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Sahelian re-greening - merging a view from above with one from below

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I. Abstract

In the early 2000's scientists noticed an increase in biomass production in the Sahel for the period 1982-2002 (a process which is referred to as 'greening'). The goal of this thesis was to investigate the greening phenomenon at the local scale in 4 villages in south-central Niger and compare results of the investigation with the already available regional scale studies. Theoretical starting points for this study were: the micro-macro scale paradox in the Sahelian studies and the critical research about 'received wisdoms' and environmental narratives of African landscapes. Methods for this study were: visual interpretation of remote sensing data (aerial photographs and satellite images) and collection of farmers' knowledge during a fieldtrip (PRA and personal interviews). This study identified that greening was not a uniform or strong process in four villages. Greening primarily concerned appearance of new trees, whereas big old trees continued to disappear. Not only rainfall was a reason behind greening, but also human factor played a substantial role. The greening phenomenon should be investigated critically, as far as its meaning for the affected land users is not clear.

Key words: greening, environmental degradation, landscape change, land use change, Niger, the Sahel.

II. Preface

The work with this thesis included a fieldwork in Niger organized by a research project based at the Stockholm Resilience Center (further referred as SRC) in cooperation with the Department of Human Geography (Stockholm University) and CRESA (University of Abdou Moumouni, Niamey). The project investigated social-ecological dynamics behind recent landscape changes in the Sahel (last 50 years). The project was particularly interested in possible correlations between the landscape changes and tenure rights, socio-economic activities, international humanitarian interventions, land use innovation techniques etc.

Within the project five students from Stockholm University and six students from University of Abdou Moumouni were selected. In the field students were divided into two different groups, with one of them working in the department of Mayahi and the other one in the department of Miria. Both departments are situated in south-central Niger. The fieldwork for this paper was conducted in Mayahi.

The fieldwork took place in the late rainy season, beginning of dry season 2009, i.e. harvest period (September – October 2009).

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IV. Introduction

a. Background for this study

For the last three decades the global climate and environmental change has been bringing more and more attention in science, media, and politics. Scientists have been asked about consequences of the climate and environmental change for human societies. It has been hard for scientists to answer these questions straightforwardly, because there were myriad of gaps 'in our understanding of the contingent and nonlinear interactions between global climate change, regional land changes, and human vulnerabilities and adaptations to environmental change…' (IPCC, WGI, 2007 as in Lioubimtseva & Henebry, 2009, p. 963). But, there are already places which have been experiencing dramatic shifts in natural conditions due to the climate and environmental change. Studies of these places provide precious knowledge about the influence of the climate change on human societies as well as humans' mitigation and adaptation strategies. The African Sahel is one of the aforementioned places. (Lenton et al., 2008, p. 1789).

In 1970's and 1980's the Sahelian region was subject to an extreme lack of precipitation, which had stark consequences for the population of the region, primarily in the form of a famine. The desertification and drought became important questions on the international agenda, which was reflected at the United Nations Conference on Desertification, held in Nairobi in 1977 (UN, 1997). Since then, understanding of changes in the Sahelian landscapes and climate has been one of the most important questions for the research of arid environments (Batterbury, 1998, p. 361).

An extensive number of scientific articles has been published on the issue of the Sahelian climate and landscape changes – describing the landscape and climate dynamics, identifying consequences of changes for the local population, finding causal links and driving forces (Timberlake, 1985; Brown and Wolf, 1985; Reij & Smaling, 2008; Anyamba & Tucker, 2005; Eklundh et al., 2005; Eklundh & Sjöström, 2005; Herrmann et al., 2005; Seaquist et al., 2008; WRI, 2008; Tougiani et al., 2009). The most common approach in telling the environmental history of the region has tended to describe it as a place of a uniform environmental degradation (Brown & Wolf, 1985, Timberlake, 1985, UNEP, 2003). This presentation of environmental degradation included 'overgrazing and the 'desertification' of drylands, the wide-spread existence of a 'woodfuel crisis', the rapid and recent removal of once pristine forests, soil erosion, and the mining of natural resources caused by rapidly growing populations' (Leach & Mearns, 1996, p. 1). In contrary to that, a number of scientists started to question these assertions by saying that conventional stories of 'gloom and doom' in the form of soil degradation and disappearance of trees were not uniformly true in the Sahel (Leach & Mearns, 1996; Fairhead & Leach, 1996).

Following the critique of conventional stories by Fairhead and Leach (1996) and Leach and Mearns (1996), researchers showed that in many districts of the Sahel loss of vegetation either stopped or return of vegetation took place (process of 'greening' and 're-greening') (Gray, 1999; Reij & Smaling, 2008; Reij et al., 2005; Rinaudo, 2007; Tougiani et al., 2009). Whereas the 'greening' phenomenon has been widely discussed in the scientific literature for the last 5-7 years, there are still many empty spots in this research that should be covered, such as reasons behind different forms of greening in different districts of the Sahel, driving forces of greening (especially human factor), the influence of greening on farmers' livelihood etc.

b. Statement of the problem

A substantial part of the greening research has been done at a coarse resolution with the use of coarse satellite images, coarse demographic and agricultural statistics (Anyamba & Tucker, 2005; Seaquist et al., 2008). Scientists, politicians and researchers used this data to tell the African success stories – how farmers adapted to harsh environment and succeeded in improving it (see: WRI, 2008). But in studies of the Sahel, a micro-macro scale paradox is likely, i.e. the data, concerning landscape and environmental changes, collected at broader scale, could be significantly different from the data collected at a narrower scale (Gray, 1999). The reason for this paradox is that in two different places, which are geographically close to each other, 'greening' or 'desertification' could happen in different forms and at a different speed, due to dynamism of ecosystems in Africa. (Dahlberg, 1996, p.3). Research of greening which is based only on the regional scale data risks misrepresenting the situation. For example, regional data on rainfall might not reflect strong variability of rainfall within the region. (Dahlberg, 1996, p. 4).

At the same time, a significant part of the discussion about greening comes from people having personal interest in the greening story, rather than from impartial researchers (see: Larwanou et al., 2006; Rinaudo, 2007; Tougiani et al., 2009). Members of agroforestry agencies in African countries, employees of international development projects created a discourse of African 'greening'. Due to the attractiveness of the 'greening story', as being a rare case of human success against the changing environment (Polgreen, 2007), the 'greening story' has become a common wisdom. But, already in the middle of 1990's several researchers (Fairhead & Leach, 1996; Tiffen et al., 1994; Leach & Mearns, 1996; Dahlberg, 1996) showed that in the case when the judgment comes from common wisdom, the research should be very careful in giving labels, such as 'degraded', 'green' or 'restored'. In one of the central studies of this theoretical stance, Fairhead and Leach (1996) exemplified how one can 'misread the African landscape' in calling it degraded, based only on the common wisdom. Instead of accepting this common wisdom, the research of changing African environments should treat it critically and analyze it with the help of existing historical data (Fairhead & Leach, 1996, p. 288, Börjeson et al., 2008, p. 525).

In conclusion, a comprehensive understanding of the Sahel's greening should collect the local scale data (local scale cases of greening, farmers' knowledge about greening) and compare this local scale data with the existing data produced at the regional scale. Moreover, this comprehensive understanding should not assume the existence of the greening phenomenon, but rather investigate and understand it historically, as far as ' "change" shouldn't be assumed but empirically verified' (Reij, 2005, p. 419).

c. Motives and goals

The major goal of this thesis was to improve the understanding of the recent environmental changes in the Sahel. In order to reach this goal the following research question has been formulated: **How does the data on greening collected at the local scale correlate with the data on greening collected at the regional scale?**

Based on this research question the following **aims of the study** appeared:

- Study recent changes in the number of trees in four villages in Niger – Garin Sangaya, Gouliske, Warzou, May Sakoni (the interpretation of aerial photographs and satellite images).
- Investigate the environmental history in two villages (Warzou and May Sakoni) based on farmers' knowledge about environment.
- Compare farmers' perceptions of the environmental changes (such as 'green village', 'brown village', 'greening', 'degradation') with the changes around the villages observable on aerial photographs and satellite images.
- Compare the local scale data, collected from the 3 first stages, with the results of the regional wide studies made by previous researchers. Try to understand and explain discrepancies and similarities in two types of data.
- Read through the available scientific papers about environmental change and 'greening' in semi-arid regions (particularly the Sahel) and relate the findings of this thesis to the current debate on the issue.

d. Site description

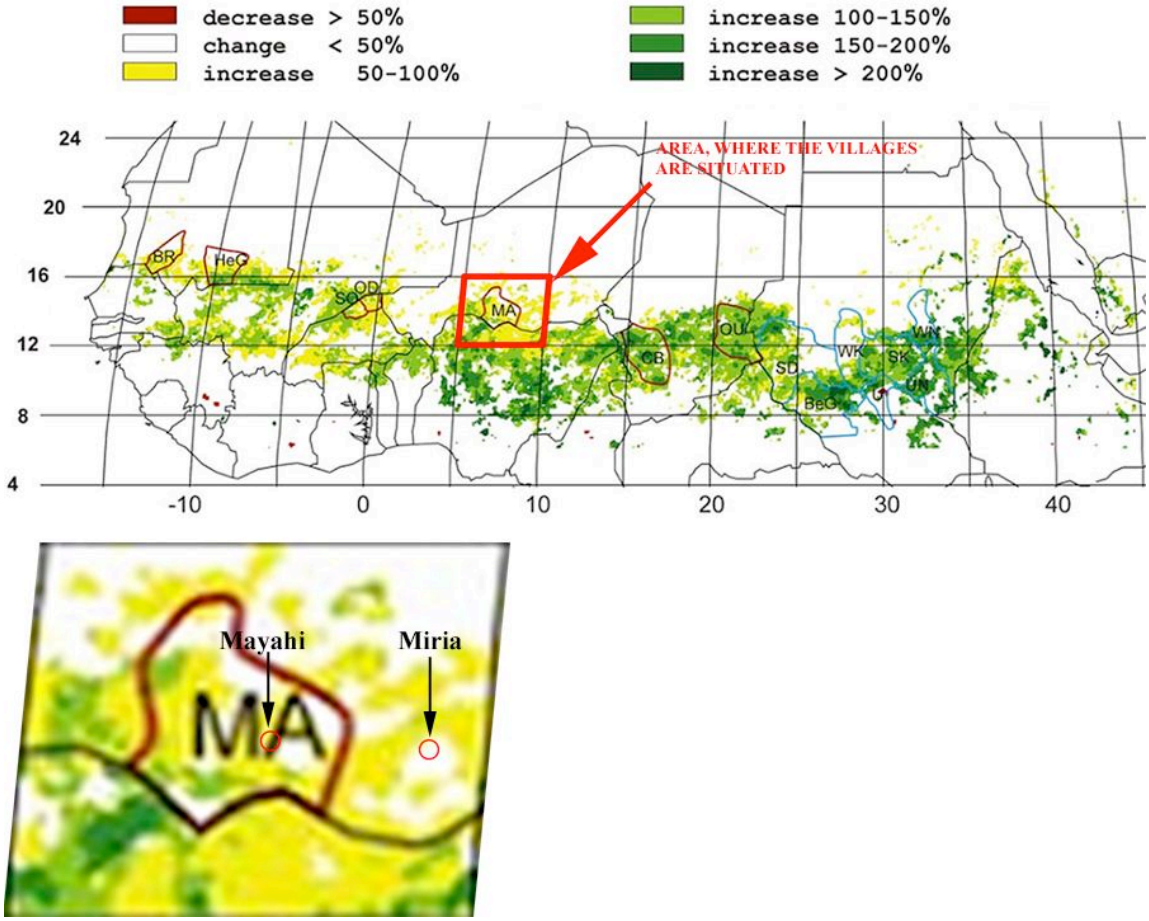

Figure 1 Areas of this study in relation to the NDVI based map of the Sahel (based on Olsson et al., 2005, p. 559)[*]

[*] Olsson, L, Eklundh, L and Ardö, J (2005): 'A recent greening of the the Sahel – trends, patterns and potential causes', *Journal of Arid Environments*, Vol. 63, Issue 3, pp. 556-566.

Niger has been chosen as a place for this study for two reasons. Firstly, changes of landscape in Niger have been in interest of researchers since long time (for example, Aubreville, 1973). After the droughts of 1975 and 1984 the Sahelian countries such as Niger got even bigger interest from the scientific community (Journal of Arid Environments, Vol. 63, Issue 3). Secondly, environmental changes in Niger are not yet completely understood, because scientists can't get an agreement on the driving forces of changes (Seaquist et al., 2008).

In Niger, the south-central parts of the country have been chosen for the study. These parts are the areas where the changes of vegetation are the most explicit (Reij et al., 2005; Rinaudo 2007). At the same time, the particular areas selected for this study have not been studied before, unlike other parts in Niger.

The choice of the villages was done by Nigerien researchers, since they had been working with the issue of greening for a long time, so, their expertise was considered to be the most reliable. The task was to find pairs of villages, where one village was subject to recent greening (green village) and the other one not (brown village). The villages were supposed to have similar biophysical preconditions (e.g. precipitation patterns, topography, parental soil material) and be geographically close to each other. Two pairs of villages selected by the Nigerien counterparts were: Garin Sangaya (brown) and Gouliske (green); May Sakoni (brown) and Warzou (green). May Sakoni and Warzou were situated in the department of Mayahi, in the north- eastern part of the Maradi region. Garin Sangaya and Gouliske were situated in the department of Miria, in the central part of the Zinder region.

Maradi and Zinder regions border with the northern parts of Nigeria, and economies, politics and populations are closely interlinked in these regions.

As it is possible to see on the Figure 1 on page 6, both areas (Mayahi and Miriah) are situated in the areas, where greening was rather average compared to other places in the Sahel, i.e. areas are not in the core of greening and not in the marginal areas. In Mayahi greening was stronger than in Miria. Moreover, according to Figure 1, Miria villages were situated in some sort of a non green trough, where in general the area was subject to patchy greening, but exactly the territories of villages were situated in a non green patch.

Mayahi's and Miria's population is largely sedentary and rural. A majority of the population belongs to the Hausa culture, but there are also settlements of nomadic herders such as Peuhl and Touareg (Banoin & Jouve, 2000, p. 92; Lund, 1993, p. 2).

The climate in south-central Niger is 'typical' Sahelian with a short rainy season (from June to September) and a long dry season (October to May). In the Mayahi department an average rainfall is about 333 mm per year (as much as 200 mm per year in the north of the department and 450 mm in the south) (Banoin & Jouve, 2000, pp. 92-93; Gnomou & Bloch, 2003, p. 2). In Miria, an average rainfall is about 356 mm per year (Lund, 1998, p. 53; Gnomou & Bloch, 2003, p. 2). Variability within the rainy season is high, as well as between rainy seasons of different years; consequently, droughts are a fairly common feature (Banoin & Jouve, 2000, pp. 92-93; Gnomou & Bloch 2003, p. 3; Joet et al., 1998, p. 33). The landscape is relatively flat with minor variations in the altitude. Sandy soils with low fertility are the most common. (Banoin & Jouve, 2000, p. 93).

As far as Mayahi villages are the study sites for this thesis, it is worthy to give more detailed account on them. According to the 2006 census, there are 1143 inhabitants in Warzou and 1269 inhabitants in May Sakoni. Agriculture is one of the

main sources of living in both villages with cassava, millet, sorghum, chickpeas and peanut being the major crops. Agriculture takes place during the rainy season, and fairly often a current harvest is not enough for a household to survive until the next one. Consequently, farmers make their leaving also by small businesses, petty trading and temporary migrations.[*] In both villages, scattered trees are present in agricultural fields and are primarily used by population as firewood, forage, and construction material.

e. Definitions

In order to avoid any misunderstanding, it is necessary to give precise definitions to the terms that are used in this thesis.

Greening	In general, **greening** means an increase in biomass (vegetation) (Olsson et al., 2005). Greening in a more narrow sense includes only an increase **in the number of trees** (Tougiani et al., 2009). The goal of this paper is to study greening historically through the use of aerial photographs and satellite images. Greening in a more narrow sense should be used, because changes in the number of trees are clearer than changes in biomass as a whole on aerial photographs and satellite images.
Degradation	In a broader sense degradation means 'various interrelated processes, such as the deterioration of soil, structure (e.g. the loss of nutrients) and the reduction of biomass (e.g. number and species of wildlife)' (Kessler and Laban, 1994 as in Van Haaften & Van de Vijver, 2003, pp. 85-86). In this study **degradation** is taken in a narrow sense, and it **only means decrease in the number of trees**.
Regional scale	For example, a scale of the Sahel or Niger as a whole. The data made at the regional scale is usually coarse, but covers large territory
Local scale	A scale of one village and its territory.
The village scale visual interpretation of changes	An analysis of changes in the number of trees based on aerial photographs and satellite images, which cover the village territory. The analysis is made through visual interpretation of changes in grid cells. The size of one grid cell is 500 by 500 meters in the terrain
The individual field scale visual interpretation of changes	The analysis of changes in the number of trees based on aerial photographs and satellite images, which cover the territory of one particular field belonging to a farmer, who has been interviewed during the fieldwork.
The village territory	The land belonging to a village. For Warzou and May Sakoni, the coordinates of the village territory, according to villagers' knowledge, were taken during the fieldwork.[†]

[*] This data comes from my colleague (Olivia Puill), who investigated socio-economic aspects of livelihood in Warzou and May Sakoni.

[†] They were collected by Burkinabe colleague Maurice Savadogo

	For these two villages, a village territory means territorial lands within the limits of these coordinates. For Gouliske and Garin Sangaya, these coordinates weren't collected. In this case neighboring villages, observable on aerial photographs and satellite images, served as the limits of the village territory. That was the reason why Goliske's and Garin Sangaya's village territories were significantly bigger than the village territory of Warzou or May Sakoni.
A green village	A village that presumably was subject to recent greening.
A brown village	A village that presumably wasn't subject to recent greening, or was subject to greening, which wasn't as strong as in a green village, or was subject to degradation.
Farmers' knowledge	Farmers' perceptions of greening and degradation (how do they see the chronology of changes in the number of trees); farmers' explanations of driving forces behind greening and degradation; farmers' memories about the events correlating to greening and degradation.

Table 1. Definitions

f. Previous research

Studies based on the remote sensing data

Studies based on the remote sensing data are a large part of the research on the Sahel's greening. This kind of studies became possible with the launch in 1978 of the Advanced Very High Resolution Radiometer (AVHRR) by the National Oceanic and Atmospheric Administration (NOAA). By the beginning of 2000's there was enough data collected by the radiometer to investigate vegetation dynamics in the Sahel. For this purpose researchers used the normalized difference vegetation index (NDVI). NDVI is based on the comparison of infrared and visible surface reflectances. The result of the NDVI method is a raster based map of the Sahelian region, where it is possible to show the vegetation changes in each grid cell (as the one presented in Fig. 1 above). The NDVI serves as a good indicator of changes in biomass production. (Anyamba & Tucker 2005, p. 597 – 599), but with the use of the NDVI the resolution of a grid is 8x8 km on the surface (Anyamba and Tucker, 2005; Seaquist et al., 2008, Olsson et al., 2005).

Based on the NDVI method a number of papers were published (Anyamba and Tucker, 2005; Herrmann et al., 2005; Olsson et al., 2005), which served as a baseline for the studies of greening. Anyamba and Tucker (2005), for example, tried to measure the variability and trends of land surface conditions in the Sahel as represented by vegetation index data. The analysis included the period between July 1981 and December 2003. The method of analysis was the historical comparison of the NDVI only during the growing season in the Sahel, which corresponded to the period between middle of July to the beginning of October. The resolution of the data was 8x8 km., the span of the research was the whole Sahelian belt. In order to explain the driving forces of greening, the researchers compared results of the NDVI historical analysis with the available rainfall data (Anyamba and Tucker 2005, p. 597).

The conclusion of the research paper was that during 1980's the Sahel experienced drier than normal conditions, which corresponded to the negative trends in the NDVI. Since the beginning of 1990's until 2003 the Sahel experienced wetter than normal conditions, which corresponded to the positive trends in the NDVI. Rainfall and greening were closely coupled over the region, but researchers noted a patchy (uneven) increase of NDVI over different regions (particularly over Chad and Mali). The conclusion was that there might be other driving forces of greening besides rainfall (Anyamba and Tucker 2005, p. 610).

Studies of Olsson et al., (2005) and Herrmann et al., (2005) were similar to the one of Anyamba and Tucker (2005). Through the various applications of the NDVI it was proven that between 1982 and 2003 there was greening in the Sahel in the form of up to 50 % increase in the NDVI (Hermann et al., 2005, p. 398). In many areas greening took place faster or slower than could be predicted by rainfall only. Researchers suggested that a further investigation was necessary, which would try to understand weaker causative factors of greening (supposedly human influence) (Herrmann et al., 2005, p. 402).

Seaquist et al. (2008) tried to measure the human influence on greening at the Sahelian scale. They compared the NDVI dataset for the period 1983-2002 with the vegetation dynamics predicted by a vegetation computer model. They also related the results of this comparison to the state-of-the-art datasets on demographics, pasture, and cropping intensity (Seaquist et al., 2008, p. 3048). They reached the conclusion that '(d)emographic and agricultural pressures in the Sahel were largely unable to account for differences between simulated and observed vegetation dynamics… and livestock grazing is generally not an important driver of vegetation greenness in the Sahel' (Seaquist et al., 2008, p. 3054).

The final remark in all the papers presented above (Anyamba & Tucker, 2005, Herrmann et al., 2005, Olsson et al., 2005, Seaquist et al., 2008) was that further investigation of greening phenomenon should be done at a more precise resolution than 8x8 km.

The work by Eklundh and Sjöström (2005) was an attempt to use more precise resolution. The major goal of their research was to compare the results of the NDVI based data at 8x8 km. resolution with the Landsat images for 4 different locations in 4 countries (Niger, Mauritania, Sudan, Central African Republic), and relate them to the rainfall data (Eklundh and Sjöström, 2005, p.1).

Similarly to the previous researchers, Eklundh and Sjöström (2005) reached the conclusion that, based on NDVI analysis, the Sahel experienced greening for the period between 1982 and 2002 (approximately 51 % of analyzed grid cells). Comparison of NDVI and Landsat data with rainfall data lead them to the conclusion that rainfall doesn't completely explain the greening. This comparison also showed that areas with a strong positive trend in NDVI have been greening on Landsat images as well (Eklundh and Sjöström 2005, p. 4). From analysis of Landsat images, it was concluded that greening takes different forms in different areas: in Sudan and Mauritania it was particularly strong; in Central African Republic there were negative changes instead of greening; in Niger greening took place in agricultural fields, which was different from the other three countries.

The conclusion of Eklundh and Sjöström (2005) was that the further understanding of greening phenomenon requires conducting research according to several conditions: 1. to continue measuring greening at a finer resolution than the one

of 8x8 km. coarse resolution of the NDVI data; 2. to conduct interdisciplinary research to measure human influences on greening (Eklundh & Sjöström, 2005, p. 4).

Studies based on the local knowledge of the environment

As one can see from the presentation of the research papers made above, scientists working exclusively with the remote sensing data were quite successful in denoting the greening phenomenon and measuring it at the Sahelian scale. However, these scientists (Anyamba & Tucker, 2005, Olsson et al., 2005, Herrmann et al., 2005, Seaquist et al., 2008, Eklundh & Sjöström, 2005) came up with the conclusion that an exclusive analysis of the NDVI based remote sensing data was not enough to understand the greening phenomenon, because this data failed to explain driving forces behind greening. It was necessary to conduct research with the use of the finer resolution remote sensing data and continue to search for explanations of driving forces. In search for these explanations, some scientists tried to investigate greening phenomena based on interviews, memories and perceptions of local land users (e.g. Rinaudo, 2007, Tougiani et al., 2009, Mortimore, 2005, Banouin and Jouve, 2000).

Tougiani et al., (2009) for example, identified a success story in Niger. In a descriptive form they told the story that, in Niger, introduction of Farmer Managed Natural Regeneration (FMNR) of trees led to the re-greening of 5 millions hectares (Tougiani et al., 2009, p. 377). FMNR included 'systematic selection, pruning, and protection of stems, sprouting from living trees' (Tougiani et al., 2009, p. 381).[*] This technique was invented in the middle of 1980's by the western development agencies and successfully introduced to Niger. In Aguie district of Niger, for example, the use of FMNR together with the Desert Community Initiative (DCI)[†] of farmers led to the sustainable resource management (firewood) (Tougiani et al., 2009, p. 377). The FMNR and DCI were the 'keys to reversing desertification and attaining sustainable rural livelihoods…' (Tougiani et al., 2009, p. 388).

It is possible to find a few studies of the Sahel's greening similar the one by Tougiani et al (2009), e.g. Rinaudo 2007, Banouin and Jouve 2000, Larwanou et al., 2006. But, as Gray (1999) showed, the understanding of changing environments couldn't be told only with the use of photographs or only with the use of interviews, since changes which were 'apparent on one scale (aerial photographs at the regional scale) were met with responses which were apparent at other scales (by conducting interviews with farmers or sampling soils at the field scale)' (Gray 1999, p. 330). In order to understand the greening, it was necessary to coordinate remote sensing data with ethnography, which usually was a difficult task (Lambin and Guyer 1994 as in Gray 1999). The studies based on such coordination are discussed further below.

Studies trying to connect remote sensing data with local knowledge

The basis for this 'combined approach' was the work by Fairhead and Leach (1996), who, in the beginning of 1990's proved how important it was to properly read the changes in African landscape. With a critical approach to the common wisdom

[*] More detailed account on FMNR is presented in Appendix 1.

[†] DCI was an initiative funded by International Fund for Agricultural Development (IFAD). DCI means '(n)ew governance structures, which include marginalized groups, implement monitoring and enforcement systems enabling communities to manage land and regenerating trees' (Tougiani et al., 2009, p. 377). 'Farmers took central role in managing DCI project activities and in planning, organizing and evaluating their own actions' (Tougiani et al., 2009, p. 383).

stories, in this case telling us that farmers were responsible for deforestation, Fairhead and Leach (1996) showed how people actually improved the environments around them. The book by Fairhead and Leach (1996) started a new critical approach to the studies of changing African environments. Through the coupling of historical remote sensing data and interviews, memories and perceptions of local land-users, this approach tried to investigate as thoroughly as possible the reasons behind changes, the importance of human factor for changes, the historical trajectories of landscape changes and the reasons behind the different perceptions of changes by land-users, politicians, researchers etc.

This new theoretical approach influenced the greening research as well. The papers by Gray (1999), Reij et al., (2005) and Reij and Smaling (2008) are a good example.

In their work Reij et al (2005) showed how land use changes in Burkina Faso led to the significant improvement of environment and livelihood. According to them, in 1980's, farmers in Burkina Faso introduced new soil and water conservation techniques (SWC's) as a response to the drought conditions of the 1970's and 1980's (Reij et al., 2005, p. 643). For their study Reij et al., (2005) assumed that SWC's brought significant improvement to livelihood and environment (increase in yield, increase in the number of trees on cultivated lands, greater availability of forage, increased investment in livestock, decreased outmigration etc.) in the northern part of the Central Plateau in Burkina Faso (Reij et al., 2005, p. 644). To investigate these assumptions they coupled different sorts of data related to a number of villages in Burkina Faso: 1. soil samples; 2. farmers' knowledge; 3. high-definition satellite images and aerial photographs. The goal of the research was to compare villages with experience in SWC's with villages, where SWC's were still absent.

Reij et al., (2005) came up with the conclusion that 'on cultivated lands with SWC's one finds an increase in woody species. Many fields were devoid of vegetation until SWC's practices were used. On cultivated fields without SWC's the changes are much less spectacular compared to fields that were rehabilitated with SWC's (Reij et al., 2005, p. 653.). Reij et al., (2005) concluded that SWC were very important factor for the greening in the villages in Burkina Faso, but not the only factor as far as macroeconomic changes also presumably played role in triggering agricultural intensification and environmental improvement (Reij et al., 2005, p. 657).

From different studies, which were similar to the one by Reij et al (2005), Reij and Smaling (2008) claimed that in the Sahel one can find 'a plethora of proven successes in agriculture and land management'. Their examples included Central Plateau in Burkina Faso and the influence of SWC's on the agriculture and vegetation cover, Illela district in Niger and the use of SWC's, woodlots in Ethiopia etc. Authors came up with the conclusion that in Sub Saharan Africa 'there are many successes in the field of crop and animal production, input use and land management, SWC's and farmer empowerment' (Reij and Smaling 2008, p. 418).

Another good example of a multi-scale research of landscape changes in the African context is the work by Gray (1999). In her research that lasted for 8 years in Burkina Faso, Gray (1999) tried to answer the question 'Is land being degraded in southwestern Burkina Faso?' In the notion of degradation, Gray included the changes in forest territory and fallow lands, changes in nutrients, and farmers' knowledge. As a research methodology, she decided to combine data from different scales, such as: broad scale – aerial photos; narrower scale – soil samples in the villages, and farmers'

knowledge about the changes in the quality of soil and their agricultural practices (Gray 1999, p. 330-331).

The conclusion of Gray (1999) was that from the scale of aerial photographs, it is possible to see the degradation, as far as the 'land under cultivation increased at the expense of forest and fallow'. Farmers' knowledge confirmed the results of the aerial photographs analysis. But, from the fields' nutrient analysis, it was impossible to detect significant decrease in the level of nutrients. The reason for these different results from different scales was in the adaptation strategies of farmers, who responded to the lack of fallow land by intensifying their treatment of land. (Gray 1999, p. 339). Gray reached the conclusion that the answer to the question 'Is land being degraded?' depended on scale and scope of enquiry' as well as the definition of 'degradation' (Gray 1999, p.342).

V. Methodology

a. Data sources

Finding answers to the research questions included several stages. First of all, it was necessary to investigate dynamics of changes in the number of trees in four villages of this study. For this purpose historical datasets of aerial photographs and satellite images were an appropriate choice. It was decided to obtain historical sets of photographs and images for as long period as possible covering the same areas in all four villages. In practice I managed to get only the aerial photographs for 1975, the Quickbird satellite images for 2009 (Warzou, Garin Sangaya, Gouliske) and the GeoEye satellite image for 2010 (May Sakoni). These photographs and images served as a first source of data for this study.

Secondly, it was necessary to investigate driving forces behind the changes in the number of trees. From the regional wide studies it was apparent that the rainfall was the main driving force of changes, but there were also minor driving forces (Herrmann et al., 2005). The theoretical setting of this study was that apart from rainfall, it was humans, who create changes in the environment around them (Fairhead & Leach, 1996). It was decided to investigate the human factor through the knowledge of Nigerien farmers, which served as the second major source of data for this study.

Thirdly it was necessary to collect the data concerning the greening phenomena at the regional scale. As far as the regional scale dynamics of greening were well studied before by scientists dealing with the NDVI data (Anyamba & Tucker, 2005, Olsson et al., 2005, Seaquist et al., 2008, Eklundh & Sjöström 2005), previous research served as a third source of data.

b. Methodological strategy

As far as the goal of this thesis was to understand the greening phenomenon rather than quantify it, the emphasis has been on a qualitative methodological strategy. The qualitative strategy was relevant for this thesis, because it allowed understanding '(h)ow humans arrange themselves and their settings and how inhabitants of these settings make sense of their surroundings through symbols, rituals , social structures, social roles and so forth' (Berg, 2007, p. 8).

There was awareness about the disadvantages of the qualitative methodological strategy such as subjectivism, problems with replication, generalization, and lack of transparency (Bryman, 2001, pp. 282-283).

Qualitative methodological strategy was particularly important for generating the data out of farmers' knowledge. **The method of interviews has been used in order to generate the data about the driving forces of greening out of farmers' knowledge.**

An attempt has been made to mitigate the disadvantages of qualitative research strategy through the coupling of the farmers' knowledge data with the data generated out of aerial photographs and satellite images. Still, it was crucial to remember that the goal of this study was to see whether there are changes or not, and if yes, what form they take. Precise measurements of changes (trees per hectare) were outside the scope of this study. Considering these points as well as time constraints of this study, a visual

interpretation of changes in the number of trees was considered to be an appropriate method (Eklundh & Sjöström, 2005). Even if visual interpretation didn't allow producing the exact numbers of trees per hectare, it was enough to see the changes quickly, understand where they were happening and in what forms. **The method of the visual interpretation was used in order to generate the data about the historically observable changes in trees.** This method allowed producing data being detailed enough to compare with farmers' knowledge.

c. Timing

The original setting of this study was to make the analysis of aerial photographs and satellite images first, and then do the fieldwork. Such setting allowed seeing the dynamics of tree changes before the fieldwork, so that fieldwork would be more efficient in regards of the choice of interviewees and themes for interviews. In reality the 1975 aerial photographs were obtained only in late October 2009, after the end of the fieldwork, and the satellite image for May Sakoni came only in February 2010. Hence, stages of this study changed their order. However, the change of the order wasn't necessarily a disadvantage, since I didn't have preconceived idea about dynamics of greening, so that I was less biased in interviewing farmers.

Firstly, there was a fieldwork data collection during 10 weeks stay in the villages of Mayahi region (Warzou and May Sakoni).Secondly, there was interpretation of aerial photographs and satellite images during January, February and March 2010. Thirdly, there was synthesis of data during April and May 2010. Below these stages are described in more details.

d. Methods used in this study

Before the description of the methods used for this thesis it is necessary to mention the issue of ethics. A substantial part of this thesis is based on farmers' knowledge about the changes of landscape around their village, in general, and in their fields, in particular.

During the fieldwork the purpose of interviews and PRA exercises were clearly stated to the participants. Only farmers, who wanted to participate in the study, were chosen.

As far as some stories presented in this thesis might be sensitive for farmers, their names will not be shown. In the discussion on methods below it will be presented that I used the coordinates of the farmers' fields for my analysis of remote sensing data. In order to exclude any possibility to trace back a farmer's story to his field (i.e. to identify a farmer), this part of the remote sensing data analysis will not be shown as well.

Stage 1. Fieldwork Mayahi (Warzou and May Sakoni) September – November 2009

Before (and at the beginning of) fieldwork the background data collection has taken place. It took the form of reading up-to-date scientific papers, accessing and analyzing the historical records and the reports of the involved governmental and non-governmental organizations. In Mayahi (Niger) visited organizations included the agricultural department, hydraulic agency, environmental and forestry protection

agency, as well as existing development projects.

The data collection in the villages included: 1. a participatory rural appraisal (PRA) session with farmers of a village; 2. informal interviews with farmers, who served as key-informants for this study; taking the GPS coordinates of key-informants fields and making simple inventories of woody species.

PRA

The PRA served as a general introduction to the study sites (Reij et al., 2005, p. 645). The PRA also helped for the initial choice of key-informants. People, who showed involvement in answering the questions, or have been pointed by others, as possessing some valuable data, were asked for further interviews (Dahlberg, 1996, p. 7).

Choice of the participants for the PRA sessions was done according to the gatekeeper principle, when research concentrated on the knowledge of key persons of influence (Clayman & Reisner, 1998, p. 179). Chiefs of the villages were chosen as power and knowledge gatekeepers, so, they, themselves, participated in PRA sessions and they selected other participants.

The gatekeeper principle has been chosen because neither students, nor interpreters visited or cooperated with village inhabitants before. Moreover, respect to a gatekeeper guaranteed friendliness and willingness to cooperate from local population.

The use of a gatekeeper brought some additional moments as well. The chiefs of the villages were normally quite elderly people, so their choice of the PRA participants usually included people of their age or even older. Hence, opinions and memories of younger persons tended to be excluded. In order to evade such situations younger person were interviewed separately, although they didn't have the same understanding and changes over time as elderly persons.

A PRA session included creation of historical timelines for a village and a mental map of a village.

The historical timelines addressed major political events, as well as changes in such parameters as rainfall, soil fertility, harvest productivity, tree density, firewood accessibility and the adaptation strategies during famine.

A mental map of a village and the village territory has been done in order to see the community's vision of their village. Mapping included drawing on the ground of a simple map including major buildings of the village, roads, neighboring villages, wells etc. After farmers had created a rough sketch of their village, they were asked to show the differences in soil fertility around the village. In order to do that they have been asked to show their own fields and compare the fertility in relation to the fields of their neighbors.

In total, the PRA in Warzou took two sessions (about 3 hours each) with about twenty farmers as participants, whereas the PRA in May Sakoni took two sessions (about 2 hours each) with about 8-10 farmers as participants.

Coherent with the previous research (Reij et al., 2005; Gray, 1999), the use of the PRA turned out to be useful for this study. It was possible to get farmers interest as well as to suggest them simple and clear techniques to answer the questions. Getting farmers' knowledge on changes (on firewood accessibility, trees' density etc.) were particularly efficient with the use of the PRA.

There were negative points with the use of the PRA as well. Group discussions with farmers brought big attention from the village inhabitants. In such conditions some of the participants felt shy in answering questions. It was possible to partly solve this problem by asking same questions in different forms.

Personal Interviews

After the PRA sessions, interviews with the selected key-informants took place. In total, 13 farmers were interviewed. Interviews were held in the fields belonging to farmers, since the basic idea was to tie the story of a farmer concerning land use and landscape changes as close as possible to the actual terrain (Börjeson, 2004, p. 60).

There were 9 questions for interviews, which were divided in 3 clusters. The following subjects has been addressed during the interview: cluster one – general data about a farmer and his/her field (since when he/she has been cultivating the field; variations of harvest during the cultivation etc); cluster two – historical changes in tree density on the field and reasons behind them, historical changes in land use and reasons behind them, farmers knowledge about greening and degradation processes; cluster three – farmers handling and protection of trees, interactions with nomadic herders concerning the use of trees.*

In spite of the existence of these clusters of questions interviews took a very informal form, where the questions were rather general subjects of discussion. If a particular topic became specifically interesting the contents of an interview could have deviated substantially from the initial questions.

Before and during the interviews coordinates of the fields' borders were taken with a GPS. At the same time, the inventory of woody species on the field has been made. These data has been collected for the use during the aerial photographs and satellite images visual interpretation.

After the end of an interview the snowballing principle has been used for the choice of a next interviewee. It meant that the current respondent was asked about other persons, who might be interesting for interviewing, because they possessed important knowledge or memories (Goodman, 1961 as in Eland-Goossensen et al., 1997, p. 319). The reason for the use of snowballing was that in interviewing farmers, the most important thing was to create the story of landscape and land use changes as comprehensively as possible, even if this story would come from a limited number of people (i.e. quality was more important than quantity). The snowballing principle permits to find persons, who possess valuable information without spending resources (primarily time) (Eland-Goossensen et al., 1997, p. 319). The snowballing principle turned out to be quite helpful in this research, since almost every interview added some new information about land use and landscape changes. Moreover, farmers, chosen by this technique, normally were quite cooperative and active in answering questions.

In the fieldwork the major interest was to collect qualitative data about how farmers and environment affect each other. In this case the study was about farmers who experienced changes and/or responded to them, rather than about farmers who didn't. That was the reason for setting precise parameters on snowballing. The following parameters have been given to farmers for snowballing: 1. a person possessing valuable information about landscape and land use changes (for example, cultivating the fields since long time, or introduced an innovation technique, or was specifically successful in keeping his field fertile and green); 2. the position of the field in relation to the village (so to cover various directions from the village); 3. a person having more than one field (in order to collect knowledge of the same farmer related to different fields. I thought that farmers might have different experiences from the fields situated at different distances from human settlements, because of the varying access to the land on behalf

* A complete list of questions is presented in Appendix 2.

of other land users. That turned out to be true).

Setting precise parameters on snowballing led to a limitation of the data collected during the fieldwork. The collected data reflects knowledge of farmers, who experienced changes in trees on their fields. The data doesn't reflect opinions of farmers who didn't experience changes.

Sometimes some stories about landscape and land use repeated themselves, because the current interviewee was a close friend or a relative of the previous person. In this case an advice of the chief of the village has been asked for the choice of the next interviewee.

Stage 2. Visual Interpretation of Changes on Aerial Photographs and Satellite Images

Upon return to Stockholm, an access to the aerial photographs from 1975 (IGN 1975 Maradi ND 32 VIII; IGN 1975 Zinder EST ND 32 X)* and the satellite images from 2009-2010 (images from the Quickbird satellite: village of Warzou, taken on 12th of September 2009, villages of Garin Sangaya and Gouliske, taken on 20th of September 2009; images from the GeoEye satellite: village of May Sakoni, taken on 10th of March 2010) has been provided.

The scale of 1975 aerial photos was equal to 1:60000. Photographs were black and white. The image from the GeoEye satellite was multispectral with the spatial resolution of 1.65 by 1.65 meters. The images from the Quickbird satellite were multispectral with the spatial resolution of 1.84 by 2.44 meters.

1975 aerial photos have been scanned on a high quality scanner at the resolution of 1588 pixels per square inch, with the consequent approximate spatial resolution of 0.96 by 0.96 meters.

Satellite images have been converted to 8 bit colored images through the color channel redistribution and reconversion in Photoshop. The major disadvantage of this method is the loss of authentic coloring. However, for the purposes of this study 8 bit satellite images were considered as more than sufficient for their visual comparison with 1975 photos.

With the help of Google Earth and Adobe Photoshop the lines marking the coordinates of the villages' territory and the fields of the interviewed farmers have been overlaid on the satellite images and aerial photos. From that the matching pairs of composite photos and images have been selected. The images and photos have been trimmed to represent only the territory of a village. At last, for each village there was a pair of photo and an image (one from 1975, another from 2009 (2010 in case of May Sakoni)) covering the same territory.

Further, through the use of Garmin Map Source and Adobe Photoshop, a grid has been created on each photo with a grid cell size of 500 by 500 meters in the terrain. At this stage visual interpretation of greening has been conducted.

Interpretation of greening based on aerial photographs and satellite images has been done for all four villages (in Mayahi and Miria). The fieldwork was conducted only in Mayahi, so there were no data on the coordinates of the fields and farmers knowledge from Miria. Therefore, for the villages in Miria region the visual

* Seasonality is an issue that was not addressed within this study. It was decided that, even if photos are taken in different seasons of a year, trees are still there, and it will be possible to see them on a photograph. This supposition turned out to be true, but still the issue of seasonality is a reasonable critique to this thesis.

interpretation has been done only at the village scale. For the villages in the Mayahi region it has been done at the individual field scale and at the village scale.

Visual interpretation included following stages:

1. **Detecting changes and interpreting them.** This stage was dedicated to the preliminary detection of changes in the number of trees. **The major goal of the visual interpretation was to see whether there were any changes or not. If there were changes, where they happened and in what forms.** The interest was to see changes, and only then try to categorize them. Categories and classes that are presented below were created only after this preliminary detection and interpretation of changes. The categories and classes were created to represent as clearly as possible the changes observable on the photographs.
2. **Definition of categories.** During the first group interview in Warzou, it became clear that farmers separate changes in trees into two different categories: changes in big trees and changes in small trees. It was decided that it might be useful to use the same categories for the visual interpretation. Changes in each grid cell were interpreted as changes in big trees and changes in small trees. Big trees were distinctive black or dark green dots, with the diameter not less than a millimeter at the scale of 1:30000. Small trees were distinctive black or dark green dots, with the diameter less than a millimeter at the scale of 1:30000. On 1975 photographs trees were not always clearly identifiable (due to the quality of the photos). In this case, photographs from 2009 helped to interpret the photographs from 1975.*
3. **Definition of classes.** In each category several classes were created. For big trees it was: Class 0 – no big trees at all; Class 1 – 'few trees' – 1 or 2 trees on a grid cell; Class 2 – 'average number of trees' – 3 to 6 trees on a grid cell; Class 3 – 'many trees' – more than 7 trees on a grid cell. For small trees the classes were: Class 1 – 'few trees' – circa less than 10 percent of an area of a grid cell covered with small trees; Class 2 – 'average number of trees' – circa half of an area of a grid cell is covered with small trees; Class 3 – 'many trees' – whole area of the grid cell is covered with small trees. The same classes were used for all four villages
4. **Creation of the example charts**. For each class of each category a most representative grid cell was selected both from 1975 photo and 2009 photo. These most representative grid cells were used as example charts to interpret the aerial photographs and satellite images.
5. **Village scale visual interpretation of changes**: every grid cell from both images (1975 and 2009) were regarded and related to one of the classes with the help of the charts created at the stage 4. Grid cells covering the same territory were analyzed simultaneously. If a grid cell didn't experience changes in the number of trees, then the same class has been given to this grid cell. If a grid cell experienced greening, then it was reflected in giving a higher class to it on a 2009, 2010 image. If a grid cell experienced degradation, then it was reflected in

*Sometimes 1975 aerial photographs gave an ambiguous impression: it was hard to say whether it was a tree or not on a photograph. Due to the quality of the photos, trees became too bright on the photograph (they were not dark grey anymore, but rather light grey). In case of old and big trees, 2009-2010 satellite photographs helped to distinguish trees from technical flaws.

giving a lower class to it on a 2009, 2010 image.

6. When the visual interpretation has been finished for the whole village territory, MS Excel tables were made, which showed the number of grid cells of each class in 1975 and in 2009, 2010.
7. **Individual field scale visual interpretation of changes (only Warzou and May Sakoni).** The grid cells with the fields of the interviewed farmers have been copied from the photographs and images of the village territory. After that, the interpretation of changes has been done using the same classes as during village scale interpretation of changes.
8. **Creation of the color encoding chart. C**hanges in classes have been color encoded: with blue color meaning degradation on the cultivated land, red color meaning greening on the cultivated land. The logic behind the chart was as follows. Firstly, the changes in classes were ranged according to the primary parameter: 1. for changes meaning greening, the more trees there are on the field nowadays, the stronger the color is; 2. for changes meaning degradation, the fewer trees there are on the field nowadays, the stronger the color is. Then, the changes were ranged according to the second parameter – the magnitude of changes, i.e. how strong greening/degradation was. The bigger the magnitude of changes (both greening and degradation), the stronger the color is. No coloring means absence of changes. The example of the color encoding chart is provided below.

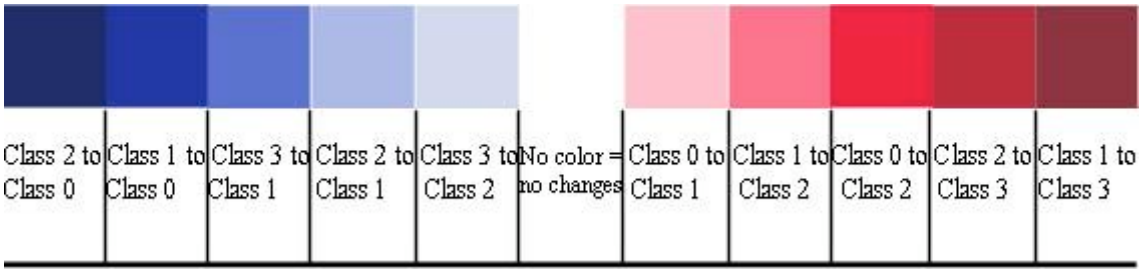

Figure 2 Color encoding chart

9. **Creation of the color encoded 'images of changes'**.
    - Village scale (all four villages). On the 2009, 2010 satellite images grid cells that changed classes were color encoded according to the chart. As a result for each village there were two color encoded 'images of changes': one showing changes in big trees and another showing changes in small trees.
    - Individual field scale (only Warzou and May Sakoni). Changes on the fields of interviewed farmers were color encoded as during the previous stage. The result of this work was a part of a satellite image, on which the limits of a field were shown. The area within the limits was color encoded according to the chart. The images of this part of the visual interpretation will not be presented due to ethical considerations, but an example which represents changes in trees on a **fictional field** in a shape of a square is shown in Figure 3.

Figure 3 Example of the individual field scale visual interpretation

Stage 3. Synthesis of data

Firstly, the s**ynthesis** has been done **for the data collected and analyzed within this study.** This synthesis was based on the **summary on the visual interpretation of changes and the summary on farmers' knowledge.**

The work over these summaries included four stages:

1. **Synthesis of the data from the village scale visual interpretation of changes (all four villages)**. For all four villages trees dynamics for the last 35 years were summarized.
2. **Comparison between the results of the individual field scale interpretation with the results of the village scale interpretation (only May Sakoni and Warzou)**. A corresponding part of the image of changes from the village scale visual interpretation was put together with the image of changes from the individual field scale interpretation. Then, I could see, whether there were discrepancies between the two interpretations, and, if they were, I tried to understand why.
   This comparison has been done for two reasons. First, to double check the method of visual interpretation.* Second reason for this comparison was to see whether there are differences in tree dynamics between a field of a farmer and the grid cell (s), where this field is situated. It was suspected that even at the scale of 500x500 meters, it would be possible to see different dynamics of trees in the fields belonging to different farmers.
   It will not be possible to present this part of the analysis in the results due to the question of ethics. Therefore, a **fictional example** of the comparison is shown in the Figure 4. There are two images from two different types of visual interpretation. The one to the left represents the color encoded farmer's field. The one to the right is the same area taken from the village scale visual interpretation. Such comparison has been done for the fields of all interviewed farmers. Results of this comparison will be presented in the Table 10 with a subsequent discussion.

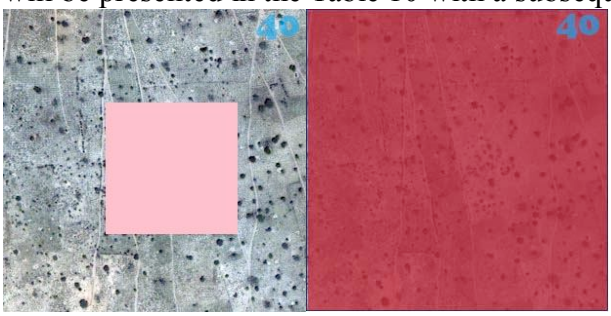

Figure 4 Example of the comparison between the results of the individual field scale visual interpretation and the village scale visual interpretation

* The visual interpretation is based on a personal interpretation and there is always a risk of making it wrongly. This comparison allowed checking the interpretation, because the visual interpretation at the village scale is different from the visual interpretation at the individual field scale. On the individual field scale, it is easier to concentrate on disappearance or appearance of individual trees. On the village scale, it is necessary to concentrate on the impression from the photos, as far as it is impossible to go to each individual tree on a grid cell.

3. **Synthesis of the data from group and personal interviews (only May Sakoni and Warzou)**. Data from personal and group interviews was analyzed and general conclusions were made.
4. **Synthesis of the data from interviews with the data from the aerial photographs and satellite images' (only Warzou and May Sakoni).** At this stage an effort has been done to understand, how the data from interviews helps to understand the dynamics observable on aerial photographs and satellite images.

When the summaries (on the visual interpretation and the farmers' knowledge) were ready, the data from them was compared with **the regional scale data on greening**. It meant that an attempt has been done to compare the results of this study with the results of the published articles dealing with greening phenomenon at the regional scale. After this comparison the discussion has been made addressing the relation of this thesis for the greening research.

VI. Results

a. The Visual Interpretation of Changes

Mayahi department

Warzou

In Warzou changes on 71 grid cells, which covered the village territory, were interpreted. Below, the joint tables of the interpretation and the images of changes are shown:

Big trees

	1975	2009
Class 0	24	23
Class 1	20	24
Class 2	17	19
Class 3	10	5

Table 2. Warzou, changes in big trees

6 grid cells (# 1, 2, 19, 24, 28, 33) changed their classification from Class 0 to Class 1. 5 grid cells (# 52, 53, 59, 60, 71) changed their classification from Class 1 to Class 2. 1 grid cell (# 69) changed its classification from Class 2 to Class 3. Total number of grid cells with greening is 12.

5 grid cells (# 46, 47, 48, 55, 58) changed their classification from Class 1 to Class 0. 3 grid cells (# 14, 27, 32) changed their classification from Class 2 to Class 1. 1 grid cell (# 41) changed its classification from Class 3 to Class 2. 3 grid cells (# 40, 49, 50) changed their classification from Class 3 to Class 1. Total number of grid cells with degradation is 12.

Small trees

	1975	2009
Class 0	0	0
Class 1	10	4
Class 2	26	29
Class 3	35	38

Table 3. Warzou, changes in small trees

6 grid cells (# 10, 29, 37, 48, 58, 66) changed their classification from Class 1 to Class 2. 6 grid cell (# 19, 28, 30, 40, 41, 50) changed their classification from Class 2 to Class 3. Total number of grid cells with greening is 12.

3 grid cells (# 43, 51, 52) changed their classification from Class 3 to Class 1. Total number of grid cells with degradation is 3.

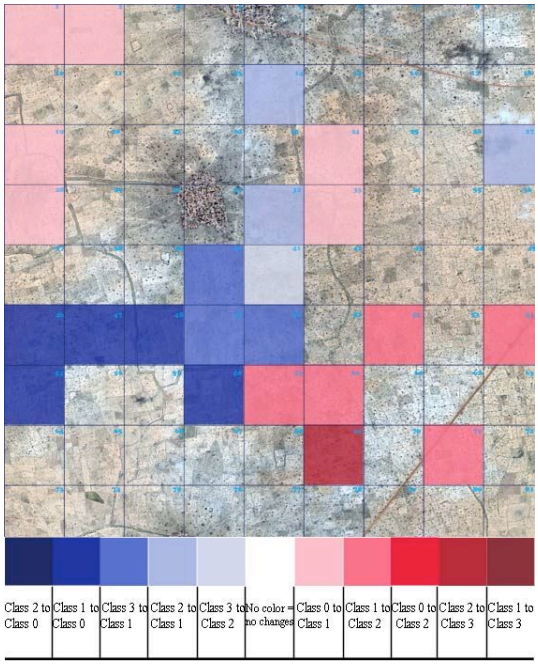

Figure 5 Image of changes ,Warzou, , big trees.

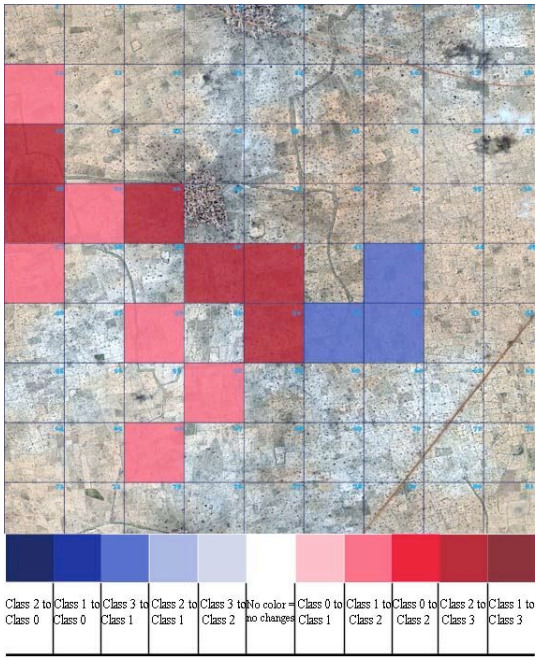

Figure 6 Image of changes ,Warzou, small trees.

Warzou summary:

The number of big trees stayed stable in Warzou, even if changes in big trees happened on roughly 34 % of grid cells (24 out of 71). Out of 24 grid cells with changes 12 showed greening and 12 – degradation.

The village territory of Warzou was subject to greening in small trees. Changes involved 21 % of grid cells (15 out of 71). Both greening and degradation were present, but the signal of greening was significantly stronger than the signal of degradation.

Both in big trees, and in small trees, grid cells with changes tended to be situated in patches. This situation was particularly clear in case of the grid cells with degradation: a patch in south-western direction (from Warzou) in big trees, and a patch in south-eastern direction in small trees.

Grid cells were subject to different dynamics in big trees and small trees, i.e. a grid cell, which was subject to greening/degradation in big trees, wasn't subject to greening/degradation in small trees (further in the thesis such situation will be referred as 'difference of dynamics'). For example, whereas 3 grid cells to the south of Warzou (# 40, 41, 50) were subject to greening in small trees, in big trees they were subject to degradation. Only two grid cells (# 19, 28) were subject to similar dynamics of changes (greening) both in big trees and small trees.

May Sakoni

In May Sakoni changes on 49 grid cells, which covered the village territory, were interpreted. Below, the joint tables of the interpretation and the images of changes are shown:

Big trees

	1975	2010
Class 0	17	12
Class 1	31	27
Class 2	1	7
Class 3	0	3

Table 4. May Sakoni, changes in big trees

4 grid cells (# 5, 8, 11, 36) changed their classification from Class 0 to Class 1. 1 grid cell (# 20) changed its classification from Class 0 to Class 2. 5 grid cells (# 24, 30, 31, 32, 41) changed their classification from Class 1 to Class 2. 3 grid cells (# 18, 19, 26) changed their classification from Class 1 to Class 3. Total number of grid cells with greening is 13.

Small trees

	1975	2010
Class 0	0	0
Class 1	20	12
Class 2	29	31
Class 3	0	6

Table 5. May Sakoni, changes in small trees

7 grid cells (# 24, 27, 30, 31, 44, 47, 48) changed their classification from Class 1 to Class 2. 1 grid cell (# 19) changed its classification from Class 1 to Class 3. 5 grid cells (# 2, 4, 12, 18, 26) changed their classification from Class 2 to Class 3. Total number of grid cells with greening is 13.

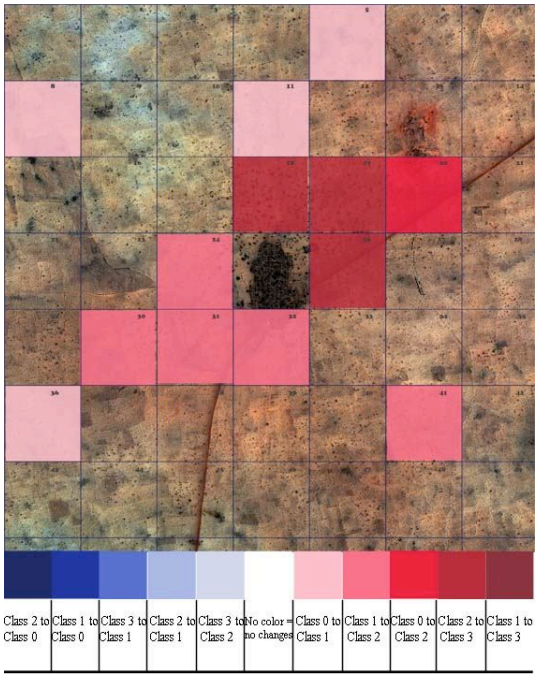

Figure 7 Image of changes, May Sakoni, big trees

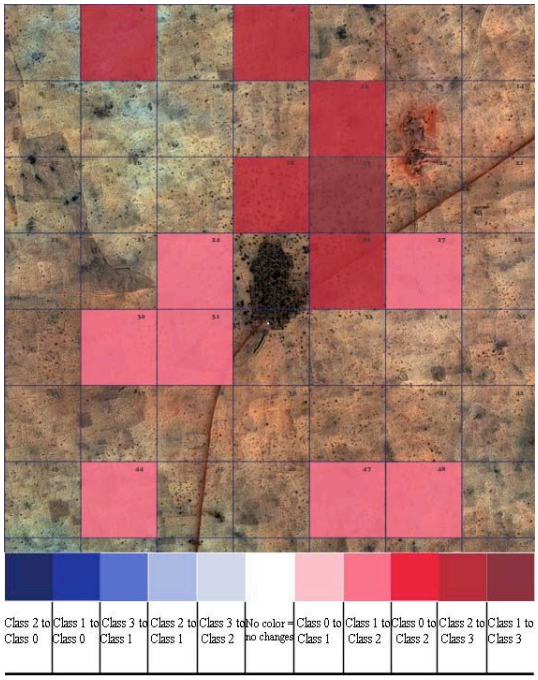

Figure 8 Image of changes, May Sakoni, small trees

May Sakoni summary:

In May Sakoni, the village territory was subject to greening in big trees and small trees. In both cases greening was present on 20 % of grid cells (13 out of 49). There were no grid cells showing degradation.

Major part of grid cells with changes was situated in two patches in south-western, and north-eastern direction from May Sakoni. Within these two patches similar dynamics of changes could be observed both in small trees and in big trees on the majority of grid cells, i.e. if a grid cell was subject to greening in small trees, then it was also subject to greening in big trees (further in the thesis such situation will be referred as 'similarity of dynamics').

Miria department

Gouliske

In Gouliske changes on 143 grid cells, which covered the village territory, were interpreted. Below, the joint tables of the interpretation and the images of changes are shown:

Big trees

	1975	2009
Class 0	51	52
Class 1	43	50
Class 2	29	30
Class 3	20	11

Table 6. Gouliske changes in big trees

4 grid cells (# 54, 79, 93, 136) changed their classification from Class 0 to Class 1. 1 grid cell (# 81) changed its classification from Class 1 to Class 2. 1 grid cell (# 48) changed its classification from Class 2 to Class 3. Total number of grid cells with greening is 6.

5 grid cells (# 22, 23, 38, 47, 63) changed their classification from Class 1 to Class 0. 2 grid cells (# 59, 90) changed their classification from Class 2 to Class 1. 4 grid cells (# 1, 2, 3, 5) changed their classification from Class 3 to Class 2. 6 grid cells (# 15, 16, 26, 27, 56, 100) changed their classification from Class 3 to Class 1. Total number of grid cells with degradation is 17.

Small trees

	1975	2009
Class 1	34	16
Class 2	43	61
Class 3	66	66

Table 7. Gouliske, changes in small trees

9 grid cells (# 33, 62, 68, 117, 131, 137, 138, 140, 141) changed their classification from Class 1 to Class 2. 1 grid cell (# 104) changed its classification from Class 2 to Class 3. 9 grid cells (# 32, 40, 41, 42, 43, 44, 52, 53, 54) changed their classification from Class 1 to Class 3. Total number of grid cells with greening is 19.

10 grid cells (# 4, 5, 6, 14, 15, 27, 34, 46, 47, 100) changed their classification from Class 3 to Class 2. Total number of grid cells with degradation is 10.

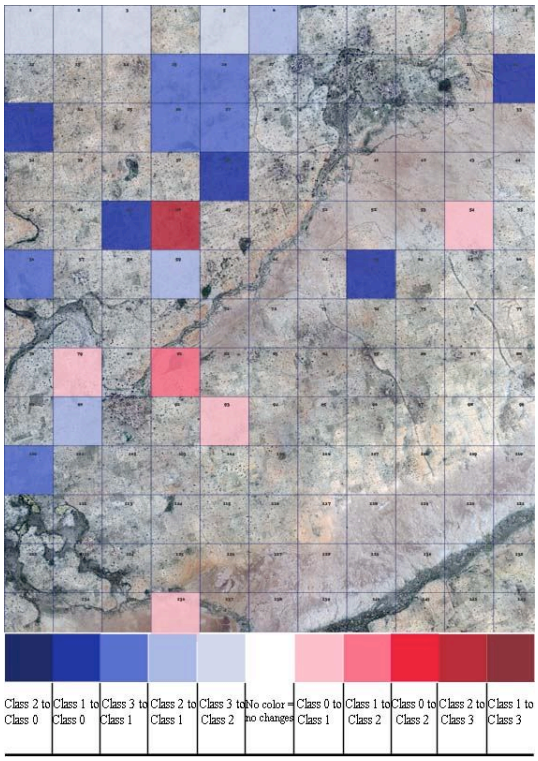

Figure 10 Image of changes, Gouliske, big trees

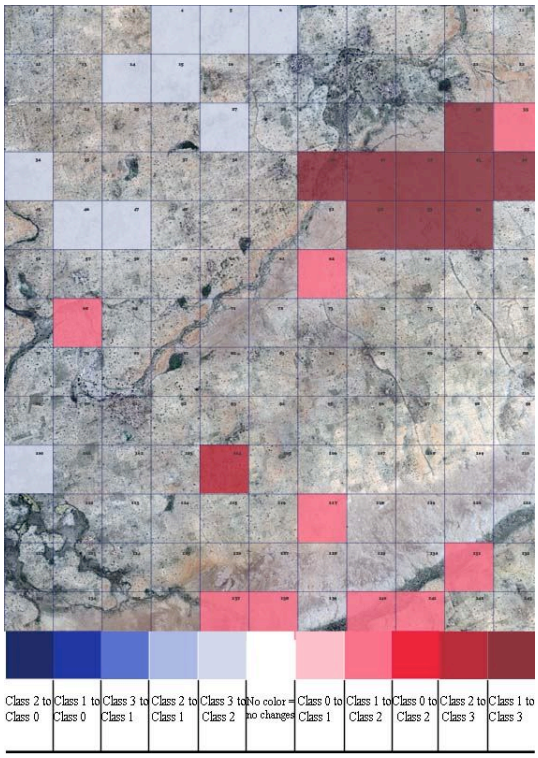

Figure 9 Photograph of changes, Gouliske, small trees

Gouliske summary:

The village territory of Gouliske was subject to degradation in big trees. Changes involved 18 % of grid cells (23 out of 143).

In small trees both greening and degradation were present in Gouliske, but the signal of greening was stronger than the signal of degradation. Changes involved 20 % of grid cells (29 out of 143).

Both in big trees and small trees grid cells with changes tended to be situated in patches: for example, the patch with degradation in big trees to the north of Gouliske, or the patch with greening in small trees to the north-east.

Both in big trees and small trees majority of grid cells with degradation were situated in the area to the north of Gouliske. There were 5 grid cells with similarity of dynamics – they were subject to degradation both in big trees and in small trees. In this area the degradation signal was stronger in big trees than in small trees.

There were very few grid cells with greening in big trees. These grid cells were scattered over the village territory. For small trees, however, majority of grid cells with greening in small trees were in a patch to the north-east of Gouliske. These grid cells were almost barren in 1975.

Garin Sangaya

In Garin Sangaya changes on 120 grid cells, which represented the village territory, were interpreted. Below, the joint tables of the interpretation and the images of changes are shown:

Big trees

	1975	2009
Class 0	16	11
Class 1	36	39
Class 2	42	50
Class 3	26	20

Table 8. Garin Sangaya, changes in big trees

5 grid cells (# 84, 94, 104, 106, 119) changed their classification from Class 0 to Class 1. 6 grid cells (# 35, 42, 51, 65, 71, 116) changed their classification from Class 1 to Class 2. 2 grid cells (# 45, 64) changed their classification from Class 2 to Class 3. Total number of grid cells with greening is 13.

2 grid cells (# 16, 43) changed their classification from Class 2 to Class 1. 6 grid cells (# 47, 61, 74, 76, 109, 110) changed their classification from Class 3 to Class 2. 2 grid cells (# 62, 75) changed their classification from Class 3 to Class 1. Total number of grid cells with degradation is 10.

Small trees

	1975	2009
Class 0	0	0
Class 1	6	9
Class 2	38	26
Class 3	76	85

Table 9. Garin Sangaya, changes in small trees

1 grid cell (# 84) changed its classification from Class 1 to Class 2. 12 grid cells (# 7, 8, 27, 30, 35, 42, 43, 45, 77, 109, 110, 111) changed their classification from Class 2 to Class 3. Total number of grid cells with greening is 13

4 grid cells (# 82, 93, 119, 120) changed their classification from Class 2 to Class 1. 3 grid cells (# 61, 62, 97) changed their classification from Class 3 to Class 2. Total number of grid cells with degradation is 7.

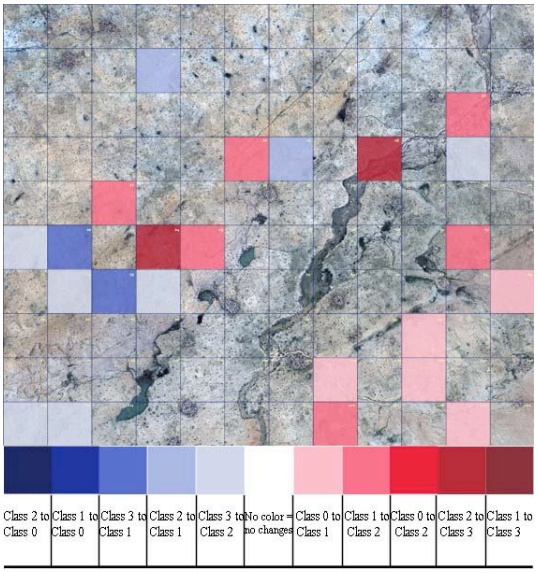

Figure 11 Image of changes, Garin Sangaya, big trees

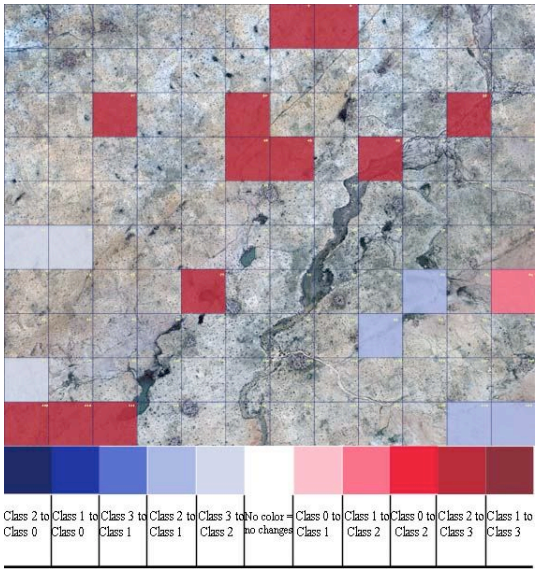

Figure 12 Image of change, Garin Sangaya, small trees

Garin Sangaya summary

There was no clear pattern of changes in big trees around Garin Sangaya. Changes in both directions (greening and degradation) have happened. Changes involved about 19 % of grid cells (23 out of 120).

In small trees changes in both directions (greening and degradation) took place, but the signal of greening was stronger than the signal of degradation. Changes involved about 17 % of grid cells (20 out of 120).

Both in big trees and small trees grid cells with changes were situated in small patches scattered over the village territory. Neither similarity of dynamics nor difference of dynamics was particularly evident in Garin Sangaya. There was one area to the west of Garin Sangaya which was subject to degradation in big trees (5 grid cells), and small trees (2 grid cells).

Summary on the Visual Interpretation of Changes

As it was presented in the introductory parts of this thesis, it is impossible to present the images of changes from the individual field scale visual interpretation due to the issue of ethics. However, that interpretation has been done for each and one of the fields of the interviewed farmers. Even if it is impossible to show the actual results of the individual field scale visual interpretation of changes, the summary on this interpretation is presented below. So, the summary on **big trees is:**

- According to the individual field scale interpretation, in Warzou only one field out of nine was subject to changes in big trees. This field was subject to greening. In May Sakoni three fields out of seven were subject to greening. Neither in Warzou, nor in May Sakoni there were fields with degradation.
- According to the village scale interpretation, in three out of four villages, grid cells with changes comprised less than 20 % of the total number of grid cells. Only in Warzou changes involved 40 %.
- According to the village scale interpretation, May Sakoni was the only village, where the village territory was subject only to greening. In three other villages both greening and degradation were present on the village territory. Majority of grid cells with greening in May Sakoni (8 grid cells) happened in two, adjacent to the village, patches (to the north-east and south-west) The patch to the north-east has experienced particularly strong greening (from Class 1 to Class 3, and from Class 0 to Class 2).
- According to the village scale interpretation, there was no clear pattern of changes in big trees around Garin Sangaya and Warzou. Changes in both directions (greening and degradation) have happened.
- According to the village scale interpretation, the village territory of Gouliske was subject to degradation. 6 grid cells with greening were situated in a scattered manner and their changes in big trees were rather weak. Grid cells with degradation form a big patch in northern direction from Gouliske. It should be noted that these patch is very far from Gouliske.
- Patchiness of grid cells with changes is typical to all four villages.

Small trees:

- According to the individual field scale interpretation, in Warzou five fields out of nine were subject to greening in small trees. In May Sakoni three fields out of seven were subject to greening. Neither in Warzou, nor in May Sakoni there were fields with degradation.
- According to the village scale interpretation, in all four villages, grid cells with changes (negative and positive) presented less than 20 % of the total number of assessed grid cells.
- According to the village scale interpretation, Warzou and May Sakoni were subject to greening in small trees. The changes took the following forms: from Class 1 to Class 2; from Class 2 to Class 3. Only May Sakoni out of all four villages didn't have grid cells with negative changes.
- According to the village scale interpretation, in Garin Sangaya and Gouliske both greening and degradation took place. But, the signal of

greening was stronger than the signal of degradation.

- According to the village scale interpretation, in 3 villages (Warzou, May Sakoni, Gouliske) grid cells with changes tended to be situated in patches, i.e. involving 2 or more adjacent grid cells.

b. Farmers' knowledge (Warzou and May Sakoni)

This part is dedicated to the individual farmers' knowledge. It should be said that the body of the text represents only farmers' responses, my comments, if any, are presented in footnotes.

Group interviews (PRA)

Warzou

Since the very first question about the evolution of trees in Warzou, farmers separated the notions of small trees and big trees.

Big trees: For farmers a big tree is a tree higher than 10 meters.

Small trees: for farmers, a small tree is any tree ranging from a small sprout and up to quite a big tree (5-6 years old) up to 5-7 meters.

According to farmers, since 1960's and untill today, the quantity of big trees has been consistently decreasing. Insufficient rainfall and falling soil productivity have been making it difficult for big trees to survive in the fields.

According to farmers, smaller trees followed the decrease tendency until 1980s. Around 1989 it was the lowest quantity of trees of any kind – both small and big. If the process of decrease would have continued with the same pace as it was in 1980s, today one wouldn't be able to see any trees in the field. However, since 1980's the quantity of smaller trees started to increase due to intentional preservation of sprouts. Farmers said that big trees have been disappearing and they were replaced by smaller trees. Many times farmers mentioned the importance of FMNR for the success in regeneration of young trees.

From the group interview in Warzou farmers' perception of changes in the number of trees could be presented in the Diagram 1.

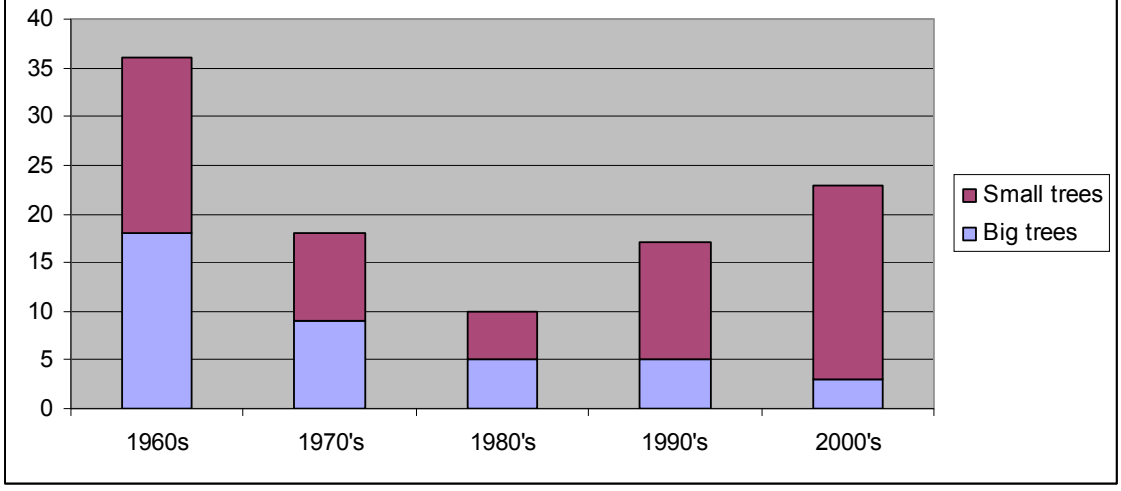

Diagram 1, Evolution of tree quantity in Warzou (from group interview)

May Sakoni

According to farmers, the history of tree density in May Sakoni show a persistent decrease since 1950s until today. The reason for this decrease was the increase in the population, which caused rising pressure on land. The rising pressure on land together with the lack of rainfall led to a very quick degradation of soils and disappearance of trees.

Sprout preservation techniques appeared in May Sakoni not earlier than 2004. According to farmers, since then there was an increase in the number of small trees, but this increase situation was not that common. Farmers were not able to separate their memories about big trees and small trees, e.g. they said that small trees followed the same pattern of changes as big trees.

From the group interview in May Sakoni farmers' perception of changes in the trees could be presented in the Diagram 2.

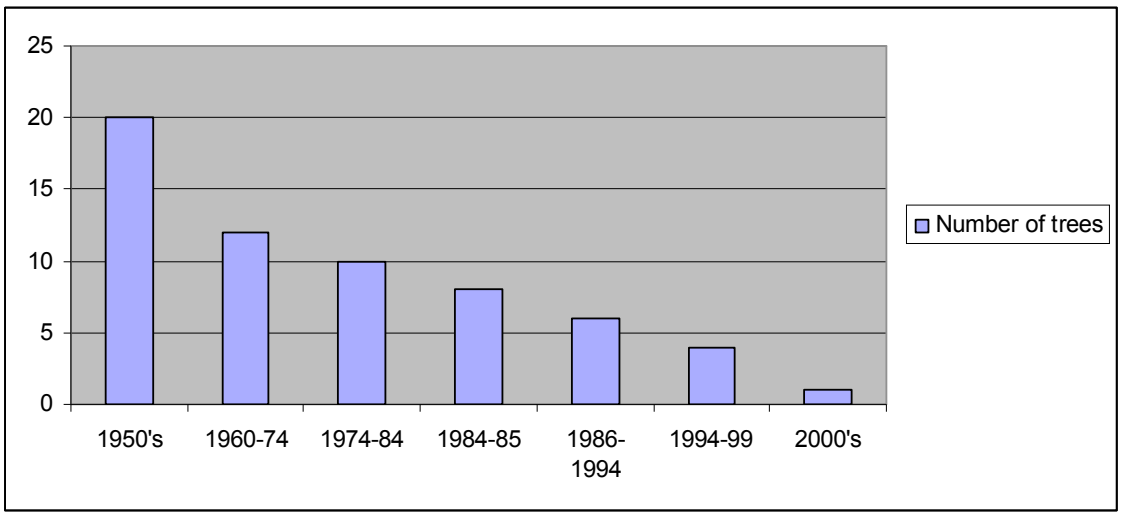

Diagram 2, Evolution of tree quantity in May Sakoni (from group interview)

The day of the PRA, our interpreter wanted to buy firewood in May Sakoni. It was impossible to buy the firewood in the village, as nobody sold it. So he had to drive to the neighboring village to buy it. I asked Informant 13 why people from May Sakoni didn't sell firewood. He answered that around May Sakoni if one wanted to make firewood business, there was not even one field where one could continuously cut branches without eventually destroying all trees. That was the reason why in May Sakoni there was no firewood for sale. But the villages around didn't have any "shame". They simply stole the firewood from the fields belonging to the people of May Sakoni and sold them.

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Individual interviews

The data will be presented as follows: firstly, the diagram of farmer's perceptions of changes in the number of trees will be shown, then, the story of the farmer will be presented.

Warzou

Informant 1 and Informant 2

Informant 1 and Informant 2 were two brothers from Warzou. Each of them had two fields (one close to the village, another one far away). Their fields were adjacent to each other. Both of them were very helpful in answering questions actively and trying to help to the research. It was decided that it might be interesting to get as much information as possible from both them and compare it.

The Diagram 3 reflects perceptions of both brothers for all their fields. This diagram is identical to the one presented during the group interview.

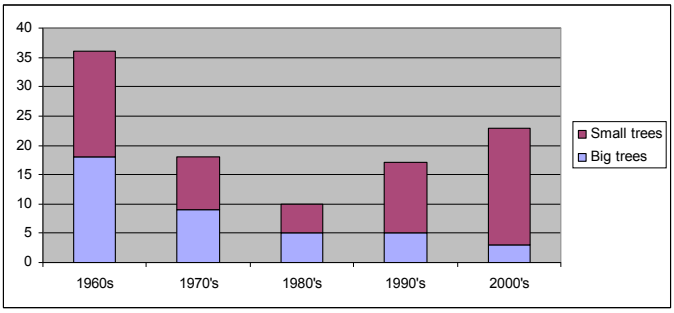

Diagram 3, Evolution of tree quantity in the fields of Informant 1 and Informant 2.

Informant 1

Informant 1 has two fields, which he has been cultivating for the last 50 years.

On the field, which was close to the village, there were 7 trees, while on the field, which was far from the village, there were 12 trees. According to Informant 1, such number of trees was the minimum he could remember. 40 years ago there were a lot of trees (almost a forest). Before 1963, Informant 1 had ca. 40 trees on the fields. Since then the number of big trees has been consistently decreasing.

The number of small trees has been decreasing until 1980. Since 1980's, the tendency was reversed and the number of small trees has been increasing.

According to Informant 1, the lack of rainfall was the principal reason behind the disappearance of big and small trees. The reason behind the increase of small trees since 1980s was FMNR. Informant 1 started FMNR on the field close to the village 13 years ago and on the field far from the village 16 years ago. Informant 1 has been practicing protection of trees for a long time (at least 40 years), but the techniques of FMNR came to the village only 16 years ago. Today small trees on the fields are the result of FMNR. With FMNR there are still not enough trees, so, 3 years ago Informant 1 took trees from the Nigerien Department of the Environment and planted them.

Agents of the agroforestry service[*] regularly visit his field in order to check upon the progress in FMNR.

Farmers preserve trees for many reasons. Informant 1 especially insisted on the value of the Gao tree[†]. It was important for the field, because it allowed for water

[*] National Institute of the Agronomic Research (INRAN/CERRA).

[†] Faidherbia Albida, a tree, which is unlike other trees in the Sahel, sheds its leaves during the rainy season and retains its leaves during the hot season (FAO 1974a as in Doran et al., 1983).

penetrating the soil, and at the same time it allowed for the sunlight reaching the millet. The Gao also resists to droughts. It grew quickly and gave fruits, which were used for the forage of animals.

According to Informant 1, trees didn't help in stopping degradation of soils. The fertility of soil greatly decreased since 1960s, and continued to decrease due to the increasing pressure. If you had 100 kg of millet from a field in 1960's (without fertilizers), in 2000's from the same field you could hardly have 20 kg (without fertilizers). Preference to millet was not natural to farmers, according to Informant 1. Farmers had to give preference to it, due to poor soils. Farmers can not wait for other crops to mature.

Comparing experiences from fields located at different distance from the village.

Informant 1 had very different experiences between his two fields. The reasons for the difference were: 1. area - the area of the field that was close to village was very small, as he gave some territory of it to the construction of a public school; 2. the distance to the fields was different; 3. the different number of trees on the field. The field, which was close to the village, had much less big and small trees than the other one.

The difference between the fields was in the damage inflicted to trees. There were two primary sources of damage to the trees: animals and thieves. Animals inflicted the biggest damage to the young trees on the field close to the village. After the end of the agricultural season, anyone's animals could graze in Informant 1's field. Very often these animals would break or damage young trees that Informant 1 planted. That was the reason why he had been trying to protect young trees with the fences made out of acacia branches, but it didn't always work. The field far from the village didn't suffer that much from animals, because of the distance from the village.

Damage by thieves was not that big on the field close to the village, because Informant 1 visited it every day. In the other field, in contrast, thieves damaged trees quite often. This damage has been decreasing every year, and all farmers tried to bring attention to the problem of thieves. Thieves from neighboring villages started to understand the value of trees. In 2009 the damage to trees in his field was less than in the past, but it was too early to say that it was acceptable.

The story showing the understanding of trees as property was given by Informant 1 in the following form. If Informant 1 catches a thief he warns him and asks him, why he didn't plant trees or protect them on his own field. If a thief tried to protect his own trees, next time the thief would have his own trees to cut. Informant 1 warned the thief that, if he would catch this thief one more time, he would complain to the Department of the Environment in the Mayahi city, which was the local administrative center. Thieves were primarily from the neighboring villages. Informant 1 explained that the neighboring villages didn't have their own initiatives for FMNR, planting and preservation of trees.

Informant 2

Informant 2 inherited his field from his father in 1989. But he had cultivated the fields even before.

Since 1960's trees started to disappear from the fields. That process significantly intensified in 1970's. An intense disappearance of trees continued approximately for 10

years. After 1985 the decrease of big trees slowed down, but the decrease itself was still in place in 2009. Informant 2 emphasized that the decrease of big trees was typical for the majority of fields belonging to Warzou. However, for his particular field to the west the decrease wasn't that strong, as far as this field has never had many big trees. The field was situated on a natural elevation, and because of that, it was exposed more to the wind erosion than other fields. So it was always hard for trees to develop on this field.

The number of small trees has been decreasing until 1980. Since 1980's, the tendency was reversed and the number of small trees in increasing. Old trees are disappearing and being replaced by young trees. Informant 2's perceptions of changes in the number of trees could be summarized in the Diagram 3.

According to Informant 2, major reason behind big trees disappearance was rainfall. The dates that Informant 2 identified as dates of changes in dynamics were quite close with major droughts. Another factor behind changes was the management of trees. In the past farmers didn't care about trees, so it was easier for them to disappear**.** That carelessness changed and gave place to FMNR, which was very important for tree preservation. Informant 2 started the tree preservation in the form of FMNR in 1980, and he was quite successful in doing that. Young trees on his field far from the village were the result of this preservation. The idea about FMNR was given to him by a development project[*], or his brother, who might have participated in the project. Without FMNR, one day farmers would wake up without any trees at all.

Informant 2 protected trees because they produced leaves and fertilized land, as well they produced forage for animals.

Informant 2 confirmed the idea that greening is not affecting quality of soil, which is still decreasing due to the pressure. There was not enough land for all people in the village; there was not enough land to make fallows, so the soil became poor.

[*] Informant 2 couldn't remember the name or any details about the project.

Informant 3

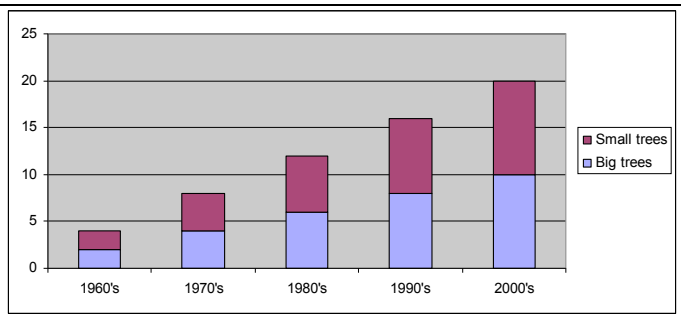

Diagram 4, Evolution of tree quantity in the fields of Informant 3.

Informant 3 started cultivating this field since 1984, when he inherited it from his father.*

According to Informant 3, there were more trees in 2009 then in 1963. 2009 was the maximum in terms of tje number of trees.

Informant 3 couldn't identify major reasons behind changes in the number of trees. He said, though, that one of them was in FMNR. He started to practice FMNR approximately in 1989, which he copied from his neighbors. Other farmers started FMNR earlier, since Informant 3 claimed that the first applications of FMNR took place in Warzou around 1983-84.

Main reason for farmers' preservation and regeneration of trees was formulated by Informant 3 in a sentence: more trees – more food. Farmers respected trees, because trees provided food, pasturage and firewood.

Informant 3 stressed that trees didn't help in combating the decrease in the soil fertility. Because of the decreasing soil fertility, farmers had much less food than in the past.

* For Informant 3 it was hard to understand the concept of decades. That is why he related the changes in the number of trees to the major political events in Niger, which later have been connected to years by me.

Informant 4

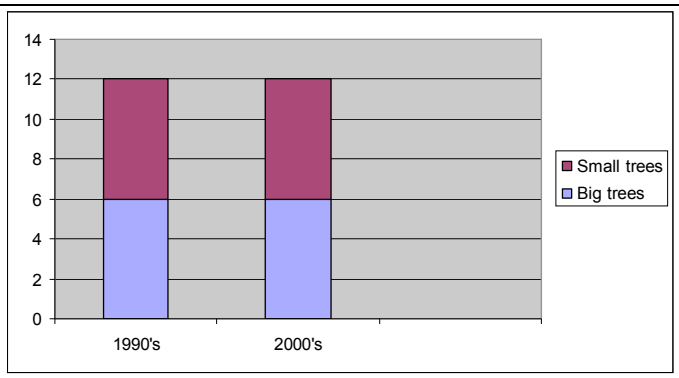

Diagram 5, Evolution of tree quantity in the fields of Informant 4.

Informant 4, who was 32 years old, has been cultivating his field for the last 10 years.

The quantity of trees didn't vary for the last 10 years. There was desertification, since the soil became poor, but it didn't affect trees. Trees on the field were present even before he started to cultivate it.

There was no special protection of old trees on his behalf, there was only protection on behalf of the Department of the Environment.*

But, then he stated that the quantity of trees was very important for quality of the field, because trees helped against wind erosion and drought. He wanted to augment the quantity of the trees on the field. He followed FMNR on his field, which he learned from his neighbors. He started FMNR the same year when he got the field, but he still didn't reach any results.

* During the interview, Informant 4 was inconsistent. Firstly, he said that he didn't protect trees, since he didn't know the reason for the preservation of old trees.

Informant 5

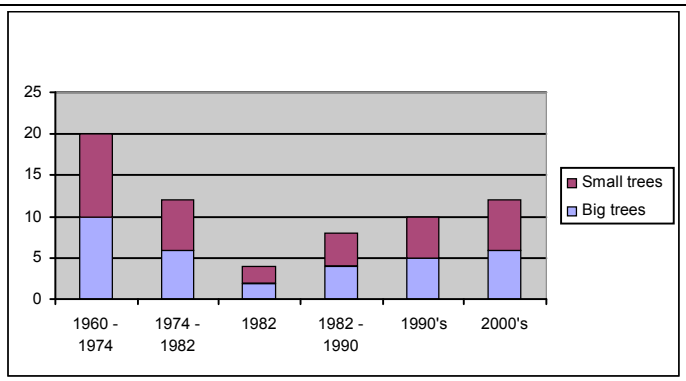

Diagram 6, Evolution of tree quantity in the fields of Informant 5 Ramane

Informant 5 inherited the field in 2005 from his father, but he had started to work on it in 1958, so, he has been working on the field for almost 51 years.

In the past there were more big old trees. 1960 – 1974 were the maximum number of big and small trees. In 1974 they started to disappear. 1982 was the year when the number of trees was minimal. After 1982 the number of trees started to augment and in 2009 the number of trees was sufficient.

According to Informant 5, the major reason behind the variations of trees was rainfall. Another reason was wind erosion, which became particularly strong in 1974 (it eroded the soils around the village).

Restoration of trees was connected to the introduction of FMNR. In 2000s with FMNR there was greening, but it took place only in the places where people practice agriculture. The disappearance of trees still took place on the communal lands, because there was none to protect them.

Informant 5 practiced FMNR on his field. His father started it 22 years ago. The father learned the technique from his neighbors. The original source for the ideas about FMNR was a person, who lived in Kotare (a neighboring village). Everybody in Warzou and Kotare learned the innovation from him.

Informant 6

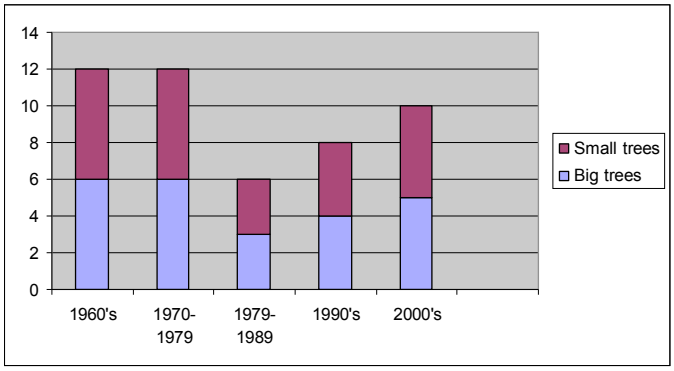

Diagram 7, Evolution of tree quantity in the fields of Informant 6.

Informant 6, who was 52 years old, inherited the field 22 years ago. But, he has been cultivating it since his childhood.

Big trees were on the field when he was a child. When his father cultivated this field, there was an average number of trees (not much, not less). In 1979 trees started to disappear and that was the beginning of a catastrophe. Trees disappeared not only in 1979, but in the following years as well. As for 2009 there were enough trees. Today has been returning.

The reason for the disappearance of trees was rainfall and temperature (it was too hot). Informant 6's father tried to preserve trees, because his principal occupation was herding. He kept many trees for animals to stay under shadow. That helped him in understanding the techniques of FMNR well before actual term of FMNR appeared. So, Informant 6's father started to practice FMNR long before the rest of the village.

His father was a herder until he became old. After him, his brother took the herd. Actually Informant 6 was a herder as well, but at the moment of the interview animals were to the north, since there was not enough food in the region.

Informant 6 felt that trees helped him to prevent the desertification of his field. They prevented wind and rain erosion of soil. In the past desertification was present on this field, but today he has enough trees. However, on the other field, which belongs to him he feels desertification.

Informant 6's family belonged to the herders' community, and that helped him in applying extra amounts of dung in comparison to the rest of villagers. In the past he moved the herd from one field to another for a year. There were many cattle, consequently there was much more dung available to use. In 2009 it was necessary to augment fertilization, because of the degradation of soils. Soils were much more productive in the past. The reason for the degradation was overpopulation and the absence of available fields for the increasing population. Instead of 1 farmer there were 10.

Informant 6 had problems with herders. They cut branches of trees. The reason for the conflicts was that he had many Gao trees in his field. According to Informant 6, farmers, who had many Gao trees in their field, also had problems with herders, because they wanted to cut branches.

Informant 7[*]

Informant, who was 35 years old, inherited the field 5-7 years ago from his father. He has never cultivated it before.

On the field there were 6 trees. They were on the field before he started to cultivate it.

He protected trees for construction and firewood; also he knew the value of the Gao tree, which helped for increasing the fertility of the field. Gao's fruits served as fertilizers for the field. Trees bring shade.

He practiced FMNR on his field. He learned the techniques of FMNR from his father. He makes it for the prevention of wind erosion and the firewood. With FMNR Informant 7 met a problem. During his absence somebody cut trees (young trees). Thieves make severe damage to his field. But, the damage by the thieves decreased because of the cultural shifts. Before, it was fairly common to do fences out of young trees. Today people prefer walls from clay.

[*] It was not possible to construct the diagram of Informant 7's perceptions of changes, since he didn't provide them. He has been cultivating the field only recently and couldn't answer the question, whether there had been changes in the number of trees or not.

May Sakoni

Informant 8, Informant 9 and Informant 10

During the group interview in May Sakoni, farmers mentioned several times that in 1980's there was some westerner, who planted trees and tried to teach farmers the tree management techniques. Farmers said that the westerner eventually planted a grove close to the village. This story sounded interesting for investigating the importance of human factor for greening. So, three farmers, whose fields were close enough to the grove, have been interviewed. Below, their interviews are presented together.

Informant 8

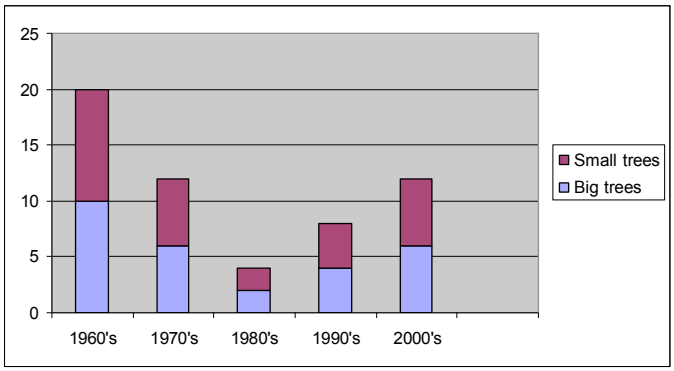

Diagram 8, Evolution of tree quantity in the fields of Informant 8

Informant 8 inherited this field in 1979, but he has been working on it for the last 60 years.

During the time when his father cultivated the field there were enough trees (Informant 8 said that then it was actually a forest on the field). In 1970s due to the drought trees started to disappear. 20 years ago it was the minimum number of trees that Informant 8 could remember. After that the return of trees began. In 2009 the number of trees could be called as average, it was bigger than 20 years ago, but it was still less than the one that was during 1960's. Moreover the species of new trees are not the same as it was before the 1979 (more Gao trees (Faidherbia Albida), whereas before there was more malga (Cassi sieberana) and hano (Boswellia dalzielli)).

According to Informant 8, the principal reason behind the variation of trees was rainfall. Secondary reason was the human factor. People started to plant trees and preserve them. Informant 8 and his father preserved trees for the sake of various domestic purposes.

Changes in the view of the value of trees were important for greening**.** At some point people understood the importance of trees for agriculture, and trees became being considered **as property.** 20 years ago trees started to be considered as a valuable resource that belonged to someone. Taking somebody's trees became a crime. It became hard to touch a tree belonging to somebody else.

According to Informant 8, the comeback of trees took place everywhere around the village, but much bigger changes on his field were the result of the work of a westerner, who planted trees 28 years ago. This westerner planted a grove, with a high tree density, and he presented to the villagers following reasons for the creation of a grove: 1) it would help to prevent the disappearance of existing trees in the fields around it; 2) stop the wind erosion of the soils; 3) create a public place, where the villagers would be able to have various kinds of ceremonies.

Informant 9

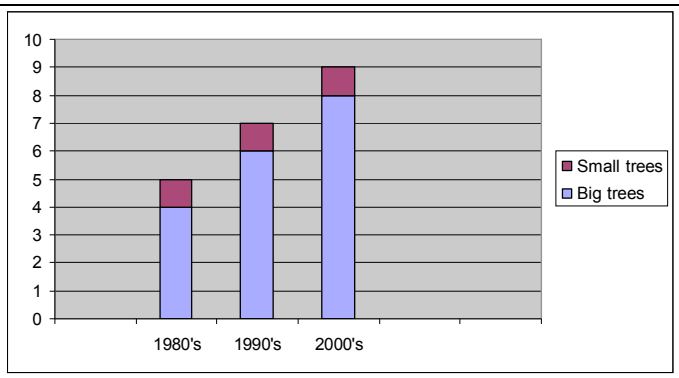

Diagram 9, Evolution of tree quantity in the fields of Informant 9

Informant 9, who was 72 years old, bought his field in 1974. He didn't work on this field before.

When Informant 9 bought this field there were only 5 big trees. In 2009 there were 30 trees. Some of these 30 trees were already on the field when he got the field, and he managed to preserve them. Another part of these 30 trees were planted by him. He started to plant trees 10 years ago, when he got to know the techniques of successful planting of trees from a neighbor, who used to work close to the Maradi city.

Informant 9 said that smaller trees, appearing by the natural regeneration, have never been present in substantial number on his field. That was the reason why he didn't practice FMNR as well. There were not enough small sprouts on the field to do that.

Informant 9 preserved existing trees and planted new ones, because he knew the value of trees. Trees were helpful in bringing animals and consequently the organic fertilizers. Additionally, trees helped in the prevention of the wind erosion. **But, there was a negative side in having trees on the field as well. Trees attracted more caterpillars during their attack, because they preferred to stay in the shade. Birds preferred to attack the crops that were situated close to the trees. In any case, positive sides of having trees on the field were more important for Informant 9, so he** wanted to increase the number of trees on the field.

Informant 9 was a specific farmer. He possessed several fields with a big area. He also was a successful food seller. In total, he managed to accumulate quite substantial funds, and he was able to invest them in more intensive agriculture than the rest of the interviewees. He was the only farmer, who has been able to buy mineral fertilizers for his agricultural activities.

Informant 10

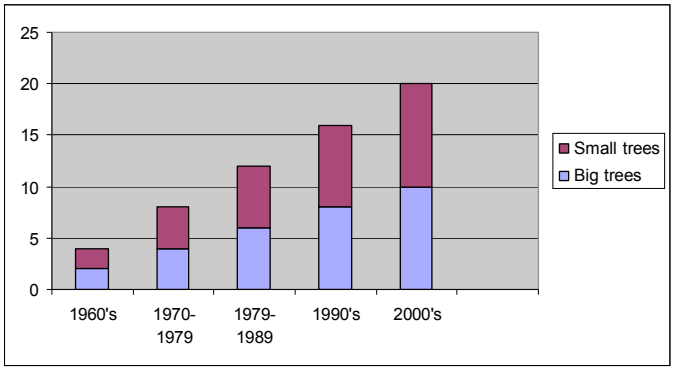

Diagram 10, Evolution of tree quantity in the fields of Informant 10

Informant 10 knows this field for the last 60. Before he started to cultivate the field, there were fewer trees than now, because his father didn't preserve them. During his parents time there were only 2 trees on the field. Now it is the maximum, the biggest number ever.

The primary reason behind the changes of trees was rainfall. Human factor was another reason behind the changes. Some trees on the field were due to the westerner, who planted trees. Informant 10, however, stressed that the relative 'greenness' of his field was more due to his personal acquisition. 30 years ago he inherited the field from his father, and since then he started the preservation of trees. He saw that the disappearance of trees negatively affected the quality of soils through increased wind erosion. Informant 10 started to plant new trees and to preserve existing ones. Because of that, he was the only person in the village who got a reward from the environmental office in the form of food as a retribution for the preservation of old trees.

When Informant 10 started protection, it didn't take particularly systematic form, he just tried to preserve the valuable species of trees appearing on the field, or he planted additional seedlings (primarily neem – lat. Azadirachata indica). Much later he was introduced to the new trees preservation techniques, particularly FMNR. FMNR helped him even more in conducting protection. In 2009 he tried to preserve all known species of trees.

Informant 10 stressed that the return of trees didn't influence so much the fertility of soil. It helped in preventing wind degradation, but the soil quality has been steadily decreasing due to the misuse.

Informant 11

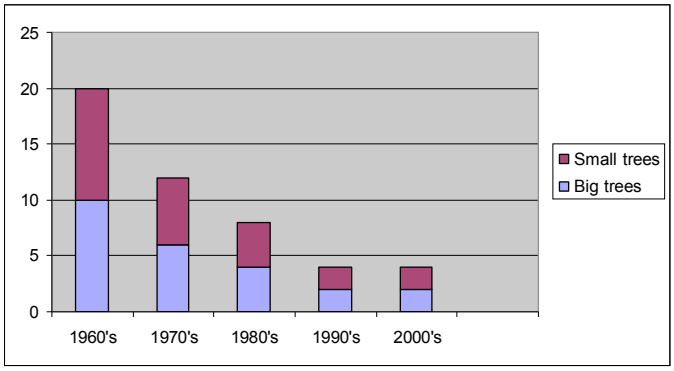

Diagram 11, Evolution of tree quantity in the field of Informant 11

Informant 11, who was 50 years old, inherited his field 16 years ago, but he worked on the field even before.

Answering the question about tree cover dynamics, Informant 11 said that 40 years there were many trees. The disappearance of trees started 30 years ago, and it continued ever since. 2009 was the minimum of trees. It was possible to see other villages on a big distance, because there were no trees. The decrease wasn't sharp or abrupt, it was gradual and it continued for a long time. Terrain becomes barren step by step.

On the field there was no regeneration of trees. Small trees followed the dynamics of big trees in permanent degradation.

The reason for the degradation was the lack of rainfall. The increase of population was another reason for the degradation; the demand for firewood has been steadily increasing for the last decades. Neighbors or firewood merchants stole branches from his field. Small trees were negatively affected because of the free access of cattle after the agricultural season. Every year he planted trees, but cows, destroyed them later on

Every year he tried to preserve trees, but it was not efficient for the reasons showed above. He started FMNR 16 years ago after the agents of the Department of the Environment introduced him to it, but it didn't give substantial changes for him. His field was too close to the village, so, any success in preservation of trees would be altered by neighbors stealing the branches for firewood.

Informant 12

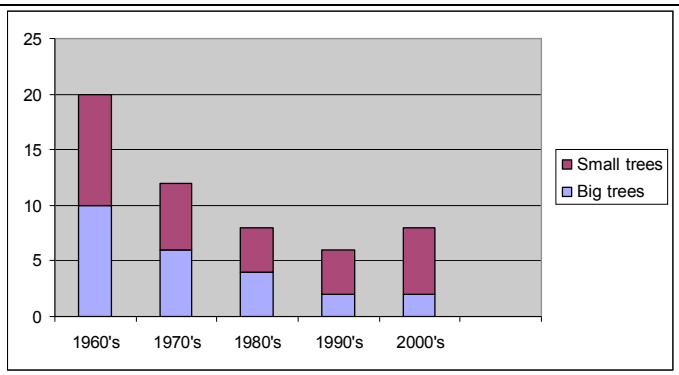

Diagram 12, Evolution of tree quantity in the field of Informant 12

Informant 12, who was 57 years old, inherited his field 30 years ago, but he cultivated it even before.

Disappearance of big trees took place naturally. In 1960's there was a lot of trees, but with the decreasing rainfall they started to disappear. In 1970 trees disappeared very quickly. In 2009 big trees disappeared as well, but the process was slower than it was before. Small trees were at their minimum around 15 years ago. In 2009 the number of small trees was average. It was bigger than 15 years ago, but it was still not enough.

The reason for the disappearance of trees was the lack of rainfall. Even in 2009 there was insufficient rainfall. The reason for the slowing down of the disappearance in 1990's was the use of FMNR. Without FMNR trees would have disappeared at all.

According to Informant 12, he heard about FMNR on the radio 15 years ago and he immediately started to practice it. In 2009 he couldn't say that he was satisfied with the results of FMNR.

Informant 12 always tried to preserve trees, since they were helpful in combating wind erosion. His father also tried to preserve trees. Protecting trees wasn't that easy for Informant 12, as far as he had problems with the wood thieves from the neighboring villages.

Informant 13

Informant 13 had two fields around May Sakoni. One of them was situated very close to the village in southern direction; another one was very far to the south-west.

The field that was close to the village was analyzed both at the individual field scale interpretation, and at the village scale interpretation. The second field was analyzed only at the individual field scale, and consequently it couldn't be compared with the results of the village scale interpretation.* Interviews, however, covered both fields. Even if the comparison of different scales of interpretation was impossible for the second field, the comparison between the fields was still possible.

Informant 13, who was 67 years old, inherited his fields 40 years ago, but he cultivated them for the last 50 years.

First field

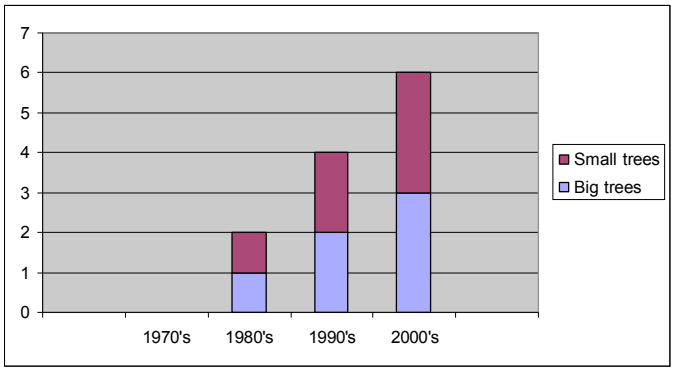

Diagram 13, Evolution of tree quantity in the field of Informant 13, field close to the village.

The field was really small, around one hectare. In 2009 it had only 3 big trees (bigger than 10 meters high), some 4-5 small trees, and several bushes. 40 years ago, according to Informant 13, there was no trees on the field. Field was actually empty. So, in 2009 the field had more trees than ever before. But the situation with trees could have been much better on this field.

In 2009 it was 20 years since he started preservation of trees on this field, and he was not satisfied with the results. In May Sakoni there was a farmer, who had started protection of trees long before 1985. By 1985 he got so successful in protecting trees, that environmental service agents gave him 3 bags of maize. Other farmers saw that and started to replicate his experience (among them was Informant 13). With time farmers understood that trees were helpful against the wind erosion and for the fertilization of fields. Without small trees animals wouldn't be able to stay on the field. Unfortunately for Informant 13, this field turned out to be too close to the village and it suffered a lot from firewood connected branch cutting on behalf of his co villagers. Because of the

* It turned out to be that the second field (far from the village) was situated beyond the limits of the village territory. During the trimming of the photographs for the village scale interpretation, the part, where this field was situated has been cut out and not interpreted. As it was written in the introduction, for May Sakoni and Warzou the territory of the village meant the territory that belonged to the village, according to villagers' perceptions. The case with Informant 13 raised the question that this definition of the village territory was not really appropriate for research. From my colleague I learned a presumable reason for this situation: in Niger marriages between persons from neighboring villages are fairly common. In this case the exchange of the fields takes place. So, the limits of the village territory could be still perceived as being static, whereas in reality there are many villagers, who possess fields outside the perceived village territory.

field's position it was too easy for people to break the branches when young trees reached certain size. That was the reason for his dissatisfaction with his preservation of trees.

Informant 13, however, has another field, where the results of his activities in preserving trees were much more successful.

Second field

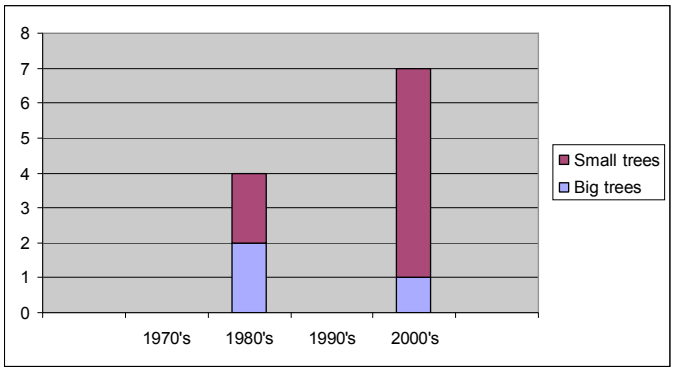

Diagram 14, Evolution of tree quantity in the field of Informant 13, field far from the village.

Informant 13 started preservation of trees (FMNR) at this field 20 years ago as well. In 2009 Informant 13 was happy about the results of his actions. In his opinion, on this field there were many young trees. The majority of trees were not older than 3 years old. Only very limited number of trees were relatively mature (more than 5-7 years old). According to Informant 13, all the trees on the field were the result of his preservation actions (FMNR).

20 years ago the territory of this field was barren; since all trees disappeared from it (both big and small). The reasons for disappearance of trees were as follows:

1. Sahel fires in the past. There was so much non-cultivated land around the villages, and it was so fertile, that there were a lot of weeds on them. In order to clear these fields from weeds, farmers used fire, to burn the weeds. As a consequence trees on the field were burnt as well. In addition, in the past there was a problem with illegal hunters, who hunted on animals in the Sahel. They used fire to trap them and the result was again in burning trees.
2. There used to be no proper surveillance of trees on the fields. As far as this field was far from May Sakoni, villagers from neighboring villages were able to steal branches and damage trees whenever they wanted. With time, however, people's attitude has changed. By 2009 people were afraid of making damage, because victims started to file complaints to the state environmental agency. In 2009 the damage was less, because of the fear. Informant 13 was almost satisfied with the current situation.
3. He had problems with herders, as far as they cut branches during the night. He couldn't blame any one of them, because there were so many of them, and they acted during the night. Also, it was very dangerous to quarrel with them, as far as they were armed.

Informant 13 stressed the fact that with changes in the number of trees, he still didn't feel any improvement in the soil fertility. Even in 2009 the soil was very poor in quality. But, at the very least, trees prevented the further wind degradation.

Summary on Farmers' Knowledge

Personal stories were helpful in understanding the results of the visual interpretation. In general, farmers' perceptions corresponded with what could be seen on aerial photographs and satellite images. But, instead of photographs for big periods (such as 35 years in this study), it was necessary to obtain photographs for each decennial, so to track process instead of just results. Like in the case of Informant 6, it was impossible to test his perceptions of changes, since trees decreased to some level and then increased to the original level within 1980's and 1990's. With the photos of this study, it was possible to see original number of trees and the number of trees in 2009, 2010, but not the variations in 1980's and 1990's.

Summary Warzou

1. The number of big trees has been decreasing since 1960's, because of the lack of rainfall. Number of young trees has been increasing since 1980's. According to farmers, the reason for the increase of the number of young trees since 1980's was FMNR and changes in the attitude to trees as property.
2. Trees didn't bring back soil fertility. But, they helped to prevent wind degradation. The degradation of soil was still there due to misuse.
3. The more Gao trees there were in the field, the more conflicts there were with herders
4. Greening took place only where there were owners, communal lands continued to degrade.
5. Trees on fields suffered from various types of stealing (for cooking, construction, reselling). Type of stealing depended on the location of a field in relation to the village. Type of stealing also affected the degree of the damage.
6. Informant 1 said that he has been cooperating with the employees of the INERA/CRESA for a long time. They often visited his fields in order to check upon the progress of FMNR.

Summary May Sakoni

1. During the group interview, farmers said that the number of trees had been consistently decreasing since 1960's. In personal interviews, the opinions of farmers were different: some of them said that the degradation took place as in 1970's, some of them said that degradation was there, but it was weaker than it was in 1970's, some of them said that the greening took place. In general, the story of persistent degradation since 1960's didn't find support in personal interviews.
2. According to personal interviews, 1970's were the period, when trees disappeared very quickly. The reasons for disappearance were: drought, the Sahel fires, and the absence of surveillance of the fields by farmers. Since 1980's trees started to come back. Reasons for the restoration were FMNR, planting (whether by farmer or westerner), change in the view of trees as property.
3. Even with more trees on the fields, the degradation of soil was still there. Trees helped to combat wind erosion, they gave shade and forage (especially the Gao tree)
4. Trees on fields suffered from various types of stealing (for cooking, construction, reselling). Type of stealing depended on the location of the field in

relation to the village. Type of stealing also affected how big damage to trees was.

5. Farmers experienced changes in environment very differently, whereas some of them managed to get benefits of it (Informant 9, who planted trees), others didn't benefit at all (Informant 11, who tried to preserve trees but failed, because of the damage by cattle and thieves)

c. Individual field scale versus village scale (only Warzou and May Sakoni)

This part is dedicated to the comparison of the results of the individual field scale visual interpretation with the results of the village scale visual interpretation. As it was mentioned in the introductory parts to this thesis, this comparison was done for two reasons: 1. to double check the method of visual interpretation; 2. to see whether there were different dynamics of changes between individual fields and the grid cells where these fields were situated.

The comparison will be presented in the form of a table. If a farmer had more than one field, then, it is possible to see that in the second column of the table. Comparison per each category (big and small trees) is provided. For better visibility, boxes with the results of the interpretations are color encoded according to the color encoding chart (the same as for the images of changes).

Farmer's ID	Field no	Village	Category	Results according to the individual field scale visual interpretation	Results according to the village scale visual interpretation
Informant 1	1	Warzou	Big	No change	No change
			Small	No change	No change
	2		Big	No change	No change
			Small	From Class 0 to Class 1	From Class 1 to Class 2
Informant 2	1		Big	No change	No change
			Small	From Cass 1 to Cass 2	No change
	2		Big	No change	No change
			Small	From Class 0 to Class 1	From Class 1 to Class 2
Informant 3	1		Big	From Class 0 to Class 1	From Class 3 to Class 1
			Small	From Class 1 to Class 2	From Class 2 to Class 3
Informant 4	1		Big	No change	No change
			Small	No change	From Class 3 to Class 1
Informant 5	1		Big	No change	No change
			Small	From Class 1 to Class 3	No change
Informant 6	1		Big	No change	From Class 3 to 2 on half of the total area

			Small	No change	No change
Informant 7	1		Big	No change	No change
			Small	No change	No change
Informant 8	1	May Sakoni	Big	From Class 1 to Class 3	From Class 1 to Class 3
			Small	From Class 1 to Class 2	From Class 2 to Class 3
Informant 9	1		Big	From Class 2 to Class 3	From Class 1 to Class 3
			Small	No change	From Class 1 to Class 3
Informant 10	1		Big	From Class 1 to Class 3	From Class 1 to Class 3
			Small	From Class 1 to Class 2	From Class 2 to Class 3
Informant 11	1		Big	No change	No change
			Small	No change	No change
Informant 12	1		Big	No change	From Class 0 to Class 1 on half of the total area
			Small	From Class 1 to 2	From Class 2 to Class 3 on half of the total area
Informant 13	1		Big	No change	From Class 1 to Class 2
			Small	No change	No change
	2		Big	No change	Not measured*
			Small	No change	Not measured

Table 10. Comparison between individual field scale and village scale visual interpretations

In total, there are 32 cases in which the individual field scale interpretation has been compared to the village scale interpretation. Out of these 32:

- Number of cases, where **the results of the interpretations are the same** - 15
- Number of cases, where the **results between interpretations are not significantly different**, i.e. direction of changes (greening/degradation) is the same according to both interpretations, while the classification is different – 8
- Number of cases, where the **results of the interpretations are significantly different** - 7
- Number of fields, where the **interpretations were not compared** – 2.

From these results it is possible to say that in the majority of cases (23 out of 32) classifications from two different interpretations were same or quite similar. More

* See explanations on the p. 48.

interestingly for the study, there were 7 cases in which results of the visual interpretations were substantially different. Reasons for these differences will be discussed in the discussion part of the thesis together with more details and references to farmers' knowledge.

VII. Discussion

a. Methods

Visual interpretation of changes

First of all, it is necessary to discuss **differences in classification between the village scale interpretation and the individual field scale interpretation.** Comparison of the results of the individual field scale interpretation with the results of village scale interpretation was very helpful. As it was expected, individual field scale interpretation allowed verifying classification of grid cells. It reminded how careful the visual interpretation should be in seeing changes on remote sensing data. It also reminded about one of the major limitations of visual interpretation method – difficulty to replicate. But, an effort was done in this thesis to meet this shortcoming, by elaborating a set of transparent criteria for detecting changes. I don't think that, if someone decides to redo the visual interpretation in four villages of this study, the results will be significantly different from mine (that is not to say that it will be easy to redo it). Moreover, close correlation of my results with the NDVI based map (discussed later) gives me extra confidence that the method of visual interpretation was correct.

There were several reasons for the differences between the results of the village scale interpretation and individual field scale interpretation. First of them was methodological. The method of visual interpretation depended on personal evaluation. This evaluation took different forms on two different scales of analysis. On the village scale, I concentrated on a visual impression from the photographs and images. The idea was to denote the changes on the grid cell based on general impression, rather than count each individual tree. This general viewing of photographs and images tended to be too radical (both in seeing greening and degradation), compared to what was actually on the remote sensing data. On the individual field level, it was easier to concentrate on the disappearance or appearance of individual trees. Bad quality of 1975 photographs could be mitigated by 'deciphering' them with the help of 2009 photo (i.e. it was possible to see that some dotes, that could be considered as technical flaws of the photo, were actually trees and vice versa). So, the individual field scale interpretation gave more moderate view of changes. That was the reason why in cases of Informant 1, Informant 2, Informant 10, and Informant 12 the classification of changes at the individual field scale was more moderate in respect of magnitude than on the village scale. This situation happened in the majority of cases of differences between village scale and individual field scale interpretations. These differences in classification were not as big, as to affect significantly the results of the study.

The second reason for the differences was connected with the question of different scales of analysis. A field of a farmer was smaller than a 500x500 meters grid cell. Sometimes, during the village scale interpretation it was possible to see that some minor part on a grid cell was subject to changes, which were different from the changes of a major part of the grid cell. In this case the classification of the grid cell reflected only the changes of the major part. This exception of the minor changes didn't happen during the individual field scale interpretation, and it was possible to make the classification of changes more precisely. That was the reason for the differences between the generalized classification of a grid cell and a more precise classification of a field, as in case of Informant 5.

Differences in the interpretations were also connected to the issue of an individual farmer's influence on changes in his field. As it was said before, results of the

village scale interpretation were generalized, and, as far as a grid cell usually included several fields of several farmers, this generalization made it hard to see the influence of individual farmer's actions. The results of the individual field scale interpretation were more precise, because they were related only to one field of one farmer. In cases of Informant 9 and Informant 3 it was possible to discover from the interviews that possibility to plant trees instead of preserving them or big amounts of manure were reasons for specific dynamics of tree changes within their fields compared to the fields of their neighbors. This issue will be discussed in more details in the part dedicated to the driving forces of landscape changes.

Interviews

In consistence with previous research (Schelcht & Buerkert, 2004), farmers knowledge was a relevant source of data for investigating landscape and land use changes. In the majority of cases farmers were able to remember quite precisely major dates of climatic changes in Sahel. Farmers' perceptions of changes in the number of trees were rather consistent with the tree variations observable on aerial photographs and satellite images. In addition to that, farmers provided a lot of data on the driving forces of tree changes.

This study showed again how cautious a researcher should be in collecting local knowledge. Understanding of different experiences of different farmers came only from personal conversations, when a farmer was interviewed in his field and asked about trees more substantially (i.e. trees he could see in his field) rather than abstractly (trees in general). The mixture of group interviews in the village with personal interviews in the field was a success in this study. This mixture allowed for a check-recheck of the farmers' knowledge. A very important example came from May Sakoni, where during the group interview in the village farmers told that trees had been consistently decreasing in number since 1960's, and later in personal interviews in the fields only one farmer confirmed that point of view.

It is also worth mentioning the issue of interpreters for the interviews in this study. I had an easy going interpreter, who was always ready to cooperate and to work during late hours. This interpreter was an employee at the local Department of the Environment, and he was familiar with the issues that I tried to investigate. His expertise and knowledge often served me in understanding some issues that farmers were not able to explain. At the same time, the expertise of the interpreter brought some negative sides as well. During the interviews it was impossible to distinguish between what farmers actually said, and what interpreter added. I tried to solve this issue by asking the interpreter, whether it was farmers' opinion or his own, but even today I am aware that the data from my interviews might be biased in a way of being too 'optimistic' compared to the reality. In such circumstances, the best strategy would have been to return to the same farmers after some time, but use an impartial interpreter. Unfortunately that was impossible in this.

Concluding the discussion on the methods used for this thesis I should say that both of them were useful and efficient. The visual interpretation of changes at the individual field scale and farmers' knowledge were a good addition to the village scale visual interpretation. Together they gave better results than the village scale visual interpretation alone. Addition of the individual field scale interpretation allowed verifying the classification of changes. Farmers' knowledge helped to understand the

driving forces and the processes behind the changes that I could see on the remote sensing data.

The data from interviews was biased towards the farmers, whose fields were subject to changes, i.e. it was not a representative sample of fields. But, this data together with the data from the visual interpretation still served the purpose of answering the research questions.

The use of methods at different scales is a beneficial strategy for studies of changing environment (Gray 1999), as far as each scale produces different results concerning the greening. At the regional scale of the Sahel, it is possible to see a general overview of greening and have an impression that it is a uniform signal across the Sahel. At the village scale, it is possible to see that not only greening takes place, but also the degradation, although the greening signal is usually stronger. From the scale of individual farmers it is possible to find the confirmation for the greening phenomenon, but again greening is not uniform and highly varying even at very small distances.

b. Local scale interpretation of greening versus regional scale data on greening

Dynamics

In the beginning of the discussion it is worthy to remind about the villages' position in relation to the greening signal in the Sahel. As it was mentioned in the introductory parts to this thesis (see Figure 1), according to the NDVI based map, Mayahi and Miria villages were situated in an area, where greening signal was rather average, if to compare with other zones in the Sahel. The greening signal in Mayahi villages was stronger than the one in Miria. Miria villages were situated in some sort of a non green trough, where in general the area was subject to patchy greening, but exactly the territories of villages were situated in a non green patch.

This view of greening in Mayahi and Miria derived from coarse scale data corresponded closely with the results of the visual interpretation of changes made in this study. From the visual interpretation the greening phenomenon was not as clear as on the Sahelian scale. In three out of four villages grid cells with changes comprised only 20% of the village territory (in total, ca. 60 grid cells out of 312). Both greening and degradation have been taking place, but in the majority of cases (except Gouliske big trees) the signal of greening was stronger than the signal of degradation. The fact that only May Sakoni showed a clear signal of greening (as well as the signals of greening in May Sakoni and Warzou were stronger than in Gouliske and Garin Sangaya) confirmed the idea that Mayahi was subject to a stronger greening than Miria. Strong signal of degradation that was present in Gouliske, in my opinion, is a reflection of a fact that Miria villages were in a non green trough.

The choice of the villages influenced the results in a very certain way. It is hard to say whether 20% of grid cells with changes from the visual interpretation were comparable with an average signal of greening from the NDVI map. However, in my opinion, it seemed reasonable to say that they are. The logic to this opinion was as follows. If greening was detected as: as an significant increase of the NDVI on circa 50% of the territory of the Sahel (Eklundh & Sjöström, 2005), that included areas with very strong greening such as south of Niger and areas, where greening was rather marginal, such as central Niger, close to the Sahara desert. Villages of this study were in the area, where greening was not strong and not weak, then, it seemed reasonable to

expect that on aerial photographs and satellite images greening wouldn't be very explicit, greening would be rather moderate in magnitude (it wouldn't be possible to see a forest in 2009, where there was a desert in 1975), and it would cover only parts of the total territory. So, the changes on aerial photographs and satellite images detected in this thesis followed quite closely the dynamics observable on the NDVI based coarse resolution maps, and such conclusion was consistent with findings of previous researchers (Eklundh & Sjöström, 2005).

The studied areas included only agricultural lands. From the interpretation of greening, it was possible to support the finding of Eklundh and Sjöström (2005) that in Niger greening has been taking place in agricultural lands, which was not common to other Sahelian countries. My opinion was that it was the consequence of the human factor importance for greening, but, this opinion could be confirmed (or rejected) only within a research made in a span of several countries.

Driving forces

According to farmers, trees dynamics were closely correlated with rainfall, as far as rainfall was the major driving force behind tree changes. 1970's were pinpointed as the minimum in terms of trees. That was the period, when trees disappeared very quickly. The reasons for disappearance were drought, Sahel fires, and absence of surveillance of the fields by farmers. In 1980's trees started to come back. But, this restoration concerned primarily new small trees, whereas big old trees continued to disappear. Today in the fields big trees are being replaced by smaller ones. The reason for that, according to farmers, is that there is still not enough rainfall and soil is not fertile enough for big trees to survive.

In the interviews, farmers confirmed that apart from rainfall human factor played an important role for greening. That was coherent with suppositions of previous researchers, who worked at the regional scale with remote sensing data only (for example, Herrmann et al., 2005, p. 410). Farmers responded to the droughts of 1980's and 1970's by changing their practices. They started to protect naturally regenerating trees (FMNR) or they planted new trees. Farmers also started to value trees as property: before trees were considered to be a common property, but today they are a property of an individual farmer, and damage to trees is a crime. According to farmers, these two factors (FMNR and trees as property) played an important role for greening.

The vision of human societies adapting in a certain way to droughts is supported by the findings of Tougiani et al., (2009), Rinaudo (2007) and Reij et al., (2005). Further part of this chapter is dedicated to a more detailed discussion of the human factor of greening in the villages of this study.

According to farmers, **FMNR** played a structuring role for the protection of trees, i.e. protection of trees existed in both villages since long time, but FMNR brought some kind of a proven framework of actions, which a farmer was supposed to follow in order to succeed in preserving trees. FMNR appeared in the villages around the beginning of 1990's. There was no consent among farmers on the source of FMNR, but it definitely proved being efficient for preservation of trees.

Success of FMNR depended to a certain degree on a position of a field in relation to human settlements. Farmers told me that whether a field was close to a settlement, small trees (i.e. the result of FMNR) trees might suffer from the local thieves, searching for daily firewood. Whether the field was far away, it was more secure from local thieves, but thieves from neighboring villages (often firewood

resellers) might start stealing it.

According to Informant 13, local thieves presented usually bigger threat for trees than thieves from neighboring villages, because it was harder to persecute local thieves for the theft. Local thieves usually collected firewood for daily consumption (i.e. cooking stealing). Cooking stealing happened on the fields that are on average distance from a village. It shouldn't be too close, because the owner could easily detect stealing. It couldn't be too far, because than it was too hard to transport firewood. Since it was children and women who were responsible for the household firewood collection, this type of stealing was rarely punished, due to cultural norms.

Stealing for reselling and construction happened on remote fields. It was rare that persons from the same village would steal from each other for reselling. Rather villagers from neighboring villages would steal from the fields of farmers from another village. In opposite to cooking stealing, long distance thieves were men. In this case, appearance in 1980's of an idea about trees as property (discussed further) radically changed the situation. In 2000's the long-distance thefts still took place, but their number was significantly lower than in the past. It was too dangerous to cut illegally someone else's trees, as far as a thief risked ending up being fined for that.

Stealing for feeding cattle happened on remote fields as well. Sometimes it was nomadic herders, who would do that to feed their cattle. This type of damage was especially strong on the fields, where there were many Gao trees.

The fact that Gao trees had different consequences for a farmer looks interesting for the further research. It is well proven how beneficial a Gao tree is for a farmer (Doran et al. 1983). In this study it was mentioned many times by farmers that Gao trees helped them in many ways: by giving forage and firewood, by preventing wind degradation, by having reversed seasonality. The ultimate idea of any farmer in applying FMNR was to have as many Gao trees as possible. But, it was mentioned by two farmers (Informant 6 and Informant 4), as well as a local expert (my interpreter working for the Department of the Environment), that having many Gao trees in a field caused farmer to have many conflicts with nomadic herders and neighbors, who would break Gao branches to feed cattle. These multidirectional consequences of greening (farmer benefited and faced discomfort from having many Gao trees) will be discussed one more time in the thesis.

The discussion on the stealing leads me to another reason for greening mentioned by farmers - the change in the view of **trees as property**. In many interviews it was said that before 1980's trees were not considered as a property and the damage to them was not considered to be a crime. Today farmers see trees as their property, and, if they manage to catch the perpetrator, they complain to the Department of the Environment. The change of valuing trees brings me to an old discussion on the importance of property rights for resource management. According to Informant 5, greening in Warzou took place only on cultivated land, which belonged to farmers, while trees on communal lands continued to disappear, since there was nobody to protect them. Whether there is a tragedy of the commons (Hardin 1968 as in Deese, 2008, p. 152) leading to the destruction of the common resource (such as trees in this study), or there is a success in the self-management of resources leading to improving resource conditions (Ostrom 2010, p. 72), property rights or at least farmers' perceptions of property rights were important for greening phenomenon to a certain

extent in the villages of this study. [*]

Findings of this thesis, concerning the importance of the human factor for greening, are consistent with conclusions of previous researchers working in Niger (Tougiani et al., 2009; Rinaudo, 2007). But, it is not impossible to be as optimistic about the effects of FMNR and property rights as Tougiani et al., (2009) and Rinaudo (2007). In their papers FMNR and property rights were presented as bringing significant difference to farmers' livelihood via the substantial greening on agricultural lands. But, in the villages of this study it was impossible to see the substantial greening. That was particularly clear in the case of farmers, who claimed that current trees in their fields were the result of FMNR (such as Informant 1, Informant 2, or Informant 13).

Personal contribution of an individual person however can bring substantial differences to greening. An important message from this study was that changes in environment (such as increased rainfall and decreasing soil fertility) could be experienced very differently by different farmers. Some farmers might try to benefit from the changes in environment, by investing more resources in the field, such as Informant 1 and Informant 3. Some farmers might not respond to changes in environment at all, and continued business as usual practices, such as Informant 4. That led to the situation, when the signal of greening could vary even between very close areas (as in the case of Informant 3 field comparison between village scale and individual field scale). Eventually these different actions of farmers are reflected in the **patchiness of areas with changes** on aerial photographs and satellite images.

Similar to the Sahelian scale, at the local scale it was possible to notice a patchy structure of areas with changes in trees (Anyamba & Tucker 2005, p. 610). That was particularly evident in the case of May Sakoni and Gouliske. From the data received in the interviews, it is possible to suggest that patchiness of greening is due to the human factor.

From the interviews it became clear that the diffusion of ideas (such as FMNR) was not something instantaneous, it rather took time for farmers to find out new agricultural techniques from their neighbors, friends or development projects. If someone in a village started to practice new agricultural techniques, such as FMNR, it didn't' mean that the whole village immediately followed his example. The patchiness on the village scale could be explained by the fact that it was easier for the person introducing innovation to spread his ideas to the owners of adjacent fields (especially because they were usually his relatives). He spread ideas and neighboring farmers started to practice the same technique, altogether leading to a patch of greening.

In the majority of cases it took time for such innovation ideas to reach someone living in an opposite end of a village and having fields far away from the field of the innovator. For example, at a very late stage of the fieldwork in May Sakoni my Nigerien colleague, Amadou Mamane, was on the way to interview a person about the use of FMNR (which, according to other farmers, started from 5 to 16 years ago in the village). But, the interviewed farmer had no idea about FMNR whatsoever. If this farmer has never heard about FMNR, perhaps his neighbors didn't practice it as well. Together their actions led to the creation of a patch with degradation or with no changes.

In May Sakoni it was possible to learn another story about the importance of individual actions for patchiness of areas with changes. There the work of a westerner in 1980's created a really big difference for several farmers. Westerner's ideas about

[*] Another student from the SRC's project (Friederike Mikulcak) investigated this issue in the Miria department.

planting trees in a grove on the outskirts of the village influenced the fields adjacent to the grove, which were subject to a significant greening during the last 35 years. The grove and the fields of neighboring farmers formed together a patch with the strongest signal of greening in all four villages of this study.

Concluding this discussion about patchiness, I should say that different actions of farmers led to different signals of changes (i.e. patches with greening or degradation). That led to different experiences of farmers, who often had opposing perceptions and explanations of changes (for example Informant 11 against Informant 13). That was the starting point to the next part of the discussion, which would concern readings of changes in the landscape by different people.

'Misreading African Landscape'

May Sakoni and Gouliske turned out to be the best cases in this study to test different readings of landscape (Fairhead & Leach, 1996). In the beginning of the fieldwork May Sakoni was considered to be a brown village, while Gouliske was a green one. In May Sakoni during the group interview, farmers confirmed the 'brown' status by saying that trees were persistently disappearing from 1960's. However, in the personal interviews held in the fields only one farmer confirmed the story of a uniform degradation. Others said that degradation was there, but it was weaker than it used to be in 1970's, or that degradation concerned only big trees or that greening has been taking place. Moreover, the visual interpretation of changes showed that May Sakoni turned out to be the only village that could be called green, while Gouliske was brown.

This story reminds us that, whether the discussion is about greening or desertification, one should not base understanding of African landscapes solely on the commonly accepted wisdom or environmental narrative (Fairhead and Leach 1996). It is always necessary to verify that narrative by different sources (specifically with the use of historical data). As far as the choice of green/brown villages couldn't be supported from the analysis of remote sensing data, it became clear that the vision of the green/brown villages concept on behalf of Nigerien counterparts was different from the one that was in my mind, and in the minds of farmers.

A change in the environment (such as greening) is something that is measurable and identifiable. Eventually, there is only one orthodoxy (Fairhead and Leach 1996, p. 279): there are more/less trees than in the past. But, reflections on changes in environment differ between different people (Fairhead and Leach 1996, p. 279). Politicians want to see more trees in the form of 'a great green wall' in the Sahel, which will protect countries from desertification. They brought this idea to the international agenda since 2005 (Dell'amore, 2009). Scientists supported the idea that trees were important for the preventing 'undesirable ecological shifts' (Manning et al., 2006, p. 311). Other scientists found that the number of trees has been increasing across the Sahel (Anyamba & Tucker, 2005, Olsson et al., 2005 etc.), and human societies could be partly responsible for that (Herrmann et al., 2005, Reij et al., 2005, Rinaudo 2007, Tougiani et al., 2009, this thesis). Finally, local officials dealing with the issues of greening, being encouraged by this rising interest in trees from politicians, journalists, scientists etc, managed to identify green villages and brown villages. It is possible to see how many parties there were in the discussion about greening, and it is not a fact that their understanding of greening was the same.

But, farmers discourse on greening might be very different from the ones described above (Fairhead and Leach 1996, p. 295). Farmers stressed that trees helped

only to fight wind erosion, and gave forage, firewood and shade to cattle (particularly the Gao tree). According to them, trees didn't not bring back fertility, which consistently decreased since 1960's due to the misuse of the land (no fallows, not enough manure etc). Even more interestingly, in some interviews, informants claimed that having trees in the field was not always an advantage, since trees created favorable conditions for pests and birds to damage crops (Informant 9) and also caused more conflicts with other land users (the Informants 4 and 6). For farmers, fertility of the soil was the most important parameter of the field. According to them, greening did take place in the Sahel recently, but only if to consider greening as an increase in the number of trees. On the contrary, if to include soil fertility in the definition of greening (as farmers did in reality), then it wouldn't be possible to see only degradation.

In this respect, it seems to me that, the same way as it was twenty years ago with the degradation narrative (Blaikie 1989 as in Gray 1999, p. 330), we do not take greening phenomenon critically. There was no greening per se; it only existed in relation to people, who conceived it as being greening. Before trying to measure and investigate it, we should know for whom and why greening was important?

VIII. Conclusions

In the introductory part to this thesis the research question was formulated as: How does the data on greening collected at the local scale correlate with the data on greening collected at the regional scale. Now, it is possible to answer that.

Dynamics of greening phenomenon investigated at the local scale correlate closely with the dynamics observable at the regional scale. With the help of the NDVI it is possible to predict with a sufficient accuracy what kind of a greening signal is observable on higher resolution aerial photographs and satellite images (areas, which are green on regional scale maps, are green on the higher resolution remote sensing data as well). This conclusion is consistent with findings of Eklundh and Sjöström (2005). Additionally, the local scale data allows investigating greening with finer details. With the help of the local scale data it is possible to see changes concretely (e.g. greening in big trees, small trees) rather than in a more generalized way (increase of the green biomass) derived from the regional scale NDVI.

Moreover, as it was previewed, the local scale data helps to see the driving forces of greening. Farmers are an excellent source of knowledge concerning the environmental history of the area around their village. Through the coupling of farmers' knowledge and the remote sensing data analysis it is possible to understand better how human factor is actually responsible for greening (for example, the issue of patchiness of areas with greening).

It is certain that rainfall is the major driving force behind greening. But, individual farmers are able of shaping the landscape through their practices. Some of them are able to respond to increasing rainfall and make the greening signal on their fields more substantial. At the same time, other farmer doesn't respond to changes in rainfall and on their fields greening is not really remarkable.

In the end, it is worthy to remind the finding that I consider to be the most important. Our view of the Sahel's greening as a rare case of human success against changing environment (Harris, 2007) should be very cautious and critical. Even if human societies are a minor driving force behind greening, the greening phenomenon might be not as important for these societies as it is often presented. That is a consequence of the fact that these societies' understanding of greening differs substantially from the one, which is presented by politicians, researchers and journalists.

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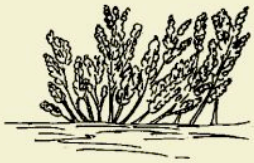
X. Appendixes

a. Appendix 1

FMNR in practice

1. FMNR depends on the existence of living tree stumps in the fields to be re-vegetated. New stems which can be selected and pruned for improved growth sprout from these stumps. Standard practice has been for farmers to slash this valuable re-growth each year in preparation for planting crops.



2. With a little attention, this growth can be turned into a valuable resource, without jeopardizing, but in fact, enhancing crop yields. Here, all stalks except one have been cut from the stump. Side branches have been pruned half way up the stem. This single stem will be left to grow into a valuable pole. The problem with this system is that when the stem is harvested, the land will have no tree cover and there will be no wood to harvest for some time.

3. Much more can be gained by selecting and pruning the best five or so stems and removing the remaining unwanted ones. In this way, when a farmer wants wood she can cut the stem(s) she wants and leave the rest to continue growing. These remaining stems will increase in size and value each year, and will continue to protect the environment and provide other useful materials and services such as fodder, humus, habitat for useful pest predators, and protection from the wind and shade. Each time one stem is harvested, a younger stem is selected to replace it.

Species used in this practice in Niger include: *Strychnos spinosa*, *Balanites aegyptiaca*, *Boscia senegalensis*, *Ziziphus spp.*, *Annona senegalensis*, *Poupartia birrea* and *Faidherbia albida*. However, the important determinants of which species to use will be: whatever species are locally available with the ability to re-sprout after cutting, and the value local people place on those species.

Source: Rinaudo (2007)[*]

[*] Rinaudo, T (2007): 'The development of Farmer Managed Natural Regeneration', *Leisa Magazine*, Vol. 23, Issue 2, June 2007.

b. Appendix 2

Questions for interviews*

Cluster # 1. Harvest

1. **How is the harvest this year? Is it good or bad? How do you define good or bad harvest? In your opinion what is the primary reason for bad/good harvest (rain, amount of sunlight, trees, practices)?** *Comment est la récolte cette année ?Est-elle bonne ou mauvaise ? Comment définissez-vous une bonne anéee et une mauvaise année (précipitation, insolation, arbres, pratiques agricoles)?*
2. **Can you distinctively remember a year of a very good/bad harvest (Remind about 1983)? How was it different from the others?** *Pouvez-vous vous rappeler d'une année ou la recolte a été particulierement bonne ou mauvaise (rappeler 1983, 2005)?Quelles sont les differences avec les autres annees*
3. **For how long are you cultivating this field?** *Depuis combien de temps cultivez-vous ce champs ?*

Cluster # 2. Trees, objects of landscape and the land use/land cover stories

1. **How old is that tree? Did you plant/recultivate it or it is there just by natural reasons? Why? Why do you have an empty spot on your field here? Why didn't you plant anything here? How many trees older than 25 years do you have on your field? Why do you preserve them? What is the importance of trees for you?** *Quel age a cet arbre là ? L'avez vous planté ou régénéné ou bien est-il là naturellement ? Pourquoi ? Pourquoi y a-t'il un endroit sans arbre dans votre champs ? Pourquoi n'y avez-vous rien planté ?Combien d'arbres ont plus de 25 ans sur votre terrain ?Pourquoi les avez-vous sauvegarde ? Quelle est l'importance de ces arbres pour vous ?*
2. **We see 10 (20, 30,40 etc) trees on this field. Was it always like this? Is the number of trees was the same in 1950s (1960s, 1970s, 1980s, 1990s, 2000)? If there were deterioration (increasing or abrupt drop) why was it and when (use the participatory timeline for examples)? (If they don't remember, remind the 1983 as an example). What is desertification/greening in your understanding (number of trees, productivity of soil, mass of millet, etc)?** *On voit 10 (20, 30, 40 etc.) arbres dans ce champ. En a-t-il toujours ete ainsi ?Le nombre d'arbre était-il le meme dans les années 1950 (1960, 70, 80, 90, 2000)? S'il y a eu une détérioration (augmentation ou diminution abrupte), quand cela s'est-il produit, et pourquoi (utiliser la méthode de chronologie participative)?(S'ils ne s'en souviennent pas, leur remémorrer 1983 comme exemple, ainsi que le travail de Tony avec le programme travail contre nourriture) Selon vous, y a-t'il un reverdissement ou une désertification (nombre d'arbres, productivité de la terre, masse de millet etc.)*

* There are some mistakes in the language, and some of the questions are formulated rather vaguely. The reason for that is because it was decided to present the exact version, which was used in the field.

3. **Does the number of trees important for the quality of a field? Did you intentionally make any steps to increase (decrease) the number of trees on the field? If you practice FMNR, when did you start it, why? Where did you get an idea about it? We see here that it is primarily gao tree, which is planted on the field (can you explain why it is gao, Tony's question)? Did you do any other steps to increase the quality of the field (put more manure, started to use fertilizers? When did you start these changes and why?** *Le nombre d'arbre est-il important pour la qualite des sols de votre terrain ?Avez-vous intentionnellement pris des mesures pour augmenter/réduire le nombre d'arbres dans votre champs ? Si vous pratiquez la RNA, quand l'avez-vous commence , et pourquoi ? Ou en avez eu l'idee ? On voit que vous avez surtout de l'arbre gao dans votre champs, pourquoi avez-vous conserve/planté le gao en particulier (question de Tony)?*
Avez-vous fait d'autres actions pour ameliorer la fertilite de vos sols (engrais) ?Quand avez-vous commence a changer et pourquoi ?

Cluster # 3. Throw of the trees (abattage)

1. **We see the tree that is severely (intermediately, slightly) cut. Why was it cut?** *On voit que cet arbre a* été *séverement (modérement, légerement)* élag*ue/coup*é *? Pourquoi a-t'il* été élag*ué/coup*é *?*
2. **Did somebody teach you how to cut the branches or you learn it by yourself. Do you cut the branches of trees for making them more shady? Do you cut the branches of trees for the forage? Do you cut the branches for construction? Is it just your personal preference in cutting the branches or you are following some system?** *Est-ce que quelqu'un vous a appris a* élaguer *ou bien l'avez-vous appris seul ?Coupez-vous les branches des arbres pour leur donner plus d'ombre ? Les coupez-vous pour les donner en fourrage pour le bétail ? Pour la construction ? Est-ce votre choix propre de couper les branches ou bien suivez-vous une quelconque tendance ?*
3. **Is someone else allowed to cut down the branches of your trees? Are there any conflicts or cooperation with the pastoralists about the use of the trees (Jean Paul's hypothesis about the cooperation of peasants with pastoralists. Give the example of gao tree)?** *Est-ce que quelqu'un peut couper les branches de vos arbres ? Rencontrez-vous des difficultés avec les pastoralistes quant a l'usage de vos arbres ?(l'hypothese de Jean Paul a sujet de la cooperation entre les paysans et les pasteurs. Exemple de l'arbre gao)*