unusable outside of its context (Moore, 2007). Although quantitative data is often treated as objective, all data are situated and needs to be treated as such and therefore pre-existing qualitative data is not less reliable or useful than any other kind of data (Moore, 2007). While Heaton (2004) links methodology and data, Moore (2007) connects research questions and methodology. Their different perspectives and approaches to secondary data analysis clearly reflect their differentiating worldviews, or epistemological backgrounds. Like many mixed methods researchers, Moore (2007) seem to have a pragmatic worldview where emphasis is put on the research problem rather than the methods, and the methodology is adapted thereafter (Creswell, 2014). In this study I have followed this way of approaching secondary qualitative data; pre-existing interview material of herders from Peikulam were seen as valuable information that would help me understand the research problems and as with any other type of data used for this study, context and reflexivity issues were considered through careful evaluation of the process of data gathering.

5 Analysis of empirical findings

The quantitative and qualitative data are presented and analyzed in this chapter, first separately and then together. Since all data, regardless of epistemological foundation, has to undergo some sort of analysis when compiled and formulated into a comprehensive text the data and analysis will not be presented in separate chapters. This chapter is divided into three main sections which are focusing on different parts of the research problem. The first section addresses the first research sub-question, which is about remotely sensed land cover changes in the study area. The second section is mainly drawing on qualitative data and focuses on the second research sub-question about pastoralist perceptions of land cover change in southern Tamil Nadu. The third section is a comparative analysis of the quantitative and qualitative data together. Hence, the focus of this section is on the third research sub-question about what similarities and differences to land cover change can be found from RS observations and pastoralist understandings. The three sub-questions are jointly answering the overarching research question, and therefore a broad and overarching answer to this question will not be provided until the subsequent concluding chapter.

5.1 Observed land cover changes through remote sensing

The results from the satellite image classifications and post-classification change detection analysis are presented in this section. Here, the findings will also be discussed and analyzed in relation to relevant literature on the subject.

5.1.1 Classification results and accuracy assessment

The classified Landsat images from 1992, 2000 and 2014 are shown in Appendix I. The overall accuracy of the classified maps were 89.6% for the 1992 classification, 83.8% for the 2000 classification, and 86.9% for the 2014 classification (Table 1). The overall accuracy of the 2000 classification did not exceed the commonly used benchmark of 85% (Tsarouchi et al., 2014) and it was not used for the post-classification change detection analysis. However, the 85% benchmark is only a suggested point of reference and since the 2000 classification almost met this criterion, it was still considered good enough to be used for some further discussion on the changing land cover. The kappa statistics for the 1992 classified image was 0.83, which according to Landis & 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).

Table 1. Results of the accuracy assessment of the 1992, 2000 and 2014 land cover maps.

1992 Landsat 5 TM	Water	Built-up land	Agricultural land	Shrubland	Open land	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
Shrubland			3	**27**		30	90.0
Open land		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	Shrubland	Open land	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
Shrubland		3	11	**24**		38	63.1
Open land			9		**49**	58	84.5
Reference total	11	10	154	34	51	260	
Producer	100.0	40.0	84.4	70.6	96.1	Overall accu-	

accuracy (%)						racy: 83.8%	

2014 Landsat 8 OLI/TIRS	Water	Built-up land	Agricultural land	Shrubland	Open land	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
Shrubland			7	**16**	1	24	66.6
Open land			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%	

Changes between all land cover classes and all years are shown in Figure 2 and from this it can be read that the most significant changes that have occurred between the years 1992 and 2014 are an increase of agricultural land (+7.3%) and a decrease of open land (-7.1%). The remaining land cover classes have seen less extensive changes; built-up land (+0.9%) and water (+1%) had increased marginally while shrubland (-2.1%) decreased a little. Through visual interpretation of the land cover maps (Appendix I) it appears like much of the decrease of open land and increase of agricultural land has occurred in the Srivaikuntam area but the land cover in the Tirunelveli study site seem to have gone through similar changes, in particular the southeastern part. Srivaikuntam has also seen a substantial loss of open land between the years 1992 and 2014 and also some increase in agricultural land. The land cover changes of the Peikulam study site is more difficult to visually interpret because the landscape appears more fragmented and complex which highlights the need for qualitative inquiry.

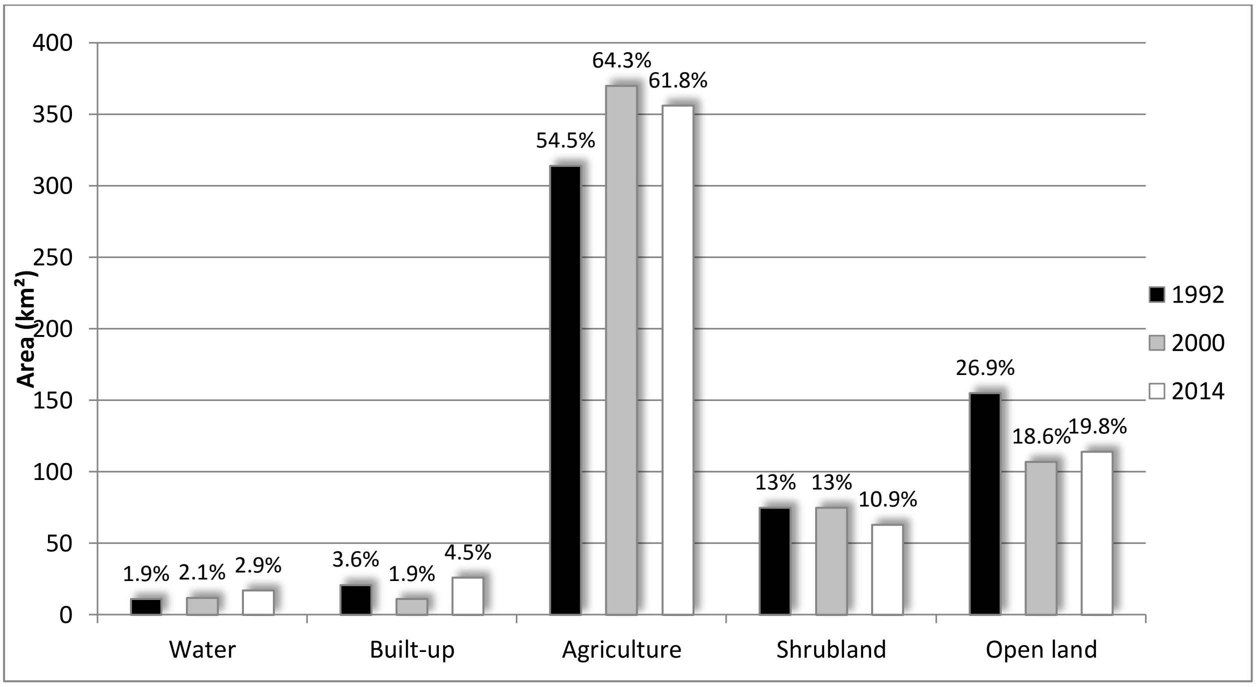

Figure 2. Area of land covers classes in the classified images from 1992, 2000 and 2014.

Most of these changes appear to have occurred between the years 1992 and 2000. Overall, agricultural land has decreased by 2.5% between the years 2000 and 2014 while open land have increased by 1.2% within the same time period according to the classification results. The lower accuracy of the 2000 classification could be the reason behind this rather inconsistent result. User and producer accuracy are greatly varying between the land cover classes and years. Built-up land and shrubland scored lowest in the accuracy assessment for all years, and any land cover changes that involve these classes should therefore be interpreted with great caution. Since this study is focusing on changes in pastoral lands, which are found within the class open land, the poor accuracy of the two mentioned classes are considered acceptable. User and producer accuracy of the land cover class 'open land' scored well above the suggested benchmark of 85% for both the classifications of 1992 and 2014, although for the 2000 classification the user accuracy of open land was only 84.5%. However, this image will not be used for the post-classification change detection analysis and therefore it will not affect the results presented in the next section.

5.1.2 Change detection analysis

The background of this study was that diminishing pastoral lands had been observed across India (Jodha, 1985; Chaudry et al., 2010; Tsarouchi et al., 2014; Sharma et al., 2003) and that a similar development was expected to have occurred in southern Tamil Nadu. Hence, the post-classification land cover changes which involve the class open land are of particular interest to this study, and these are presented in Appendix II and Figure 3. Cartographically it was unfeasible to visualize all changes that have occurred between all classes in a readable map. All land cover changes which did not involve the class open land were therefore left out from this map.

The post-classification change detection analysis showed that the by far most significant change that have occurred between the years 1992 and 2014 was in the category “open land to agricultural land” which stands for 66.78% of the land cover changes. Surprisingly and rather contradictory, the second largest category was “agricultural land to open land” which accounted for 27.56% of the changes. By visually interpreting the change detection map, it appears as if the transformation of open land to agricultural land has occurred across the whole study area. However, “agricultural land to open land” is mostly found in the Peikulam study site although this category is present to some extent at all four study sites. Generally, the land cover changes in Peikulam appear to be more dispersed and widespread compared to the other study sites. In Ambasamudram and Srivaikuntam land cover changes are much more clustered and there is a tendency of less detected changes along the Thamirabarani River. In Tirunelveli there is a clear trend of land cover changes occurring along the boundaries of the study area, away from the city center.

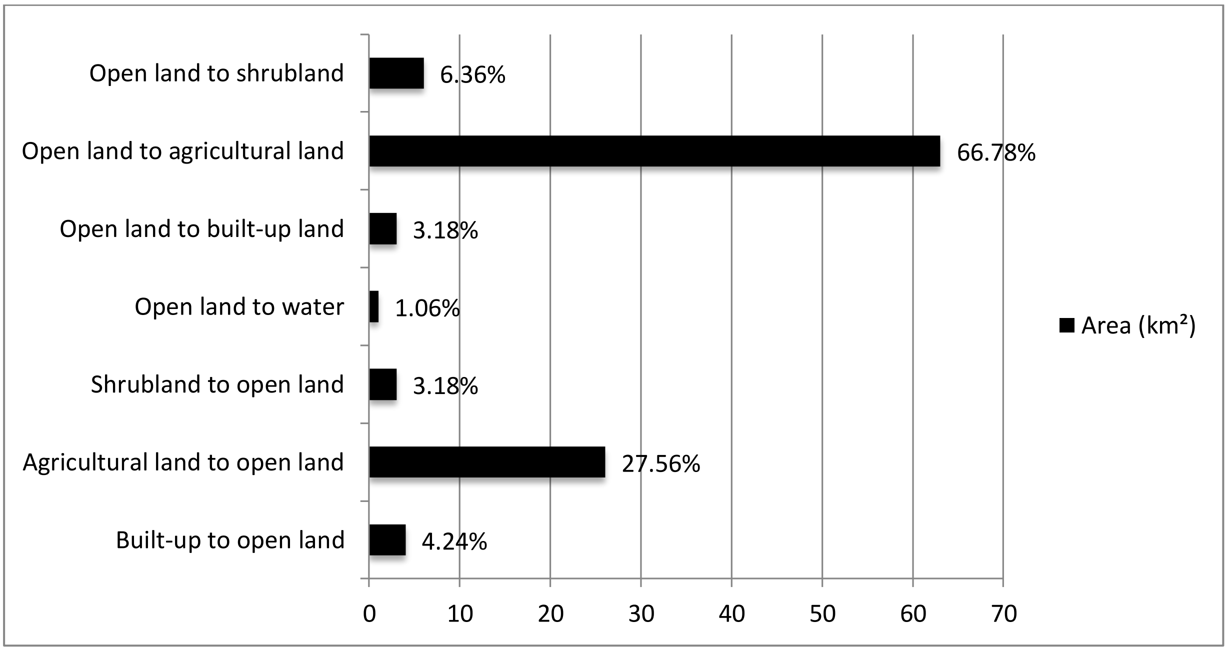

Figure 3. Land cover change classes between 1992 and 2014.

5.1.3 Discussion on RS observed land cover changes

Findings from the post-classification change detection analysis will be discussed here with the aim to answer the first research sub-question about how the land cover has changed in the study area between the years 1992 and 2014 according to RS observations.

The post-classification change detection showed that the most common change that had occurred was in the category "open land to agricultural land" followed by "agricultural land to open land". This rather contradictory result could indicate that open land and agricultural land have been mixed up in the classifications, and the accuracy assessment is to some extent supporting this assumption. However, the user and producer accuracy for each of these classes is above 85% for both classifications which should be considered satisfactory according to Tsarouchi et al. (2014). Although the overall accuracy of the classified images was good, the user and producer accuracy of some individual classes were less satisfactory. Built-up land scored low in the accuracy assessment because urban areas where houses are interspersed with vegetation and other land covers are very difficult to classify using Landsat satellite imagery since multiple land covers are likely to be captured within one pixel, which is 30 x 30 meters on the ground (Lwin & Murayama, 2013). However, seemingly contradictory results such as simultaneously diminishing and expanding pastoral lands and cultivated areas are not necessarily results from a failed land cover classification. It could also tell about the complex dynamics of land cover change, because it is possible for a landscape to be both improved and degraded at the same time (Jiang, 2003), which again points to the need for a qualitative approach. The result could also be interpreted as an indication of how land cover change patterns are more complex than a linear transformation process from what Cronon (1991) calls first nature into second nature, meaning a natural environment into an artificial one. If we leave out ideas of natural stability (Robbins, 2001) and original pristine environments (Cronon, 1996) and see land cover change as a continuous and intricate process, it might be easier to understand and accept seemingly contradictory results of land cover change detections.

According to the change detection analysis, some areas have seen considerably less changes than others. For example, there is a tendency of less detected changes along the Thamirabarani River and near the center of the district capital Tirunelveli. Presumably, this has to do with the area around Thamirabarani having been cultivated for a very long time and that the land in Tirunelveli has been built-up for many years, which means that no transformation between the land cover classes used for this classification has occurred at these locations. However, this does not mean that no changes may have occurred. Although RS images are sometimes seen as inherently neutral and GIS users often aim to interpret land cover changes objectively (Aitken & Kwan, 2010), the results are greatly influenced by individual interpretations and decisions made during the process. Selection of data, sensor system, acquisition dates, image enhancement techniques, training samples, and land cover classes to be used for the classification are all examples of decisions that were made by me during the process. Therefore, this post-classification change detection analysis only shows changes that have occurred between the land cover classes that I have defined based on the training samples I have chosen using the techniques and data that I considered appropriate for the purpose of this study. Once again, this shows on the subjectivity of knowledge in general and the limitations of positivist RS methodology in particular (Nightingale, 2003). This subjectivity need to be highlighted and discussed, but it does not reduce the usefulness of RS as a technique providing valuable information about the large-scale land cover, which could be better understood in combination with qualitative data. Thus, the next section will present the qualitative findings which will later be compared and analyzed together with the results from the RS observations.

5.2 Pastoralist understandings of land cover change

Qualitative data that were generated from interactions with pastoralists are presented in this section. First, the pastoral migratory route is mapped and explained, followed by an analysis of how the Peikulam herders understand their changing environment. Thereafter follows a discussion on the overall perceived land cover and livelihood changes which will put the herders' perceptions into a wider context through linking it to relevant literature.

5.2.1 Migratory routes and location of important and diminishing pastures

The PM session resulted in a map (Figure 4) showing the Peikulam herders' migratory routes as well as important pastures that they are using today and pastures that are diminishing or have become unavailable to them. Important and diminishing pastures were marked by the participants on the reference maps and geographically located based on available landmarks. Due to the presumed spatial imprecision of these locations, a 1 km buffer zone was created around the marks. However, the diminishing pastures in the Peikulam area was not created using a buffer zone since this is the participants' home grounds and they were able to be more geographically precise. The participatory map shows all villages and place names that were mentioned by the herders that could be confirmed and located on reference material (e.g. Google Earth and Google Maps).

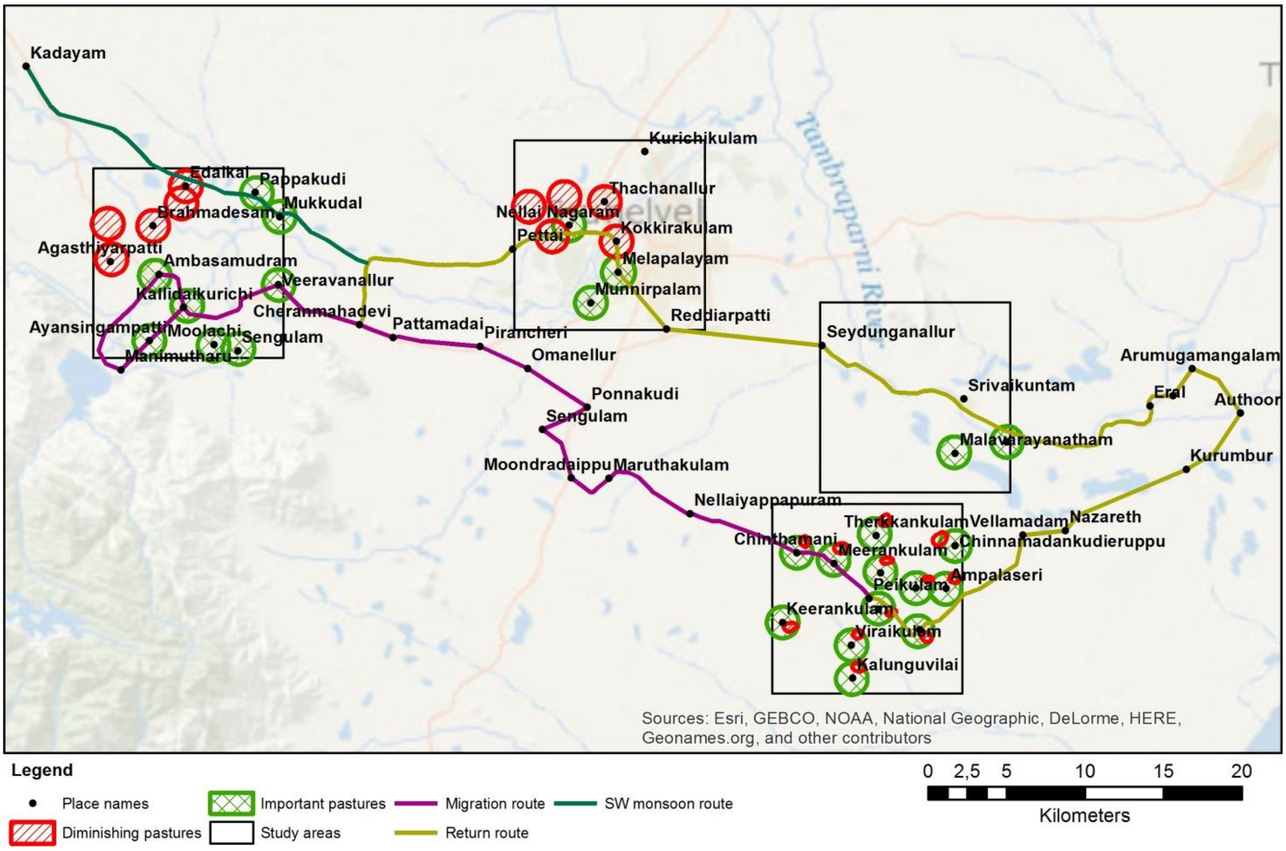

Figure 4. Participatory map showing the migratory routes, important pastures, and diminishing pastures.

The migratory routes were drawn directly on an overview map of the area by the participants. This drawing was then adjusted during the digitizing process to be correlating with the place names that the herders said that they passed through since not all of these were shown on the overview map.

The produced map does not intend to depict the exact migratory route; neither does it illustrate the route all herders from Peikulam are taking. However, a majority of the herders during the participatory mapping session agreed on that this approximate route is commonly used during their migrations. The herders also explained that not everyone takes the same migratory route and that there are two groups of herders whose migratory routes differ. The only factor defining these two herder groups seem to be their slightly differing migratory routes. The first group of herders starts migrating from Peikulam towards Ambasamudram in mid-February to mid-March. They stay in the Ambasamudram area during the hottest summer months until mid-May to mid-June, and then they start migrating towards their grazing grounds in Tirunelveli. In mid-July to mid-August they reach Kurumbur via Srivaikuntam, Alwarthirunagari and Eral and in mid-October to mid-November they return to Peikulam. In total this group of herders is out for eight months.

The second group of herders stays at their home grounds in Peikulam until mid-May to mid-June when they start migrating directly towards Kurumbur and Alwarthirunagari. Unlike the first group, they do not go to the Ambasamudram area because there is enough grazing at their home grounds when the first group migrates. The first group of herders joins the second group somewhere along their route, probably around Alwarthirunagari, after having been to Ambasamudram and Tirunelveli. In mid-July to mid-August they all go to Eral and Vellamadam before returning to Peikulam in mid-October to mid-November. The second group of herders is out for approximately six months in total. In case there are good rains during the South West monsoon in June to September, some of the herders from the first group will go from Tirunelveli to Kadayam via Pettai and Mukkudal. From Kadayam, they will go back to Ambasamudram instead of returning to Peikulam, making their total migration route considerably longer.

5.2.2 Changing conditions for pastoralist livelihoods

Six issues were identified as impediments to pastoralist livelihoods in southern Tamil Nadu. These issues are (not in order of importance); 1) proliferation of invasive species, 2) animal diseases, 3) physical obstacles on the migratory route, 4) changing land use patterns, 5) deterioration of village institutions, and 6) stigmatization of pastoralism. These are all issues that affect how pastoralists understand land cover change in the area, either by directly altering the landscape or through social processes which have more indirect effects on land use, and thus were seen as important to the herders in terms of land cover change. All information in this section was derived from interactions with the Peikulam herders, either through qualitative interviews or discussions during the PM session.

5.2.2.1 Proliferation of invasive species

The invasive species prosopis has been present in the region for as long as the interviewed herders can remember, but during the last 10-15 years they have experienced an increase and it has developed to become a greater problem to them. Although all interviewees and PM participants seem to agree on that the spreading prosopis constitutes a change in the landscape that is affecting their livelihoods, not everyone sees it as a major problem. It is possible to graze in landscapes covered by prosopis; the issues with prosopis rather seem to be associated with health problems for the sheep. The interviewed herders have reported that their sheep get hurt by the tree's thorns and start limping and that they get sick by eating its fruits. Some of the respondents have even deemed prosopis to be the main reason for them to migrate towards Ambasamudram during fruiting season, since they perceive that area to be lesser prosopis covered. Contrastingly, a few of the interviewed herders did not view prosopis as a problem. One herder even claimed the fruits to be good feed for his sheep, and although he perceived animal diseases as the most critical problem, he did not make the connection between prosopis and diseases like the other herders did.

The fast proliferation of prosopis might be the most obvious and visible change that has occurred in the landscape in recent years, and although it was commonly brought up by the respondents as an issue, many of the herders did not seem to have reflected much on it. Their teenage children, who were present at the participatory mapping session, explained that this was because they were so used to it that they did not see it as a problem anymore.

5.2.2.2 Animal diseases

Many of the interviewed herders and PM participants seem to view animal diseases as the greatest threat to their livelihoods. Symptoms of these diseases that have been mentioned include mouth ulcers, blue tongue, running nose, fainting, and diarrhea. Various causes to these diseases have been brought up by the herders, one of the most common being the spreading of prosopis whose fruits are accused of poisoning the sheep and thorns are believed to be making them limp. Another cause of diseases that was commonly brought up was rains; during years of heavy rains illness among the sheep seem to escalate and many of the herders have lost a substantial part of their herds to various diseases during years of heavy monsoons. A less mentioned cause of animal diseases was agricultural pesticides. Whatever the causes of these diseases are, it is perceived as a great problem to the interviewed herders and it is a problem that is escalating. Although the connection between land cover change and animal diseases might not be obvious at first, the interviewees brought it up as an important issue which is largely caused by the changing landscape. It is also a good example of how qualitative interviews helped me to gain a more holistic understanding about the research problem by moving beyond physical changes in the landscape.

5.2.2.3 Physical obstacles on the migratory routes

Fencing is an issue that is increasing according to the interviewed herders and PM participants. Fences are obstructing their migratory routes and make some seasonal grazing grounds unavailable to them. Fencing seems to mostly occur in regards of agricultural land and is mainly associated with tree crops like coconut and banana. However, grasslands and previous commons (poramboke) are also getting privatized, fenced and converted to housing lots or agricultural land. Some farmers also have their own animals and have therefore put up fences to protect their pastures. According to some of the herders fencing of land is often done by immigrants from the neighboring state Kerala while local farmers do not fence their lands and allow them to graze their fields after harvest. However, other herders have said that fencing is done by locals as well as immigrants. Fencing seems to complicate the herders' migration because it makes it difficult to find grazing grounds along the way. This means that the herders have to rush between pastures and due to this rush, and because of the fragmentation of the landscape fencing leads to, herders are often forced to move along roads.

Roads, and in particular the national highways, are also fragmenting the landscape and are seen by some herders as obstacles because of the danger heavy traffic means to their sheep. However, due to other obstacles in the landscape, they are often forced to migrate along roads and occasionally they will need to cross major roads and highways. For this reason, they have to move late at night when there is less traffic. Some herders did not perceive roads as a problem because they could easily choose alternate routes where highways are avoided and in case they need to cross a busy road they would wait until late night or early morning to minimize risks of accidents. These herders seemed to see it as a necessary adaptation strategy rather than a problem.

5.2.2.4 Changing land use patterns

Changes in land use and more specifically expanding agricultural land and built-up land have been mentioned by many interviewees and PM participants as issues that are complicating their livelihoods. When the participants at the PM session were asked about what the main cause behind the diminishing pastures were, the first answer that came to their mind was the expansion of agricultural lands. Cultivated land is said to be expanding across the whole study area although some particular regions have seen more agricultural expansion than others. This development becomes especially evident to the herders during years of heavy rains, because then land that is usually not cultivated are used for agriculture as well, which makes lands available for grazing even smaller.

Some grazing grounds near villages and towns have also been lost due to expanding residential areas. In the area around the district capital Tirunelveli, nearly all grazing grounds have been lost according to the herders. The herders also witnessed similar developments where grazing grounds have been lost to expansion of villages in the Ambasamudram area. Their home grounds around Peikulam seem to have been mostly spared from these kinds of developments. In this particular area other issues seem to be more critical.

5.2.2.5 Deterioration of village institutions

Village commons, or poramboke, used to be protected by village law and these grounds were often used for grazing in the past. Most of these grounds now seem to have diminished or disappeared completely due to agricultural encroachment, conversion to housing lots, or fencing. According to the herders, the village institutions that used to protect the poramboke are not respected anymore and some of these lands have now been sold by the village landlord.

One herder also told about an association of herders with around 85 members in the village Ramanujampudur, 6 km North West of Peikulam, which used to exist in his father’s days. The members of this association used to pay deposit and in return the association could help out in times of need, for example in case their sheep got injured or stolen. However, this association is not functioning anymore because of internal conflicts among its members and because less people earns a living as herders nowadays. This large herder’s association seemed to be unique to the village of Ramanujampudur because of the high density of herders in this village at that time.

5.2.2.6 Stigmatization of pastoralism

There are social stigmas around herding and although this is not something new, it is an issue that is perceived by some of the herders as an enduring problem. The herders themselves feel like other people look down on them and several of them have experienced being chased away or even attacked by farmers and villagers. Certain villages and areas seem to be avoided for these reasons. For example, one herder said that they used to go to the village Srivaikuntam some 20 years back but today they do not go there anymore because the villagers there are non-accommodating and sometimes even violent against them.

Social stigmatization of herding could have consequences on the future of pastoralism in the region. All herders except from one that were asked if their children would come to the same profession answered that they would not. The reasons behind this were that herding is perceived as a difficult and physically very demanding occupation with very low income. Both the herders and their children seemed to favor college education or work within the agricultural or commercial sectors. Hence, they were not optimistic about the future of their profession. One of the herders thought lifting the social stigmas would require an improved marketing system and a “better” lifestyle; however, the herders themselves do not have the financial means for making such improvements.

5.2.3 Discussion on overall perceptions of change

The following discussion aims to contextualize the herders’ perceptions of land cover change and changing conditions for pastoralism in southern Tamil Nadu by connecting it to relevant literature on the subject. The focus is on the second research sub-question regarding pastoralist understandings of land cover change.

According to the Peikulam herders, the landscape and pastoralist occupation are going through several significant changes. Concrete examples of changes in the landscape that are perceived as impediments to the pastoralist livelihood are physical obstacles such as infrastructure and fences. The four lane North-South corridor highway, which is the longest running highway in India and a result of the massive national highway development program, is cutting right through the Tirunelveli study site. (National Highways Authority of India, 2016). Fencing is also fragmenting the landscape and forces pastoralists to choose alternate migratory routes, often along roads, and because of the risk of traffic accidents they often need to migrate late at night when there is less traffic. Disturbed migratory routes due to physical obstacles such as highways and other infrastructural development have been identified as a major livelihood threat to pastoralism at other locations in India. For example, pastoralists of the Indian Himalayas have been forced to adapt similar strategies of changing their routes and constantly being on the move during their migration. Livestock deaths due to traffic accidents have also been reported occurring relatively frequently in that area (Sharma et al., 2003).

The main drivers of land cover change are by the pastoralists perceived as agricultural encroachment on pasture lands and expanding residential areas around villages and towns. Such changes in land use patterns have also been observed at several other locations in India (Tsarouchi et al., 2014; Sharma et al., 2003). Encroachments on village commons have led to an almost complete disappearance of poramboke, which is also a development that has been reported elsewhere in India (Sharma et al., 2003; Jodha, 1985). Similarities can be seen between the collapse of the large herder association in the village Ramanujampudur and the breakdown of village institutions in Rajasthan, western India which used to protect and regulate use of common pastures (Sharma et al., 2003). Diminishing poramboke also needs to be understood in a historical socio-economic context. Land ownership changed during the 20th century when the land owning castes Brahmins and Vellalas, who also held the political power in the region, turned to high skilled occupations outside of the agricultural sector. Another driver of change was that many landless laborers emigrated to neighboring countries during this time (Gomathinayagam, 2012). The Tamil Nadu Land Reforms (Fixation of Ceiling on Land) Act which came into effect in 1960 aimed at distributing land among landless poor by setting a ceiling on how much land a single family could own (The Tamil Nadu Land Reforms (Fixation of Ceiling on Land) Act, 1961). Although good in intent, it could be argued that these laws were never implemented with any level of seriousness and that unequal land ownership patterns largely remains. However, following this land reform, new land owning castes emerged (Gomathinayagam, 2012) and CPRs rapidly declined due to privatization, which was inexplicitly encouraged by public policies (Jodha, 1989). Privatization was meant to benefit the rural poor but it did not work out as intended, and in the end it was the more well-off households that benefited the most, and very little was done to protect common grazing lands (Jodha, 1989). The changing land ownership patterns was a process that developed over many decades (Gomathinayagam, 2012) and this development is important for understanding land cover change in Tamil Nadu. It provides partial explanation to the perceived disappearance of pastoral lands in favor of agricultural land and housing lots, and it also gives an idea about how pastoralists are treated in government policies.

Government attitudes towards pastoralism are reflected in rural development strategies which are centered on agriculture development, and in some cases see pastoralism as an environmentally degrading activity (Sharma et al., 2003). Perhaps these ideas can be traced back to the generally negative stereotypes that exist about pastoralists in India. Stigmatization of pastoralism has created a feeling of social exclusion and this feeling is not unique to pastoralists of southern Tamil Nadu. The seemingly collective low self-esteem that existed among pastoralists in western India (Sharma et al., 2003) seem to be present among the Peikulam herders as well to some degree, and despite extensive changes in education system these ingrained forms of discrimination does not seem to change. According to interviews, physical attacks and hostile attitudes have made the herders avoid certain areas for grazing, and hence the negative stereotypes against pastoralists are also affecting their migratory routes and land use in the area. Marginalization might also be a reason behind why a majority of the interviewed herders were the last individuals in their families to engage in this occupation. Education is valued by the herders today and seems to be seen as a way for their children to get out of their marginalized social status and the demanding occupation of pastoralism. Sharma et al. (2003) also found that youths from herding households that had received education at any level no longer viewed pastoralism as a viable livelihood option.

The connection between diseases and prosopis seem to have some support in scientific literature. It has been reported that long-term ingestion of prosopis by cattle could result in death, and also that its pollen is likely to cause some allergic reactions like running nose and breathing difficulties (Duke, 1983). These are also some of the symptoms that were mentioned by the herders. Another cause of animal disease could also be the constituent species Lantena camera, which according to Robbins (2001) is toxic, and elsewhere in India has been blamed for thousands of livestock deaths every year (Sharma et al., 2003).

When interpreting qualitative data about land cover change it is also beneficial to reflect on circumstances like climatic fluctuations, because it has been shown to influence on peoples' perceptions of environmental change. During years of normal precipitation the environment is perceived as stable or even improving, while a dry year could lead to that the interviews are focused on issues around drought (Jiang, 2003). Most interviews and participatory activities for this study were done right after the 2015 northeast monsoon which was exceptionally wet and led to excessive rains far above normal in Tamil Nadu (Kurian, 2016). This might have subconsciously influenced the herders' perceptions of land cover change, possibly overemphasizing issues related to excessive raining. Indeed, rains were mentioned rather frequently as a problem since animal diseases were reported to escalate during years of heavy rains and some of the herders had therefore recently lost many of their sheep. During years of good rains, lands that are usually not cultivated are commonly cropped as well which also makes the conversion of pastures into agricultural land more prominent and widespread after an exceptionally rainy season. However, this unusually wet monsoon did not impact on the change detection analysis since the satellite images used were acquired in March and April of 1992 and 2014. These years were both preceded by somewhat dry northeast monsoons; 375.7 mm and 400.5 mm for 1991 and 2013 respectively, which is in sharp contrast to the 952.9 mm for the same period of 2015 (India Water Portal, 2012; Tirunelveli District, 2016).

In sum, the land cover in southern Tamil Nadu is perceived as changing and the main changes that have occurred are transformation of open grazing lands into agricultural land and to a lesser extent built-up land, particularly on the outskirts of villages and towns. Disappearing commons due to privatization of land and deterioration of the village institutions that used to protect poramboke is another perceived change that has led to modifications of the landscape. Proliferation of the fast growing prosopis is also perceived as a significant land cover change, which is believed to be an important cause of the aggravating problem with animal diseases. Physical obstacles due to infrastructural development and fencing are also seen as significant constraints to the pastoralist livelihood. Heavily trafficked roads mean direct danger to the livestock and obstacles like fences are fragmenting the landscape which forces the herders to choose alternate routes. Some previously important grazing grounds have also been inaccessible because of local villagers' hostility towards pastoralists. The stigmatization of pastoralists seems to have created a collective low self-esteem and a feeling of hopelessness regarding the future of their profession. Finally, the perceptions of land cover change should be understood in a wider context where climatic fluctuations may impact perceptions of land cover change and the relative size of different livelihood impediments.

5.3 Comparative analysis of quantitative and qualitative data

This chapter will address the third research sub-question about what similarities and differences in land cover change could be identified based on RS observations and pastoralist understandings. Hence, the quantitative and qualitative data will be compared and analyzed together here.

According to the RS observations the land cover in the study area has changed in the following way between 1992 and 2014; open land and shrubland has decreased by 7.1% and 2.1% respectively, while built-up land and water had seen a minor increase of 0.9% and 1%. Agricultural land accounted for the largest change, namely an increase of 7.3%. The by far most significant change between land cover classes that was identified through RS was between open land and agricultural land; 66.78% of the detected changes were open land that had been transformed into agricultural land. Pastoralist understandings about land cover change confirmed that open grazing lands are being converted into agricultural land but also pointed out that built-up land is encroaching on pasture lands, particularly near villages and towns. Their understandings about the changing landscape also involved spreading of invasive vegetation, animal diseases, physical obstacles in the landscape, loss of village commons due to weakening institutions, and stigmatization of pastoralism.

The findings from the quantitative and qualitative parts of this study clearly illustrates the value of combining RS with perceptions on the ground because the changes in the landscape could not have been understood using exclusively quantitative methods like RS, but interviews alone could not have captured the large-scale patterns of land cover change. A purely qualitative study on the same subject would likely have resulted in an exaggeration of the extent of grassland loss that have occurred since such changes might be perceived as more extensive than they are according to RS analysis. RS provides a valuable overview of land cover changes, which can be investigated more in-depth using qualitative data. Significant perspectives about the landscape and the changing conditions for pastoralism would have been missing if a conventional RS approach was used. Like Mialhe et al. (2014) showed in their study on participatory GIS in the Philippines, the two data types complement and authenticate one another since information about the environment that cannot be observed from space can be provided through local knowledge bringing an additional dimension to land cover change studies (Mialhe et al., 2014). Both perspectives are valuable and important for understanding social-natural processes in the landscape (Hermann et al., 2014).

In addition to telling different, but equally important, parts of the story about land cover change (Jiang, 2003) mixed methods studies like this one could also help bring forward discrepancies between the results. Analyzing these discrepancies is likely to lead to valuable information and clues about the changing landscape (Nightingale, 2003). In this way, a seemingly contradictory result could be even more interesting and useful than a neatly correlating result would have been. For example, even though both the RS analysis and the qualitative data indicate that one of the most prominent land cover changes that have occurred in the area is open land that has become agricultural land, there is no obvious correlation between the two information sources regarding the exact locations where these changes have occurred (see Appendix II). The locations that the pastoralists marked out as disappearing pastures during the participatory mapping session were not the same locations where the RS analysis detected major changes. There could be many explanations to this result. It could have to do with that the land cover changes the pastoralists witnessed about were in fact restricted to small but important pastures, while the RS analysis could only detect large-scale changes in the landscape. According to Nightingale (2003) inconsistencies between RS observed changes and oral stories about environmental change can help make it clear that the participants refer to small but significant and easily accessible areas. It has previously been shown that resource users may perceive a certain land cover change as more extensive than it actually is because of the significance of the locations where land cover change has occurred (Nightingale, 2003). A complication of qualitatively investigating land cover change also lies in the scale because of the limited knowledge many people have about processes at landscape level which in turn often leads to conflicting views about the landscape (Jiang, 2003). Humans create mental representations of spatial environments in their minds, sometimes referred to as “mental maps”, and these representations are subjective understandings of individuals’ environments that may contain personal details such as social relations, histories, and memories (Wario et al., 2015). Hence, comparisons of peoples’ perceptions of land cover changes will inevitably contain contradictions. On the one hand, the scale and ambiguity of qualitative spatial data could be seen as a limitation, e.g. the herders could not be very spatially precise outside of their home grounds and there were some contradictory views regarding perceived livelihood impediments. On the other hand, this is also what makes qualitative information valuable in combination with RS observations since the latter provides a technique for improving our understanding of large-scale spatial patterns that might be difficult to comprehend using our mental maps. Mental representations of spatial environments are also connected to the lifeworld, because individuals that share lifeworlds are more likely to perceive their surroundings in a similar way. PM activities could be seen as a way of translating the participants’ spatial understandings into a language that we understand or a format that is compatible with geographic information systems. Assuming that there are multiple realities and ways to understand the surrounding environment, this translation process might “distort” information which could be an explanation to why quantitative and qualitative spatial data is sometimes difficult to combine and when brought together sometimes contains contradictions and ambiguities.

Another possible reason for the discrepancies between RS observed changes and pastoralist perceptions of change could be that the perceived shrinkage of pastoral lands is caused by something other than conversion of one land cover class into another, e.g. physical obstacles like fences and roads. These are physical obstacles that make certain routes and grazing lands inaccessible for pastoral activities even though the land cover has not changed per se, and these cannot be detected through RS observations using coarse resolution satellite imagery. From a land user perspective, inaccessible pastures equals lost pastures and this might partly explain why some areas have been marked out as diminishing pastures by the herders even though no significant changes in land cover could be detected through RS observations. These kinds of physical obstacles could also explain why the herders seem to perceive the shrinkage of pastoral lands to be more extensive than the change detection analysis suggests.

The mismatch between the data sources regarding the exact locations of diminishing pastures could also be a result of that the participants at the mapping session felt pressured to be geographically precise in their answers although they were actually not certain about the locations. This is a risk when working with participatory mapping approaches (Corbett et al., 2006). As a marginalized social group, pastoralists have had limited access to high quality formal education and illiteracy is common (Sharma et al., 2003), and it could be argued that the participants might have found it difficult to interpret the reference maps during the participatory mapping sessions which in turn could lead to inaccurate spatial information. They might also have felt pressured to deliver results that are pleasing to the researcher team consisting of a foreigner and several highly educated researchers from ATREE. Even though buffer zones were created around their marks of diminishing pastures in order to minimize the risk of such errors and to make the qualitative spatial information vaguer, it is possible that the qualitative spatial data have caused discrepancies between RS observed and perceived changes in the landscape.

When comparing quantitative and qualitative data, irregularities between the two sources of data become visible which might not otherwise have been noticed. The fast proliferation of invasive species, in particular the tree prosopis, which was reported by the interviewed herders, does not appear in the RS change detection analysis. According to the change detection analysis the land cover class shrubland, which prosopis landscapes should be classified as, has decreased by 2.1% between the years 1992 and 2014. This is in stark contrast to the stories told by pastoralists, who portrayed the spreading of prosopis as one of the most obvious and widespread changes that had occurred in recent years. Possibly, this is because areas that have been completely covered by prosopis have been classified as agricultural land since it is very difficult to distinguish between different types of vegetation on satellite images with coarse spatial resolution, and some tree crops are likely to have similar spectral signatures as prosopis canopies. This would mean that the increase of agricultural land which was detected through RS is exaggerated since this category might include what should have been classified as an increase in shrubland. The accuracy assessment indicates that these two land cover classes have been mixed up at several occasions, which supports this assumption. The spreading of prosopis which the pastoralists describe has been observed at other locations in India. In western India, the fast proliferation of prosopis and constituent species constitutes a major change in the landscape which affects livestock rearing in the region (Robbins, 2001; Sharma et al., 2003).

A similar development has also been observed in Tamil Nadu, and particularly the southern districts of Tirunelveli and Ramanathapuram (Jaishankar, 2009).

Analyzing discrepancies between the results have further illustrated the benefits of comparing RS observations to pastoralist perceptions of land cover change since it has highlighted aspects that would have been lost without a mixed methods approach. These discrepancies have shown that pastoralists are probably referring to small but significant pastures when they talk about diminishing pastures, and that the perceived shrinkage of pasture lands are likely to be reinforced by physical obstacles which fragments the landscape and makes certain grazing areas inaccessible. The coarse resolution satellite imagery might also have caused some misclassifications which might not have been noticed without qualitative information about the changing environment. In addition to a more complete and comprehensive analysis of land cover change dynamics, a methodology that integrates RS and pastoralist perceptions can therefore provide a deeper understanding of the landscape through a comparative analysis of the quantitative and qualitative data in order to bring forward similarities and differences between them.

6 Conclusions

In this last concluding chapter, the overarching research question will be answered which reads as follows: *In what ways can existing qualitative GIS methods be improved by combining remote sensing observations to pastoralist perceptions of land cover change in southern Tamil Nadu?*

Using a mixed methods approach helped to gain a wide perspective on the research problem and the different methods worked to emphasize different aspects of the issue with shrinking pastoral lands. Change detection analysis through RS observations showed that the most significant land cover change that had occurred were open land that had been converted into agricultural land. However, the second largest land cover change that had occurred were agricultural land that had become open land. Hence, the RS results indicated rather complex land cover change dynamics that move away from narratives of natural stability and the rural landscape as a natural environment which is threatened by modern development. Such large-scale changes on the landscape level might have been difficult to understand through interviews only.

Qualitative data provided valuable insights into pastoralist understandings of land cover change and the perceived causes behind these changes. It was found that pastoralists in the region also saw agricultural expansion as a major issue; however, this seemed to be just one out of many perceived livelihood impediments. Other critical issues were the proliferation of invasive species, animal diseases, physical obstacles on the migratory routes, the deterioration of village institutions, and the enduring stigmatization of pastoralism.

Additionally, valuable insights were gained by comparing the results and highlight similarities and differences between RS observed land cover change and pastoralist understandings. The gap between quantitative and qualitative data indicated that the diminishment of pasture lands that have occurred might be confined to rather small but significant locations to the pastoralists, and that factors like obstacles in the landscape could reinforce perceptions of shrinking pastures. These results indicate that a policy to improve pastoralist conditions based on only RS observations would most likely fail since most obstacles are not in the domain of detectable changes.

This study has illustrated the strengths and limitations of both methodologies on their own and the partiality of knowledge in general. It has shown on the usefulness of combining pastoralist understandings with RS to produce more complete analyses of land cover change. Involving non- and semi-sedentary social groups in GIS activities has the potential of producing more socially inclusive and democratic GIS techniques, particularly for groups normally not able to take part in, or be heard by, scientific research and policy-making. Further research is needed to improve on this knowledge and to understand and determine the causes of discrepancies between the results, which have only been speculated in here. This could be done through investigating the issues experienced by pastoralists more thoroughly by adding more qualitative components. A better understanding of how to utilize pastoralist knowledge in land cover change studies could lead to improved natural resource management of pastoral lands as well as providing support to vulnerable pastoralist livelihoods.

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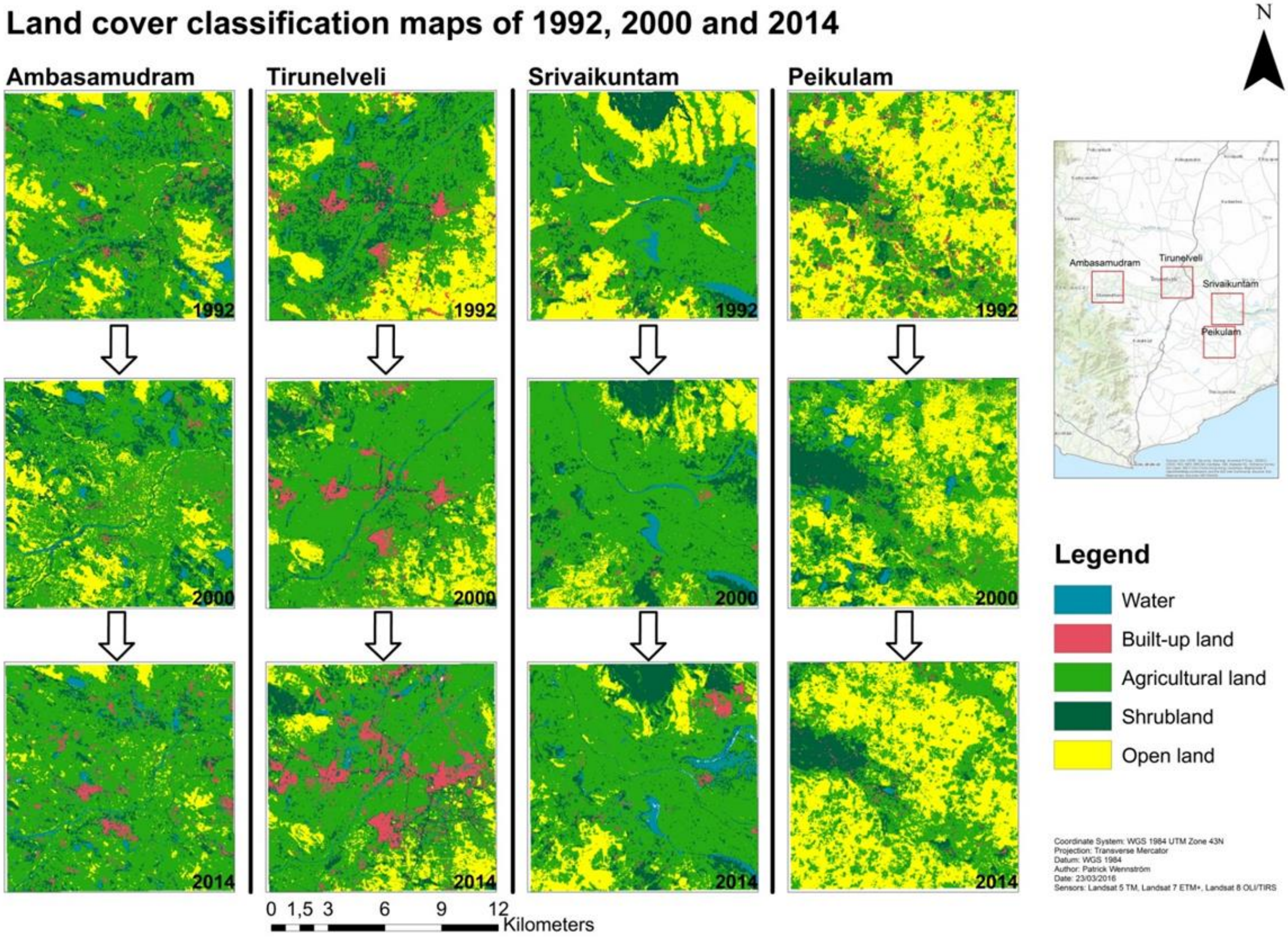
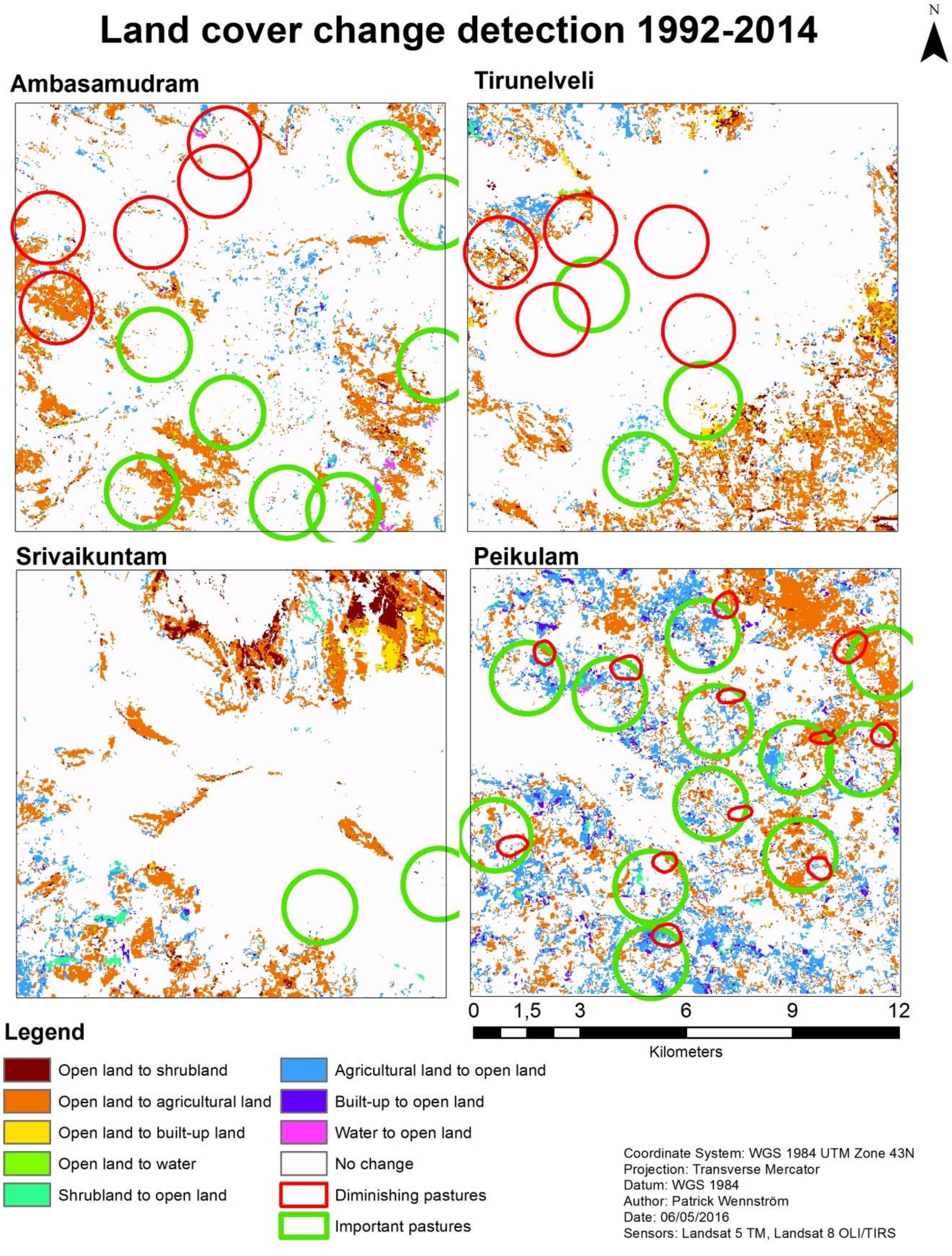
Appendix I



Land cover classification maps of 1992, 2000 and 2014
N
Ambasamudram
Tirunelveli
Srivaikuntam
Peikulam
1992
2000
2014
Ambasamudram
Tirunelveli
Srivaikuntam
Peikulam
Legend
Water
Built-up land
Agricultural land
Shrubland
Open land
Coordinate System: WGS 1984 UTM Zone 43N
Projection: Transverse Mercator
Datum: WGS 1984
Author: Patrick Wennström
Date: 23/03/2016
Sensors: Landsat 5 TM, Landsat 7 ETM+, Landsat 8 OLI/TIRS
0 1,5 3 6 9 12
Kilometers

Appendix II


Land cover change detection 1992-2014
N
Ambasamudram
Tirunelveli
Srivaikuntam
Peikulam
0 1,5 3 6 9 12
Kilometers
Legend
Open land to shrubland
Open land to agricultural land
Open land to built-up land
Open land to water
Shrubland to open land
Agricultural land to open land
Built-up to open land
Water to open land
No change
Diminishing pastures
Important pastures
Coordinate System: WGS 1984 UTM Zone 43N
Projection: Transverse Mercator
Datum: WGS 1984
Author: Patrick Wennström
Date: 06/05/2016
Sensors: Landsat 5 TM, Landsat 8 OLI/TIRS

Appendix III

Interview guide: Peikulam herders

Opening the interview

- Name and age:
- Since how many years are you in this occupation?
- Do you have any other occupations besides herding?
- What are your family members doing?
- How many sheep do you own?

Main interview

- Where do you take your sheep for grazing? (Place names, villages, landmarks)
  - Winter:
  - Summer:
- What places do you pass on your way to the grazing grounds? (Place names, villages, landmarks)
  - Winter:
  - Summer
- Are you going to the same grazing grounds today as you did when you started herding?
  - If yes: Do you take the same route?
  - If no: Why? Where did you go before?
- Have you noticed any changes in the landscape on the grazing grounds?
  - If yes: What kind of changes?
- How is it to be a herder today compared to when you started in this occupation?
- What problems or obstacles do you experience as a herder?
  - What do you think is the cause of these problems?
- Have you experienced any of the following problems during your time as a herder?
  - Fencing of farms
  - Roads, railways, or buildings blocking the way
  - Expanding villages
  - Expanding farms
  - Animal diseases
  - Invasive species (prosopis)
  - Diminishing grasslands

Closing the interview

- What do you think about the future of your occupation?
- Is there something that you would like to add?