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Changes in cultural landscapes and their impacts on the biodiversity of an alpine eco-system

Master's thesis (Double Degree Programme)

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14.03.2011

…meditieren Sie über den Bildern…

Werner Schneider (2010)

Danksagung

Gedankt sei in erster Linie meinem Vater, welcher zu Beginn des Studiums meinen Ehrgeiz förderte… gegen Ende dann die Geduldsprobe gelassen auf sich nahm.

Herzlich Bedanken möchte ich mich auch bei all jenen, die diese Diplomarbeit möglich gemacht haben!
Ohne Ernst Partl vom Naturpark Kaunergrat wäre die Idee und Inspiration zu der Arbeit nie geboren worden. Weiters haben mich Herr DI Hermann Gspan und Herr DI Dr. Michael Haupolter von der Tiroler Landesregierung tatkräftig bei der Beschaffung von notwendigen Geodaten unterstützt! Auch die (oft zeitintensive) Betreuung am IVFL durch Prof. Werner Schneider und Prof. Reinfried Mansberger war hervorragend. Prof. Friedrich Reimoser danke ich für seine tatkräftige Unterstützung und den Mut innovative Methoden auszuprobieren.
Meinem sehr geschätzten Mitbewohner und GIS Tutor, Daniel Wuttej danke ich für fachliche und technische Unterstützung und meinem Freunden und Bekanntenkreis für Geduld und Kraftschöpfpausen.

Abstract

This thesis investigates into the changes of the land cover in the northern part of the nature reserve Kaunergrat and the resulting impacts on biodiversity issues during the last 60 years. Between three points in time (1953/54, 1970/71 and 2001/03) changes of the land cover were assessed. For the years 1953/54 and the years 1970/71 orthophotos had to be created from aerial images, for the investigation period of 2001/03 orthophotos already existed. The land cover was interpreted and delineated for all three points in time. From the changes in land cover, effects on native species could be derived and discussed.
From the 1950ties to the years 2001/03 a densification of light coniferous forests took place in big parts of the area under investigation. The evolution towards denser forests reduced retreat areas and habitats for many alpine species that are dependent on cultural landscapes. Unfortunately, most of the assessed impacts on the investigated species had to be rated negatively (Capricorn, deer, black grouse, capercaillie, rock partridge). Only the rock ptarmigan seemed to have slightly benefited from the occurred land cover changes. From a species-diversity perspective the land cover development in the northern part of the Kaunergrat during the last 60 years had to be rated as negative.

Abstract

Diese Diplomarbeit untersucht Veränderungen der Landbedeckung im nördlichen Teil des Kaunergrates während der letzten 60 Jahre und deren Auswirkungen auf Aspekte der Biodiversität. Die Änderungen der Landbedeckung wurde zwischen drei verschiedenen Zeitpunkten erhoben: 1953/54, 1970/71 und 2001/03. Für die Jahre 1953/54 und 1970/71 mussten aus Luftbildern Orthophotos erstellt werden, für die Jahre 2001/03 waren diese schon vorhanden. Für alle drei Zeitintpunkte wurden im ersten Teil dieser Diplomarbeit Landbedeckungskarten erstellt. Die Veränderungen der Landbedeckung beeinflussen Größe und Qualität der Habitate von einheimischen Arten. Im zweiten Teil wurden Zusammenhänge und mögliche Auswirkungen der Landbedeckungsveränderungen auf Wildtiere des Kaunergrats dargestellt. Von den 1950igern bis zu dem Jahr 2001/03 konnte eine Verdichtung der

Wälder in großen Teilen des Untersuchungsgebietes festgestellt werden. Diese Verdichtung der Wälder beeinflusste viele Wildtierarten, welche in der Nähe alpiner Kulturlandschaften vorkommen und lichte Wälder als Habitate nutzen. Die Habitate einiger dieser Tierarten wurden von dieser Entwicklung und unter den in dieser Arbeit erhobenen Gesichtspunkten negativ beeinflusst (Steinbock, Reh und Hirsch, Birkhuhn, Auerhahn und Steinhuhn). Lediglich das Schneehuhn scheint von der veränderten Landbedeckung leicht profitiert zu haben. Vom Standpunkt der Artenvielfalt aus gesehen muss die Entwicklung im nördlichen Teil des Kaunergrats während der letzten 60 Jahre negativ beurteilt werden.

Changes in cultural landscapes and their impacts on the biodiversity of an alpine eco-system

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1. Introduction, aim of the thesis

Land use in alpine regions was traditionally characterised by a fine scale, sustainable agriculture, which understood the need for an agricultural approach that was adapted to a very vulnerable alpine eco-system.
Over hundreds of years, the local residents of mountainous regions have developed specialised agricultural techniques to live off the land in awareness of alpine conditions.

In the past 50 years an enormous and rapid change of land use has taken place in most industrialised alpine countries.
Because of the harsh environmental conditions, extensive alpine agricultural production was not able to compete with the lowland, more intensive production. Therefore the traditional sustainable ways of land use gave way to a new, different approach to the mountainous environment.
New infrastructure was developed, settlement density in the valleys increased. Big touristy projects, such as skiing resorts and hiking trails marked the landscape. Alpine agriculture decreased. This development has been accompanied by strong migration towards the cities. The main area of income has shifted from agricultural production towards seasonal tourism.

This master thesis aims to investigate this incredibly fast structural changes in alpine regions, by the example of the nature reserve of the `Kaunergrat`.
It assesses the changes of the land cover in the Kaunergrat over the past 50 years.
Then it seeks to evaluate the effects of these changes of the land cover on the biodiversity of a vulnerable alpine ecosystem.

2. The area of investigation

The nature reserve `Kaunergrat` is a mountain range in Austria, in the `Ötztaler Alps`, which reaches from the Inn valley towards the Austrian/Italian borders (fig 1).

Fig 1: Location of the nature reserve of the "Kaunergrat" in Austria, in the Tyrol (Naturpark Kaunergrat, n.d.).

The object of research covers an alpine area of approximately 100km^2 in the northern part of the nature reserve of the `Kaunergrat` (fig.2). In total it encloses 58.920 hectares of alpine environment. The highest point of the nature reserve is represented by the `Wildspitze`, the highest mountain of the Tyrol, with 3768m altitude.

Among its protected areas are natural forests, high mores, and arid grasslands with a high bio-diversity, wildlife resting areas and cultural landscapes (Naturpark Kaunergrat, n.d.).

The mountain range "Kaunergrat" is characterised by a very dry, continental climate. Temperature fluctuations between night and day and between the seasons are high. The high, surrounding mountain ranges have a shielding effect on precipitation. Therefore precipitation only ranges between 700 and 900mm. The average temperatures reach from –3℃ in February to 13℃ in July (measurements at the Piller).

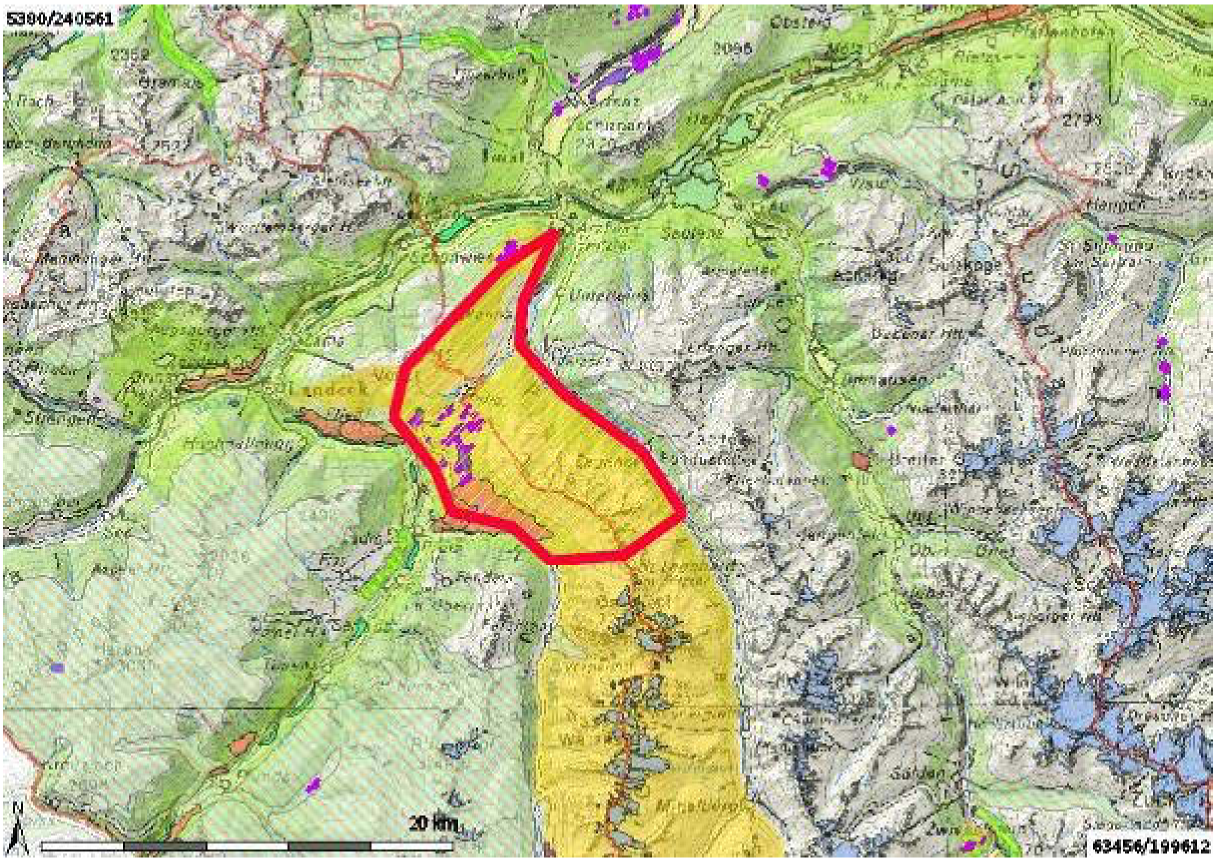

Fig. 2: The area shaded in yellow and surrounded by the red marker represents the area of research in the nature reserve Kaunergrat (Tiroler Landesregierung, 2010).

The geology of the area of interest is dominated by mica slate in its most southern parts. Zones of granite and gneiss can be found in the middle, and in the northern parts, mica slate and quartzphyllite characterise the geology.

Because of the enormous differences in altitude, nearly all vegetation-zones can be found in the nature reserve Kaunergrat.

The valleys are dominated by more or less intensively used agricultural grasslands and pastures which are often accompanied by stripes or small aggregations of trees and bushes. Above the valleys, montane and subalpine spruce forests, often mixed with pine and larch, adjoin. These forests are often interrupted by shrub-covered avalanche tracks. A particularity of the region is the occurrence of high moors in the montane zone.

The subalpine belt is characterised by larch/Swiss stone pine mixed forests and by shrub and dwarf shrubs. This is also the zone, where in the more advantageous places, most alpine pastures, usually covered in mat-grass, occur. Above the timberline (at about 2300m), the alpine level adjoins with natural alpine pastures and rock and rubble (Hotter & Aschaber, 2001).

Fig. 3: Mountain range of the Kaunergrat in winter. (Florian Wille, 2009)

3. Methods

3.1. Data

- **Aerial images**

Aerial images detect electromagnetic energy which has interacted with the earth's surface and the earth's atmosphere. This detection can either be photographic or electronic. These electromagnetic signals are then converted to an image (Lillesand et al., 2008).

For this study, a large number of aerial images arranged in a block have been used. These aerial images completely covered the area of investigation. In order to produce a time series and therefore to evaluate the change in the landscape pattern, these aerial images were shot in the years of 1953 and 1971 and were acquired from the BEV (Bundesamt für Eich und Vermessungswesen) and partly provided by the province of the Tyrol.

- **Orthophotos**

To round up the time series of landscape pattern, up-to date orthophotos were used.

"As implied by their name, orthophotos are orthographic photographs. They do not contain the scale, tilt, and relief distortions characterizing normal aerial photographs. In essence, orthophotos are 'photomaps.' Like maps they have one scale, (…) and like photographs they show the terrain in actual detail (not by lines and symbols). Hence, orthophotos give the resource analyst best of both worlds: a product that can be readily interpreted like a photograph but one on which true distances, angles and areas may be measured directly" (Lillesand et al., 2008, p.169).

The orthophotos used for this study covered the whole investigation area. As the whole area could not be covered by one flight, they have been pieced together in a jigsaw of orthophotos of the years 2001 and 2003.

- **Ground control points**

Ground control points are physical marks on the ground. Their position is known in some defined coordinate system or datum. These ground control points have to be fixed and have to be easily identifiable on both map and photo (Lillesand et al. 2008). In this study ground control points were used to transform the aerial images from the 1950ties and the1970ties into orthophotos. They were kindly supplied by Dipl.-Ing. Hermann Gspan of the provincial government of Tyrol.

- **Digital terrain model**

"Digital terrain models (DTMs) are topographic models of the "bare earth" that enable users to infer terrain characteristics that may be hidden in the digital surface model (DSM). A DTM has cultural features such as buildings and roads, and vegetation canopy digitally removed, leaving just the underlying terrain."
(Intermap technologies, 2011) For this thesis, a digital terrain model (1*1meters; raster format), of the investigation area was kindly supplied by the provincial government of the Tyrol.

- **Biotope map**

A detailed biotope map is used as a reference for classifying and analysing landscape typology. It also was provided by the provincial government of the Tyrol.

3.2. Software

- **Erdas Imagine**

Erdas Imagine is a software created by the company Erdas inc.. It enables the user to perform remote sensing image analysis and spatial modelling in order to create new information.

- **LPS**

LPS is a module of the software "Erdas Imagine". It consists of a range of photogrammetric tools. With LPS it is possible to produce digital terrain models, to perform photogrammetric triangulation, produce ortho mosaics and analyse 3d features (Erdas inc., 2010).

In this study, LPS was used to transform aerial images into orthophotos and to create comprehensive orthophoto mosaics.

- **Arc VIEW 9.3.**

The GIS software Arc View by ESRI is one of the most common GIS software and perhaps a standard setter in GIS application (Lang & Blaschke, 2007). In this study, Arc View was used to produce maps, calculate areas, analyse landscape features and to visualise the results.

- **V-late**

V-late is a vector-based tool, which calculates the most common landscape-metrics that are applied in landscape-ecology. It was developed by the Z_GIS centre for geo-Informatics, Salzburg and can be downloaded as a free-ware product and add-on for Arc-GIS 9.3.

3.3. The creation of orthophoto mosaics

For this thesis, the first step towards a GIS based analysis of the structural diversity of a landscape is to create orthorectified images of the aerial pictures of the 1950ties and the 1970ties. In this chapter the photogrammetric approach of creating orthophotos is described in short. A detailed technical report can be found in the appendix A.

3.3.1. The interior orientation

The first step was to restore the **interior orientation** of the aerial images with the help of the software LPS.

If it is assumed that an aerial picture reflects an exact central projection, then the parameters of the interior orientation are given by the camera constant c and the image focal point H (X/Y). In this case, the camera constant describes the distance of the projection centre to the image focal point H.

In reality, an aerial image includes distortions produced by the inaccuracy of the aerial image camera. These distortions can be compensated through the calibration of the camera in a laboratory and the resulting information in the calibration protocol (Kraus, 1994). Fig. 4 displays a sketch of the main parameters of the interior orientation.

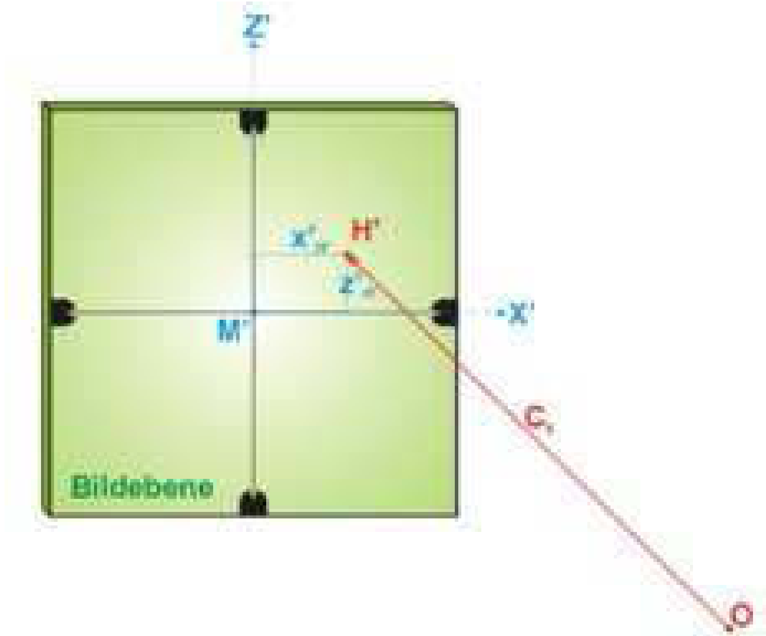

Fig. 4: The interior orientation: The location of the projection center O relative to the image plane is described by the camera constant c and the image focal point H (Joachim Bäcker, 2007).

In order to restore the interior orientation the

- Camera constant
- The Image focal point
- And the calibrated image coordinates of the fiducial marks

were entered into the software LPS.

Then the locations of the fiducial marks on the scanned aerial images were measured with the help of LPS. Through these inputs LPS was able to calculate transformation parameters and with the aid of a 2D transformation it could then restore the interior orientation.

3.3.2. The absolute exterior orientation

In this study a large number of aerial images had to be transformed.
Therefore, to establish the absolute orientation, the method of "aero triangulation" was chosen and executed by LPS.
In comparison to the orientation of single images or stereo models, the method of "aero triangulation", results in higher speed and a higher accuracy, with less ground control points necessary. Many images can be orientated simultaneously, and areas which are missing ground control points may be covered (Kraus, 1979).

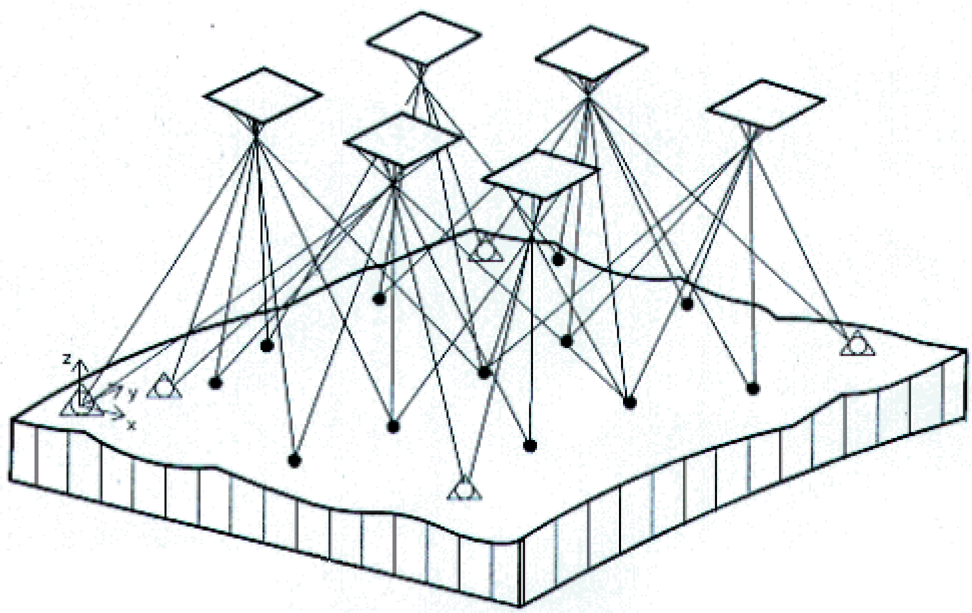

Fig. 5: Aerial triangulation (Caldwell J. 2006).

As a prerequisite to aero triangulation LPS enables the user to generate tie points by which the images with an approximate crosswise overlap of 60% and a lengthwise overlap of 20% could be connected and joined (fig. 6).

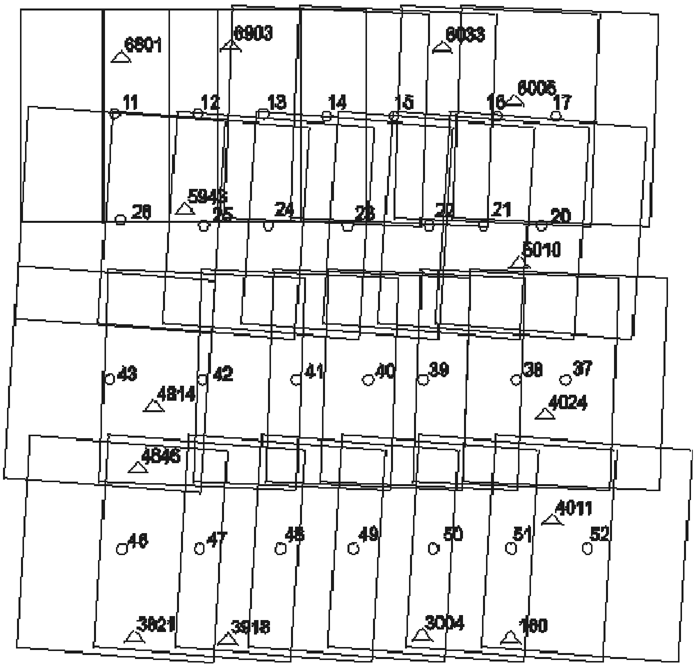

Fig. 6: Block arrangement of aerial images with tie points (Jakkola, 1994).

By further transformation and with the aid of ground control points, the **absolute exterior orientation** could be restored from this block of aerial images. The absolute orientation describes the surface of the images, fitted into the geographic coordinate system and projection, which are applied to the investigated landscape (Kraus, 1997). Six ground control points per stripe were chosen. Those points had to be clearly identifiable on the aerial pictures and well distributed at the end and the beginning of each stripe.

3.3.3. Orthophoto creation

In order to create an orthophoto, the geometric distortions of an absolutely orientated aerial image have to be removed. This could be accomplished by using a digital elevation model. Each pixel of the original aerial image is then resampled to its rectified place in the orthophoto (see fig. 7), (Lillesand et al., 2008).

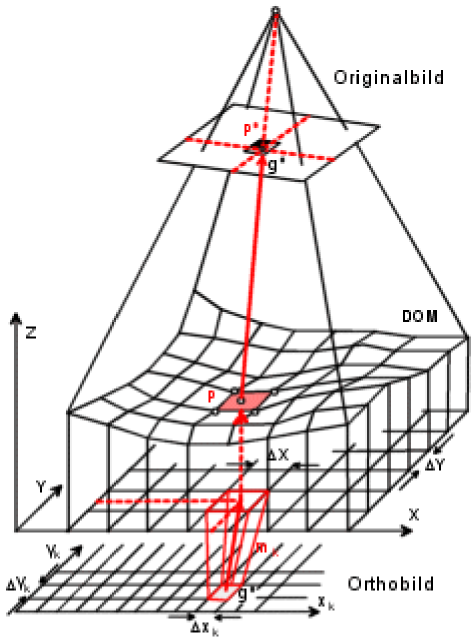

Fig 7: Rectification of an aerial image with the aid of a digital elevation model in order to create a rectified orthophoto (Landratsamt Starnberg, 2008).

3.4. The interpretation of land cover from aerial photos

The next step towards an analysis of the change of structural diversity was to interpret, classify and structure the information given by the time series of orthophotos.

Basically there are two methods for classifying remotely sensed information.

- For visual interpretation an interpreter studies the orthophotos. Sometimes other sources, like maps or study reports are additionally used to acquire information about the area or objects under investigation. Based on these studies a classification relating to the matter of interest can be made.
- In digital image classification, visual interpretation is being replaced by an automated procedure. Statistical decision rules analyse and classify the spectral data of an image. Sometimes these decision rules also analyse the geometry, patterns or shapes of features. According to these decision rules a land cover class can be assigned to each pixel in the image (Lillesand et al.2008).

For this study the method of visual image interpretation was chosen.
Although this procedure often is more work intensive, more subjective and perhaps less modern, it was selected for two reasons. First, as the area under investigation is situated in the high alps, the same classes of land cover are often set in varying positions of exposition, inclination and altitude. Additionally, no multispectral information for the orthoimages taken in the 1970ties and 1950ties was available, as the images were black and white images only. These two aspects make it very difficult for automated classification to classify pixels according to spectral information.

3.4.1. Compilation of an interpretation key

The interpretation key for this thesis was based on the already existing interpretation key of the "Biotopkartierung Tirol" by the Federdral Government of Tyrol, Department of Environmental Protection (see Appendix B).
This interpretation key can be found in the "Gesamtaufnahme der Kernzone; Naturparkprojekt Kaunergrat, (Pitztal-Kaunertal) Endbericht" (Hotter & Aschaber 2001).
As this interpretation key for the "Biotopkartierung Tirol" was established for the use of colour/ infrared orthoimages and applicable only in combination with terrestrial investigation, for this thesis it had to be modified and adapted.

The modifications of the classes chosen for the interpretation key had to meet the following criteria:

- Classes had to be defined with respect to land cover. "The term land cover relates to the type of feature present on the surface of the earth.(…) The term land use relates to the human activity or economic function associated with a specific piece of land" (Lillesand et al., 2008, p.213).
- The different classes of land cover had to be recognisable on black and white orthophotos by clearly distinguishable features. According to Olson, (1960) some basic characteristics of orthophotos include: "shape, size, pattern, tone, texture, shadows, site, association and resolution" In: (Lillesand et al., 2008, p.191).

Eventually, 14 classes of land cover were chosen and distinguished:

- Intensive anthropogenic land use
- Without land use
- Wetlands
- Water bodies
- Alpine meadows above 2500 m
- Agricultural alpine meadows
- Scrubs
- Alpine meadow-forest (with a canopy cover between 5% and 15%)
- Forests-alpine meadows (with a canopy cover between 15% and 30%)
- Forests (with a canopy cover between 30% and 100%)
- Scrub-forest biotopes complex
- Scrub-meadow biotope complex
- Scrub-meadow-forest biotope complex
- Young forests

A detailed description and illustration of the interpretation key can be found in the appendix C.

3.4.2. Interpretation of land cover

The delineation of land cover classes was undertaken under consideration of two guidelines:

- The pattern of land cover must not have gaps
- The patches of land cover must not overlap (fig. 8)

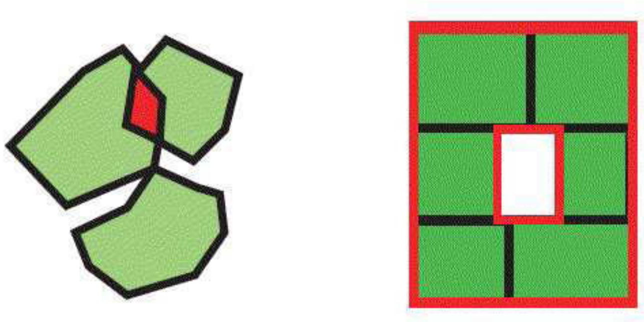

Fig. 8: The two guidelines for digitising: Must not overlap and must not have gaps (Demel, W., 2005).

The pattern of land use in the Kaunergrat was visually interpreted and delineated according to the interpretation key and digitised with the software ARC View 9.3.. The digitising was based on the orthophoto mosaics from the years 2001/2003, the 1970ties and the 1950ties.

To be able to delineate the three different classes of canopy cover included in the interpretation key, several reference sites for percent canopy cover were created. Parcels of 100*100 meters were drawn in Arc View 9.3.. The forest canopy cover included inside the parcels was digitised. To avoid distortion effects, each tree was only digitised with a circle corresponding to its estimated ground projection around its centre and not as seen in the photo with radial displacement effects. Then the percent canopy cover was calculated for each parcel. These parcels were used for visual comparison while identifying and delineating the different classes of canopy cover on the orthophotos (fig. 9).

Fig. 9: Parcels with the varying canopy covers of 53%, 19% and 7%.

A compilation of all the test site parcels can be found in the appendix D.

Eventually the resulting land cover maps were validated in respect to the guidelines with the Arc View 9.3. topology function.

3.5. The assessment of biodiversity

3.5.1. Status quo of biodiversity in Austria

The protection of natural biodiversity has been a burning issue in Europe since the 1970ties.

In 1983, Austria signed the "Convention on the conservation of European wildlife and natural habitats" in Bern. Due to this agreement, biodiversity became a matter of international law in Austria and manifested itself in the hunting and nature protection laws of the provinces of Austria.
This convention pursued a minimum protection of nearly all wild living species and their habitats and a maximum protection for endangered species and their habitats (Council of Europe,1997).

In the 1990ties Austria ratified the international "Convention on biological diversity" which was opened for signature in Rio de Janeiro 1992 and went into force in 1993 with the agreement of 193 national states. Its three main objectives include:

- To conserve biological diversity
- The use of biological diversity in a sustainable fashion
- To share the benefits of biological diversity fairly and equitably.

The implementation of this convention took place in the establishment of "thematic programmes" and "cross cutting issues" addressing these thematic programmes. The results of the implementations of these programmes depend on the work of parties, the secretariat and intergovernmental and other organisations (Convention on biological diversity, 1993).

As a consequence to the “Convention on biological diversity” the European union established the concept of “Natura 2000”. “Natura 2000” is a program legally based on the Habitats Directive (Council Directive 92/42/EEC) and the Birds’ Directive (Council Directive 79/409/EEC). It established a network of natural protection areas throughout Europe to preserve the habitats of endangered species (European Union, 1995-2010).

3.5.2. Concepts of biodiversity

There are many various definitions of the term “biodiversity”. The Convention on Biological Diversity (Rio de Janeiro 1992) for example defines biological diversity as follows:
"Biological diversity" means the variability among living organisms from all sources including, inter alia, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems” (Convention on biological diversity, 1993).
Altogether, two main concepts of biodiversity have emerged:

1. Blab et al., 1995, see biodiversity as a concept of three layers.
- The gene-diversity forms the bottom layer
- As a second layer, the species diversity is regarded
- And the third layer describes the diversity of habitats

Often, biological diversity is measured at the layer of species diversity, as there are many well established methods for counting species and deriving diversity indexes from them. Two of the most famous diversity indexes regarding the species diversity are the Simpson Index (Edward H. Simpson, 1949) and the Shannon Index (Weaver, C.E. Shannon, 1949).

2. From a landscape-ecological perspective the diversity concept of Whittaker (1972) is more appropriate. Whittaker (1972) classifies the
- α - diversity, which is often referred to as species diversity, as it describes the diversity in an certain area or habitat

- The β - diversity, a term to describe the change of diversity between two different areas or habitats
- And γ - diversity to express the species diversity of different areas or habitats within an ecosystem or region.

For this thesis, orthophotos and delineated biotope maps visualize the changes of the land cover from past till present. Therefore, the changes in bio diversity over time in this thesis are investigated regarding the diversity of habitats which for this thesis is represented by the delineated land cover polygons. From the information given by the development of land cover polygons, information on vegetation cover and species diversity is derived.

3.5.3. Issues on species diversity

For this thesis it was not possible to regard all the occurring species in the Nature reserve Kaunergrat.
The forest biotopes altogether (forests with a canopy cover between 30% and 100% and forest-meadows with a canopy cover between 15% and 30%) amount to 45% - 46% of the area under investigation throughout all three investigated time intervals (see chapter 4). Therefore forest biotopes make up the largest amount of the biotopes in the area of investigation. Species that solely prefer forest biotopes were not regarded in this thesis, as the focus was biodiversity and species dependent solely on forest biotopes have a big and stable habitat to live in anyway.
A number of species that seem to be representative for alpine regions and that are fairly well studied have been chosen to analyse the effects of the changes in the land cover.
Within the project "Alp Austria" Huber & Bergier (2006) identified a number of key species that live in close relationship to, and dependence of alpine agriculture. In this thesis, those species have been regarded more closely.
Depending on the available data, potential habitats were modelled for those species so that the resulting sizes of potential habitats could be compared over all three time intervals.

It has to be stressed that the resulting potential habitat maps do not display the actual occurrence of the concerning species but they visualize habitat factors which were mentioned by the literature and could be mapped according to the available data!.

Where data were not sufficient to model potential habitats, indicators for habitat quality were derived or statements on the development of habitat quality were made.

4. Changes of land cover in the Kaunergrat

4.1. Orthophoto mosaics

From the aerial images of the 50ties and 70ties and the orthophotos of the years 2001/2003 a time series of orthophoto mosaics of the investigation area (fig. 10-13) was created.

Fig. 10: Orthophoto mosaic of the investigation area from the years 1953 and 1954

The overall relative geometric accuracy for the orthophoto mosaic of the 1950ties can be described by an error of up to 5 meters in remote areas and between 2 and 3 meters in most locations of the orthophoto. Each pixel covers an area of 0.31*0.31 m.

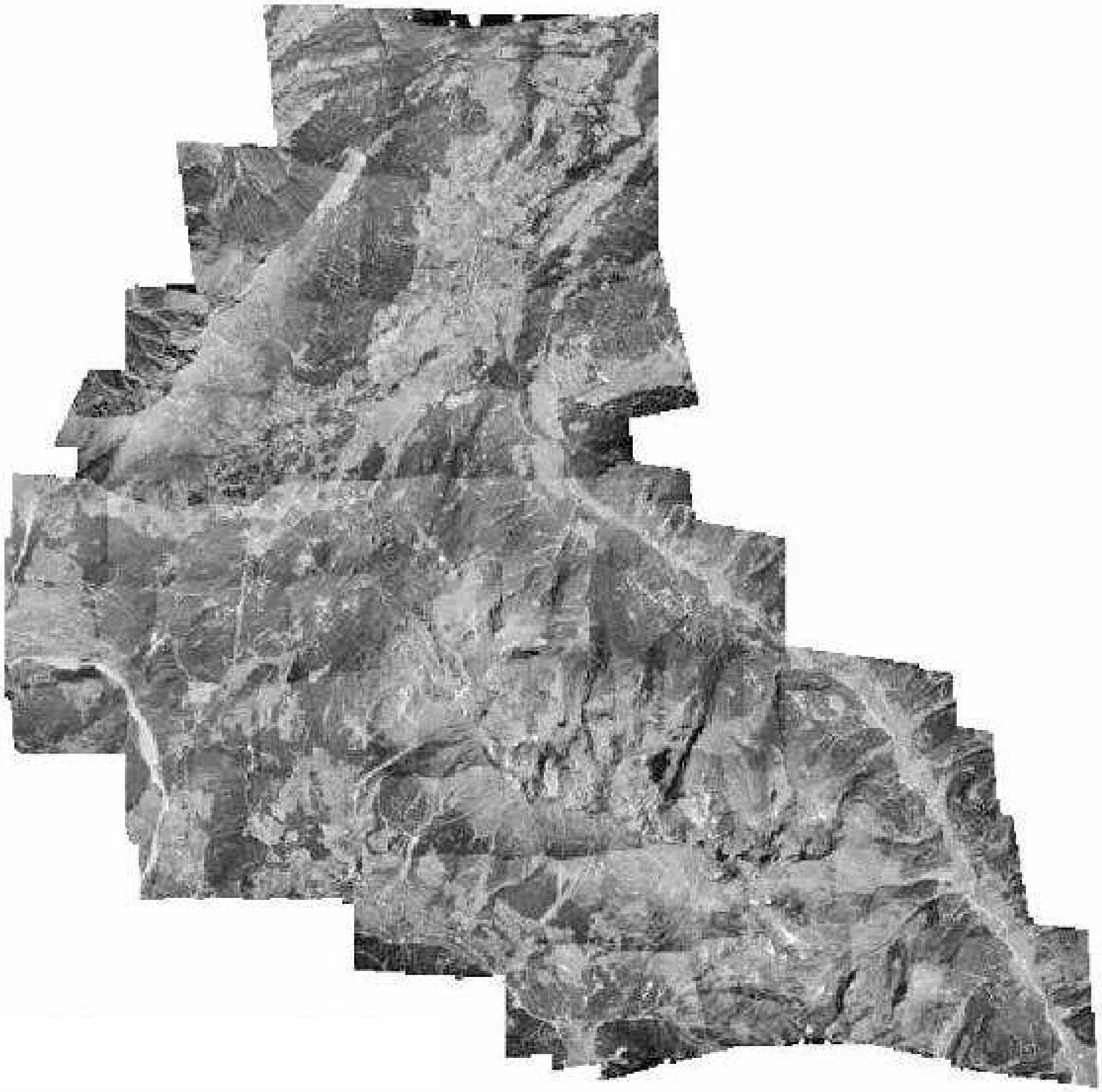

Fig.11: Orthophoto mosaic of the investigation area from the years 1970 and 1971

The relative geometric accuracy for the orthophoto mosaic from the 1970ties ranges from an error of 4 m in remote areas to an error of 2-3 meters in more accessible locations. The pixel size is 0,26*0.26 meters.

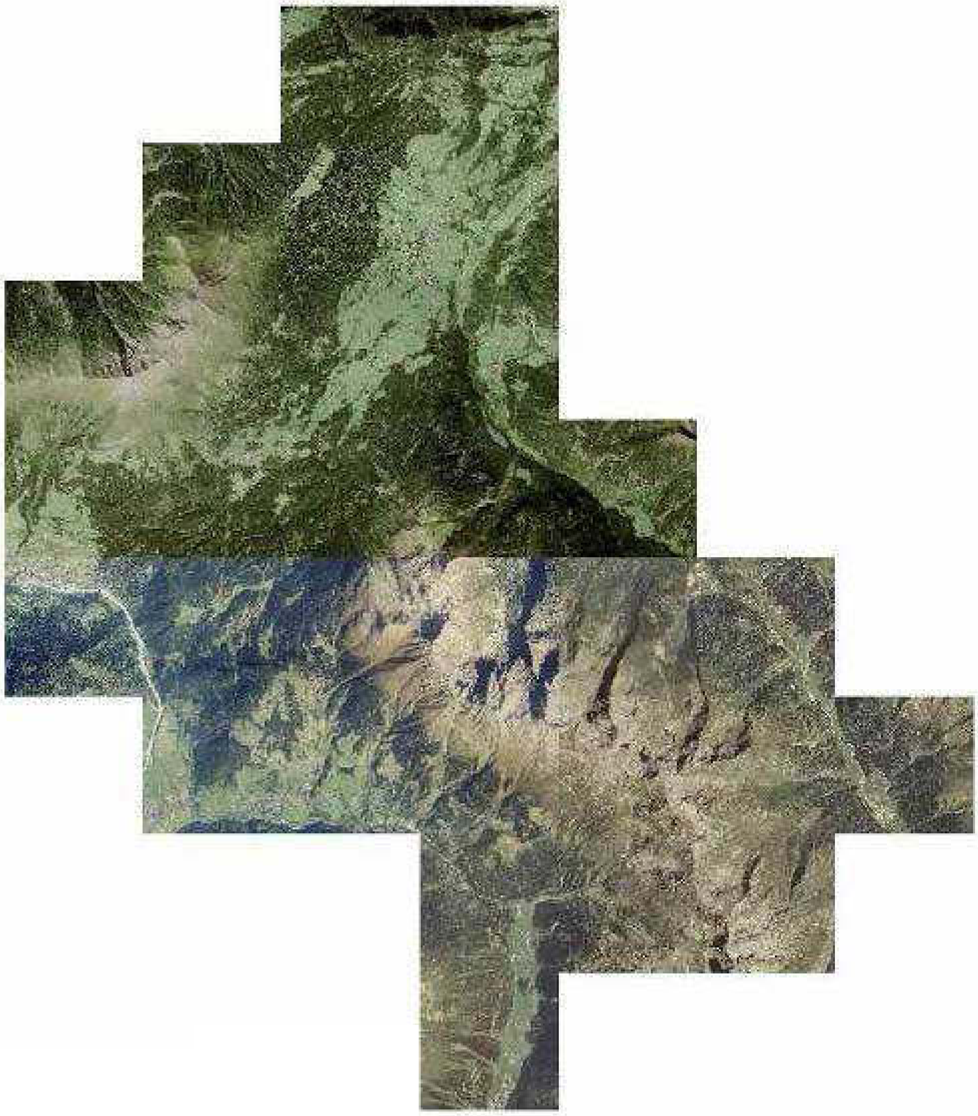

Fig.13: Orthophoto mosaic of the investigation area from the years 2001 and 2003

The size for the pixel in the orthomosaic of the years 2001 & 2003 is 0,25*0,25 meters. The northern and the southern parts of the orthophotos of 2001 and 2003 show differences in illumination, this was not a problem for interpretation as both parts fitted together very well and features were clearly distinguishable on both halves.

4.2. Land cover maps

The land cover in the investigation area was interpreted and delineated for the 50ties, 70ties and for the years 2001/2003 (fig.15, 16 &17).

The minimum mapping unit for land cover polygons was chosen with approximately 100 m^2 .This very small minimum mapping unit was chosen in order to be able to take small huts and anthropogenic objects into account. Nevertheless, for some land cover categories, the need arose to adapt the minimum mapping unit. For land cover categories with multiple features such as scrub – meadow mosaics or meadows with a forest canopy cover between 5% and 15% a minimum mapping unit between 400m^2 and 1000m^2 was chosen according to the arrangements of patterns and features.
Because of the missing space in the resulting land cover maps, the legend is displayed separately (see fig.14).

Fig. 14: Legend for land cover maps

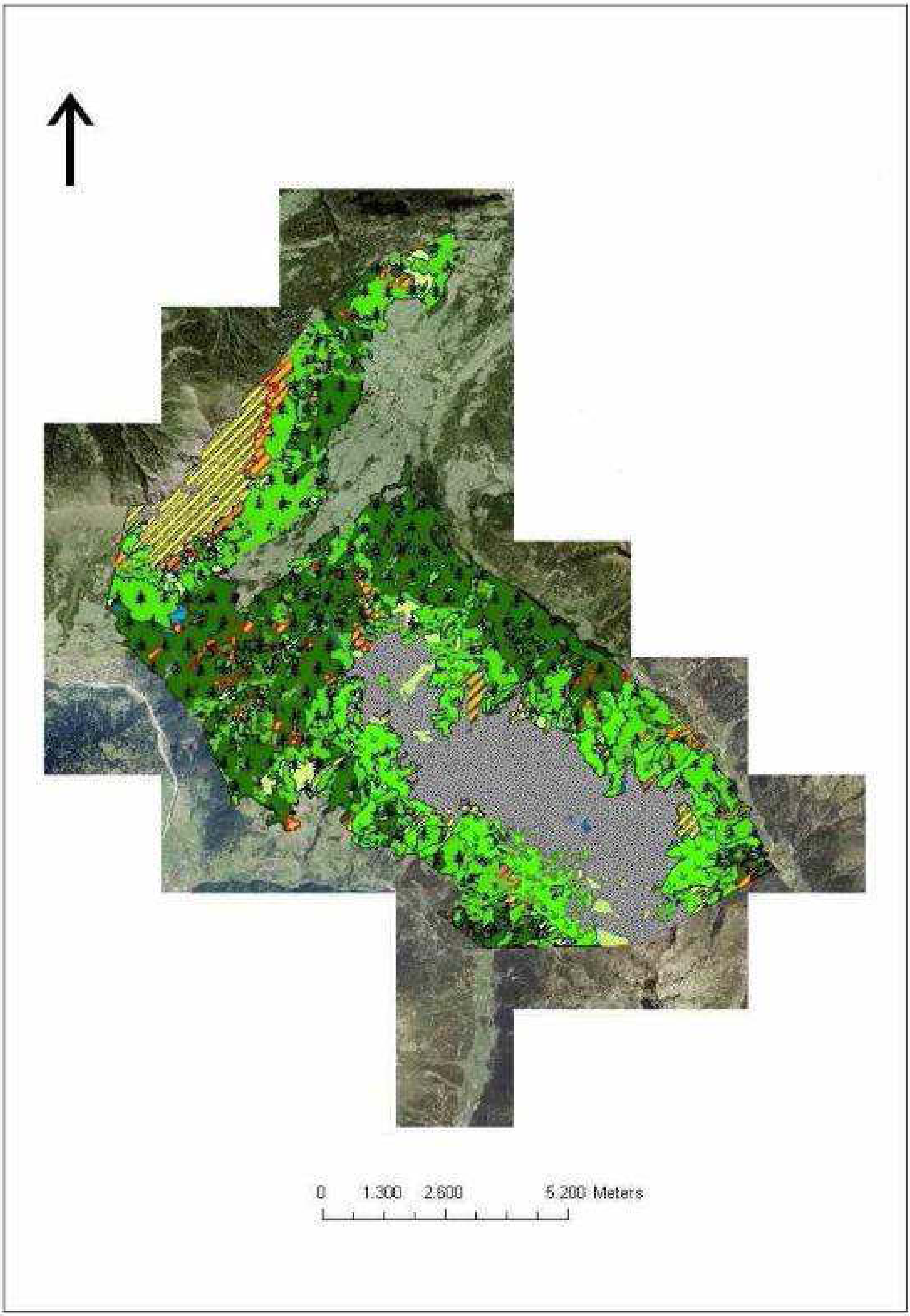

Fig.15: The land cover in the Kaunergrat in the years 2001 and 2003

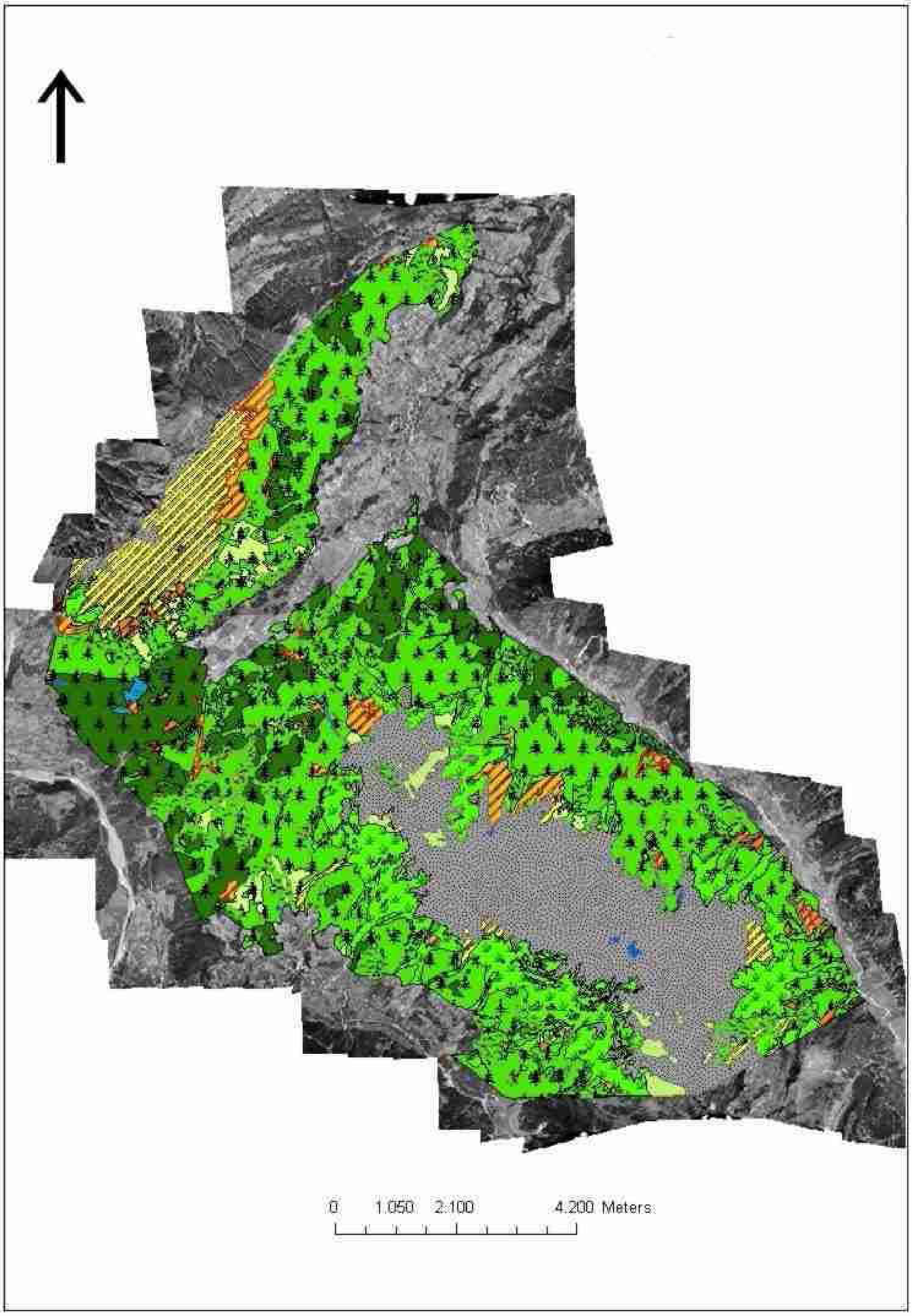

Fig.16: The land cover in the Kaunergrat in the years of 1970 and 1971

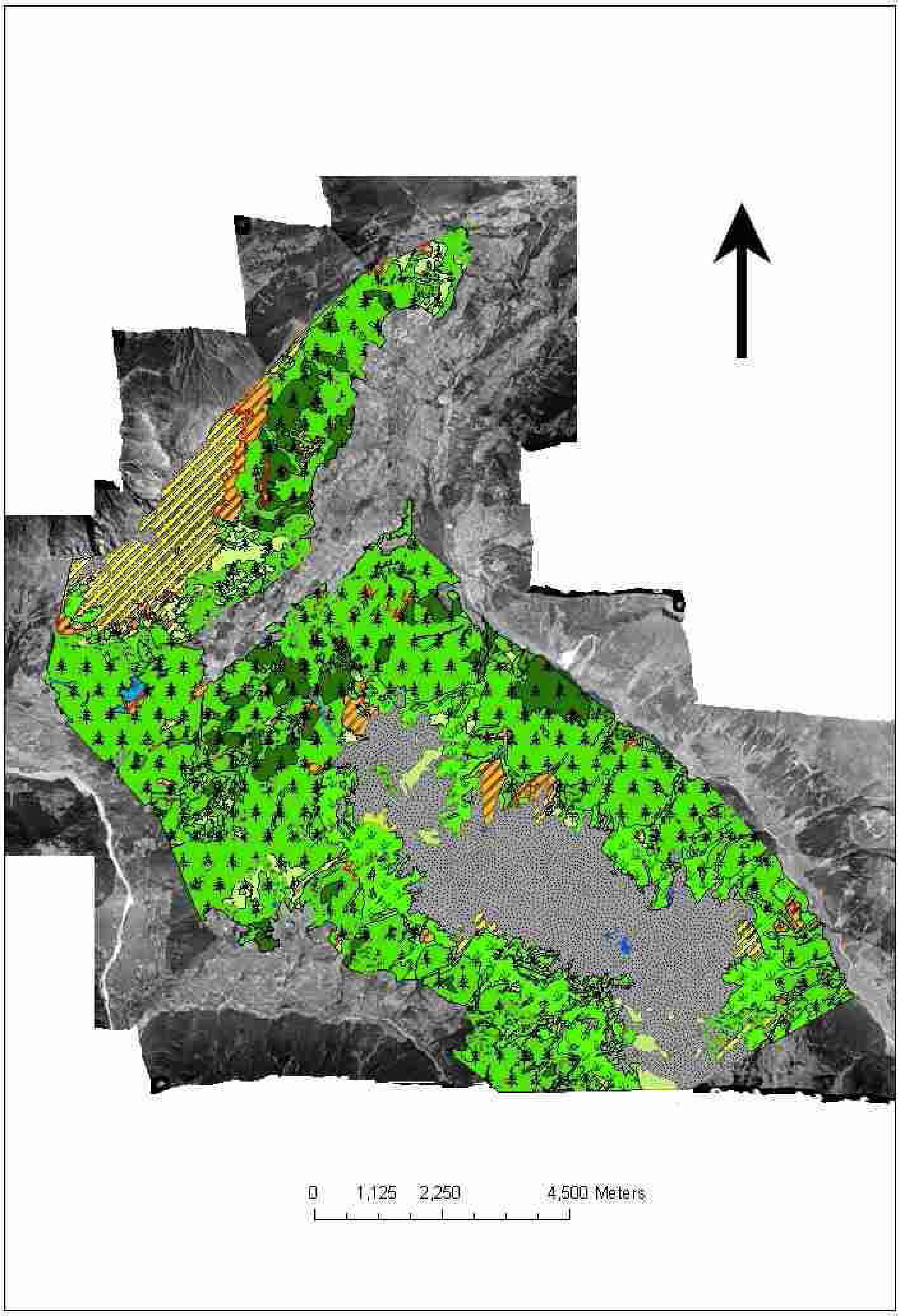

Fig.17: The land cover in the Kaunergrat in the years of 1953 and 1954.

4.3. Changes of the land cover over time

As a first step, to analyse the changes of land cover over time, the total area of the different land cover classes for all three dates used for the investigation was calculated. The results are displayed in the figures 18-20.

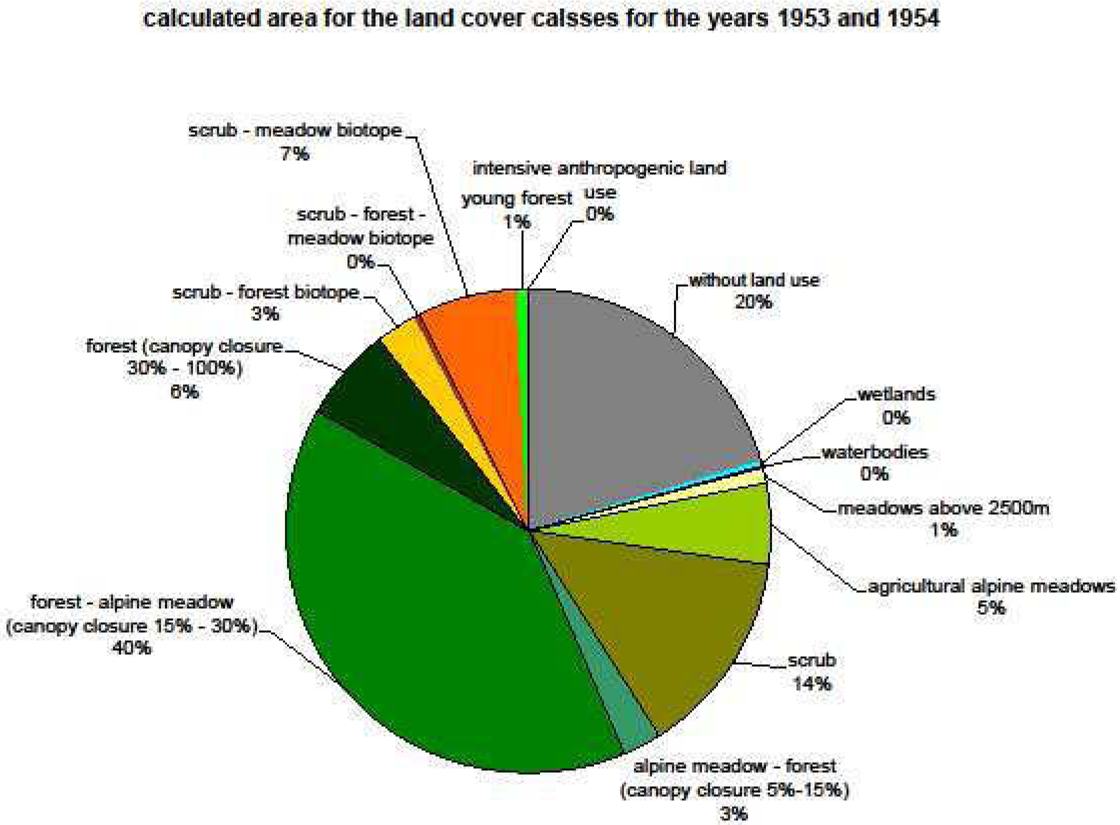

Fig.18: Total area for the different land cover classes for the years 1953 and 1954.

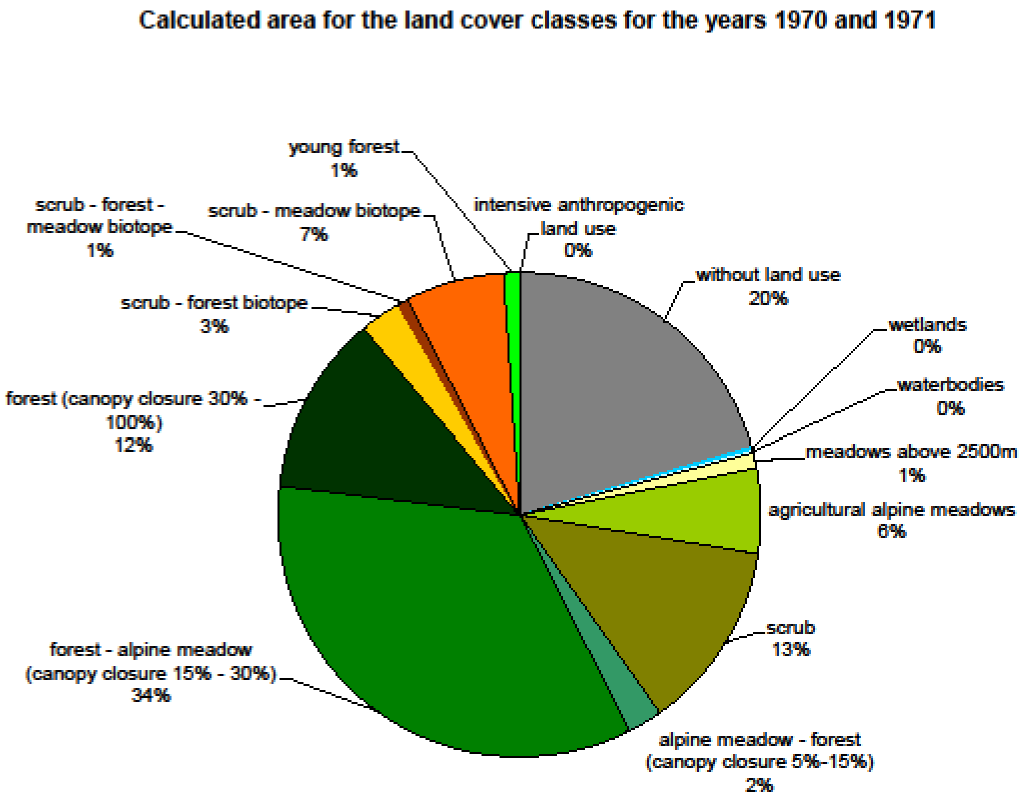

Fig.19: Total area for the different land cover classes for the years 1970 and 1971

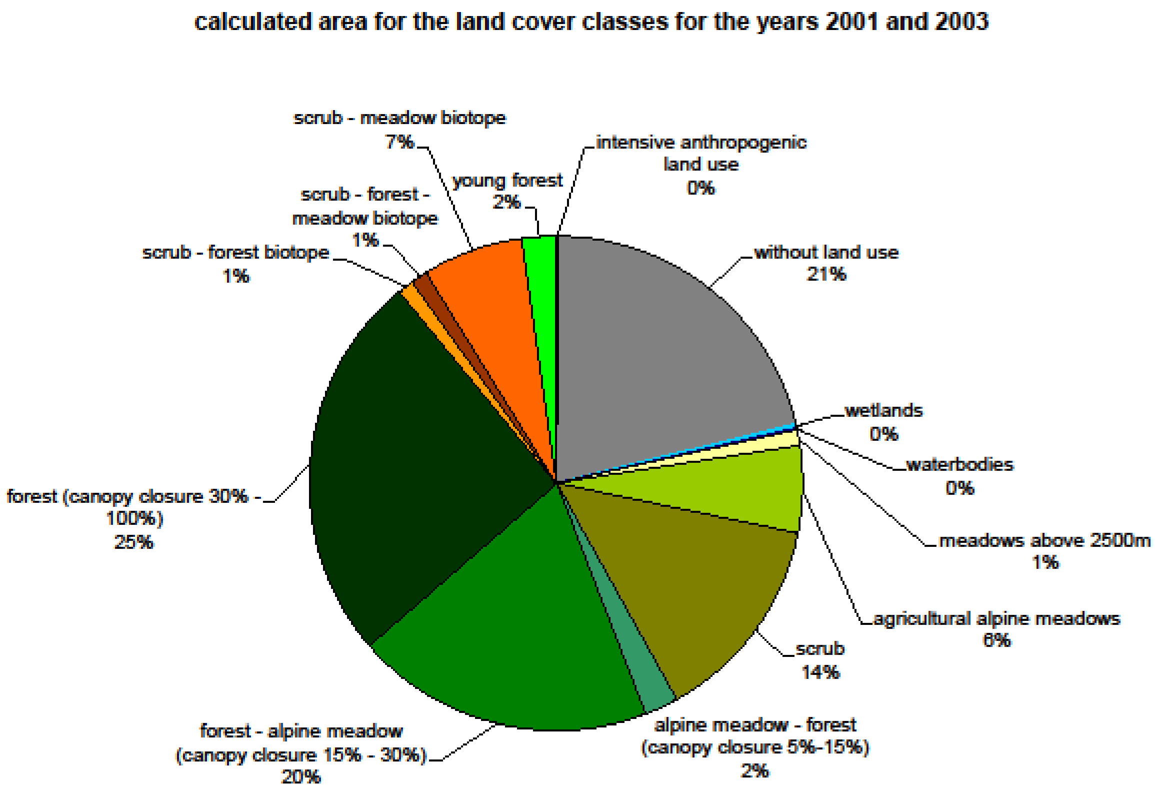

Fig.20: Total area for the different land cover classes for the years 2001 and 2003

Throughout this thesis, changes of area percentages are described in terms of "percentage points" which describe the arithmetic differences of percentages.
The most significant change, which immediately catches the eye, concerns the land cover class "forest – alpine meadow; canopy closure 15-30%". This forest type decreased by 6 percentage points from the years of 1953 and 1954 to the years 1970 and1971 and then it decreased even more, by 14 percentage points from the years 1970 and 1971 to the years of 2001 and 2003.
Just as significantly, thicker forests, of the land cover class "forest-canopy closure 30-100%" have gradually increased in the investigation area by 19pp from the years of 1953 and 1954 until the years 2001 and 2003. Alpine meadows, containing a low proportion of forest: "alpine meadows-forest; canopy cover 5-15%" reduced by one pp from the 1950ties to the 1970ties. The proportion of scrub, in the investigation area, reduced by one pp from the 50ties to the 70ties and then increased again by one pp until the years of 2001 and 2003. An increase of "alpine agricultural meadows" can be observed from the 1950ties till the 1970ties. The one percent of the investigation area, containing "young forests", increased by one pp from the 1970ties till the years of 2001 and 2003. The area of "scrub-forest-meadow biotope complexes" decreased by one pp from the 1950ties until the 1970ties while scrub-forest biotopes decreased by 2 pp between the 1970ties and the years 2001/03. No significant changes could be observed for the land cover classes "meadows above 2500m"; "water bodies", "wetlands", "without land use" "scrub-meadow biotope complex" and "intensive anthropogenic land use".
The following chapter will try to interpret the most significant changes in the land cover, which especially occurred in the land cover classes of "forest-alpine meadow, canopy cover 15%-30%", "forest, canopy closure 30%-100%", "scrub", "alpine agricultural meadows", "alpine meadow-forest, canopy closure 5%-15%", "scrub-forest-meadow biotope", "scrub-meadow biotope" and "young forests".
The change in the land cover over time is visualized in the fig. 21.

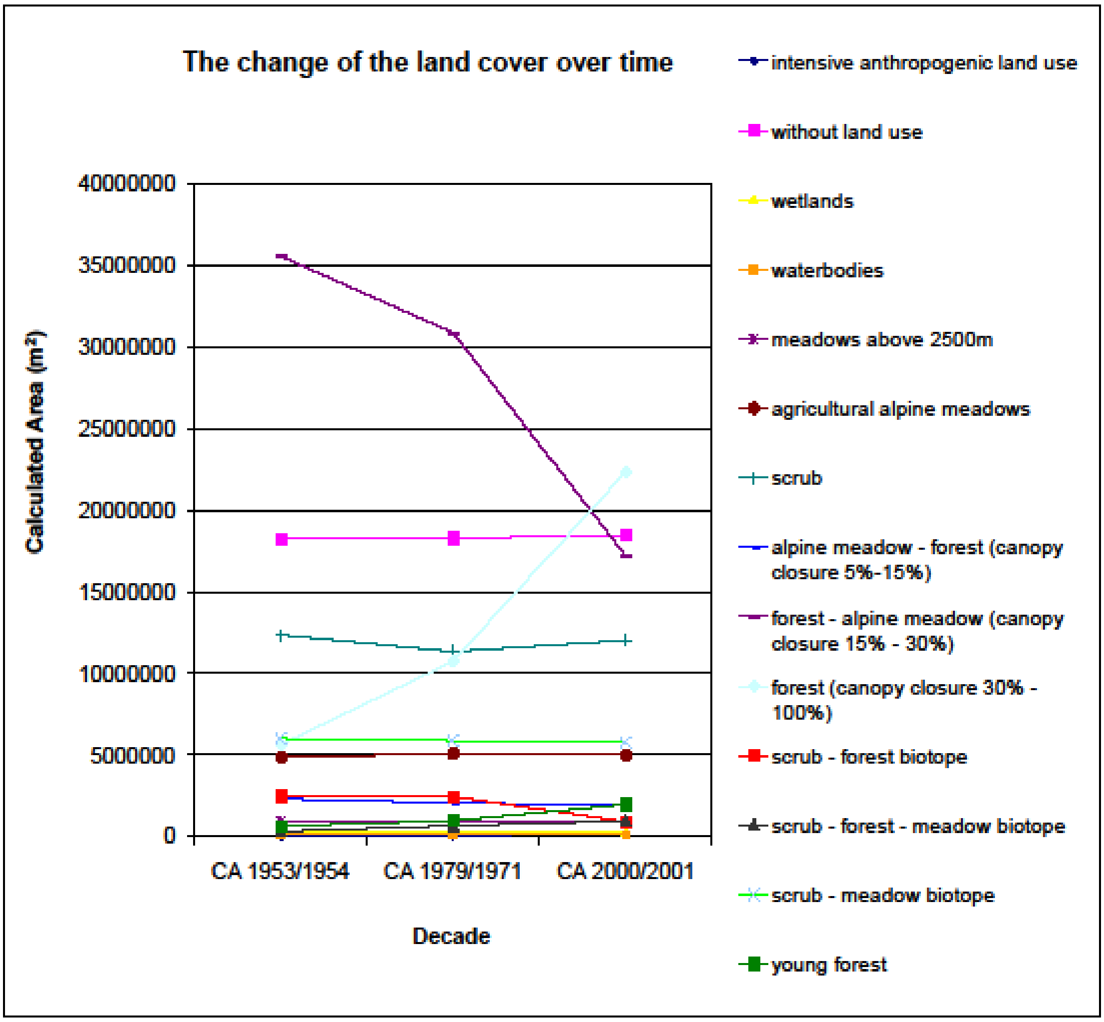

Fig. 21: The changes of the areas for the different land cover classes over time.

4.4. Analysis of the changes of the land cover vegetation

4.4.1. Forest-alpine meadow; canopy closure 15-30%

The land cover class “forest - alpine meadows with a canopy cover between 15% – 30%” describes a biotope that is characterized by forests intermingled with open areas. The composition of tree species for the area under investigation are mainly coniferous trees such as pine, larch, spruce, fir and the Swiss stone pine, but in lower areas also single broad leaf trees can be found.

From a wildlife ecological perspective, light forests in alpine zones are regarded as necessary habitats for the survival of the capercaillie *(Tetrao urugallus)* (Huber&

Bergier 2006, p.22), and provide shelter for many other species such as the capricorn (Deutz 2001) or the black grouse (Zeller, 2008).

The figures 22 & 23 visualize how the land-cover of forests, with a canopy cover of 15-30%, has developed within the last 50 years.

In figure 22, the light green patches, together with the purple patches, describe the land cover of forests (with canopy cover 15%-30%), as it used to be in the 1950ties. The purple patches display the areas where forests (c.c. 15%-30%) were located in the 1950ties but also in the 1970ties; and the dark green patches, together with the red patches display the location of this type of land cover during the 1970ties.

Figure 23 displays the evolution of forests (c.c. 15%-30%) from the 1970ties until the years 2001/2003. The light green and purple patches display forests (c.c. 15-30%) for the 1970ties. The purple patches describe the locations where this type of land-cover existed in the 1970ties, but also in the years of 2001/2003 and the dark green and purple patches visualize the distribution of forests (c.c. 15%-30%) for the years 2001/2003.

Generally, the decrease of forests with a canopy cover of 15% - 30% by 20pp (see figures 18-20), can be observed in the maps for the last 50 years (figures 22&23).

This decrease can be investigated more closely with further GIS analysis. (The area of forest; cc.15%-30% in the 50ties; is clipped with the land cover in the years 2001/2003 in Arc Map, and the area that was covered by forests during the years 2001/03 is clipped with the land cover during the 1950ties).

Analysis with reveal that 48% of the area, which was completely covered in forests with a canopy cover of 15%-30% in the 1950ties, in the years of 2001 and 2003 became covered with much denser forests (forests with canopy cover of 30-100%). Only 38% of the area which was originally covered by forests with a canopy cover of 15%-30% remained the same type of land cover in the years of 2001/2003. It is also noticeable that while about 4% of the area has turned into scrub, about 3% became covered by young forests and 2% turned into a scrub-forest biotope.

When looking back in time, it can be discovered, that of the area which was covered by forests with a canopy cover 15% - 30% in the years of 2001/2003, about 80% was also covered by the same land cover type in the 1950ties. About 6% of that area which had a canopy cover of 15%-30% in the years 2001/2003 was covered in denser forests and equally 6% was covered by much lighter forests with a canopy closure of 5%-15%. It is also noticeable that 4% of the area was covered by scrub, 2% by a scrub-forest biotope and 1% by agricultural meadows.

When looking at the area where forests with a canopy cover between 15% and 30% were located at least at one point of time during the investigation period, it can be summarized that, between the 1950ties and the years 2001/2003, open habitats, such as forests with a canopy cover between 5-15%; scrub-forest biotopes, scrub or agricultural meadows were by trend replaced by denser forests (e.g. canopy cover 15% - 30% or canopy cover 30-100%).

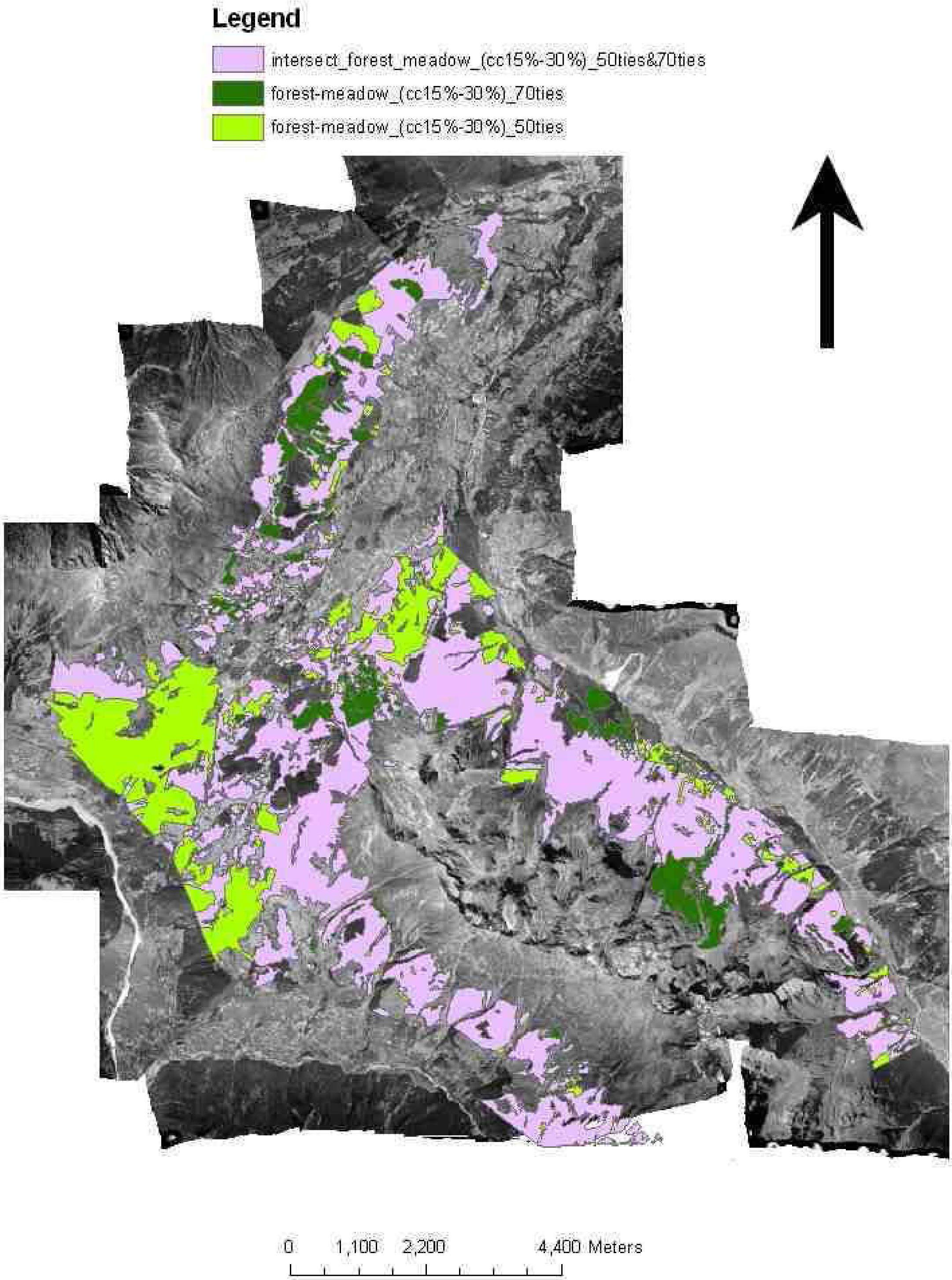

Fig.22: The evolution of forests (c.c.15%-30%) from the 1950ties until the 1970ties.

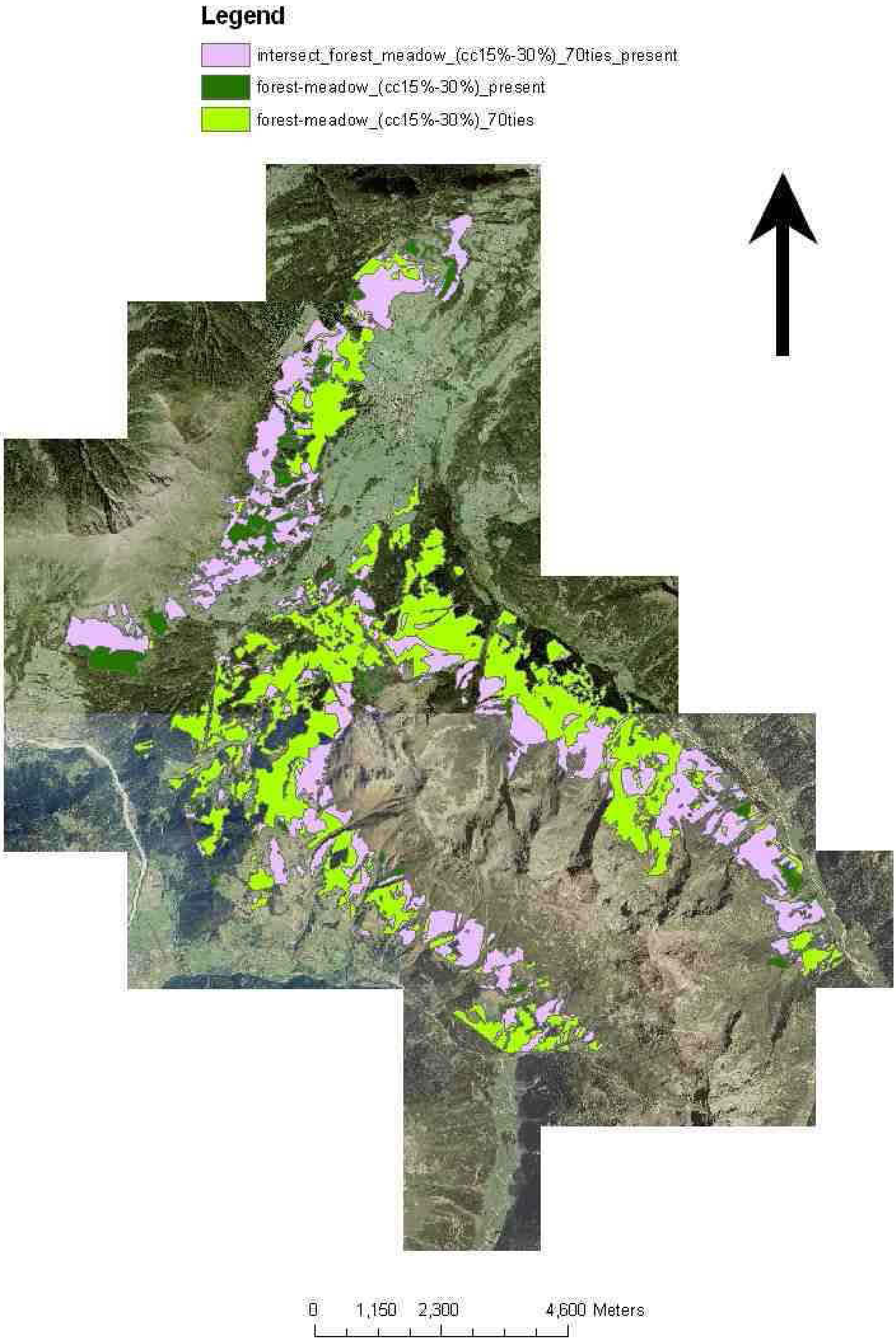

Fig.23: The evolution of forests (canopy cover 15%-30%) from the 1970ties until the years 2001/2003

4.4.2. Forest; canopy closure 30%-100%

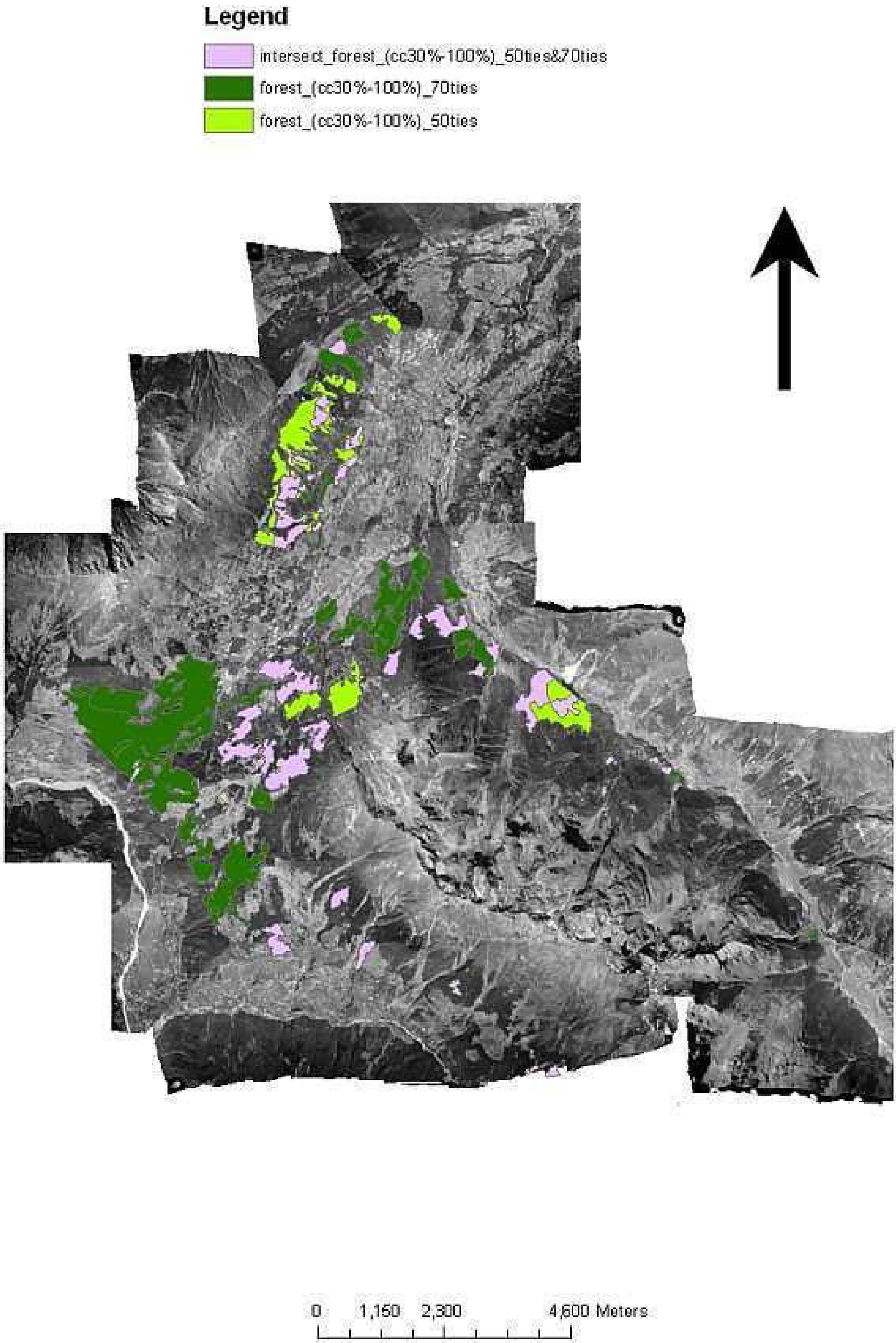

Fig.24: The evolution of forests (c.c.30%-100%) from the 1950ties until the 1970ties.

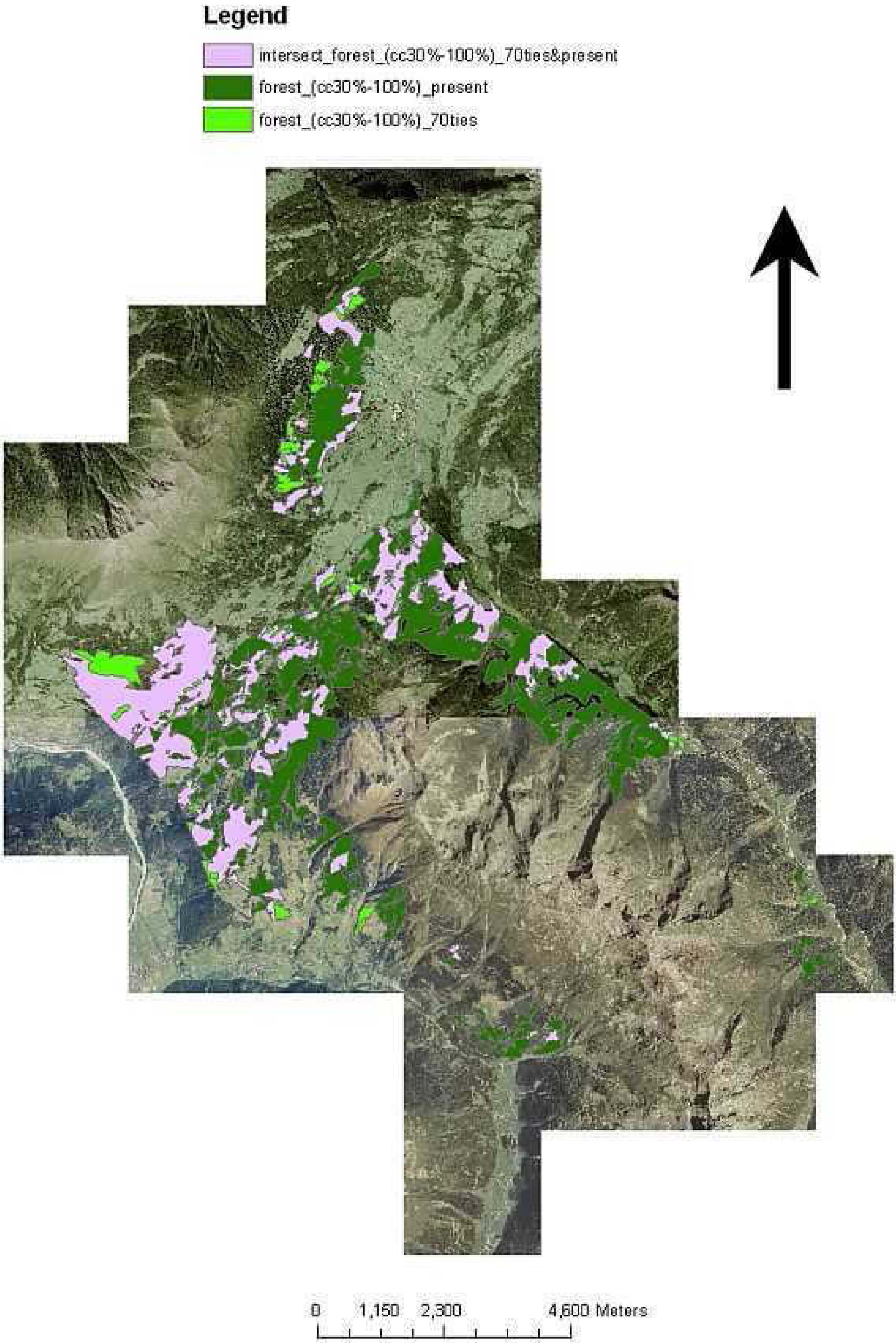

Fig.25: The evolution of forests (c.c.30%-100%) from the 1970ties until the years 2001/2003.

Per definition of the Interpretation key (see appendix C) forests with a canopy cover between 30% and 100% mainly consist of coniferous trees such as larch, pine, spruce, fir and the Swiss stone pine, but also single broad leaf trees can be found in the lower areas.

Holzner et al (2007) mention the decrease of overall species diversity if dense forests increase in an environment that is already mainly covered in forests. Nevertheless, the importance of forests for the protection against natural hazards in an alpine environment needs to be emphasized. On the other hand, Ott et al. (1997), p. 24 stress that agriculture in alpine environments has lead to a destabilisation of the mountain forests.

They mention that in comparison with primeval forests, forests in an agricultural environment might be too tightly or irregularly clustered, due to open or sealed soils caused by agriculture.

Figures 24-25 show the evolution of dense forests between the 1950ties, the 1970ties and the years of 2001/2003.

In fig. 24 the light green together with the purple patches display the area, that was covered by dense forests in the 1950ties. The purple and dark green patches visualize the area covered in the 1970ties. The purple patches display the area that was covered by dense forests in the 1950ties and also in the 1970ties.

In fig. 25 the light green together with the purple patches display the area, that was covered by dense forests in the 1970ties. The purple and dark green patches visualize the area covered in the years of 2001 and 2003. The purple patches display the area that was covered by dense forests in the 1970ties and also in the years of 2001/2003.

The land cover of forests (canopy cover 30%-100%) increased strongly in area over the last 50 years. In the 1950ties, 6% of the area under investigation was covered in dense forests. In the 1970ties the area of dense forests increased to 12% and in the years of 2001/2003, forests covered a total of 25% of the investigation area!

This evolution of forests can be inspected more closely with the help of a GIS analysis. (The area of forest; cc.30%-100% in the 50ties; is clipped with the land use in the years 2001/2003 in Arc Map, and vice versa).

66% of the area, which was covered by dense forests in the 1950ties, remained dense forests in the years 2001/2003. Noticeably, 19% turned into lighter forests with

a canopy cover of 15%-30%. 6% of the area which once was dense forest became covered by scrub and 5% turned into younger forests after probably having been cleared or cut down.
From the 1950ties to the years 2001/2003, the area of dense forests increased by 19pp. From this enormous increase, the question arises, what types of land cover were replaced? Closer investigation shows that only 17% of the area covered in dense forests in the years 2001/2003 were also covered by dense forests in the 1950ties. A total of 77% of the area was covered by lighter forests in the 1950ties, with a canopy cover between 15% and 30%. 2% was covered with younger forests, 2% by scrub and 1% was covered by scrub-forest biotopes.
In summary, between the 1950ties and the years of 2001/2003, a strong tendency towards a densification of forests can be observed in the area of investigation.

4.4.3.Scrub

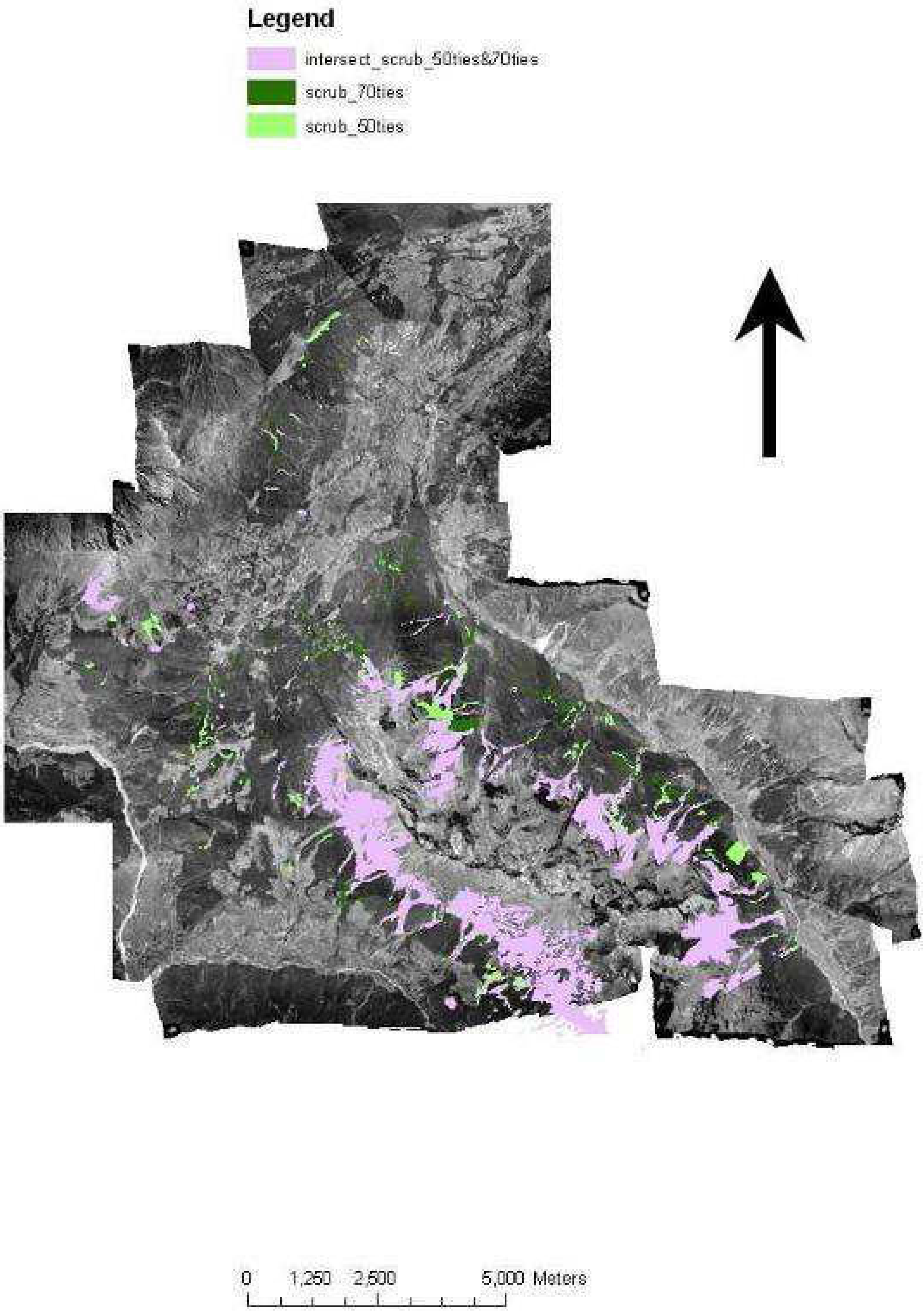

Fig. 26: The evolution of scrub from the 1950ties until the 1970ties.

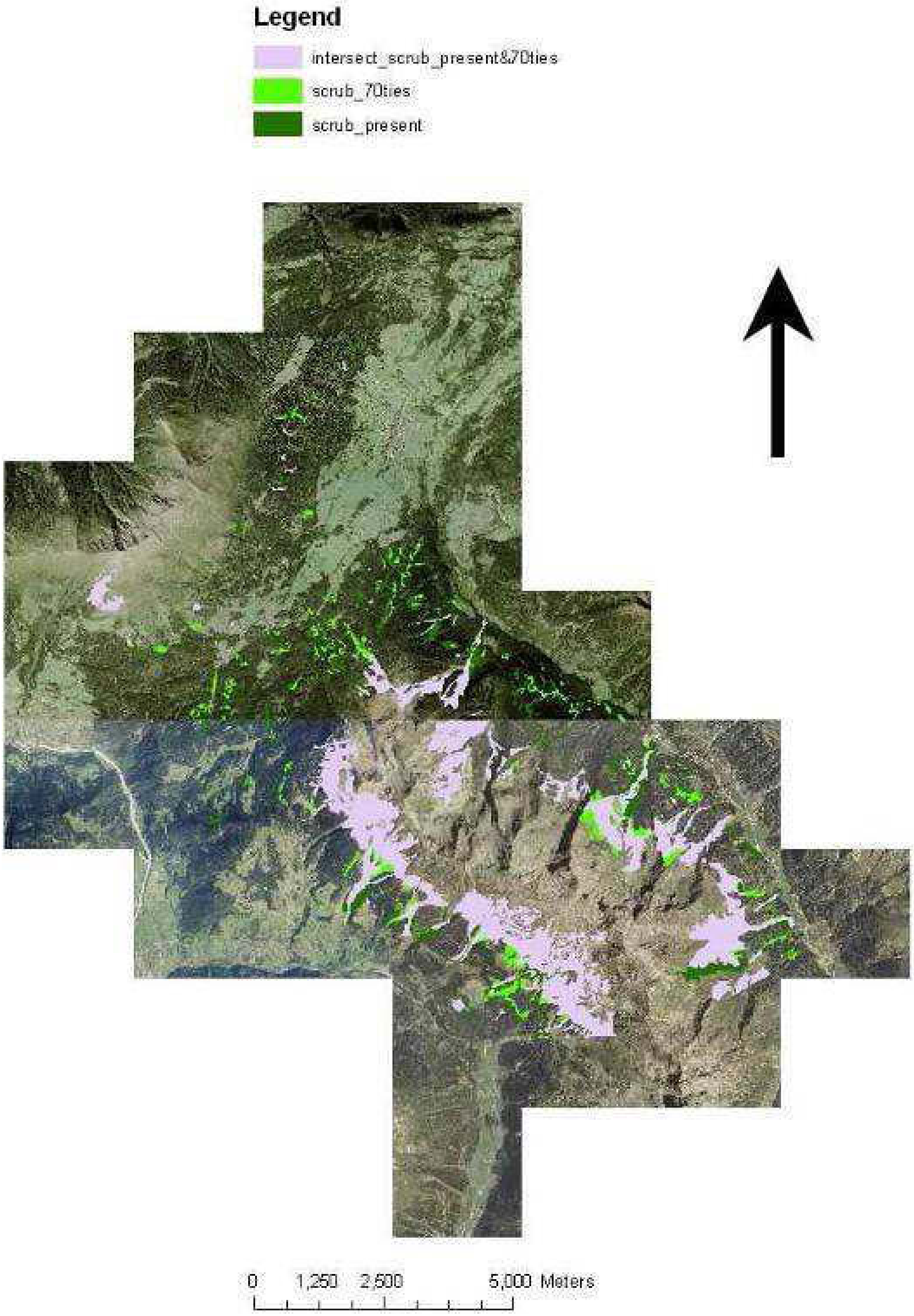

Fig. 27: The evolution of scrub from the 1970ties until the years 2001/2003.

The land cover class of scrubs for this thesis is defined as a composition of green alder, dwarf scrubs and mountain pines. Holzner et al. (2007) p. 251, state that from the perspective of small animals and ground vegetation, mountain pines can be rated similar to forests. Below mountain pines a micro climate different to that of open pastures can be found and the conditions for soils are similar to those in forests. If closed patches of mountain pines increase in area, the plants and animal species that need open pastures will be replaced by forest inhabitants. Holzner et al. rate the increase of mountain pine as a loss for biodiversity, because the already rare open land species have to give way to the much more widespread forest species. Dwarf shrubs, such as blueberry, crowberry or cranberry on the other hand, may provide precious food supply and shelter for wildlife (Schweiger, 2001), (Wöss et al., 2008). Hotter & Aschaber (2001) emphasize the importance of the pioneer character of scrubs in alpine environments. Especially mountain pines and green alders improve the stabilization of soils and protect against erosion, avalanches and rock fall.

Figures 26 & 27 display the changes of the land cover type “scrub” between the 1950ties, the 1970ties and the years 2001/2003.

Scrub used to cover 14 % of the investigation area during the 1950ties. In the 1970ties, the area covered by scrub decreased lightly by 1 pp. Then during the years 2001/2003, the region covered by scrub again gained 1 pp in area.

When analysing this process, it can be observed that of the area, which was scrub in the 1950ties, 82% stayed scrub also in the 1970ties, but a total of 12% evolved into forests (with a canopy cover between 15% and 30%), only 2% of the area was utilized for agricultural purposes and turned into meadows.

When regarding the change of scrub between the 1970ties and the years 2001/2003, it can be noticed that 80% of the area covered by scrub stayed the same, but noticeably 5% were turned into agricultural meadows. 3% turned into forests (with canopy cover 15%-30%) and 4% turned into denser forests (with a canopy cover of 30% to 100%). Furthermore, 4% evolved into younger forests.

Of the area that was scrub in the 1950ties, 77% stayed covered in scrub in the years of 2001/2003. A fact that deserves attention is that, of the area which was covered in scrub in the 1950ties, a total of 6% was utilized for agricultural usage and turned into meadow until the years 2001/2003 and 5% turned into forests (with a canopy cover of 15%-30%). When looking backwards in time, 79% of the area which was scrub in the years 2001/2003 also was covered by scrub during the 1950ties. 3% of that area were agricultural meadows, but 13% were covered by forests (canopy cover 15%-30%) and 3% were covered by denser forests.

Regarding these developments, in the area that was covered by scrub, a light trend during the last 50 years towards the reduction of forests and the utilisation of agricultural meadows can be noticed.

4.4.3. Alpine agricultural meadow

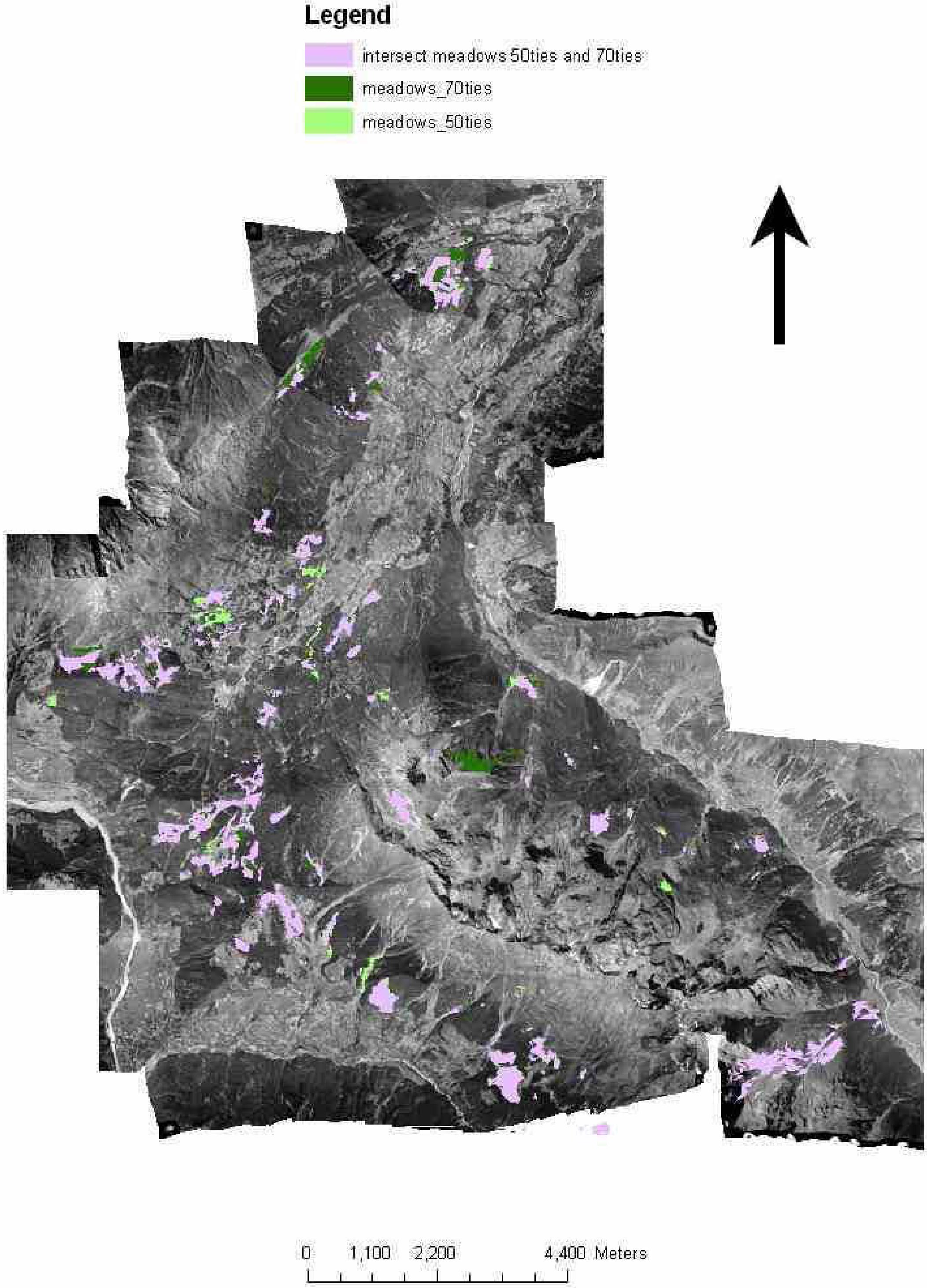

Fig.28: The evolution of alpine agricultural meadows from the 1950ties until the 1970ties.

Fig.29: The evolution of alpine agricultural meadows from the 1970ties until the years 2001/2003.

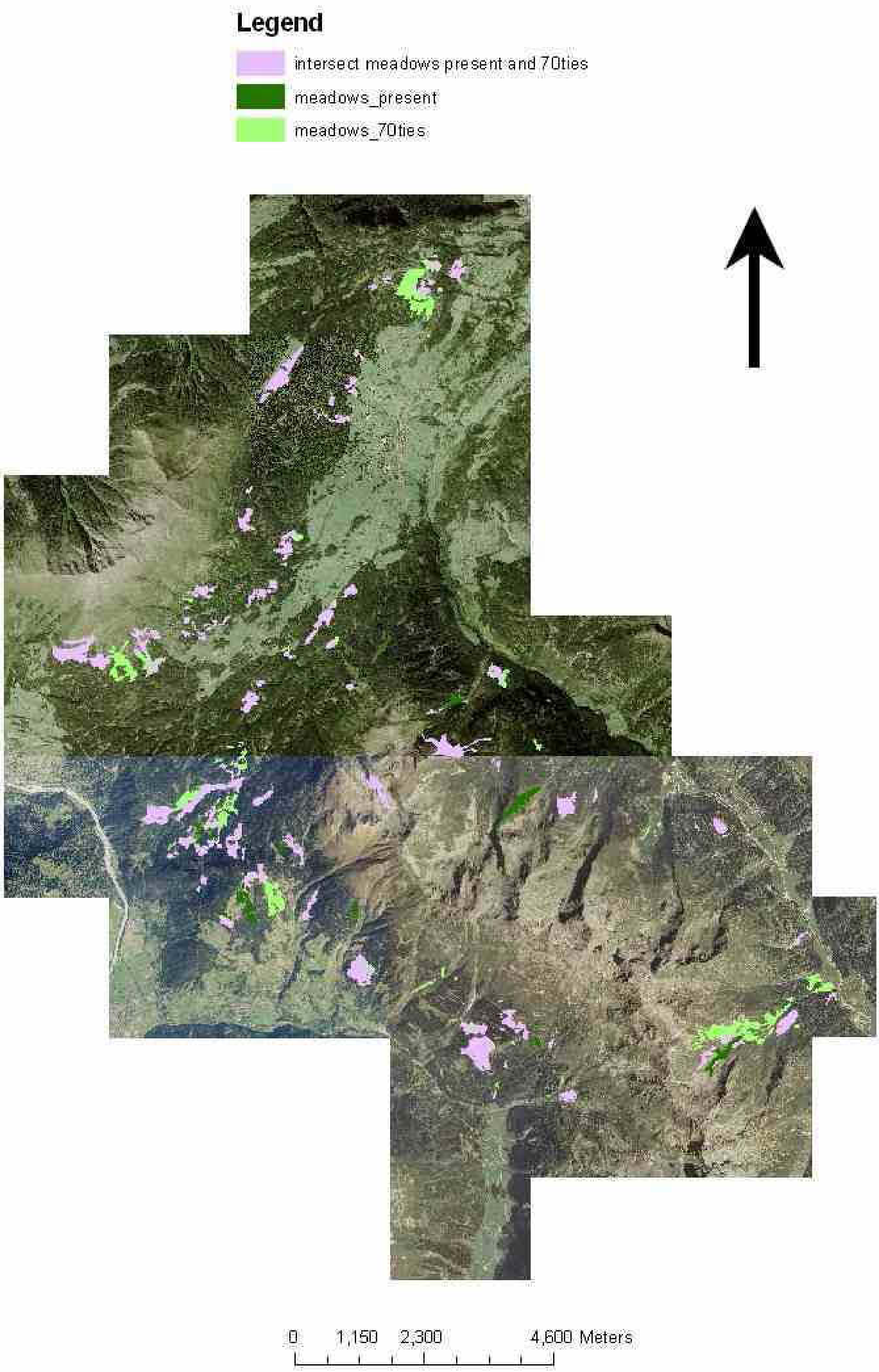

Fig.29: The evolution of alpine agricultural meadows from the 1970ties until the years 2001/2003.

According to the interpretation key, the land cover class of alpine agricultural meadows includes all kinds of meadows that occur in the area of investigation and lie below 2500m of inclination or 80% declination. In particular, these meadows and plant societies include: tall forbs (subalpine); meadows with crested dog's tail; mat-grass meadows, neglected grasslands, extensive grasslands on acidic soils, purple moor grass and intensively used grasslands (below 80% declination).

According to Holzner et al. (2007), p.109, grazed agricultural meadows are important to assure a high plant and species diversity throughout the alpine, the sub-alpine and the montane altitudinal zones. Meadows that are not grazed anymore will turn to forests within a few decades. This process of succession will not increase overall diversity in an area that is already covered by forests to a high percentage.

Figures 28 & 29 display the development of alpine meadows during the last 50 years. In fig. 28 the light green patches represent the location of alpine meadows during the 1950ties and the dark green patches show their locations during the 1970ties. The purple patches display the locations where meadows were situated both in the 1950ties and the 1970ties.

In figure 29 the light green patches show the locations of meadows in the 1970ties and the dark green patches display alpine meadows and their locations during the years 2001/2003.

When looking at the development of alpine meadows, it can be noticed that from the 1950ties until the 1970ties the accumulated area of alpine meadows increased by one percent point and then decreased again by 1pp until the years 2001/2003.

After closer investigations it can be noticed that of the area which was covered by meadows during the 1950ties, only 64% remain meadow until the years 2001/2003.13% turned into wooden-pastures with a forest canopy cover of 5%-15%, and 4% turned into forests intermingled with open areas with a canopy cover of 15-30%, 3% turned into dense forests. Further 8% turned into scrub, 3% into a scrub-meadow biotope and 2% evolved into young forests.

The area that is covered by meadows during the years 2001/2003 was also covered by meadows by 73% during the 1950ties. 6% was scrub 7% was covered by wood pastures with a canopy cover between 5% and 15%, and 5% was covered by wooden pastures with a canopy cover between 15% and 30%. A further 6% was covered by young forests and 3% by a scrub meadow biotope.

4.4.4. Meadow-forest; canopy closure 5%-15%

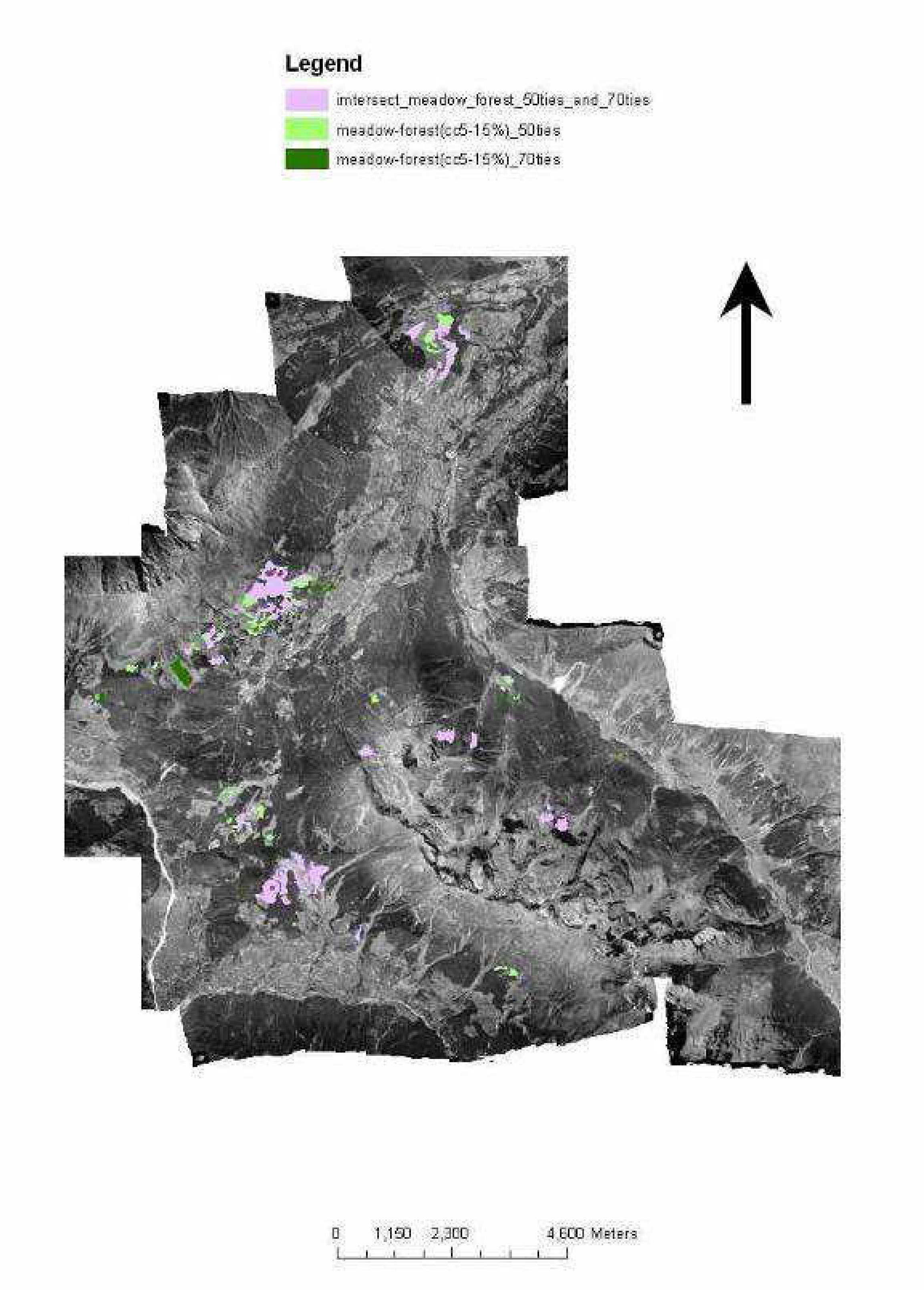

Fig. 30: The evolution of meadow-forest (canopy closure 5%-15%) from the 1950ties until the 1970ties.

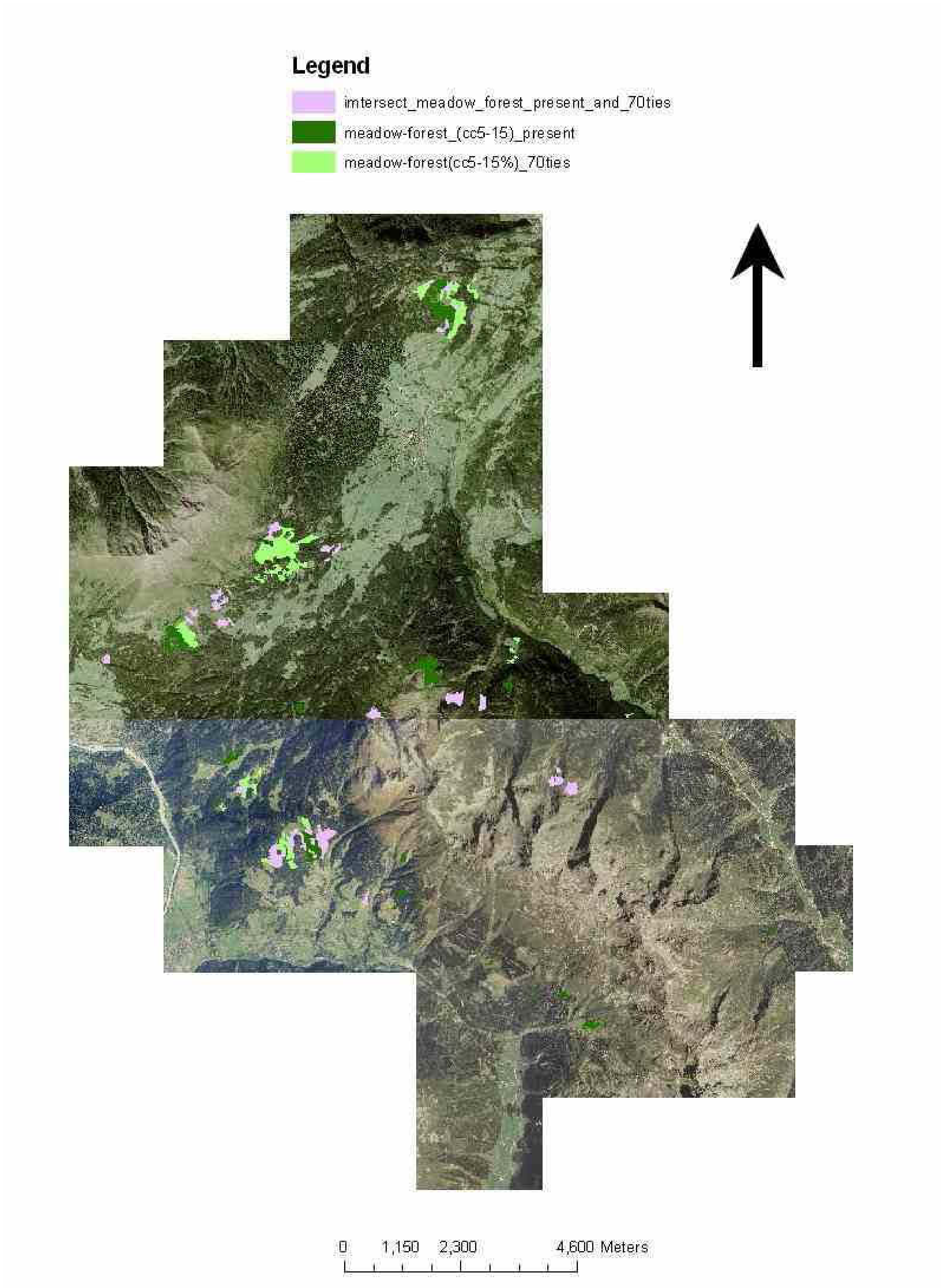

Fig. 31: The evolution of meadow-forest (canopy closure 5%-15%) from the 1970ties until the years 2001/2003.

Per definition in the interpretation key, meadow-forests with a canopy cover between 5% and 15% are agricultural meadows that are intermingled with single standing trees or groups of trees with a canopy cover between 5% and 15%. Machatschek & Kurz (2006), p.209 regard wooden pastures generally as a positive influence on diverse vegetation patterns and therefore on the structural diversity of habitats. Yet, they take into account that when rating the influence of wooden pastures on biodiversity factors such as location, grazing intensity, canopy cover, the type of animal and the type of management play an important role. When grazing is happening in forests, which have not been grazed before, they understand that roots might become damaged and a danger of ground compaction is present.

Huber & Bergier (2006) also stress the importance of light forests as a habitat for the capercaillie (*Tetrao urugallus*).

The light green patches in figure 30 show the areas that have been covered by a meadow-forest biotope (with a canopy cover between 5% and 15%) during the 1950ties. The purple patches display the areas which both in the 1950ties and in the 1970ties were covered by a meadow forest biotope, and the dark green patches show the area which was covered during the 1970ties. In figure 31, the light green patches display the areas which were covered by these wooden pastures during the 1970ties, the purple patches show this type of land cover for both the 1970ties and the years of 2001 & 2003 and the dark green patches display the areas where meadow forest biotopes were located during the years 2001/2003.

Calculations of the total area in the area under investigation show that the area which was covered by a meadow-forest biotope was reduced from 3 % to 2 % from the 1950ties to the 1970ties.

When investigating into this shift it can be found that of the land that was covered by meadow-forests (canopy cover 5%-15%) during the 1950ties, 78% remained wooden pastures (canopy cover5%-15%) until the 1970ties. A total of 10% were turned into agricultural meadows and even more, 11%, grew into denser forests with a canopy cover between 15% and 30%.

Furthermore, analysis shows that of the land which was covered by wooden pastures with a canopy cover 5%-15% during the 1970ties, 87% also was covered by the same land cover class during the 1950ties. 5% was covered by alpine agricultural meadows and a further 5% by denser forests with a canopy cover between 15% and 30%, whereas 3% were covered by scrub.

Regarding this shift in the land cover it can be concluded that from the 1950ties to the 1970ties wooden pastures with a canopy cover between 5% and 15% to a certain extent gave way to alpine agricultural pastures and denser forests with a canopy cover between 15% and 30%.

4.4.5. Scrub-forest-meadow biotope

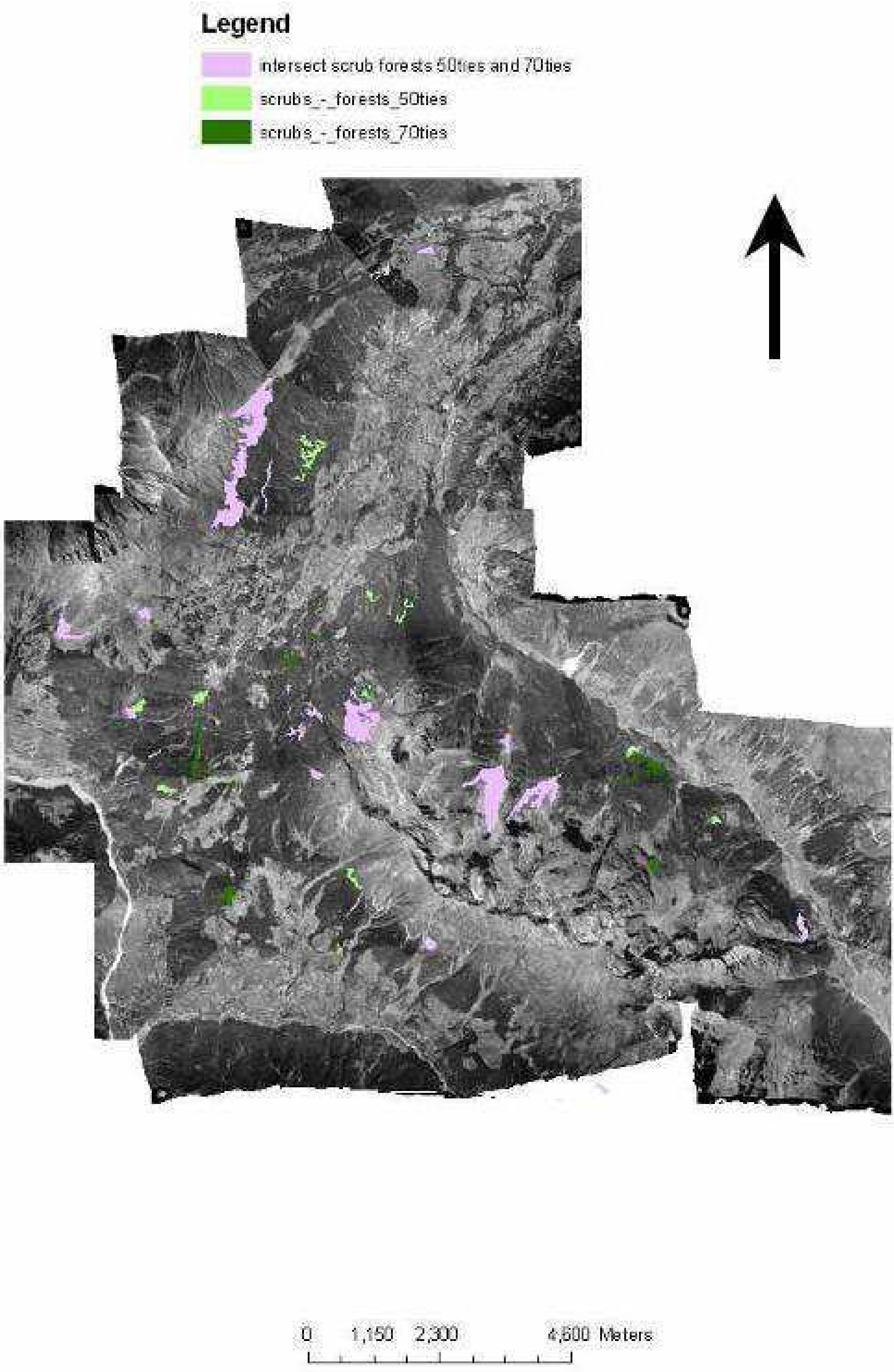

Fig. 32: The evolution of scrub-forest-meadow biotope from the 1950ties until the 1970ties.

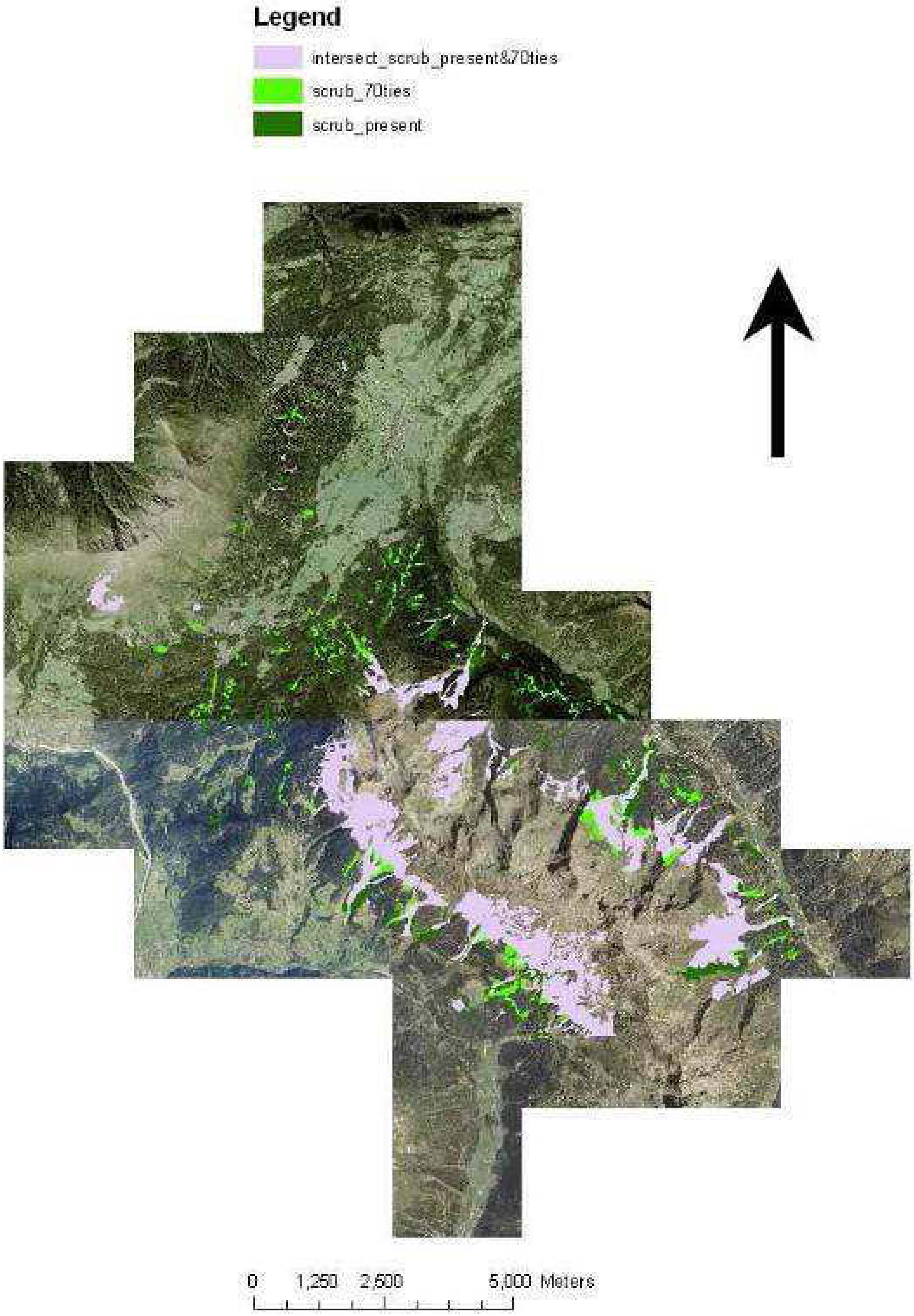

Fig. 33: The evolution of scrub-forest-meadow biotope from the 1970ties until the years 2001/2003.

Biotopes of small intermingled patches of scrubs, meadows and forests present areas where many alternating site conditions can be found on a small scale. These biotopes generally occur when grazing is given up and succession brings back scrubs and forest plants. According to Holzner (2007) a small scale variety in biotope, vegetation and structure implies a high habitat diversity for small animals and therefore a high diversity per patch. Huber und Bergier (2006), p.20, stress the importance of open habitats which are intermingled with scrubs and trees and lie in the subalpine/alpine zone, for the survival of the black grouse (*Tetrao tetrix*) and the rock partridge (*Alectora graeca*).
Figures 32 & 33 show the development of such mosaic-like patches.
From the 1950ties till the 1970ties these habitats decreased by 1 pp.
A detailed investigation shows the following transformations of the land cover:
Of the area which was covered by a forest-scrub-meadow biotope during the 1950ties, 69% stayed the same type of land use in the 1970ties. 16% of that area became covered by forests with a canopy cover between 15%-30% and 6% became covered by even denser forests with a canopy cover between 30% and 100% in the 1970ties. Furthermore it can be noticed that 4% turned into a scrub meadow biotope and 3% into young forests, 2% turned into scrub.
When looking back in time, it can be noticed that of the area which was covered by a scrub-forest-meadow biotope during the 1970ties, 32% were covered by the same type of land cover throughout the 1950ties. A total of 35% was covered by forests with a canopy cover of 15%-30%. Furthermore, 20% were young forests and 12% were scrub.
Regarding these developments, a trend towards the densification of forests can be made out and also that the increase of area for the scrub-meadow-forest mosaic might have happened due to a decrease of young and light forests (with a canopy cover between 15% and 30%).

4.4.6. Scrub-forest biotopes

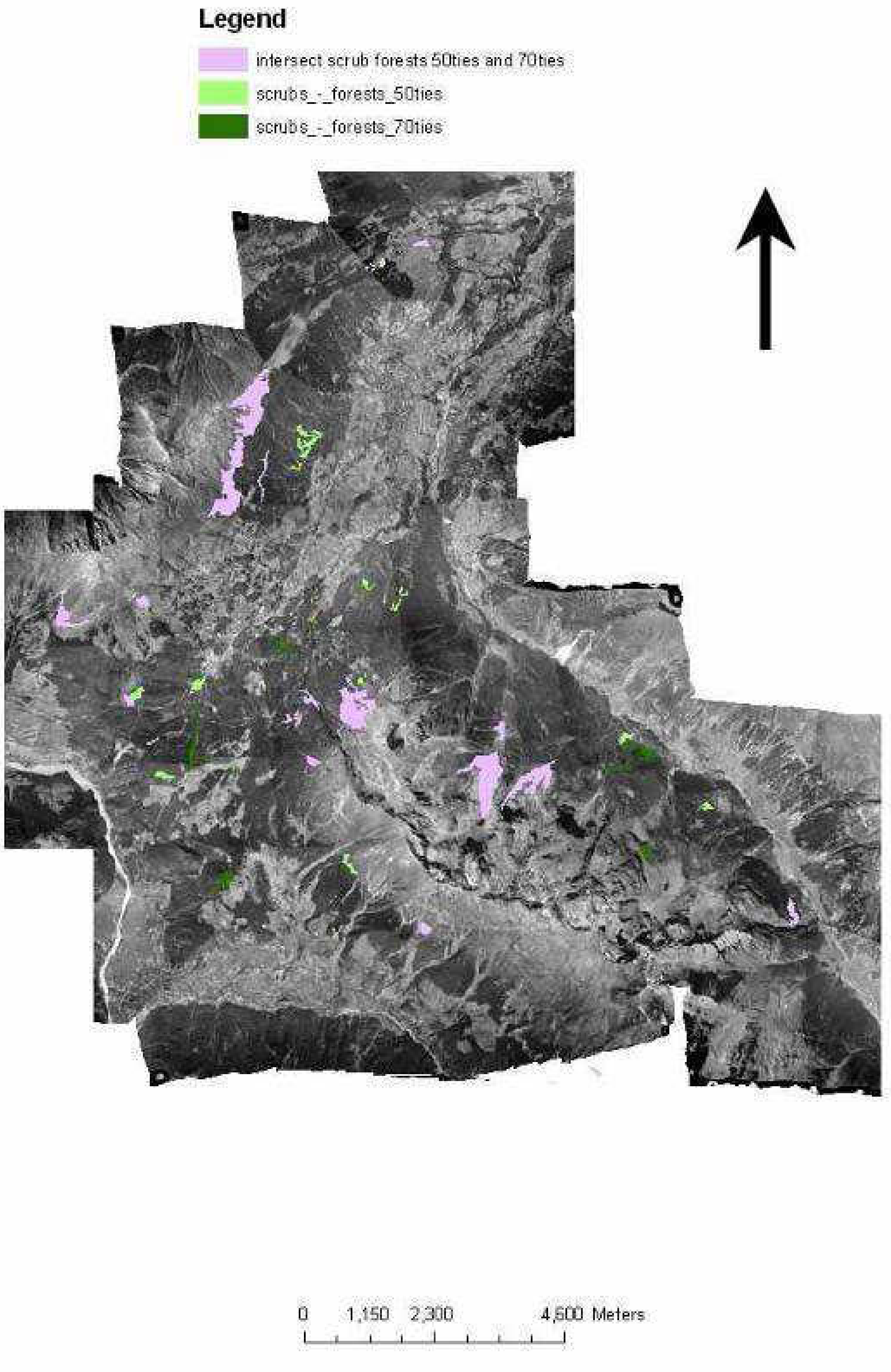

Fig. 34: The evolution of scrub-forest biotopes from the 1950ties until the 1970ties.

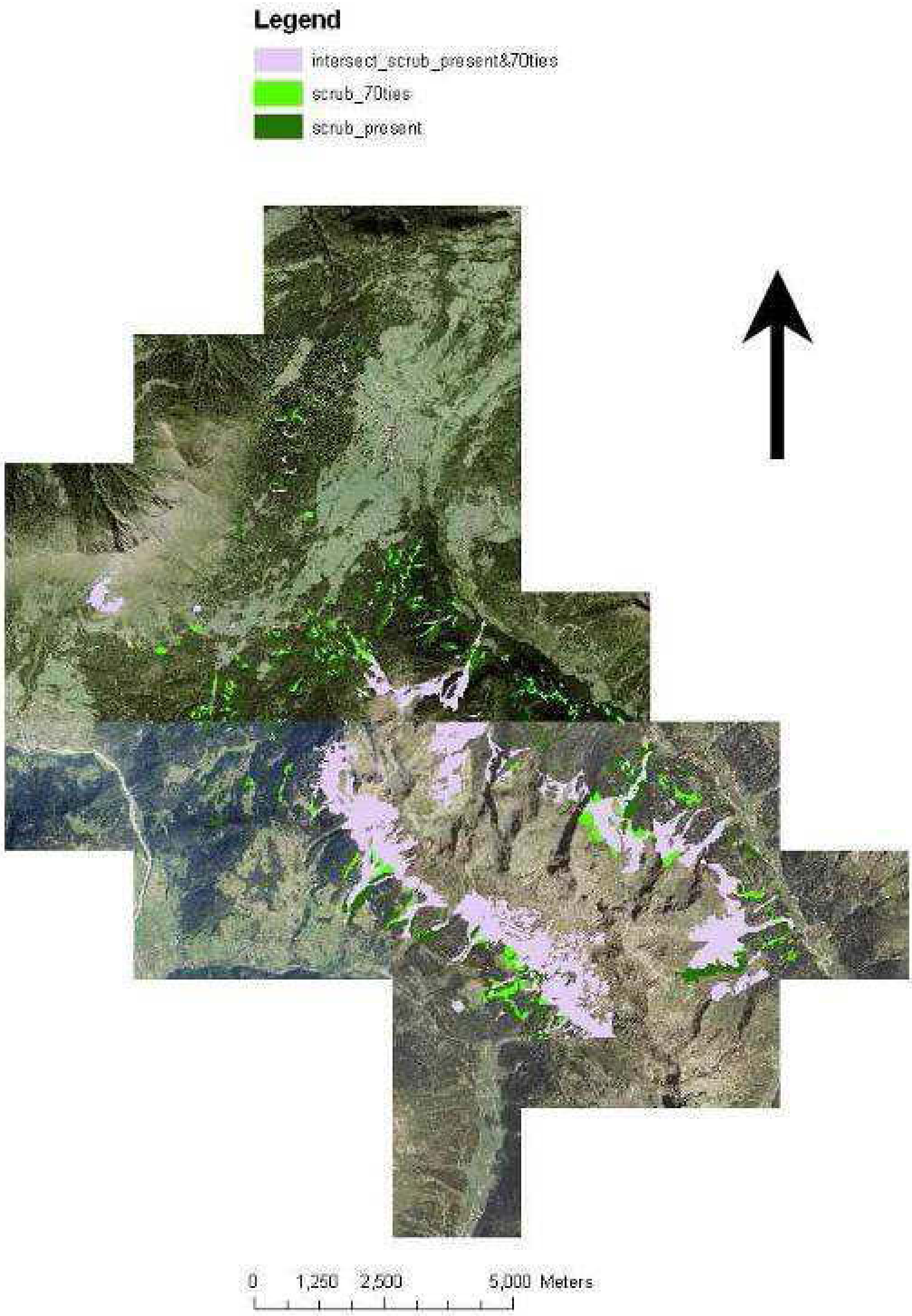

Fig. 35: The evolution of scrub-forest biotopes from the 1970ties until the years 2001/2003.

When looking at the developments of the scrub forest biotopes throughout the area of investigation, it can be observed that scrub forest biotopes decreased by 2 pp from the 1970ties to the years 2001/2003.

Of the area which was covered with scrub forest biotopes during the1950ties 60% remained scrub forest biotopes during the years 2001/2003. 14 % evolved into forests (with a canopy cover between 15% and 30%) and 13% into even denser forests (with a canopy cover between 30% and 100%). A further 5 % evolved into agricultural meadows and 2% into scrub meadow biotope complexes.

Of the area that was covered by scrub forest biotopes during the years 2001/03, 56% also was covered by scrub forest biotopes during the years 1953/54. 31% of that area was covered by light forests (with cc 15%-30%) during the 1950ties and 3% by dense forests (cc 30%-100%). A further 7% was covered by scrub, 1% by agricultural meadows, 1% by meadow-forests and 1% by scrub meadow biotope complexes.

4.4.7. Young forest

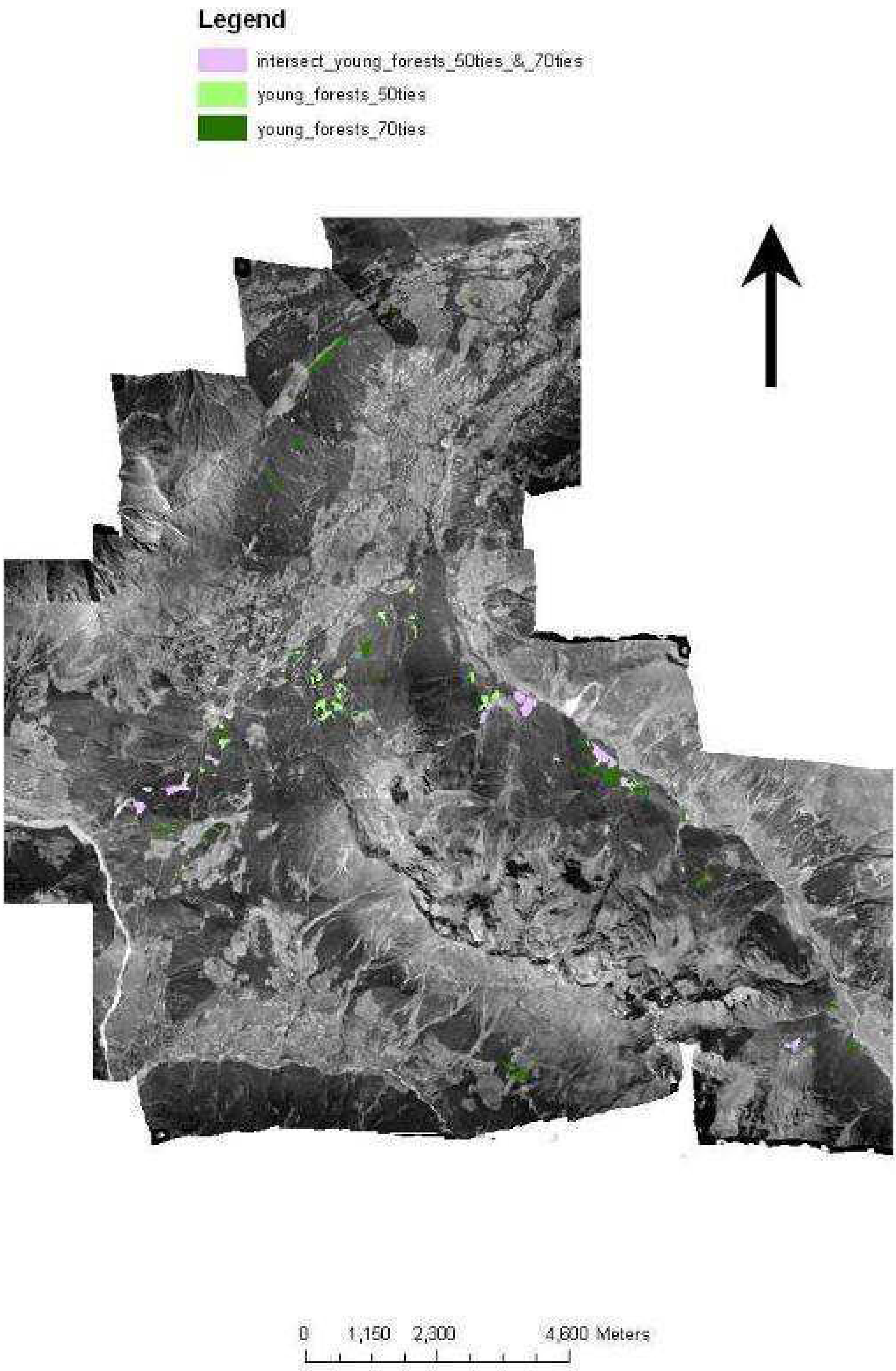

Fig. 36: The evolution of young forests from the 1950ties until the 1970ties.

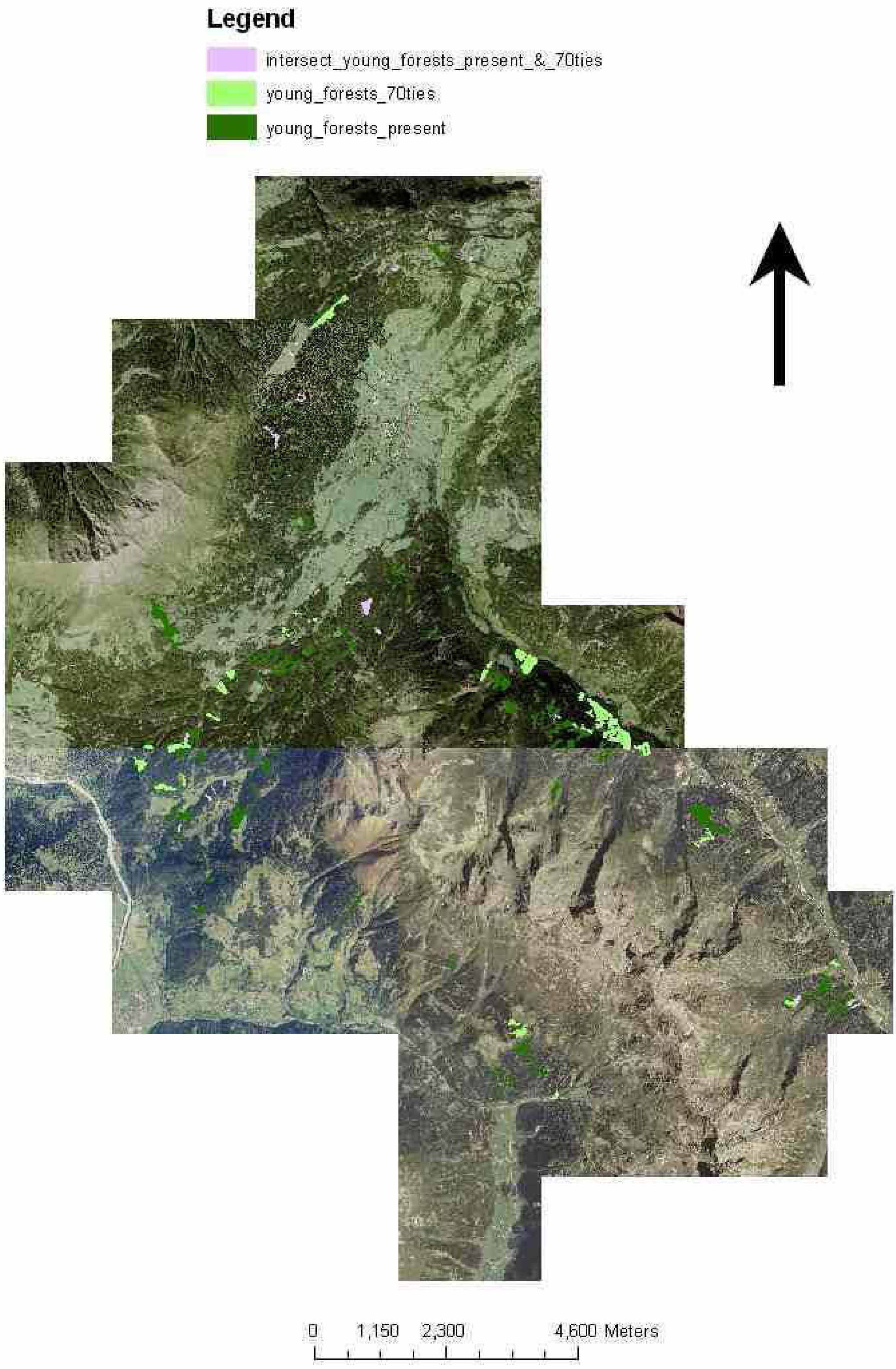

Fig. 37: The evolution of young forests from the 1970ties until the years 2001/2003.

Young forests offer cover for hoofed game. Especially during times of recovery and when young game is being raised, young trees provide camouflage and protection from extreme weather events. An even distribution throughout the whole forest area leads to a good dispersal of hoofed game and browsing damage may be minimised (Baumann et al., 2001p.8).

Figures 36 and 37 display the evolution of the vegetation of young forests. This forest type has increased by 1 pp from the 1970ties to the years 2001/2003.

The process of this evolution can be investigated more closely. When looking at the development from the 1970ties until the years 2001/2003, it can be seen that of the area that was covered by young forests during the 1970ties a total of 63% grew into dense forests (with a canopy cover between 30% and 100%) – a natural process of succession. Further 12% evolved into less dense forests with a canopy cover between (15% and 30%). 20% stayed young forests and 3% were turned into scrubs.

When looking at the area that was covered by young forests during the years 2001/2003 it can be made out that during the 1970ties 50% still was covered in forests (with a canopy cover between 15% and 30%). 16% was covered in scrubs, and 17% by dense forests (with a canopy cover between 30% and 100%). A further 9% of that area was covered by a forest – meadow biotope and 3% was covered in meadows. Only 1% of the area that was young forests during the years 2001/2003 also was covered by young forests during the 1970ties.

The forests in the area under investigation are largely coniferous forest, with a high percentage of pinewood, larch and spruce. These types of trees are relatively fast growing trees. Therefore the developments from the 1970ties to the years 2001/2003 imply a trend of natural succession from young forests to dense and less dense high forests.

5. Impacts of the changes in land cover on the species diversity

5.1. Hoofed game

5.1.1. Capricorn (*Capra ibex*)

The capricorn inhabits the high alps. It needs extensive rough and rugged rock ridges for shelter which are traversed by bands of grass and scrubs and are surrounded by alpine pastures. For food intake the capricorn mainly grazes upon alpine pastures. Meadow-scrub biotopes are also appropriate, if the percentage of scrub does not overweigh. This alpine biotope serves the highly specialized capricorn as a summer habitat. During winter capricorns retreat to southerly exposed slopes and ridges where the snow never accumulates too much. Winter habitats should have an inclination of between 30° and 50°. If the slopes a re steep enough, they store warmth and always keep a little grass available. During late winter and early spring capricorns can be found in sparely covered, open larch / pine forests and on alpine pastures reaching below 1600m of altitude (Meile et al. 2003).

Deutz (2001) suggests a forest with canopy cover below 30% as appropriate late winter /early spring capricorn habitats.

The ideal biotope for the capricorn covers a whole mountain range, one single standing mountain is not big enough to satisfy the capricorns demand for space (Meile et al. 2003).

Meile et al. suggest a minimum areal of 40 ha. They also state that the limiting factors for capricorn habitats usually are the available winter habitats.

For this thesis the habitat factors mentioned in the literature for the capricorn have been mapped for the two time intervals of the 1970ties and the years 2001/2003 in the area of investigation. For this purpose, the data of the land cover maps for the two time intervals have been analysed and processed by Arc Map according to the habitat factors mentioned by the literature (see tab.1).

Tab.1: Habitat factors for the potential habitat map of the capricorn

Core biotopes	In order to map the potential occurrence of the capricorn, the following land cover classes were selected as core biotopes: • Without land use: According to the definition of the interpretation key the land class "without land use" contains features of "rubble or rock, sometimes intermingled with scarce scrubs and grasses, extrazonal rock vegetation, biotopes of the alpine and nival zone and snow cover" (See appendix C.) • Alpine meadows above 2500m
Additional biotopes	• Alpine agricultural meadows • Scrub-meadow biotopes • Scrub-forest biotopes • Scrub-meadow-forest biotopes • Scrubs • Meadow-forests (with a canopy cover between 5% and 15%) • Forest-meadows (with a canopy cover between 15% and 30%)
Size requirements	Core biotopes must exceeded the size of the minimum areal of 40 ha
Neighbourhood requirements	• Core biotopes that are smaller than 40ha but within a distance of 500 m of those core biotopes that exceeded the size of 40 ha are also regarded as suitable habitats • Only additional habitats, that touch the boundaries of the core biotopes or are surrounded by those additional habitats that touch the boundaries of the core habitat are regarded as suitable potential habitats
Topographic requirements	• The potential capricorn habitat was restricted to areas above 1500 m in altitude. • In the maps, steep slopes (between 30° and 50° of

	inclination) with southerly aspects that lie inside the potential habitat are displayed as locations suitable as a winter retreat for the capricorn.

In order to investigate the development of the potential habitat of the capricorn, the overall development of capricorn populations in Austria needs to be taken into account.

The alpine capricorn used to be a threatened species throughout the alps as it was hunted for its horns, skin or for food. By 1821 the alpine capricorn was nearly extinct and the total alpine population was reduced to only 50 or 60 animals in the Gran Paradiso Massif between the Piedmont and the Aosta valley. From that time onwards various measures were applied to preserve this population and by the year 1911 Switzerland started to successfully reintroduce the *Capra Ibex* to its natural alpine environment. Following this success, reintroductions took place in other alpine countries. In Austria the first reintroductions began in the 1950ties. (WAZA 2011). In the Tyrol – where the investigation area of the Kaunergrat is located, successful re-introductions of capricorns started in the year 1953 in the Pitztal (Ullrich, 2009).

Because the capricorn only started inhabiting the Tyrolean alps from the mid 1950 ties onwards, this thesis only derives potential habitats for the years 1970/71 and 2001/03 and neglects the time interval of the 1950ties.

Aggregated habitat factors for the capricorn (2001/2003): Calculated area: 39. km^2 Potential winter retreat of the capricorn: Calculated area (2001/2003): 5 km^2 Aggregated habitat factors for the capricorn 1970/71 Calculated area: 45 km^2 Potential winter retreat of the capricorn: Calculated area 1970/71: 5 km^2

(To compensate possible inaccuracies of land cover maps, the resulting calculated areas are rounded to whole square kilometres)

The calculated areas of the potential habitat for the capricorn show that its potential habitat within the area under investigation became smaller by about 13% from the years 1970/71 to the years 2001/03 (see fig. 38 & 39). Nevertheless, those figures

must be regarded with care, as the reason for a larger potential habitat throughout the 1970ties mainly depended upon forests being more open during the 1970ties than during the years 2001/03. Open forests (with canopy cover below 30%) may serve as late winter /early spring habitats (Deutz, 2001) but they are no limiting factor to the capricorn habitat. Also, in the literature no information as to how far capricorns range into open forests and away from their core habitats (rocky slopes) could be found. Therefore this parameter could not be included in the potential habitat model and all open forests that are connected to the core habitat were taken into account.
Unfortunately, no actual occurrence data for the capricorn in the Kaunergrat were available. Therefore validation of the potential habitat map against real occurrence data was not possible.

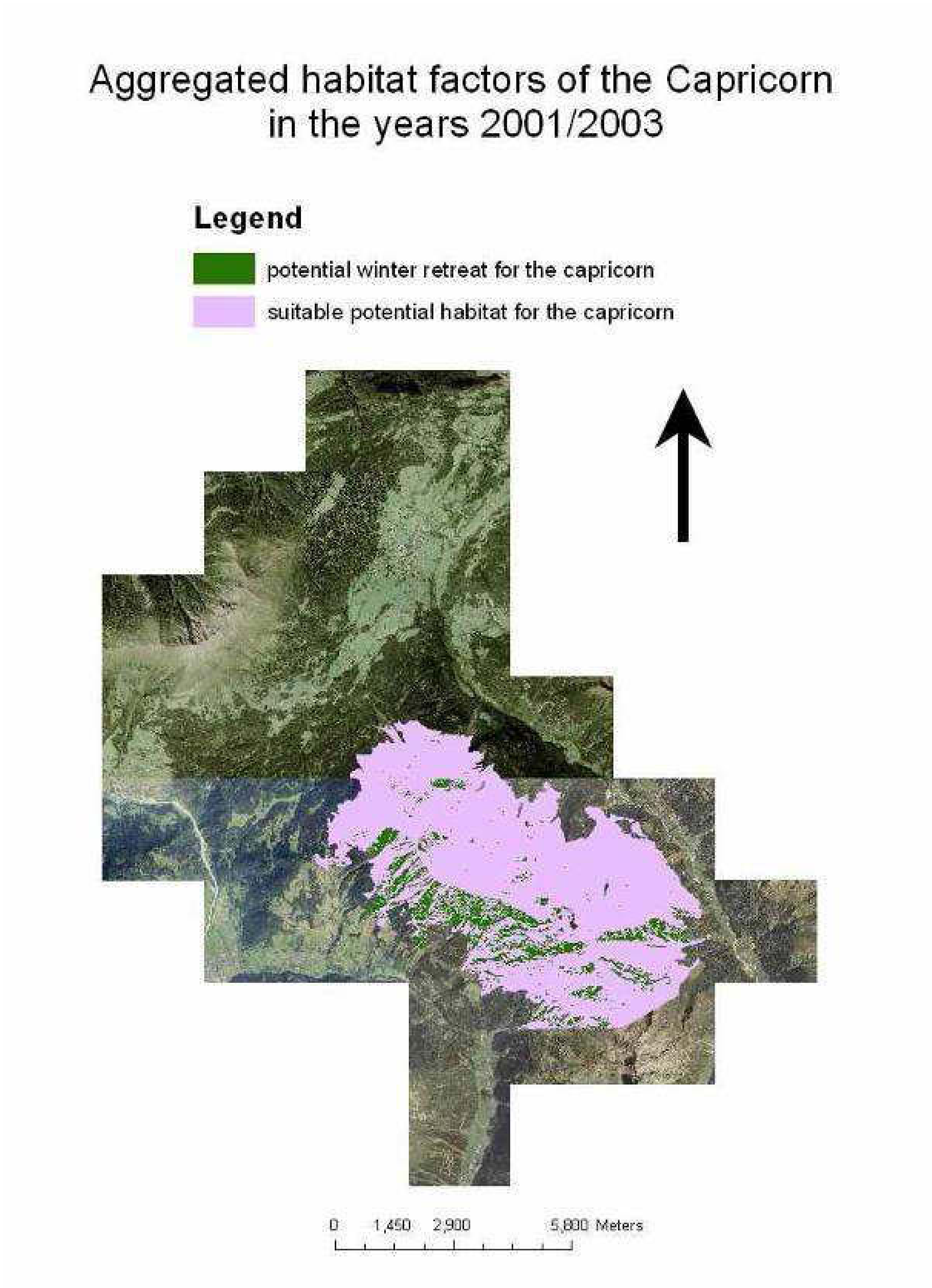

Fig. 38: Aggregated habitat factors of the capricorn during the years 2001/2003

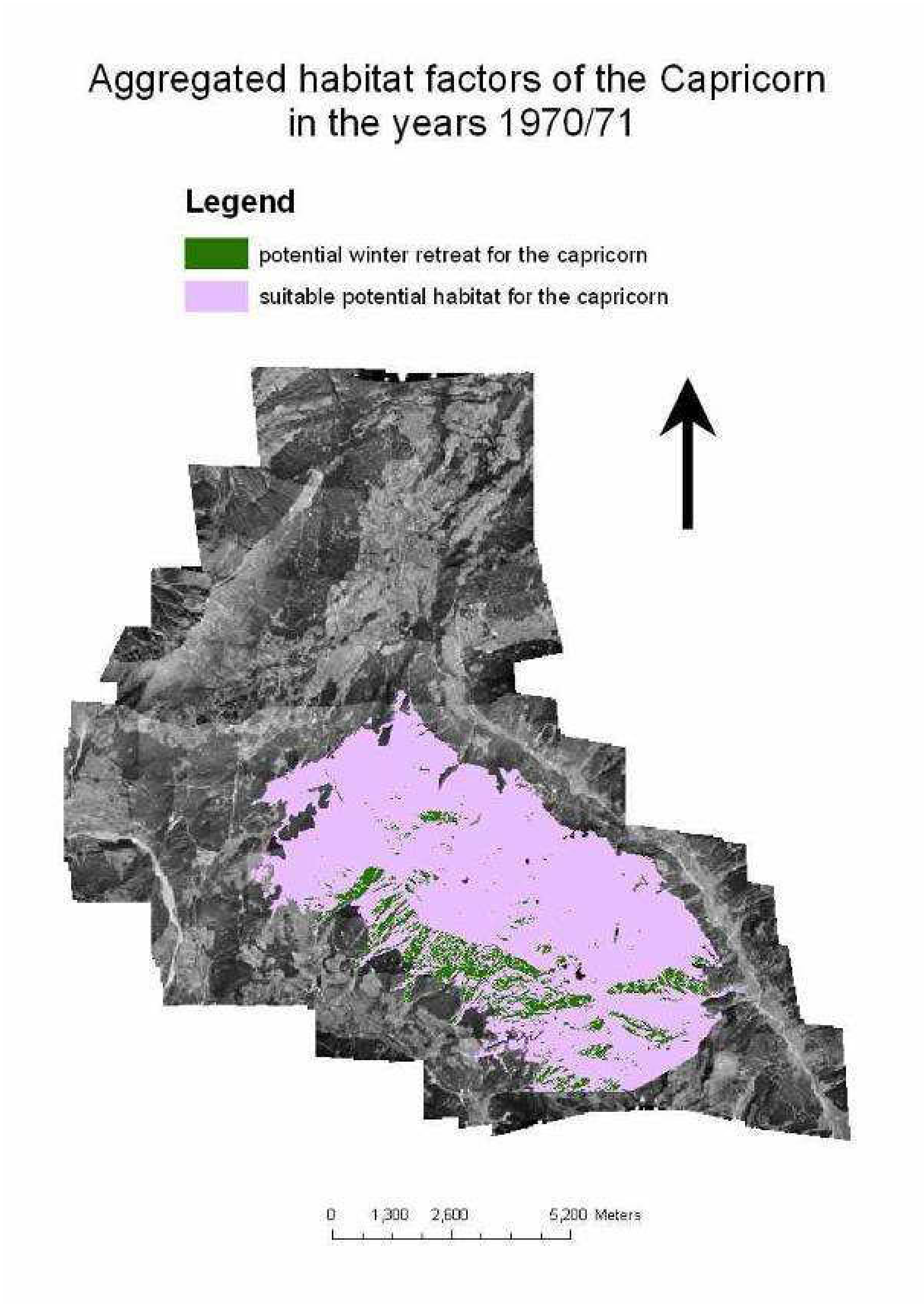

Fig. 39: Aggregated habitat factors of the capricorn during the years 1970/71

5.1.2. Chamois (*Rupicapra rupicapra*)

The chamois inhabits alpine pastures, steep rock ridges, areas covered by dwarf-scrubs, forests, steep canyons and ravines. Typically, the chamois can be found between 1500 and 2500 meters of altitude. Wherever the chamois settles, steep slopes (30°-60°) that provide cover and shelter are never far (Miller, 2009).
In early winter the chamois seeks out steep slopes around the timber line. Then, during high winter flat, windswept and therefore snow free peaks provide food and steep rock slopes or canyons provide food and shelter (Schnidrig-Petrig, 2009). Schnidrig-Petrig (2009) states that the open and half open cultural landscapes of the subalpine and montane altitudinal zones are ideal to cover the chamois` requirements for fresh grasses, herbs and leafs. The home ranges of male chamois can have a size of up to 800 ha. The female home ranges lie at about 300 ha.
According to Schnidrig-Petrig agricultural alpine landscapes have advantages as well as disadvantages for the chamois. Due to the traditional utilization of forests for grazing, dense forests became lighter and new grazing areas were also provided for the chamois. Furthermore grazing and mowing of alpine pastures improves diversity of herbs and therefore provides more diverse food supply. On the other side Schnidrig-Petrig (2009) states that coexistences of chamois with goats and sheep may cause several problems. Because they are zoologically related, they have similar requirements for habitats and food and therefore may compete with each other. Another problem arises because sheep, goats and chamois are prone to similar diseases and therefore endangered by infection.

From the information found in the literature the author was not able to delineate a potential habitat as the chamois is an extremely adaptable animal regarding its habitat demands (Reimoser, 2002).

Nevertheless, a few interesting trends in chamois habitat change throughout the last few decades can be made out. According to Miller (2009) the chamois was found to have moved downwards during the last few decades and have started to re-inhabit forests parallel to the process of abandonment of mountain villages and traditional agriculture. Reimoser (2002) states that because of a tendency towards more touristic activities above the timberline and a higher hunting pressure the chamois started utilising forests as habitats more frequently throughout the last few decades. This development might cause problems with forestry, (browsing etc.) (Reimoser 2002). Whether this process also affects forests and chamois populations in the Kaunergrat, the author cannot conclude from the available data.

5.1.3. Roe Deer (*Capreolus capreolus*) and Red Deer *(Cervus elaphus*)

Originally the roe deer inhabited mixed broad leaf forests. In places where broad leaf trees were replaced by the faster growing fir trees, the roe deer adapted well to the coniferous forests. It likes the forest edges, rich in bushes and scrubs and forests bordering in alpine pastures and open areas. Only when the population density increases, the roe deer will start inhabiting the inside of dense forests. In the alps the roe deer can be found up to an altitude of 2000 m (Stubbe,1997).
According to Osgyan (2007) home range areas vary between 5 ha and 50 ha for the male roe deer and about 6 ha for the female roe deer, depending on food availability.

The red deer has adapted itself throughout its history to varying environmental conditions. It can be found in quite dense forests as well as in half open and open landscapes. When choosing its habitat, the red deer is very flexible although half open structures are preferred (Huber & Bergier, 2006). Drechsler (2004) suggests that the ideal habitat of the deer consists of highly structured mixed forests and bushes.
According to Huber & Bergier (2006) the varying pattern of a landscape shaped by alpine agriculture provides intermingled biotopes of open and half open landscape elements as well as forests. Therefore those agricultural landscapes provide an optimal habitat for the deer.
Home range male red deer in the alps vary between 36 ha and 232 ha (Bützler, 2001).

Holzner et al.(2006) state that both the deer and the roe deer profit by more landscape diversity and more and wider border lines between the forests and open landscapes.

According to the habitat information found in the literature both the deer and the roe deer like the transition zones between suitable biotopes.
Therefore the author suggested that the accumulated border lines between biotopes suitable for the deer and roe deer might serve as an indicator for available transition zones between the investigated points in time.

As suitable biotopes for the deer and the roe deer the following land cover classes have been chosen:

- Agricultural alpine meadows
- Scrub
- Meadow-forests with a canopy cover between 5% and 15%
- Forest-meadows with a canopy cover between 15% and 30%
- Forests with a canopy cover between 30% and 100%
- Scrub-forest biotopes
- Scrub meadow biotopes
- Scrub forest meadow biotopes
- Young forests
- Wetlands

For all three periods of investigation the accumulated length of the border lines of those biotopes was calculated in Arc Map.

The results are the following:

During the years 2001/2003 the accumulated length of the border lines comes to a total of 1325 km

During the years 1970/71 the accumulated length of the border lines comes to a total of 1457 km

During the years 1953/54 the accumulated length of the border lines comes to a total of 1227 km

According to those results the habitat in the investigation area had the maximum of transition zones between suitable biotopes during the 1970ties.
Nevertheless it has to be kept in mind that it is very difficult to interpret those results. The actual occurrence of the deer and roe deer is dependent not only on the transition zones but on many other factors that cannot be regarded by this thesis such as hunting, feeding, fragmentation etc.

5.2. Grouses

5.2.1. Rock ptarmigan (*Lagopus mutus*)

The rock ptarmigan colonizes treeless areas from the timber line up to the open rock ridges in the high mountains. The rock ptarmigan can be found in areas where the distance between timber line and peaks is at least 150-200 meters in altitude and that are not solely covered by rock (Huber & Bergier, 2006). Their habitat ranges between heights of 2800 meters of altitude and areas below the timber line to 1300-1400 meters (Boltzheim et al., 1973). Due to anthropogenic influences on the land (forest clearings and the establishment of extensive alpine pastures) the habitat of the rock ptarmigan was widened till below the timber line (Huber & Bergier, 2006)
According to Schweiger (2010) the rock ptarmigan prefers areas that are scarcely covered by scrubs (20-50%) and have a high degree of rock cover. A diverse, small scale mosaic biotope of meadows and scrubs are ideal for the rock ptarmigan as it offers increased structural diversity, food and cover. Scarce vegetation offers enough free space for the chicks to move around and rocks provide look-out points, shelter and camouflage (Schweiger, 2010, p. 16 & 17).
In the year 2005 Reimoser and Wildauer conducted a study to map the mating locations of the rock ptarmigan in the Tirol. As a result they produced a map that shows the occurrence of rock ptarmigans throughout the Tirol. The red spots in Fig 40 mark the occurrence of rock ptarmigan in the Kaunergrat during the year 2005

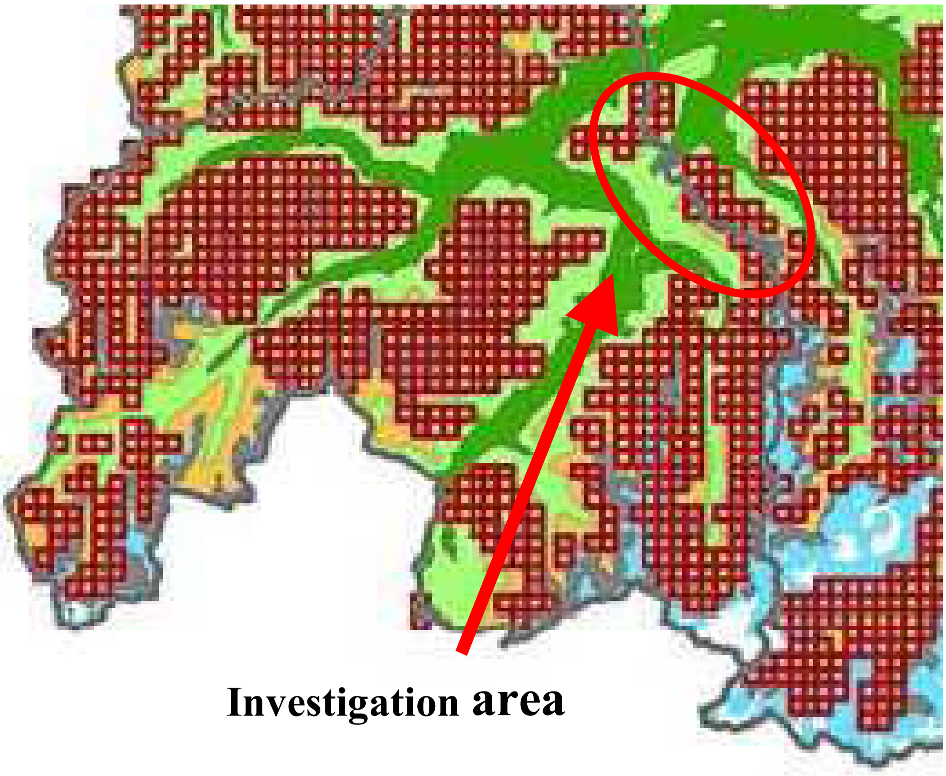

Fig 40: Occurrence of the rock ptarmigan in the Kaunergrat in the years 2005 (Reimoser & Wildauer 2006, p. 19).

For this thesis the above mentioned habitat factors for the rock ptarmigan were mapped for the time intervals between the 1950ties, the 1970ties and the years 2001/2003 in the area of investigation. For this purpose, the data of the land cover maps for all three time intervals have been analysed (see tab. 2).

Tab.2: Habitat factors for the potential habitat maps of the rock ptarmigan

Core biotopes	• According to the definition of the interpretation key the land cover class "**without land use**" contains features of "rubble or rock, sometimes intermingled with scarce scrubs and grasses, extrazonal rock vegetation, biotopes of the alpine and nival zone and snow cover" (see appendix C.) • As the rock ptarmigan also likes to inhabit open biotopes with intermingled mosaics of scrubs and meadows, the

	land use class “**scrub-meadow-biotope**” was added in locations that border the land use class “without land use”. • To take into account the gradual transition zones that often occur between alpine and sub-alpine biotopes, a buffer of 200 meters was added to the core biotopes.
Additional biotopes	The following land use classes were regarded as open biotopes and partly suitable for the rock ptarmigan: • Scrubs • Meadow-forests with a canopy cover between 5% and 15% • Scrub-meadow-forest biotope • Alpine meadows above 2500m • Agricultural alpine meadows
Size requirements	-
Neighbourhood requirements	The additional biotopes are not a main habitat for the rock partridge. But, in order to take into account the intermingled transition zones between biotopes, they were added to the habitat map, but only in places where they border the rocky regions of the land cover class “without land use” and additionally are situated inside the buffer zone of 200 meters.
Topographic requirements	-

The resulting maps show that the potential habitat of the rock ptarmigan has not been altered much during the last 50 years, regarding the changes in the land use in the Kaunergrat. The accumulated areas for the potential habitats across all three time periods do not show big fluctuations (figures 41, 42, 43).

Aggregated habitat factors of the rock ptarmigan: Calculated area (2001/2003): 33 km^2

Aggregated habitat factors of the rock ptarmigan: Calculated area 1970ties: 32 km^2

Aggregated habitat factors of the rock ptarmigan: Calculated area 1950ties: 33 km^2

(To compensate possible inaccuracies of land cover maps, the resulting calculated areas are rounded to whole square kilometres)

The light changes in area on the maps of the habitat factors, imply that the potential habitat for the rock ptarmigan was largest during the 1950ties and the years 2001/03. During the 1970ties it reduced by about 3%. When looking at those changes in area, the scale and the size of the area under investigation with about 94 km^2 and the size of the potential habitat of the rock ptarmigan ranging between 32km^2 and 33$km^{2,}$ should be kept in mind. These light changes might not be significant regarding possible inaccuracies of delineation. It should also be kept in mind that the maps only display the influence of the changes of land cover on the rock ptarmigan. Other factors such as human interference, fragmentation, etc., could not be taken into account by this thesis but they also have influence on the habitat of the rock ptarmigan.

Validation of potential habitat maps:

In the year 2010 Reimoser et al. (2010) conducted a study on occurrence of the rock ptarmigan in several reference sites throughout the Tyrol with the help of the Austrian hunters association, which participated in the study. One of the investigated reference sites was the Kaunergrat. For the study the area under investigation was divided into parcels of 100ha. Then each parcel in which the rock ptarmigan had been sighted was marked (Reimoser et al. 2010). Those maps with parcels of sightings were kindly supplied for the validation of the potential habitat maps by Prof. Friedrich Reimoser.

To evaluate the GIS generated potential rock ptarmigan habitat according to realism the area covered by the potential rock ptarmigan habitat in the years 2001/03 was compared with the parcels of 100ha where rock ptarmigans had actually occurred. Out of 68 parcels in the area of investigation, all but 4 (94% of the area covered by the parcels) at least partially were covered by the potential habitat map. No part of the area of the potential habitat map lay outside of the parcels with the occurrence data.

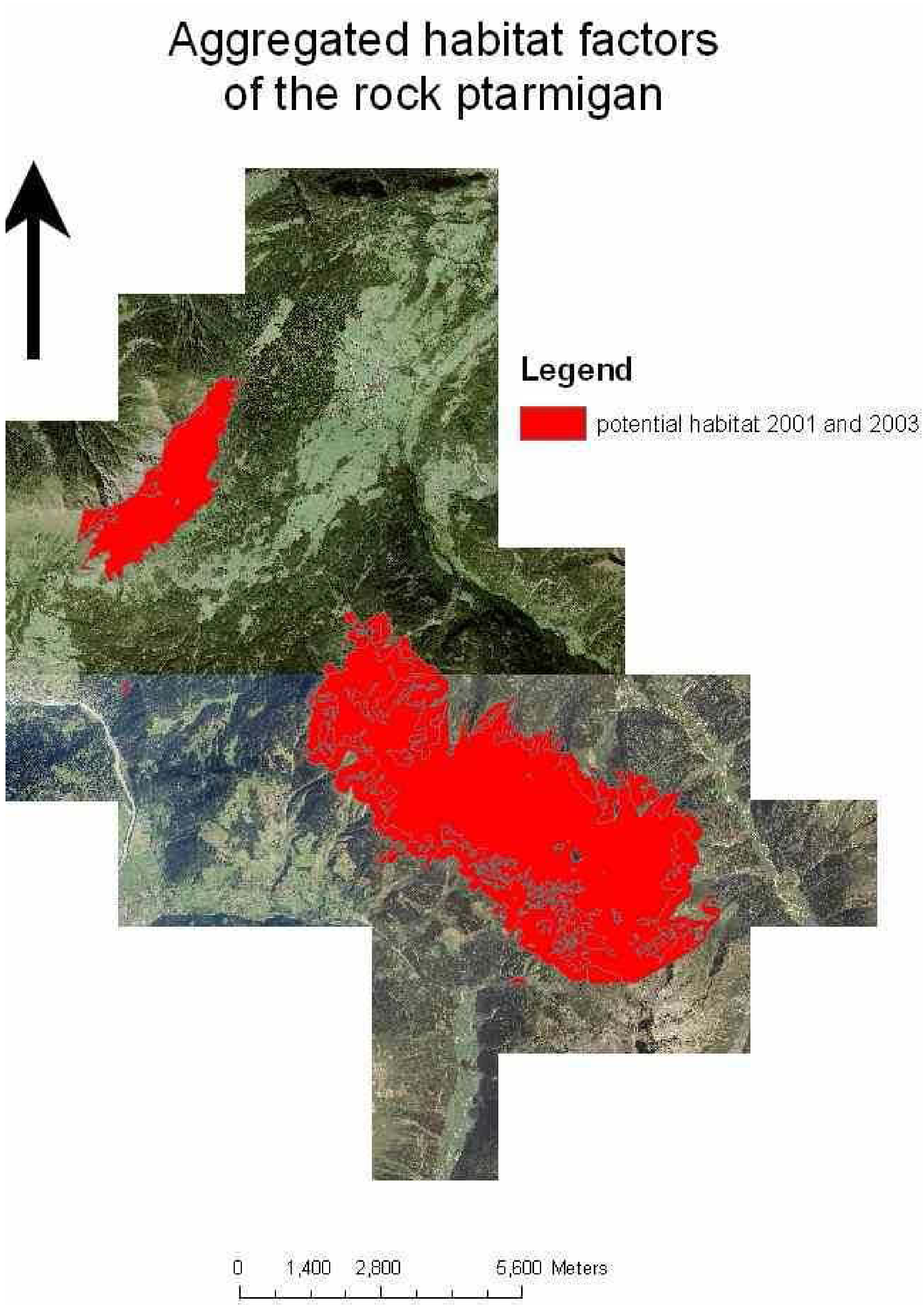

Fig. 41: Aggregated habitat factors of the rock ptarmigan during the years 2001/2003.

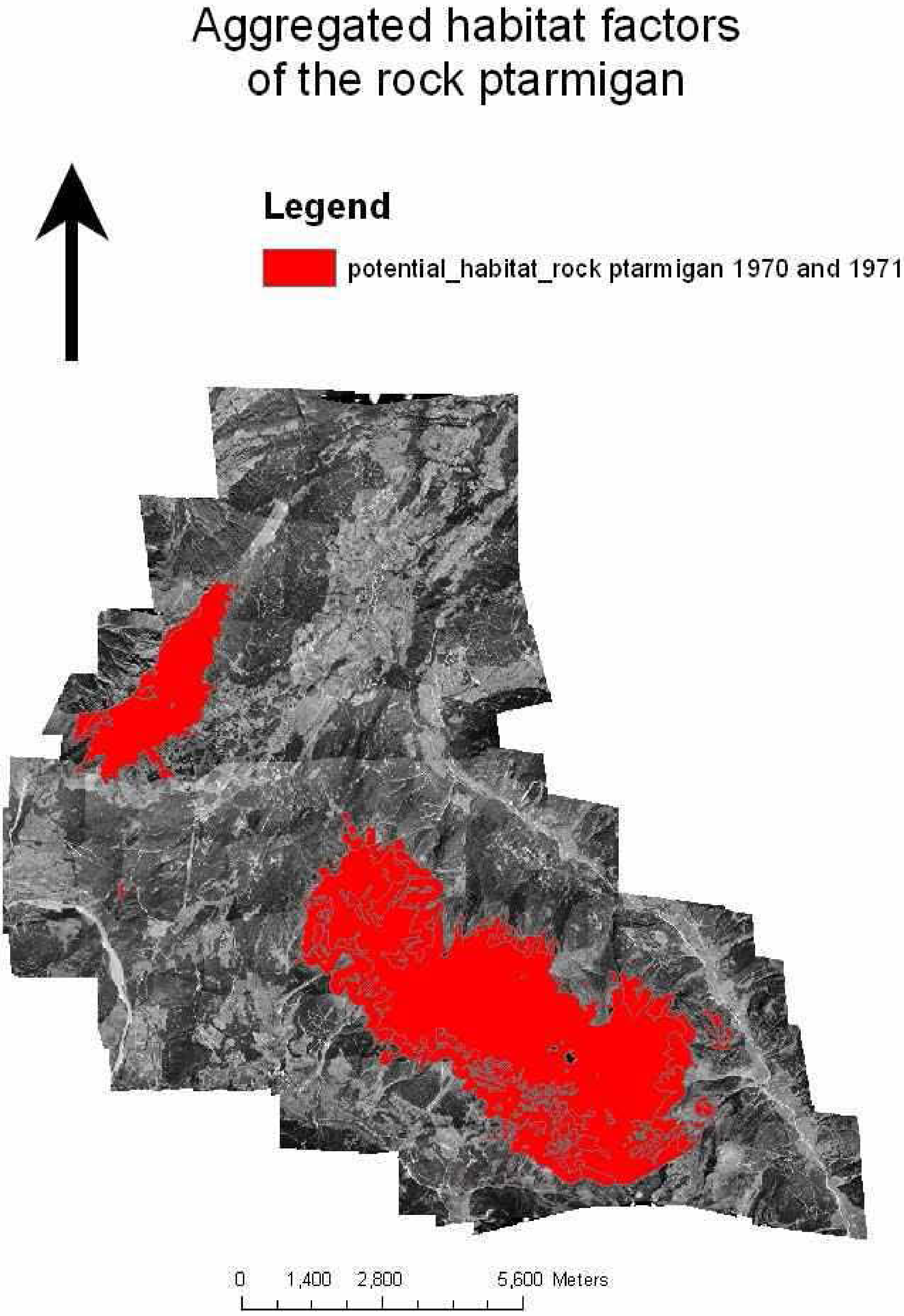

Fig. 42: Aggregated habitat factors of the rock partridge during the years 1970 and 1971.

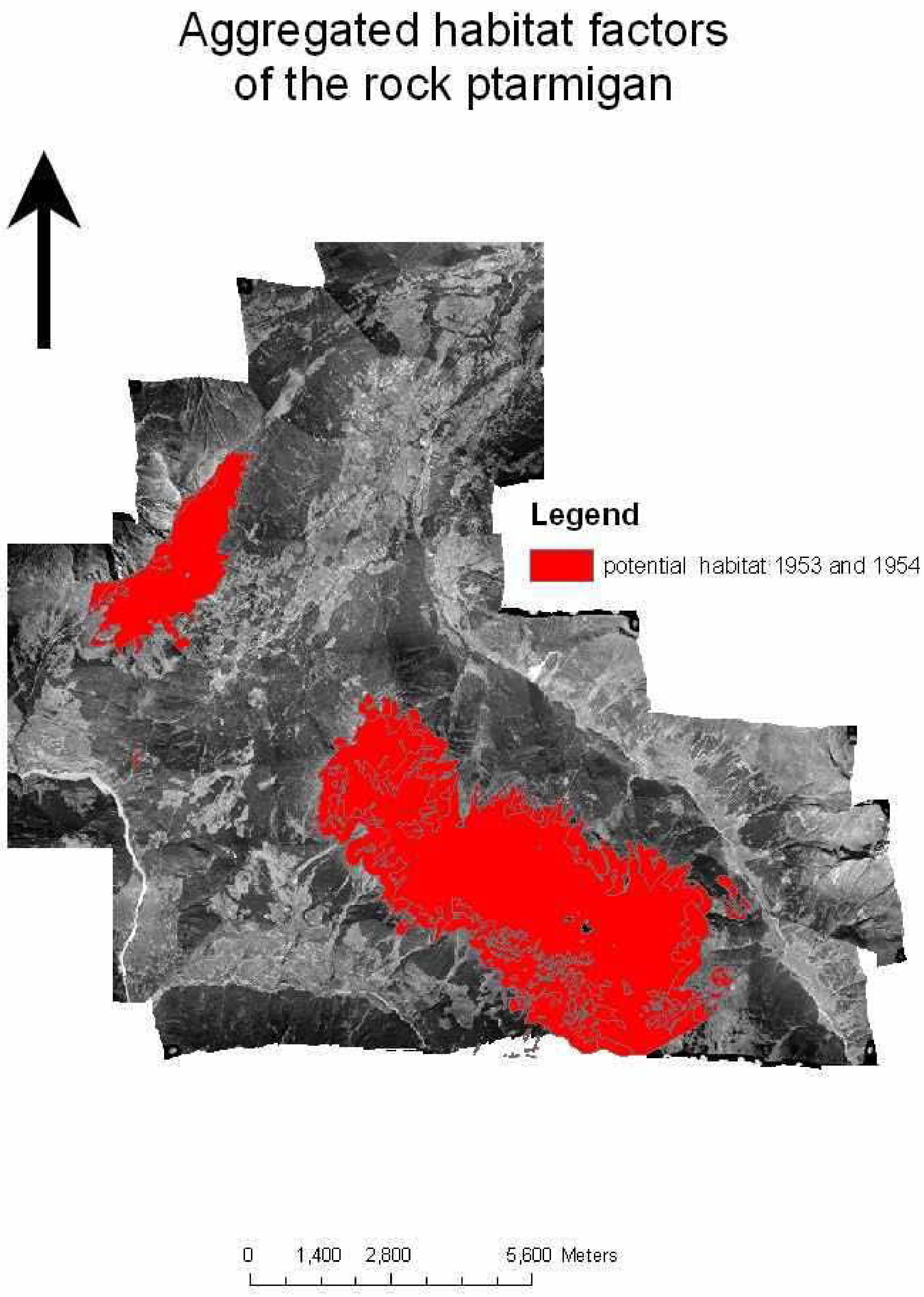

Fig. 43: Aggregated habitat factors of the rock ptarmigan during the years 1953 and 1954.

5.2.2. Black grouse (*Tetrao tetrix*)

The black grouse inhabits transition zones between forests and open pastures. In the alpine area this kind of habitat can be found at a gradually declining timber line with wide area of open space and scrubs. The tree composition does not matter to a big extent. The ideal habitat for the black grouse can be found around alpine pastures below the timber line (Huber & Bergier, 2006).

Especially the mosaic like biotopes, where trees, scrubs and meadows are found in a small scale pattern provide shelter, food and enough open space necessary for landing and takeoff. According to Wöss et al. (2008) the black grouse has a ranging area of up to 500 hectares, but Zeller (2008) states that ranging areas lie between 160 and 340 hectares. According to Zeller (2008), various man-made black grouse habitats have been generated from the Neolithic age onwards due to forest clearings and grazing management. He mentions that the largest open grazing areas throughout central Europe nowadays are situated in the Alps. Zeller states that the population of the black grouse in central Europe has reduced during the last 50 years, especially due to the changes in traditional land use (Zeller. 2008, p.106-107).

According to Zeller, British studies showed that within forests, light boreal forests with a canopy cover between 15% and 40% represent ideal habitat conditions for the black grouse.

In the lowland regions, the black grouse has suffered by the intensification of agriculture. In the alpine, sub alpine and montane areas major problems for the habitat of the black grouse arose by the strict delineation of forests and agricultural pastures. The traditional cultivation of wooden pastures in mountain areas created habitats with intermingled pastures and forests and floating transitional zones between these two biotopes. Wooden pastures provided half open biotopes with a scarce growth of trees. These habitats were perfect for the black grouse. Due to the intensification of agriculture, pastures and forests became segregated, no trees were allowed to grow on pastures and the open forests grew denser. This development may have negative effects on a population that once was numerous but nowadays is endangered (Reimoser, 2006).

The red spots in Fig 44 mark the occurrence of black grouse in the Kaunergrat during the year 2005:

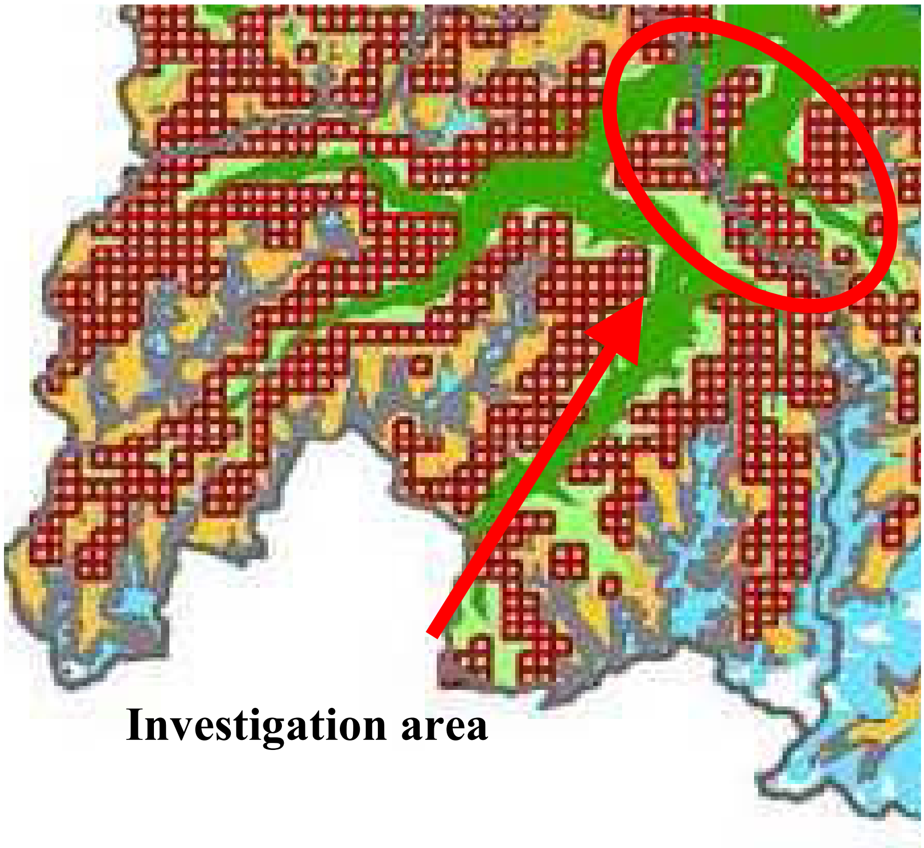

Fig 44: Occurrence of the black grouse in the Kaunergrat in the year 2005. (Reimoser & Wildauer, 2006, p. 19)

For this thesis the habitat factors that are mentioned in the literature for the black grouse have been mapped for the three time intervals of the 1950ties, the 1970ties and the years 2001/2003 in the area of investigation. For this purpose, the data of the land cover maps for all three time intervals have been analysed and processed by Arc Map according to the habitat factors mentioned in the literature (see tab.3).

Tab.3: Habitat factors for the potential habitat maps of the black grouse

Core biotopes	• Scrubs • Scrub meadow biotopes complexes • scrub meadow forest biotope complexes

	• agricultural alpine meadows • meadow-forests with a canopy cover between 5% and 15%
Additional biotopes	• forests-meadows with a canopy cover between 15% and 30%
Size requirements	-
Neighbourhood requirements	The additional habitat was only added in places where it touched the borders of the core habitats.
Topographic requirements	-

The mapping of the potential black grouse habitats across the three time intervals and depending on the changes of land cover, show the following results:

Accumulated potential habitat area 2001/2003: 43 km^2
Accumulated potential habitat area 1970ties: 56 km^2
Accumulated potential habitat area: 1950ties: 61km^2

(To compensate possible inaccuracies of land cover maps, the resulting calculated areas are rounded to whole square kilometres)

The maps (Fig. 45, 46, 47) display that the potential habitat area for the black grouse was largest during the 1950ties. The potential habitat reduced by 8% from the years 1953/54 to the years 1970/71. From the years 1970/71 till the years 2001/03 it again reduced by 22%.In total the potential habitat reduced by 30% in area from the 1950ties until the years 2001/03.
It should be kept in mind that the maps only display the influence of the changes in land use on the potential habitat of the black grouse and that other influencing factors such as human interference, tourism, fragmentation etc. are not included.

Aggregation of habitat factors of the black grouse 2001/03

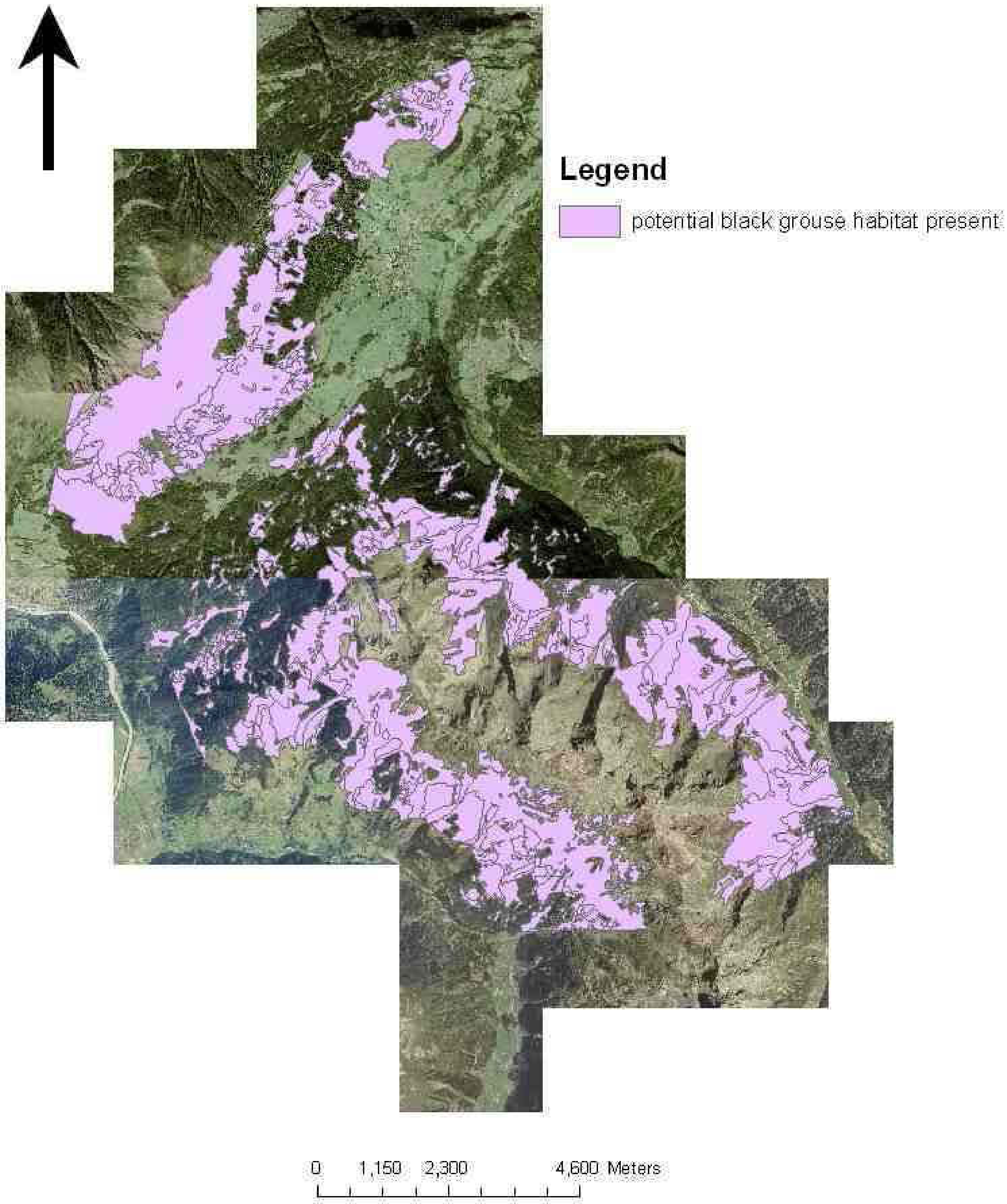

Fig. 45: Aggregated habitat factors of the black grouse during the years 2001/2003.

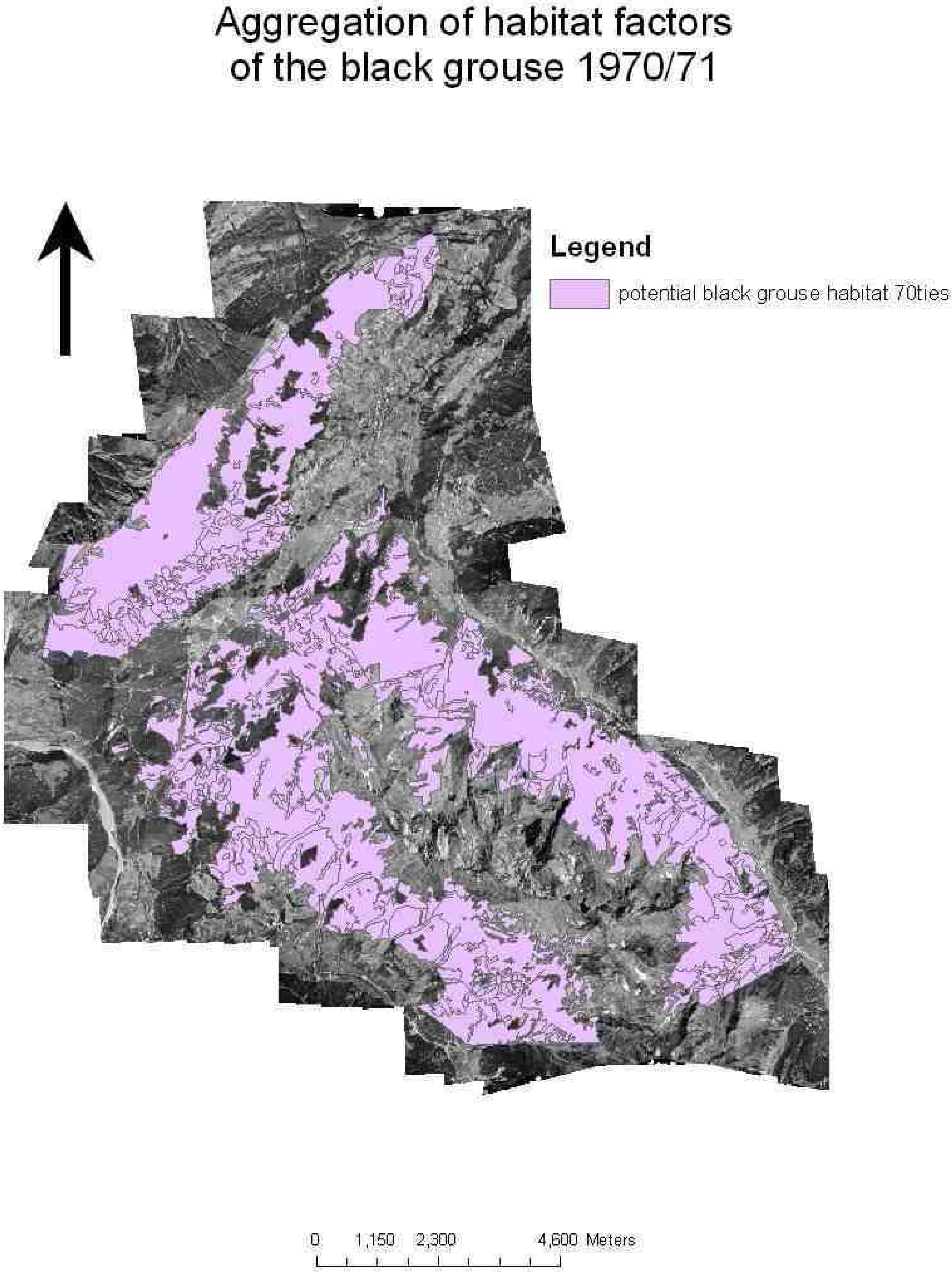

Fig. 46: Aggregated habitat factors of the black grouse during the years 1970 and 1971.

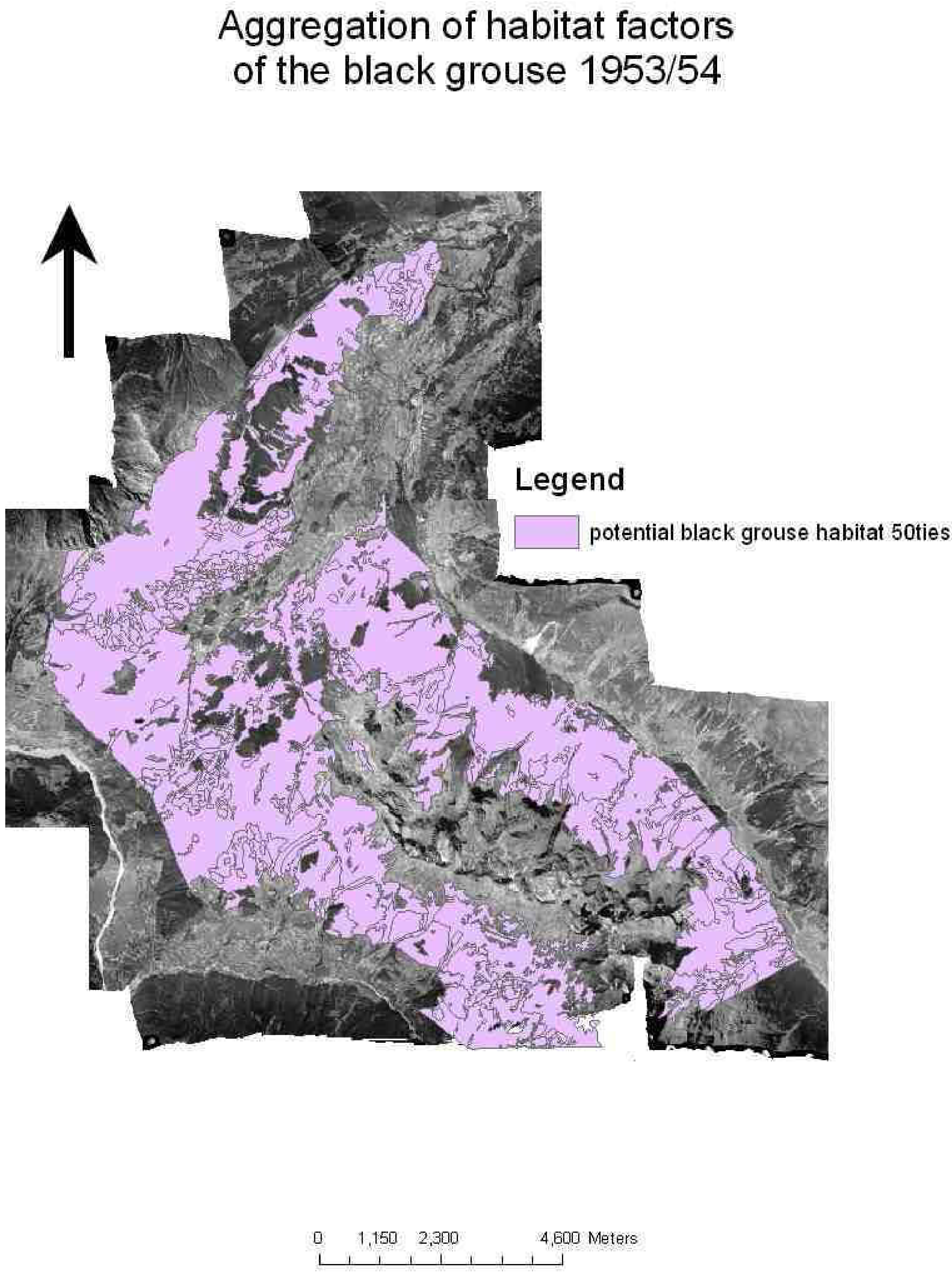

Fig. 47: Aggregated habitat factors of the black grouse during the years 1953 and 1954.

Validation of potential habitat maps:

Reimoser et al., (2010) conducted a study where they investigated into the occurrence of the black grouse in the Kaunergrat. For the study the area under investigation was divided into parcels of 100 ha. Then each parcel in which the rock ptarmigan had been sighted was marked (Reimoser et at. 2010).
Those maps with parcels of sightings were kindly supplied for the validation of the potential habitat maps by Prof. Friedrich Reimoser.

To evaluate the GIS generated black grouse habitat according to real sightings the area covered by the potential black grouse habitat in the years 2001/03 was compared with the parcels of 100 ha where black grouses had actually occurred. All of the parcels where sightings had occurred were covered or partly touched by the potential black grouse habitat but 40% of the GIS generated potential black grouse habitat lay outside the area covered by the parcels where sightings had occurred.

5.2.3. Capercaillie (*Tetrao urugallus*)

The capercaillie is an inhabitant of light forests and dependant on an undergrowth of a mosaic of scrubs, young trees and bare grounds (Huber & Bergier, 2006, p.22).
In the last 50 years, forests in Austria became denser, especially due to the abandonment of wooden pastures or because of silvicultural reasons. The Capercaillie lost its habitats necessary for survival. This loss of habitat resulted into decreasing capercaillie population in Austria (fig.47) (Reimoser, 2006). Reimoser also mentions that for browsing during winter, pine and fir are needed. According to Huber & Bergier (2006) the capercaillie was found to have moved to higher altitudes, because the alpine agriculture and wooden pastures provide precious retreat areas for the capercaillie.
Beat Fritsche (2004) investigated into the influence of relevant habitat parameters on the habitat quality of the capercaillie. In his thesis he concluded that canopy cover, inclination and the variability of canopy cover were the three key parameters to describe habitat quality for the capercaillie (Fritsche, 2004, p.47-48). According to Fritsche, forests with a low degree of canopy cover have dense ground vegetation and the trees develop a low reaching crown that provides shelter and food. He states

that several studies mentioned an optimum canopy cover between 40% and 60 %. Further Fritsche suggests that the slope for an adequate capercaillie habitat must not exceed 20° of inclination.

The home ranges of the capercaillie in areas with a strong vertical structure were described with about 30 ha by Boltzheim et al., (1973).

This study has observed a big increase in denser forests. Between the 1950ties and the years 2001/2003 the percentage of the area under investigation covered by forests with a canopy cover between 30% and 100% rose from 6% to 26%. As the capercaillies` preferred habitats should offer forests with between 40 % and 60% canopy cover, no direct conclusions can be drawn from this process due to the available classifications on the created land cover maps.

Studies by Reimoser & Reimoser (2006) show that the population of the capercaillie in the region (in the districts of Landeck and Imst) has decreased during the last 50 years (fig.47).

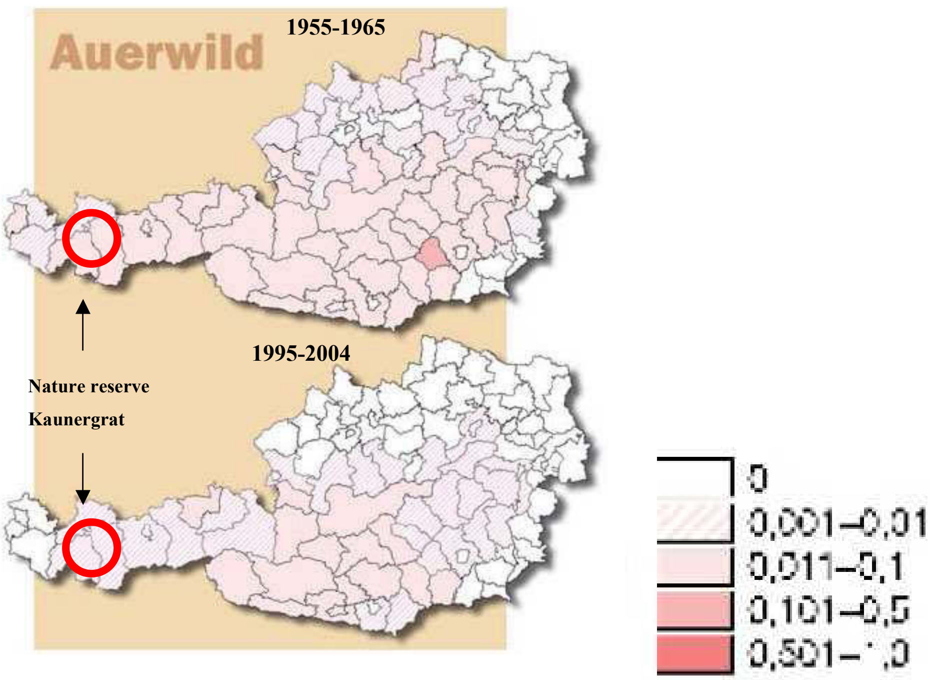

Fig. 47: The maps show the average yearly hunting (killing) density for the capercaillie (per 100 ha area) for the ten year periods of 1955 till 1964 and 1995 till 2004 (a density of 0.01 means 1 capercaillie is shot in 10 years on an area of 100ha) (Reimoser & Reimoser, 2006, p. 10).

It is possible that the densification of forests might be a reason for the decrease of the capercaillie in the area. Nevertheless it has to be kept in mind that many other factors (e.g. fragmentation, human activity, ground vegetation) that could not be investigated by this thesis also play an important role for occurrence of the capercaillie.

5.2.4. Rock partridge (*Alectoris graeca*)

The rock partridge needs open areas for survival. Its preferred habitats are rough slopes that are covered by mosaics of different types of pastures, open soils, rubble and rock which are then and again intermingled with bushes and trees. The rock partridge avoids dense forests. (Boltzheim et al., 1973).Those habitats are common in the high mountains, but in lower regions they are only present because of the influence of men. Habitats for the rock partridge were developed where steep slopes were kept open due to the traditional alpine agriculture and the necessity to utilize hay and pastures for grazing. According to Huber & Bergier, the abandonment of traditional alpine pastures will lead to a loss of habitat for the rock partridge (Huber & Bergier, 2006).
Although preferring mosaic patterns, intermingled with rock and rubble Hafner (1994) suggests that the ground coverage with vegetation must at least range between 40%-60% in winter and 80-90% in summer. According to Hafner (1994), the rock partridge prefers steep slopes between 30°-45° of i nclination because there snow cannot accumulate so easily and does not last so long in springtime. In the mountain range of the “Hohe Tauern” rock partridges have been observed most commonly between 1.700 and 2300 meters of altitude although their preference of altitude differs throughout the year (Hafner, 1994, citation after: Dvorak & Michal et al., 2005, p 271)
Boltzheim et al. (1973) state that according to comprehensive Swiss studies the rock partridge populates slopes with easterly, southerly and south-westerly expositions.

For this thesis the habitat factors that are mentioned in the literature for the rock partridge have been mapped for the three time intervals of the 1950ties, the 1970ties and the years 2001/2003 in the area of investigation. For this purpose, the data of the land cover maps for all three time intervals have been analysed and processed by Arc Map according to the information in the literature (see tab.4).

Tab.4: Habitat factors for the potential habitat maps of the rock partridge

Core biotopes	the land cover classes of • Without land use • Agricultural alpine meadows • Scrub meadow biotope complexes • Scrub meadow forest biotope complexes • Forest meadows with a canopy cover between 15% and 30% • Meadow forests with a canopy cover between 5% and 15% were considered as open or half open biotopes and suitable for the rock partridge.
Additional biotopes	-
Size requirements	-
Neighbourhood requirements	-
Topographic requirements	Further, only those suitable biotopes that were located between 1700 and 2300 meters of altitude were selected. Additionally, of the appropriate areas located in the appropriate altitude only those with an easterly, southerly and south easterly exposition were chosen as suitable potential habitats for the rock partridge. On the resulting maps the preferred steep slopes between 30% and 40% of inclination are also displayed.

The mapping of the potential rock partridge habitats across the three time intervals and depending on the changes of land cover, show the following results (fig.48, 49, 50).

Accumulated area for the preferred potential rock partridge habitats on steep slopes for the years 2001/2003: 4 km^2 Accumulated area for the potential rock partridge habitats during the years 2001/2003: 10 km^2 Accumulated area for the preferred potential rock partridge habitats on steep slopes for the years 1970/71: 4 km^2 Accumulated area for the potential rock partridge habitats during the years 1970/71: 11 km^2 Accumulated area for the preferred potential rock partridge habitats on steep slopes for the years 1953/54: 4 km^2 Accumulated area for the potential rock partridge habitats during the years: 1953/54 11 km^2

(To compensate possible inaccuracies of land cover maps, the resulting calculated areas are rounded to whole square kilometres)

The development of the potential rock partridge habitat shows that it was at its largest during the years1953/54 and 1970/71. From the 1950ties until the years 2001/03 the potential habitat of the rock partridge in the investigated area in the Kaunergrat has reduced by about 9%.

Unfortunately, no actual occurrence data for the rock partridge in the Kaunergrat were available. Therefore validation of the potential habitat map against real occurrence was not possible.

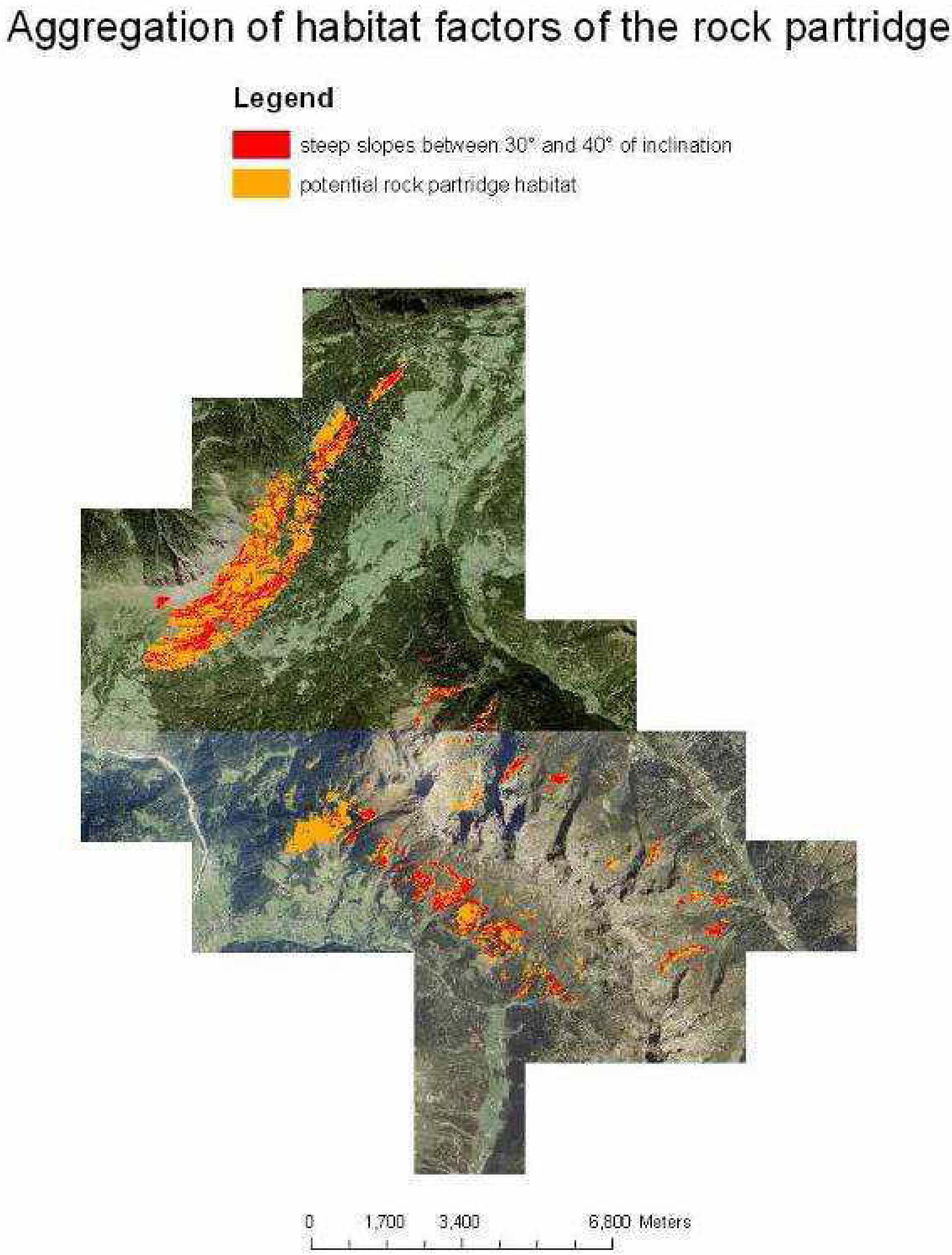

Fig. 48: Aggregated habitat factors of the rock ptarmigan during the years 2001/2003.

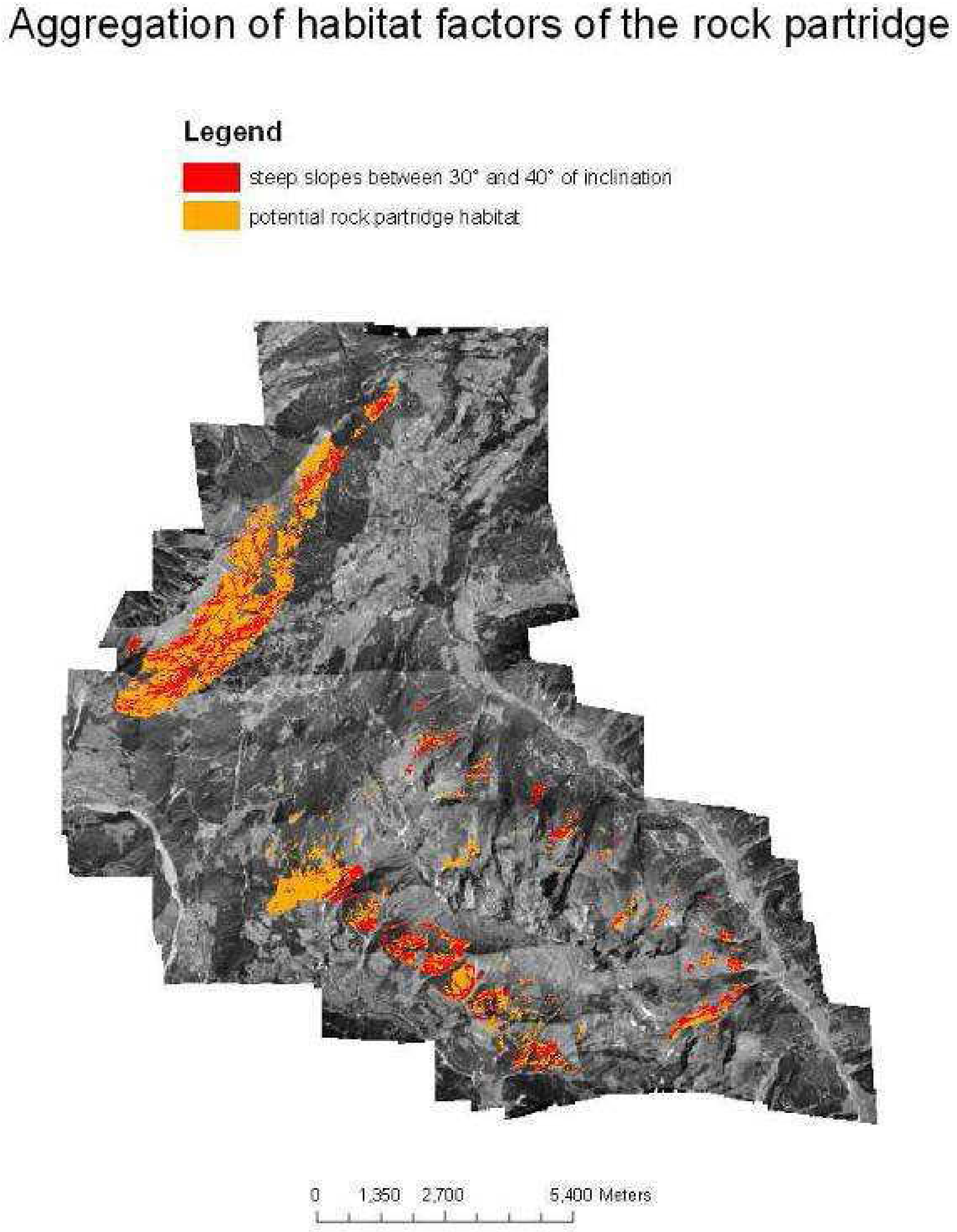

Fig. 49: Aggregated habitat factors of the rock ptarmigan during the years 1970/71.

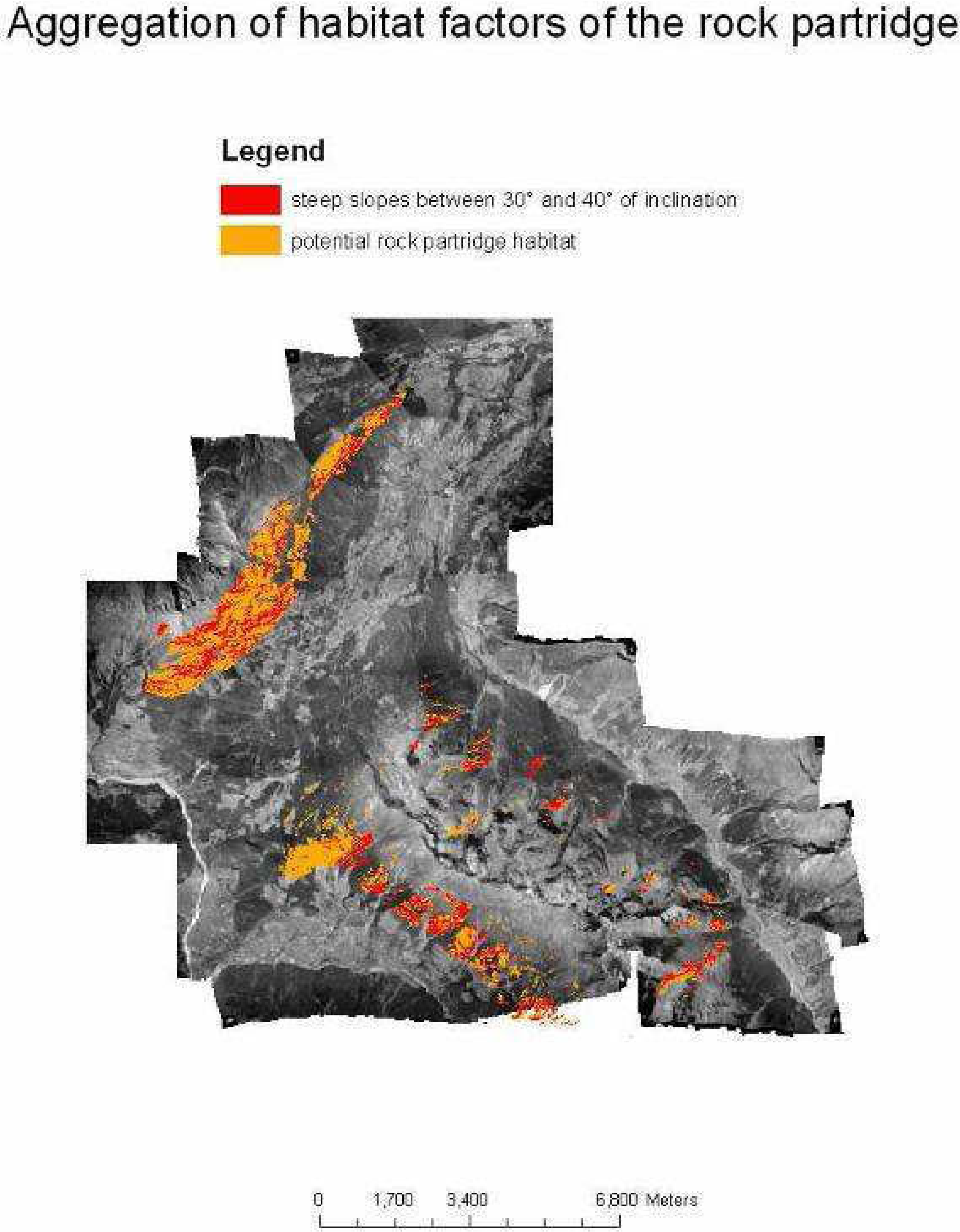

Fig. 50: Aggregated habitat factors of the rock ptarmigan during the years 1953/54.

5.3. Marmot (*Marmota marmota)*

According to a map produced with the aid of the Austrian hunters association, an autochthonous population of marmots inhabits the Kaunergrat. On the "Venetberg" which is the name of the large, single standing mountain that borders the northern end of the area of investigation a marmot population is missing (Preleuthner, 1995).

The marmot typically inhabits pastures in a zone that reaches about 400- 600 meters from the timberline upwards (Forter, 1975). It populates open areas like alpine pastures with short grass that are sometimes intermingled with rocks and rubble. In any case the marmot needs soils that are deep enough to dig its burrow. Due to forest clearances and the utilization of agricultural land in the alpine and subalpine zone the timber line was shifted. The marmot uses these newly created open areas as a habitat and therefore can also be found as lowly as the montane zone (Huber & Bergier, 2006). Preleuthner (1995) states that, according to the hunting statistics, most marmots can be found between 1800 and 2200 meters of altitude, but her maps regarding the occurrence in the Kaunergrat show marmot populations above 2200m throughout the whole Kaunergrat. Arnold (1999a) states that due to the sensitivity towards heat, marmots never inhabit areas below 800m of altitude. Marmots spend the winter time sleeping in their burrows.

From the available land cover maps and the applied classification of land cover it was not possible to derive potential habitat maps for the alpine marmot.

Nevertheless, evaluation of existing hunting statistics show interesting information regarding the development of marmot occurrence in the region.

Reimoser & Klansek (2006) state that throughout Austria, the alpine marmots have widened their habitats and increased in occurrence from 1955 to 2004. In the hunting period 1995-2004 the hunting density of the alpine marmot in the district of Landeck (which includes the western half of the area of investigation) has reached 5 Individuals per 100 ha per year (fig.51). This hunting density could not be reached in a former hunting period (1955-1965). Through the abandonment of alpine pastures, potential marmot habitats were lost to succession. Although possible marmot habitats where reduced in the last few decades, various re-introduction efforts showed good results (Reimoser & Klansek, 2006).

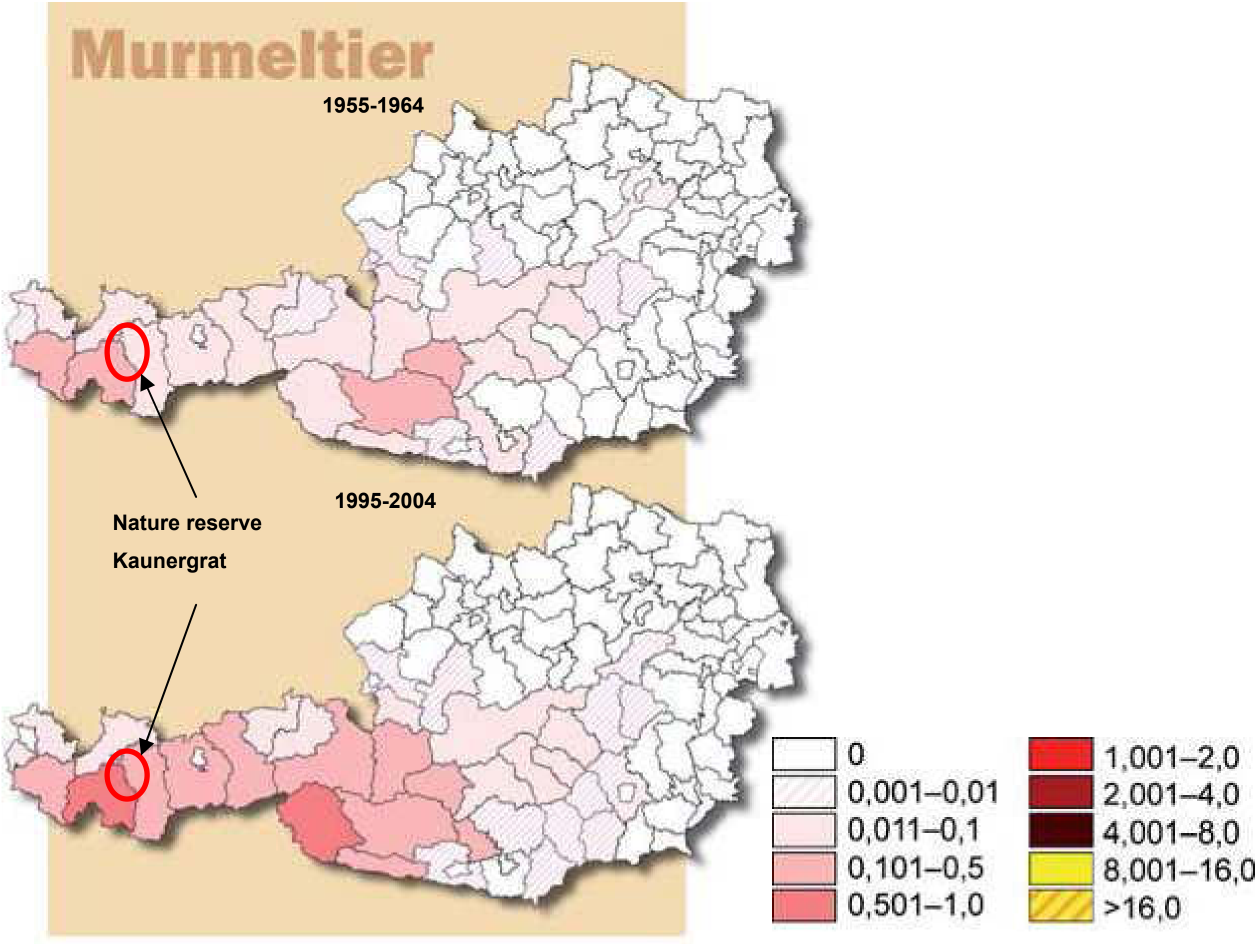

Fig. 51: The maps show the average yearly hunting (killing) density for the alpine marmot (per 100 ha area) for the ten year periods of 1955 till 1964 and 1995 till 2004 (a density of 0.01 means 1 marmot is shot in 10 years on an area of 100 ha) (Reimoser & Klansek, 2006, p. 9).

6. Summary

This thesis investigates into the changes of land cover in the northern part of the Kaunergrat from the early 1950ties until the years 2001/2003. It derives impacts of these land cover changes on the biodiversity of this alpine eco-system.
The most significant changes in the land cover concerned the density of forests. In total 20% of the area under investigation transformed from rather light forests or wooden pastures with a canopy cover between 15% and 30% to denser forests with a canopy cover between 30% and 100%.
Alpine meadows with a very low proportion of forest (with a canopy cover between 5% and 15%) reduced by 1 pp from the 1950ties to the 1970ties. A reduction of scrub by 1 pp can be observed from the 1950ties till the 1970ties but from the 1970ties till the years 2001/03 scrub increased again by 1 pp. Parallel to the reduction of scrub an increase of agricultural alpine meadows from the 1950ties to the 1970ties can be noticed and similar to the increase of scrub an increase of young forests from the 1970ties to the years 2001/03 occurred. Biotopes of intermingled patches of scrubs, forests, and meadows decreased by 1 pp from the 1950ties to the 1970ties while scrub-forest biotopes decreased in area from the 1970ties to the years 2001/03 by 2pp (see fig. 52). When looking at those results it should be kept in mind that very low fluctuations in land cover area might be due to possible accuracy errors caused by the delineation of land cover maps.

In a second step this thesis derives habitat factors from the available data and analyzes their influence on the habitat size or quality for key species that inhabit the alpine zones and cultural landscapes.
Among the investigated species are hoofed game, such as the capricorn, the chamois, the roe and the red deer; grouses such as the rock ptarmigan, the black grouse, the capercaillie, the rock partridge and the alpine marmot.
This thesis investigates the habitat size or quality between three points in time and analyses the developments of habitats which resulte from the changes of land cover.
It has to be stressed that the resulting potential habitat maps or quality indicators do not display the actual occurrence of the concerning species but they visualize habitat factors which are mentioned in the literature!

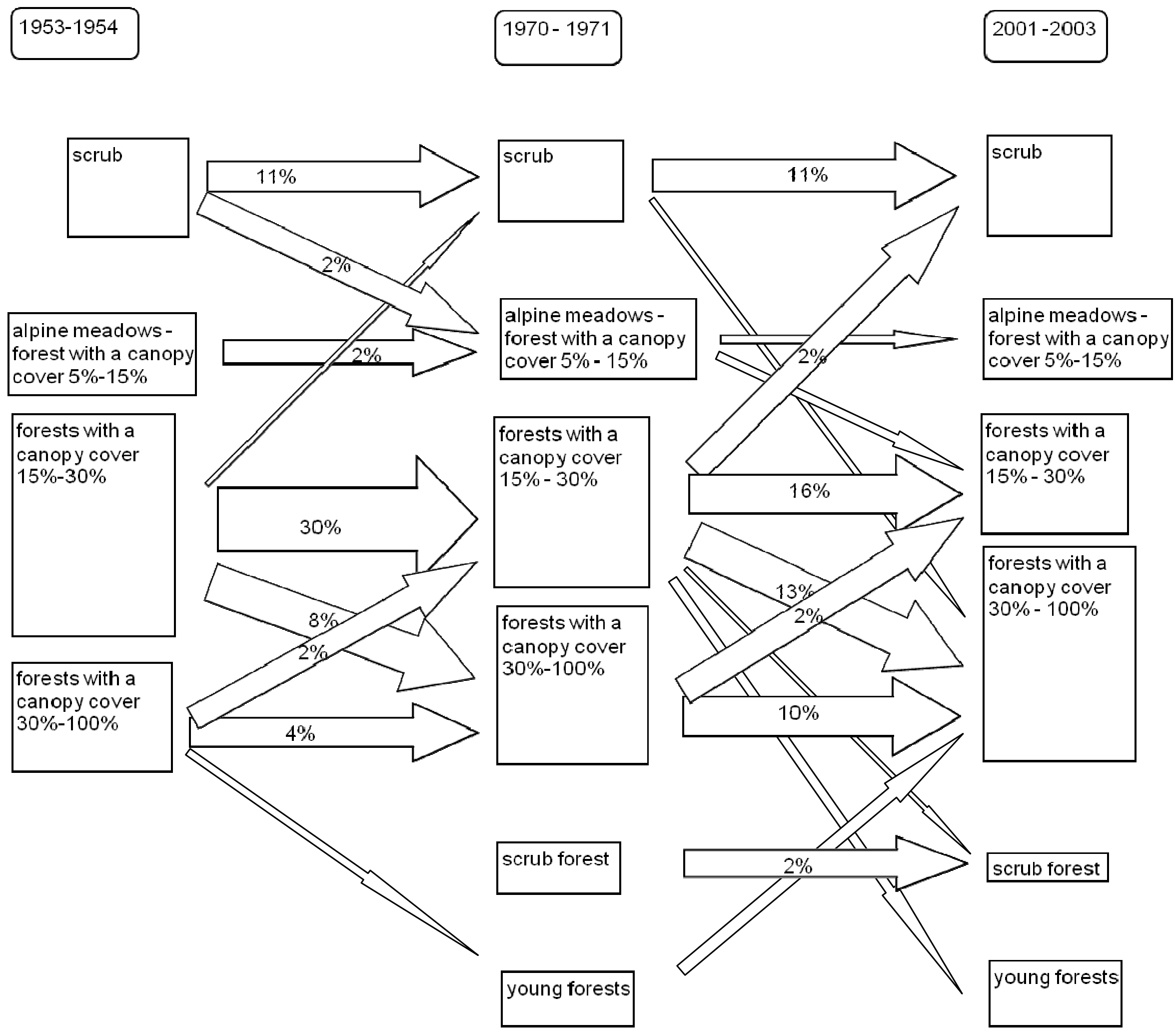

Fig. 52: Main flows of land cover as percentage points of total investigation area (changes in land cover smaller than 1pp are not displayed in the diagram)

- A GIS based model of a potential habitat for the **capricorn** , which was derived regarding the land cover changes, showes that its possible habitat reduced by about 13% from the 1970ties to the years 2001/2003. (As the capricorn was only re introduced in the Kaunergrat during the late 1950ties, the investigation period of 1953/54 could be neglected).
- For the **chamois**, it was not possible to model a habitat or derive quality indicators but literature research reveales that the chamois seemes to have moved downwards during the last few decades. It shows a tendency to disappear from the high exposed mountain peaks and ridges and move into

light forests. It was not possible to find out within this thesis, whether this was also the case for the area of investigation.

- As an indicator for habitat quality for the **roe deer and red deer**, transition zones between different types of deer biotopes were chosen. The calculation of the border lines between favourable deer biotopes for the land cover maps during the 1950ties, the 1970ties and the years 2001/03 reveals that most /longest transition zones were available during the investigation period of 1970/71.
- For the **rock ptarmigan** a GIS based model was derived from the land cover maps for all three time periods of investigation. The potential habitat area for the rock ptarmigan was largest during the 1950ties and the years 2001/03. Throughout the 1970ties it reduced by about 3%.
- A potential habitat was also modelled for the **black grouse**. Calculations of habitat area show that the habitat was largest during the 1950ties. The potential habitat reduced by 8% from the years 1953/54 to the years 1970/71. From the years 1970/71 till the years 2001/03 it again reduced by 22%.In total the potential habitat reduced by 30% in area from the 1950ties until the years 2001/03.
- From the available data it was not possible to model a potential habitat for the **capercaillie**, but according to Reimoser, (2006) the hunting density of capercaillie in the area of investigation decreased throughout the last few decades. This development happened parallel to a densification of forests in the Kaunergrat. As the capercaillie needs open forests and avoids dense forests the decrease in hunting density might result from the densification of forests.
- For the **rock partridge** a GIS based model could be derived from the land cover maps for the three time periods of investigation. The potential habitat area for the rock partridge was largest during the 1950ties and the years 1970ties. From the 1970ties to the years 2001/03 the potential habitat decreased by about 9%.
- For the **alpine marmot** no potential habitat could be modelled as the classification of land cover types and resulting land cover maps were unsuitable. Nevertheless, Reimoser & Klansek (2006) state that throughout

Austria, the alpine marmots have widened their habitats and increased in occurrence from 1955 to 2004. The reason for this increase of occurrence probably is not due to the natural environment but because of various re introduction efforts by the Austrian hunters association. The hunting density in the districts of Landeck and Imst (the Kaunergrat is located in the middle) has increased throughout the last few decades (Reimoser & Klansek, 2006).

Table 5 rates the development of habitat size or quality in the northern part of the Kaunergrat through all three time intervals of investigation and according to the results of this thesis.

Tab. 5: Probable development of habitat size or quality in the northern part of the Kaunergrat between the years 1953/54 and 2001/03.

Species	**1953/54**	**1970/71**	**2001/2003**
Capricorn	n.d.	++	- -
Chamois	n.d.	n.d.	n.d.
Roe deer / Red deer	-	+	-
Rock ptarmigan	+	-	+
Black grouse	+	-	- -
Capercaillie	+	n.d.	-
Rock partridge	+	n.c.	-
Alpine marmot	n.d.	n.d.	n.d.

+……. increased in size or quality

++……increased a lot in size (over 10%) or quality

- ……..decreased in size or quality

- -…….decreased a lot in size (over 10%) or quality

n.d…..no data

n.c…..no change

From the 1950ties to the years 2001/03 a densification of light coniferous forests took place in major parts of the area under investigation. Those light forests provide a habitat for many alpine species that occur in and are dependent on cultural landscapes. The evolution towards denser forests reduces retreat areas and habitats. This change of land cover during the last 60 years in the northern part of the Kaunergrat has various impacts on species habitats. Unfortunately, most of the assessed impacts on the investigated species have to be rated negatively (Capricorn, deer, black grouse, capercaillie, rock partridge). Only the rock ptarmigan seems to have slightly benefited from the occurred land cover changes. From a species-diversity perspective the land cover development in the northern part of the Kaunergrat can be rated negatively.

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9. Appendix

Appendix A

Technischer Bericht zur Orthophotoerstellung über das Untersuchungsgebiet „Naturpark Kaunergrat“

2009/10

LV Nr.: 857.306

„Naturpark KAUERNERGRAT“

Die Erstellung von flächendeckenden Orthophoto-Zeitreihen

Unter der Betreuung von:

Prof. Reinfried Mansberger

Immitzer Markus

Erstellt von:

Stefan Kapeller, h0007453

Nina Weber, h0019623

Inhaltsverzeichnis

1. Einleitung

Das Untersuchungsgebiet dieser Arbeit, der„Naturpark Kaunergrat“, liegt in den Ötztaler Alpen in Tirol und ist geprägt durch Jahrhunderte lange Bewirtschaftung.
Mit Hilfe einer Zeitreihe von Orthophotos aus den 50er, 70er und 90er Jahren, sollen die damit einhergehenden Landnutzungsänderungen im Untersuchungsgebiet analysiert werden Abb. 1)

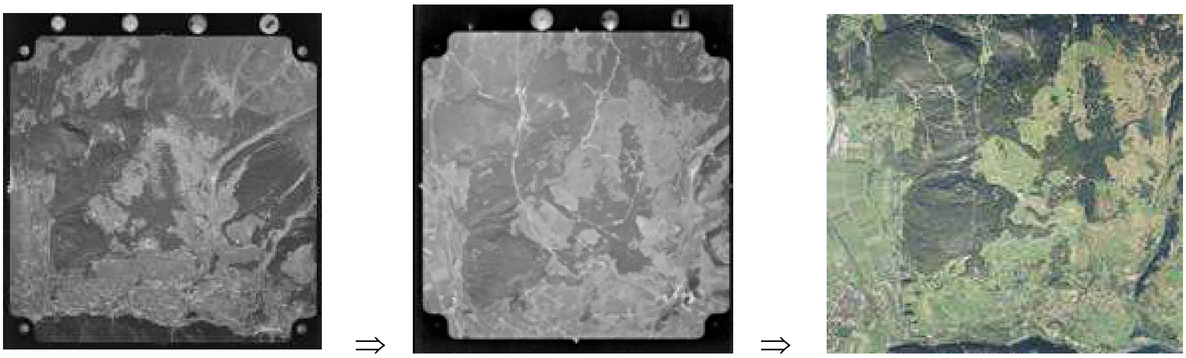


Abb. 1 Kauns im Kaunertal in den Jahren 1953, 1972 und 2006. Quelle: BEV (1953), Land Tirol (1971), Tiris (2006).

Dieser technische Bericht widmet sich der Umwandlung von Luftbildern der 50er und 70er Jahre in Orthophotos mit Hilfe der Methodik der Aerotriangulation.

2. Software

Zur Lösung dieser Aufgabenstellung wurde mit Erdas Imagine der Firma Erdas inc. und dem integrierten Modul LPS (Leica Photogrammetry Suite) gearbeitet.

- Erdas Imagine ist ein Programm um Fernerkundungsanalysen durchzuführen und um räumliches Modellieren zum Zweck neuer Datengewinnung zu betreiben.
- Das Programm LPS besteht aus einer Abfolge von photogrammetrischen Tools. Mit LPS können Höhenmodelle erzeugt, photogrammetrische Triangulation durchgeführt, Orthomosaike erzeugt und 3D Merkmale analysiert werden (Erdas inc., 2010).

3. Definition des Projektes

Luftbilder enthalten sachliche und thematische Informationen (z.B. Häuser, Berge, Vegetation etc.), jedoch enthalten sie keine Informationen über ihre räumliche Lage auf der Erdoberfläche. Daher muss mit Hilfe eines Referenzsystems beschrieben werden, wo diese sachlichen Informationen der Luftbilder auf der Erdoberfläche anzufinden sind (Lang, 2007).

Für die Umwandlung der Luftbilder der 50er und 70er Jahre in Orthophotos, muss also zuerst die räumliche Lage des Projektes definiert werden.

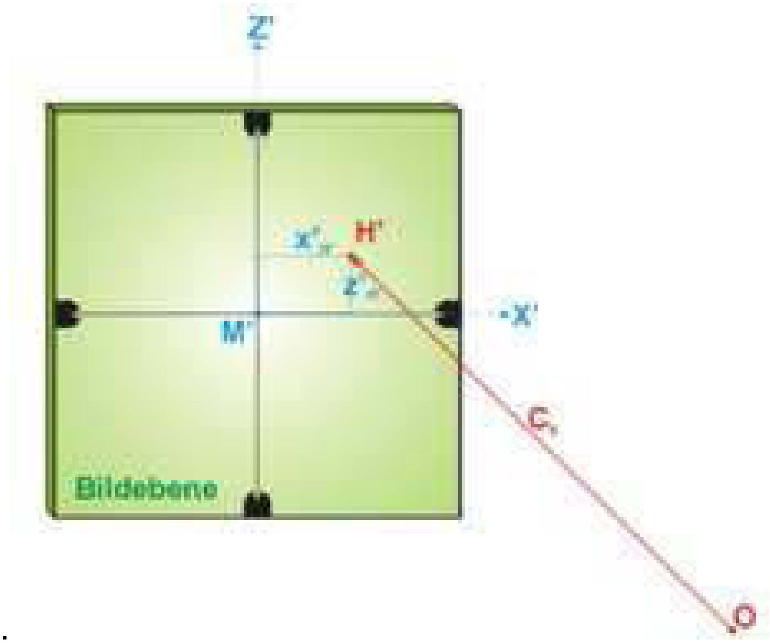
Um die räumliche Lage des Projektes beschreiben zu können, müssen folgende Daten in der Software LPS definiert werden:

Für West-Österreich, wo das bearbeitete Untersuchungsgebiet liegt, wird meistens das Koordinatensystem „**Gauss Krueger M-28**“ verwendet. Das Gauss Krueger System beruht auf einer transversalen Mercator Projektion, welche eine Projektion der Erdoberfläche auf einen Zylinder darstellt. Der **Längenursprung** des Gauss Krueger M28 Koordinatensystems liegt **10° 20’** östlich von Greenwich (28° östlich von Ferro) und **5 000 000m nördlich des Äquators (false northing –5 000 000)** (Institut für Fernerkundung Vermessung und Landinformation, 2009).

Die Lage und Orientierung, sowie die Art des Referenzellipsoids werden im geodätischen Datum festgelegt. In Österreich wird das Datum MGI Hermannskogel verwendet, welchem ein Bessel Ellipsoids mit dem Fundamentalpunkt am Hermannskogel bei Wien zugrunde liegt.

4. Herstellen der inneren Orientierung

Der erste Schritt um aus einem Luftbild ein Orthophoto herzustellen, besteht darin, die „Innere Orientierung“ der Messkamera, mit welcher die Bilder aufgenommen wurden, wiederherzustellen. Wenn man davon ausgeht, dass ein Messbild eine exakte Zentralprojektion wiedergibt, so bestehen die Parameter der inneren Orientierung aus der Kamera Konstante c und dem Bildhauptpunkt H (X/Y). Die Kamera Konstante c beschreibt in diesem Fall den Abstand vom Projektionszentrum zum Bildhauptpunkt H (Kraus, 1994). Abbildung 2 zeigt eine schematische Darstellung der Hauptparameter der Inneren Orientierung einer Messkammer.



.

Abb. 2 Innere Orientierung: Die Lage des Objektzentrums O in relativ zur Bildebene wird durch die Kamera Konstante c und den Bildhauptpunkt H beschrieben (Joachim Bäcker, 2007).

In Wirklichkeit jedoch gibt es Ungenauigkeiten in der Optik, der Photographie und der Kameramechanik einer Luftbildkamera. Um diese Ungenauigkeiten auszugleichen, wird die Kamera im Labor kalibriert. Das Protokoll dieser Kalibrierung enthält dann die notwendigen Informationen um die Parameter der inneren Orientierung wiederherzustellen (Kraus, 1994).
Für die diesem Projekt vorliegenden Bilder der 50er und 70er Jahre war leider kein Kalibrierungsprotokoll verfügbar. Es wurde daher auf ein anderes Protokoll desselben Kameratyps, jedoch aus dem Jahr 1978, zurückgegriffen.

Für die innere Orientierung der Bilder der 70er Jahre wurden folgende Informationen eingegeben:

- Das Rotationsystem wurde mit **Omega, Phi & Kappa** festgelegt.
- Die **durchschnittliche Flughöhe** betrug **3000m** .
- Unter Kamera ⇒ New Kamera wurde der **Kamera Typ 21at7** festgelegt, welcher auf den Rändern der Luftbilder sichtbar war.
- Kamerakonstante: 210.42
- **Hauptpunkt: x_0: - 0,019. y_0: 0,012**

- **Die Bildkoordinaten der Rahmenmarken** wurden wie in Tabelle 1 angegeben. Da die verwendeten Bilder aus den Jahren 1971 und 1973 Bildnegative waren, jene für das Kalibrierungsprotokoll verwendete jedoch Bildpositive, mussten teilweise die Vorzeichen der x-Werte, ebenso wie beim Bildhauptpunkt, ausgetauscht werden):

Tab. 1 Bildkoordinaten der Rahmenmarken mit korrigierten Vorzeichen (nach Wild, 1978).

	x	**Y**
1	- 81.995	81.993
2	- 82.000	- 81.998
3	82.003	- 82.001
4	81.999	81.998

Die Innere Orientierung kann nun folgendermaßen wieder hergestellt werden:
Dasselbe Bild wird in zwei verschiedenen Koordinatensystemen angenommen. Im einen erscheint das Bild im „Pixel Koordinatensystem“, welches durch den Scan - Prozess eines analogen Bildes (Zeilenrichtung, des Scanners und Scanrichtung, Pixelgröße) festgelegt wird. Das andere Koordinatensystem wird als das Bild bzw. Kamera - Koordinatensystem bezeichnet. Es wird durch die Koordinaten und Achsen der Rahmenmarken (Abb. 3) definiert, welche durch das Kalibrierungsprotokoll gegeben sind.

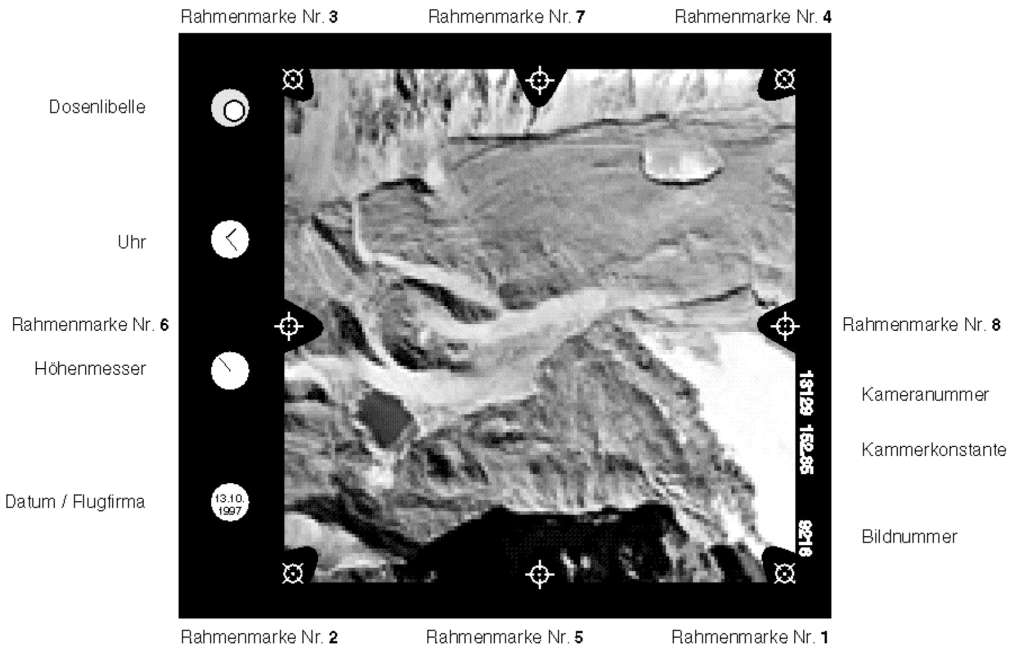


Abb. 3 Luftbild mit Rahmenmarken (Universität Zürich, s. a.).

Nun können mit Hilfe von LPS die Rahmenmarken im Pixelkoordinatensystem gemessen werden. Die Befehle im LPS lauten: Frame Editor ⇒ interior orientation
Die Genauigkeit der bestimmten Koordinaten der Rahmenmarken zeigt sich im berechneten Restfehler (RMSE). Ein guter Wert dafür liegt unter 0,2 Pixel.
Durch die nun bestimmten Rahmenmarken können mit Hilfe einer 2D Transformation Transformationsparameter berechnet werden und die innere Orientierung (= System der örtlichen Aufnahme) zum Zeitpunkt der Aufnahme wiederhergestellt werden Current frame ⇒ run .

5. Herstellen der äußeren Orientierung

Nachdem das System der örtlichen Aufnahme (= Ergebnis der inneren Orientierung) nun bekannt ist, muss zuerst über die „relative äußere Orientierung“ ein „Modell Koordinatensystem“ (= Stereomodell) erstellt werden, welches anschließend, in dem Verfahren der „absoluten äußeren Orientierung“ in ein übergeordnetes Objektkoordinatensystem (z.B. ein Landes Koordinatensystem), eingepasst wird (Abb. 4).

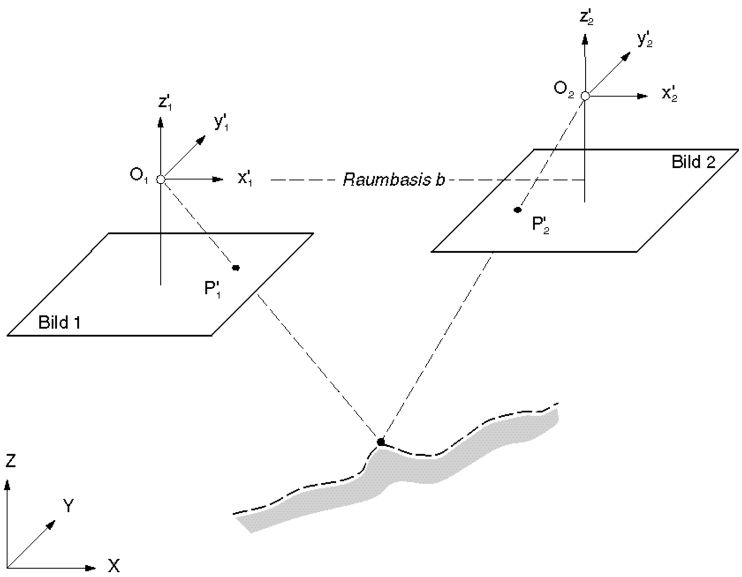


Abb. 4 Stereomodell: Modell im „Modell Koordinatensystem“, das übergeordnete Koordinatensystem (Objektkoordinatensystem, z. B. Landes-Koordinatensystem) ist noch unbekannt. Quelle: Prinz, 2007.

Da in dieser Übung nicht nur mit einzelnen Bildpaaren, sondern mit einer großen Anzahl von Bildverbänden gearbeitet wurde, wurde eine Methode der

Aerotriangulation eingesetzt; die sogenannte „Blockausgleichung mit unabhängigen Modellen“.

Mit Hilfe der Aerotriangulation können anstelle von einzelnen Bildpaaren, größere Bildverbände simultan ausgewertet werden. *„Die Methoden der Aerotriangulation befreien die Photogrammetrie von dem Zwang, in jedem Stereomodel mindestens drei Passpunkte terrestrisch bestimmen zu müssen. Mit der Aerotriangulation können Gebiete ohne Festpunkte überlappt werden.“* (Kraus, 1994).

5.1. Die relative äußere Orientierung

Mit dem Befehl exterior orientation und dem anschließenden initial exterior orientation wurde die relative äußere Orientierung im LPS eingeleitet.
Die **Querüberlappung** der Luftbilder wurde mit **60 %** angenommen und die **Längsüberlappung** mit **20%** definiert. Die **Bildgröße betrug 16 * 16 cm**. Weiters wurde die **Filmgröße (Film size) mit 6 inches** angegeben. Die **einzelnen Reihen** und entsprechende **Flugrichtungen** wurden definiert, worauf das Programm LPS die Bildreihen in einem Übersichtsfenster anordnete.
Der nächste Schritt bestand darin, die Bilder zu verknüpfen, um ein Stereomodell im Modellkoordinatensystem erstellen zu können. Dazu mussten identische Verknüpfungspunkte (Tie points) gefunden werden, welche ein Bildpaar entweder durch die Längsüberlappung oder die Querüberlappung verbindet (Abb. 5).

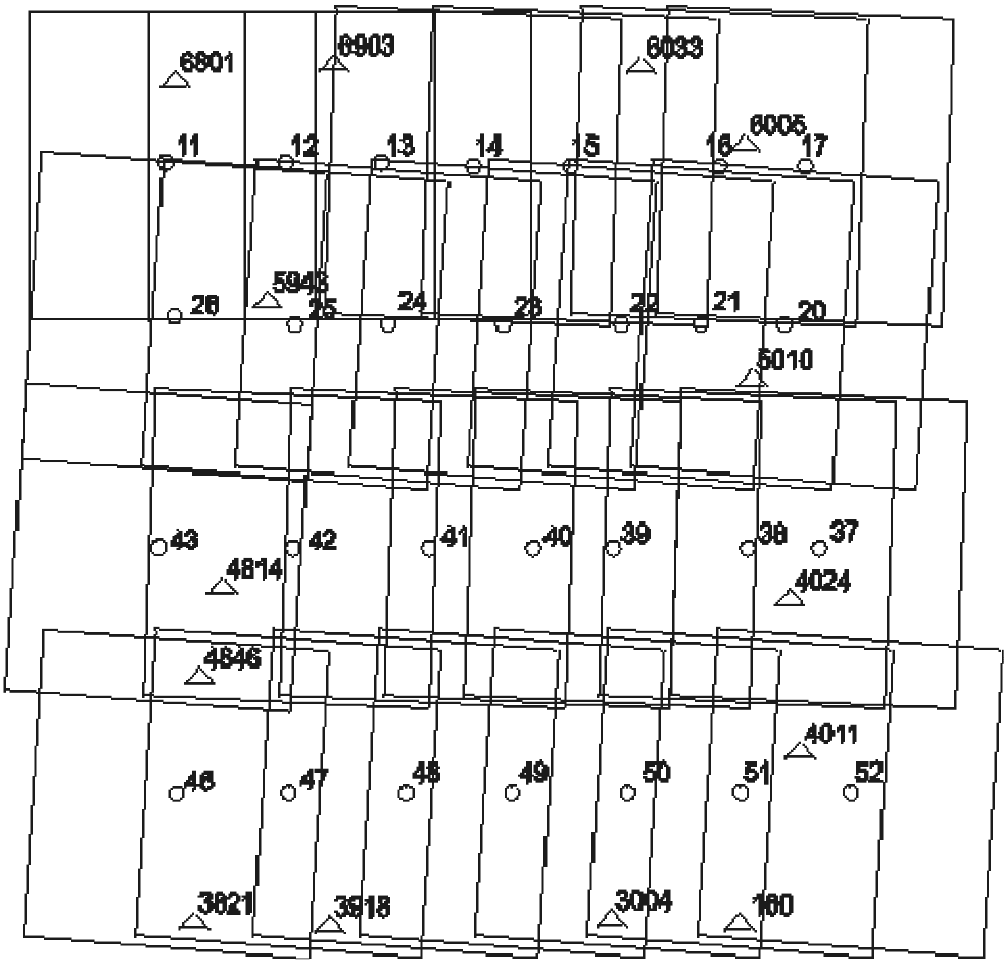


Abb. 5 Verknüpfungspunkte (Tie points). Quelle: Jakkola, 1994.

Die Verknüpfungspunkte (mind. 2-3 pro Bildpaar; gut verteilt); wurden mit LPS eingemessen:

Mit Hilfe des Frame Editors gelangt man unter Point measurement zu einem Werkzeug, mit welchem mit add Verknüpfungspunkte gesetzt werden können + (Abb. 6).

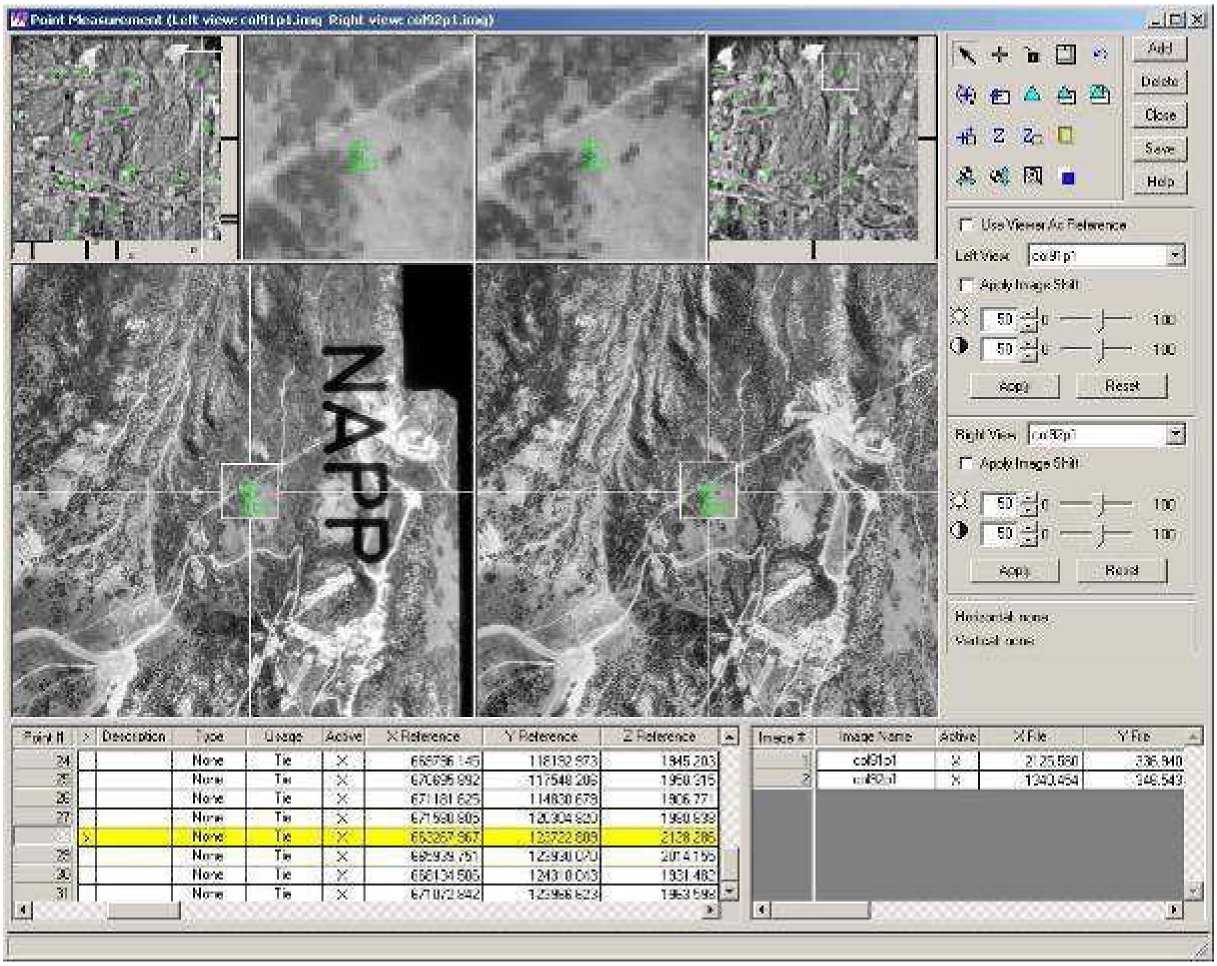


Abb. 6 Generieren der Verknüpfungspunkte im LPS. Quelle: Prinz, 2007.

Zuerst wurden die einzelnen Bilder mit Hilfe der Querüberlappung zu Reihen verknüpft und anschließend die Reihen mit Hilfe der Längsüberlappung zusammengefügt.

Unter automatic tie point measurement kann LPS anschließend automatisch ergänzende Verknüpfungspunkte generieren. Dabei wurden folgende Einstellungen vorgenommen:

Automatic tie point measurement => properties => search size.

Active images only => tie points, no transfer => run. Edit all images.

Somit kann LPS die Lage der einzelnen Reihen im Modellkoordinatensystem bestimmen und die relative äußere Orientierung herstellen.

5.2. Die absolute äußere Orientierung

Durch eine weitere Transformation (räumliche Ähnlichkeitstransformation), kann das Modellkoordinatensystem in das übergeordnete Objektkoordinatensystem eingepasst werden.

Um diesen Prozess vollziehen zu können, sind Passpunkte notwendig (Kraus, 1997). Passpunkte sind physische Punkte am Boden der Landschaft. Ihre Position ist innerhalb eines vordefinierten Koordinatensystems (z.B. Gauß Krueger System) bekannt. Diese Punkte müssen fixiert und leicht auf dem Luftbild und in der Landschaft identifizierbar sein (Lillesand et al., 2008).

Im Fall dieses Projektes wurden Vollpasspunkte (Punkte mit bekannter Höhenangabe) herangezogen. Hierfür musste die vorhandene Excel Liste der Passpunkte zunächst noch etwas modifiziert werden. Die oberste Zeile (x, y, Höhe) der Excel Liste musste gelöscht, die Dezimalstellen angeglichen und die Datei als Textdokument (.txt) gespeichert werden. Mit Import points und import options wurde dann die AscII Liste (.txt) der vorhandenen Passpunkte in das LPS importiert.

Die Qualität und Eignung der Passpunkte wurde im Tiris (Geoinformationsystem des Landes Tirol), Arc View und Google earth überprüft.

Es wurden sechs Punkte pro Streifen, deren Lage eindeutig auf den Luftbildern auszumachen war, und am Anfang und am Ende jedes Streifens gut verteilte waren, ausgewählt. Die Punkte wurden in der importierten Passpunktliste markiert und dann unter point measurement mit dem Befehl add gesetzt. Die Punkte mussten auf beiden Bildern eines Bildpaares gesetzt werden. Wenn in der Punkte-Liste alle betroffenen Punkte aktiv geschalten sind, kann das LPS über den Befehl aerial trianglation die absolute äußere Orientierung herstellen. Weist das Ergebnis tolerierbare Restfehler auf, so kann es mit accept akzeptiert werden.

6. Orthophoto Erstellung

Um ein Orthophoto generieren zu können, muss das absolut orientierte Luftbild noch entzerrt werden. Dies wird mit Hilfe eines DOMs bewerkstelligt. Für diese Arbeit wurde ein DOM mit der Auflösung von 5*5 m durch das Land Tirol zur Verfügung gestellt. Jedes Pixel des originalen Luftbildes wird über das Digitale

Oberflächenmodell neu angeordnet und somit rektifiziert (Lillesand et al., 2008; siehe Abb. 8).

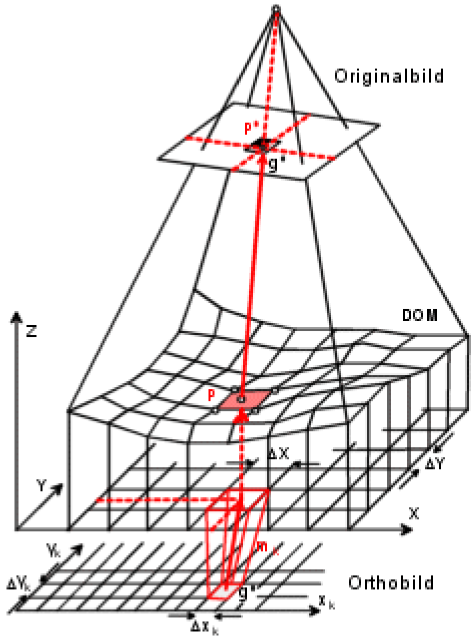


Abb. 7 Um ein Orthophoto zu erstellen wird jedes einzelnen Pixel eines Luftbildes mit Hilfe des DGMs rektifiziert (Landratsamt Starnberg, 2008).

Im LPS wird der Entzerrungs-Prozess mit orthophoto resampling eingeleitet. Unter general wurden der active area 85% zugewiesen. Als DTM Source wurde ein durch das Land Tirol bereitgestelltes digitales Oberflächenmodell des Naturparks Kaunergrat angegeben. Die output cell size wurde mit x: 0,2m und y: 0,2m festgelegt. Unter advanced wurde die resampling methode nearest neighbour angegeben. Mit resample wurde dann das entzerrte Orthophoto erstellt.
Die Qualität des Orthophotos hängt sehr stark von der Exaktheit des verwendeten DOMs ab. Treten im Orthophoto Verzerrungen auf, ist es oft notwendig das Oberflächenmodell zu überarbeiten.

Um die einzelnen Orthophotos zu einem flächendeckenden Orthophoto Mosaik zusamenzufügen, wurde unter process => mosaic das Mosaic tool verwendet (Abb. 10).

Abb. 8 Zusammenfügen von Orthophotos zu einem Bild- Mosaikverband. Quelle: Tiris, 2006, eigene Bearbeitung.

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Appendix B

The Interpretation key for this Thesis was based on an already existing interpretation key, developed by Hotter, M., and Aschaber, R., 2001 for the “Gesamtaufnahme der Kernzone; Naturparkprojekt Kaunergrat, (Pitztal-Kaunertal) Endbericht”.

For this purpose, Hotter M. and Aschaber R., chose 20 classes of Vegetation, as displayed in table 1.

FIR-Code	**Objektkennung**	**Beschreibung**
1	AGL	Gletscher, Eisfläche
2	ABSS, AFE	silikathaltige Block- und Schutthalde und extrazonale Felsfluren/-rasen (unter der Waldgrenze)
3	AFVS	Felsvegetation auf silikathaltigem Fels
4	AKB	Krummholzbestand (Latschen)
5	AGH, AGW, AGHS	Grünerlengebüsch (incl. Birkenbuschwald), subalpine Weidengebüsche an Hängen, subalp. Hochstaudenflur
6	FGR, FGS, FHM, FHS, FKS, FNW	Großröhrichte, Großseggenrieder, Hochmoorvegetation, Hochstaudenflur (nicht subalpin), Kleinseggenrieder (Punkt ab 0,5 ha Fläche)
8	ASBS	Schneeböden auf Silikatgestein (Punkt oder. Linie)
9	AZHS	Zwergstrauchheiden
10	ARSS, MKB, MMRS, MLE, FPW	alpiner Rasen silikatisch, Kammgras- und Borstgrasweiden (Weidegesell. +Lägerfluren), bodensaure Magerrasen, extensiv genutzte landw. Flächen, Pfeifengraswiesen
11	GQS	Quellfluren (mit Gerinne, Punkt od. Linie, ab 0,5 ha Fläche)
12	AFF	Felsen ("vegetationslos")
13	SGE	Blaiken
14	RD_P, MSF	planierte Piste ("auffällige Defizitfläche"), Sonderflächen
15	GS	Stillgewässer (See, Tümpel), (Punkt od. Fläche ab 0,5 ha)
16	ANS	Biotop der Nivalen Stufe (Moränen...)
17	WWG	Gehölzfreie Au (Furkationsstrecken)
18	MLI	intensiv genutzte landw. Flächen
19	FMBP	Latschen-/Spirkenhochmoore
20	WALD	Alle Waldtypen mit Baumartenanteilen in 1/10 Stufen (Laubholz alle Laubbaumarten, Nadelholz: Fichte Zirbe, Lärche Weisskiefer)
21	WWW	Weiden-Auengebüsche
	MLF	Lesesteinhaufen und Steinmauern (nur Linie oder Punkt)
	MWR	Strukturreiche Waldränder (Linie)

	TH	Totholz (Punkt)
	GFW	Wasserfall (Punkt)

Tabel 1: The interpretation key for the „Gesamtaufnahme der Kernzone; Naturparkprojekt Kaunergrat, (Pitztal-Kaunertal) Endbericht" as developed by Hotter, M., and Aschaber,R., 2001 at: http://www.schabl.at/p_kauner.html

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KUSCHE, W., ASCHABER, R., HILGER, S.,: Vom Luftbild zum Tourismusangebot - Erfassung von Basisdaten zur Einrichtung des Naturparkes Kaunergrat (Pitztal - Kaunertal), Tirol. Symposiumbeitrag AGIT 2001. Viewed: 25.07.2010 at: http://www.schabl.at/p_kauner.html

Appendix C

Interpretation key

Code: 1

Label: intensive anthropogenic land use.

Description: skiing slopes, sealed area, landfills.

Orthophoto perceptibility: apparent dump sites, sealed areas.

Colour: variable.

Structure: variable.

Example:

Code: 2

Label: without land use.

Description: Rubble or rock sometimes intermingled with scarce scrubs and grasses. Extrazonal rock vegetation. Biotopes of the alpine and nival zone, snow cover.

Orthophoto perceptibility: obvious rubble, rock or snow, mostly above the alpine zone.

Colour: grey or white.

Structure: smooth to rough.

Example:

Code: 3

Label: wetlands.

Description: Highmore vegetation, mountain pine bogs, tall forbs and reed beds.

Orthophoto perceptibility: mostly recognisable through a pattern of greenish-brownish bog, surrounded by scrub and forest. Where wetlands are situated above the timber line or inside of meadows, they are recognisable through a lightly darker colouring (dark green, bluish to brownish) than the surrounding meadows.

Colour: green, bluish or brown.

Texture: mostly smooth in the centre and gradually growing rougher towards the edges.

Example:

Code: 4

Label: water bodies.

Description: Water bodies, lakes and ponds.

Orthophoto perceptibility: recognisable as blue, green or brown areas situated in rubble, rock or meadows or forest.

Colour: blue, green, brown.

Texture: smooth, even surface.

Example:

Code: 5

Label: alpine meadows above 2500m.

Description:

Meadows above 2500m or 80% (40°) declination. These alpine meadows exist independently of grazing and farming practices.

Orthophoto perceptibility: meadows often surrounded by or interspersed with rubble or rock.

Colour: dark green.

Texture: smooth.

Example:

Code: 6

Label: agricultural alpine meadows.

Description:

Tall forbs (subalpine); meadows with crested dog's tail; mat-grass meadows, neglected grasslands, extensive grasslands on acidic soils, purple moor grass, intensively used grasslands (below 80% declination).

Orthophoto perceptibility: greenish meadows.

Colour: brown-green, light –green, green.

Texture: smooth.

Example:

Code: 7

Label: scrub.

Description:

Mountain pine, green alder, subalpine dwarf shrub.

Orthophoto perceptibility: dark green, spotted, rough or smooth areas**.** On the contrary to trees, a very small, or no shadow.

Colour: dark green.

Texture: rough.

Example:

Code: 8

Label: alpine meadow - forest (canopy closure: 5 - 15%).

Description: Network of agricultural pastures and forest with 5-15% canopy cover.

Orthophoto perceptibility: green meadow intermingled with single trees or tree groups.

Colour: mostly lighter green but also dark green patches.

Texture: smooth, but also rough spots**.**

Example:

Code: 9

Label: forest - alpine meadow (canopy closure: 15 - 30%).

Description: A network of forest and open areas with a canopy cover between 15 and 30%. The tree species compositions mainly consist of coniferous trees such as spruce, larch, pine and the Swiss stone pine but also single leaf trees can be found in the lower areas.

Orthophoto perceptibility: meadow intermingled with forest.

Colour: mostly darker green but also patches of lighter green.

Texture: rough, but also smooth spots.

Example:

Code: 10

Label: forest (canopy closure 30 - 100%).

Description: All types of forest: deciduous forest, coniferous forest, pinewood, Swiss stone pine, larch, spruce.

Orthophoto perceptibility: tight forest.

Colour: dark green.

Texture: rough.

Example:

Code: 11

Label: scrub - forest - biotope complex.

Description: Scrub-forest mosaic.

Orthophoto perceptibility: scrubs intermingled with trees or tree groups.

Colour: dark green.

Texture: rough, spotted.

Example:

Code: 12

Label: scrub - forest - meadow - biotope complex.

Description: Scrub – forest – meadow mosaic.

Orthophoto perceptibility: intermingled scrubs, trees and pasture.

Colour: light to dark green.

Texture: smooth to rough.

Example

Code: 13

Label: scrub - meadow- biotope complex

Description: Scrub – meadow mosaic

Orthophoto perceptibility: pasture, spotted with scrubs

Colour: light green, spotted with dark green patches.

Texture: smooth, spotted with rough patches

Example:

Code: 14

Label: young forest

Description: young forest

Orthophoto perceptibility: tight growing, small trees.

Colour: a lighter green than surrounding older forest and a darker green than surrounding meadows.

Texture: rough, but not as rough as older forest.

Example:

Appendix D

Canopy Cover

Canopy cover 36%

canopy cover 13%

Canopy cover 20%

canopy cover 42%


Canopy cover 53%


canopy cover 7%


Canopy cover 33%


canopy cover 18%