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Structural Adjustment in Agriculture and Landscape Change

Three Case Study Communities in Trentino's Mountain Areas (Italian Alps)

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Preface

Con questo lavoro di ricerca si chiude un capitolo importante della mia formazione accademica e della mia crescita personale. Ho voluto dedicarlo alla mia terra, il Trentino, che come tante altre regioni alpine mostra nel suo paesaggio forti contraddizioni tra passato e presente, tra identità e mutamento culturale.

Un ringraziamento sentito va alla mia famiglia e ai miei amici, che mi hanno sostenuto (e sopportato) durante i miei studi. In particolare vorrei ringraziare Hanno per la sua amicizia e il suo aiuto concreto in questi anni passati a Vienna. Un grazie anche a Luca e Silvia per la simpatia ed il supporto tecnico.

Sono riconoscente al mio relatore Univ. Doz. Dr. Karl Buchgraber per la disponibilità e fiducia dimostrate nei miei confronti, come ai correlatori Univ. Prof. Dr. Ulrike Tappeiner dell'Università di Innsbruck e Greame Buchan della Lincoln University in Nuova Zelanda. La mia gratitudine va anche a Dr. Tasser dell'Accademia Europea di Bolzano, il quale mi ha seguito con pazienza nella definizione ed implementazione del metodo di analisi.

Voglio esprimere un sentito grazie anche a tutte le istituzione della Provincia Autonoma di Trento che ho coinvolto durante il mio lavoro, in particolare il Servizio Statistica, il Servizio Urbanistica e Tutela del Paesaggio, il Servizio Foreste e Fauna, nonché le amministrazioni comunali interessate.

La mia ricerca parla di un paesaggio trentino che soffre. Possa essa risvegliare l'attenzione sull'importanza di conservare un patrimonio ambientale, economico, e di identità prezioso per l'oggi e per le generazioni future.

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1. Introduction

The term 'landscape' is quite a controversial one, since it can be defined in different ways depending on the field of application (e.g. landscape architecture, landscape ecology, landscape conservation, etc.). The European Landscape Convention defines landscape as "an area, perceived by people, whose character is the result of the action and interaction of natural and/or human factors" (Council of Europe, 2000, p. 3). Hence, a landscape includes not only the geological structure of the land, its soils, animals and its vegetation, but also the pattern of human activity – fields, forests, settlements and local industries – both past and present (Lucas, 1992).

Landscapes are not static but change trough space and time in response to changes in the interaction of their natural and anthropic components (Bürgi et al., 2004; Backhaus et al., 2007). Specifically, land use changes are responsible for many of the dynamics occurring at the landscape level, the more so as they have reached unprecedented rates in the last century (Burggraaff & Kleefeld, 1998; Schneeberger et al., 2006). Among others, polarisation of agricultural land use (intensification vs. extensification/abandonment), infrastructure development, urban sprawl, tourism and leisure activities are influencing and deeply transforming cultural landscapes worldwide (Meuus et al., 1990; Fabbri, 1997; Friedl, 2002; Lasanta-Martìnez, 2005; Calvo-Inglesias et al., 2006; Mottet et al., 2006; Alexandra & Riddington, 2007; Haase et al., 2007; Van Doorn & Bakker, 2007).

Rural landscapes in the European Alps have not been preserved from these processes (MacDonald et al., 2000; CIPRA, 2002; Penz, 2003, Bätzing, 2005; Baldock et al., 2006). In particular, the inexorable decline of mountain farming since World War II as well as the concomitant socio-economic changes have profoundly altered the relationship between Alpine people and their environment. Raising economic efficiency has allowed society to give up the extensive and decentralized use of landscape resources – which was the central trait of the traditional agricultural economy – and to concentrate productive activities at more favourable sites, while abandoning less favourable ones. As a result, traditional cultural landscapes have started to disappear.

During the last decades, the high rates of landscape change in Alpine areas have attracted the attention of planning and policy, and raised the need to study the phenomenon and its underlying causes. Knowledge about historical landscape conditions and landscape evolution over time allows understanding the links between landscape change and environmental, economic, and socio-cultural variables. It can therefore facilitate and improve predictions about the future state of landscapes, support landscape and conservation planning, and guide policy making (Marcucci, 2000).

Consequently, landscape change in the Alps has become a major object of research (Höchtl et al., 2005; Baur et al., 2006; Giupponi et al., 2006; O'Rourke, 2006; Tappeiner et al., 2006; Bogner, 2008). However, while landscape change dynamics have been analysed in detail in some regions, some other lack comprehensive studies about the topic. For instance, the Province of Trento (North-East Italy) still belongs to the 'grey zones' of landscape change research.

The present degree thesis intends to fill this research gap by investigating recent landscape changes in Trentino's mountain areas. For this purpose, a diachronic landscape analysis over the period 1954-2006 was performed following the repeated aerial photograph interpretation model proposed by Tasser et al. (in print). However, since landscape change mapping could not be carried out on the entire territory of the Province due to time constraints, a case-study community approach was adopted. In particular, three communities were selected which represent the three major directions of agricultural and socio-economic change in Trentino's mountain areas. Respectively,

- the community of Lomaso has experienced a process of agricultural intensification and specialisation in the dairy sector thanks to the favourable climatic and geomorphologic conditions of its territory;
- the community of Terragnolo has faced strong depopulation and massive farm abandonment due to its geographic and socio-economic marginality;
- the community of Transacqua is characterized by a dynamic specialisation in livestock farming and a strong economic integration with the tourism industry.

The analysis and comparison of landscape change in three fundamentally different communities allows covering a wide spectrum of land use systems and socio-economic structures, thus providing a comprehensive overview of landscape evolution in the region.

The main research questions posed by the present degree thesis can be formulated as follows:

- Which are the spatial and temporal rates and patterns of landscape change in Lomaso, Terragnolo, and Transacqua over the period 1954-2006?
- How do they differ among the three case study communities?
- How can they be explained using available bio-physical and socio-economic data?

In answering these questions, particular attention is paid to recent structural adjustment in agriculture and its impacts on traditional land use systems and cultural landscapes. Hence, important sub-questions are:

- How has the different evolution of agricultural structures affected cultural landscapes in the three case study communities?
- Which kind of agriculture is most effective in limiting land abandonment and forest re-growth?

The introduction is followed by a back-ground chapter addressing the issue of agricultural structural change in the Alps and in Trentino. Subsequently, the three case study communities are briefly described as to their natural conditions and socio-economic structures, with a special focus on the agricultural sector. The third chapter comprehensively illustrates the material and methods used. In the fourth chapter, the salient results of diachronic landscape analysis are presented and discussed with the help of secondary literature and official statistics. The thesis ends with some conclusive remarks, a brief outlook, and the summary.

2. Background

Agriculture has been the major driver of recent land use and landscape changes in the European Alps (MacDonald et al., 2000). Hence, considering the evolution of the agricultural sector over the last decades is fundamental to understanding observed landscape changes. In the present chapter, recent structural change in agriculture is addressed at different spatial scales, namely the European Alps and Trentino (Northwest Italy). Furthermore, the impacts of agricultural structural adjustment and the related socio-economic changes on traditional rural landscapes are considered. Particular attention is given to Trentino, as it represents the study area of this research work.

2.1 The broad context: agricultural adjustment in the European Alps

Agriculture and its socio-economic role in the Alps have been experiencing profound changes over the last 50 years (Penz, 1984; Groier, 1993; Bätzing et al., 1996; CIPRA, 2002). The evolution from a subsistence oriented to a market oriented agricultural system represented the end of the *Agrarzeitalter*[1] and the beginning of a new, post-agricultural era (Tappeiner et al., 2006). Within a few decades, agriculture lost the central economic, social, and cultural role it had played for thousands of years, rapidly moving to the margins of the scene.

Structural change in agriculture had already begun with the industrial revolution, but accelerated to an unprecedented level after World War II (Bätzing, 2005). Its imperatives were mechanisation, rationalisation and specialisation (Schermer & Kirchengast, 2006). Consequently, traditional, labour-intensive farming practices, which had generated and maintained a cultural landscape of extraordinary richness through decentralized and extensive agricultural land use (Maurer et al., 2006), were progressively substituted by modern, capital-intensive production systems (Penz, 2003). Farm abandonment, concentration processes, and a growing polarisation of land use trends were the consequences, with intensification of fertile and plane areas in the valley floors on the one side, and extensification/abandonment of marginal, steep, badly accessible, and poorly productive areas on the other (Buchgraber, 2004; Gusmeroli et al., 2006). Trepl (1987) summarizes such development as the transition from a divergent (diverse) landscape to a convergent one, in which land use patterns are simplified and become spatially monotone. This process has not come to an end yet (Soliva et al., 2008).

However, the patterns of structural change in agriculture have been extremely heterogeneous across the Alpine bow due to significant national, regional, and local specificities. Tappeiner et al. (2003) classify all municipalities of the Alps into eight homogeneous agrarian structure region

[1] age of agriculture

types, which reflect different directions of socio-economic and agrarian development (fig. 1). This classification is based on a clustering exercise which includes 43 indicators on natural environment, demographics, economy, and agriculture. The eight agrarian structure region types are defined as follows.

1. The *high labour, intensive crop region* is characterized by a mild climate and is suitable for intensive crops such as fruit, vine, vegetables, and flowers. Thanks to agriculture's high productivity in this region, average farm size is small and the percentage of farm abandonment as well as the percentage of unused agricultural land are low. All three indicators suggest a stable overall situation.
2. The *labour-extensive arable land region* is characterized by favourable conditions as to slope steepness, relief energy, and altitude. Arable farming predominates (more than 61%), average farms size is comparatively big, and the percentage of farm abandonment is high.

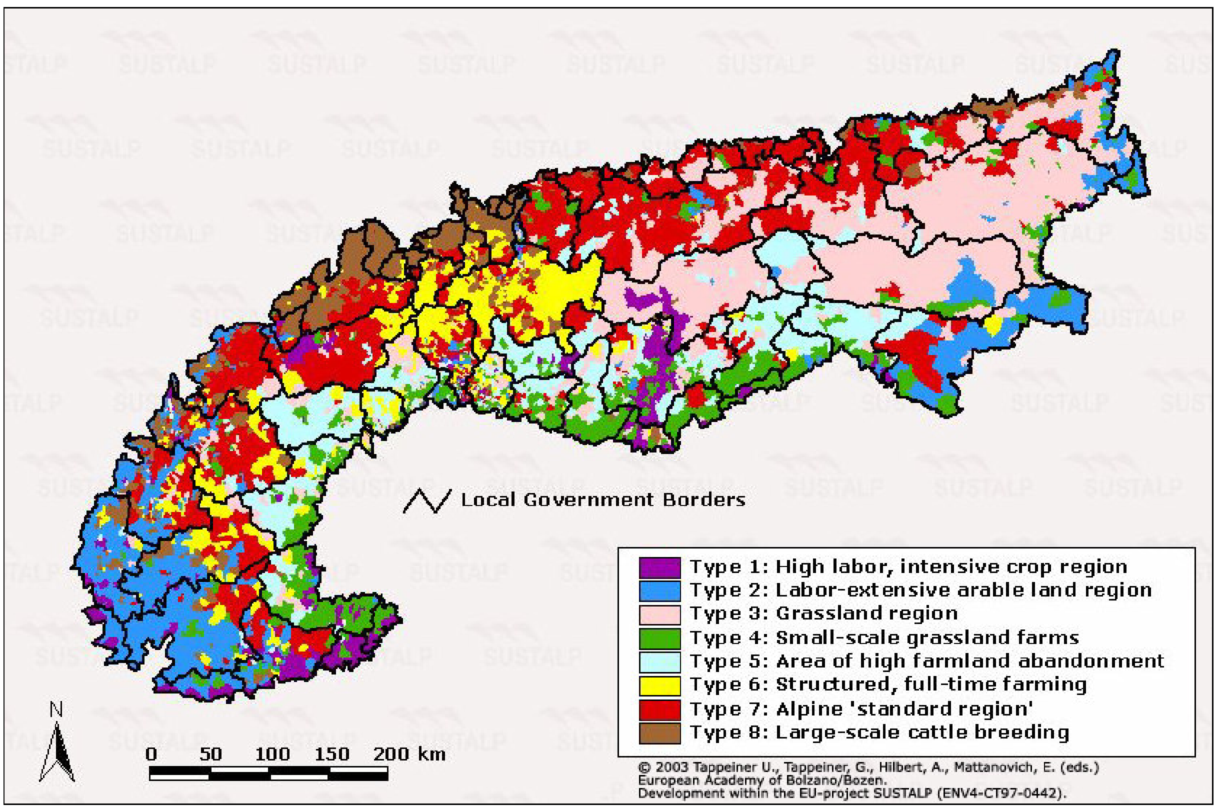


Fig. 1. The Alps and their municipalities classified by eight agrarian structure types in the framework of the SUSTALP project (source: Tappeiner et al., 2003, s.p.).

3. The *grassland region* is characterized by a dynamic specialisation in livestock farming and an economic integration with the tourism industry. The migration balance is fairly stable and the percentage of farm abandonment is at the lowest level. Notably, this region experiences a rapid transition from full-time to part-time farming.

4. The *small-scale grassland farms region* is characterized by a high average age of farm owners, an extremely high share of farms with less than 5 ha usable agricultural area (UAA), labour-intensive systems as well as a fast growing percentage of abandoned land. The high labour intensity indicates the lack of alternatives to agriculture.
5. The *area of high farmland abandonment* is characterized by unfavourable geo-morphologic conditions (high relief energy and slope steepness), very small farms, and a high share of unused usable agricultural area (over 72%). Agriculture has already collapsed or is collapsing in the region.
6. The *structured, full-time farming region* is characterized by the highest level of farm abandonment but relatively low rates of land abandonment. This situation results from a strong focus on full-time farming, the shut-down farms are mainly used for part-time farming. The increase in livestock density per ha and a high share of specialized pasture farms indicate a tendency towards intensification of agriculture (livestock farming in particular). The striking difference of this region type from the others can be ascribed to Switzerland's new agricultural policy.
7. The *alpine standard region* is characterized by a moderate rate of farm abandonment, a low proportion of agricultural employment (4,1%), and high tourism intensity. The share of part-time farms is high and markedly growing.
8. The *large-scale cattle breeding region* is characterized by favourable geo-morphologic conditions. The usable agricultural area represents a high share of the municipality area and the share of agricultural employment is particularly high (11%). The proportion of big farms (>10 ha UAA) is relatively high as well. Farms are run by young full-time farmers and are fairly intensive, to a large extent specialized in pasture farming.

The reasons behind the heterogeneity of structural development patterns across the Alpine bow are manifold and complex (Tappeiner et al., 2006). However, Bätzing (1992) identifies two main directions of change by distinguishing two different socio-economic and agricultural systems: the Romanic farm type and the Germanic farm type. Table 1 summarises their salient characteristics.

The Romanic farm type developed mainly on the Southern side of the Alps, in dry and climatically mild areas. By tradition, Romanic farms are self-sufficient systems: agricultural production is mixed and highly diversified, with arable crops (maize, rye, barley, pulse, potatoes) and livestock (mainly dairy farming) accompanied by minor crops such as vegetables, fruit, herbs, hemp, and so on. Farm size is very small – subsistence arable farming is labour intensive rather than land intensive – and characterized by spatially scattered, miniature plots (high level of land fragmentation and dispersion). These structural traits can be ascribed to the succession right, which provides for an equal distribution of heritage among the children (*Realteilung*). While intensively used land such as arable and meadows are privately owned, pasture areas, alpine pastures as well as forests normally belong to the community, which represents the centre of social and economic activities.

From a landscape perspective, Romanic regions are dominated by small groups of houses, surrounded by terraces on sunny and dry slopes (arable crops). Hence, meadows and pastures are located on shady aspects and at mid to high altitudes, where forested areas have been strongly reduced.

Tab. 1. Comparison of the Romanic and Germanic farm types as to agricultural production, farm size, property structures, succession rights, socio-economic life, and landscape characteristics (information source: Bätzing, 2005)

	Romanic farm type	Germanic farm type
agricultural production	mixed arable/livestock farms	specialized livestock farms
	silviculture low importance	silviculture high importance
farms size	small – miniature farms	medium - big farms
property structures	high fragmentation - miniature plots	low fragmentation - big plots
	high spatial dispersion of plots	low spatial dispersion of plots
	intensively used land (arable, intensive meadows) is private other agricultural land (pastures, alpine pastures, forest) is owned by the community	private land, alpine pastures sometimes under shared ownership
succession rights	*Realteilug*: each child gets an equal share of inheritance	*Anerbenrecht*: one child gets the whole inheritance
centre of socio-economic life	community	farm
landscape characteristics	groups of houses/villages	scattered houses
	terraces	almost no terraces
	forested area small	forested area large

The Germanic farm type developed in those areas, where extensive arable farming was not feasible due to adverse climatic conditions, in particular in the moist and climatically rough valleys of the Central and Northern Alps. Historically, Germanic farms are characterized by the dominance of livestock farming (both dairy and meat production), while arable farming plays a secondary role. Farm size is comparatively big – subsistence livestock farming is more land intensive than arable farming – and land property structures are much more favourable, with big plots normally concentrated around the farm centre. In fact, the succession right ensures the maintenance of a constant farm size by attributing the whole heritage to only one of the children (*Anerbenrecht*). Land is to a large extent privately owned, shared ownership is not infrequent for alpine pastures. The farm represents the very centre of social and economic activities and is perceived as the element of continuity between past, present, and future generations.

In Germanic regions, villages are substituted by scattered houses and terraces are normally not present, as they would impede pasturing and hay production. Forests still occupy a fairly high share of agricultural land and play a significant economic role for the farm (silviculture).

Due to the above described peculiarities, the Romanic and the Germanic farm type reacted in different ways to the profound socio-economic changes which occurred with the industrial revolution (Penz, 2003; Rieder, 2004). These differences became particularly visible in the first half of the 1960s, when arable farming collapsed in Alpine regions. This general collapse was due to a) the pull-effect of the 'European economic wonder' on the Alpine labour force b) the significant increase of agricultural productivity in the lowlands through mechanisation and technical progress (Bätzing, 2005).

The Romanic farm type, for which arable crops had played a major role, was strongly affected by this development: it rarely managed to adapt by modernizing its structures and specializing in livestock farming. In particular, small farm size as well as high land fragmentation and dispersion hindered capacity building and the introduction of modern land management practices. Additionally, the dependence on the community as to the management of commonly owned land suffocated individual innovation and entrepreneurship, contributing to the maintenance of the *status quo*. As a result, the collapse of arable farming in the Alps went along with the collapse of the Romanic farm system, with extremely high rates of farm abandonment and the remaining farms being managed part-time by elder farmers. This is particularly true for the Italian Alps, where most communities fall into the categories *area of high farmland abandonment* and *small-scale grassland farm region* (fig. 1). Though, the structural adjustment is still in progress: the high share of farmers over 45 years indicates that large parts of the Italian Alps will face a precarious situation in the next future (fig. 2). The point of non-reversibility has been already reached (Barberis, 1996).

On the contrary, the Germanic farm type could better adapt to the changing socio-economic environment. The collapse of arable farming, which had played an ancillary role in that economy, represented the chance to abandon self-sufficiency and fully specialize in livestock farming (dairy, meat production, breeding etc.). Comparatively big farm sizes and favourable land property structures, alongside with high land mobility from shut-down farms to surviving farms, positively affected this development. Besides land concentration processes, intensification of valley floors, mechanisation, and rationalisation (where possible) allowed farms to maintain a certain level of competitiveness. Additionally, the lower degree of dependence on community owned land and the dominance of private property guaranteed higher flexibility to the individual farmer, thus fostering innovation. Hence, the Germanic farming system did not collapse but experienced a profound structural change. Its peculiar succession right preserved farms from fragmentation, thus facilitating the generational change between father and son. In fact, the share of farmers over 45 years is much lower in Germanic regions (fig. 2).

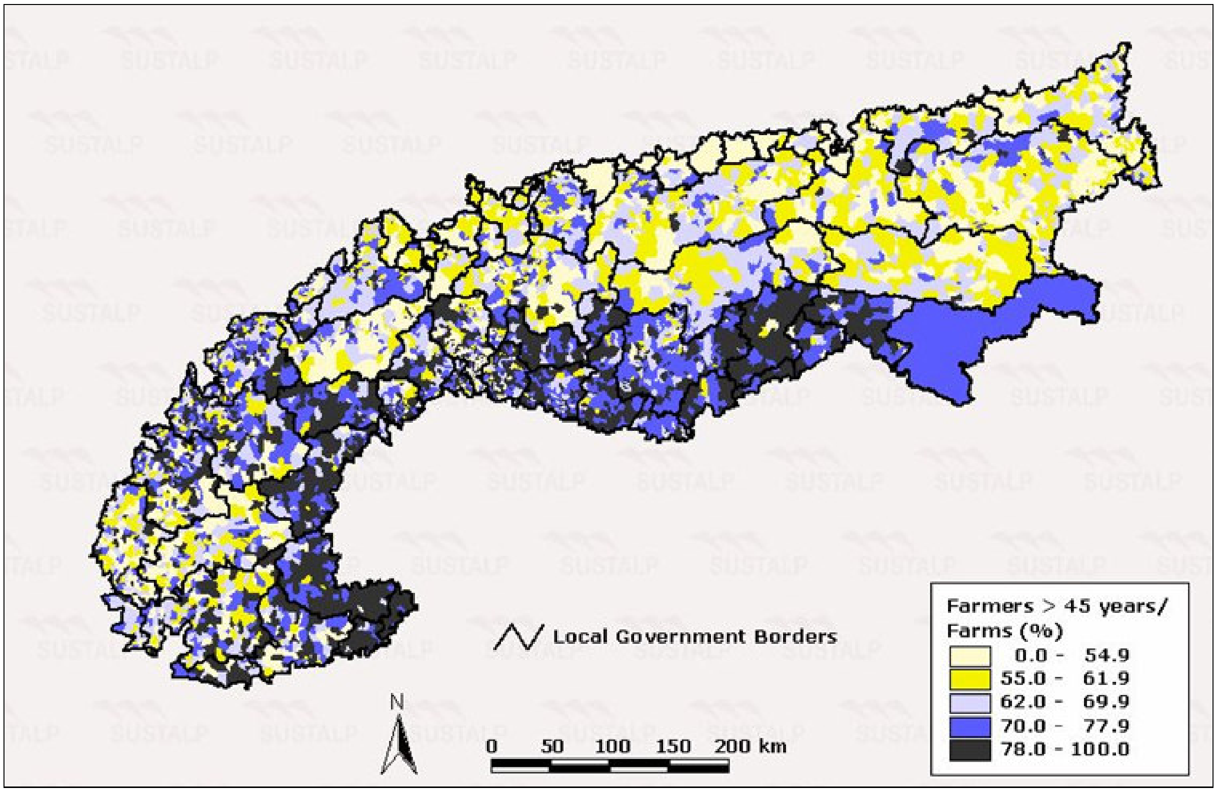


Fig. 2. Share of farmers with more than 45 years in the municipalities of the Alps (source: Tappeiner et al., 2003, s.p.).

Besides the structural differences discussed above, differences in the political system and the agriculture support policies between Romanic and Germanic mountain areas contributed to widen the gap (Bätzing, 2005; Schermer & Kirchengast, 2006). In particular, the structural weakness of the Romanic farm type was exacerbated by poor mountain farming subsidization policies. Romanic regions are by chance located in centralistic States (Italy and France), which were not able to effectively manage the collapse of traditional farming. In Italy, few resources were invested into mountain farming subsidisation and they often did not reach the base. In France, intervention policies in favour of mountain farmers arrived late (*Loi Montagne* in 1985) and took a long time to produce the expected effects. Instead, the federalist state structures of Germanic regions (Austria, Germany, and Switzerland) allowed decentralized support and subsidization programmes, thus easing the transition from traditional to modern farming systems.

In the following, the process of structural adjustment in agriculture is examined in further detail for the province of Trento, which is traditionally dominated by Romanic farm structures. After a brief introduction to Trentino and its agriculture, recent development patterns are addressed by means of a statistical analysis.

2.2 The narrow context: agricultural adjustment in Trentino

2.2.1 The Province of Trento

The Autonomous Province of Trento is situated in North-East Italy (fig. 3) and has a surface of approximately 6.200 km^2. It borders the Autonomous Province of Bolzano-South Tyrol to the North, the Region Lombardia to the West and South-West, and the Region Veneto to the East and South-East. Geographically, it belongs to the Central Southern Alps and is comprised between the Vinschgau-Pustertal line to the North and the Po plane to the South. The Province has a predominantly mountainous character: 69,8% of its territory lie above 1.000 m asl, 19,9% above 2.000 m asl. The Western part is dominated by the metamorphic Adamello (3.539 m asl) and Cevedale (3.764 m asl) Massifs and the dolomitic Brenta Range (3.173 m asl), the Eastern part by the porphyric Lagorai Range (2.754 m asl), the granitic Cima d'Asta Massif (2.847 m asl), and the Dolomites. It is traversed by the Adige river, which represents the geographic 'spinal column' of the region. From an administrative point of view, Trentino comprises 11 Districts and 233 municipalities. It has a population of 477.017, 22,0% of which are resident in the county town of Trento (31.12.2001; ISTAT, 2004).

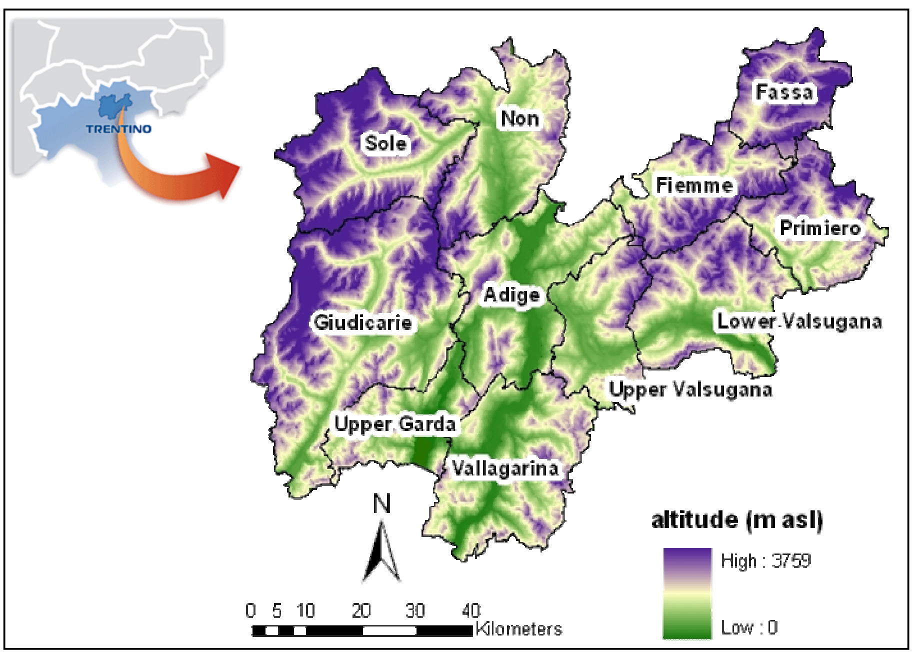


Fig. 3. The Autonomous Province of Trento, its altitudinal patterns, and its 11 Districts (own data elaboration).

2.2.2 Trentino's agriculture: an overview

The most striking feature of Trentino's agriculture is the enormous diversity of its products, which range from oil around the Garda Lake to wine in the Adige and Sarca valleys, from apples in the Non and Lower Sole valleys to strawberries and cherries in the Upper Valsugana, from vegetables in the Gresta valley to dairy and meat in the grassland dominated areas West and East of the Adige valley (Masini, 1917; Marchio et al., 1998; Bazzanella, 2007). This agricultural diversity reflects the extreme climatic and geo-morphologic diversity of the region and is associated to heterogeneous agricultural structures: seven of the eight agrarian structure region types described by Tappeiner et al. (2003) are present in Trentino (fig. 6a).

In particular, viticulture and apple production have been experiencing a significant development in both quantitative and qualitative terms in the last 50 years (Bridi et al., 1995). Barberis (1996) defines these sectors as the "Gewinner"[2] (p. 14) of structural change in agriculture: in 2000, they accounted for almost 40% of Trentino's total agricultural revenues on just 5% of total agricultural area (Sassudelli et al., 2002).

Viticulture is widespread in the dry and climatically favourable Sarca and Adige valleys, where a well developed cooperative system ensures market access and good prices to a multitude of small part-time farmers. In 2000, Trentino had 9.054 ha cultivated to vine by 10.544 farmers, with an average farm size of 0,86 ha (ISTAT, 2003). In the same year, total production exceeded 111.000 tons, which accounted for approximately € 120 million revenues (20,9% of total agricultural revenues; Sassudelli et al., 2002).

While viticulture has a long tradition in Trentino (De Mozzi, 1960), apple production has experienced a significant development in more recent years, in particular in the Non and Lower Sole valleys and in some areas of the Adige and Valsugana valleys. Total production jumped from 78.000 tons in 1951 (Lorandini, 2005) to 477.000 tons in 2000, accounting for € 106 million revenues (over 18% of total agricultural revenues; Sassudelli et al., 2002). In spite of small production scales – apples are cultivated on 12.084 ha land by 8.136 farmers, with an average farm size of 1,48 ha (ISTAT, 2003) – processing and marketing are highly centralized. In fact, two major cooperatives, Melinda and La Trentina, control over ¾ of total apple production.

As to Trentino's mountain areas, livestock farming is traditionally the dominant (and often the only possible) form of agriculture, with grassland representing a consistent share of total agricultural land. Cattle farming – and dairy in particular – is the main production sector, while sheep, goat, and pork farming play a subordinate role. However, cattle farming has been declining since the 1950s in the region (Bridi et al., 1995). In 2000, Trentino had just 1.741 cattle farmers – they were 27.004 in

[2] "winners"

1961 (ISTAT, 1963) – and 45.147 cattle, with an average farm size of 25,9 cattle (ISTAT, 2003). Cattle farming accounted for approximately € 64 million revenues (11,2% of total agricultural revenues) in the year 2000 (Sassudelli et al., 2002). Figure 4 provides an overview of the composition of Tretino's total agricultural revenues by sector in the year 2000.

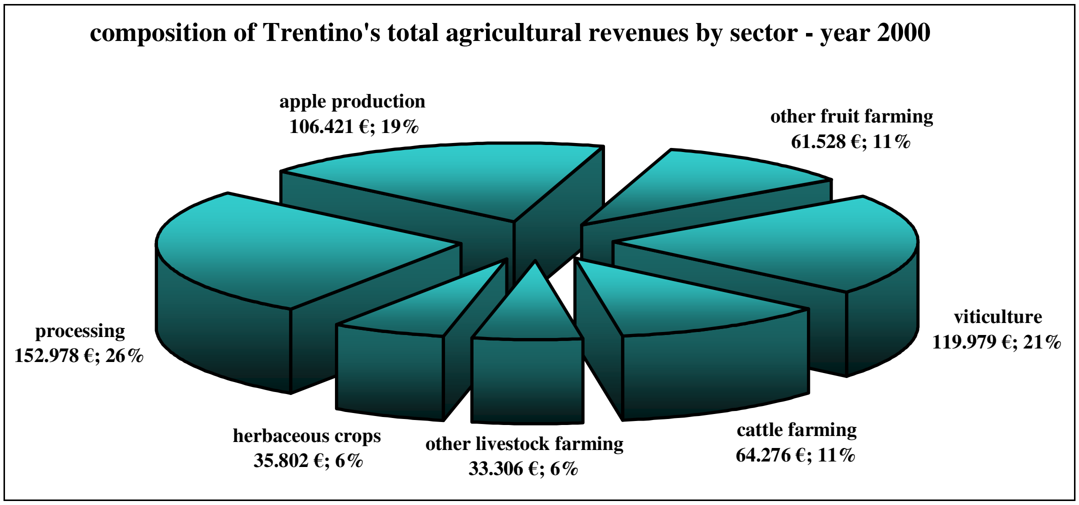


Fig. 4. Composition of Trentino's total agricultural revenues by sector in 2000 (data source: Sassudelli et al., 2002).

2.2.3 Definition of data

In the following sections, structural change in Trentino's agriculture is briefly described on the basis of statistical data which range from the year 1900 to 2000. Particular attention is given to livestock farming, due to the major role it plays in mountain areas.

Note that the heterogeneity of data sources and of measured parameters does not always allow comparisons over the whole 20th century. Consequently, the present analysis focuses to a large extent on the period between 1960 and 2000, in which the Italian Statistics Institute (ISTAT) took census of agriculture on a regular base following more or less constant criteria and definitions. Though, the comparison with data prior to World War II or even World War I – when possible – allows a better understanding of the profound evolution of the agricultural sector in the transition from a subsistence based to a market oriented economic activity. For this period, a census of agricultural from the year 1900 (Austrian Empire) and one from the year 1930 (Fascism) are considered. Both census refer to years of 'normal economy' before the World Wars and are therefore particularly suitable for the purpose of temporal comparison.

Other socio-economic data stem from the census of population of the period 1921-2001 and were elaborated by the Statistics Service of the Autonomous Province of Trento, while data on specific parameters were extracted from several authors and regional statistics. Table 2 provides an overview of the main data sources used.

Tab. 2. Overview of the data sources used for describing recent structural changes in Trentino's agriculture

Year	Source	Survey
1900	Royal-Imperial Central Commission for Statistics (Austria)	census of agriculture
1930	Central Statistics Institute of the Italian Kingdom (ICS)	census of agriculture
1961, 1970, 1982, 1990, 2000	ISTAT	census of agriculture
1921, 1931, 1951, 1961, 1971, 1981, 1991, 2001	ISTAT	census of population

The proposed analysis of structural adjustment in Trentino's agriculture is not exhaustive but intends to highlight the salient traits of an extremely complex process of socio-economic change which has been referred to as "rivoluzione verde"[3] (Bridi et al., 1995, p. 210).

2.2.4 Demographic aspects

One of the most relevant aspects of structural change in agriculture is the inexorable reduction of the number of farms and of the share of agricultural employment (Tappeiner et al., 2006). In Trentino, the number of farms decreased by almost 50% between 1930 and 2000, falling from 60.921 to 34.694 units (tab. 3). The highest farm abandonment rates can be observed in the 1960s and 1970s, with a certain stabilisation in the last decades. Nonetheless, as one third of farmers was older than 65 years in 2000 (ISTAT, 2003), a further significant decline is expected in the next future.

Tab. 3. Evolution of the number of farms in Trentino over the period 1930-2000 (data sources: ICS, 1934; ISTAT, 1963, 1972, 1986, 1992, 2003)

	1930[4]	1961	1970	1982	1990	2000
number of farms (absolute)	60.921	56.974	48.462	37.723	36.069	34.694
number of farms (% of 1930)	100	93,5	79,5	61,9	59,2	56,9

Figure 6b visualises the spatial patterns of farm abandonment at the community level between 1961 and 2000. The number of farms decreased most dramatically in the grassland dominated areas North-East (Fassa, Fiemme, Primiero valleys) and West (Upper Sole and Non, Rendena, Giudicarie valleys) of the Adige valley, due the collapse of small scale livestock farming after World War II

[3] "green revolution"

[4] Note that at the time of the Italian Kingdom, the Province of Trento included some municipalities that nowadays belong to the Province of Bolzano and the Province of Brescia (Bronzolo, Cortaccia, Egna, Magrè, Montagna, Ora, Salorno, Termeno, Trodena, Valdagno di Trento, Valvesino). For the purpose of comparison, the farms located in those municipalities were subtracted from the total number of farms reported by the census.

and the lack of options for agricultural production. On the contrary, farm abandonment was more moderate in the intensive crop regions, where the positive development of apple and vine farming guaranteed higher profitability and competitiveness (Bridi et al., 1996). The marked difference between the Upper Non (cattle farming) and the Lower Non (apple farming) is emblematic in this respect. A moderate decrease can be observed in structurally weak, marginal areas as well (Valsugana valley, Tesino basin, Upper Cembra valley and some communities of the Giudicarie valleys). This might be attributed to a lack of alternatives to agriculture (Gubert & Osti, 1989) and to the high share of retired people (Baroldi et al., 2007), who often work as part-time or hobby farmers.

Note that the definition of 'farm' adopted by the ISTAT is very wide and includes all technical-economic units provided with land which a) produce agricultural products b) are managed by a physical person, a society or a public body[5]. Farms without agricultural land are taken into account as well. This definition is indeed over-inclusive, as it sets neither a minimum farm size nor income-based criteria. For example, a hospital which owns a vineyard or an employee who owns 5.000 m^2 grassland are classified as 'farms'.

A more realistic picture of the situation is provided by the Provincial Archive of Agricultural Enterprises (APIA). The APIA is the register of professional farms and is subdivided into two sections: the first section includes full-time farms, while the second comprises part-time farms defined according to precise norms (e.g. number of hours of work per year). In 2006, a very exiguous number of farms – namely 9.202 – was registered in the archive: 4.549 in the first section and 4.653 in the second. These numbers show the existing gap between professional farming and other forms of farming in the region (e.g. hobby farming): approximately ¾ of the ISTAT-farms are non-professional (Sassudelli et al., 2004).

As to the evolution of employment structures, Trentino has turned from a predominantly rural to a post-industrial, service based society within a few decades (tab. 4). According to Bosetti (1915), almost 80% of Trentino's population belonged to the agricultural class at the beginning of the 20th century, with a myriad of small land owners employed on their labour-intensive farms. In 1951, agricultural employment still had a significant share (40,0%), but drastically dropped in the 1960s and 1970s, reaching the level of 5,0 % in 2001.

This 'exodus' from agriculture was caused by both push and pull factors (Lorandini, 2005). On the one side, farmers' life conditions were dramatically worsening due to loss of competitiveness

[5] The ISTAT defines farm as "l'unità tecnico-economica costituita da terreni, anche in appezzamenti non contigui, ed eventualmente da impianti di attrezzature varie in cui si attua la produzione agraria, forestale o zootecnica ad opera di un conduttore, e cioè persona fisica, società od ente, che ne sopporta il rischio sia da solo […] sia in forma associata" (ISTAT, 2003, p. 21).

and inadequate income (push factor). On the other side, the general economic development of those years was generating an enormous pressure on agriculture to free labour force (pull-factor). Hence, the opportunity costs of being employed in agriculture increased dramatically, causing an unprecedented shift of workers from the primary sector to the other economic sectors (Borzaga, 1983a). In a first phase (1950s-1970s), the freed labour force either emigrated or was absorbed by the industrial sector, which reached a peak of 42,6% of total employment in 1971. Its consequent stagnation and decline were accompanied by the concurrent boom of the tertiary sector (1970s-1980s), which soon polarized the labour market. In 2001, almost 65% of workers were employed in commerce and services.

Tab. 4. Evolution of employment structures by productive sector in Trentino over the period 1951-2001 (data elaboration by the Statistics Service of the Autonomous Province of Trento)

	1951	**1961**	**1971**	**1981**	**1991**	**2001**	
Economic sector	**employees**						
	absolute values						*variation 1951-2001*
primary sector	63.414	41.079	21.378	12.707	10.791	10.223	-53.191
secondary sector	51.903	63.579	64.314	62.417	61.653	62.499	+10.596
tertiary sector	43.022	55.886	65.429	92.335	115.588	131.118	+88.096
total	158.339	160.544	151.121	167.459	188.032	203.840	+45.501
	percentage values						*variation 1951-2001*
primary sector	40,0	25,6	14,2	7,6	5,7	5,0	-83,9
secondary sector	32,8	39,6	42,6	37,3	32,8	30,7	+20,4
tertiary sector	27,2	34,8	43,3	55,1	61,5	64,3	+204,8
total	100,0	100,0	100,0	100,0	100,0	100,0	

The exodus from agriculture went along with strong migration processes from the periphery to the centre (Staluppi, 1983). In structurally weak rural areas with poor economic development, young people moved away, leaving depopulated, ageing villages behind (Ascolani, 2005). On the contrary, urban areas experienced a booming population increase and were confronted with growing demands for services and housing (Zanon, 2005). For instance, the sole town of Trento doubled its population between 1921 and 2001. Table 5 quantifies the resulting polarisation of demographic structures. In particular,

- the number of small communities (less than 500 residents) increased from 27 in 1921 to 51 in 2001, with an increase of over 60% of residents in this category;
- the number of big communities (over 10.000 residents) increased from 3 in 1921 to 5 in 2001, while the corresponding number of residents jumped from 82.741 to 184.538 (+123,0%) in the same period.

Tab. 5. Evolution of the number of communities and of the number of residents by demographic magnitude in Trentino over the period 1921-2001 (data source: Baroldi et al., 2007)

demographic magnitude (residents)	1921		1961		2001		
	comm.	residents	comm.	residents	comm.	residents	
	absolute values						*variation of residents 1921-2001*
Up to 500	27	10.365	42	14.966	51	16.884	+6.519
501 - 1.000	85	63.093	76	54.178	65	46.624	-16.469
1.001 - 5.000	102	204.614	97	189.048	95	180.679	-23.935
5.001 - 10.000	6	43.424	3	19.428	7	48.292	+4.868
10.001 - 50.000	2	31.567	4	58.731	4	79.592	+48.025
50.001 - 100.000	1	51.174	1	75.753	1	104.946	+53.772
total	223	404.237	223	412.104	223	477.017	+72.780
	percentage values						*variation of residents 1921-2001*
Up to 500	12,1	2,6	18,8	3,6	22,9	3,5	+62,9
501 - 1.000	38,1	15,6	34,1	13,1	29,1	9,8	-26,1
1.001 - 5.000	45,7	50,6	43,5	45,9	42,6	37,9	-11,7
5.001 - 10.000	2,7	10,7	1,3	4,7	3,1	10,1	+11,2
10.001 - 50.000	0,9	7,8	1,8	14,3	1,8	16,7	+152,1
50.001 - 100.000	0,5	12,7	0,5	18,4	0,5	22,0	+105,1
total	100,0	100,0	100,0	100,0	100,0	100,0	+18,0

Figure 6f visualizes the ‘winners’ and the ‘losers’ of these migration processes at the community level (period 1961-2001). While the hot spots of depopulation correspond to a large extent to the areas of high farmland abandonment, the communities with marked population increase (more than 30% between 1961 and 2001) are situated either in the Adige and Sarca valleys - where most urban agglomerates are concentrated - or in areas of high tourism density, such as Fiemme, Fassa and Rendena valleys (Gabrielli, 1998). In fact, tourism has the potential to positively affect demographic development, as it offers decentralized employment opportunities and triggers local economic development thanks to its linkages with the other economic sectors (Bätzing, 2002; Borsdorf, 2006). However, some particularly marginal communities (e.g. Folgaria, Lavarone, and Pieve Tesino) show a negative migration balance in spite of their high tourism density (fig. 6e).

2.2.5 Structural aspects

The evolution of farm size is, alongside with the reduction of the number of farms, another salient aspect of structural change in agriculture. In 1930, miniature farms (less than 1 ha total agricultural area) represented 47,0% of all farms (tab. 6): this reflects the predominant subsistence orientation of Trentino's traditional agriculture and indicates at the same time its intrinsic vulnerability. In fact, the number of miniature farms halved between 1930 and 2000, falling from 28.633 to 13.769 units. Nonetheless, their share remained very high (almost 40%). Small farms (between 1 and 5 ha), which are the most significant ones from an economic point of view (Bridi et al., 1995), dropped by 43,0% in the same period, whereas their share remained almost constant. The number of medium farms (between 5 and 10 ha) did not change significantly, but their share roughly doubled (from 5,3% to 9,0%). Finally, the number of large farms (over 10 ha total agricultural area) remained very exiguous, even if it increased in both absolute and relative terms, going up from 1.487 units (2,4%) in 1930 to 2.075 units (6,0%) in 2000.

Tab. 6. Evolution of the number of farms by total agricultural area class in Trentino over the period 1930-2000 (data sources: ICS, 1934; ISTAT, 1963, 1986, 2003)

	1930		1961		1982		2000			
TAA class[6]	**farms**	**%**	**farms**	**%**	**farms**	**%**	**farms**	**%**	*variation 1930-2000*	*%*
less than 1 ha	28.633	47,0	21.016	36,9	14.145	37,5	13.769	39,7	-14.864	-51,9
1,00 - 4,99 ha	27.547	45,2	28.025	49,2	17.108	45,4	15.701	45,3	-11.846	-43,0
5,00 - 9,99 ha	3.254	5,3	5.389	9,5	3.989	10,6	3.127	9,0	-127	-3,9
10,00 - 49,99 ha	1.079	1,8	1.846	3,2	2.014	5,3	1.591	4,6	+512	+47,5
50 ha and more	408	0,7	673	1,2	467	1,2	484	1,4	+76	+18,6
total	60.921	100,0	56.949	100,0	37.723	100,0	34.672	100,0	-26.249	-43,1

The distribution of total agricultural area among farm size classes completes the picture (tab. 7). In the main, Trentino's agriculture was and still is characterized by a multitude of tiny farms

[6] Note that in the 1930 and 1961 census total agricultural area classes are slightly different than in the 1982 and 2000 census. In particular, they differ as to the upper and lower limit (up to 1 ha, 1,01 – 5,00 ha, 5,01 – 10,00 ha etc. in the 1930 and 1961 census). This difference, however, does not affect overall comparability in a significant manner.

cultivating a small share of total agricultural land, while the remaining land is managed by comparatively few large farms. The latter are to a significant extent silvo-pastoral farms and include municipalities and other public bodies (Bridi et al, 1995).

Between 1930 and 2000, all farm size classes, except for the class 10 to 50 ha, experienced a decrease of agricultural land, which was more marked for miniature (-47,1%), small (-44,9%), and medium (-22,6%) farm sizes. Besides the non-quantifiable transfer of land from smaller to larger farms, this reduction can be ascribed, at least to some extent, to the higher rates of farmland abandonment for farms with less than 10 ha. Total agricultural land is in fact calculated on a farm base (ISTAT, 2003). Additionally, land consumption through urbanisation and infrastructure development is more likely to affect small farms in peri-urban areas than big silvo-pastoral farms in peripheral areas.

As to large farms (more than 10 ha), the development was quite idiosyncratic. The farm size class 10 to 50 ha gained almost 10.000 ha between 1930 and 1961, but steadily lost agricultural land thereafter. The farm size class 50 ha and more lost 12,1% of agricultural land between 1930 and 1961, remaining stable in the following decades. However, both classes slightly increased their share of total agricultural land.

Tab. 7. Evolution of total agricultural area by total agricultural area class in Trentino over the period 1930-2000 (data sources: ICS, 1934; ISTAT, 1963, 1986, 2003)

	1930[7]		**1961**		**1982**		**2000**			
TAA class	**TAA (ha)**	**%**	**TAA (ha)**	**%**	**TAA (ha)**	**%**	**TAA (ha)**	**%**	*variation 1930 – 2000 (%)*	*%*
less than 1 ha	12.525	2,2	9.866	1,9	6.531	1,3	6.628	1,4	-5.897	-47,1
1,00 – 4,99 ha	66.132	11,8	67.711	13,0	40.870	8,4	36.411	7,7	-29.721	-44,9
5,00 – 9,99 ha	27.378	4,9	36.664	7,0	27.119	5,5	21.188	4,5	-6.190	-22,6
10,00 - 49,99 ha	27.439	4,9	30.608	5,9	35.530	7,3	29.882	6,4	+2.443	+8,9
50 ha and more	427.653	76,2	375.834	72,2	379.083	77,5	375.549	80,0	-52.104	-12,2
total	561.127	100,0	520.683	100,0	489.133	100,0	469.658	100,0	-91.469	-16,3

The analysis of census data leads to the conclusion that farm size and agricultural land distribution have not experienced revolutionary changes since the 1930s. In fact, existing land property patterns have been basically maintained: 85,0% of farms still have less than 5 ha total

[7] For the year 1930, data on the distribution of total agricultural area among farm size classes was extracted from Bridi et al. (1995), as this information was not entailed in the census possessed by the author. Therefore, the municipalities no more belonging to Trento province (see footnote n. 4) are included in the analysis. However, as their total agricultural area totals only 28.257 ha, they do not significantly affect overall comparability of data.

agricultural area (they were 92,2% in 1930) and still cultivate 9,2% of agricultural land (14,0% in 1961).

This development indicates the intrinsic resistance of land property structures to concentration processes. Above all, a) the Romanic succession right b) low land mobility, and c) high prices for agricultural land have protected individual property and hindered the consolidation of a significant number of professional farms (Bridi et al., 1995). Additionally, the high share of publicly or commonly owned land – approximately 7/10 of total land (INEA[8], 1947) – has represented a significant obstacle to farm enlargement, thus contributing to the preservation of the *status quo*.

Data on the average usable agricultural land per farm confirm this hypothesis: in the period between 1930 and 2000, average farm size increased by only 0,4 ha (+11,1%), reaching 4,2 ha in the year 2000 (tab. 8).

Tab. 8. Evolution of average usable agricultural area per farm in Trentino over the period 1930-2000 (data sources: ICS, 1934; ISTAT, 1963, 1972, 1986, 1992, 2003)

	1930	**1961**	**1970**	**1982**	**1990**	**2000**	*variation 1930-2000*	*%*
farms[9]	60.921	56.949	48.331	37.638	35.997	34.672	-26.249	-43,1
UAA (ha)[10]	232.445	212.244	179.182	148.695	149.908	146.988	-85.457	-36,8
Average UAA/farm	3,8	3,7	3,7	4,0	4,2	4,2	+0,4	+11,1

However, aggregated data must be interpreted with care. For instance, Sassudelli et al. (2004) observed major differences between 'professional' farms (more than 300 hours of work per year) and non-professional ones as to average farm size and its rate of change. In 2000, professional farms managed an average usable agricultural area of 10,8 ha, while the remaining ISTAT-farms had an average size of 0,55 ha. Similarly, the average farm size of the former increased by 12,5% between 1990 and 2000 (from 9,6 ha to 10,8 ha), while the latter did not experience any significant enlargement. These data suggest an 'agriculture of two speeds', in which professional farming evolves in response to market pressures whereas non-professional (hobby) farming maintains small scales according to its recreational function.

Similarly, aggregated data do not provide information about the spatial patterns of farm size development across the region. As figure 6d shows, the picture is quite heterogeneous. In particular, three main directions of change can be identified.

[8] Italian Institute of Agricultural Economics
[9] Farms without agricultural land are not included.
[10] Usable agricultural area was not directly measured in the 1900, 1930, and 1961 census and was therefore calculated as the sum of arable land, grassland, and permanent crop land.

- In the grassland dominated areas North-East (Fassa, Fiemme, Primiero valleys) and West (Upper Non, Sole, Rendena, Giudicarie valleys) of the Adige valley, surviving farms have managed to specialize in livestock farming, and have consequently increased their usable agricultural area through land purchase, land lease, and/or use of publicly owned pasture land.
- In the remaining grassland dominated areas (Valsugana, Ledro, Lower Giudicarie, Upper Cembra, Leno valleys as well as Folgaria and Lavarone plateaus) livestock farming has either collapsed or maintained small scales. Hence, farm enlargement (if any) has been limited.
- In the intensive crop areas dominated by fruit farming and viticulture (Non, Adige, Sarca, lower Cembra valleys), change in farm size has been fairly moderate, with either a modest increase or a modest decrease of average usable agricultural land.

The macroscopic difference between those areas which have specialized in livestock farming and those which have focussed on intensive crops is attributable to disparate causes. Specifically, following aspects can be highlighted.

- The economic productivity of grassland is much lower than that of intensive crop land (Pohl, 1996). Hence, much larger areas are necessary in livestock farming in order to reach a critical mass.
- Land prices are much higher in intensive crop areas than in grassland areas (INEA, 1998). Therefore, farm enlargement is more difficult in the former.
- Higher farmland abandonment in grassland dominated areas has (at least partly) freed grassland surfaces, thus increasing land availability and easing farm enlargement (Sassudelli et al., 2004).
- Census data include publicly owned pastures. As a consequence, average farm size is particularly big in areas rich in high-altitude pasture land. In these communities, declining farm numbers automatically result in an increase of average usable agricultural area available to each farm.

Figure 5 visualises the share of small farms - defined by Tappeiner et al. (2003) as farms with less than 5 ha usable agricultural land - at the municipality level across the whole Alpine bow. Trentino belongs to the structurally weak ‘Italian standard region’, characterized by the Romanic farm system and its peculiar small scales. Again, the grassland dominated areas mentioned above (North-East and West of the Adige valley) show farm sizes above the average.

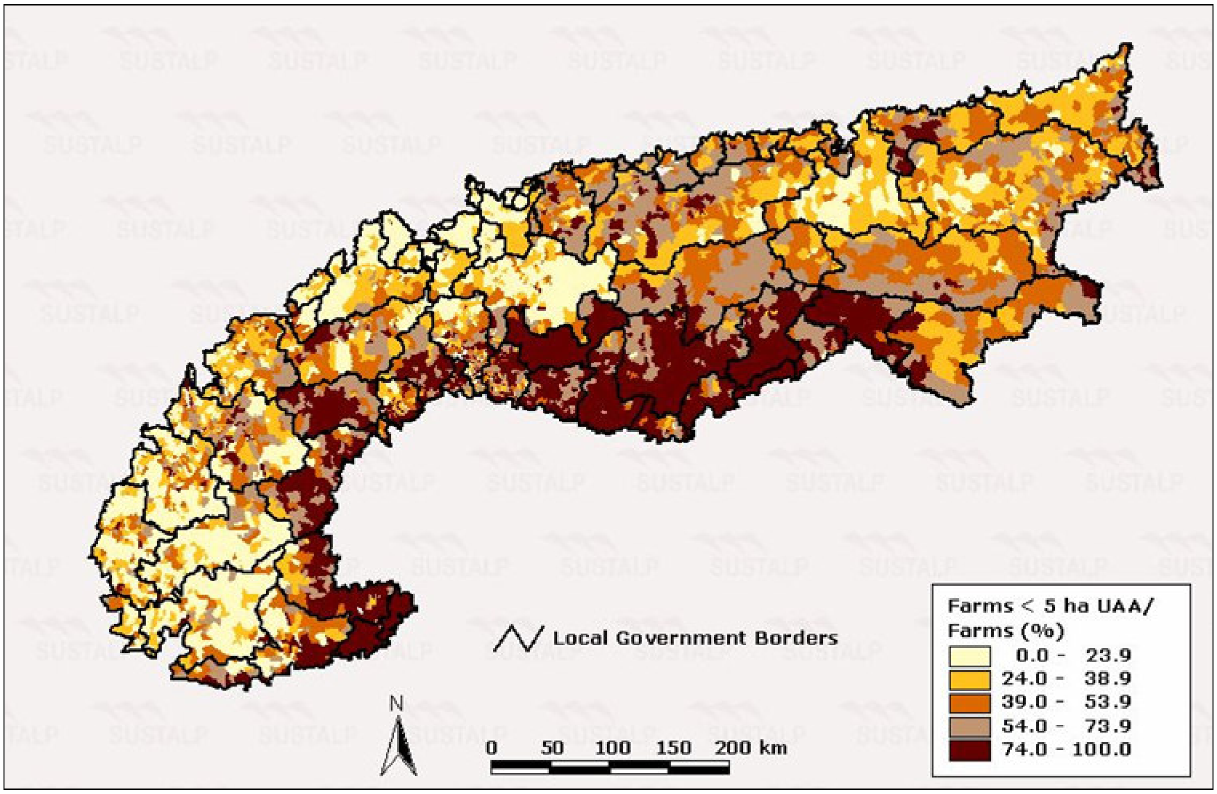


Fig. 5. Share of miniature farms (less than 5 ha usable agricultural area) in the municipalities of the Alps (source: Tappeiner et al., 2003).

Besides the small farm sizes, Trentino's agriculture traditionally suffers from a high degree of property fragmentation and dispersion (Faccini, 1968). Already at the beginning of the 20th century, several authors addressed this structural deficiency as well as the resulting implications for the modernisation of the agricultural system (Kirchlechner, 1904; Bassi, 1910; Bosetti, 1915). In an article published in 1919 with the title 'Il problema agricolo trentino: crisi agrarie'[11], Ruatti wrote: "[il trentino] polverizza la campagna in appezzamenti di pochi ari, lontani dei chilometri gli uni dagli altri, e tagliuzza la casa paterna coi fratelli e vi aggiunge delle curiose appiccicature di locali, rende complicatissimo il sistema di servitù e diritti"[12] (p. 10). According to the INEA (1947), the average plot size of privately owned land – which makes up slightly more than 1/4 of total land – was of 0,88 ha at the end of World War II. At that time, 67% of plots were smaller than 0,5 ha. Recent census data confirm this state of things: in 2000, the average plot size of farms with less than 20 ha total agricultural land was of 0,4 ha (ISTAT, 2000). As Bätzing (2005) notes, land property fragmentation and dispersion represent the main hindrances to farm enlargement and modern land management practices.

[11] Trentino's agricultural problem: agricultural crises

[12] "[the farmer] fragments the land in tiny plots, scattered all over at a distance of kilometres from one another, and subdivides his father's house with his own brothers and enlarges it with curious ensembles of rooms, he makes the system of property rights extremely complex" (translation by the author).

Finally, another relevant aspect of structural change regards the reduction of labour intensity in agricultural production (tab. 9). With the industrial revolution, labour costs severely increased, thus becoming the most expensive production factor (Penz, 2003). Raising labour costs contributed to the above described exodus from agriculture on the one side, and triggered mechanisation and rationalisation of agricultural practices on the other.

In Trentino's agriculture, the total number of days of work per year dropped from 7.217.587 in 1970 to 3.965.952 in 2000 (-45,0%), and the average number of days of work per year and farm decreased from 149 to 114 (-23,5%; ISTAT, 1972, 2003). This development is ascribable not only to farm abandonment and mechanisation - the number of tractors increased by 245% between 1970 and 2000 (ISTAT; 1972, 2003) - but also to the shift from full-time farming to part-time farming (already observed by Gios in 1979).

As table 9 shows, the number of full-time farms – defined by Barberis (1996) as farms with more than 300 days of work per year – steadily decreased between 1970 and 2000, falling by 2.833 units (-37,4%) and reaching a share of 13,7% of all farms in 2000. An even more marked reduction affected the category 50 to 300 days of work per year, which lost almost 11.000 farms (-48,6%). On the contrary, the number of farms with less than 50 days of work per year remained nearly constant, while its share significantly increased (from 37,8% to 52,9%). The collapse of livestock farming (high labour intensity) on the one side and the concurrent flourishing of small-scale, intensive fruit and vine farms (low labour intensity) on the other might explain the trend. The small average size of fruit (1,48 ha) and wine (0,86 ha) farms, which make up almost 53% of all farms, supports this assumption. These farms are often run as part-time or even hobby farms, and represent to a large extent the relicts of former subsistence farming (Leonardi, 1996).

Tab. 9. Evolution of the number of farms by labour intensity in Trentino over the period 1970-2000 (data sources: ISTAT, 1972, 1986, 1992, 2003)

	1970[13]		**1982**		**1990**		**2000**			
performed days of work/year	**farms**	**%**	**farms**	**%**	**farms**	**%**	**farms**	**%**	*variation 1970-2000*	*%*
less than 50	18.330	37,8	15.523	41,2	17.941	49,7	18.350	52,9	+20	+0,1
50,00 -299,99	22.558	46,6	15.736	41,7	12.703	35,2	11.603	33,4	-10.955	-48,6
300 and more	7.574	15,6	6.464	17,1	5.425	15,1	4.741	13,7	-2.833	-37,4
Total	48.462	100,0	37.723	100,0	36.069	100,0	34.694	100,0	-13.768	-28,4

[13] Data are not available for 1961.

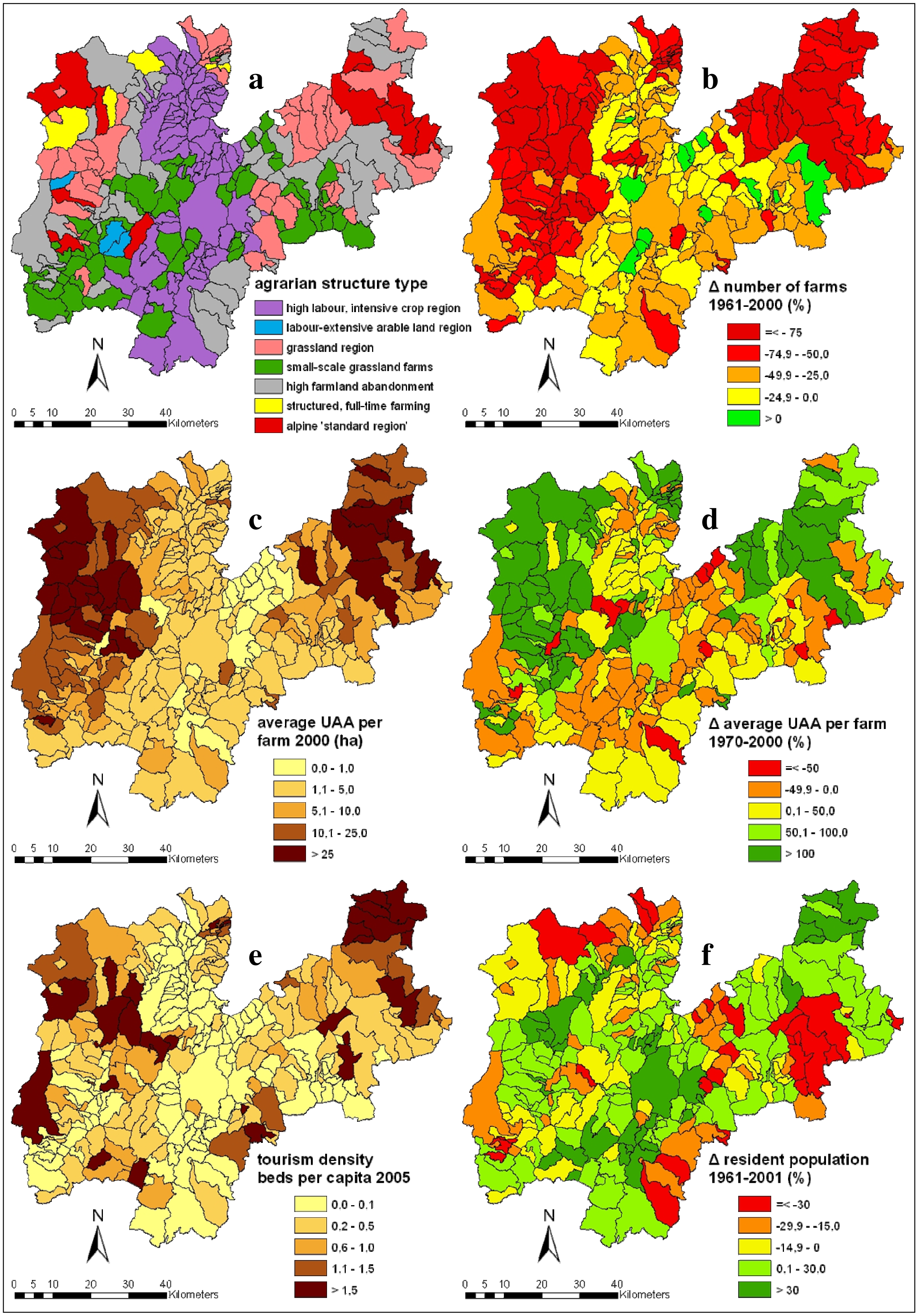


Fig. 6. Different aspects of recent structural change in Trentino's agriculture and society at the community level (data sources: 6a, Tappeiner et al., 2006; 6b, ISTAT, 1963, 2003; 6c, ISTAT, 2003; 6d, ISTAT, 1972, 2003; 6e, Savorelli et al., 2007; 6f, ISTAT, 2004; own data elaboration).

2.2.6 Agricultural land use

The demographic and structural changes described so far have been accompanied by major changes in agricultural land use (tab. 10, fig. 7). A first salient aspect is the reduction of usable agricultural area by 41,2% between 1900 and 2000, with a particularly accentuated drop in the 1970s. Indeed, urban and infrastructure development alone do not justify such a reduction. A considerable part of this productive land was either actively afforested or abandoned becoming first fallow land, then bush land, and finally forest. Carriero and Wolynski (2005) estimate that 18.218 ha (almost 3% of Trentino's surface area) were 're-conquered' by forests between 1973 and 1999 as a consequence of the high farmland abandonment of the previous decades.

Tab. 10. Evolution of agricultural land use in Trentino over the period 1900-2000 as reported by agricultural census (data sources: Kirchlechner, 1904; ICS, 1934; ISTAT, 1963, 1986, 2003)

	1900	**1930**	**1961**	**1982**	**2000**	
land use	**ha**					*variation 1900-2000*
arable	43.948	42.312	17.634	6.583	4.125	-39.823
grassland	197.570	182.815	177.726	120.315	120.119	-77.451
ligneous crops	8.378	7.318	16.884	21.797	22.745	+14.367
UAA	249.896	232.445	212.244	148.695	146.989	-102.907
forest	300.577	298.975	290.137	284.538	308.749	+8.172
TAA[14]	552.616	546.214	520.683	489.133	469.658	-82.958
	% UAA					*variation 1900-2000 (%)*
arable	17,6	18,2	8,3	4,4	2,8	-90,6
grassland	79,1	78,6	83,7	80,9	81,7	-39,2
ligneous crops	3,3	3,2	8,0	14,7	15,5	+171,5
UAA	100,0	100,0	100,0	100,0	100,0	-41,2
	% TAA					*variation 1900-2000 (%)*
forest	54,4	54,7	55,7	58,2	65,7	+2,7
TAA						-15,0

As to the composition of the usable agricultural land over the last century, significant directions of change can be identified. In particular, arable land collapsed, falling from 43.948 ha in 1900 to 4.125 ha in 2000 (-90,6%), while ligneous crops (mainly apples and wine) boomed, jumping from

[14] The total agricultural area also includes 'other area'.

8.378 ha to 22.745 ha (+ 171,5%) in the same period. Both developments reached their 'acute phase' in the 1950s and 1960s.

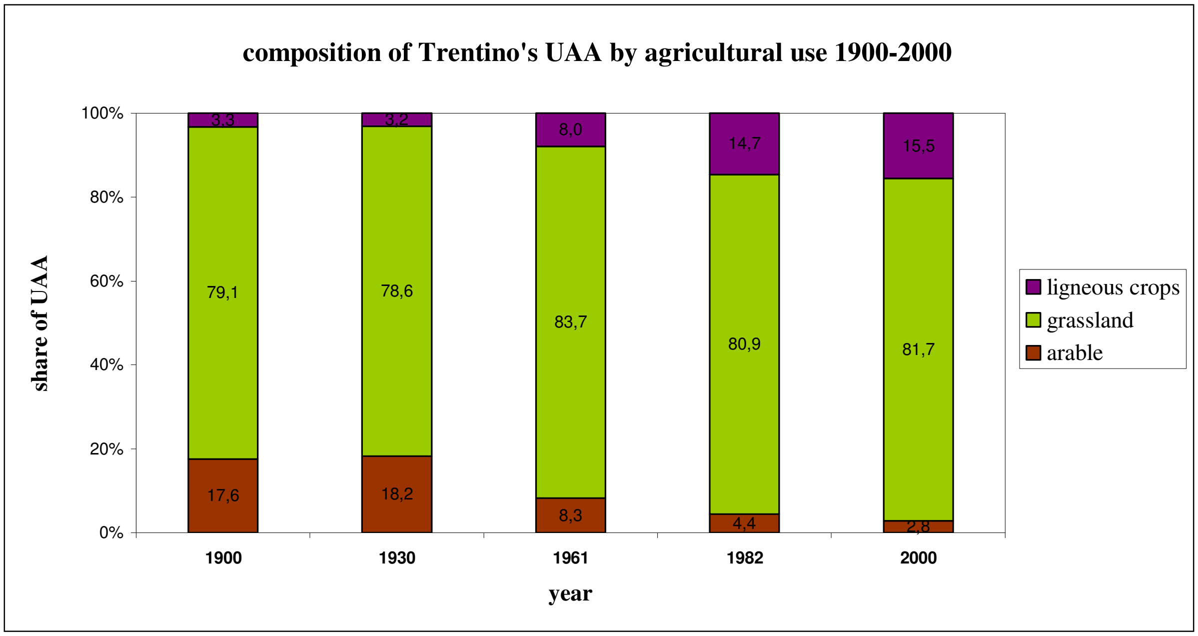


Fig. 7. Evolution of usable agricultural area by agricultural land use in Trentino over the period 1900-2000 (data sources: Kirchlechner, 1904; ICS, 1934; ISTAT, 1963, 1986, 2003).

Before World War II, arable land had played a central role in Trentino's subsistence economy (Ruatti, 1919b). In 1930, approximately ¼ of it was cultivated with potatoes, ¼ with wheat, ¼ with maize and the remaining ¼ with other crops such as legumes and vegetables (ICS, 1934). However, arable crop production did not cover domestic demand, due to unfavourable climatic and geo-morphologic conditions in many valleys. According to the *Consiglio Provinciale d'Agricoltura*[15] (in Bosetti, 1919), wheat production hardly reached 9.000 tons in 1900, which sufficed to satisfy internal requirements for approximately 3 months. Hence, significant quantities of food had to be imported. The situation worsened in 1906, when the Tyrolean government imposed heavy import taxes on grains coming from Italian regions, thus making Trentino dependent on food imports from Budapest (Bosetti, 1915, Ruatti, 1919b). This state of things explains why farmers were forced to cultivate even unsuitable areas with arable crops, and in particular with maize. Maize was one of the basic components of local diet (*polenta*), but could be hardly imported from other regions of the Austrian Empire, where that crop was not so popular. As Ruatti (1919b) wrote: "la coltivazione di granoturco in zone d'esagerata altezza trova precisamente la sua giustificazione nel fatto che il

[15] Provincial Council for Agriculture

contadino voleva assicurasi almeno parte di tale prodotto per evitare lo sbilancio annuale causatogli da ginocchi di borsa a Budapest"[16] (p. 8).

As previously illustrated, the collapse of arable farming coincided with the 'economic wonder' of the 1960s and the end of subsistence farming in the Alps. In Trentino, this collapse was particularly accentuated due to the high share of arable land, which was rapidly converted into grassland. Higher fodder availability in the valley floors, alongside with the crisis of small-scale livestock farming, boosted the process of land abandonment, thus deeply transforming traditional landscape structures. In fact, grassland area decreased by almost 60.000 ha (-34,3%) between 1961 and 1982, 'moving' from high altitudes and steep slopes down into the valley bottoms. The *dezentral-flächenhafte Nutzung*[17], which had characterized Trentino's landscape for centuries, was soon substituted by polarized patterns of land use (intensification vs. extensification/abandonment).

At the same time, climatically more favourable areas (Adige and Sarca valleys in particular) experienced the consolidation and expansion of their viticulture, which had been strongly supported by the Austrians in the second half of the 19th century (Mader, 1907). Already at that time, the high profitability of viticulture induced farmers to convert their grassland, arable land, and mulberry tree cultivations into vineyards. In 1910, Trentino cultivated over 6.000 ha to vine, and exported 80% of its production (Bosetti, 1915). Bassi (1910) strongly criticized this development, arguing that specialisation was making farmers more and more vulnerable to market dynamics. Nonetheless, viticulture continued to expand after World War II, reaching a high level of specialisation, both in technical (mechanisation) and organisational (cooperative system) terms. Nowadays, Trentino is a competitive, export oriented vine growing region, with 7.763 ha (85% of total vine area) dedicated to DOC-DOGC quality wine production (ISTAT, 2003).

An even more revolutionary development affected the fruit sector (mainly apples). As Trentino was a particularly suitable location for fruit farming (Non, Lower Sole, Upper Valsugana valleys and Trento basin), the Austrians fostered its expansion with the aim to satisfy domestic demand in the rest of the Empire. Yet, apple production reached just 2.000 tons in 1915, representing less than 1% of total agricultural revenues (Bosetti, 1915). Only in the 1960s and 1970s, thanks to the development of modern production systems (irrigation, mechanisation, chemical pest control etc.) and to a growing demand, apple farming flourished: in 2000, apple production reached 477.000 tons (approximately 18% of total agricultural revenues; Sassudelli et al., 2002). In the Non and Lower Sole valleys, however, specialisation in apple farming has created almost mono-structural agrarian

[16] "The cultivation of maize in areas of excessive altitude was justified by the fact that farmers wanted to ensure at least part of this product in order to avoid the consequences of Stock Exchange drops in Budapest" (translation by the author).

[17] decentralized-extensive land use

systems, the vulnerability of which is becoming evident in times of stagnant prices, increasing production costs, and severe competition. Product innovation (e.g. apple derivates) as well as diversification of agricultural production (e.g. cherries, strawberries, etc.) represent the future challenges for these areas.

2.2.7 The decline of livestock farming

While intensive crop systems can be defined as the 'winners' of structural change in Trentino's agriculture, livestock farming belongs, together with arable farming, to the 'losers'. The abrupt end of traditional subsistence economy, in which almost every family had a stable with a couple of cows and some other livestock (Penz, 2003), induced an inexorable process of decline, with livestock farming progressively losing its central socio-economic role (Lorandini, 2005). At the beginning of the 20th century, the livestock sector still accounted for almost 70% of Trentino's subsistence base and 46,4% of total agricultural revenues (Bosetti, 1915). Nowadays, it contributes for only 17,4% to total agricultural revenues (Sassudelli et al., 2002). Not only intrinsic deficiencies such as high labour intensity, low economic productivity, small scales, high property fragmentation, but also extrinsic factors such as bio-climatic and geomorphologic limits on intensification, labour scarcity through strong depopulation, and growing competition from the Po plane contributed to this declension.

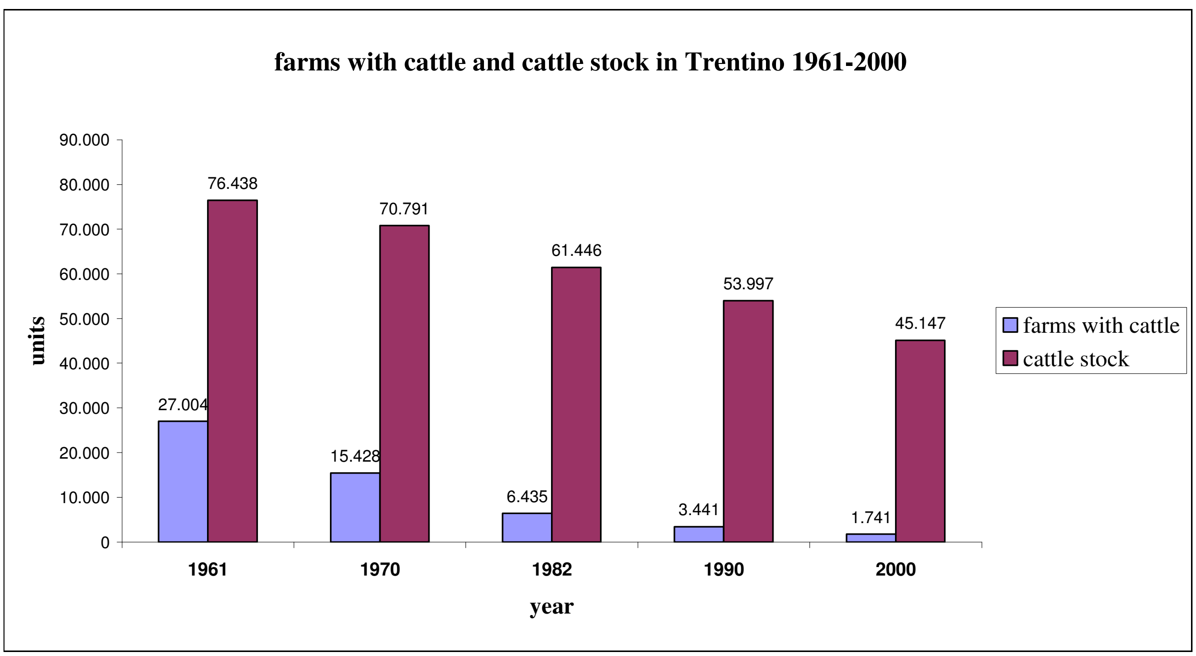


Fig. 8. Evolution of the number of farm with cattle and of the number of cattle in Trentino over the period 1961-2000 (data sources: ISTAT, 1963, 1972, 1986, 1992, 2003).

As to the development of cattle farming since the 1960s, figure 8 is quite eloquent. The number of cattle farms decreased by 93,5% between 1961 and 2000, halving from each decade to the other. In 2000, Trentino counted only 1.741 farms with cattle. Nonetheless, the decrease of cattle stock was less dramatic (-40,9%) due to significant concentration and specialisation processes. In fact, the average number of cattle per farm increased by almost 10 times, jumping from 2,8 units in 1961 (subsistence economy) to 25,9 units in 2000 (market economy).

Within a few decades, the multitude of miniature cattle farms which had characterized Trentino's mountain areas for centuries disappeared. While in some communities cattle farming completely died out, in many others only a few innovative farmers, often not more than a couple, managed to adapt by enlarging and rationalizing their farms, thus reaching a certain degree of specialisation. In the remaining communities, cattle farming survived but is now on the way to extinction, as farms are small scaled and run by elder farmers.

Figures 9a and 9b show the spatial patterns of current cattle farm size and its evolution across the Province. Interestingly, the increase of average number of cattle per farm was less accentuated in areas with a significant tourism density (Fiemme, Fassa, Primiero, Rendena, and Sole valleys in particular), where farm size remained comparatively small. This can be explained through a) better off-farm income opportunities and higher share of part-time farming b) higher valued added of agricultural production through local markets for specialty products (e.g. beef, cheese, and other milk derivates).

However, in communities with very high tourism density (more than 1,5 beds per capita), agriculture has been exposed to a strong competition for the production factors labour and land, which have been concentrated in the tourism sector and related economic activities. In fact, Tappeiner et al. (2003) classify some of the communities with the highest tourism density (Dimaro, Molveno, Folgaria, Lavarone, Pozza, Mazzin, Campitello) as areas of high farmland abandonment (fig. 6a and 6e).

Farm enlargement was the highest in the Exterior Giudicarie, where particularly favourable climatic and geomorphologic conditions – suitable for arable farming – allowed a high level of agricultural intensification and specialisation. In fact, Trentino's largest cattle farms are concentrated in these areas (average farms size over 50 cattle). A significant increase of average cattle number per farm can be observed in the Lower Adige valley (in particular in the communities Brentonico and Avio), in some communities of the Valsugana valley, and throughout the Non valley as well.

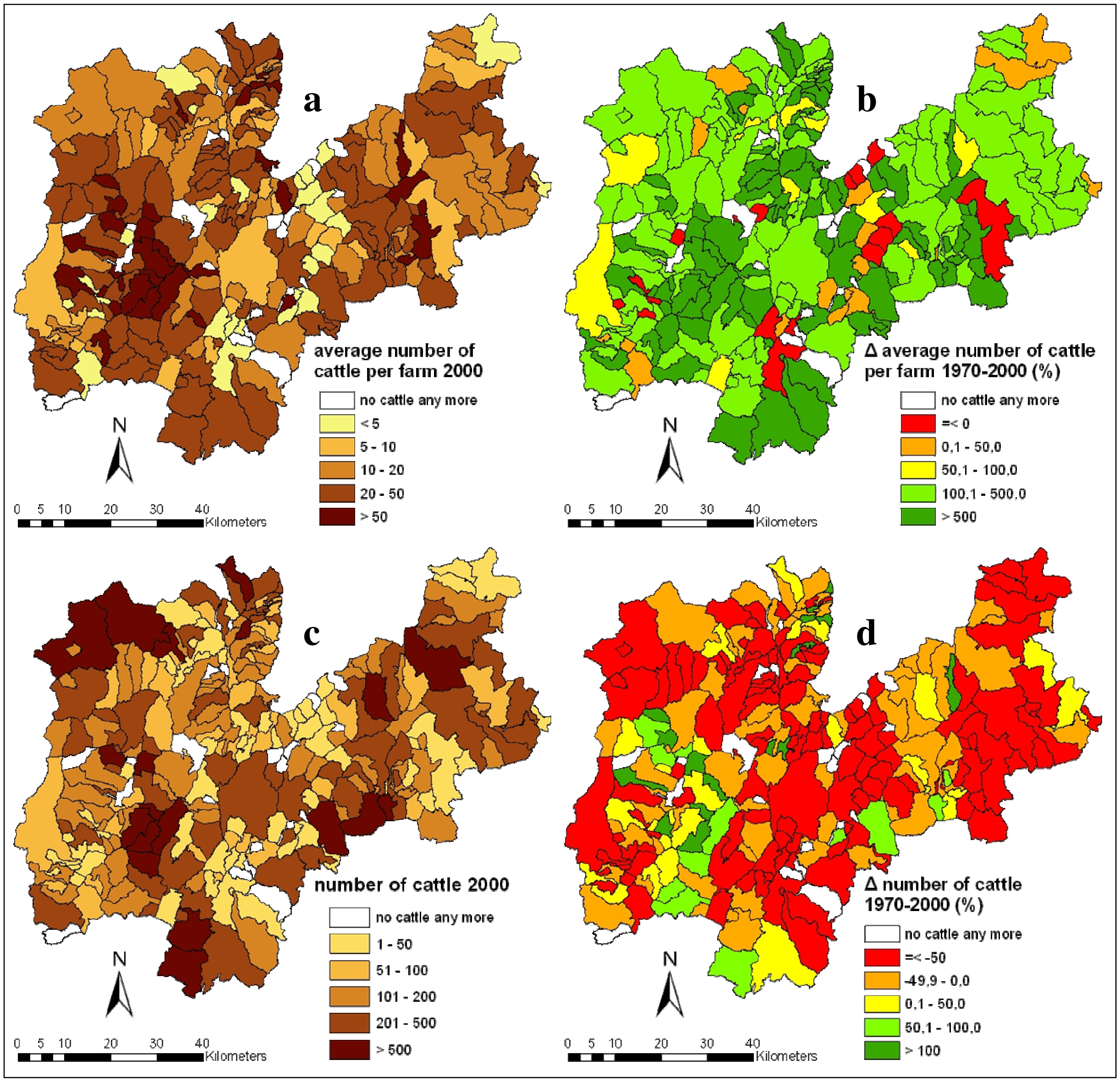


Fig. 9. Evolution of the number of cattle and of the number of cattle per farm at the community level in Trentino over the period 1970-2000 (data sources: ISTAT, 1972, 2003; own data elaboration).

Regarding the evolution of cattle stock and its spatial distribution, a strong polarisation occurred in the last decades (fig. 9c and 10d). While the majority of Trentino's communities lost considerable shares of their bovine herds between 1970 and 2000, some areas experienced a completely opposite trend. In particular, cattle stock substantially increased in the Giudicarie valleys, and in other single communities across the region. This aspect, alongside with the above described development patterns, suggests that cattle farming has not completely retreated from the region, but it has progressively concentrated at favourable locations, where the chance to maintain a certain level of competitiveness is higher. Cozzi et al. (2006), however, doubt about the sustainability of intensive production systems in mountain areas, the more so as they are a mere imitation of the cattle farms of the Po valley. This strategy, which was and is questionable from an ecological and social point of view, is showing its economic limits as well, as growing production costs and stagnant milk prices are bringing these capital intensive farms into debt.

Table 11 shows the evolution of the number of cattle farms and cattle by total agricultural area class between 1961 and 2000. In particular, the following directions of change can be highlighted.

- Farm size shifted from small to larger scales. The share of cattle farms with more than 10 ha total agricultural land increased from 5,2% in 1961 to 43,6% in 2000, while miniature farms (less than 1 ha total agricultural area) almost disappeared in the same period.
- Cattle shifted from small to large farms. The number of cattle held by farms with more than 10 ha total agricultural area tripled between 1961 and 2000, in spite of an overall reduction of 40,9% in cattle stock.

Tab. 11. Evolution of the number of cattle farms and of the number of cattle by total agricultural area class in Trentino over the period 1961-2000 (data sources: ISTAT, 1963, 1986, 2003)

	1961		**1982**		**2000**		*variation 1961-2000*	
TAA class	**farms**	**cattle**	**farms**	**cattle**	**farms**	**cattle**	**farms**	**cattle**
	absolute values							
without TAA	9	35	16	1.823	3	189	-6	+154
up to 1 ha	3.319	5.005	195	636	30	181	-3.289	-4.824
1,01-5,00 ha	18.011	44.388	3.108	12.602	469	3.710	-17.542	-40.678
5,01-10,00 ha	4.346	18.200	1.830	13.386	480	5.818	-3.866	-12.382
> 10 ha	1.399	8.810	1.286	32.999	759	35.249	-640	+26.439
total	27.084	76.438	6.435	61.446	1.741	45.147	-25.343	-31.291
	percentage values							
without TAA	0,0	0,1	0,3	3,0	0,2	0,4	-66,7	+440,0
up to 1 ha	12,3	6,5	3,0	1,0	1,7	0,4	-99,1	-96,4
1,01-5,00 ha	66,5	58,1	48,3	20,5	26,9	8,2	-97,4	-91,6
5,01-10,00 ha	16,0	23,8	28,4	21,8	27,6	12,9	-89,0	-68,0
> 10 ha	5,2	11,5	20,0	53,7	43,6	78,1	-45,7	+300,1
total	100,0	100,0	100,0	100,0	100,0	100,0	-93,6	-40,9

A similar development can be observed with respect to the distribution of cattle farms and cattle by size of cattle stock between 1970 and 2000 (tab 12). The number of farms with 50 cattle and more increased by 661,8% in 30 years, jumping from 34 in 1970 to 259 in 2000, whereas the number of cattle held in this category increased by 509,8%, reaching 58,2% of total cattle stock in 2000. In the last census, the first farm ever with more than 500 cattle was registered in Trentino. A positive trend can be observed for farms with 20 to 49 cattle as well, while smaller farms experienced an astonishing decline.

Tab. 12. Evolution of the number of cattle farms and of the number of cattle by farm size in Trentino over the period 1970-2000 (data sources: ISTAT, 1972, 1986, 1992, 2003)

	1970		**1982**		**1990**		**2000**		*variation 1970-2000*	
farm size (cattle)[18]	**farms**	**cattle**	**farms**	**cattle**	**farms**	**cattle**	**farms**	**cattle**	**farms**	**cattle**
	absolute values									
1-5	12.120	32.876	3.972	11.463	1.603	4.815	589	1.740	-11.531	-31.136
6-9	2.238	16.825	1.087	7.789	599	4.327	241	1.757	-1.997	-15.068
10-19	885	12.875	770	10.225	544	7.369	291	3.953	-594	-8.922
20-49	151	4.209	422	12.478	458	14.029	361	11.439	+210	+7.230
50 and more	34	4.306	184	19.491	237	23.457	259	26.258	+225	+21.952
total	15.428	71.091	6.435	61.446	3.441	53.997	1.741	45.147	-13.687	-25.944
	percentage values									
1-5	78,6	46,2	61,7	18,7	46,6	8,9	33,8	3,9	-95,1	-94,7
6-9	14,5	23,7	16,9	12,7	17,4	8,0	13,8	3,9	-89,2	-89,6
10-19	5,7	18,1	12,0	16,6	15,8	13,6	16,7	8,8	-67,1	-69,3
20-49	1,0	5,9	6,6	20,3	13,3	26,0	20,7	25,3	+139,1	+171,8
50 and more	0,2	6,1	2,9	31,7	6,9	43,4	14,9	58,2	+661,8	+509,8
total	100,0	100,0	100,0	100,0	100,0	100,0	100,0	100,0	-88,7	-36,5

Note that despite such radical changes, 47,6% of farms still had less than 10 cattle in the year 2000. This indicates a persisting structural weakness of cattle farming in the region, and makes a further decline foreseeable. As Bridi et al. (1995) stated, “il Trentino rischia di vedere ridotto il numero delle stalle ad un punto di pericolosità per la conservazione dell’ambiente e del territorio”[19].

[18] Note that in the 1970 and 1982 census farm size classes by number of cattle units are slightly different than in the 1991 and 2000 census. In particular, they differ as to the upper and lower limit (1-5 cattle units, 6-10 cattle units, 11-20 cattle units, etc. in the 1970 and 1982 census). This difference, however, does not affect overall comparability in a significant manner. Data are not available for 1961.

[19] “The decline of Trentino’s livestock farming risks to become dangerous for the conservation of the environment and the countryside” (translation by the author).

As to the dairy sector, several authors wrote about its structures and its evolution through the 19th and 20th century (Zorzi, 1920; Gilberti, 1920; Bosetti, 1945; Zaninelli, 1978; Bridi et al., 1995). In general, it can be stated that cattle and dairy farming nearly coincide in Trentino, as no relevant specialisation in beef production ever occurred. Hence, the previous analysis of structural change in cattle farming can be applied to the dairy sector as well. However, one more aspect can be addressed at this point. In spite of extremely high farm abandonment rates and decreasing cattle stock, total milk production did not changed significantly over the last 70 years. As table 13 reports, milk production remained constant between 1938 and 2000, while the cow stock dropped by approximately 40.000 units! In fact, average milk production per cow increased from 2 tons in 1938 to 5,6 tons in 2000 (+280%), with a particularly marked progress in the 1980s and 1990s.

Tab. 13. Evolution of milk cow stock and of milk production in Trentino over the period 1938-2000 (data sources: ISTAT, 1992; Bridi et al., 1995; Sassudelli et al., 2002; ISTAT, 2003)

	1938[20]	**1951**	**1961**	**1971**	**1981**	**1990**	**2000**
total milk production (tons)	130.000	122.000	118.000	105.000	110.000	117.519	133.000
number of milk cows	65.000	60.000	52.000	37.200	35.000	28.314	23.849
average milk/cow	2,0	2,0	2,3	2,8	3,1	4,2	5,6
variation milk/cow (%)	100	100	115	140	155	210	280

This evolution is mainly due to three factors.

- Genetic improvement. For example, Rendena[21] cows increased their average milk production from around 1,5 tons (Ruatti, 1919) to 4,8 tons per lactation (Gusmeroli et al., 2006), with a simultaneous increase of average body weight from 315 kg to 500/550 kg.
- Shift to more productive races. In Trentino, the share of Holstein-Friesan cows increased from 0,4% in 1910 (Bassi, 1910) to 38,5% in 2007, when average milk production peaked at 8,5 tons per lactation (ANAFI, 2008).
- Improved cattle stock nutrition. This was reached through better fodder quality (earlier cut) on the one side, and increased share of concentrates in the ration on the other. In 2000, an average of 4,76 kg of industrial concentrates per cow was registered in Trentino (Gusmeroli et al., 2006).

The Provincial Cattle Breeders Federation played a fundamental role in this process of productivity improvement, as pointed out by Bridi et al. (1995).

[20] Data on milk production and number of cows was extracted from Bridi et al. (1995) for the years 1938-1981 (note that the number of cows is estimated and therefore differs from that reported by the census). For the years 1991 and 2000, the respective census as well as regional statistics on agricultural production were used.
[21] Rendena is an autochthon race, formerly widespread in the Giudicarie valleys. Nowadays, this threatened race counts only 3.995 units, most of which are held in the Provinces of Trento and Padova (ANARE, 2008).

Concerning the development of livestock (including sheep and goats) over the 20th century, interesting trends can be highlighted (tab. 14). Cattle more than halved between 1900 and 2000, falling from 102.377 to 45.149 units. As already discussed, extremely high rates of farm abandonment accompanied such a reduction.

Tab. 14. Evolution of cattle, sheep, and goat stock in Trentino over the period 1900-2000 (data sources: Kirchlechner, 1904; ICS, 1934; ISTAT, 1963, 1972, 1986, 1992, 2003)

	1900[22]	**1930**	**1961**	**1970**	**1982**	**1990**	**2000**
livestock type	**units**						
	absolute values						
cattle	102.337	96.447	76.438	70.791	61.446	53.997	45.149
of which cows	56.831	55.315	47.106	42.236	28.770	28.314	23.849
sheep	33.489	15.188	10.620	7.793	13.977	14.435	20.642
goats	35.305	24.249	6.509	3.113	2.923	3.874	5.463
	percentage values (reference year 1900)						
cattle	100,0	94,2	74,7	69,2	60,0	52,8	44,1
of which cows	100,0	97,3	82,9	74,3	50,6	49,8	42,0
sheep	100,0	45,4	31,7	23,3	41,7	43,1	61,6
goats	100,0	68,7	18,4	8,8	8,3	11,0	15,5

Sheep stock experienced a peculiar development. In 1850, Trentino counted 200.000 sheep (Bosetti, 1915), which dropped to 33.489 units in 1900, attaining a minimum in 1971 (just 7.793 units). In the subsequent decades, it significantly increased, until it reached a new maximum of 20.642 units in 2000. This development can be explained as follows.

- Under the Austrian Empire (until World War I), restrictive forest laws were introduced to address the problem of forest damage by goats. However, the same restrictive criteria were applied to sheep, the number of which was actively reduced. Additionally, strong emigration from rural areas and epizootic diseases contributed to the drastic diminution of sheep numbers in the Province (Bosetti, 1915).
- The socio-economic changes in the immediate decades after World War II and the consequent decline of livestock farming further decimated the sheep stock.

[22] As Bosetti (1915) noted, data on livestock units underestimate the real numbers. In fact, farmers tended to declare the lowest possible number of livestock units, as they feared additional taxes and tariffs. Bosetti estimates an additional 10% for data from the 1900 census. This might be applied to the 1930 and 1961 census as well (the ISTAT itself addressed this aspect in the 1961 census).

- Since the 1970s, European support policies have triggered a renaissance of sheep farming (Sassudelli et al., 2004). Besides the increase of sheep stock, average farm size raised from 11,2 sheep per farm in 1970 to 54,5 sheep per farm in 2000.As Staub et al. noted (2002), extensive sheep farming is not particularly labour-intensive and is suitable as a part-time activity.

A similar development affected the goat stock, even though its 'renaissance' was less evident. In 2000, Trentino counted just 5.463 goats, which correspond to 15% of the 1900 goat stock. The small average number of goats per farm (10,5 units) indicates the predominant 'hobby-orientation' of goat farming. According to Baur et al. (2006), the decrease of goat stocks across the alpine bow is a good indicator of the transition from a poor society - goats are the 'cows of poor people' – to a welfare society. From a landscape conservation perspective, the decline of goat farming alleviated the problem of poor forest regeneration, but it favoured natural succession to shrub and woodland on extensive pasture land (Baur et al., 2006).

As Sassudelli et al. (2004) note, both sheep and goat farming have progressively concentrated along the Lagorai mountain range (Eastern Trentino), which is characterized by extensive alpine pastures. In particular, sheep farming has considerabily grown in the Primiero and Lower Valsugana valleys, while goat farming is concentrated in the Fiemme valley, where goat milk transformed and commercialized by a local cheese factory.

2.3 Structural change in agriculture, land use polarisation and cultural landscapes

2.3.1 From a divergent to a convergent landscape

The term landscape is quite controversial, since it can be defined in different ways depending on the field of application (Andreotti, 1998; Pedroli et al., 2006). Duncan and Judy Poore, in their writing for the International Symposium on Protected Landscapes held in 1987, realized the complexity and hybridity of the term: "Many things are encompassed in our understanding of the word landscape: the geological structure of the land, its soils, animals and its vegetation; the pattern of human activity – fields, forests, settlements and local industries – both past and present" (Poore & Poore, 1987, in Lucas, 1992, p. 2).

According to Phillips (1998), since there are cultural aspects to practically every landscape on Earth, it follows that almost all landscapes fall into the category of 'cultural landscapes'. Cultural landscapes are the result of the combination and interaction of natural assets with past and present human activities (Council of Europe, 2000; Tress et al., 2001; Phillips, 2002), and represent a 'middle ground' (Mitchell & Buggey, 2000, p. 42) between nature and culture. They are not static but change trough space and time in response to changes in the interaction of their natural and anthropic components (Bürgi et al., 2004). In particular, land use changes and land conversion are responsible for many of the dynamics occurring at the landscape level, the more so as they reached unprecedented rates in the last century (Burggraaff & Kleefeld, 1998; Schneeberger et al., 2006).

Alpine rural landscapes are subject to these processes as well (CIPRA, 2000). Until the industrial revolution, cultural landscapes represented the ecologic and material base of human life in Alpine areas (Bätzing, 2005). In fact, food and energy scarcity forced people to extensively use landscape resources in a 'regenerative' way, with the aim to secure their own and the following generations' livelihoods (Gios, 1983). This intergenerational thinking ensured temporal landscape stability through slow rates of landscape change (Baldock et al., 2005). At the same time, decentralized production patterns provided for spatial landscape diversity. Indeed, subsistence farming and the associated variety of disturbance regimes (different land use forms and intensities), alongside with the extreme diversity of physio-geographic factors, guaranteed structurally heterogeneous landscape mosaics with a high habitat and species diversity (Bohner, 1998; Dierschke & Briemle, 2002; Nagy et al., 2003; Maurer et al., 2006, Plieninger et al., 2006). Trepl (1987) defines this 'old cultural landscape' as a divergent one, in which ecosystems are temporally stable and spatially diverse.

The industrial revolution marked the end of the 'agricultural era' in the Alps and profoundly altered the relationship between people and their landscapes (Penz, 2003). Raising economic efficiency allowed the newly formed industrial society to give up the extensive and decentralized use of landscape resources – which had been the central trait of the agricultural society – and to concentrate farming activities on the most productive areas, while abandoning less productive ones. Consequently, human pressure on landscapes rapidly changed from diffuse and well-distributed to discontinuous and localized, thus causing contrasting trends at the landscape level (Gusmeroli et al., 2006). Bätzing (2005) describes the resulting process of land use polarisation as follows: "War die Raumstruktur der Agrargesellschaft noch dadurch geprägt, dass *alle* landwirtschaftlich nutzbaren Flächen mit einem System vielfach abgestufter Nutzungsintensitäten bewirtschaftet wurde, […] so gibt es in der Industriegesellschaft nur noch eine sehr intensive Nutzung (wobei die Intensität im Laufe der Zeit immer gröβer wird) oder gar keine Nutzung. […] Bestand Natur in der Agrargesellschaft in erster Linie aus Kulturlandschaft, […] so zerfällt sie in der Industriegesellschaft in die beiden Pole «Produktionsraum» (mit der absoluten Dominanz des Menschen über Natur) und «Wildnis» (mit einer relativen Dominanz des Menschen über Natur"[23]

[23] "While the agricultural society was still characterized by a spatial structure in which all agriculturally usable land was cultivated over a wide range of intensities, in the industrial society there is either a very intensive land use (the intensity of which increases trough time) or no land use at all. […] While nature primarily consisted of cultural landscape in the agricultural society, in the industrial society it disintegrates into the two poles «production space» (with an absolute dominance of man over nature) and «wilderness» (with a relative dominance of man over nature)" (translation by the author).

(pp. 117-118). Trepl (1987) defines this ‘new cultural landscape’ as a convergent one, in which ecosystems are temporally unstable and spatially monotone.

Both intensification and extensification/abandonment have significant implications for the stability and diversity of landscapes in Alpine areas (Meuus et al., 1990, Mühlenberg & Slowik, 1997; MacDonald et al., 2000; Schellenberg, 2002; Bassignana et al., 2003; Buchgraber, 2003).

Intensification of land(scape) use is spatially discrete but sectorally diffuse: while it occurs only at certain locations, it affects different economic sectors, from agriculture (e.g. increased inputs, higher stocking densities), and tourism (e.g. booming outdoor sports, concentration of ski tourism), to urban and infrastructure development (e.g. urban sprawl, need for better mobility). The resulting spatial concentration of human activities generates an unsustainable pressure on landscape resources, thus reducing the regeneration capacity of ecosystems and increasing their lability (Bätzing, 2005). Landscape degradation and uniformity are the consequences.

On the contrary, human pressure on landscapes drastically decreases where extensification and abandonment occur. In fact, the diffuse human disturbance that traditionally ensured ecologic stability through bio-cultural diversity ceases due to the retreat of agriculture and anthropic presence from marginal areas. The consequent biological succession on formerly cultivated land destabilizes ecosystems, reduces species and habitat diversity, and simplifies landscape structures (Cernusca et al., 1996; MacDonald et al., 2000; Tasser et al., 2001). As a result, the complex landscape mosaics which characterized the old ‘divergent landscape’ are now substituted by monotone bush and forest extensions in the new ‘convergent landscape’.

2.3.2 Implications of structural change in agriculture for Trentino’s cultural landscapes

The polarisation of agricultural land use is a generalized process across the Alpine bow, even though it assumes different intensities according to national, regional, and local specificities (Tappeiner et al., 2003). In general, its impacts on traditional cultural landscapes are more marked in Romanic regions, where the collapse of agriculture has caused extensive land deception and landscape degradation (Barberis, 1996; Höchtl et al., 2005; Giupponi et al., 2006, Mattana, 2006). Baldock et al. (1996) have identified the particular vulnerability to marginalisation and abandonment of small-scaled, extensive, mixed arable and livestock farming systems, which traditionally occurred in Romanic mountain areas. Trentino has not been preserved from these developments (PAT, 1977; Borzaga, 1983b; Gorfer, 1987; Carriero & Wolynski, 2005; Sarzo, 2006).

Land use polarisation and its implications for Trentino’s cultural landscapes can be addressed at two different spatial scales: the regional and the local level.

At the regional level, the dichotomy between the Adige valley and its side valleys has affected not only the demographic and economic development (centre vs. periphery; Baroldi et al., 2007), but also the agricultural sector (intensification vs. extensification/abandonment). In fact, while the Adige valley and some nearby valleys have experienced a considerable intensification of agricultural land use through the expansion of viticulture and fruit farming, in the grassland dominated areas West and East of Trento the dramatic decline of livestock farming has been accompanied by a general process of extensification and abandonment (Leonardi, 1996).

At the local level, polarisation of agricultural land use has occurred in each 'regional pole', with the concentration of farming activities at favourable sites and the consequent retreat of agriculture from less favourable ones. Since these processes are still in progress, the gap is expected to further widen both regionally and locally.

The centre

As to the 'centre', which includes the Adige, Lower Sarca, Lower Non valleys as well as the Pergine basin, mixed farming systems (ligneous crops, arable, and livestock farming) have been completely substituted by specialized monocultural systems (vine or apples; Lorandini, 2005). Besides the environmental problems related to the intensive use of agrochemicals (Morteani et al., 2002; Wheeler et al., 2002), landscape monotonisation and biodiversity loss are the major consequences of agricultural intensification in these areas (Stenico, 1987). The diverse landscape described by Bosetti (1915) – a complex mosaic of grassland, arable land, and vineyards intercalated by hedges, mulberry trees and other fruit trees – has been transformed into a uniform one, with poorly structured vine and apple cultivations intercalated by pylons and asphalted roads. As Bätzing (2005) underlines, the resulting loss of traditional biodiversity affects not only crop varieties but also the associated biodiversity (plants, birds, insects, soil organisms etc.).

Note that agricultural intensification in the lowlands has been accompanied by a booming infrastructure and urban development along the Adige axis (Zanon, 2005; picture 1). Land consumption through sealing has primarily affected highly productive agricultural soils in the valley floors, thus jeopardizing the agricultural potential of urban communities (Gios, 1983). For instance, the city of Rovereto (the second largest city in Trentino) lost almost 150 ha (-26,3%) vineyards and fruit orchards between 1971 and 2000 due to industrial and demographic growth in the valley bottom (ISTAT, 1972, 2003).

In spite of their 'centrality', these areas have been locally affected by processes of land extensification and abandonment at geographically marginal, less favourable sites (Zanon, 2005). In more recent years, peri-urban areas have been experiencing a 'renaissance' in both demographich (Baroldi et al., 2007) and agricultural terms, with viticulture re-occupying formerly cultivated land on low altitude slopes. However, at higher altitudes the lack of production alternatives and the concurrent disappearance of livestock farming have caused grassland reversion to naturals scrub or woodland, resulting in a (almost complete) loss of landscape heterogeneity and mosaic features. Again, the municipality of Rovereto lost 727 ha (-81,2%) meadow and pasture land between 1971 and 2000 mainly because of forest re-growth at mid to high altitudes (ISTAT, 1972, 2003).

Picture 1. Urban sprawl around Trento (picture by the author).

The periphery

As to the pole ‘grassland areas’, which includes the mountain areas West and East of the ‘centre’, land use extensification and abandonment relate to the cessation of traditional land management practices (mowing, grazing, small-scale arable cultivation) and the reduction of zoo-anthropic pressure to a mass inadequate for arresting successional processes on grassland (picture 2).

Until World War II, grassland resources were extensively used in Trentino’s mountain areas: “Non un palmo di terreno dove crescesse un filo d’erba, dai dirupi più scoscesi, dai prati di monte ai pascoli arborati, dalle erbe estratte dai campi alle foglie degli alberi, tutto venne utilizzato per il bestiame. Altrimenti è impossibile pensare come soli circa 43.000 ha di prati posti molte volte a enormi altezze […] possano mantenere circa 100.000 capi di bovini (oltre agli altri animali) sia pure per tre quarti dell’anno”[24] (Ruatti, 1919b, pp. 7-8).

[24] “Every span of land with some grass, from the steepest cliffs, from the mountain meadows to the pastures intercalated by trees, from the weeds extracted from the fields to the leaves of the trees, everything was used to feed the livestock. Otherwise it’s impossible to explain how only 43.000 ha meadows, often located at enormous altitudes, could feed 100.000 bovines (in addition to the other livestock) for three quarters of the year” (translation by the author).

Picture 2. Estensive forest re-growth on former pasture land in the Vanoi valley - Trentino (picture by the author).

The structural changes affecting mountain farming since the 1950s have strongly reduced the demand for forage, thus generating a 'grassland surplus' in the region (for the concept of grassland surplus see Buchgraber et al., 2003 and Rösch et al., 2007). In particular, following aspects have contributed to this phenomenon:

- the collapse of decentralized, small-scale livestock farming;
- the reduction of ruminant livestock (cattle, sheep, goats);
- the substitution of local forage with increasing quantities of imported concentrates and top-quality fiber sources such as lucerne or corn silage (Gusmeroli et al., 2006);
- the decline of pasturing due to permanent stabulation (Cozzi et al., 2006);
- the increased grassland productivity in the valley floors through intensification processes;
- the increased grassland area in the valley floors due to the conversion of former arable land to grassland.

Census data suggest a sub-optimal use of the resource 'grassland' in the region and indicate a high susceptibility of grassland to abandonment. In Trentino, the share of farms with grassland and without livestock steadily increased between 1961 and 2000, jumping from 28,5% to 46,0%. At the same time, the share of farms with cattle collapsed, falling from 47,6% in 1961 to 5,0% in 2000 (fig. 10). Penz (2003) notes that land leasing has occurred only to a limited extent and normally affects flat and good accessible land plots. In fact, many of the shut-down (miniature) livestock farms have retained their grassland plots as "garanzia contro la precarietà dell'impiego extra-agricolo"[25]

[25] "guarantee against the precariousness of non-agricultural employment" (translation by the author)

(Lorandini, 2005, p. 499), often refusing to lease them out to larger farms. As a result, fodder availability has continuously diminished with onward farm abandonment, and larger farms have been forced to import fodder and concentrates as they could not lease enough grassland.

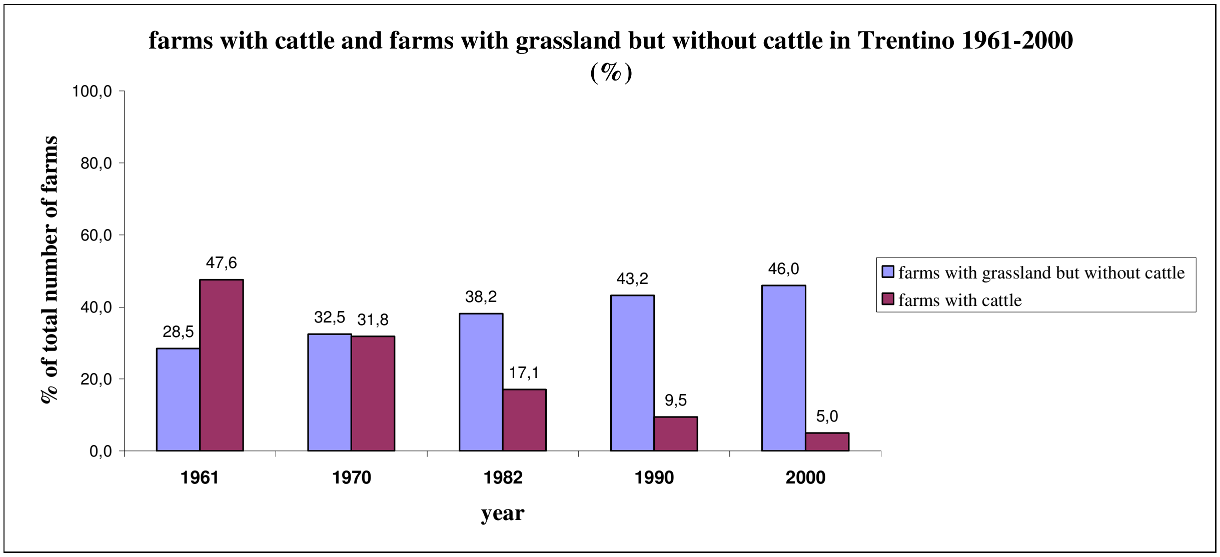


Fig. 10. Evolution of the number of farms with cattle and of farms with grassland but without cattle in Trentino over the period 1961-2000 (data sources: ISTAT, 1963, 1972, 1986, 1992, 2003).

The reduced pressure on local fodder resources and the consequent loss of grassland areas to scrub and forest put Trentino's cultural landscapes seriously at risk. This is specially true for areas with existing high forest cover, where land abandonment which leads to further woodland is not desirable in terms of retaining a certain degree of landscape complexity (MacDonald, 2000). Bridi et al. (1995) express their concern about the current process of landscape degradation in Trentino: "E' convinzione generale che, se non vi saranno ulteriori decisive interventi che coinvolgono l'intero tessuto rurale dei nostri paesi, rischieremo la fine di talune aree appenniniche. Anche l'ipotesi delle squadre di operai che tagliano l'erba e le mucche della Pro Loco non sono poi tanto lontane in talune Valli del Trentino dove l'attività agricola è marginalizzata sul piano culturale ed urbanistico ancora prima che su quello economico"[26] (pp. 392-393).

In spite of the general trend towards extensification, even Trentino's grassland areas have been experiencing a certain polarisation of agricultural land use. Besides the dichotomy between intensification in the valley floors and abandonment/forest re-growth on poorly productive, badly accessible areas, a spatial concentration of cattle farming at favourable locations has occurred in the last decades (in particular Giudicarie valleys). Hence, whereas the available grassland area per

[26] "It is generally recognized that, if no further, decisive intervention involving the entire rural fabric of our communities is undertaken, we will end up like some areas of the Appenines. The hypothesis of groups of workers mowing our meadows and of cows engaged by the tourism office is not that far away in some valleys of Trentino, where agriculture is marginalized not only on the economic, but also on the cultural and urban planning level" (translation by the author).

cattle[27] has generally increased across the region (mainly because of the decline of cattle stock), it has considerably increased in some communities due to specialisation and concentration processes (fig. 11a and 11b). Note that grassland consumption through conversion to other land uses (e.g. intensive crops, urban development, afforestation) might co-explain this decrease.

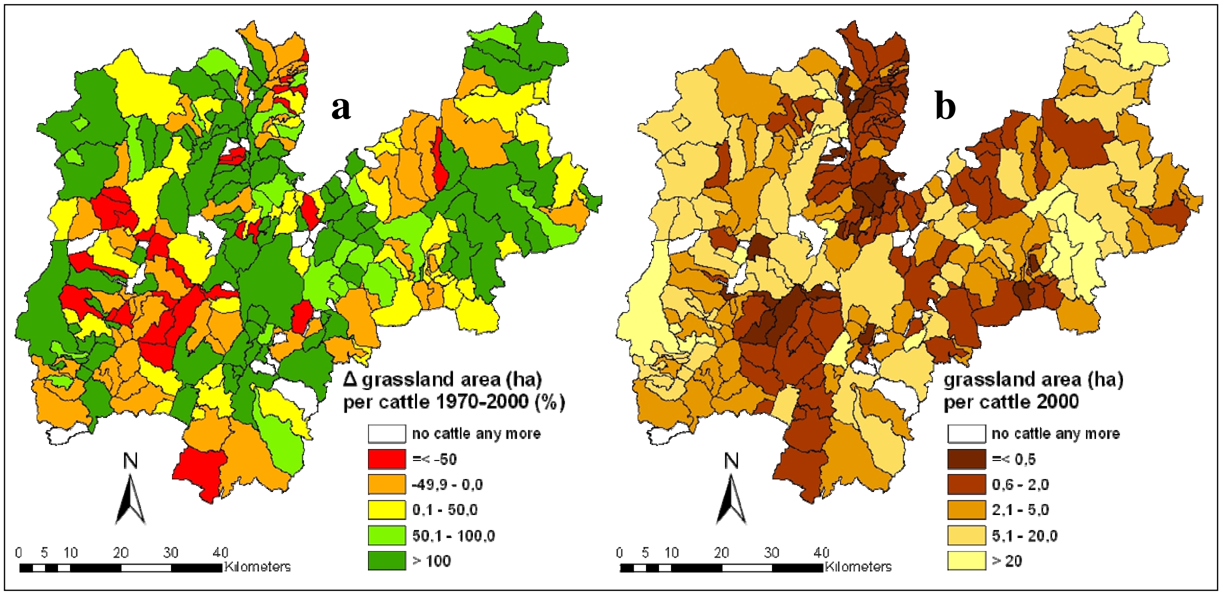


Fig. 11. Evolution of average grassland area per cattle at the community level in Trentino over the period 1970-2000 (data sources: ISTAT, 1972, 2003).

Both developments can be considered as detrimental for the stability of Trentino's cultural landscapes. In particular,

- an increase in available grassland area per cattle unit indicates a general extensification of grassland use and a consequent high potential for landscape degradation (Buchgraber et al., 2003);
- a decrease in available grassland area per cattle unit does not necessarily entail a more extensive use of local fodder resources. Cozzi et al. (2006), in a study carried out in the Asiago mountains (Vicenza province), show that intensive cattle farms are less and less dependent on local forage and pasture resources, and increasingly rely on nutrient imports (low fodder autonomy). Agricultural land use is concentrated in the valley floors, where grassland often becomes a pure nutrient acceptor, while non-mechanisable, marginal grassland as well as alpine pastures are abandoned.

[27] Note that the average grassland area per cattle is calculated as ratio between total grassland area and total cattle stock within a community. Therefore, alpine pastures and extensive grassland are included. This might distort actual livestock density in communities where alpine pastures and extensive grassland represent a considerable share of total grassland area. Additionally, cattle is often brought to alpine pastures from other communities or even other provinces. Nevertheless the proposed indicator, alongside with the development of cattle stock, allows to identify general development trends.

A concomitant process of land(scape) use polarisation has affected the tourism sector, which has its traditional 'hot spots' in the dolomitic valleys Rendena, Fiemme, Fassa, and Primiero. In these areas, the spatial concentration of tourism at specific locations (e.g. Madonna di Campiglio, Andalo, Moena, San Martino di Castrozza) has been accompained by an excessive urban and infrastructure development[28], with detrimental effects for the local agricultural potential and the attractiveness of cultural landscapes (Andreatta, 1998; Leonardi, 2005). In particular, the extensive sealing of highly productive agricultural land around tourism centres has irreversibly shrunk the 'agricultural corridor' between village and forest, thus forcing agriculture to a progressive retreat from the region (Gios, 1983; Gorfer, 1992). Alongside with soil sealing in the valley floors, further land abandonment in the uplands has contributed to a significant loss of aesthetic quality at the landscape level. This loss is detrimental *per se* and for the consequences it has on the tourism sector and the local economy as a whole (Schacht, 2003; Simmen et al., 2006).

[28] The tourism community of Pinzolo (Rendena valley) provides a good example in this respect. In 2001, Pinzolo had a population of 3.052 inhabitants and counted 5.273 'second homes', i.e. flats and houses which are not permanently inhabited. Most of these houses are owned by tourists (Bartaletti, 2008).

3. Case study communities

In the present section, the three case study communities Lomaso, Terragnolo, and Transacqua are briefly described as to their natural conditions, socio-economic structures, and agriculture (for an overview see tab 15). These communities were selected for the purpose of landscape change analysis because they are representative examples of different directions of agricultural structural change in Trentino's mountain areas. In particular,

- Lomaso has experienced a process of agricultural intensification and specialisation in the dairy sector thanks to the favourable climatic and geomorphologic conditions of its territory;
- Terragnolo has faced strong depopulation and massive farm abandonment due to its geographic and socio-economic marginality;
- Transacqua is characterized by a dynamic specialisation in livestock farming and a strong economic integration with the tourism industry.

The selection of the case-study communities also considered the classification into the agrarian structure region types proposed by Tappeiner et al. (2003). Lomaso is classified as *alpine standard region* with a probability of 0.56 and as *labour-extensive arable land region* with a probability of 0.41. Terragnolo is classified as *area of high farmland abandonment* with a probability of 0.99, while Transacqua belongs to the *grassland region* with a probability of 0.99 (fig. 12).

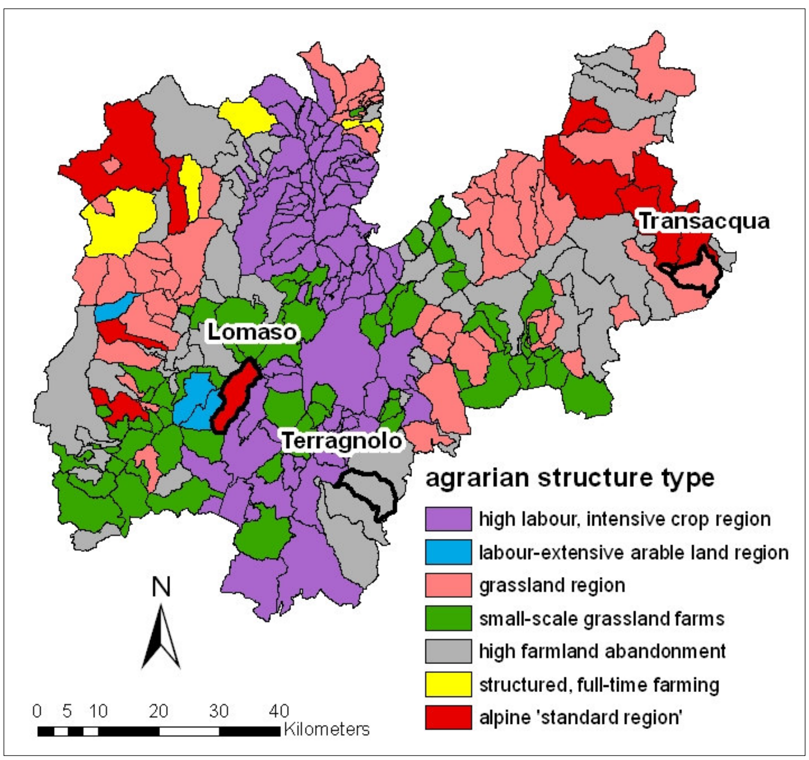


Fig. 12. Trentino's municipalities classified by agrarian structure type and the case study communities Lomaso, Terragnolo, Transacqua (data source: Tappeiner et al., 2003).

Tab. 15. Salient data about the natural conditions, the recent socio-economic evolution, and the agricultural sector in Lomaso, Terragnolo, Transacqua, and Trentino (various data sources)

	Lomaso	**Terragnolo**	**Transacqua**	**Trentino**
natural conditions				
surface area (km^2)	41,6	39,6	35,6	6.208,4
mean annual precipitation (mm)	1.084	1.124	1.301	-
mean temperature (°C)	9,7	10,4	8,8	-
lowest/highest point (m asl)	296/1.664	347/1.869	683/2.500	0/3.759
mean altitude (m asl)	877	1.144	1.413	1.401
mean slope (degrees)	22	32	29	26
socio-demographic conditions				
population 2001 (n)	1.408	749	1.940	477.017
Δ population 1921-1961 (%)	-23,2	-25,4	-0,3	+ 1,9
Δ population 1961-2001 (%)	-9,6	-58,9	+ 18,4	+ 15,7
employed in the primary sector 1961/2001 (%)	48,0 / 9,4	15,1 / 2,8	26,8 / 4,0	25,6 / 5,0
employed in the secondary sector 1961/2001 (%)	19,1 / 32,1	63,8 / 40,4	42,0 / 26,7	39,6 / 30,7
employed in the tertiary sector 1961/2001 (%)	33,9 / 58,5	21,1 / 56,8	31,2 / 69,3	34,8 / 64,3
young people (=<14 years) 1961/2001 (%)	20,9 / 14,8	21,3 / 10,4	25,2 / 7,6	22,6 / 15,0
old persons (>= 65 years) 1961/2001 (%)	10,0 / 19,9	10,1 / 26,4	9,0 / 21,2	10,2 / 15,7
tourism density 2005 (tourism beds per capita)	0,4	0	0,5	0,3
agriculture				
farms 2000 (n)	154	261	65	34.694
Δ farms 1970-2000 (%)	-28,0	-35,2	-18,7	-28,5
utilisable agricultural area 2000 (ha)	744,2	1.097,7	524,9	146.989
Δ UAA 1970-2000 (%)	-39,1	-6,1	-41,6	-18,0
non utilized agricultural area 2000 (ha)	358,1	299,6	11,4	11.120
farms with 100 ha UAA and more 2000 (n)	0	1	1	180
usable agricultural area 2000 < 100 ha (%)	100	28,6	73,4	42,4
average UAA per farm 2000 < 100 ha (ha)	4,8	1,2	6,0	1,8
share of farms > 5 ha UAA 2000 (%)	20,8	2,7	38,5	7,5
grassland 2000 (% UAA) and Δ 1970-2000 (%)	55,5 (-47,2)	99,3 (-1,4)	99,9 (-41,4)	81,7 (-23,9)
arable land 2000 (% UAA) and Δ 1970-2000 (%)	41,3 (-29,2)	0,6 (-68,1)	0,1 (-88,4)	2,8 (-46,2)
ligneous crops 2000 (% UAA) and Δ 1970-2000 (%)	3,2 (+401,0)	0,1 (-96,7)	0 (0)	15,5 (+ 2,3)
farms with tractors 2000 (%)	47,4	16,8	60,0	40,0
farms with cattle 2000 (n)	23	0	21	1.741
Δ farms with cattle 1970-2000 (%)	-82,9	-100	-68,6	-88,7
cattle units 2000 (n)	1.835	0	409	45.147
Δ cattle units 1970-2000 (%)	+ 55,5	-100	-25,5	-36,2
cattle units per farm 2000	79,8	0	19,5	25,9
Δ cattle units per farm 1970-2000 (%)	+ 806,8	-100	+ 137,8	+ 563,0
cattle units/ha UAA 2000 (cattle/ha)	2,5	0	0,8	0,4
Δ cattle units/ha UAA 1970-2000 (%)	+ 150,0	-100	+ 33,3	+ 150,0
full-time farms 2006 (n, % of ISTAT farms)	29 (18,8)	0 (0)	20 (30,8)	4.549 (13,1)

3.1 Lomaso

The community of Lomaso (picture 3) is located about 20 km South-West of Trento (46°1’ N, 10°52’ E; 41,6 km^2 surface area) in the Exterior Giudicarie, at the confluence of the Dal and Duina rivers. Orographically, it belongs to the Upper Sarca valley and is delimited by the Sarca river to the North/North-West, by the rio Carera and Fiavè plateau to the West, by the monte Misone (1.803 m asl) to the South/South-West, and by the monte Casale (1.632 m asl) to the East. In the 2001 census it counted 1.408 inhabitants (ISTAT, 2004), distributed among the villages of Campo Lomaso (municipality seat), Comano, Dasindo, Godenzo, Lundo, Poia, Ponte Arche and Vigo Lomaso.

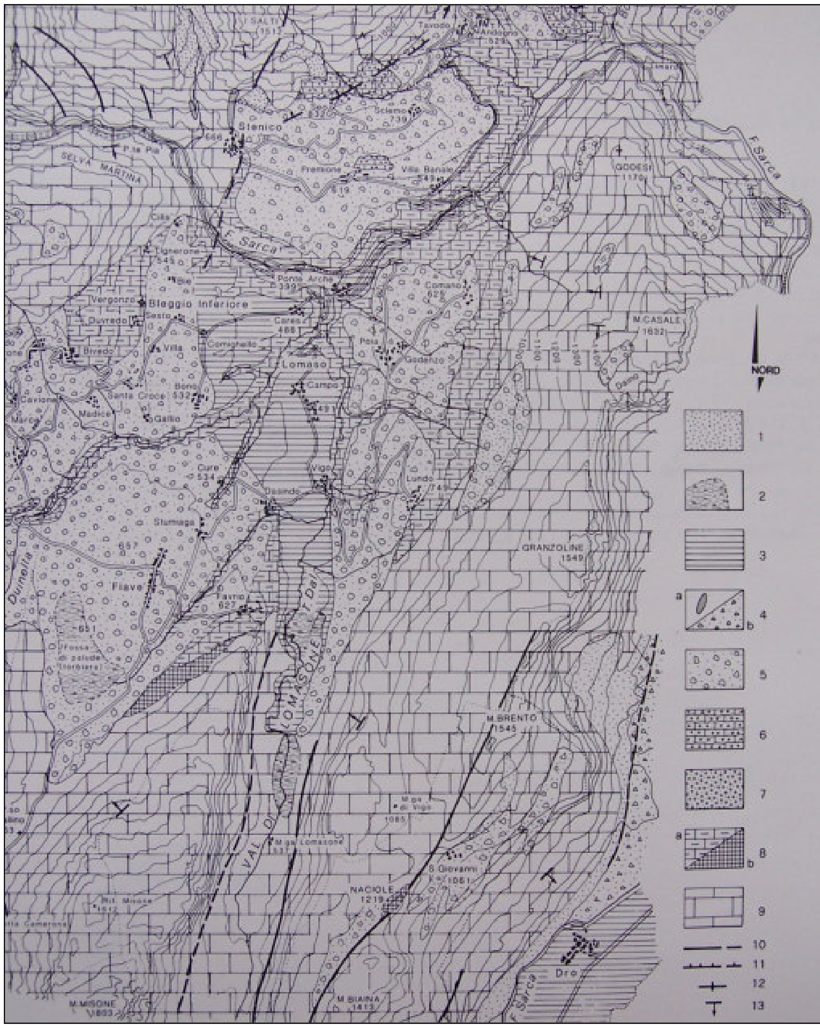
Picture 3. Maize fields in the Lomaso plateau and the hamlet of Campo (on the right) photographed from the foot slopes of the Monte Casale (picture by the author).

3.1.1 Geology and geomorphology

From a geological point of view, the Exterior Giudicarie are delimited by the granitic (tonalite) Adamello massif to the West, the dolomitic Brenta range to the North, and the calcareous Altissimo and Casale formations to the South and to the East respectively (for a detailed description see Parisi, 1988).

In particular, the territory of Lomaso can be subdivided into two main subunits, the Lomaso plateau and the Misone-Casale massifs. The former (500-800 m asl) has an Eocenic mudstone base that formed 60 million years ago from marine claystone rich in lime and microfossils. In the Quaternary, this base was covered with morenic detritus originating from the Adamello-Brenta and with fluvial gravels and sands, which shape today’s valley bottom. The latter (800-1.800 m asl) are

Mesozoic limestone formations emerging to the east and to the South-West. While the base of the Misone stems from the Trias, its top-layer as well as the Casale stem from the Giura. Essentially, Lomaso is a long, flat Eocenic plateau delimited by Mesozoic mountains (Tomasi, 1987). Figure 13 provides an overview of the salient geological features in the region.



1. *falda* detritus

2. recent floods, peat bogs and mashes

3. postglacial floods

4. stadial morenic cordon

5. Würmian moraines

6. interglacial conglomerates

7. pre-Würmian moraine

8. Eocenic mud and cley lime-stones

9. limestone from the Cretacic and antecedent eras

10. faoults

11. overslidings - layer posi-tion

12. vertical

13. moderate slope

Scale: 1:100.000

Fig. 13. The geological structure of the Lomaso basin (source: Paris, 1988, p. 18).

Geomorphologically, Lomaso is characterized by relatively low relief energy and low slope steepness (fig. 14). The val Lomasone and the Lomaso plateau create an ample and flat valley bottom, surrounded to the East and to the North by terraced slopes and wide plane areas. The adjacent slopes of the monte Casale rarely exceed 40 degrees of steepness, and end in a high plateau along the summit line. Only the 600 m high claystone walls which delimit the val Lomasone to the east (monte Blestone) and to the west (monte Misone) provide for a more ‘alpine’ landscape. The highest point reaches 1.664 m asl, the lowest 296 m asl. However, almost half of the territory lies under 800 m asl.

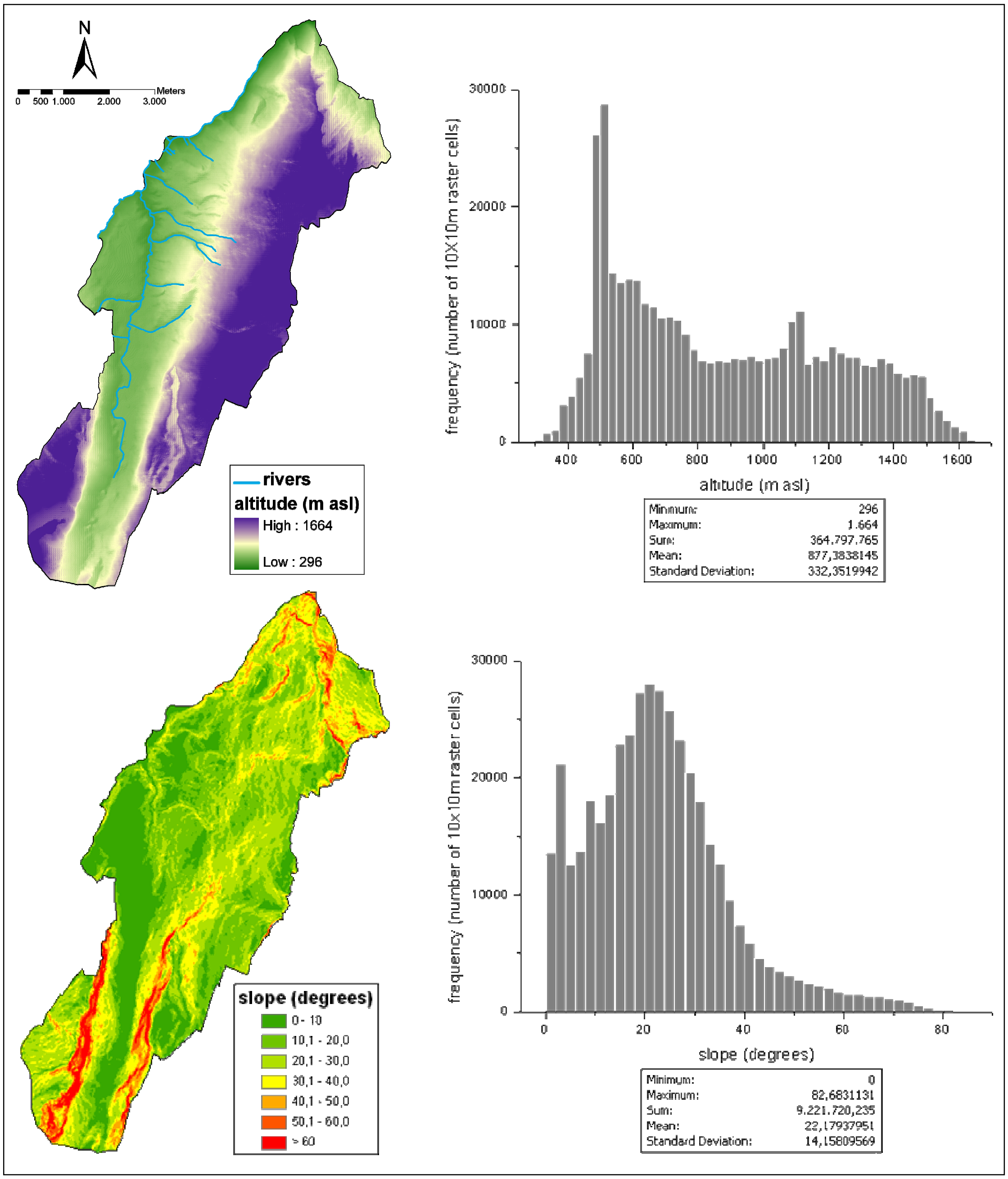


Fig. 14. Geomorphologic characteristics of Lomaso (altitudinal patterns and slope steepness; own data elaboration).

3.1.2 Climate

The geographic position of the Exterior Giudicarie, located on the 'borderline' between the Garda Lake to the South and the Brenta Dolomites to the North, deeply affects their climate (Conci & Zambini, 1989). In fact, while the latter partly protect them from cold air masses coming from North and North-West, the former brings a submediterranean influence from South and South-East. Consequently, the continental climate of the inner Alpine valleys (e.g. Sole valley) overlaps with the sub-mediterranean climate of the Southern Prealps (Pedrotti, 1987).

Long-time data series on meteorological parameters are available for a weather station located in San Lorenzo in Banale (720 m asl), which borders Lomaso to the North (Loose, 1983). The mean annual precipitation is of 1.084 mm, with two precipitation peaks in Mai and November respectively (equinoctial precipitation regime). The winter and summer seasons are comparatively drier. This precipitation regime differs from that of more continentally influenced valleys further North (e.g. Sole valley), where precipitations are concentrated in the summer period (July and August), and from that of the Garda Lake, where annual precipitation is much lower (Pedrotti, 1987).

As to the temperature regime, mean annual temperature reaches 9,7 °C (against 13,3 °C on the northern shore of the Garda Lake), with an average maximum temperature of 25,5 °C and an average minimum temperature of -5,5 °C. The thermic winter (mean temperature under 5 °C) goes from December to March, while the thermic summer (mean temperature above 15 °C) lasts over 4 months, from June to the beginning of Oktober (Loose, 1983).

From a bioclimatic point of view, Sboarina and Cescatti (2004) classify the climate of the Exterior Giudicarie as temperate-oceanic hypertemperate-humid, following the Wolrdwide Bioclimatic Classification System.

3.1.3 Soils and vegetation

As Loose (1983) notes, there is a general lack of comprehensive data about Trentino's soils and their features. The most complete pedological study available to date is a map of soils published by Ronchetti (1965) with a scale of 1:250.000. According to Ronchetti's map, most soils occurring in the Exterior Giudicarie are of carbonatic origin, as they formed on calcareous and dolomitc rocks or on morenic and fluvial detritus of prevailing carbonatic nature. In particular, three main soil types can be identified in Lomaso.

- Brown soils and calcareous brown soils (*Braunerden* and *Kalkbraunerden*) are located in the valley floor and at lower altitudes. They represent the most evolved and deep soils in the area and are normally cultivated to arable crops or intensive grassland thanks to their high fertility (e.g. high organic matter content, good water retention capacity).
- Rendzina soils are less fertile (thin, poor in clay, rich in skeleton) and located at mid to high altitudes. They are generally cultivated to pasture land or covered with forests/shrubs.
- Peat and mash soils locally occur in the Val Lomasone and are not used for agricultural purposes, as they produce fodder of inferior quality due to their water regime and the unfavourable floristic composition of their phytocenosis.

As to vegetation, the Exterior Giudicarie comprise all major vegetation elevation zones from submontane and montane to subalpine, alpine and nival. However, the alpine and nival elevation zones do not occur in Lomaso, while the sub-alpine elevation zone only marginally affects its territory (the highest point reaches only 1.664 m asl).

The submontane elevation zone (up to 900 m asl) coincides with the agriculturally dominated valley floor, where forest cover is extremely low. However, mixed, thermophile deciduos forest with *Ostrya carpinifolia*, *Fraxinus ornus*, and *Quercus pubescens* (*Orno-Ostryetum*) still occur on steep, non-cultivated slopes.

The montane elevation zone (900-1.600 m asl) is characterized by mesophile beech and fir forests (*Abieti-Fagetum*), with a gradual switch from beech to fir as elevation increases. The mitigating influence of the Garda Lake prevents the establishment of a significant *Picea* belt in these areas (Conci & Zambanini, 1989), whereas Pinus silvestris is locally diffused.

The sub-alpine elevation zone (1.600-2.200 m als) is not well represented in Lomaso, but would be characterized by *Picea* forests[29] at lower elevations and extensive *Pinus mugo* formations at higher altitudes (*Mugo-Ericetum* on sunny aspects, *Mugo-Rhododendretum* on shady aspects).

A comprehensive overview of the floristic features of Lomaso and the Exterior Giudicarie is provided by Pedrotti (1987). Biotopes of particular floristic interest are located in the Lomasone valley (4 km south of Campo Lomaso), with highly bio-diverse peat bogs (e.g. *Rhycosporetum albae*, *Phragmites australis*) and marshes (*Caricetum elatae* with *Carex elata*, formerly used to weave chair seats).

3.1.4 Economic and demographic conditions

The community of Lomaso has been experiencing profound socio-economic changes in the last century due to a progressive "Deagralisierung"[30] (Loose, 1983, p. 59) of its traditional society (for a comprehensive overview see Dalponte, 1987).

The evolution of employment structures are quite eloquent in this respect (tab. 15). According to the 1931 census[31], approximately 30% of resident population was fully employed in agriculture, while another 16,5% had a part-time agricultural employment. Similarly, 48% of residents declared to be employed in agriculture in 1961. In the subsequent decades, agricultural employment inexorably decreased, reaching a minimum of 9,4% in 2001. This comparatively high value (the

[29] The *Piceetum subalpinum* is more diffused in the continentally influenced parts of the Giudicarie valleys, namely Rendena, Genova, and Breguzzo valleys.
[30] "de-agriculturation"
[31] During Fascism, the municipality of Lomaso included areas that nowadays belong to other communities (approximately 24,2 km^2). Hence, data from the 1930 census of agriculture and the 1931 census of population are not directly comparable with post-war census data. However, they provide useful information about pre-war socio-economic structures in the community.

provincial average stands at 5,0%) is partly attributable to the favourable natural conditions, which allow a certain degree of agricultural specialisation, and partly to relatively good off-farm income opportunities in neighbouring urban agglomerates (Gorfer, 1987).

Besides a larger plastics producer and two construction firms with more than 20 workers, the industrial sector is characterized by small handicraft businesses. The 2001 census of industrial activities registered 29 'industrial' businesses and 108 employees (3,7 employees on average), with a negative trend in the period 1991-2001 (-17,1% and -15,0% respectively; Mariabella, 2005). As 192 persons were employed in the secondary sector in 2001, it can be deduced that a consistent share of industrial employees work outside the community. The Tione basin and the Lower Sarca valley represent the major destinations for employment-related trips (Loose, 1983).

The tertiary sector absorbs almost 60% of local work force, with an uneven distribution of employees between commerce (35,4%) and services (64,6%). In particular, tourism has been gaining relevance since the early 1970s, when the thermal centre of Comano was fully renovated and enlarged. Even though tourism density is still relatively low in Lomaso, with 0,4 tourist beds per inhabitant in 2005, neighbouring communities such as Bleggio Inferiore (0,6 tourist beds per inhabitant) and San Lorenzo (0,7 tourist beds per inhabitant) show a more solid tourism structure ('significant tourism intensity' according to Bätzing, 1993; Savorelli et al., 2007). The multiplier effects of this moderate tourism development on local economic life are most evident in the village of Ponte Arche (2 km north of Campo), which has become the centre of infrastructural, urban, and economic growth in the region (Gorfer, 1987).

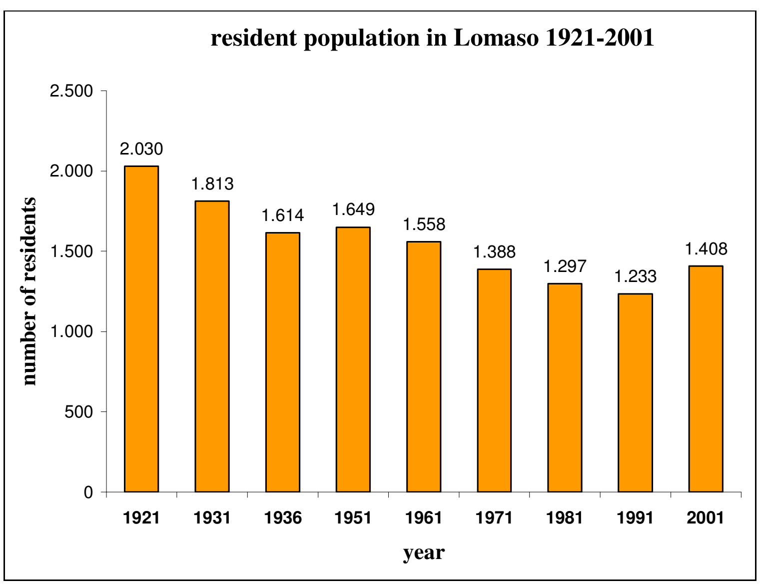


Fig. 15. Evolution of resident population in Lomaso over the period 1921-2001 (data elaboration by the Statistics Service of the Autonomous Province of Trento).

From a demographic perspective, the community of Lomaso is now experiencing a 'renaissance' after a long period of depopulation (fig. 15). In fact, the number of residents steadily decreased between 1921 and 1991, due to emigration and ageing population. The efforts made in the 1960s and 1970s by the Autonomous Province of Trento to boost industrial development in the area failed to slow down this process. However, the more recent tourism development and the improved mobility infrastructure (shorter distances to bigger economic centres) have contributed to invert the trend. Resident population increased by 14,2% in the decade 1991-2001 thanks to new, young families moving in. The process of repopulation is mainly affecting the villages of Campo and Ponte Arche in the valley bottom. Instead, more peripheral hamlets are gradually moving to the margins of the economic and demographic growth.

3.1.5 Agriculture

The character of Lomaso's agricultural landscape is related to the exceptionally favourable geomorphologic and climatic conditions of its territory. The flat and wide valley bottom (Lomaso plateau) is particularly suitable for intensive arable farming and is nowadays dominated by irrigated potato and maize fields, whereas the steeper surfaces to the east are terraced and cultivated to grass. On these slopes, which rarely exceed 20° of inclination, the mild climate allows the cultivation of apples and, locally, cherries. A wide forest belt separates the valley floor from the extensive pasture region on the monte Casale, which is characterized by low elevation and low slope steepness.

In the last century, Lomaso's agriculture has undergone a continuous process of change in response to exogenous specialisation stimuli. As Dalponte (1987) notes, the focus of agricultural production has moved from mulberry trees and cereals to wheat, then to potatoes, and finally to maize and specialised cattle farming just within 80 years. This has been accompanied by the decline of self-sufficiency agriculture and the concurrent restructuring of farming systems (for a comprehensive analysis see Loose, 1983).

Salient data on more recent structural changes in agriculture are shown in table 15. The rate of farm abandonment (-28,0% of farms between 1970 and 2000) is in line with the provincial average (-28,4%), while mean farm size (4,8 ha usable agricultural area) is slightly higher than in the rest of the province (4,2 ha). Interestingly, average farm size decreased by 15,9% between 1970 and 2000, as usable agricultural area decreased faster than the number of farms. However, the comparatively high share of farms larger than 5 ha (20,8%) indicates favourable property structures in the community (the provincial average is of 7,5%). These medium to large farms cultivate 86,3% of total usable agricultural area (ISTAT, 2003).

The reduction of usable agricultural area has been extremely high in Lomaso, almost double as high as the provincial average (-39,1% in 30 years). In particular, the extensive abandonment of pasture surfaces in the uplands are responsible for this decline (Gorfer, 1987). On the contrary, the observed reduction of arable land is not attributable to abandonment but to the conversion of terrazzo floors and steeper surfaces from arable to grassland. Ligneous crops (and specifically apples and cherries) experienced a positive trend between 1970 (4,9 ha) and 2000 (25,0 ha), even though they still play a minor role in the local agricultural scene. Mulberry tree plantations (silk production) were progressively eliminated after World War II and are no more present on the territory of the community.

As already mentioned, the dominant focus of Lomaso's agriculture is cattle farming (mainly dairy). Its recent development is emblematic of the transition from a subsistence-oriented agricultural system to a highly specialized, capital intensive one. Traditionally, cattle farming had been ancillary to arable farming, as it provided draft animals for ploughing and other physical work. The produced milk was normally consumed within the household, while young cattle was either sold on local cattle markets or slaughtered for domestic beef consumption. According to the 1970 census of agriculture, Lomaso counted 134 cattle breeding farms (62,6% of all farms) with an average farm size of 8,8 cattle units.

In the early 1970s, the introduction of direct payments in the dairy sector generated a deep restructuring of traditional farming practices, creating an incentive to enlarge farms and fully specialise in dairy production. Loose (1986), in his study about the agro-geography of the Exterior Giudicarie, described this process in a very pregnant way: "Die Viehbestände [nehmen] in Lomaso, Fiavè, Bleggio superiore zu. Träger dieser positiven Entwicklung sind die groβen Viehställe mit über 30 Stück Groβvieh. Diese Betriebe sind zugleich mit dem Maisanbauern identisch. Ein Groβteil von ihnen hat außerhalb der dörflichen Enge neue Wirtschaftsgebäude und Ställe errichtet, die über zahlreiche, arbeitssparende Einrichtungen, wie automatische Fütterungsanlagen, Entmistungseinrichtungen und Melkmaschinen verfügen. Die Aussiedler sind schließlich Vorreiter bei der Einführung neuer Hochleistungsmilchviehrassen, wie z.B. des Schwarzfleckviehs friesischer Abstammung, die einheimische Rasse, etwa das Rendena Rind und das alpine Braunvieh, verdrängen. Um die hohen Milchleistungen des schwarzbunten Viehs aufrechtzuerhalten, muss Kraftfutter zugekauft werden. Verbunden damit ist die ganzjährige Aufstallung, ein Trend, der auch bei den Haltern anderer Rinderrassen zu beobachten ist"[32] (pp. 30-31).

[32] "Cattle herds increase in Lomaso, Fiavè, Bleggio Superiore. Big farms with more than 30 adult cows are responsible for this development. These farms coincide with the maize farms. Most of them have erected new buildings and stables outside of the village and have installed numerous facilities to reduce the work load, for example automatic feeding systems, manure disposal systems and milking machines. The out-movers pioneer the introduction of new, highly productive races such as the Holstein Friesen, which gradually replace local races like the Rendena or the alpine Brown cattle. In order to sustain the high milk productivity of Holstein Friesen cows, farmers are forced to buy concentrates. This requires permanent stabulation, which is adopted by farms with other races as well" (translation by the author).

The 2000 census of agriculture confirms the high degree of specialisation of cattle farming in the area (tab. 15). Even though only 23 cattle breeding farms have survived in Lomaso, their average size has reached almost 80 cattle units, with an increase of 806,8% against 1970. This development has been even more accentuated in the neighbouring communities of Bleggio Inferiore and Fiavè, where average farm size exceeds 200 cattle units. Note that the increase of cattle herds and the concomitant decrease of usable agricultural area generate a raising pressure on local nutrient cycles, the more so as modern cattle farming substantially relies on nutrient imports through concentrates and fertilizers. As a consequence, arable land has become auxiliary to cattle farming not only because it provides high quality fodder (e.g. Lucerne and silo maize) but also because it represents a necessary ‘nutrient disposal system’.

As to the income structure of Lomaso’s cattle farmers, data from the Provincial Archive of Agricultural Enterprises (APIA) indicate the predominantly professional character of cattle farming in the community. In 2006, 20 cattle farmers were registered in the archive, 18 of which (90,0%) were full-time farmers. Hence, small-scale cattle farming has practically disappeared.

3.2 Terragnolo

The community of Terragnolo (picture 4) is located about 34 km South-East of Trento (45°53’ N, 11°09’ E; 39,6 km^2 surface area). Its territory includes the upper basin of the Leno river, which

Picture 4. The hamlets of Piazza and Puechem in the Terragnolo valley: trees and shrubs have fully re-conquered formerly used agricultural land around the built-up areas (picture by the author).

runs nearly from East (Borcola pass) to West (Adige valley) forming a V-shaped valley. The Leno is surrounded by the calcareous formations of the Monte Finonchio (1.603 m asl) and Monte Maronia (1.705 m asl) to the North, the Monte Maggio (1.869 m asl) to the East, the Pasubio massif (2.236 m asl) and the Sarta-Bisorte range (1.563 m asl) to the South. To the West, the valley narrows into a profound canyon before reaching the city of Rovereto. The municipality counts 33 hamlets and villages, which are concentrated on the sunny slopes north of the Leno river, and is inhabited by only 749 persons (ISTAT, 2004).

3.2.1 Geology and geomorphology

The Terragnolo valley is situated South of the Insubric line (Southern Alps) between the Adige Valley and the Pasubio massif. In the main, it is dominated by sedimentary rocks of calacareous and dolomitic nature which formed in marine environments between 220 and 60 millions years ago (for a comprehensive overview of the geological history see Braga & Finotti, 1990, fig. 16). Demozzi (2006) describes the geologic structure of the territory as follows.

- The valley bottom consists of a thick dolomitic sole (main dolestone - *dolomia principale*) which formed in ample tidal planes between 220 and 205 millions years ago (Upper Triassic). In particular, white and white-grey outcrops of stratified Calcium and Magnesium carbonates are visible up to 800-900 m asl.
- The main dolestone is progressively substituted by pure limestones at higher altitudes (up to 1.500-1.600 m asl). The so called ‘grey limestones’ (*calcari grigi*) of this layer formed in the Lower Giurassic between 205 and 180 millions years ago and are well-stratified, rich in fossils and dinosaur footprints. They are locally covered with more recent red limestones rich in ammonite fossils *(rosso ammonitico*).
- The upper and last layer comprises the summits of the Monte Finonchio to the north and the Monte Sarta to the south. It consists of stratified limestones intercalated with mudstone deposits (*scaglia rossa*) which originated between the Cretacic and the Eocene (140-37 millions years ago).

In more recent times (Quaternary), the erosive action of ice and water has shaped the geologic substrate, thus giving the Terragnolo valley its actual geomorphologic appearance. In particular, the vertical limestone walls surrounding the valley at higher altitudes are interrupted by glacial terraces between 900 and 700 m asl, where slope steepness reaches values under 20-10 degrees. However, these small balconies are followed by abrupt drops converging from both sides of the valley to the Leno river, which has carved a deep furrow in the limestone and dolestone soles.

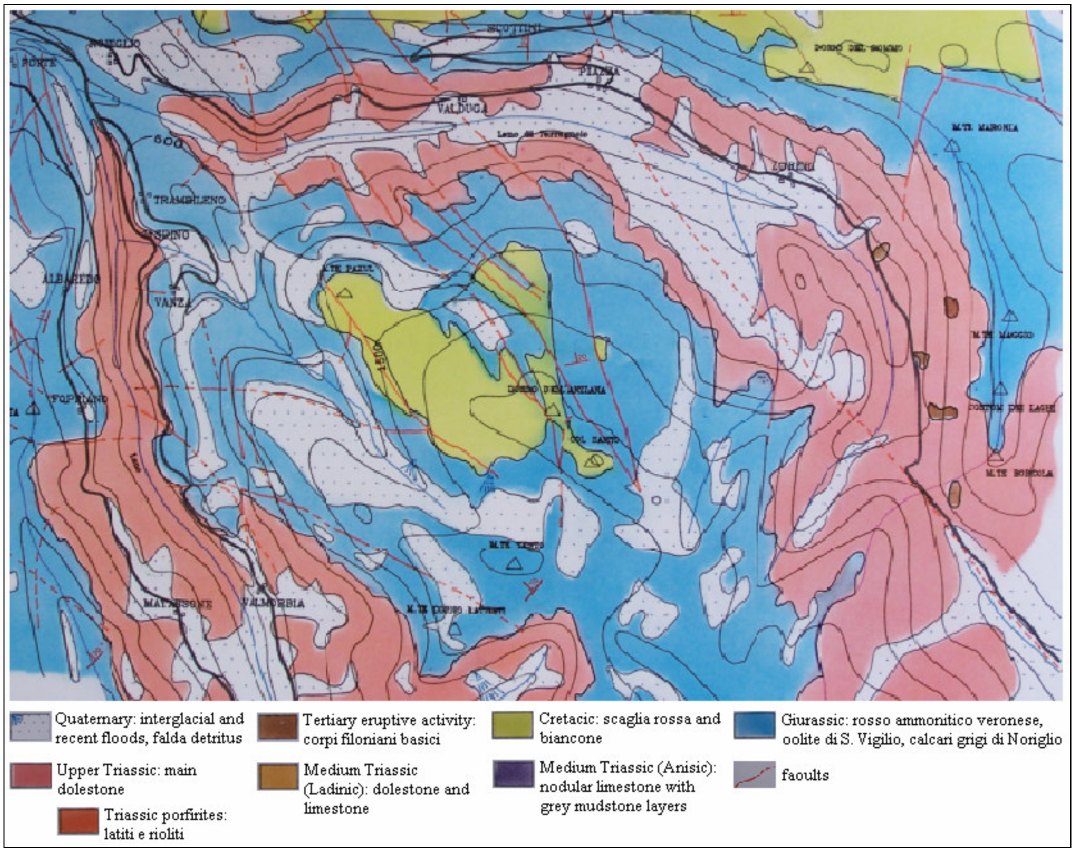


Fig. 16. Geologic structure of the Terragnolo and Vallarsa valleys (without scale; source: Braga & Finotti, 1990, p. 28).

Hence, the Terragnolo valley is characterized by extremely unfavourable conditions in terms of relief energy and slope steepness (over 85% of municipality surface is steeper than 10 degrees; fig. 17). Human settlement and agricultural activities have mainly developed on the southern slopes of the Monte Finonchio and Monte Sommo, where the wider glacial terraces and the sunny aspect offer a more favourable environment. The shady aspects south of the Leno river have been poorly anthropized and are covered with thick coniferous and deciduous forest. The highest point reaches 1.869 m asl (Monte Maggio), the lowest 347 m asl, while the mean altitude is of approximately 1.144 m asl.

3.2.2 Climate

Due to its geographic position in the Southern Alps and on the border line between the Venetian pre-Alps and the Trentino Dolomites, the Terragnolo valley is characterized by a sub-alpine climate with sub-Mediterranean influence.

Long-time data series on meteorological parameters are available for the weather station of Piazza, a village located on the sunny slopes of the Monte Finonchio at 782 m asl. Annual mean temperature reaches 10,4 °C (almost 3 °C less than in Rovereto), with absolute minima in December and January (1,9 °C) and absolute maxima in August (20,4 °C). The relatively high average temperature in the winter months is attributable to frequent phenomena of thermic inversion and to the favourable position of the weather station (south aspect). The precipitation regime is markedly sub-alpine, with a mean rainfall of 1.124 mm (period 1925-2005) and two equal precipitation maxima in the equinoctial seasons. In particular, while only 10% of rainfall occurs in January and February, more than 40% of precipitation is concentrated in Mai-June and October-November. Most rainfall events are of cyclonic origins, convective-orographic events are not infrequent in the summer months (Sarzo, 2006).

Bioclimatically, Sboarina and Cescatti (2004) classify the climate of the Terragnolo valley as temperate-oceanic hypertemperate humid, with mesotemperate humid conditions in the valley bottom along the Leno river and on the southern slopes of the Monte Finonchio. From a microclimatic point of view, the East-West orientation of the valley generates striking differences between the sunny and the shady valley side (Sarzo, 2006).

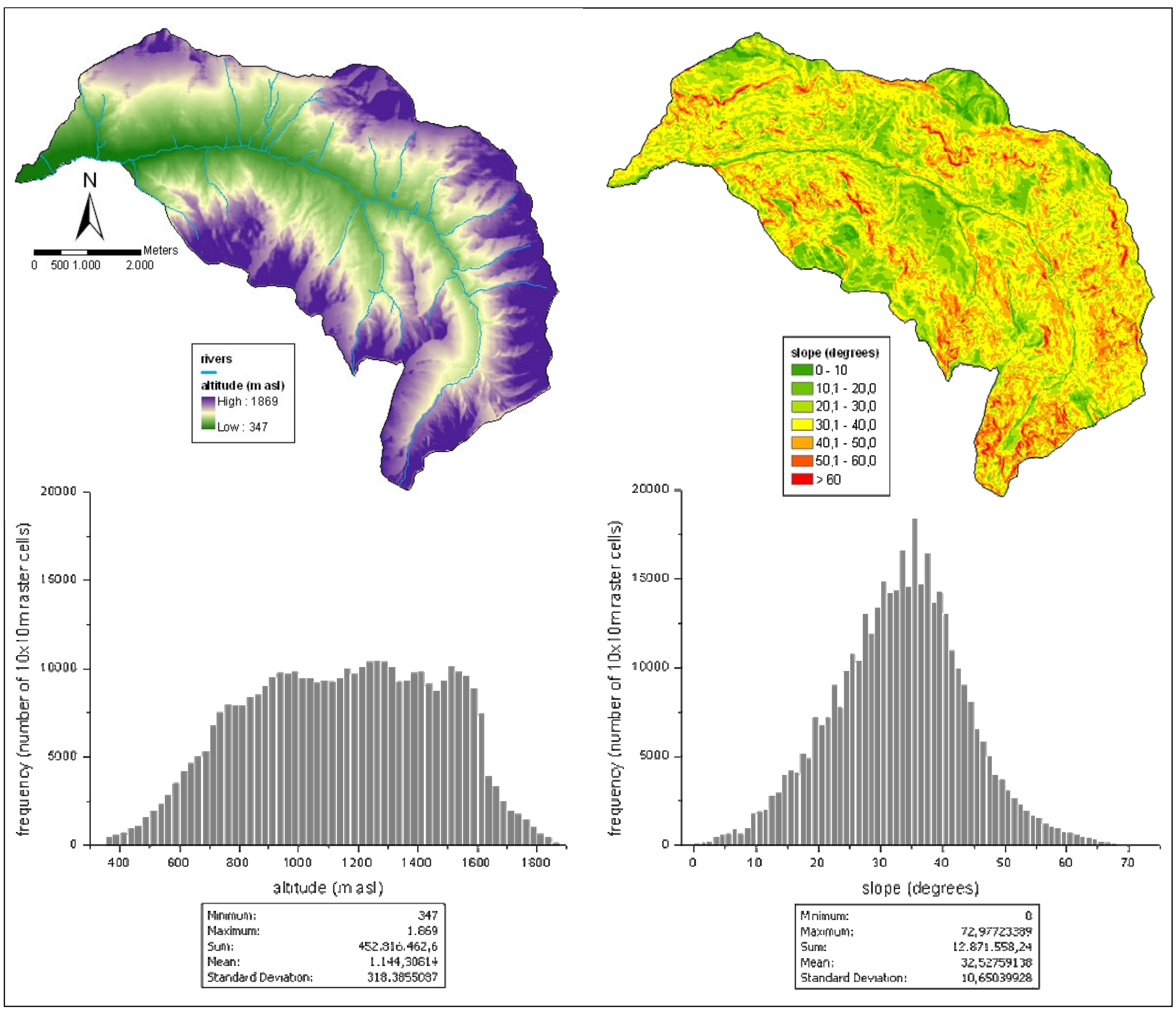


Fig. 17. Geomorphologic characteristics of Terragnolo (altitudinal patterns and slope steepness; own data elaboration).

3.2.3 Soils and vegetation

Information about the soils of the Terragnolo valley was extracted from the map of soils edited by Ronchetti (1965). The predominantly calcareous substrate and the unfavourable geo-morphologic conditions (high slope steepness in particular) did not allow the extensive evolution of deep and fertile soils as they can be found e.g. in the Lomaso plateau. Shallow rendzinas represent the dominant soil type, with proto-rendzinas and lithosoils occurring in the vicinity of rock outcrops and at higher altitudes. Such soils are generally characterized by high pH, low water retention capacity, and high skeleton content. The relative and absolute Ca excess and the complementary Na and K deficit determine a considerable nutrient stress in the topsoil, thus inhibiting plant growth and reducing soil fertility (Gubert, 2006). Only the glacial terraces north of the Leno river show better edaphic conditions. There, the accumulation of glacial/alluvional detritus as well as lower slope steepness allowed the formation of deeper and more evolved soils (brown calcareous soils) with high clay content and nearly neutral pH. These *Kalkbraunerden* are more fertile and suitable for agriculture (Ronchetti, 1965).

As to vegetation, deciduous forests dominate the Terragnolo valley on both the shady and the sunny side. However, the marked microclimatic differences between the two sides deeply influence the floristic composition of their forest cover and the altitudinal sequence of the vegetation zones. Festi (1990) provides a comprehensive map of the vegetation elevation zones in the Terragnolo valley, which includes the submontane, montane, and (lower) subalpine levels. The alpine elevation zone does not affect the territory of Terragnolo but is well-represented in the neighbouring Pasubio massif.

The submontane vegetation elevation zone is particularly pronounced on the sunny aspect, where the *Orno-Ostryetum* formation reaches altitudes of 1.000-1.100 m asl. Alongside with *Ostrya carpinifolia*, *Fraxinus ornus*, and *Quercus pubescens*, medium-sized shrubs such as *Corylus avellana*, *Cornus mas*, and *Cotinus coggygria* characterize these slopes. On the shady aspect, the *Orno-Ostryetum* is substituted by *Acer campestre* and *Tilia cordata* formations (up to 700-800 m asl), which are typical for the upper submontane level. In fact, they occur on the borderline to the *Abieti-Fagetum* on both valley sides.

The montane vegetation elevation zone begins at approximately 1.000 m asl on the sunny aspect and at 800 m asl on the shady one. It is characterized by the *Abieti-Fagetum*. On the sunny aspect, *Fagus sylvatica* is mixed with *Pinus sylvestris* at lower altitudes and with *Picea excelsa* and *Larix decidua* at mid to higher altitudes. On the shady valley side, conifers are more abundant and mainly represented by *Abies alba*.

The (lower) subalpine level affects the shady side of the Sarta-Bisorte range (1.563 m asl) in the southern part of the community and the Monte Maggio (1.869 m asl) to the east. These areas have a transitional character between the *Abieti-Fagetum* on the one side and the *Larici-Cembretum*, which covers the Dosso dell'Anziana, and the *Mugo-Rhododendretum* on the other. Hence, their structure and species composition are extremely heterogeneous. The most frequent species are *Larix decidua*, *Pinus mugo*, and *Rhododendron hirsutum*.

For an inclusive overview of the floristic features of the Terragnolo valley see Festi (1990). At the local level, the most endangered plant communities are those which traditionally accompanied mixed farming practices. The collapse of agriculture in the region puts this 'associated biodiversity' at risk and is the major source of local extinctions. In particular, the species-rich *Veronica-Euphorbion* is being progressively substituted by uniform ruderal phytocenosis (e.g. *Artemisietae*) or shrub associations on abandoned vine terraces. The same problem affects formerly used grassland and pasture land (Sarzo, 2006).

3.2.4 Economic and demographic conditions

The demographic and socio-economic development of Terragnolo is quite emblematic of the process of marginalisation which has affected large parts of the Alpine bow since the industrial revolution (Bais, 1986; Gios, 1990c; Sarzo, 2006). The geographic, orographic, topographic, and climatic constraints of this valley, alongside with the large-scale socio-economic changes occurring in the 'outside world', have created a vicious circle of marginality, abandonment, and deterritorialisation which puts the very survival of the community at risk.

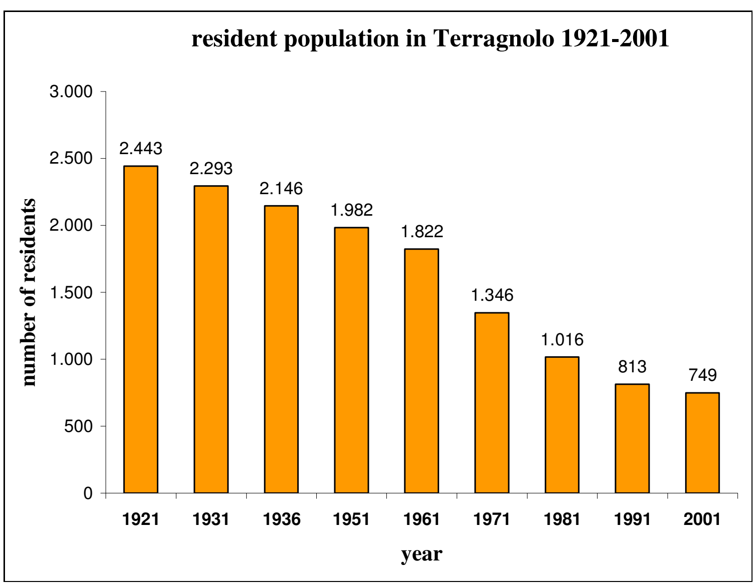


Fig. 18. Evolution of resident population in Terragnolo over the period 1921-2001 (data elaboration by the Statistics Service of the Autonomous Province of Trento).

Demographic data are quite eloquent in this respect (fig. 18). Terragnolo lost almost 70% of its population between 1921 and 2001, with a particularly marked drop in the years of the economic wonder (1960s and 1970s). Permanent emigration has been the major cause of this development (Gios, 1990c). In particular, the absolute lack of local employment opportunities has forced young work force to move elsewhere, while the remaining population has progressively aged. In fact, the share of residents older than 65 years nearly tripled between 1961 and 2001, jumping from 10,4% to 26,4% (tab. 15).

As to employment structures and their evolution, census data show that the *Deagralisierung* of Terragnolo's society was already advanced in the 1960s, with 'only' 15,1% of population being active in agriculture. Even in the 1921 census, the share of agriculture employment was comparatively low (hardly 30%). Besides the general unsuitability of the territory for farming and the totally missing link between agriculture and the market, the vicinity of the industrial centre of Rovereto in the Adige valley might explain these figures. As industrial workers could not commute every day due to lacking transportation opportunities, they were forced to abandon their agricultural activity, which was partly prosecuted by unemployed relatives on a subsistence base (Mattevi, 1957; Bais, 1986). The subsequent improvement of mobility infrastructure and the booming economic development of the Adige valley worsened the situation, as the opportunity costs of agricultural employment further increased. Depopulation, everyday commuting, and agricultural desertion were the immediate consequences. Nowadays, barely 3% of active population is employed in agriculture.

The secondary sector occupied 68,8% of workers in 1961 and still represents a fundamental income source for the community. However, as Terragnolo offers only 13 'local' workplaces in the secondary sector (Mariabella, 2005), the remaining 103 industrial workers must be employed elsewhere.

The situation is not much different in the tertiary sector, where 2/3 of workplaces are non-local and tourism is almost non-existent. The extremely high share of commuters (over 80%!) indicates the absence of local economic dynamics and the total reliance on external employment sources. Specifically, Rovereto still represents the major socio-economic pull-factor in the community, from both a demographic and an employment perspective (Turri, 1990).

3.2.5 Agriculture

The term 'Sozialbrache'[33], coined by Hartke in 1956, is quite suitable for describing the present situation of Terragnolo's agricultural landscape. *Sozialbrache* refers not only to the extensive

[33] 'social fallow'

abandonment of agricultural land but also to the underlying processes of socio-economic transformation in rural areas, recalling concepts such as *Agrarstrukturwandel*, *Höfesterben*, *Landflucht*[34] (Falcioni, 1975). Land deception and forest re-growth on formerly cultivated land are just the most visible symptoms of the vicious circle of marginalisation which affects the entire social and cultural system of this region (Sarzo, 2006). In particular, the 'retreat' of agriculture from the territory is the most salient aspect of this process of environmental and social degradation (Gios, 1990a).

Local agriculture has been permanently confronted with extremely unfavourable environmental conditions. Demographic pressure and the need for agricultural land forced farmers to extensively terrace the steep slopes south of the Leno river with high stone walls, thus creating narrow land strips. As Cesare Battisti (1923) wrote, "non v'è un solo briciolo di terreno esposto al sole- anche sull'orlo dei precipizi – dove la mano del paziente contadino non abbia lasciato traccia di sudata industria. E dove manca la terra vegetale, fra i gioghi più ardui, il montanaro ve la porta, resistendo alle fatiche più gravi pur di strappare ad essa con pertinace lavoro aspri e miseri frutti"[35] (p. 672).

The almost ubiquitary terrace floors were cultivated with mixed crops (policulture). In particular, arable was mixed with vine and mulberry trees in the lower Leno valley, and with fruit trees and meadows at higher latitudes and on the shady aspect. The 1900 census registered 196 ha arable land, 134 ha vineyards, and 12 ha grassland (Kirchlechner, 1904). The scarcity of grassland in the valley floor was compensated by high-altitude meadows and pastures, which covered 555 ha and fed 558 cattle units, 291 goats, and 93 sheep. These resources were hardly sufficient to satisfy the needs of resident population, which reached 2.466 inhabitants in 1900.

The 20th century marked the end of the subsistence economy which had dominated the Leno valley for centuries and the beginning of an irreversible process of decline. Unfavourable geomorphology, high property fragmentation , microscopic farm sizes, insurmountable limits to mechanisation, lack of specialisation options are only some of the constraints which impeded the transition to a modern agriculture in the area. In fact, Terragnolo's agriculture experienced a 'structural collapse' rather than a 'structural change', as no form of professional farming developed while subsistence farming was progressively disappearing (Gios, 1990a).

Agricultural statistics fully expresses the radicality of this evolution (tab. 15). The number of ISTAT-farms decreased by barely 1/3 between 1970 and 2000, falling from 403 to 261. However, no full-time farm and only 2 part-time farms are registered in the Provincial Archive of Agricultural

[34] structural change in agriculture, farm abandonment, exodus from rural areas

[35] "there isn't any piece of land on the sunny aspect – not even on the edge of the precipice – without a trace of the farmer's patient work. And where there is no soil, between the highest pinnacles, the farmer brings it withstanding big efforts in order to produce harsh and wretched fruits through his pertinacious work" (translation by the author).

Enterprises (APPIA). Hence, over 99% of ISTAT-farms are hobby farms representing the last relicts of former subsistence farming. The particularly low average number of days of work per farm and year (16,9) as well as the low percentage of farms with tractors (16,8%) confirm this hypothesis (ISTAT, 2003). Average farm size hardly reaches 1,2 ha usable agricultural land if we exclude commonly owned land (94,7% of usable agricultural land!) from the calculation. 11 farms share 1,1 ha vineyards (0,1 ha per farm on average) and 110 farms cultivate 7,3 ha arable land (0,06 ha per farm on average). No cow, no goat, no sheep can be found in the community. As a consequence, the 1.089,1 ha grassland and pasture land registered by the 2000 census are to a large extent fallow and covered with shrubs. Forest cover has dramatically increased, while open spaces around inhabited areas have almost disappeared (picture 4). Essentially, Terragnolo’s agriculture has vanished.

3.3 Transacqua

The community of Transacqua (picture 5) is located about 55 km North-East of Trento (46°11’N, 11°50’E; 35,6 km2) in the Primiero valley, at the confluence of the Canali and Cismon rivers. Orographically, it belongs to the upper basin of the Cismon river, which runs from North (Rolle Pass) to South (Cismon del Grappa) for 51 km before flowing into the Brenta river. The territory of

Picture 5. Transacqua village and the Pale Alte range seen from the foot slopes of the Monte Bedolè near Pieve (picture by the author).

the community is delimited by the Cimonega range (2.554 m asl) to the East, the Cereda Pass (1.369 m asl) to the North-East, the communities of Tonadico and Fiera to the North, the Monte Bedolè (1.783 m asl) to the West, the community of Mezzano to the South, and the Finestra Pass (1.814 m asl) to the South-East. With its 1.940 inhabitants (ISTAT, 2004), Transacqua is the most populous municipality of the Primiero District. Its major hamlets are Transacqua village (municipality seat), Ormanico, and Pieve, which nowadays form a continuous urban agglomerate together with the neighbouring villages of Fiera, Tonadico, and Siror.

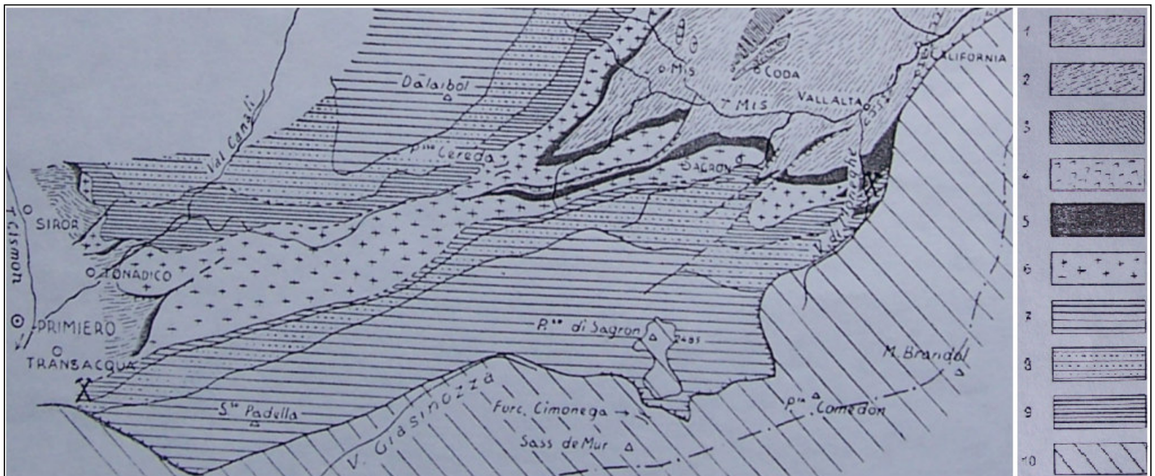
3.3.1 Geology and geomorphology

The Primiero valley is characterized by an extremely complex and various geo-litologic structure. In fact, it is situated at the convergence of the metamorphic Scanaiól massif, the Porphyiric Atesine Platform (Lagorai range), the granitic Cima d'Asta massif, and the dolomitic formations Pale di San Martino, Vette Feltrine, and Cimonega (for a comprehensive overview of the geological structures see Loss, 1875; Fratini, 1885; De Lazzer, 1984).

Geologically, the community of Transacqua encloses all major geo-litologic formations occurring in the upper Cismon basin. In particular, three main superimposed layers can be identified (fig. 19).

- The lowest and older layer is composed of metamorphic rock that originated 450 millions years ago and metamorphosed between 350 and 320 millions years ago during the Carboniferous. Its fillades and porphyroids emerge on the Monte Bedolè, which covers the western part of Transacqua's territory.
- During the Lower Permian (290-274 millions years ago), intensive volcanic phenomena created the Porphyric Atesine Platform, which runs from the Adige valley to the Rolle Pass for approximately 60 km. This 'intermediate' layer is composed of porphyric vulcanites of a reddish-brown colour (high content of iron oxides and clorites) and lies on the metamorphic base. In Transacqua, the Porphyric Atesine Platform locally emerges along the Uneda valley and in the proximity of the Cereda Pass.
- The upper and youngest layer is composed of stratified sedimentary rocks that originated between the Upper Permian and the Upper Triassic on the porphyric sole. Specifically, Val Gardena sandstones (Upper Permian) and Werfen formations (Lower Triassic) can be found on the Dalaibol range to the North and the Pale Alte-Piz de Sagron range to the East, while main dolestones (Upper Triassic) emerges on the Sass de Mur to the South-East and in the Giasinozza Valley to the South.

In the Quaternary, the geological matrix has been shaped by the erosive action of water and ice.



1. quartz fillads **2.** graphitic scists **3.** paragneiss **4.** ortogneiss **5.** basal conglomerates **6.** porphyrites and porphydes **7.**Val Gardena sandstones, Permian claystones and limestones **8.** Werfenian **9.** Anisis, Ladinic, and Carnic **10.** Main dolestone; scale 1:75.000

Fig. 19. Geologic structure of the Primiero-Agordo depression (source: Castiglioni, 1935, p. 25).

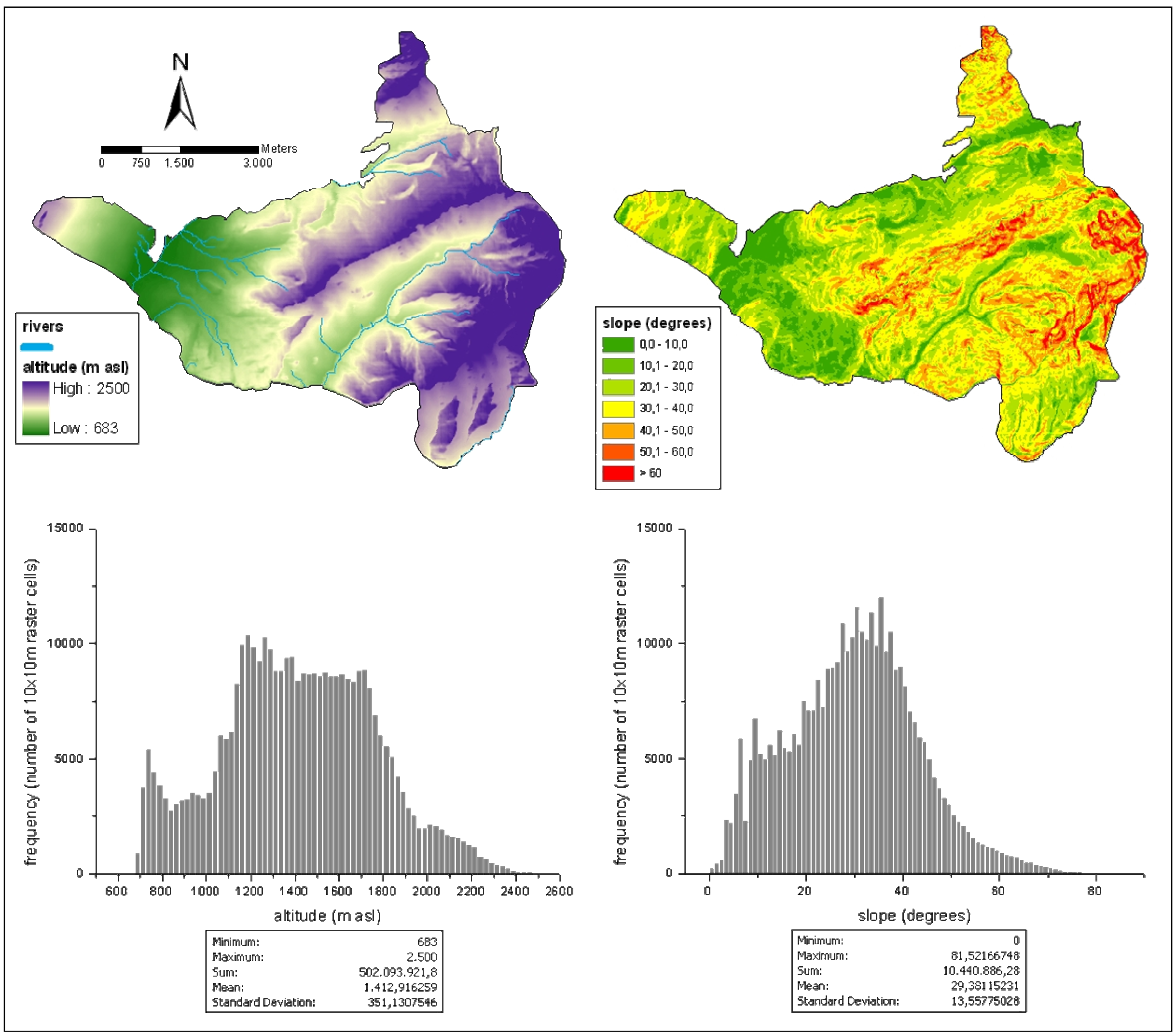


Fig. 20. Geomorphologic characteristics of Transacqua (altitudinal patterns and slope steepness; own data elaboration).

Concerning the geo-morphologic traits of the territory, Transacqua is characterized by typically alpine conditions, with a mean altitude of approximately 1.400 m asl and a mean slope steepness of 29 degrees (fig. 20). The valley floor is fairly narrow (hardly 800 m of width at around 700 m asl) and is abruptly delimited by the steep slopes of the Monte Bedolè to the West. Agriculture and settlements have mainly developed on the eastern slopes of the valley due to their more favourable conditions (low slope steepness in particular). Further East, the Pale Alte range separates the Cereda valley to the North from the Giasinozza valley to the South. The former is characterized by wide glacial terraces (Cenguei, Cereda) and extensive agricultural land use, while the latter has been poorly anthropized because of its extremely inhospitable environment. In fact, this V-shaped valley is enclosed between the steep walls of the Pale Alte (1.854 m asl) and the Cimonega ranges (2.500 m asl) and is almost totally covered with thick pine and spruce forests.

3.3.2 Climate

From a geographic point of view, the Primiero valley is located on the border line between the Venetian Pre-Alps and the Inner Alps. Consequently, its climate is strongly influenced by the continentality effect of the Alps to the North (temperature regime) and the Adriatic sea to the South (precipitation regime). However, the extreme diversity of orographic structures determines a high variability of climatic parameters across the valley.

Long-time meteorological data are available for the weather stations of San Martino (Siror), situated on a glacial terrace at an altitude of 1444 m asl, and San Silvestro (Imér), located in the valley floor at an altitude of 557 m asl. Even though the Primiero valley is protected from cold Northerlies through the Lagorai range, the thermometric parameters are typically continental. Mean temperature reaches 5,4 °C in San Martino and 8.8 °C in San Silvestro, with an altitudinal temperature gradient of 0,38 °C every 100 m. The hottest month is July (average maximum temperature of 18,8 and 24,5 °C respectively), while the coldest one is January (average minimum temperature of -7,2 °C and -5,0 °C respectively). Not surprisingly, the average maximum temperature of the coldest month is higher in San Martino (2,0 °C) than in San Silvestro (1,3 °C) due to marked phenomena of thermic inversion during the winter period (Longo, 1984).

From a pluviometric point of view, the Primiero valley is characterized by high annual precipitation sums, which reach 1.448 mm in San Martino and 1.301 mm in San Silvestro. This situation is due to the humid air masses coming from the Adriatic Sea and the Venetian Planes and condensating along the orographic barrier formed by the Pale di San Martino range (3.192 m asl). The precipitation regime is equinoctial in the valley floor, with a marked minimum during the winter months and two absolute maxima in the equinoctial seasons, and almost continental at higher altitudes, where orographic-convective phenomena provide for significant rain falls during the entire summer period. Note that the high intensity of rain fall events in autumn makes the Upper Cismon basin susceptible to floods and landslides. November 1966 is remembered by local people as the ‘catastrophic November’ because of massive flooding along the Cismon axis (Corona, 1984; Filippi Gilli, 1996).

Bioclimatically, Sboarina and Cescatti (2004) classify the climate of the Primiero valley as temperate-oceanic hypertemperate humid in the valley floor and temperate-oceanic hypertemperate hyperhumid at higher altitudes.

3.3.3 Soils and vegetation

Information about Transacqua’s soils was extracted from the map of soils edited by Ronchetti (1965). The valley floor is dominated by fertile alluvional soils which are particularly suitable for agricultural production. However, these soils have been extensively sealed through urban and infrastructure development. Deep, well developed brown soils characterize the lower foot slopes up to 800-900 m asl. They have a high organic matter content as well as a good water retention capacity, and coincide with the agriculturally used low altitude area. Brown podzolic soils can be found on the silicatic substrate of the Monte Bedolè and, locally, in the proximity of the Cereda Pass. East of the Cismon river, where the substrate is predominantly carbonatic, shallow Rendzina soils are alternated with deeper calcareous brown soils at locations with more favourable geo-morphologic conditions (e.g. glacial terraces, valley bottoms). Finally, Protorendzinas, lithosoils and rock outcrops dominate the formations Pale Alte, Cimonega, and Dalaibol.

As to vegetation, the high diversity of bio-abiotic factors (altitude, aspect, slope steepness, geologic substrate, soils, etc.) and disturbance regimes (different land use forms and intensities) is associated to a high habitat and floristic diversity across the valley (for a comprehensive overview of Primiero’s flora see Paoletti, 1891). Scalet (1984) estimates that over 1.000 plant species occur in Primiero, with extensively used meadows and high-altitude pastures representing the species richest habitats in the region. However, their progressive abandonment goes along with the increase of forested areas, which already cover the major part of the territory.

Concerning the vegetation elevation zones, Transacqua comprises the montane, subalpine, and alpine levels in an altitudinal spectrum which ranges from 683 m asl in the valley floor to 2.500 m asl on the Sass de Mur. As the valley floor is dominated by built-up areas and agricultural activities, the sub-montane vegetation elevation zone is not well represented. However, some elements of the *Tilio-Aceretum* can be found on abandoned agricultural land on the lower foot slopes.

The prevalent forest formations are the *Abieti-Fagetum* (800 - 1.400 m asl) and the *Piceetum* (1.400 - 1.700 m asl), which affect the lower and the upper montane elevation zone respectively. Though, the extensive use of *Fagus sylvatica* for wood and coal production as well as the substitution of *Abies alba* with the more valuable *Picea excelsa* have strongly reduced the *Abieti-Fagetum*, which still occurs in its representative form on the north-western slopes of the Pale Alte range. Hence, red spruce remains the dominant tree species in the montane level. *Fraxinus excelsior*, *Acer pseudoplatanus*, and *Sorbus aucuparia* occur on northern aspects and steep slopes, while *Pinus silvestris* is widespread at lower altitudes on the shallow Rendzina soils of the Giasinozza valley.

The sub-alpine vegetation elevation zone is comprised between 1.600 - 1.700 m and the tree line and is characterized by spruce in association with *Larix decidua* and *Pinus mugo*. *Pinus mugo* formations locally occur at lower altitudes (down to 1.400 m) on steep gravel slopes at the feet of dolomitic rock walls (Giasinozza valley in particular). *Pinus cembra* is underrepresented in the territory of Transacqua, but can be found on the Lagorai range.

The alpine elevation zone has a fuzzy lower border, as the tree line is strongly affected by the extreme geo-morphologic conditions of the territory. In fact, while the tree line reaches 1.900 - 2.000 m asl on the Dalaibol range, it comes down to 1.600 m asl on the Cimonega range. The alpine level is characterized by extensive rock outcrops and, locally, shrubs formations (*Rhododendron spec.*) and natural alpine grassland (Conci & Zambanini, 1985).

3.3.4 Economic and demographic conditions

The Upper Primiero District, which consists of the communities Transacqua, Fiera, Tonadico, and Siror, is a representative example of a geographically marginal area[36] where tourism development has stemmed depopulation through the creation of decentralized job opportunities. In fact, tourism has the potential to positively affect demographic trends, as it triggers local economic development thanks to its linkages with the other economic sectors. As Tappeiner et al. (2003) note, the multiplier effect of tourism lies at 1,3, i.e. one tourism job creates every third job outside of tourism.

Demographic data about Transacqua municipality corroborate this hypothesis (tab. 15 and fig. 21). Resident population increased by over 18% in the period between 1961 and 2001, determining a consistent infrastructure and urban development around the traditional hamlets of Transacqua, Ormanico, and Pieve. In 2001, Transacqua counted 1.940 inhabitiants. Only five years later,

[36] The marginality of the Primiero valley is mainly attributable to its geographic isolation and the unfavourable orographic conditions, which make the access by car particularly difficult. However, road infrastructure has been significantly improved in the last decades.

population peaked 2.096 (+8%; Lanzafame & Novello, 2007). Such increase is mainly due to immigration from nearby communities and from outside the Primiero valley. The permissive urban development policy as well as the high quality of life (good infrastructure and services, nice view on the Pala dolomites, etc.) might partly explain the observed trend.

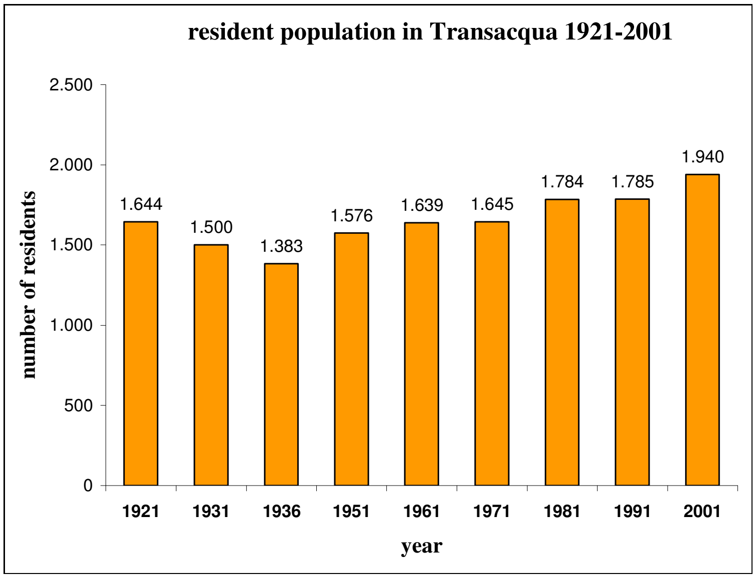


Fig. 21. Evolution of resident population in Transacqua over the period 1921-2001 (data elaboration by the Statistics Service of the Autonomous Province of Trento).

In spite of the positive demographic development, Transacqua's resident population has been dramatically ageing since the 1960s, with the share of old people (over 65 years) jumping from 9,0% in 1961 to 21,2% in 2001. The share of people under 14 years dropped from 25,2 to 7,6 in the same period. A particularly low birth rate – only 8,2 children per 1.000 inhabitants in 2001 against a provincial average of 10,2 – and the immigration of retired people seeking high quality of life are the reasons behind these figures.

As to employment structures and their evolution, the overwhelming development of the tertiary sector in the last 40 years indicates the key role tourism plays in the local economy. In 2001, almost 7 of every 10 jobs were registered in commerce and services, while they were only 3 in 1961 (Mariabella, 2005). However, the figure on tourism density (only 0,5 tourism beds per inhabitant in 2005) does not fully express the relevance of the tourism sector for the community. In fact, this figure includes only 'commercial' beds (hotels, bed & breakfast, camp sites) and excludes tourism beds in private apartments and 'second homes', i.e. flats and houses that are inhabited in some periods of the year by non-residents. Transacqua counted 301 second homes in 2005, which accounted for additional 1.555 tourism beds (Savorelli et al., 2007)! Furthermore, data from the nearby communities Fiera (0,8 tourism beds per inhabitants), Siror (3,5 tourism beds per inhabitant), and Tonadico (1,3 tourism beds per inhabitant) show a well-consolidated tourism structure in the Upper Primiero District.

The industrial sector has never experienced a relevant development in Primiero, mainly due to its geographic marginality, the poor road infrastructure as well as the polarisation of socio-economic structures around the tourism sector (Brunet, 1984). Transacqua's largest industrial enterprise employs approximately 40 people and produces tanks for civil and industrial use. The remaining 'industrial' workers are employed in minor businesses such as saw mills, hydropower stations, construction firms and handicraft. In particular, the construction sector has been experiencing a significant development in the last decades thanks to its linkage with tourism. However, the share of employment in the secondary sector (26,7%) still remains under the provincial average. Interestingly, 4 of every 10 jobs were classified as industrial in 1961. At that time, the still persisting economic isolation of Primiero forced people to produce many goods locally, thus providing for a multitude of small handicraft businesses.

Also the primary sector has faced a strong reduction of employees since the 1960s, reaching a minimum of 4% of active population in 2001. Even if tourism development has offered off-farm income sources and local markets for specialty products, it has also increased the opportunity costs of agricultural employment, thus 'pulling' labour force from the agricultural sector (Scalet, 1984). However, agriculture still plays a major role in the local economy, as it contributes to the attractiveness and environmental quality of the region.

3.3.5 Agriculture

The development of Primiero's agricultural sector since the 1960s has been tightly coupled with the growth of tourism in the area. While the more lucrative tourism business was subtracting labour force to agriculture, the primary sector did not collapse but progressively specialized in livestock farming, catching the opportunities offered by a quality-oriented local market. However, tourism demanded not only typical agricultural products, but also the aesthetic, recreational, didactic, cultural 'by-products' of traditional farming. Hence, the survival of local agriculture represented and still represents a necessary pre-condition for the success of tourism. Nowadays, the strong economic integration of agriculture with the tourism industry ensures a certain stability of agricultural structures in the area, even though it creates a situation of vulnerability arising from the more recent signs of crisis in the tourism sector.

Tourism development has not fully preserved local agriculture from structural change and land desertion (tab. 15). In the last 30 years, Transacqua lost almost 20% of its farms and over 40% of its usable agricultural area. As Scalet (G., 1984) notes, the marked reduction of usable agricultural land is related not only to farm abandonment, but also to the conversion of arable to grassland, to active afforestation of marginal land, and to a conspicuous urban development in the valley floor. However, the low value of non-utilized agricultural land registered in the last census (only 11,4 ha) indicates that the process of land abandonment has considerably slowed down.

From a structural point of view, comparatively small farm sizes dominate the agricultural scene. Excluding the largest land owner from the calculation (the municipality), average farm size was 6,0 ha usable agricultural land in 2000, with 38,5% of farms cultivating more than 5 ha land. Even though Transacqua's average farm is considerably bigger than Trentino's average farm (+1,8 ha), the dominance of grassland relativizes this advantage, as the economic productivity of grassland is significantly lower than that of intensive crop land (Pohl, 1996). Additionally, the high degree of property fragmentation and dispersion makes the rational use of fodder resources particularly difficult, thus further increasing production costs (Scalet, M., 1984).

Dairy farming represents the focus of local agriculture (99,9% of usable agricultural area is grassland). Transacqua counts 21 cattle farms with an average size of approximately 20 cattle units. Interestingly, the average number of cattle units per farm increased by only 137,8% in the last 30 years compared to a provincial average of 563,0 %. The number of cattle units per hectare usable agricultural land is fairly low (0,8) and only slightly increased between 1970 and 2000 (+33,3%). These data show that despite the economic pressure on farm enlargement and intensification Transacqua's dairy farming maintains small scales as well as a medium level of intensity. Besides the physio-geographic and climatic limits on intensification and the unfavourable land property structures, the integration with the tourism industry might co-explain such situation. In particular:

- Primiero's dairy farmers are organized in a cooperative producing traditional cheese and other milk derivates which are sold locally to both residents and tourists. This allows to keep the economic value of agricultural production at the local level and to achieve higher prices through quality products.
- Primiero's tourism sector offers additional income sources to the farmer and his/her family through agro-tourism on the farm (e.g. bed & breakfast, restaurant) and/or off-farm job opportunities in commerce and services (Scalet, G., 1984).

As to the APPIA register, a considerable share of Transacqua's ISTAT farmers (30,8%) are registered as full-time farmers. Part-time farmers make out 18,5% of ISTAT-farms, while the remaining 57,3% can be considered as hobby farmers. Note that hobby farmers and small land owners play a particularly important role for the preservation of Transacqua's traditional landscape as they maintain complex landscape mosaics through a minimum degree of disturbance (mowing) on small grassland plots around old haylofts and rural buildings in the countryside.

4. Materials and methods

4.1 Materials

For the purpose of the present work, landscape change was analysed comparing the 2006 orthophotograph Terraitaly-it2006 with the geo-referenced black & white aerial photograph from the year 1973 (Autonomous Province of Trento) and the aerial photogramms of the IGM-Istituto Geografico Militare[37] from the year 1954 (tab. 16). This material was provided by the Department of Urban Development and Environment of the Autonomous Province of Trento and was available with a 100% coverage for the three case study communities Lomaso, Terragnolo, and Transacqua.

As Bender et al. (2005) note, a state of the landscape which represents the traditional land use system should be the starting point of diachronic landscape analysis. Since European landscapes reached their highest degree of diversity in pre-industrial times, data originating from the 19th century (e.g. cadastral maps) should be included (Antrop, 1997; Tappeiner et al., 2006). However, comparability and quality of data source are of great importance with this respect. Even though an extensive land use map of Trentino is available for the year 1856 (*Culturenskelettkarte* of the Austrian Empire), its comparability with more recent orthophotographs is limited, due to their intrinsically different nature. In particular, aerial photographs allow a much more detailed analysis of landscape change, as they visualise actual land cover at the time of data acquisition and provide an extensive record of features on the ground (presence or absence of landscape objects such as trees, hedges, walls etc.; Lillesand et al., 2007).

Note that the time span considered (1954-2006) covers the salient steps of the transition from a traditional landscape to a ‘modern’ one. In fact, the cultural landscape of Trentino’s mountain areas was still characterized by traditional land use systems in the 1950s, as the industrial revolution had not affected these areas in a considerable way yet (Gorfer, 1987; Sarzo, 2006). Only in the subsequent decades the rate of socio-economic change accelerated to an unprecedented level, thus deeply transforming existing landscape patterns.

Tab. 16. Overview of the data used for visual image interpretation

Year	Material	(nominal) Scale	Coverage
2006	Colour ortophotograph	1:10.000	100%
1973	black & white aerial photograph	~ 1:25.000	100%
1954	black & white aerial photograph	~ 1:25.000	100%

[37] Military Geographic Institute

Additionally, following GIS material was used:

- official community boundaries of Lomaso, Terragnolo, and Transacqua
- digitalized road network including main, secondary, and forest roads
- digital terrain model 10x10 meters.

4.2 Methods

A diachronic landscape analysis was performed in the three case study communities Lomaso, Terragnolo, and Transacqua following the repeated aerial photograph approach proposed by Tasser et al. (in print). In particular, land use and landscape structure were mapped through visual image interpretation on the 2006 orthophotograph and subsequently changed and adapted by superimposition over the geo-referenced 1973 and 1954 aerial photographs (Integrated-Layer-Model; Brandt et al., 2002; Griffth et al., 2003; Schmidt, 2007; Van Doorn & Bakker, 2007). Field trips to the case study communities and informal conversations with local actors corroborated the results of visual image interpretation and reduced the risk of misevaluation.

In a successive step, data from image interpretation were analysed. The spatial and temporal patterns of land use and landscape structure change in the three case study communities were examined and compared. Furthermore, land abandonment (1954-2006) was mapped and its natural and spatial drivers investigated. Specifically, statistical models were elaborated in order to identify the relative contribution of different drivers (slope, altitude, aspect, distance to forest edges, distance to roads, distance to buildings, distance to inhabited areas) to agricultural land desertion.

In order to perform these tasks, three main softwares were used, namely ArcGis 9.2 for visual image interpretation, OriginPro 7.5 for descriptive statistics, and StatGraphics 5.1 for geo-statistical modelling. The following section is dedicated to a detailed description of the methods applied.

4.2.1 Visual image interpretation and landscape indicators

The basic problem of aerial photograph interpretation is that its results strongly depend on the interpreter, i.e. on an intuitively thinking subject (Förster et al., 2000). This is particularly true when image interpretation involves the delineation of the boundaries between areas of different type, as for example in land use mapping. Since these boundaries do not always correspond to discrete edges, but rather to fuzzy edges or gradations, the result is necessarily arbitrary (Lillesand et al., 2007). Additionally, the classification system adopted as well as the minimum mapping unit considered strongly influence the outcome of the interpretation process. In this respect, the lack of 'right', standard norms and methods for image interpretation and land use mapping further hinders the meaningful comparison of results from different research works (Kalke, 2000).

For the purpose of the present thesis, the method proposed by Tasser et al. (in print) for diachronic landscape analysis in alpine areas was applied. This method has been developed at the European Academy of Bolzano (Italy) in cooperation with the University of Innsbruck (Austria) and identifies indicators for the description of present and past landscape change dynamics. It has been already implemented at the community level in several parts of the Alpine bow (Schellenberg, 2002; Rieder, 2004; Stoinscheck, 2004; Schmidt, 2007), but not yet in Trentino. Therefore, its adoption guarantees a certain degree of comparability with other case-study communities in the European Alps and allows the present work to be a further piece in the Alp-wide puzzle of landscape change mapping.

Present landscape patterns and their change over the last 50 years were described by means of two indicators: land use and structural type. These indicators were digitalized for the entire territory of the case-study communities as vector data, starting backwards from the 2006 orthophotograph to the 1973 and 1954 aerial photographs. The reference scale was 1:10.000 and the minimum mapping unit 40.000 m^2 (4 ha), which correspond to 2cm x 2 cm on the 1:10.000 map.

Land use

The indicator 'land use' relates to the human activity or economic function associated with a specific piece of land (Lillesand et al., 2007). It provides information about type, intensity, and heterogeneity of human influence on the territory. As it also includes agricultural land use in its different forms, the indicator allows the analysis of the historical evolution of agriculture at the landscape level.

Tab. 17. Coding system used to classify land use (source: Tasser et al., in print)

code	class	land use
1	1	forest
	2	forest mixed 5-25%
	3	forest mixed 25-50%
2	1	ligneous crops
	2	ligneous crops mixed 5-25%
	3	ligneous crops mixed 25-50%
3	1	arable
	2	arable mixed 5-25%
	3	arable mixed 25-50%
4	1	grassland
	2	grassland mixed 5-25%
	3	grassland mixed 25-50%
6[38]	1	urban area
7	1	non usable area

[38] The code number 5 would refer to the unused agricultural area but was not considered in the present analysis.

Table 17 provides an overview of the coding system proposed by Tasser et al. (in print). The definition of land use is based on the assumption that a piece of land can be either fully dedicated to one use (single land use) or to interlocked uses (mixed land use). Land use is single when the share of other land uses is lower than 5% of the considered surface area (class 1), otherwise it is mixed. Mixed land use is further differentiated into two classes: class 2 (the share of other land uses is comprised between 5% and 25%) and class 3 (the share of other land uses is comprised between 25% and 50%). Figure 22 shows a visual example of this classification approach.

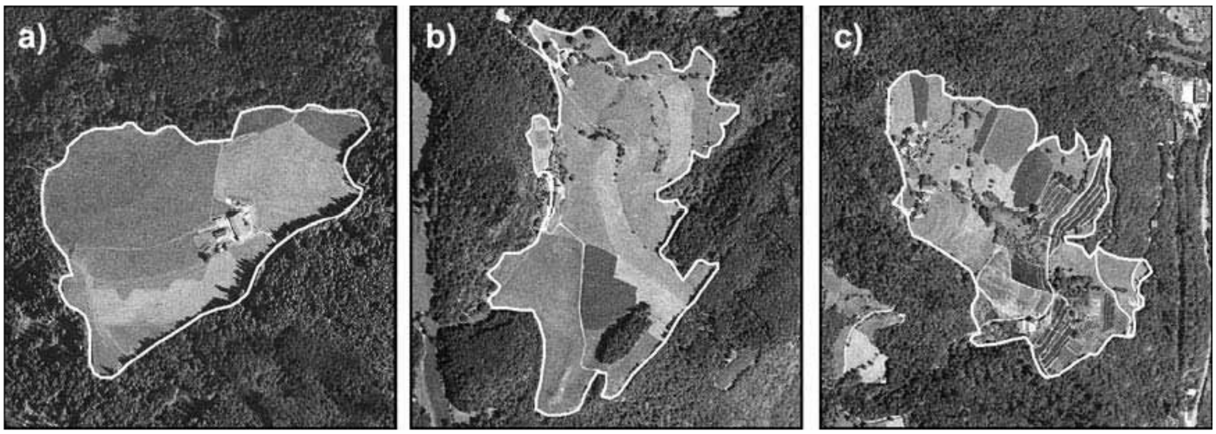


Fig. 22. Homogeinity and heterogeneity of agricultural land use: grassland example; **a)** grassland (4-1); **b)** grassland mixed 5-25% (4-2); **c)** grassland mixed 25-50% (4-3); source: Tasser et al., in print, s.p.).

Structural type

Besides the heterogeneity of land use patterns, the structural complexity of a landscape is another important indicator of its quality. For instance, structural elements such as groups of trees, hedges, and gravel areas increase the ecologic diversity of the landscape and create habitat and species rich landscape mosaics (Streeter et al., 1985). Additionally, the structural traits of a piece of land provide meaningful information about the degree of human disturbance and its evolution (Hoisl et al., 1992; Mühlenberg & Slowik, 1997; Weinstoerffer & Giradin, 2000). In particular, intensification and rationalisation of agricultural land use in traditional rural landscapes are normally associated with a simplification of landscape structures. Similarly, extensive land desertion and forest re-growth on former agricultural land negatively affect landscape quality, even though land abandonment leads in the early succession phases to an increase in structural complexity through bush vegetation and young trees.

For the purpose of the present analysis, the definition of structural types is based on the classification system developed by Tasser et al. (in print; fig. 23 and 24). The degree of structural complexity is expressed as the absolute number of structural elements (bushes, trees, hedges, rock outcrops, moors, etc..) in the area considered. Contiguous elements (e.g. trees of a hedge) are not counted separately but form one structural element. Again, the minimum mapping unit is 40.000 m^2. If the area considered is much larger than the minimum mapping unit, structural elements are counted in random plots within the area. The arithmetic mean of the number of structural elements in the analysed plots can be considered as the degree of structural complexity of that area.

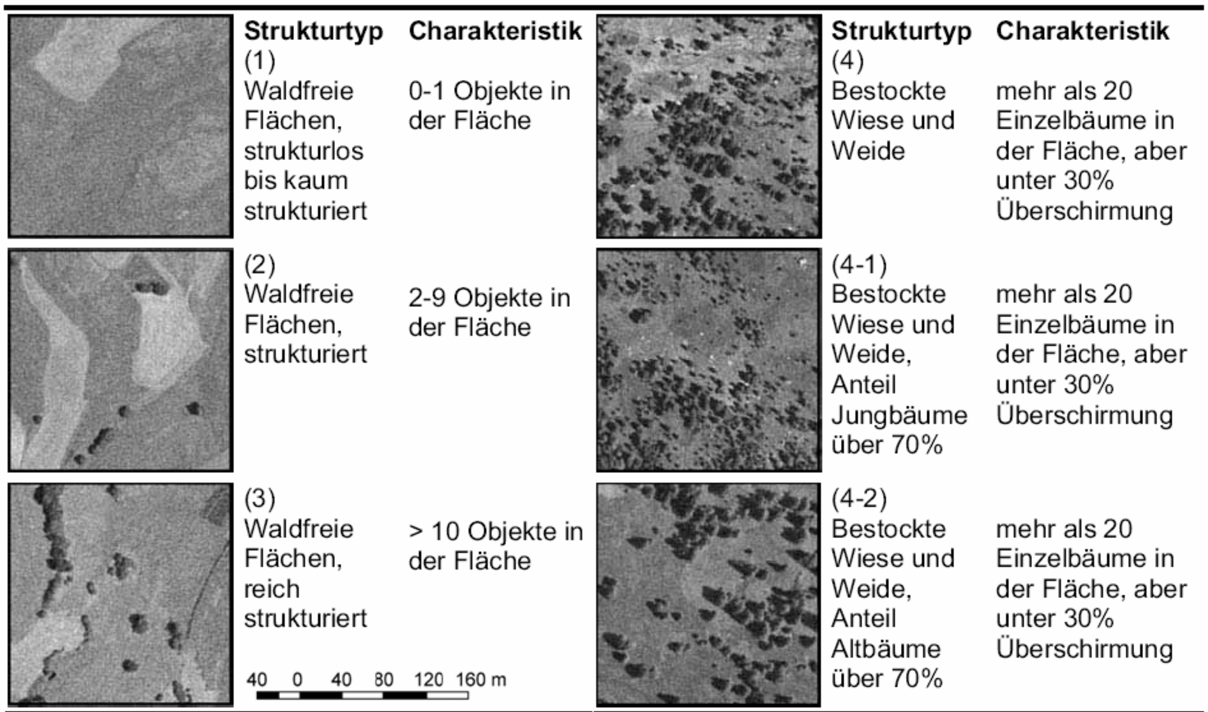


Fig. 23. Structural type classes of forest-free areas (source: Tasser et al., in print, s.p.).
Class 1: forest-free, structure-less and poorly structured areas, 0-1 structural elements in the area
Class 2: forest-free, structured area, 2-9 structural elements in the area
Class 3: forest-free, highly structured, 10 and more structural elements in the area
Class 4: scattered tree areas, more than 20 single trees in the areas but tree cover under 30%
equal share of old and young trees: 4-0
more than 70% young trees: 4-1
more than 70% old trees: 4-2

Extensive and monotone gravel areas, glaciers, and artificial river beds are classified as ‘poorly structured’ (class 1), while high altitude rocks, small screes, natural river beds and banks are considered as ‘highly structured’ areas (class 3). Areas with more than 20 single trees and a tree cover under 30% are classified as ‘areas of scattered trees’. They are further differentiated into three sub-classes according to the share of young and old trees. If young trees dominate (over 70%), the area is likely to be abandoned agricultural land (class 4-1). However, recent avalanches, Christmas tree nurseries, and forest stands damaged by wind might also belong to this class. On the contrary, old trees normally dominate traditional agro-silvo-pastoral systems such as larch pastures (*Waldweiden*) or meadows with scattered fruit trees (*Streuobstwiesen*, class 4-2). Intermediate areas with an approximately equal share of young and old trees are classified separately (class 4-0).

Finally, forests are defined as areas with a tree cover over 30%. Tasser et al. (in print) distinguish thin (tree cover between 30% and 70%) and thick forests (tree cover over 70%).

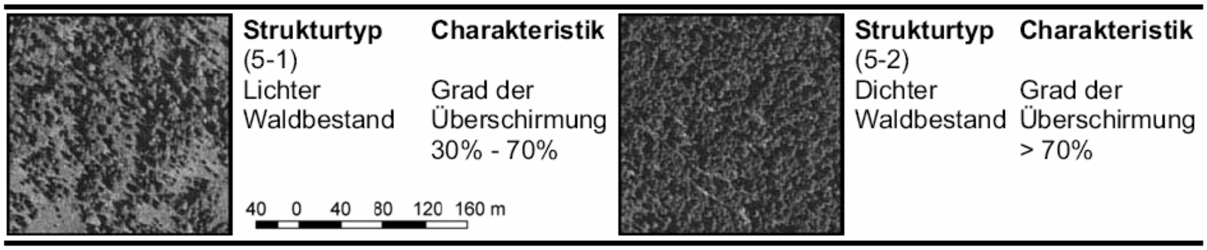


Fig. 24. Structural type classes of forested areas (source: Tasser et al., in print, s.p.).
Class 5-1: thin forest, tree cover between 30% and 70%
Class 5-2: thick forest, tree cover over 70%

Note that the indicator 'structural type' allows the identification of an array of small habitats and land uses that could not be considered by the indicator 'land use' due to the minimum mapping unit of 4 ha.

4.2.2 Data elaboration

Landscape regions

Aggregate data on the development of land use and landscape structure at the community level do not fully express the potential of the diachronic analysis performed. As the dynamics of landscape change are extremely heterogeneous within each community, the community area was subdivided into landscape regions (according to Tasser et al., in print). These are defined as repetitive, homogeneous landscape units resulting from the combination of bio-abiotic factors with human land use and human activities (agriculture, housing, infrastructure development, etc.; Schmidt, 2007).

The 'landscape region approach' has a twofold advantage. On the one side, landscape change is analysed in further detail within the community considering the diversity of physio-geographic factors and different intensities of human influence and disturbance. On the other side, the comparison of landscape dynamics between the respective landscape regions of different communities becomes possible.

The landscape regions were identified as follows:

- the cultivated valley floor, the cultivated lower slope region, and the high altitude pasture region were delimited with the help of the digital terrain model (slope and altitude) and considering the land use patterns of the 'reference landscape' of the year1954;

- the submontane, montane, and subalpine forest belt were determined in each community according to the respective literature, thus contemplating the different climatic conditions of the three case study communities;
- the alpine zone (which occurs in the only community of Transacqua) was defined according to the potential tree-line as mapped by the Forest Service of the Autonomous Province of Trento (PAT, 1992).

Figure 25 shows the spatial arrangement of the landscape regions in Lomaso, Terragnolo, and Transacqua. Table 18 summarizes the salient natural features of the landscape regions in the three case study communities.

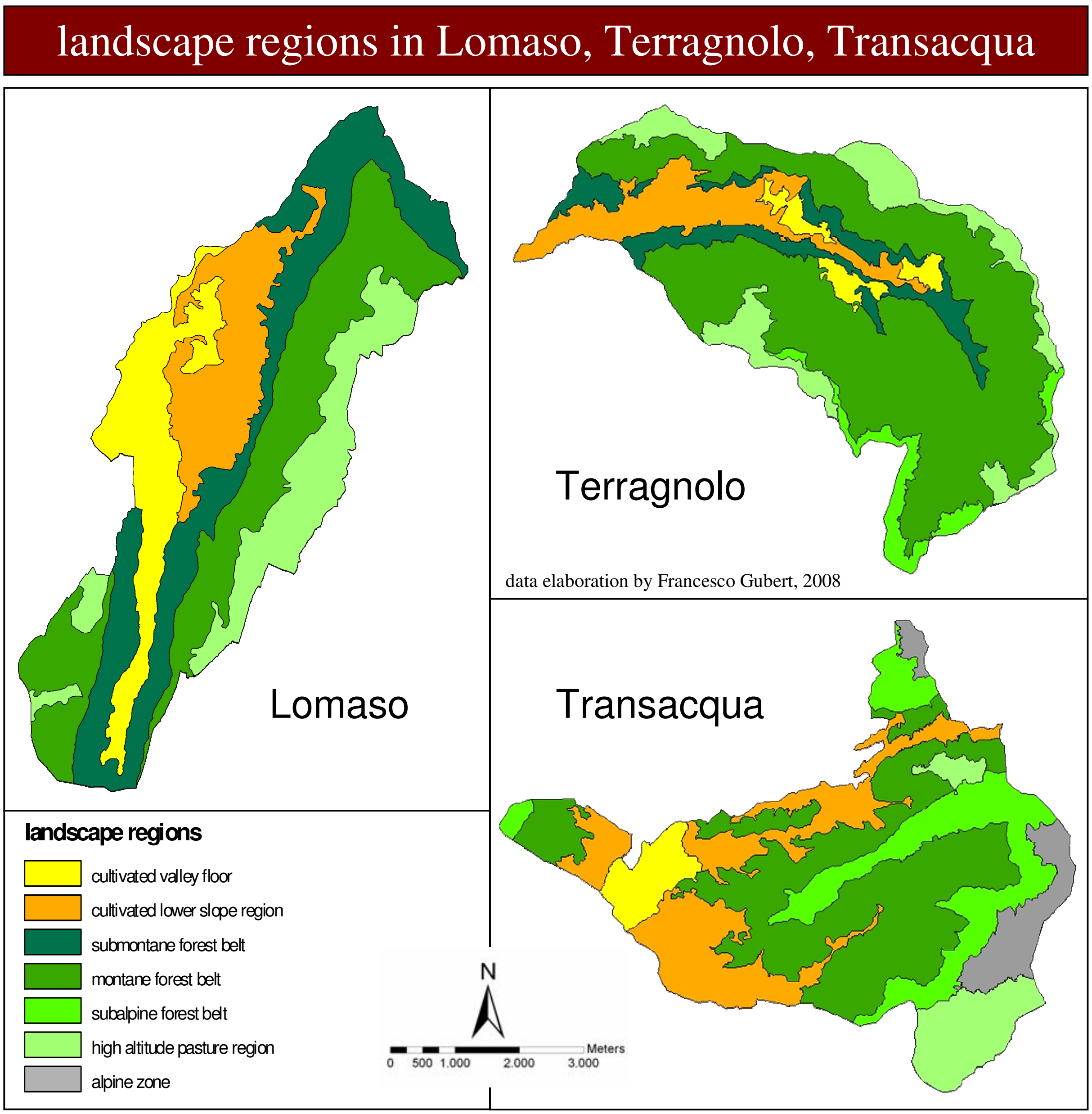


Fig. 25. Spatial delimitation of the landscape regions in Lomaso, Terragnolo, and Transacqua (own data elaboration).

Tab. 18. Landscape regions occurring in Lomaso, Terragnolo, Transacqua and their characteristics (altitude, slope, share of total area; own data elaboration)

landscape region	altitude (m asl)			slope (degrees)			share of total area (%)		
	mean value min - max								
	Lom	Ter	Tra	Lom	Ter	Tra	Lom	Ter	Tra
cultivated valley floor	**507** 382-679	**798** 655-1.088	**747** 683-840	**5,7** 0-47,1	**18,9** 2,8-42,9	**8,2** 0-34,3	15,5	3,5	4,6
cultivated lower slope region	**593** 377-856	**717** 347-1.221	**1.095** 706-1.586	**16,3** 0-49,9	**30,4** 0-64,8	**19,2** 0-53,3	14,7	11,4	21,3
submontane forest belt	**695** 296-955	**789** 429-1.026	**-**	**30,0** 0-82,3	**32,4** 0-69,9	**-**	25,6	9,7	-
montane forest belt	**1.136** 881-1.664	**1.187** 692-1.771	**1.340** 775-1.608	**29,2** 0-82,6	**35,2** 0-73,0	**30,8** 0-74,7	28,8	58,1	39,8
subalpine forest belt	**-**	**1.610** 1.486-1.861	**1.736** 1.552-2.014	**-**	**37,5** 1,4-69,3	**38,6** 0-77,6	-	4,6	18,3
high altitude pasture region	**1.341** 991-1.630	**1.527** 1.100-1.869	**1.665** 1.347-1.978	**18,1** 0-73,5	**24,1** 0-62,3	**27,0** 0-59,0	15,4	12,7	8,9
alpine elevation zone	**-**	**-**	**2.094** 1.758-2.500	**-**	**-**	**46,0** 1,1-81,5	-	-	7,1

The evolution of landscape patterns was quantified through the calculation of the surface area characterized by a particular land use or a particular structural complexity at both the aggregate and the landscape region level for each temporal step and each case study community. This allows a comprehensive comparison of landscape patterns between and within communities across the period 1954-2006. Surface area was calculated with the extension ET GeoWizard 9.7 for ArcGis 9.2 and refers to the true area of 3D surfaces.

Land abandonment

In the second step of data analysis, abandoned agricultural land was mapped at the community level. As in similar studies based on remote sensing data (Carriero & Wolynski, 2005; Kobler et al., 2005; Gellrich et al., 2007), natural forest re-growth on formerly used agricultural land was taken as proxy indicator for land abandonment. This indicator is easily measurable and observable through diachronic visual image interpretation, but does not provide information about more recent agricultural land desertion. In fact, there exists a considerable time lag between abandonment of agricultural use and natural forest regeneration. According to Baur et al. (2006), a period of 1-3 decades is necessary for shrubs and trees to re-occupy former agricultural land, depending on natural conditions and local vegetation dynamics. Hence, observed land abandonment refers to a large extent to agricultural land deserted until the 1980s and 1990s. More recent fallow land is not included in the present analysis.

Abandoned land was identified by comparing the landscape structures observed during visual image interpretation on the 1954 and 2006 aerial photographs under consideration of existing landscape structure patterns. In particular, all agricultural areas which changed from 'forest free' (tree cover under 30%) to 'forested' (tree cover over 30%) in the period 1954-2006 were mapped as 'abandoned land'. Note that actively afforested agricultural land was included in the analysis as well. Agricultural land which remained forest-free was mapped as 'non-abandoned'. However, agricultural areas above the potential tree-line (as mapped by PAT, 1992) as well as unproductive land were not considered, as forest re-growth was the measure of abandonment. Consequently, a map of land abandonment could be drawn for each case-study community.

Geo-statistical approach

Geo-statistics refers to the statistical elaboration of spatial data. In the present work, available spatial data from the three case study communities were analysed with the aim to a) describe and compare the spatial characteristics of abandoned and non-abandoned agricultural land b) model the spatial determinants of agricultural land abandonment.

In order to describe and model land abandonment, a response (dependent) variable as well as a set of predictive (independent) variables were defined. The response variable selected is binary and refers to the presence or absence of forest re-growth on agricultural land between 1954 and 2006, as proposed by Gellrich et al. (2007).

As to the set of predictive variables, the basic hypothesis was that land abandonment is related to the cost/benefit-based management decisions of landowners, i.e. that land abandonment occurs where cultivation costs are high and yield potential is low (Rutherford, 2006; Gellrich et al., 2007). Hence, the variables selected reflect the suitability of agricultural land for cultivation. In particular, they refer to the physio-geographic characteristics of the territory (slope, altitude, aspect) and to the spatial arrangement of agricultural land relative to natural and artificial landscape elements influencing land use (distance to forest edges, distance to roads, distance to buildings, distance to inhabited areas). They were selected according to existing literature on the drivers of agricultural land abandonment (Walther, 1984; Pezzati, 2001; Schellenberg, 2002; Bell et al., 2004; Kobler et al., 2005; Giupponi et al., 2006; Mottet et al., 2006; Gellrich et al., 2007; Van Doorn & Bakker, 2007; Bogner, 2008).

Table 19 summarizes the expected relationships between each of the explanatory variables and the response variable (expected sign). Altitude, aspect, and distance to forest edges were used as proxies for the yield potential of agricultural land. While yield potential was assumed to decrease with increasing altitude, the effect of aspect was not determined *a priori*. In fact, yield potential can be low on both sunny and shady aspects because of different limiting factors (water and temperature respectively). Agricultural land close to forest edges was expected to have less favourable cultivation conditions than land remote from forest edges (due to shade, woody plant seed rain, etc.). Hence, a negative relationship between the distance to forest edges and land abandonment was hypothesized.

The variables slope, distance to roads, distance to buildings, distance to inhabited areas were used as proxies for the cultivation costs. They express the ease of mechanisation of agricultural land and it accessibility by vehicles and on foot (Gellrich et al., 2007). The underlying hypothesis was that abandonment primarily occurs on land with high cultivation and accessibility costs (high slope steepness and long distance from roads, buildings, and inhabited areas).

Tab. 19. Overview of the variables selected to explain land abandonment and their characteristics

Predictory variable	**spatial resolution (m^2)**	**unit**	**expected sign[39]**	**calculation**
slope	100	degrees (°)	+	3D Analyst tool
altitude	100	meters above see level	+	DTM
aspect	100	degrees (°)	?	3D Analyst tool
distance to forest edges	100	meters	-	path distance
distance to roads	100	meters	+	path distance
distance to single buildings	100	meters	+	path distance
distance to inhabited areas	100	meters	+	path distance

Concerning data sources, slope steepness, altitude, and aspect were derived from the 10x10m digital terrain model (3D Analyst extension of ArcGis 9.2), and distances were calculated using the ‘path distance’ function (Spatial Analyst Tools of ArcGis 9.2), taking the digital terrain model as input surface raster. Distance to forest edges refers to the forest cover observed on the 1954 photogramms, while the digital road network was provided by the Autonomous Province of Trento and successively completed on the base of the 2006 orthofotograph. It comprises all asphalted and forest roads as well as tractorable gravel roads. Buildings were digitalized on the 2006 orthofotograph and include houses, haylofts, and sheds with a minimum base area of 16 m^2. Inhabited areas comprise agglomerates of houses with a minimum surface of 1 ha and less than 25% non-sealed area (Schmidt, 2007).

[39] The expected sign refers to the expected relationship between the dependent variable and the explanatory variables: (-) negative, (+) positive, (?) undetermined.

For the purpose of geo-statistical analysis, spatial data on the dependent and independent variables were extracted from the map of land abandonment. First, vector data on ‘abandoned’ and ‘non-abandoned’ agricultural land were converted into 10x10m rasters. Subsequently, each raster cell was assigned one value for the dependent variable and one value for each of the independent variables.

As to the dependent variable, each raster cell in which forest re-growth had occurred between 1954 and 2006 was attributed the value 2 (‘abandoned’), while raster cells with no forest re-growth were assigned the value 1 (‘non-abandoned’). As to the independent variables, both ‘abandoned’ and ‘non-abandoned’ raster cells received a value for slope steepness (degrees), altitude (m asl), aspect (north=0°, east=90°, south=180°, west=270°), distance to forest edges (m), distance to roads (m), distance to buildings (m), and distance to inhabited areas (m).

In the first instance, the data extraction process allowed to extensively describe and compare the spatial characteristics of ‘abandoned’ and ‘non-abandoned’ agricultural land within and between the three case-study communities. This purely descriptive statistical exercise was performed with the help of the software OriginPro 7.5, which can manage big datasets and easily plot them.

In a subsequent step, available geo-statistical data were used to model the spatial determinants of land abandonment. The software StatGraphics 5.1 was employed for this purpose. The linear regression approach, both monovariate and multivariate, was selected for statistical analysis (General Linear Model function of StatGraphics 5.1). Modelling occurred at 2 different levels. In particular,

- monovariate linear regressions allow to quantify what fraction of the observed abandonment can be explained by each single independent variable and to define the sign (positive or negative) and strength (slope of the line) of the correlation;
- multivariate linear regressions allow to quantify what fraction of the observed abandonment can be explained by the set of selected independent variables and to define the relative contribution of each variable to the explanatory power of the model.

The interrelation between land desertion and the explanatory variables identified was expected to significantly differ between the three case study communities due not only to differences in natural conditions and landscape patterns but also to the different evolution of agricultural and socio-economic structures in the last 50 years. In order to verify this hypothesis, the land-abandonment models of Lomaso, Terragnolo, and Transacqua were comprehensively compared.

5. Results and discussion

In the following, the salient results of diachronic visual image interpretation and geo-statistical analysis are briefly presented and discussed.

The chapter is subdivided into two major sections. In the first section, the spatial and temporal patterns of land use and landscape structure change in Lomaso, Terragonolo, and Transacqua are examined and compared over the period 1954-2006. Even though aggregate data at the community level provide a general overview of the main directions of change, they do not express the extreme heterogeneity of physio-geographic factors and disturbance regimes within each community (Schmidt, 2007). Hence, landscape dynamics are considered at the landscape region level as well, thus allowing a higher degree of spatial resolution.

In the second section, land abandonment and forest re-growth are quantitatively and qualitatively analysed, with a particular focus on the drivers of agricultural land desertion.

5.1 Landscape change at the community level

Figures 26-33 provide an overview of the patterns of land use and landscape structure change in Lomaso, Terragnolo, and Transacqua over the period 1954-2006. In the main, some common directions of change could be identified in the three case study communities, even if they were characterized by different intensities according to community-specific natural conditions and socio-economic dynamics. In particular:

- All three case study communities experienced a gradual increase of forested area (including forest both in single and in interlocked use) between 1954 and 2006. In Lomaso, forest cover increased by 547,0 ha (+19,0%), reaching 72,7% of total community area in 2006. Terragnolo gained 598,1 ha forest (+17,2%), the share of which exceeded 90% of total community area in 2006. The most moderate forest expansion could be observed in Transacqua, where forest cover increased by only 295,9 ha (+11,6%) within 50 years. Forest expansion was due to a large extent to natural forest re-growth on abandoned marginal and sub-marginal agricultural land, while active afforestation generally played a secondary role (Carriero & Wolynski, 2005).
- Arable land faced a marked reduction in all three communities. While arable farming totally collapsed in Terragnolo and Transacqua between 1954 and 1973, it maintained a significant share of usable agricultural area in Lomaso, thanks to more favourable geo-morphologic conditions and the development of intensive dairy farming systems (maize production). Arable land was either converted to grassland, or fully abandoned, or 'consumed' through

infrastructure and urban development, as it was normally situated in the vicinity of inhabited areas. Arable land conversion to grassland and the resulting increase in fodder availability in the valley floor boosted the abandonment of marginal grassland and forest expansion.

- Landscape structures underwent a generalized process of monotonisation and simplification at the aggregate level, with contrasting dynamics between and within the case study communities. In fact, the reduction of structural complexity in the examined landscapes could be attributed to one or more of the following processes: elimination of structural elements (edges, single trees, gravel areas, etc.) through intensification and rationalisation of agricultural land use, loss of structural richness through bush and forest re-growth on agricultural land, destruction of rural landscapes through soil sealing and infrastructure development. These processes occurred with different intensities and for different reasons within each community.

This first overview shows that the evolution of landscape patterns in Lomaso, Terragnolo, and Transacqua can be hardly generalised, as it was quite idiosyncratic and non-homogeneous. Therefore landscape changes are now considered at the landscape region level.

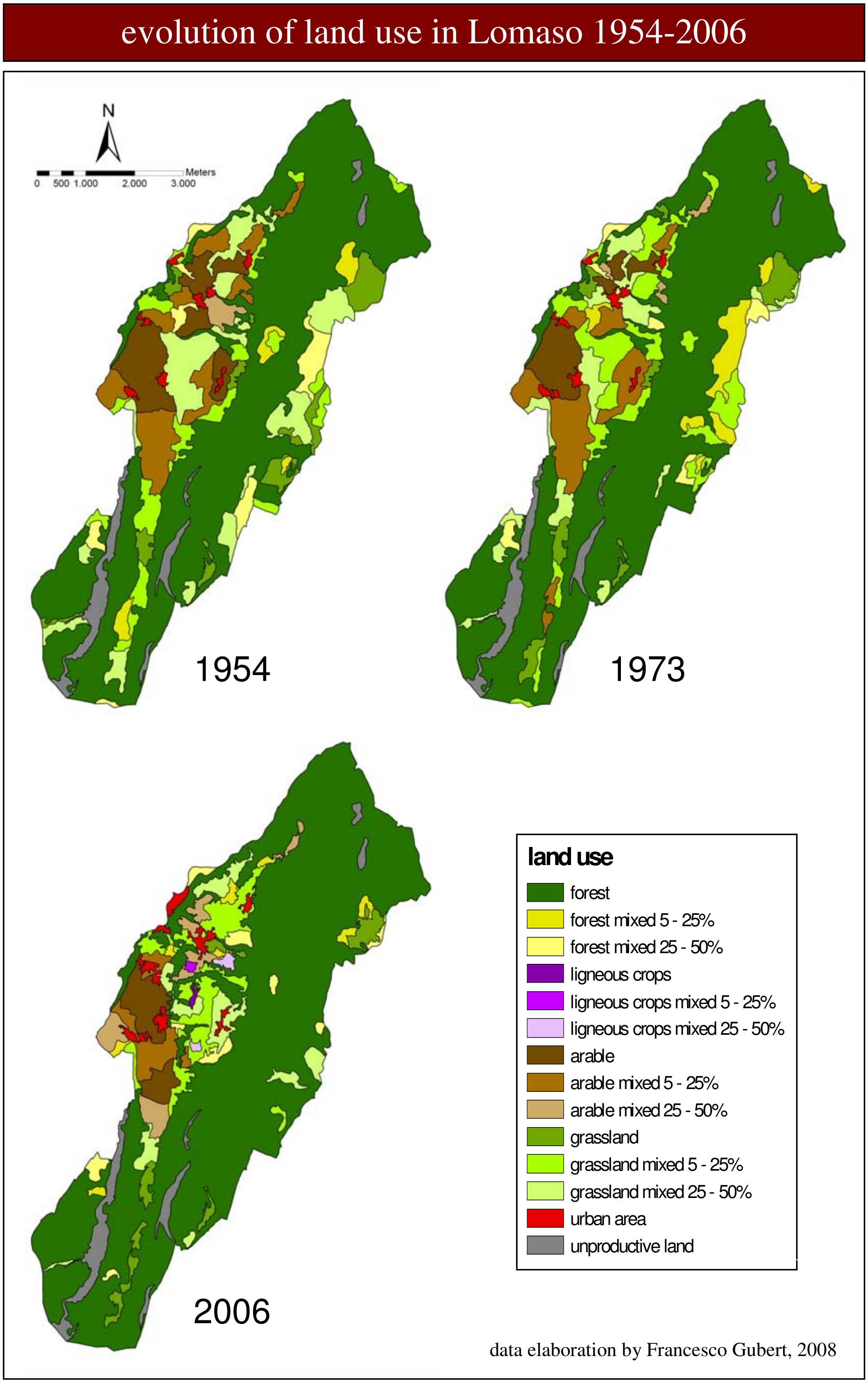


Fig. 26. Land use maps of Lomaso for the years 1954, 1973, 2006 (own data elaboration).

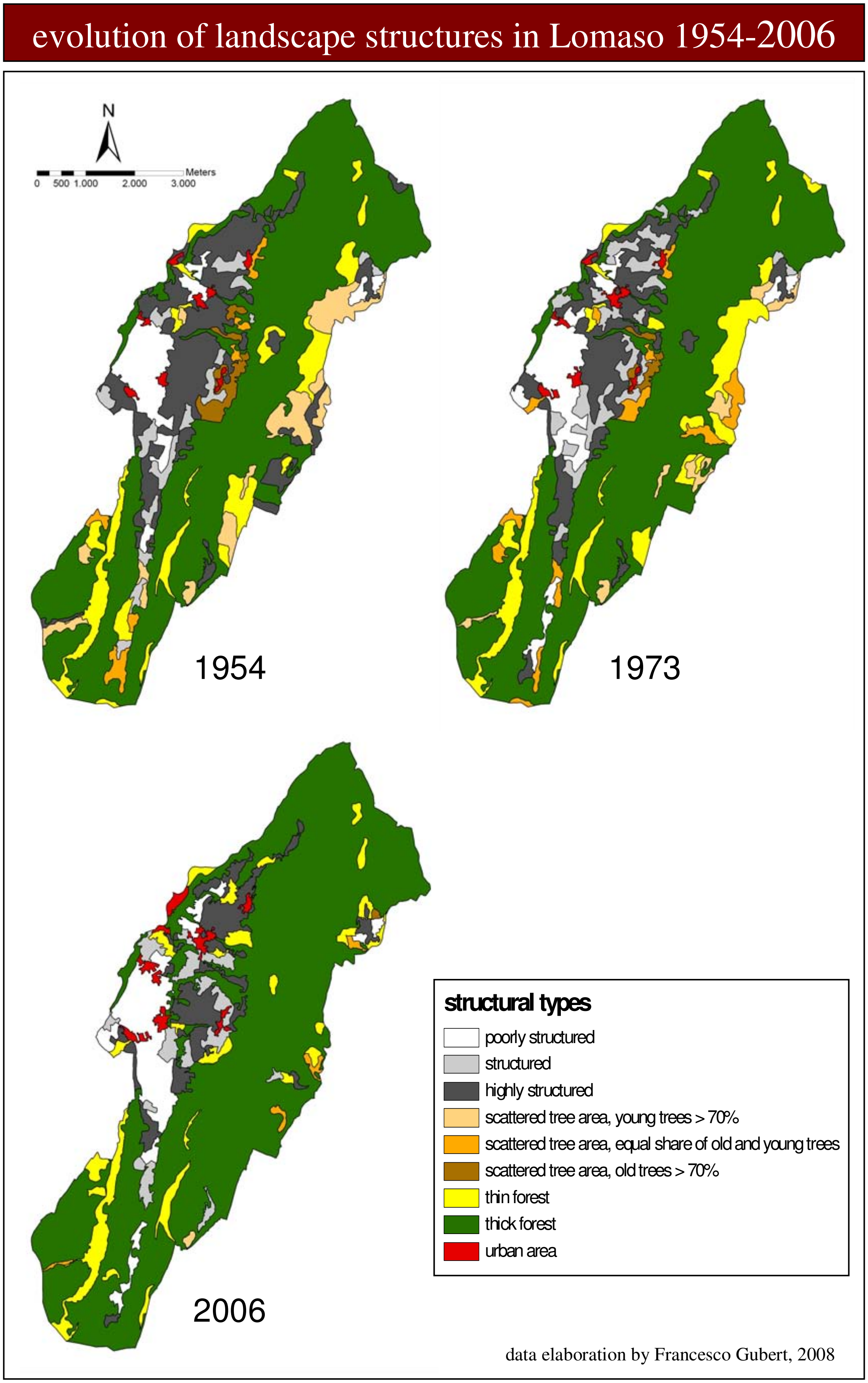


Fig. 27. Landscape structure maps of Lomaso for the years 1954, 1973, 2006 (own data elaboration).

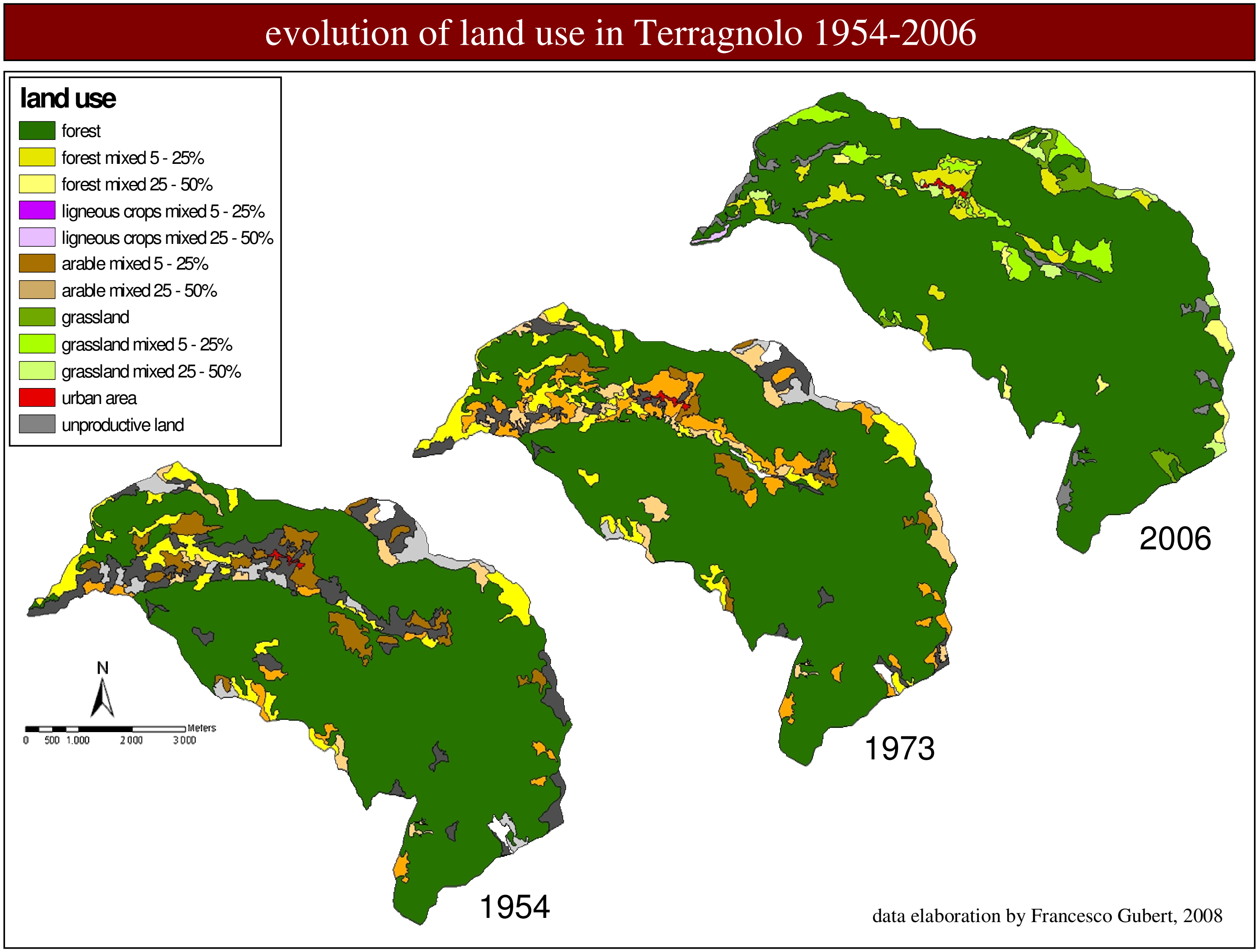


Fig. 28. Land use maps of Terragnolo for the years 1954, 1973, 2006 (own data elaboration).

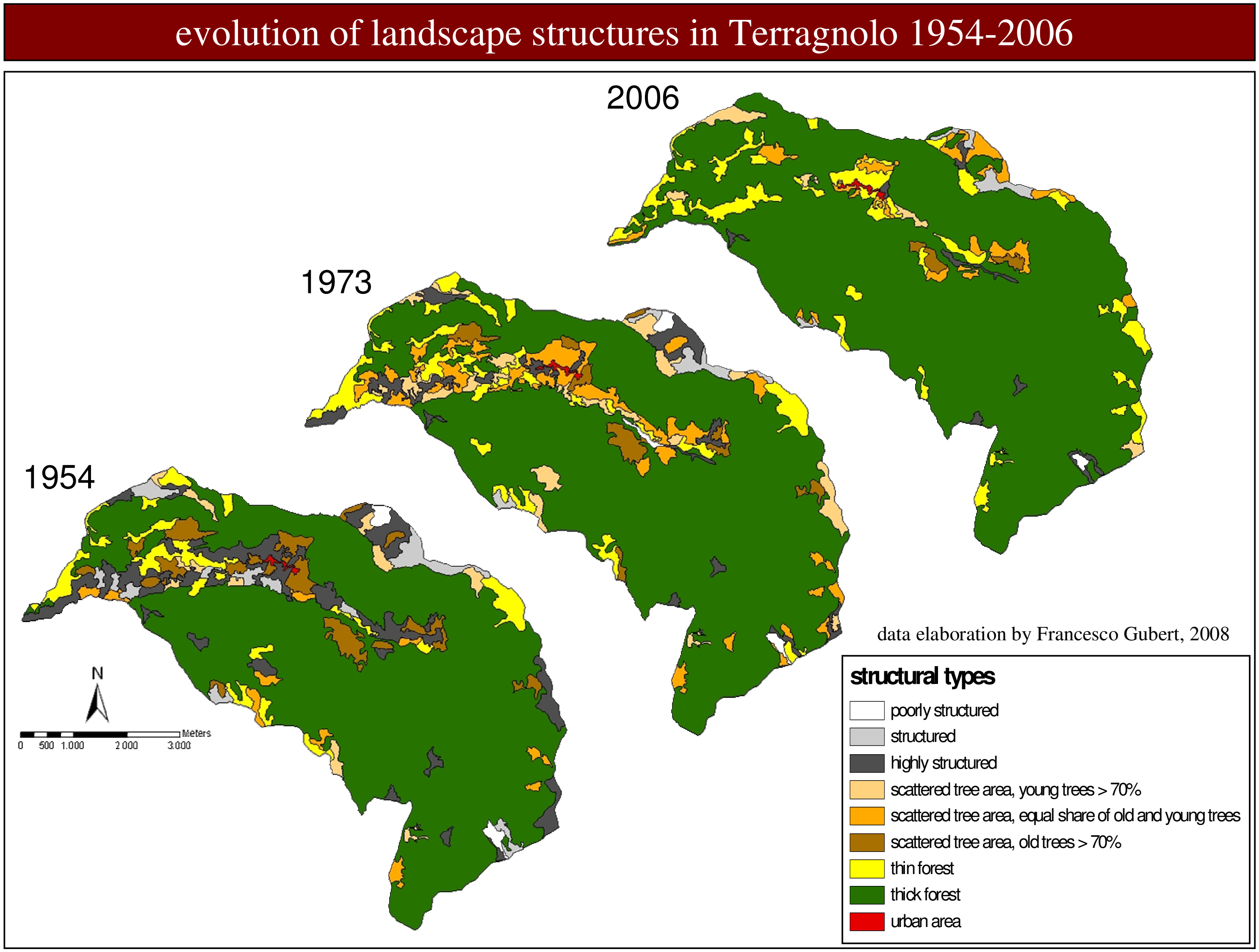


Fig. 29. Landscape structure maps of Terragnolo for the years 1954, 1973, 2006 (own data elaboration).

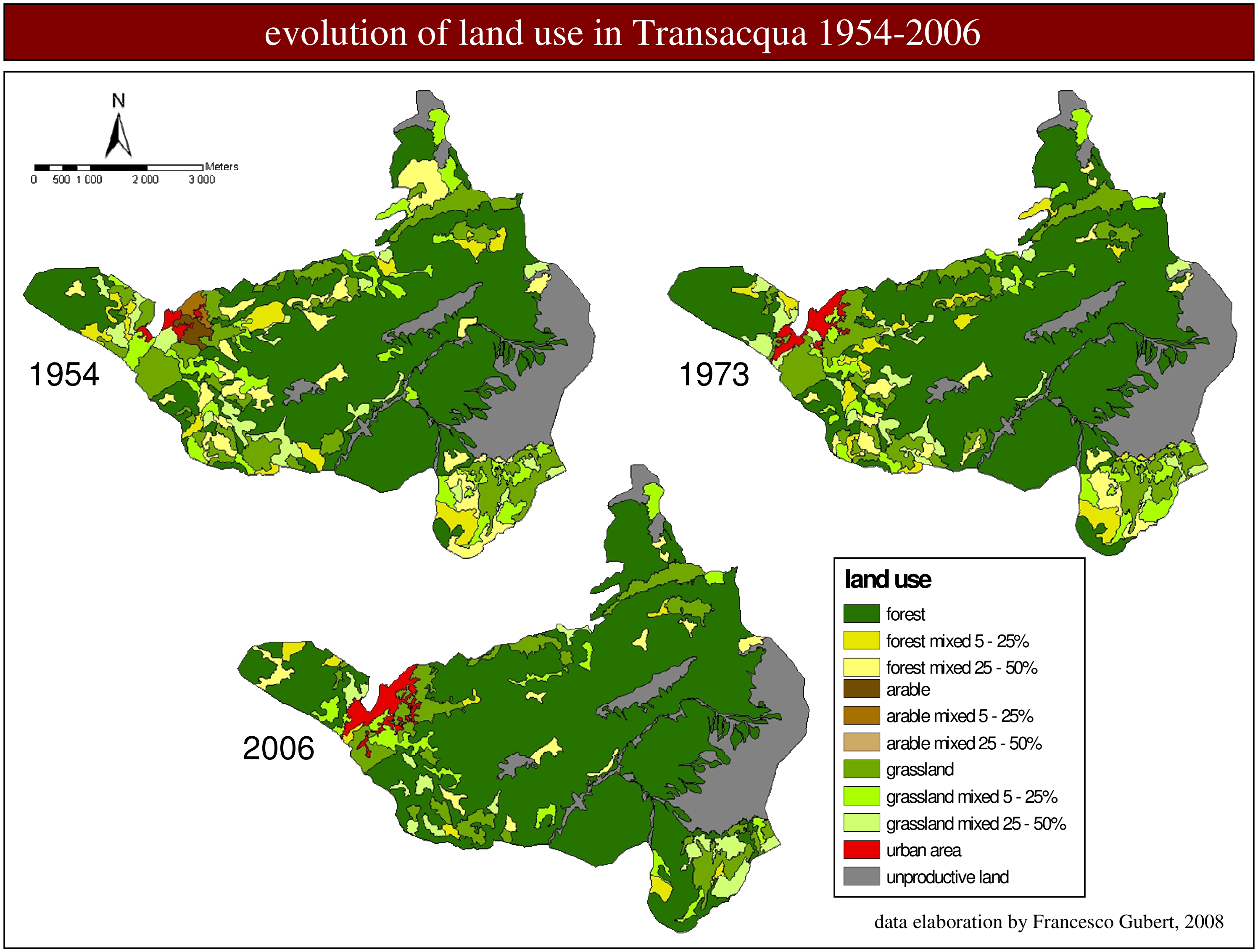


Fig. 30. Land use maps of Transacqua for the years 1954, 1973, 2006 (own data elaboration).

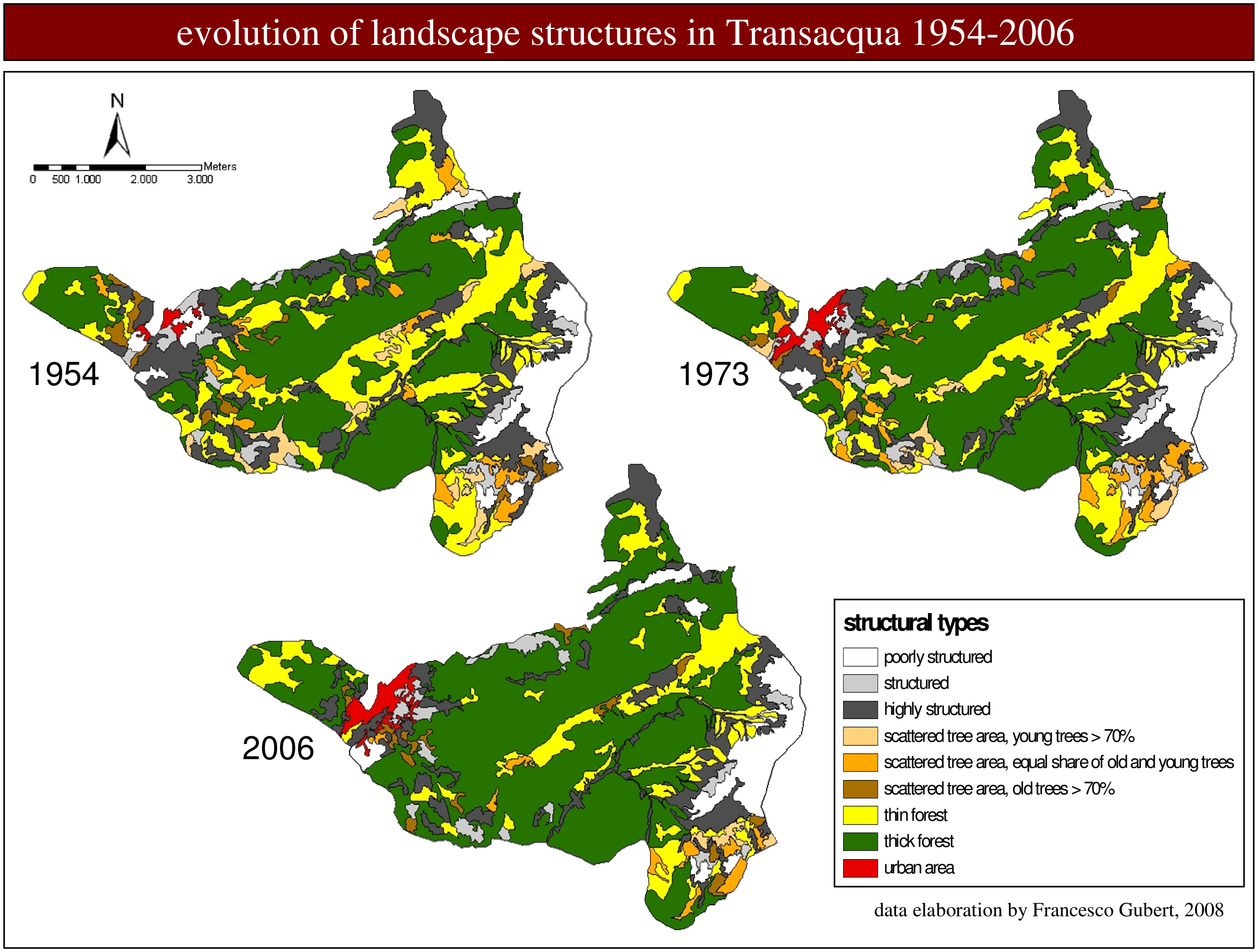


Fig. 31. Landscape structure maps of Terragnolo for the years 1954, 1973, 2006 (own data elaboration).

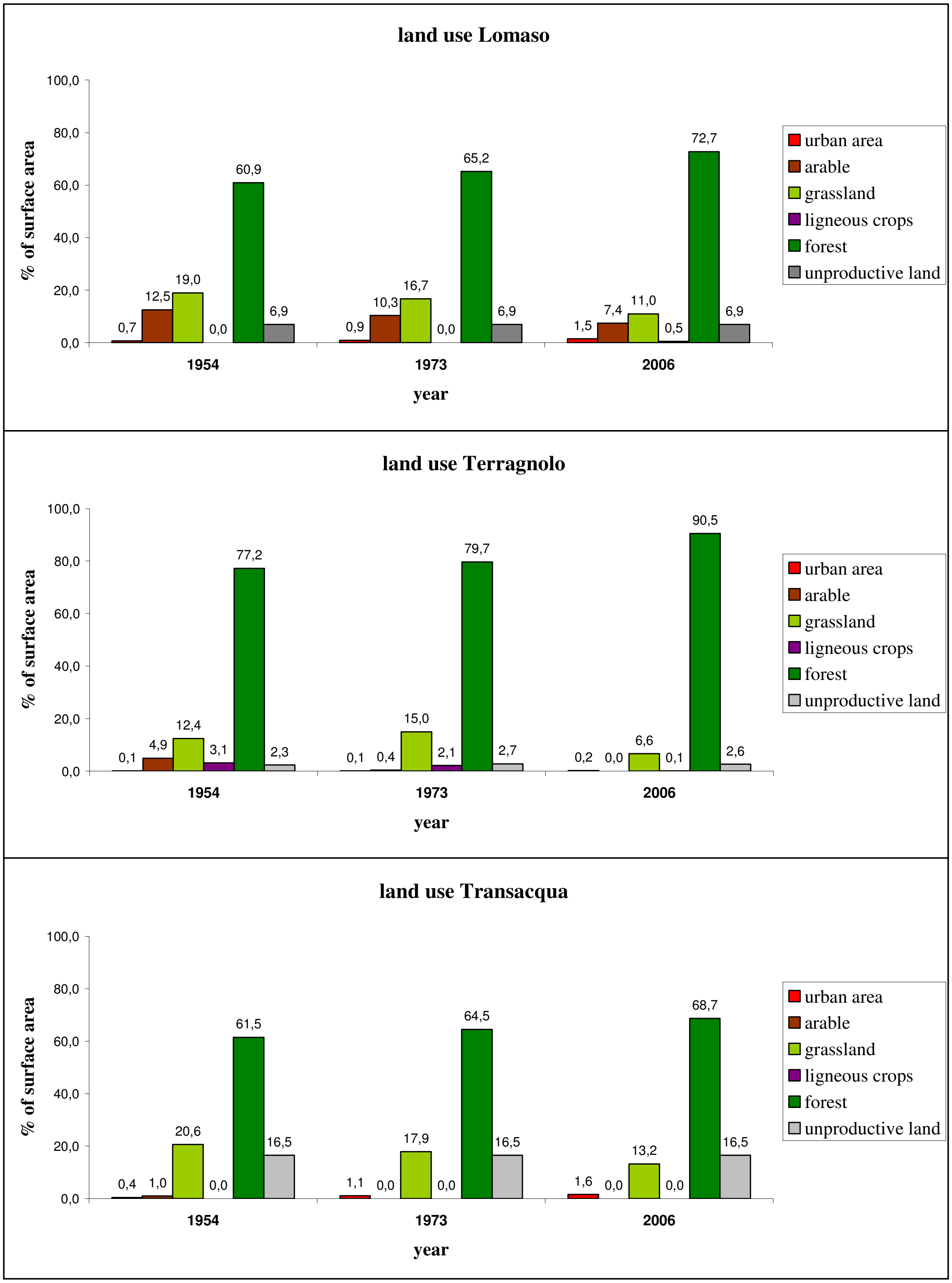


Fig. 32. Evolution of land use in Lomaso, Terragnolo, and Transacqua over the period 1954-2006.

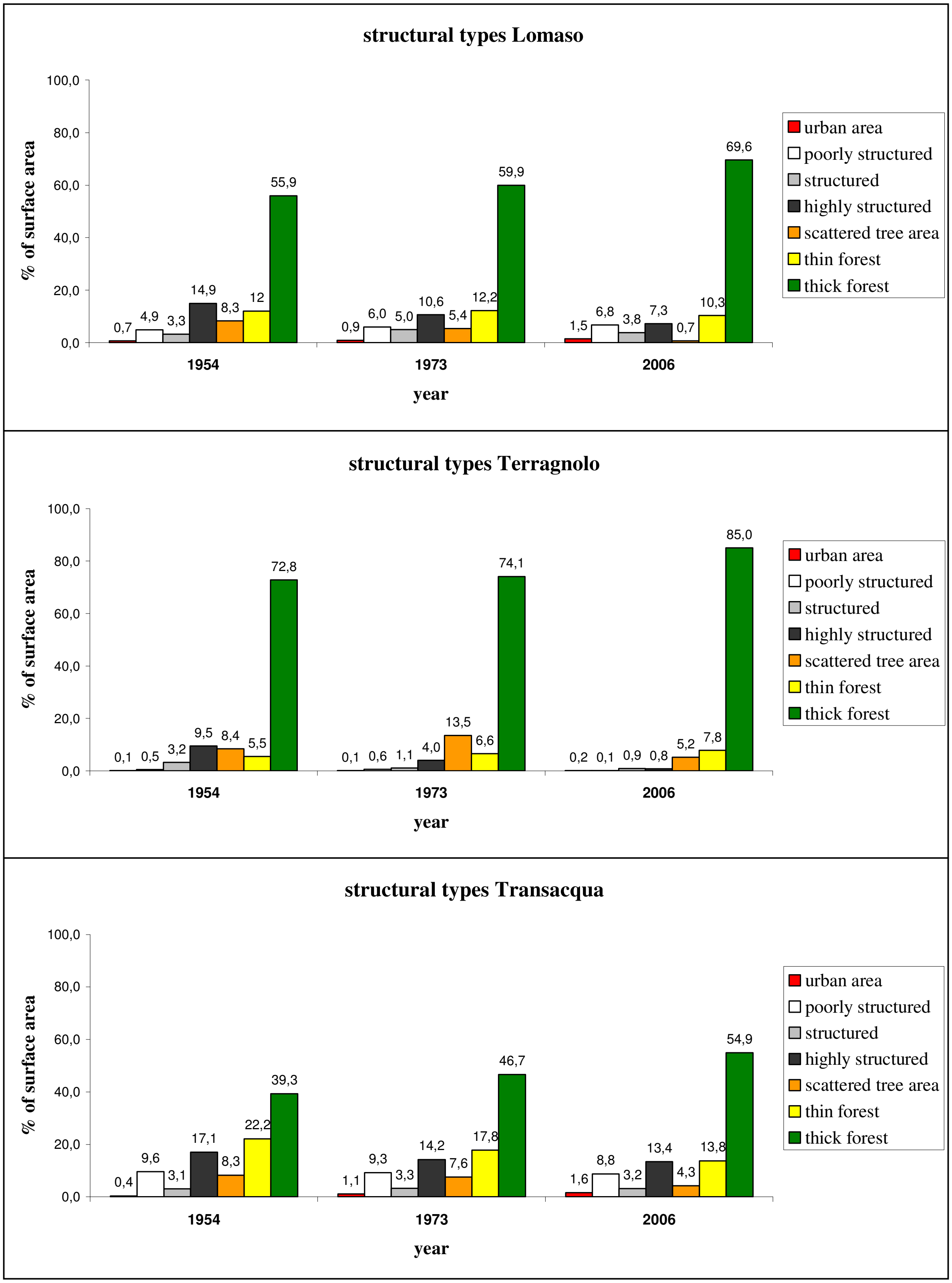


Fig. 33. Evolution of landscape structures in Lomaso, Terragnolo, and Transacqua over the period 1954-2006.

5.2 Landscape change in the cultivated valley floor

5.2.1 Landscape change in Lomaso's cultivated valley floor

Lomaso's cultivated valley floor is a wide, flat plateu with a surface area of approximately 650 ha (15,5% of total community area) and an average slope of 5,7 degrees. It is situated in the western part of the community between 382 and 679 m asl and is delimited by the terraced foot slopes of the Monte Casale to the East and the Sarca river to the West. Thanks to its favourable geo-morphologic, climatic, and edaphic conditions (brown soils and calcareous brown soils) this area is particularly suitable for arable farming and a wide range of arable crops, from potatoes and vegetables to wheat and maize.

Figure 34 shows the evolution of land use in Lomaso's valley floor between 1954 and 2006. The dominant form of land use was and still is arable land, which represented 57,9% of surface area in 1954 and subsequently decreased reaching 48,9% in 2006. This trend is only partly attributable to arable land conversion to other agricultural land uses (grassland and fruit orchards in particular). In fact, urban development around the hamlets Poia, Godenzo, Campo, Vigo, and Dasindo has mainly affected arable land in the surroundings of the old built-up areas. However, available data do show a tendency towards arable land conversion to grassland: arable land in sole use steadily decreased (from 32,2% to 20,2%), while grassland in sole use doubled (from 3,6% to 7,8%) between 1954 and 2006. Similarly, arable land in mixed use increased (from 25,7% to 28,7%), while grassland in mixed use significantly dropped (from 23,0% to 11,9%) in the same period (tab. 20). Note that the observed decrease of grassland in mixed use is also due to forest re-growth, which was particularly accentuated in the peripheral Lomasone valley and in the vicinity of the Lomasone peat bogs and marshes.

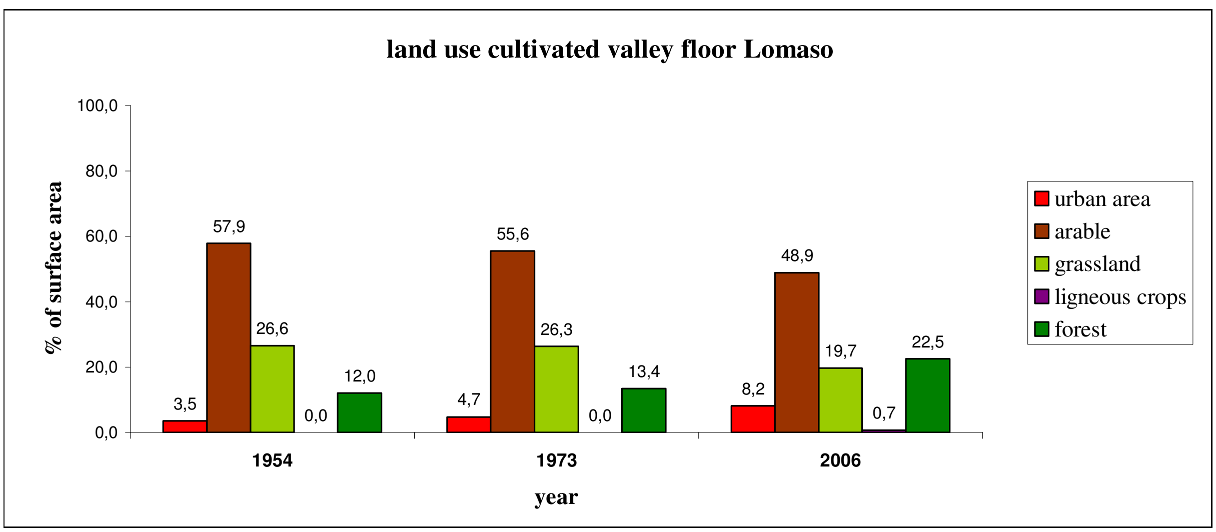


Fig. 34. Evolution of land use in Lomaso's cultivated valley floor over the period 1954-2006.

The patterns of land use change in Lomaso's valley floor are quite untypical with respect to the trends observed in Terragnolo and Transacqua and in other communities of the Alpine bow, where arable farming literarily collapsed in the 1960s (Rieder, 2004; Bätzing, 2005; Krismer, 2005). The reasons behind this evolution are manifold, but the exceptionally favourable natural conditions have surely played a fundamental role (Loose, 1983). While in other areas of the Alps arable farming was abandoned due to low productivity (e.g. raw climate) and unease of mechanisation (e.g. terraces), Lomaso's farmers could progressively intensify, rationalise, and mechanise arable land use in the valley floor following the example of their colleagues in Po plane. In particular, the introduction of guaranteed support prices in the dairy sector in the 1970s stimulated an ongoing process of specialisation in dairy farming, in the attempt to maximise milk production and minimize production costs (Loose, 1986). High-input systems were created, in which arable land became auxiliary to dairy farming as a source of high quality fodder (silo maize) and as a necessary 'nutrient disposal system'.

Note that, even though arable land has been maintained, its social and economic meaning has deeply changed. Before the 'green revolution', arable land represented the most important labour and food source for local people, who produced a variety of crops for themselves and for the market (Loose, 1986). In the 1930s, wheat, potatoes, and maize represented the major crops, followed by Lucerne, rye, barley, oats, hemp (ICS, 1934). Nowadays, the Lomaso's plateau is a continuous, irrigated maize field feeding 1.850 cattle units distributed among 23 intensive cattle farms. Besides some recently introduced fruit plantations (apples and cherries), just few potato fields still survive. Potato production has been steadily declining since World War II, in spite of the creation of a local cooperative of potato producers and the specialisation in seed tuber production (Dalponte, 1987).

The process of agricultural specialisation and intensification has deeply affected landscape structure patterns as well. As picture 35 shows, the degree of structural complexity significantly decreased between 1954 and 2006, with a particularly marked increase of structure-less and poorly structured land pieces (0-1 structural elements in the area; + 43,8%). In 2006, nearly half of Lomaso's valley floor could be classified as structure-less or poorly structured, whereas only 10,4% fell into the class 'highly structured' (10 and more structural elements in the area; - 67,7%). At the same time, scattered tree areas fully disappeared, as they were rapidly converted to forest through natural successional processes. In fact, the share of young trees in these areas was already fairly high in 1954. Note that the absence of newly formed scattered tree areas indicates a certain stability in today's landscape, as it reflects a low rate of recent land abandonment. Nevertheless, the share of thick forest more than doubled (+ 139,3%), reaching 18,0% in 2006.

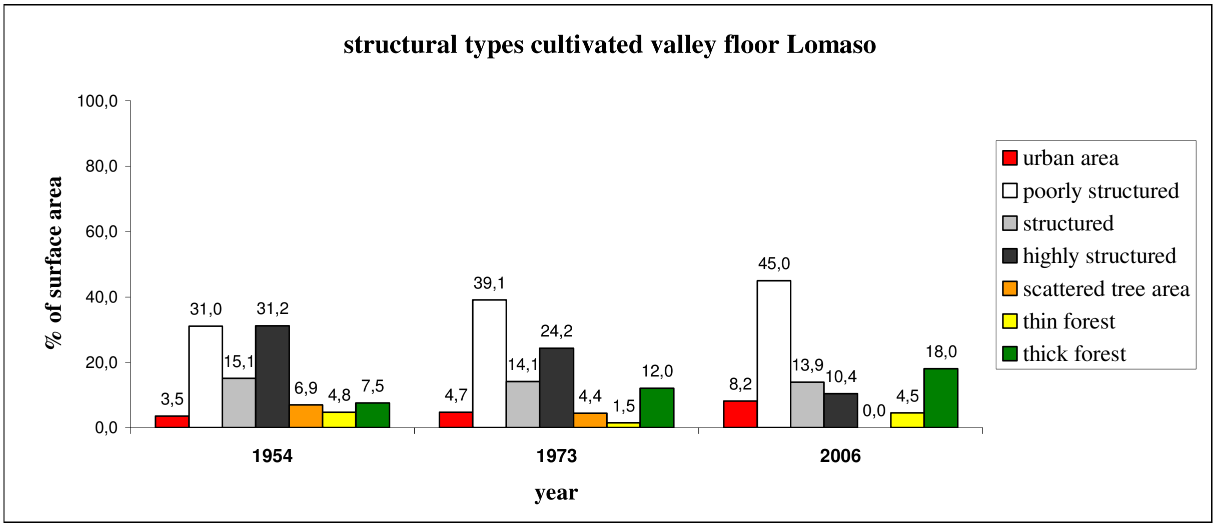


Fig. 35. Evolution of landscape structures in Lomaso's valley floor over the period 1954-2006.

As already mentioned, the structural traits of a piece of land provide meaningful information about the degree of human disturbance and its evolution. In particular, several authors report of a strong correlation between intensification of agricultural land use and simplification of landscape structures (Meuus et al., 1990; Hoisl et al., 1992; Burel & Baundry, 1995; Mühlenberg & Slowik, 1997; Hehl-Lange, 2001). Structural elements such as hedges or single trees, which characterize low intensity farming systems (Baldock et al., 1995), represent a hindrance to mechanisation and rational land management and are therefore progressively eliminated from intensively used agricultural landscapes. Not surprisingly, the reduction of structural complexity in Lomaso's valley floor is attributable to the elimination of single mulberry and fruit trees which traditionally marked the boundaries of land plots.

Even though the profitability and efficiency of farming practices increases with decreasing number of 'obstacles' in the landscape, the loss of structural complexity is detrimental to its ecologic stability and aesthetic quality. Specifically, structural elements enhance habitat and species diversity (Weber, 2003), represent important 'ecological corridors' in open landscapes (Mühlenberg & Slowik, 1997), protect soil from erosion, contribute to the regulation of water flows thus creating specific microclimates (Burel & Baudry, 1995), and enhance the recreational value of a landscape (Schacht, 2003).

5.2.2 Landscape change in Terragnolo's cultivated valley floor

From a morphological point of view, Travignolo's territory is traversed by a deep V-shaped valley running from East to West. The actual valley floor is extremely narrow and entirely occupied by the river bed. Therefore, the landscape region 'cultivated valley floor' does not include the geographic valley bottom but refers to the glacial terraces located South (Geroli, Pinterreno, Ghesteri) and North (Piazza, Puechem, Zoreri) of the Leno river. Even if these areas are characterized by more favourable geo-morphologic conditions relative to the rest of the territory, they are far from being flat and easily accessible. They represent only 3,5% of Terragnolo's total surface area and are situated between 655 and 1.088 m asl, with an average slope steepness of 18,9 degrees.

As figure 36 shows, land cover in Terragnolo's valley floor experienced revolutionary changes between 1954 and 2006. In particular, three phases could be identified.

- Collapse of arable farming: arable land, which represented the dominant land use in the 1950s (72,4%), dropped by 83,9% in the period 1954-1973, completely disappearing in the subsequent decades.
- Arable land conversion to grassland: arable land was converted to grassland or fallow land, the share of which nearly quadrupled between 1954 and 1973 (79,6% of surface area in 1973).
- Forest re-growth: abandoned land was progressively 're-conquered' by natural bush and forest vegetation. As a result, forested area jumped from 4,6% to 39,9% in the period 1973-2006.

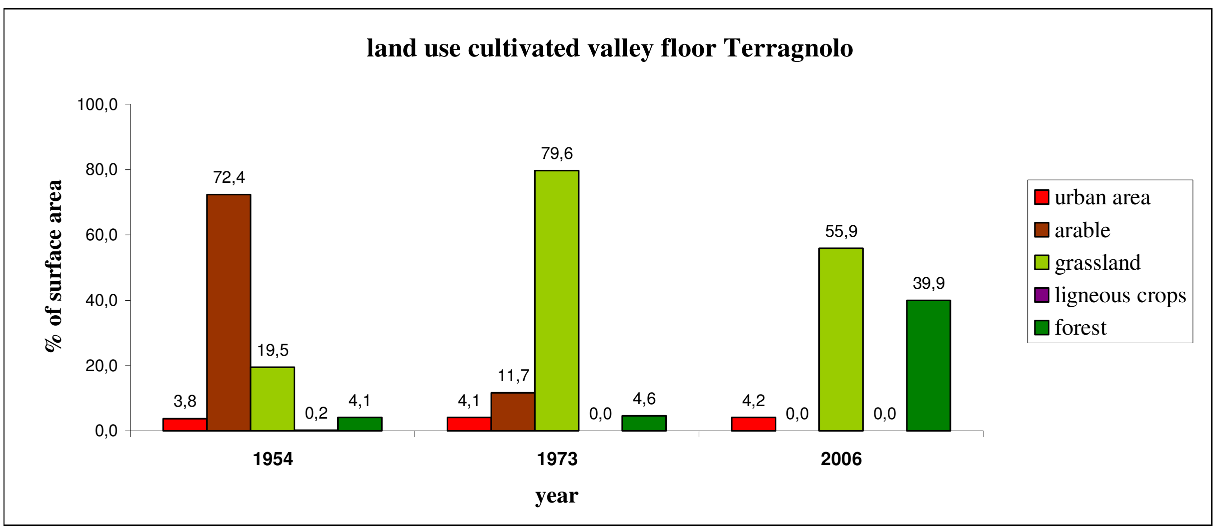


Fig. 36. Evolution of land use in Terragnolo's cultivated valley floor over the period 1954-2006.

The extremely fast evolution of land use reflects the structural collapse of Terragnolo's traditional subsistence farming and the total absence of new forms of modern and professional agriculture (Sarzo, 2006). As previously discussed, Terragnolo's agriculture has evolved in a completely different direction than Lomaso's agriculture. Unfavourable geomorphologic conditions, insurmountable limits to mechanisation, microscopic farm sizes as well as lack of specialisation options have impeded the transition to a modern agriculture in the area (Gios, 1990a). Land abandonment and landscape degradation have been the consequences, even in the vicinity of the built-up areas (picture 6).

Picture 6. Forest re-growth (left) and relicts of mixed farming systems (right) around the village of Zoreri in Terragnolo (pictures by the author).

The analysis of land use changes in Terragnolo's valley floor indicates a high degree of forest re-growth in the youngest period (1973-2006). This suggests that the antecedent conversion from arable land to grassland occurred in a passive way, as the first step of natural succession, rather than in a pro-active one (e.g. seeding of meadow or pasture vegetation). In fact, since livestock was dramatically declining, forage production was not a necessity. Due to the time lag between the cease of land use and the formation of a bush and forest stand, extensive land abandonment which occurred in the 1960s has become visible only in more recent times in the form of increased forest cover (Baur et al., 2006).

Table 20 shows that both arable land and grassland were traditionally cultivated in mixed form. As traditional farming was subsistence-based, each farm was designed as a self-sufficient, 'policultural' system (Bätzing, 2005). The terrace floors were cultivated with mixed crops, according to the principle that "un campo deve contener di tutto"[40] (Sarzo, 2006, p. 118). Mattevi (1957) calculated that in the 1950s each family in Terragnolo produced 30-40 kg barley, 70-80 kg rye, 60-70 kg wheat, 700-800 kg potatoes on average, held at least one milk cow (the average milk production per day and cow was of 10 liters), and owned some fruit and mulberry trees. Isolated fragments of these old productions systems are still visible around the hamlets of Zoreri, Campi, and Geroli (picture 6), even though the pressure of the surrounding forest vegetation as well as the high average age of local farmers make their next future predictable.

Regarding the evolution of landscape structures, a general trend towards monotonisation and simplification could be observed. In Terragnolo, however, the reduction of structural complexity

[40] "a field should contain everything" (translation by the author)

did not result from an intensification of agricultural land use but from extensive land desertion and forest re-growth. Besides the cultural and aesthetic loss related to the disappearance of traditional landscape mosaics (Glauser & Siegriest, 1997), extensive forest re-growth reduces a landscape's habitat and species diversity, thus negatively affecting its environmental quality and ecologic stability (MacDonald et al., 2000; Maurer et al., 2006).

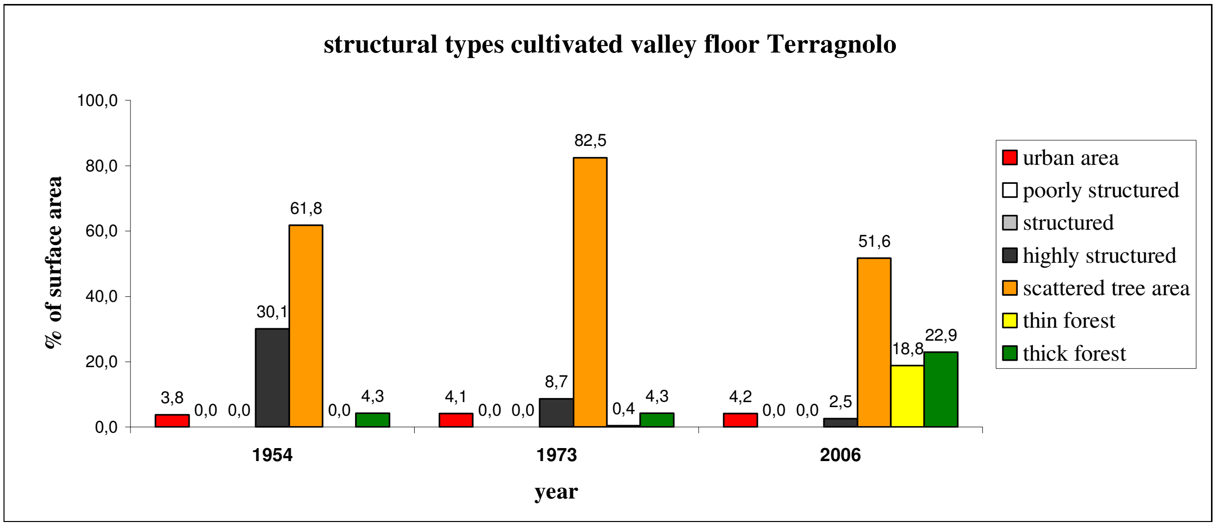


Fig. 37. Evolution of landscape structures in Terragnolo's cultivated valley floor over the period 1954-2006.

As figure 37 shows, Terragnolo's valley floor was characterized by an extremely high degree of structural richness in 1954, with 30,1% of surface area falling in the category 'highly structured' and 61,7% belonging to the class 'scattered tree area'. The high density of structural elements was due to the presence of single fruit trees scattered on arable plots and on grassland (*Streuobstwiesen*). Mattivi (1957) reports of approximately 200 cherry trees, 650 apple trees, 120 pear trees, 150 peach trees, and 510 nut trees disseminated through the Terragnolo valley in the early 1950s. Fruit was normally used for self-consumption and rarely sold to the market. Another economically relevant ligneous crop was the mulberry tree (silk production), which was present in policulture on 121 ha in 1929 (ICS, 1934). However, as silk production inexorabily declined between the two World Wars, mulberry trees experienced a significant reduction after World War II (Mattivi, 1957).

The process of extensive land abandonment which occurred in the 1950s and 1960s fundamentally transformed the old cultural landscape. The reduction of zoo-anthropic pressure to a mass inadequate for arresting successional processes boosted the development of young trees and bushes on formerly used agricultural land (increase of scattered tree are with equal share of old and young trees, tab. 21), resulting in a progressive increase of thin and thick forest area. In 2006, only 2,5% of Terragnolo's valley floor could be classified as 'highly structured', while the share of scattered tree areas with more than 70% old trees hardly reached 20% (61,5% in 1954). The comparatively high share of scattered tree areas with equal number of old and young trees (27,5%) and with more than 70% young trees (5,5%) indicate that forest re-growth is still on its way. Hence, a further increase of forest cover can be expected in the next decades.

5.2.3 Landscape change in Transacqua's cultivated valley floor

Transacqua's valley floor is fairly narrow (hardly 800 m of width) and is delimited by the steep slopes of the Monte Bedolè to the West and the more favourable foot slopes of the Monte Padella to the East. Its altitude ranges between 683 and 840 m asl, mean slope steepness reaches 8,2 degrees. In spite of very fertile soils of alluvional origin, this area is not particularly suitable for arable farming due to high annual precipitations and a raw climate. The same can be said for fruit farming. Hence, livestock and grassland farming basically remain the only options for local agriculture.

Fig. 38 sketches the evolution of land use in Transacqua's valley floor between 1954 and 2006. While the increase of forested area was fairly limited, arable land, which covered 23,1% of surface area in 1954, completely disappeared within two decades. Arable fields were partly converted to grassland, partly sealed through urban and infrastructure development. In particular, urban area experienced an exorbitant increased, as it nearly quadrupled in the period 1954-2006, at the full expenses of agricultural land.

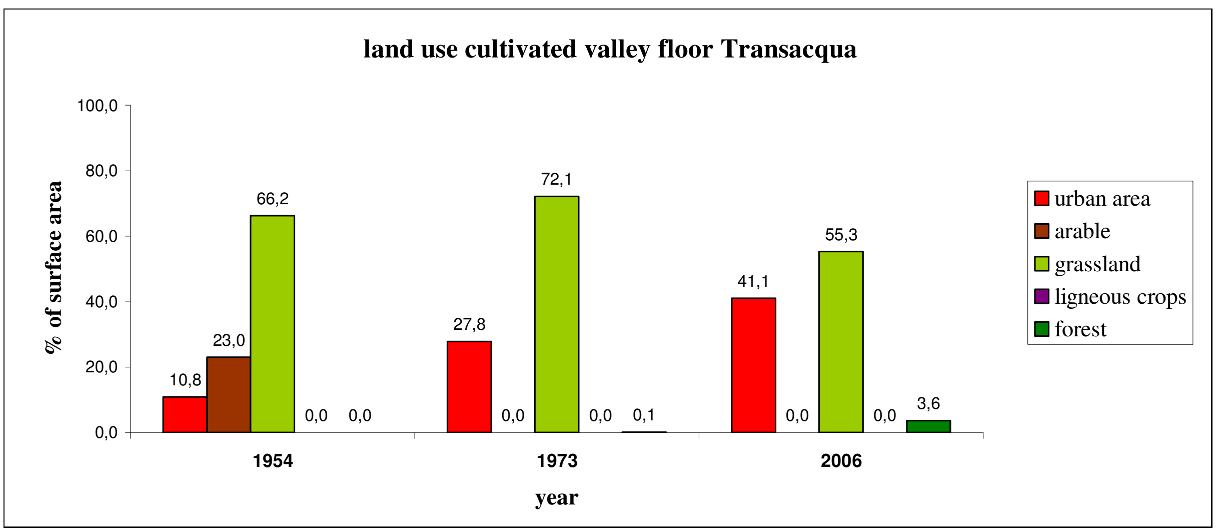
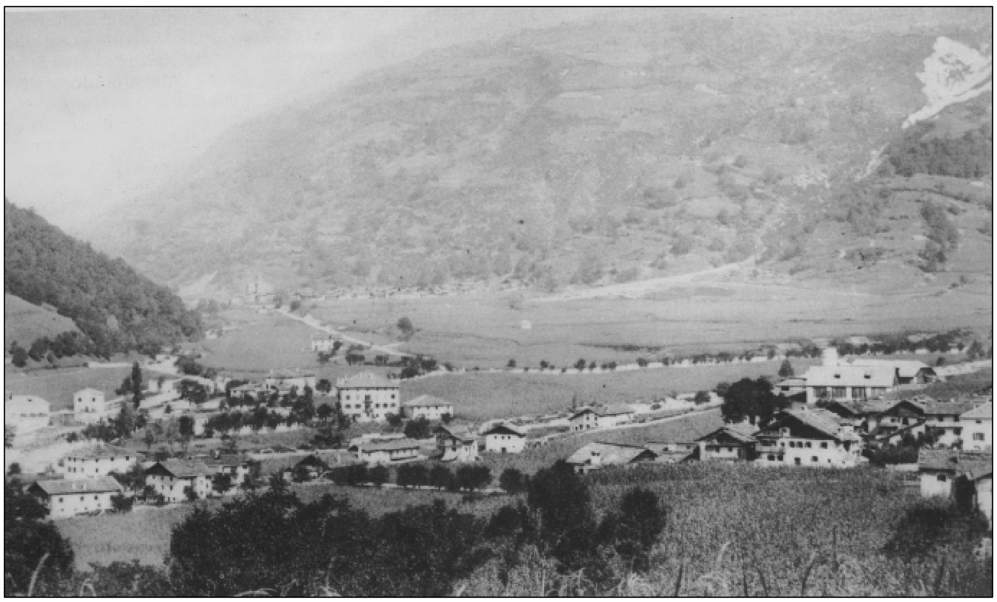


Fig. 38. Evolution of land use in Transacqua's cultivated valley floor over the period 1954-2006.

How can such extreme trends be explained? Until the 1950s Transacqua's economy was fundamentally based on subsistence agriculture. In fact, the geographic isolation of Transacqua and the Primiero valley in general forced people to differentiate their agriculture in order to cover local demands through local production. Arable land represented the major energy and material source for local population (Ruatti, 1919b). Maize, barley, rye, legumes, and potato dominated both the valley floor (picture 7). Hemp and linen were grown for the production of clothes and other utensils (e.g. ropes, sheets), and almost each family held some livestock for self-consumption (Scalet, 1984). The poorer held goats and sheep, the richer milk cows and bulls. Even scattered apples and plum trees could be found on sunny aspects in spite of the absolute unsuitability of Primiero's climate to such crops. As Gadenz et al. (1996) wrote, "the widespread welfare of the last decades which has fed the mass tourism, was still far off. The same valley bottom was the reign of the so-called 'rural civilisation', since most people were devoted to mountain agriculture and breeding, such a simple and poor economy which, however, was assuming a shape prevailing in the whole Dolomitic area" (p. 28).



Picture 7. Maize fields around the hamlet of Ormanico (right) in the first half of the 20th century (source: Brunet et al., 1984, p. 83).

In the 1960s, the economic boom of the near Venetian plane and the considerable improvement of the road network deeply transformed the socio-economic scenario. The high degree of mechanisation achieved by Venetian farmers made Primiero's agriculture totally uncompetitive, while the industrial development of the Venetian provinces boosted the growth of the tourism sector in the Primiero valley (Bettega & Marini, 1984). The immediate consequence of the growing tourism demand was urban and infrastructure development, which mainly consisted in the construction of 'second houses' in the open landscape, outside of the old built-up areas. The expansion of the construction sector created a strong pressure on agriculture to free labour force, the more so as farmers' life conditions were dramatically worsening due to loss of competitiveness and inadequate income (Scalet, 1984).

These processes grew stronger after the big flooding of 1966, which destructed large parts of the built-up areas and ruined the most fertile agricultural land. The urgency of re-construction on one side, and public incentives on the other, generated an unprecedented boom of the construction sector, in concomitance with an exponential increase of tourism flows (Bettega & Marini, 1984). Uncontrolled urban sprawl was the result: the most fertile and flat soils, which represented a scarce good in a valley like Primiero, were sealed, and the valley floor turned into a continuous urban agglomerate connecting the old hamlets (picture 8). In 2005, the community of Transacqua counted 11 hotels and 301 second homes, which accounted for 2.543 tourism beds (Savorelli et al., 2007)!

Picture 8. Growing competition between agricultural land use and urban development in Transacqua's valley floor; the red circles indicate the historic hamlets of Transacqua (right) and Ormanico (left), which are now united in an almost continuous urban agglomerate (picture by the author).

As to agriculture, the polarisation of economic activities around tourism went along with a deep restructuring of existing farming systems. Subsistence farming abruptly declined and was only partly substituted by hobby farming, as most shut-down farmers found employment in other economic sectors (construction and services *in primis*). Only some cattle farmers managed to gradually enlarge their farms and specialise in dairy production, thanks to favourable milk prices and local markets for specialty products (Scalet, 1984). Even though they maintained small structures and a medium degree of intensity, the ongoing reduction of usable agricultural land in the valley floor through urban development increased the production pressure on the remaining grassland, thus generating local phenomena of excessive nutrient loads.

Similar developments have been observed in other Alpine communities with high tourism density, where the valley floor has been extensively sealed at the expenses of 'top-quality' agricultural land (Leonardi, 2005; Bartaletti, 2008; Beritelli 2008). As Bätzing (2005) notes, tourism growth creates a direct and indirect pressure on agriculture to free land for construction purposes. On one side, tourists themselves need land for housing, services, and infrastructures (hotels, second houses, roads, car parks, tennis fields, etc.). On the other side, tourism development makes local population grow, thus further increasing land consumption through sealing. Besides the aesthetic and environmental problems related to extensive soil sealing and urban sprawl, the 'second house boom' in Alpine tourism resorts is detrimental to the quality of life (more traffic, more rubbish, more sewage), increases land and rent prices, thus excluding local population from immobiliar markets (Cortina-effect[41]), and irreversibly shrinks the 'agricultural corridor' between village and forest, forcing agriculture to a progressive retreat from the region (Gios, 1983; Nübel, 2008).

Concerning the evolution of landscape structures in Transacqua's valley floor, a high degree of structural complexity was maintained in the open landscape, in spite of the consistent urban development described above (fig. 39). The medium level of agricultural intensification as well as the interest in preserving a diverse and attractive landscape for local tourism might co-explain the relative stability of landscape structures on agricultural land. The slight increase of scattered tree area and forest cover is attributable to localized phenomena of land abandonment on steeper surfaces.

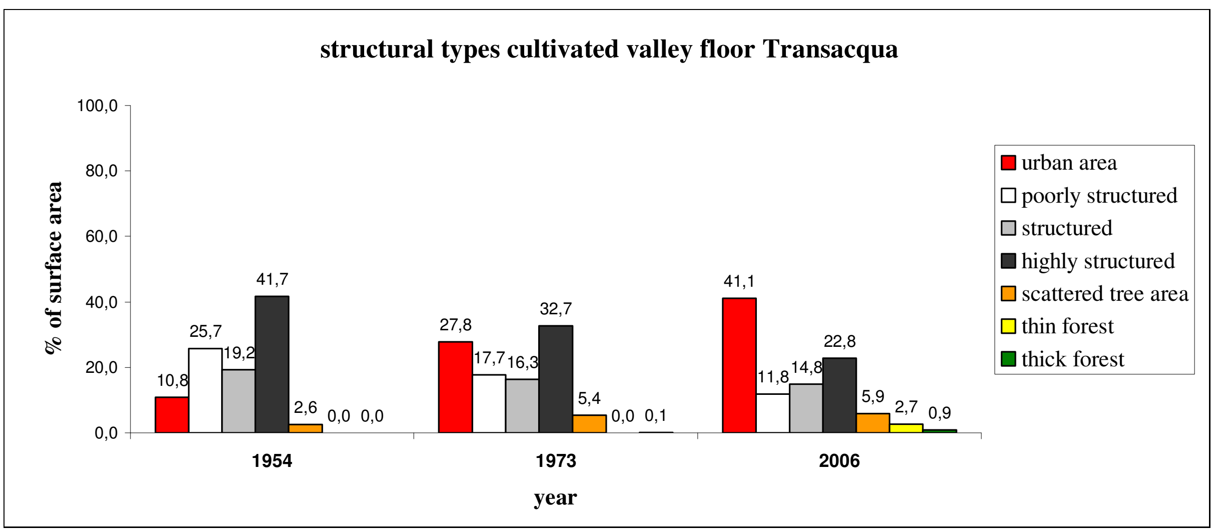


Fig. 39. Evolution of landscape structures in Transacqua's cultivated valley floor over the period 1954-2000.

[41] The so-called 'Cortina-effect' refers to a process of progressive migration of resident population from luxury tourism resorts to neighbouring villages because of excessively high house prices. Cortina, a very famous ski resort in the Italian Dolomites, has been steadily loosing residents since the 1970s (ISTAT, 2004) in spite of a booming tourism development.

Tab. 20. Sole/mixed land use in the cultivated valley floor of Lomaso, Terragnolo, and Transacqua in the years 1954, 1973, 2006 (percentage values)

	Lomaso			Terragnolo			Transacqua		
	1954	1973	2006	1954	1973	2006	1954	1973	2006
	% of surface area								
urban area	3,5	4,7	8,2	3,8	4,1	4,2	10,8	27,8	41,1
arable	32,2	21,7	20,2	0,0	0,0	0,0	12,9	0,0	0,0
arable mixed	25,7	33,9	28,7	72,4	11,7	0,0	10,2	0,0	0,0
grassland	3,6	8,3	7,8	0,0	0,0	2,6	44,8	58,4	41,9
grassland mixed	23,0	18,0	11,9	19,5	79,6	53,3	21,3	13,7	13,4
ligneous crops	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
ligneous crops mixed	0,0	0,0	0,7	0,2	0,0	0,0	0,0	0,0	0,0
forest	7,3	11,9	19,3	4,1	4,3	21,1	0,0	0,1	0,9
forest mixed	4,7	1,5	3,2	0,0	0,3	18,8	0,0	0,0	2,7
tot	100,0	100,0	100,0	100,0	100,0	100,0	100,0	100,0	100,0

Tab. 21. Composition of scattered tree areas by share of young and old trees in the cultivated valley floor of Lomaso, Terragnolo, and Transacqua in the years 1954, 1973, 2006

	Lomaso			Terragnolo			Transacqua		
	1954	1973	2006	1954	1973	2006	1954	1973	2006
	scattered tree area (ha)								
old trees > 70%	0,0	0,0	0,0	87,4	53,0	27,0	4,3	4,6	6,3
equal share of old and young trees	31,4	28,7	0,0	0,4	64,0	40,0	0,0	4,4	3,8
young trees > 70%	13,0	0,0	0,0	0,0	0,3	8,0	0,0	0,0	0,0
tot	44,4	28,7	0,0	87,8	117,3	75,0	4,3	9,0	10,1

5.3 Landscape change in the cultivated lower slope region

5.3.1 Landscape change in Lomaso's cultivated lower slope region

Lomaso's cultivated lower slope region represents 14,7% of total community area and covers the western foot slopes of the Monte Casale. It is situated between 377 and 856 m asl and has an average slope steepness of 16,3 degrees. From a geo-morphological point of view, this region is characterized by two ample plateaus (Comano and Lundo) located at higher altitude and separated from the valley floor by terraced slopes of medium slope steepness.

Figure 40 shows the evolution of land use in Lomaso's cultivated lower slope region across the period 1954-2006. The reduction of arable land was much more marked than in the valley floor, due to significant constraints to mechanisation and intensification (terraces, smaller plots, higher slope steepness, lower soil fertility). While arable land was maintained only at more favourable sites, it was extensively converted to grassland at less favourable ones. Consequently, grassland area increased by 23,2% between 1954 and 1973. However, augmented forage availability boosted the process of abandonment on steep, badly accessible, scarcely productive grassland, leading to a consistent increase of forested area in this landscape region. Forest cover jumped from 18,2% of surface area in 1973 to 44,8% in 2006.

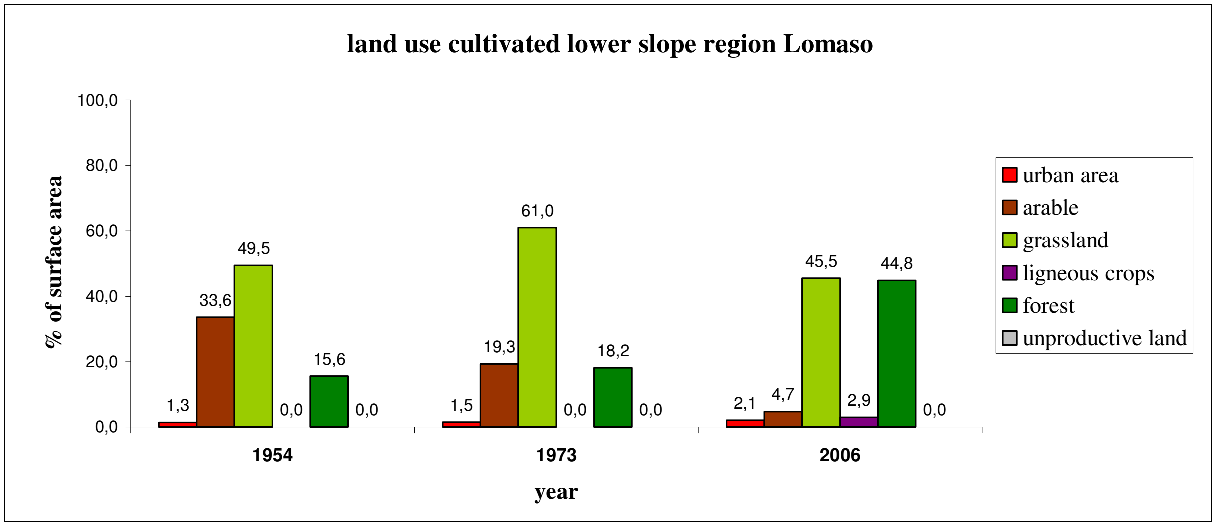


Fig. 40. Evolution of land use in Lomaso's cultivated lower slope region over the period 1954-2006.

As picture 9 shows, the result of recent land use changes has been a sharp spatial division between arable land, which dominates the valley floor, and grassland, which dominates the lower slope region on terraces formerly cultivated to arable. The growing polarisation of land use patterns between the valley floor and slopy areas reflects the high degree of rationalisation achieved by Lomaso's agriculture (Loose, 1983). As land use decisions are based on production costs and yield potential (Gellrich et al., 2007), changing cost functions and increased productivity have determined a new spatial arrangement of land uses. In particular, the intricated mosaics of small plots under various forms of cultivation which reflected the old subsistence economy have been substituted by a 'profit maximising landscape', where each landscape section specialises in the land use most fitting to its characteristics (MacDonald et al., 2000). This way, the fundamental ingredients of intensive dairy farming, namely maize (energy source), Lucerne (protein source), and hay (fibre source), can be produced cost-effectively.

Picture 9. Contraddictions in Lomaso's landscape. The picture on the left shows the sharp spatial division between arable farming in the valley floor and grassland farming in the lower slope region, where forest re-growth is on its way. The picture on the rights shows a nut tree and a mulberry tree surviving in Lomaso's intensively used landscape: the *Rumex* strip in the foreground indicates high property fragmentation and arable land conversion to grassland in the lower slope region (picture by the author).

Another interesting phenomenon affecting Lomaso's lower slope region is the recent development of fruit farming, which reached 2,9% of surface area (18,3 ha) in 2006. Fruit orchards are mainly located in the surroundings of Lundo and Poia on slopy land plots, where solar radiation is more intense. They rarely exceed 1 ha surface area, as they are to a large extent mixed to arable land and grassland. Apples and cherries represent the dominant ligneous crops (ISTAT, 2003), and are grown partly by specialized fruit farmers, partly by dairy farmers who attempt to differentiate production patterns. In 2005, only 12 fruit farmers were registered in the APIA archive: 4 of them were registered as full-time farmers, 5 as part-time farmers, and 3 as mixed dairy/fruit farmers. Hence, fruit production still plays a minor role in Lomaso's agriculture, whereas it is more widespread in the neighbouring communities of Stenico and Bleggio Inferiore, due to more favourable climatic conditions (sunny aspects).

Landscape structure patterns experienced significant changes as well (figure 41). The structural complexity of Lomaso's traditional agriculture was particularly high in the cultivated lower slope region, thanks to the presence of hedges as well as fruit and mulberry trees demarcating the boundary between land plots of different owners (Dalponte, 1984). Additionally, steeper grassland areas were used as *Streuobswiesen* or as thin mulberry tree plantations. The 1929 agricultural census reports of 780 ha agricultural land provided with mulberry trees (46 mulberry trees pro ha on average) and 80 ha agricultural land provided with apple, pear, and nut trees (25 fruit trees pro ha on average; ICS, 1934). While fruit production was normally used for self-consumption, mulberry trees represented an important income source for local population, at least until the end of the 19^{th} century. According to Gorfer (1984), more than 100 silk mills were active in Lomaso, Bleggio, and

Banale in the 1850s. They produced 6.630 Vienna pounds silk every year and employed over 250 persons, to a large extent women.

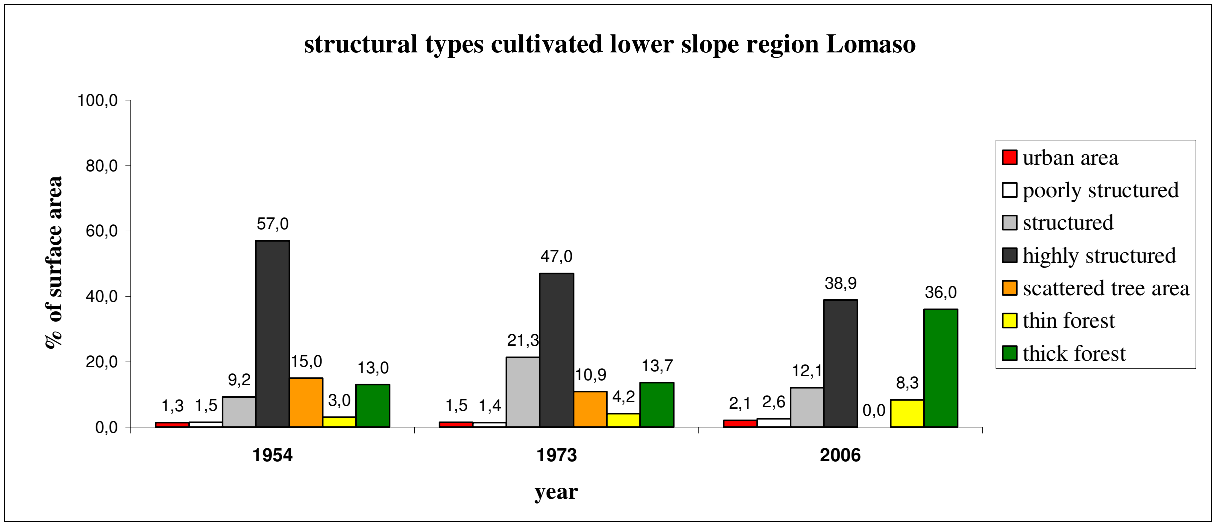


Fig. 41. Evolution of landscape structures in Lomaso's cultivated lower slope region over the period 1954-2006.

The decline of silk production, the two World Wars, and the more recent socio-economic changes have deeply transformed Lomaso's traditional landscape (Loose, 1983). Steep, bad accessible *Streuobstwiesen* and mulberry tree plantations were abandoned and progressively disappeared through bush and forest re-growth, whereas structural elements on mechanisable land were partly eliminated to facilitate farming operations. As a consequence, scattered tree areas completely went lost between 1954 and 2006 (tab. 23), and the share of highly structured agricultural land significantly dropped (- 31,7%), mainly at the advantage of thin and thick forest. Poorly structured and structured areas, on the contrary, increased in absolute terms over the same period (+ 76,8% and +31,7% respectively). Nevertheless, Lomaso's lower slope region still presents a comparatively high degree of structural complexity, with some relicts of the 'old' cultural landscape surviving at the margins of intensively used agricultural land (picture 9).

5.3.2 Landscape change in Terragnolo's cultivated lower slope region

Terragnolo's cultivated lower slope region is characterized by extremely unfavourable geo-morphologic conditions. It comprises the southern foot slopes of the Monte Finonchio and Monte Sommo between 347 and 1.221 m asl, reaching a medium slope steepness of 30,4 degrees! The lack of agriculturally usable land forced early settlers to extensively terrace these areas: they created and maintained a mosaic of microscopic land plots delimited by high stone walls and often accessible only via small stairs or narrow paths (Gios, 1990a). According to Sarzo (2006), the almost ubiquitary use of terraces is attributable to geo-environmental factors such as high slope steepness, slope evenness, high *in loco* availability of stones, and shallow soils.

Collected data on land use changes in the cultivated lower slope region fully reflect the collapse of Terragnolo's agriculture and its complete retreat from the territory (fig. 42). The evolution of land use in this landscape region is similar to the one observed in the valley floor, but much more radical. In fact, forest cover quadrupled within 50 years, reaching 85,0% of surface area in 2006. Simultaneously, open agricultural land dramatically shrunk, falling from 79,8% of surface area to 12,3%. Arable land totally disappeared in the period 1954-1973, while ligneous crops (vine in particular) experienced a more gradual decline. Grassland area initially increased due to arable land conversion to grassland, then gave way under the pressure of forest vegetation.

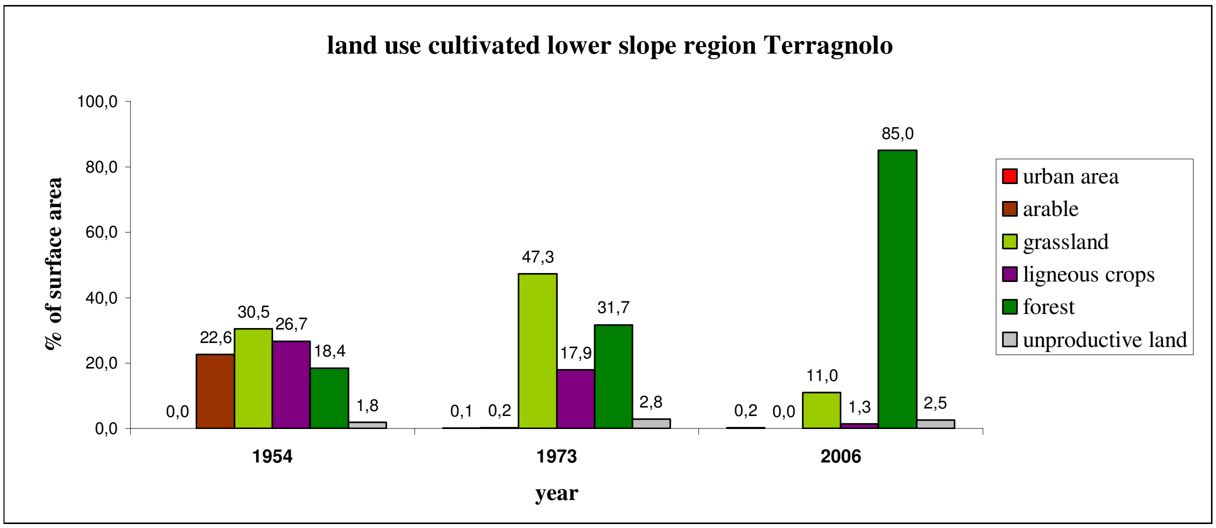


Fig. 42. Evolution of land use in Terragnolo's cultivated lowe slope region over the period 1954-2006.

As figure 42 shows, viticulture was widespread in Terragnolo's lower slope region until the 1970s. Traditionally, vine was grown for self-consumption in association with mulberry trees, fruit tress, vegetables, arable crops, and grassland. "Nei vigneti a coltura promiscua le pergole distano tra loro 4-5 metri; lo spazio tra l'una e l'altra (vanéze) è seminato un anno a patate, l'altro a frumeto o segale od orzo, e, come secondo raccolto, a grano saraceno"[42] (Mattevi, 1957, p. 57). However, some form of specialized viticulture was established at the beginning of the 20th century in response to the growing demand of the Austrian and German markets (Rigotti, 1932). Mattevi (1957) reports of 68 ha specialized vineyards, where the distance between pergolas reached 2-3 m and average grape production was of approximately 5 tons per ha.

[42] "The distance between pergolas is of 4-5 m in vineyards in policulture; the space between one pergola and the other (vanéze) is cultivated to potatoes, and every second year to wheat or rye or barley and, after the harvest, to buckwheat" (translation by the author).

As Sarzo (2006) notes, the abandonment of vineyards in policulture was a widespread phenomenon already in the first half of the 20th century. On the contrary, specialised viticulture steadily grew until the 1960s, when the industrial and economic boom rushed into Trentino. Local viticulture could not modernize due to insurmountable constraints such as high property fragmentation, small farm sizes, and poor land accessibility. In particular, the extreme geo-morphologic conditions did not allow any form of mechanisation, as the myriad of small terraced was not provided with roads but only with steep paths and stairs made of stones (Mattivi, 1957). Loss of competitiveness was the immediate consequence, land abandonment the only option. Nowadays, viticulture survives in its traditional form and in tiny fragments only around the hamlets of Valduga and San Nicolò (picture 10).

Picture 10. On the left, Relicts of viticulture around San Nicolò in Terragnolo: the large space between the pergolas was traditionally used for forage production or arable crops. On the right, shrub vegetation development on terraced slopes around Zoreri in Terragnolo (picture by the author).

Besides the loss of traditional landscape mosaics, the extensive neglect of terraces in Terragnolo's lower slope region was associated with slope destabilisation, resulting in augmented soil erosion and landslides. In fact, the observed increase in unproductive area between 1954 and 1973 is attributable not only to the construction of a hydropower station along Leno's river bed, but also to soil loss on un-maintained terraces. According to Sarzo (2006), soil erosion had always been a primary concern of local population, as high slope steepness and intensive rainfall events make terraces particularly susceptible to soil loss. Since agricultural land was a scarce good, farmers used to restore destroyed terraces back to their original state by reconstructing broken walls and collecting eroded soil from the valley bottom (Bais, 1994). This process of ongoing maintenance ensured over centuries a certain degree of slope stability. The more recent abandonment of agricultural practices has disrupted the precarious equilibrium between nature and human activities, thus increasing the likelihood of landslips and other natural hazards. As MacDonalds et al. (2000)

remark, the increased risk of natural hazards as a result of land desertion emphasises that active management of abandonment may be beneficial in maintaining or restoring environmental stability.

The extensive abandonment of agricultural land has deeply impacted the structural heterogeneity of Terragnolo's lower slope region as well (fig. 43). Structured and highly structured land pieces completely disappeared, while thin and thick forest dramatically increased, reaching a share of 88,0% in 2006. As a consequence, the ratio between forest-free and forested areas dropped from 1:0,24 in 1954 to 1:7,44 in 2006, when open landscape could be observed only in form of agricultural land in early successional stages.

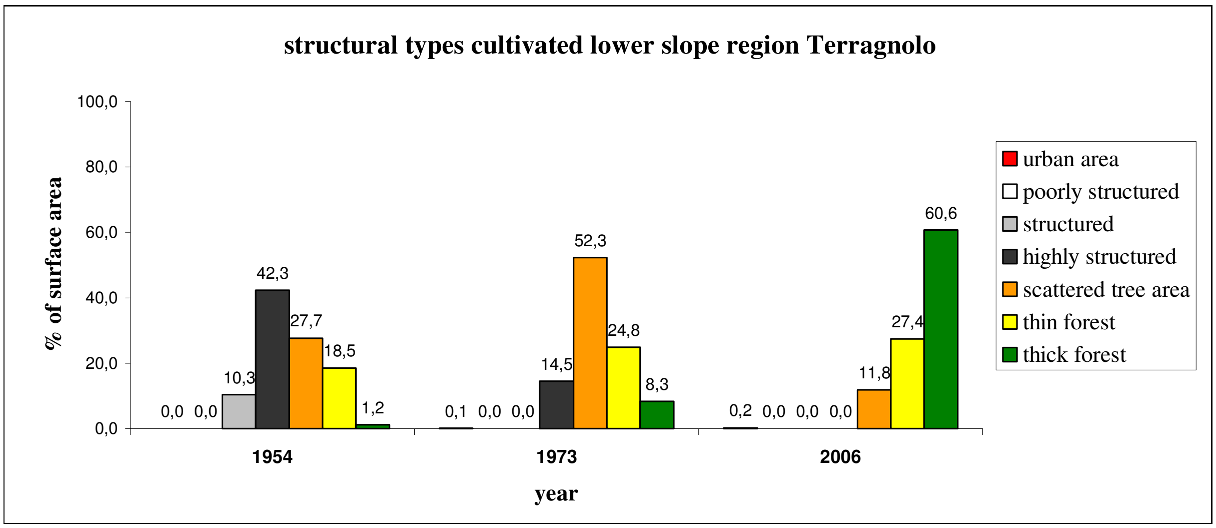


Fig. 43. Evolution of landscape structures in Terragnolo's cultivated lower slope region over the period 1954-2006.

According to Sarzo (2006), the dynamic of secondary succession and forest re-growth after land abandonment was particularly fast in Terragnolo's lower slope region due to the presence of terraces. In fact, terrace walls represent a suitable habitat for pioneer shrubs, which were often tolerated by farmers when the terraces were still cultivated. Once agricultural use ceased, these shrubs could easily conquer the fertile terrace floors (picture 10). Hence, forest re-growth occurred both through forest expansion at the margins of cultivated areas and spot-wise bush development within abandoned agricultural land. Sarzo (2006) identified *Ostrya carpinifolia*, *Fraxinus ornus*, *Prunus malaheb*, and *Cornus sanguinea* as the most frequent wood plants colonising Terragnolo's abandoned terraces. Fig 44 summarises the steps of natural succession in Terragnolo.

At the landscape level, the sharp borders that existed between differently cultivated areas have progressively dissolved, as most open areas have been phagogitated by wild bush vegetation. Höchtl et al. (2005) describe this process of large-scale, uncontrolled vegetation development in formerly cultivated landscapes as 'rewildering' (p. 86). Its ecologic and socio-economic effects are manifold. From an ecologic point of view, the total loss of landscape heterogeneity and mosaic features results in a decreased habitat and species diversity. As several authors underline (Mühlenberg & Slowik, 1997; Bätzing, 2005; Maurer et al., 2006), the biodiversity of agro-ecosystems includes not only crop varieties and livestock races, but also the so-called 'associated biodiversity' (plants, birds, insects, soil organisms etc.), which arises as an unintended by-product of different land use forms and disturbance regimes. From a socio-economic point of view, the diminishing usability and accessibility of a 'rewildered' landscape leads to a loss of historical experience, cultural knowledge, and local identity (Hunziker, 2000; Rest, 2008). In a Europe-wide study on agricultural land abandonment, MacDonald et al. (2000) found out that the increasing rarity of open space was perceived by locals as symptomatic of growing rural decline in the area and had a depressing effect on them. These perceptions can reinforce the vicious cycle of depopulation and marginalisation in structurally weak communities (Baldock et al., 1996). Furthermore, the loss of landscape attractiveness through land desertion and forest re-growth can preclude tourism development in the area, the more so as abandoned landscapes become increasingly inhospitable as a living space for humans (Höchtl et al., 2005).

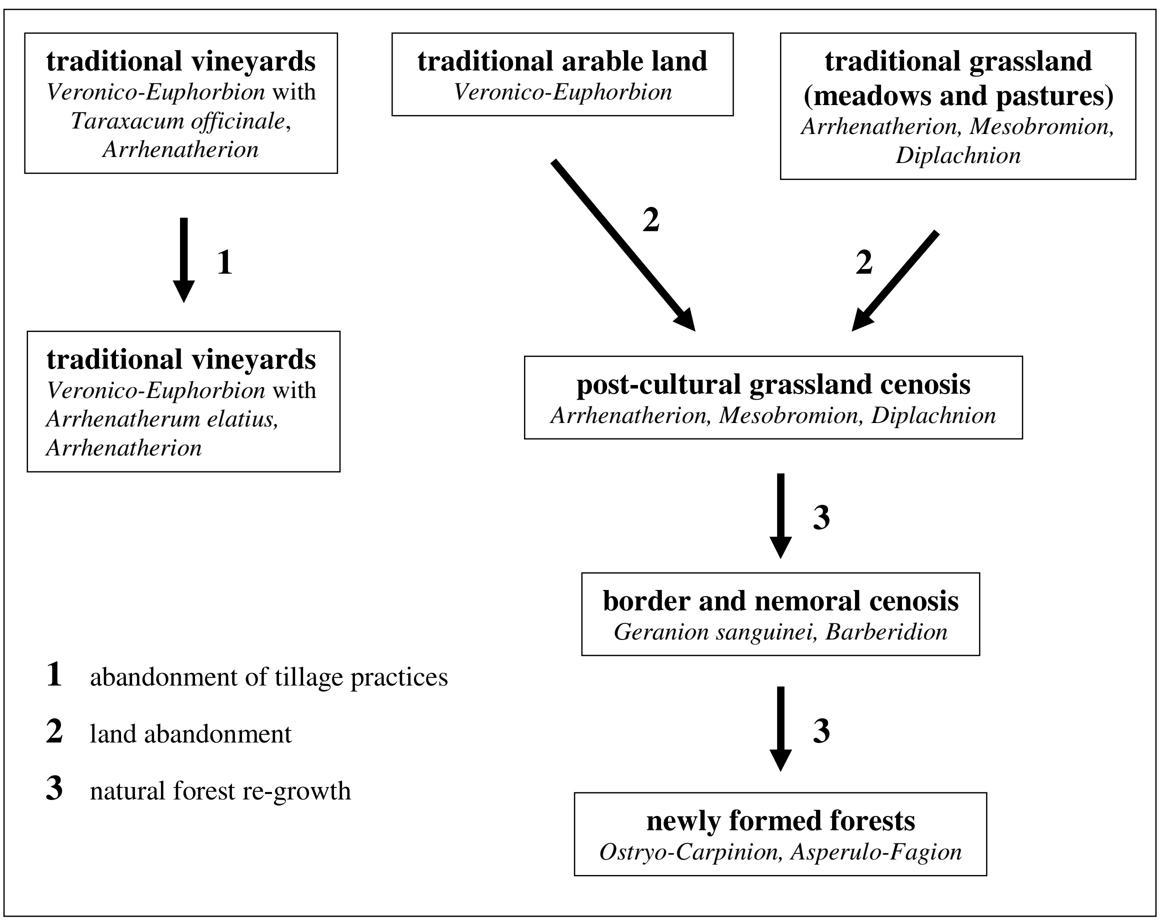


Fig. 44. Steps of natural succession on abandoned agricultural land in Terragnolo according to Sarzo (2006, p. 155, translated by the author)

5.3.3 Landscape change in Transacqua's cultivated lower slope region

Transacqua's lower slope region covers 21,3% of total community area and is situated between 706 and 1.586 m asl. It includes the eastern foot slopes of the Monte Bedolè, the area comprised between the valley floor and the Cereda Pass, as well as the Rio Grande basin. From a geo-morphological perspective, it is characterized by flat or slightly inclined natural terraces alternated with steeper areas. While the latter are normally covered with forests, the former are dominated by grassland for pasturing and hay production. This region is not permanently inhabited, but it is disseminated with small huts and haylofts, which are functional to agricultural land use.

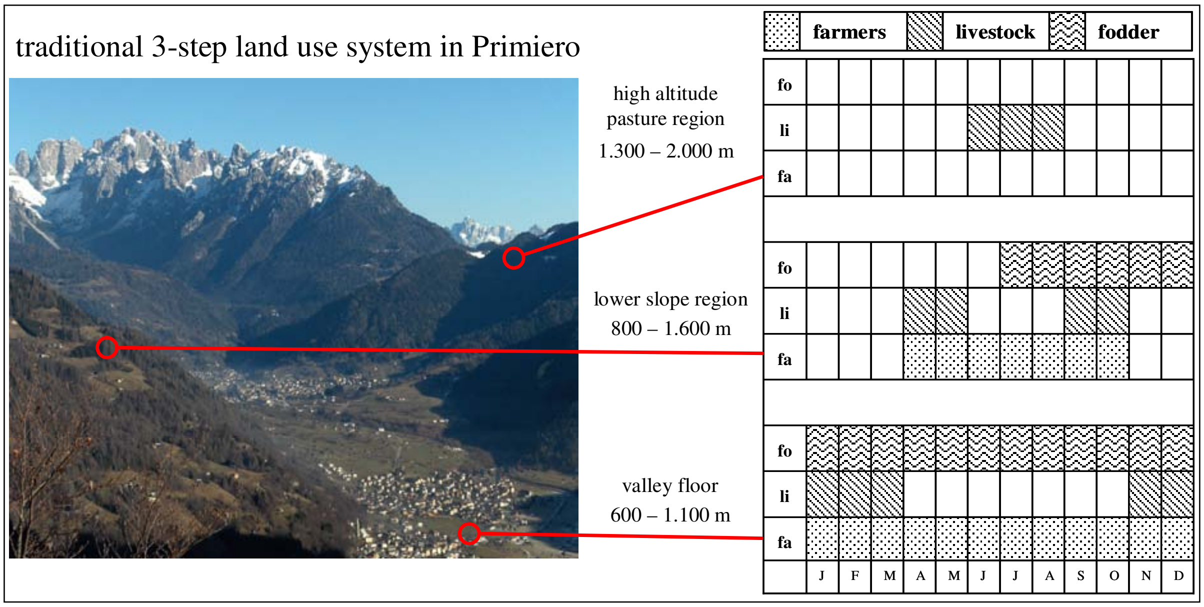


Fig. 45. Organisational structure of the traditional 3-step land use system in Primiero. The graph on the right shows the spatial and temporal distribution of farmers, livestock, and fodder resources on the territory (information source: Bettega & Marini, 1984; picture by the author, own graphic elaboration).

The spatial extent of Transacqua's lower slope region reflects the fundamental socio-economic role it played in the traditional subsistence economy of the valley. In fact, the '3-step' land use system described by Bätzing (2005) was particularly accentuated in Primiero, where its signs are still visible at the landscape level. Figure 45 visualises the organisational structure of this land use system, which was subdivided in three spatial units: valley floor, mid-altitude grassland region, and uplands. During the winter months, farmers and their livestock inhabited the valley floor, which was dominated by arable land in policulture with grassland. In spring, as forage resources were fairly scarce in the valley floor, the livestock was brought to the mid-altitude grassland region, where each farmer owned one or more huts and some grassland. Subsequently, the livestock was entrusted to local shepherds for high-altitude summer grazing on commonly owned pasture land (*malghe*). From June to August, farmers could cut the mid-altitude meadows and accumulate hay for the winter months. In Autumn, the livestock went its way back from the uplands to the valley floor, remaining in the lower slope region until the first frosts (Bosetti, 1915; Bettega & Marini, 1984).

As Scalet (1984) notes, this transhumance-based system was very labour-intensive and created relevant logistic problems for the farmer and its family. However, its economic non-viability became evident only in the early 1960s, when Transacqua's agriculture was directly exposed to the competition with Po plane. The call for rationalisation and specialisation of those years forced the surviving farmers to simplify farming practices, in the attempt to reduce the costs of farming operations. The wave of rationalisation particularly hit the mid-altitude grassland region, due to low productivity, unfavourable geo-morphologic conditions, poor accessibility and periferictity (Scalet, 1984). As a consequence, the lower slope region was most affected by land abandonment and forest re-growth. Specifically, forest cover jumped from 42,0% in 1954 to 68,5% in 2000, at the full expenses of grassland (fig. 46). Similar developments have been observed in Val d'Aosta (MacDonald; 2000), France (Grüber, 2007), and Switzerland (Baur et al., 2006).

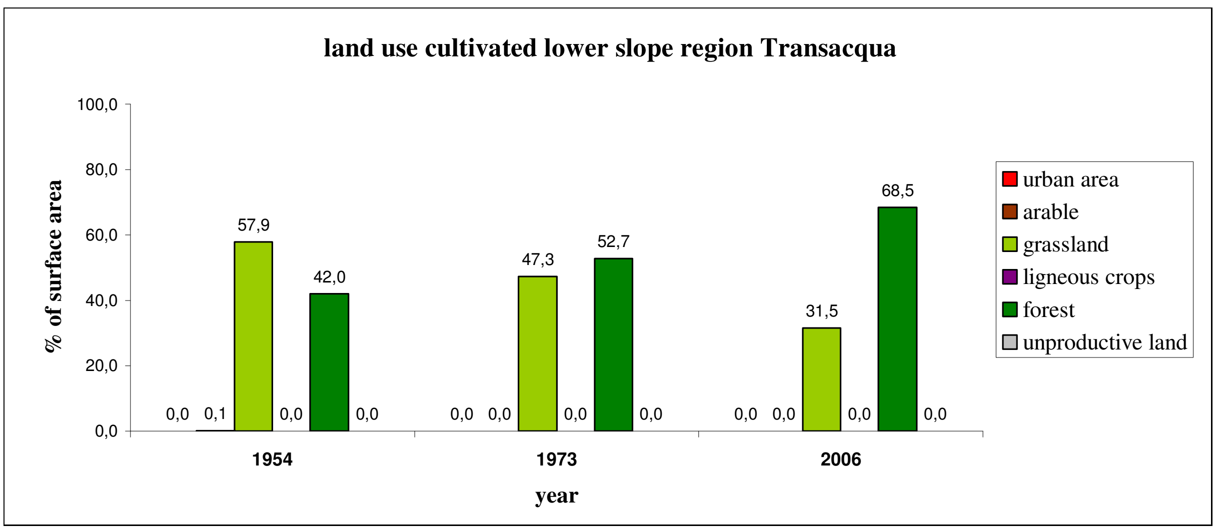


Fig. 46. Evolution of land use in Transacqua's cultivated lower slope region over the period 1954-2006.

It can be concluded that the simplification of traditional practices (transhumance of livestock farming in particular) is among the causes of land desertion in Transacqua's lower slope region. Beaufoy et al. (1994) consider the modification of traditional practices of land management as a form of adaptation in marginal grassland areas and associate it to a higher likelihood of land abandonment. However, forest expansion in Transacqua's lower slope region was comparatively low if compared with forest expansion in the lower slope region of the other case study communities. This is in line with the findings of a landscape change study conducted in the neighbouring Province of Belluno by Giupponi et al. (2007). They observed lower losses of open space through forest re-growth in communities with a moderate degree of tourism development, “probably because tourism activities are interested in maintaining a more pleasant landscape and avoiding excessive afforestation” (p. 168).

As to the evolution of structural patterns, Transacqua’s lower slope region experienced not only a significant increase of forested area, but also a progressive thickening of existing forest vegetation (fig.47). Vegetation thickening is mainly attributable to the reduction of zoo-anthropic pressure on forests (Rieder, 2004). Traditionally, forests were subject to multiple uses such as livestock grazing (including goats), strow production, timber production, and fire wood production (Bosetti, 1915; Bochatay & Plozza, 2001), which reduced natural forest regeneration and maintained a relatively thin vegetation. These silvo-pastoral structures, however, rapidly disappeared with the decline of traditional subsistence economy (Krismer, 2005).

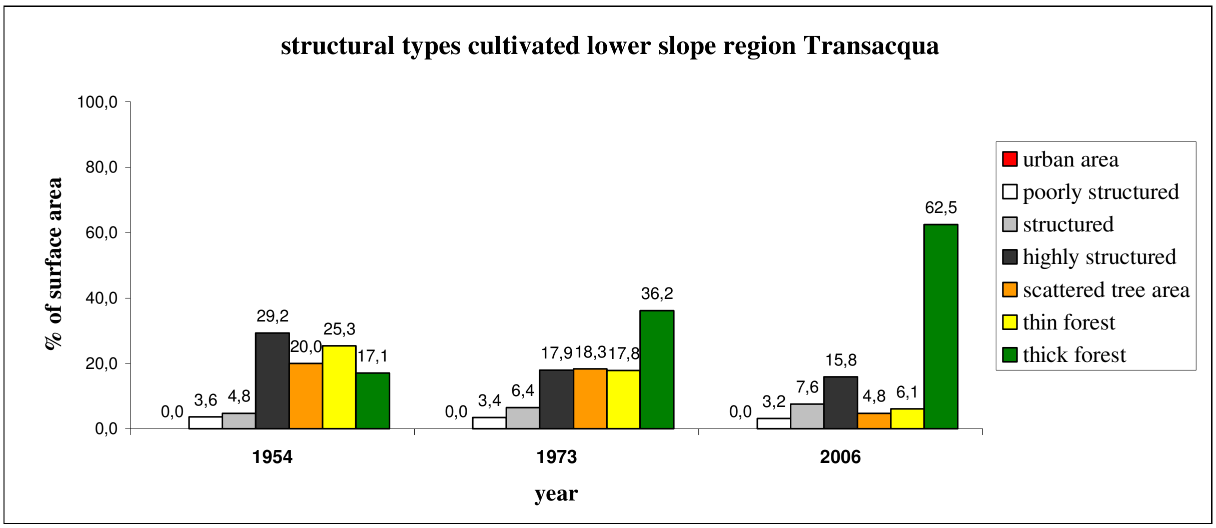


Fig. 47. Evolution of landscape structures in Trasacqua’s cultivated lower slope region over the period 1954-2006.

In the main, open spaces have maintained a relatively high degree of structural complexity, even though the type of structural elements has completely changed. In the traditional landscape, grassland areas were enriched with fruit trees (apples, pears, plums), which represented an important vitamine source for local population. They were normally located at sunny sites, often far away from the forest, in the middle of meadows. Such structural elements, however, were gradually eliminated on intensively used grassland, and substituted by single spruce or firs along forest margins or on extensively used land. Fragments of the old landscape still survive on the lower slopes of the Monte Bedolè (picture 11).

Picture 11. Rare example of *Streuobstwiese* on the lower foot slopes of the Monte Bedolè in Transacqua (picture by the author).

Tab. 22. Sole/mixed land use in the cultivated lower slope region of Lomaso, Terragnolo, and Transacqua in the years 1954, 1973, 2006 (percentage values)

	Lomaso			Terragnolo			Transacqua		
	1954	1973	2006	1954	1973	2006	1954	1973	2006
	% of surface area								
urban area	1,3	1,5	2,1	0,0	0,1	0,2	0,0	0,0	0,0
arable	9,0	3,1	0,3	0,0	0,0	0,0	0,0	0,0	0,0
arable mixed	24,6	16,2	4,4	22,6	0,2	0,0	0,1	0,0	0,0
grassland	3,6	4,0	1,8	0,0	0,0	0,0	30,4	23,3	17,3
grassland mixed	45,9	57,0	43,7	30,5	47,3	11,0	27,5	24,0	14,2
ligneous crops	0,0	0,0	0,8	0,0	0,0	0,0	0,0	0,0	0,0
ligneous crops mixed	0,0	0,0	2,1	26,7	17,9	1,3	0,0	0,0	0,0
forest	12,4	13,9	36,4	1,2	8,9	64,6	17,8	37,6	63,2
forest mixed	3,2	4,3	8,4	17,2	22,8	20,4	24,2	15,1	5,3
unproductive land	0,0	0,0	0,0	1,8	2,8	2,5	0,0	0,0	0,0
tot	100,0	100,0	100,0	100,0	100,0	100,0	100,0	100,0	100,0

Tab. 23. Composition of scattered tree areas by share of young and old trees in the cultivated lower slope region of Lomaso, Terragnolo, and Transacqua in the years 1954, 1973, 2006

	Lomaso			Terragnolo			Transacqua		
	1954	1973	2006	1954	1973	2006	1954	1973	2006
	scattered tree area (ha)								
old trees > 70%	69,8	28,7	0,0	100,2	28,1	0,0	44,5	16,5	35,1
equal share of old and young trees	22,3	41,0	0,0	26,3	168,4	49,2	57,4	78,5	4,3
young trees > 70%	4,6	0,0	0,0	17,7	75,9	12,4	60,2	52,7	0,0
tot	96,7	69,7	0,0	144,2	272,4	61,6	162,1	147,7	39,4

5.4 Landscape change in the high altitude pasture region

5.4.1 Landscape change in Lomaso's high altitude pasture region

Lomaso's high altitude pasture region comprises the summit plateau of the Monte Casale to the East and the Monte Misonetto to the West. It is characterized by relatively favourable geo-morphologic conditions, as it is situated between 991 and 1.630 m asl and has an average slope steepness of 18,1 degrees. This region includes two main *malghe*(malga Val Bona and malga di Vigo-Blestone) as well as several pasture/meadow agglomerates (Misone, Pra di Muci, Fontane). Malga Poia-Naone was excluded due to its modest dimension and its isolated position in the middle of the montane forest belt. As Bätzing (2005) remarks, high altitude pasture land is generally owned by the community in areas dominated by the Romanic farm type. This is true for malga di Vigo-Blestone and Malga Poia-Naone, but not for Malga Val Bona, which is privately owned.

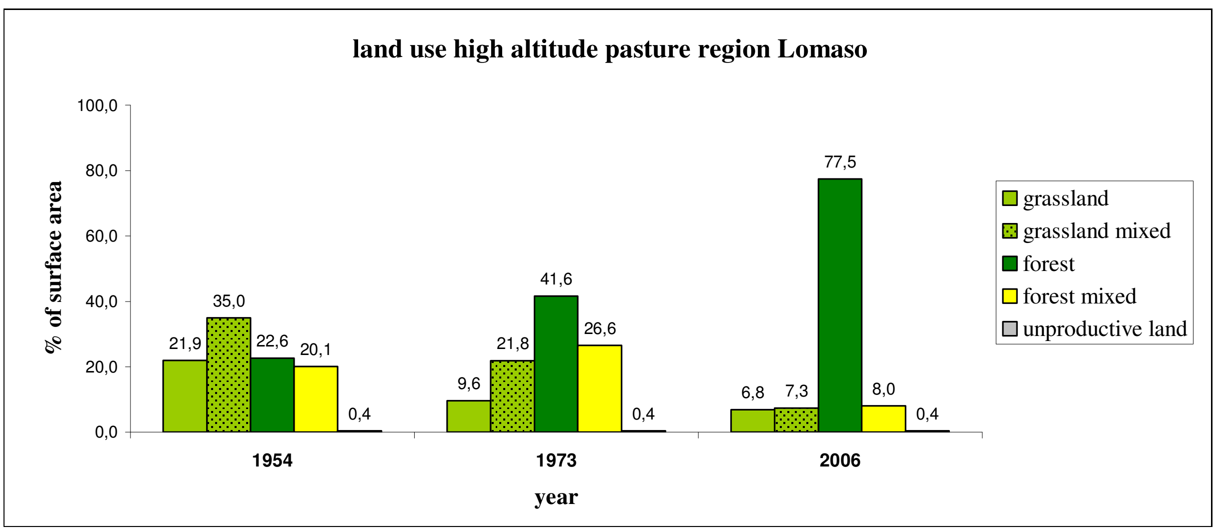


Fig. 48. Evolution of land use in Lomaso's high altitude pasture region over the period 1954-2006.

The rate of land use and landscape change was astonishingly high in Lomaso's uplands (fig. 48). In particular, forest in sole use jumped from 22,6% in 1954 to 77,4% in 2006, resulting in a drastic reduction of grassland area over the same period. Grassland in sole use lost 69,0% of its surface area, while grassland in mixed use decreased by 79,2%. Forest in mixed used decreased as well, as small grassland areas surrounded by forest were rapidly re-conquered by wood vegetation. The observed increase of forest cover is attributable partly to active afforestation (around malga Val Bona in particular), partly to natural succession on abandoned pasture and meadow land. Due to the low altitude (1.344 m asl on average), successional processes were particularly fast in this area.

Which are the reasons behind the large-scale abandonment and degradation of Lomaso's uplands? The recent evolution of livestock farming in the valley floor provides a meaningful answer to this question (Loose, 1986). Until the end of the 1960s, most dairy farmers produced milk for self-consumption, and had no interest in improving productivity. During summer, their livestock was herded in the uplands, where butter and cheese were produced and eventually sold to tourists or locals. The introduction of guaranteed milk prices in the 1970s, however, offered the possibility of a constant income source, thus boosting a process of rationalisation and re-structuring in the dairy sector. In particular, some few dairy farmers enlarged and modernised their farms in the attempt to maximise the output and minimize the costs. High-altitude pasturing did not fit into the new management practices, as personnel costs were high and milk productivity low. Furthermore, dairy factories encouraged permanent stabulation in order to reduce seasonality and homogenise production patterns. As a consequence, alpine pastures were progressively extensified or even fully abandoned. Loose (1986) concluded: "Der Rückgang der Alpwirtschaft geht daher zu einem Gutteil auf das Konto der EG-Agrarpreispolitik"[43] (p. 31).

Statistical data corroborate the assumptions illustrated above. In 1854, malga Vigo-Blestone was grazed by 55 milk cows, 40 calves, and 80 goats, and produced 1.200 kg butter and 2.100 kg cheese (Gorfer, 1987). In 1977, it counted only 25 calves (Loose, 1983), and in 2005 hardly 23 livestock units (PAT, 2005). Malga Poia-Naone, which counted 27 milk cows and 40 goats in 1854 (Gorfer, 1987), was completely abandoned, while the 25 ha of malga Val Bona were grazed by only 10 calves, 2 horses, 2 goats, and 2 sheep in 2005 (PAT, 2005). As Loose (1983) notes, besides the general reduction of the number of livestock units herded on high-altitude pasture land, there is a tendency to substitute milk cows with calves (*Galtviehalmen*) and other livestock (ovines, equines). This reflects the shift from labour-intensive to low-input grazing systems, in which personnel costs are minimized and zoo-anthropic pressure on pasture land is reduced to a mass inadequate for arresting secondary succession and forest re-growth (Aigner et al., 2003; Parizek, 2006).

[43] "The decline of high altitude pasturing is to a large extent attributable to the price policy of the European Community" (translation by the author).

Picture 12. Extensively ‘re-wildered’ pasture land in Lomaso: the summit plateau of the Monte Granzoline (in the middle) was covered with pasture land until the 1950s (picture by the author).

The evolution of landscape structures in Lomaso’s uplands shows a high rate of land abandonment and a rapid process of ‘rewildering’ (picture 12 and fig. 49). Traditional landscape mosaics have fully disappeared, giving way to monotone and often impenetrable forest stands. In particular, alongside with the increase of forested area, a certain degree of vegetation thickening could be observed. Thin forests more than halved between 1954 and 2006, while thick forests almost quadrupled in the same period. Open landscape has become increasingly rare, falling from 57,0% of surface area to 11,9%.

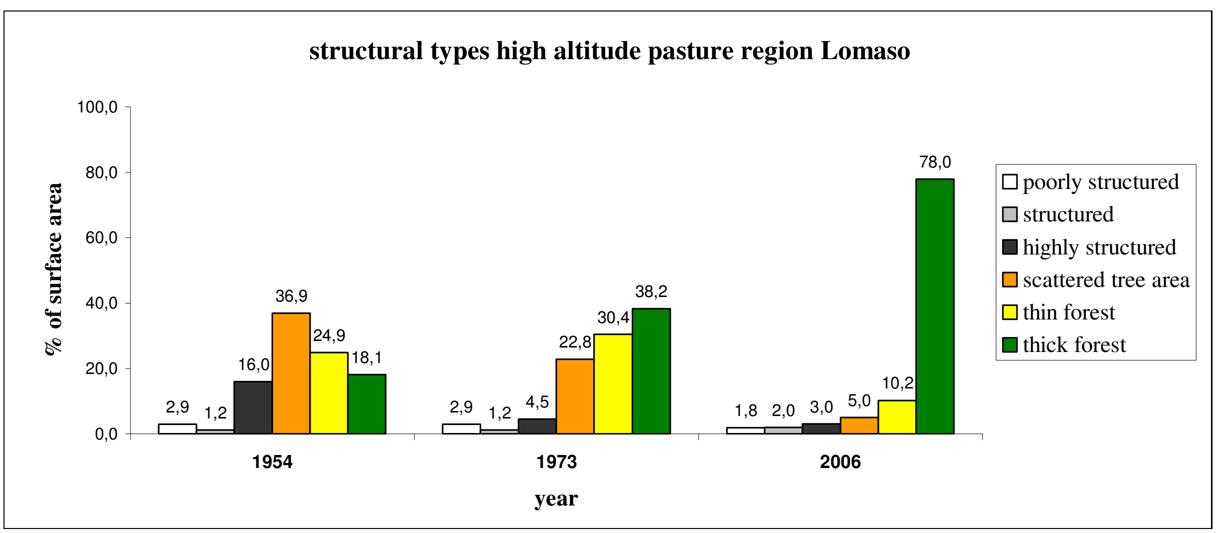


Fig. 49. Evolution of landscape structures in Lomaso’s high altitude pasture region over the period 1954-2006.

Interestingly, the share of scattered tree areas with more than 70% young trees was particularly high in 1954 (tab. 24). This indicates that high altitude pasturing was already in an advanced state of decline after World War II. The strong reduction of goat stock in the first half of the 20th century (- 85,2% between 1900 and 1929 according to Kirchlechner, 1904 and ICS, 1934) might co-explain this phenomenon. In fact, goats were traditionally herded on steeper, less productive surfaces, where they stopped successional processes by biting bushes and young trees (Baur et al., 2006). As a consequence, the decline of goat farming, which was mainly due to low productivity and restrictive forest legislations, favoured natural succession to shrub and woodland on extensive pasture land.

5.4.2 Landscape change in Terragnolo's high altitude pasture region

Terragnolo's high altitude pasture region covers 12,7% of the community area and comprises the upper slopes of the Monte Finonchio and Sommo to the North, the Monte Maggio and the Borcola Pass to the East, and the lower Dosso Alto-Col Santo rangelands to the South. It is situated between 1.100 and 1.869 m asl and has an average slope steepness of 24,2 degrees. This region includes several *malghe* (malga Maronia, malga Borcola, malga Pezzi, malga val del Lovo) as well as high-altitude meadows (Orti, Martinella, Sommo, Monte Maggio), which are to a large extent commonly owned. Malga Sarta, malga Gulva, and malga Bisorte were included in the montane forest belt, as they represent fairly small 'grassland islands' in isolated position.

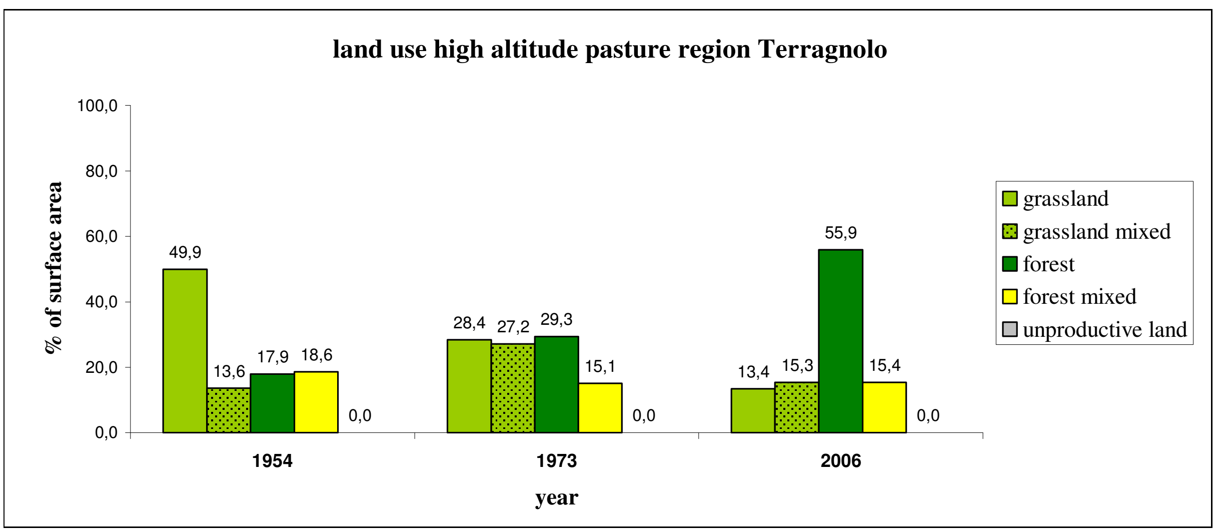


Fig. 50. Evolution of land use in Terragnolo's high altitude pasture region over the period 1954-2006.

Figure 50 summarizes the evolution of land cover in Terragnolo's uplands between 1954 and 2006. Alongside with the significant increase of forest in sole use (+213,5%), the share of grassland in sole use dramatically decreased, falling from 50,0% in 1954 to 13,4% in 2006. Simultaneously, the share of grassland in mixed use nearly doubled in the period 1954-1973, falling to its original level in the subsequent decades. This development shows that large grassland areas have been progressively jeopardized by 'forest spots' before turning to homogeneous forest stands. Krismer (2005) reports similar findings in the Carnia region.

In the main, the increase of forested area in Terragnolo's high altitude pasture region has been less accentuated than in Lomaso's uplands. However, this is attributable to higher altitude and unfavourable environmental conditions (high slope steepness, carsic soils) rather than to a lower rate of land abandonment. In fact, agriculture has almost completely retreated from Terragnolo's uplands, which have irremediably lost their productive function (Gios, 1990c).

Traditionally, the high altitude pasture region played a fundamental role in Terragnolo's subsistence economy. Forage resources were extremely limited in the valley floor due to the scarcity of usable agricultural land and the dominance of arable farming. Hay production occurred to a large extent at higher altitudes (Orti, Martinella, Sommo, Monte Maggio), where commonly owned land was subdivided among the farmers depending on their respective needs (Sarzo, 2006). These meadows were mown twice a year and produced approximately 3 tons of hay per ha and year (Mattivi, 1957). Furthermore, the community owned an array of *malghe*, which were located on the southern valley side between 1.300 and 1.800 m asl and could be used by local farmers for herding their livestock. However, the imbalance between the scarce fodder resources in the valley floor and the extreme grassland abundance in the uplands did not allow high livestock densities in Terragnolo. In 1950, only 322 bovines and 593 goats were kept in the valley (Mattivi, 1957). Hence, most 'malghe' were rent for summer grazing to livestock farmers from the neighbouring province of Vicenza (Gios, 1990c).

The collapse of Terragnolo's agriculture hit the uplands as well. Livestock farming literarily vanished within a few decades (the 2001 census did not register any livestock), causing the extensive desertion of both mown and grazed grassland at higher altitudes. The deep transformations affecting Vicenza's dairy farming worsened the situation, since rented grassland was progressively extensified and abandoned as well. Today, only malga Borcola is still grazed, the remaining 'malghe' are either occasionally used by transhumant shepherds, or lay completely fallow. Most of them (malga Maronia, malga Pezzi, malga val del Lovo, malga Gulva) have been already phagocitated by the forest.

The evolution of landscape structures in Terragnolo's uplands is fairly similar to the one observed in Lomaso (fig.51). However, the high share of scattered tree areas with more than 70% young trees (tab. 24) indicates a persisting high landscape instability. A further increase of forest cover is to be expected in the next future, if no measure to counteract forest expansion is undertaken. In particular, as Terragnolo's high altitude pasture region entirely lies under the potential tree line (PAT, 1992) and there is almost no form of direct human disturbance, open spaces are expected to fully vanish in the coming decades. The old habitats will disappear, and new habitats, such as those resulting from natural ecosystem dynamics, will form. Even though the ecologic value of freely developing landscapes and 'wilderness' areas is high *per se* (Höchtl et al., 2005), landscape change should be evaluated depending on the context in which they occur (MacDonald et al., 2000). For instance, while forest re-growth on agricultural land can be judged as positive in poorly structured agricultural landscapes, it is detrimental in areas with very high forest cover, because it implies increasing rarity of open space.

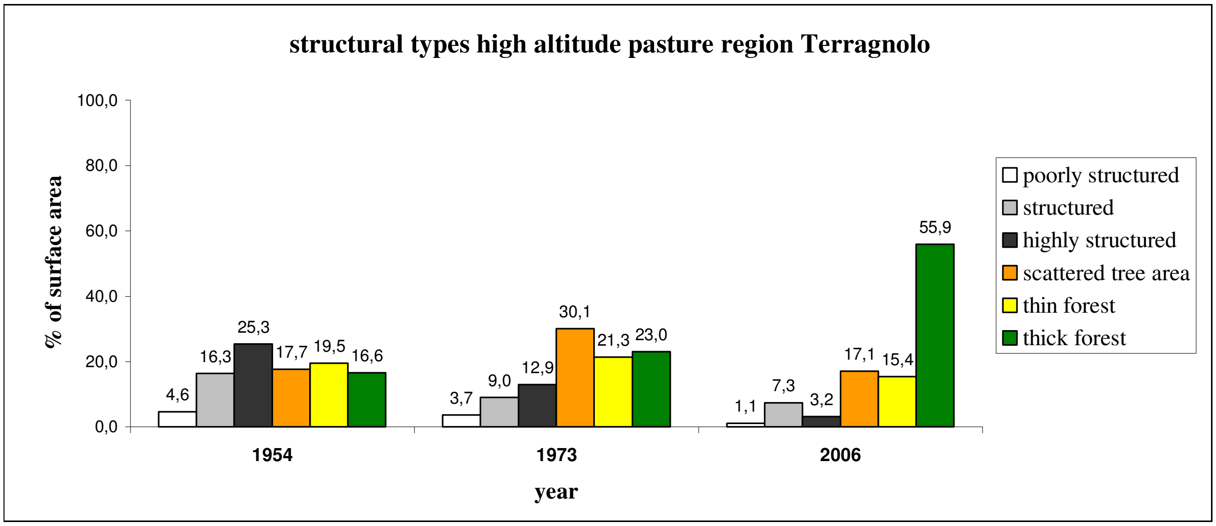


Fig. 51. Evolution of landscape structures in Terragnolo's high altitude pasture region over the period 1954-2006.

5.4.2 Landscape change in Transacqua's high altitude pasture region

Transacqua's high altitude pasture region covers only 8,9% of total community area and is situated between 1.347 and 1.978 m asl. It has a mean slope steepness of 27,0 degrees and encompasses three main *malghe*: malga Fossetta, malga Neva Prima, and malga Neva Seconda. Malga Fossetta is located in the proximity of the Cereda Pass (North-East of Transacqua village) at an altitude of 1.550 m asl. It is owned by the community of Transacqua and has approximately 20 ha pasture land. Malga Neva Prima and malga Neva Seconda are situated in the higher Noana basin, on the southern slopes of the Cimonega range. They belong to the neighbouring communities of Imer and Mezzano respectively and consist of 160 ha pasture land comprised between 1.400 and 2.000 m asl. As only malga Neva Seconda is provided with a usable cowshed, they are jointly managed as a single *malga* (malghe Neve).

The evolution of land use in Transacqua's uplands is quite dissimilar to the one observed in Lomaso and Terragnolo (fig. 52). In particular, the reduction of grassland through forest re-growth and/or active afforestation was comparatively limited: only 18,9% of existing pasture area went lost in the period 1954-2006. However, the share of grassland in sole use diminished more than the share of grassland in mixed use, since the latter represents a natural step in the transition from pasture land to forest. At the same time, forest in mixed use almost entirely turned to forest in sole use through vegetation thickening and forest expansion on isolated pasture plots. As a result, the share of forest in sole use increased from 4,7% in 1954 to 42,3% in 2006.

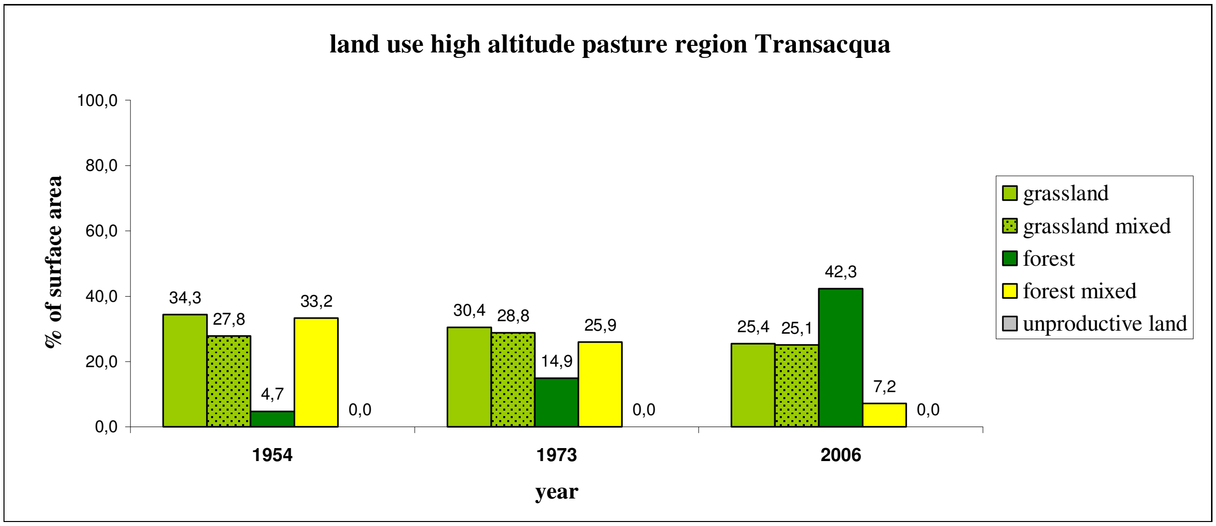
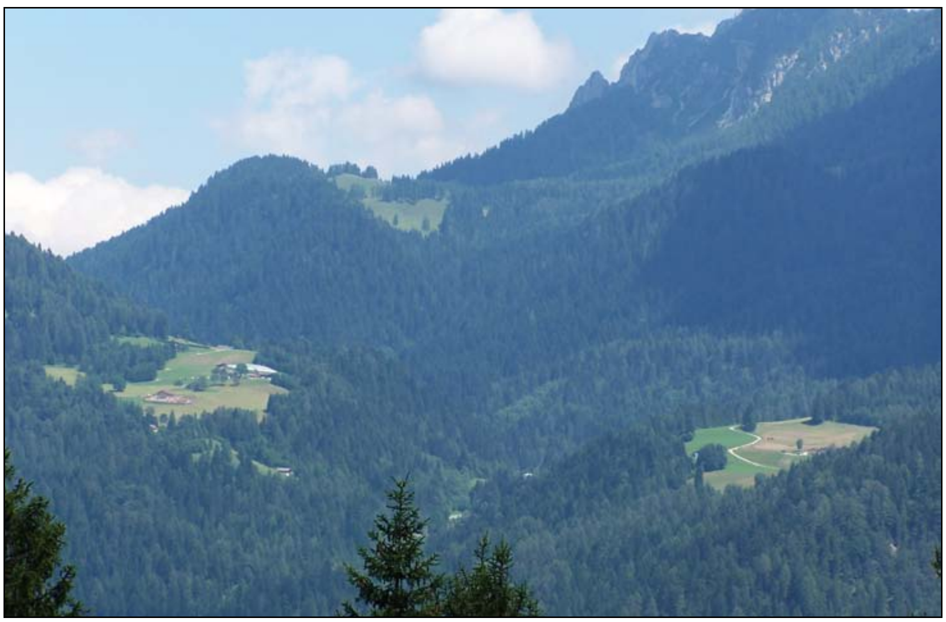


Fig. 52. Evolution of land use in Transacqua's high altitude pasture region over the period 1954-2006.

These figures show that Transacqua's high altitude pasture region has not experienced the structural collapse which has affected the uplands of the other case study communities. In spite of declining livestock numbers and the economic pressure on farms to rationalise their production patterns, the traditional practice of summer pasturing has been maintained in this community. In fact, both malga Fossetta and malghe Neve are yearly utilized for livestock herding between June and September. In 2005, the former counted 3 milk cows, 28 calves, 12 horses, 96 sheep, and 29 goats, while the latter were grazed by 61 milk cows, 35 calves, 3 horses, and 69 sheep (PAT, 2005). In either cases, the livestock belongs to a group of farmers and is entrusted to a shepherd or local farmer. The produced milk is normally transported to the cooperative cheese factory in Mezzano, where it is transformed to matured hard cheese (Nostrano di Primiero). The *in-situ* production of milk derivates has been steadily declining in the last decades due to severe hygienic restrictions (e.g. HCCP regulations), but still survives on both *malghe*.

Summer herding of livestock has always been an integral element of Primiero's mountain farming (Scalet, 1984) and still persists notwithstanding increasing logistic and management costs.

In fact, it contributes to the success of agricultural production in small structured enterprises by widening farm's fodder resources (Aigner et al., 2003), by reducing work load during the summer months, by improving health, fertility, and productivity of young animals (Brugger & Wohlfahrter, 1983), by offering the opportunity of product differentiation towards quality through natural, healthy, and highly valued products (Battaglini et al., 2004), and by providing further income sources from tourism (Corti, 2004). In particular, the moderate tourism density which characterises the Primiero valley might co-explain the persistence of such a traditional farming practice. Alpine pasture utilisation is tightly coupled with tourism because it contributes to the ecological quality as well as the aesthetic attractiveness of mountain areas (Schacht, 2003). Additionally, it offers a range of products and services to local tourism such as traditional food products, refreshment and catering possibilities, overnight stays, contact with animals and nature, contact with local culture and traditions, maintenance of paths and roads, etc.



Picture 13. Grassland islands in Transacqua's forests. In the background, the high altitude pastures of Malga Fossetta (picture by the author).

A good example of integration between the system *malga* and tourism is provided by malga Fossetta (picture 13), which offers gastronomic and (agri)cultural experiences to families and hikers during the summer months, thus exploiting the economic chances offered by the local tourism market. This creates an incentive to maintain the practice of summer grazing, and guarantees its economic viability.

As to the evolution of structural patterns in Transacqua's high altitude pasture region, a certain degree of landscape stability could be observed in comparison to Lomaso and Terragnolo (fig. 53). The most evident change affected thick forests, the extent of which significantly increased between

1954 (5,4%) and 2006 (27,7%). This increase is attributable not only to vegetation thickening in already existing thin forest stands, but also to localised phenomena of land abandonment and forest re-growth on pasture land. In particular, structured and poorly structured areas steadily diminished, while highly structured and scattered tree areas remained almost constant, as they represent transitional stages to the establishment of forest stands.

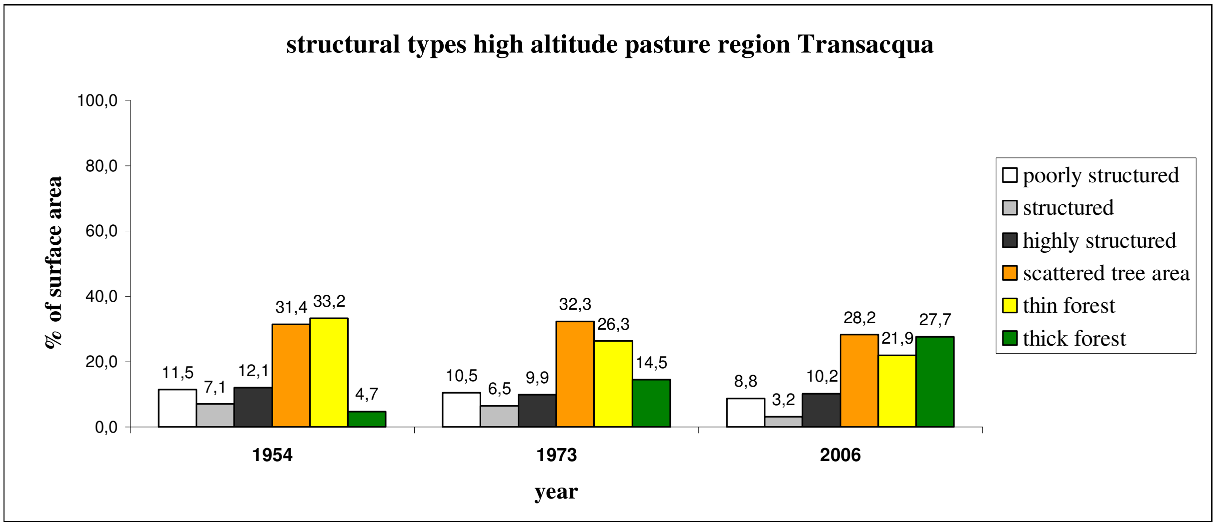


Fig. 53. Evolution of landscape structures in Transacqua's high altitude pasture region over the period 1954-2006.

Tab. 24. Composition of scattered tree areas by share of young and old trees in the high altitude pasture region of Lomaso, Terragnolo, and Transacqua in the years 1954, 1973, 2006

	Lomaso			Terragnolo			Transacqua		
	1954	**1973**	**2006**	**1954**	**1973**	**2006**	**1954**	**1973**	**2006**
	scattered tree area (ha)								
old trees > 70%	0,0	0,0	3,1	16,1	10,1	0,0	14,9	3,9	18,7
equal share of old and young trees	8,9	64,9	25,8	24,4	40,8	61,6	52,6	88,3	55,2
young trees > 70%	241,6	90,2	5,3	56,6	114,1	31,7	42,1	20,7	24,8
tot	250,5	155,1	34,2	97,1	165,0	93,3	109,6	112,9	98,7

Interestingly, the structural traits of malga Fossetta and malghe Neve have evolved in fairly different directions. Malga Fossetta has basically maintained its original structures, as almost no forest re-growth occurred in the period 1954-2006. Favourable geo-morphologic conditions, good accessibility, and the integration with tourism are the reasons for the observed landscape stability. On the contrary, malghe Neve have experienced a progressive reduction of livestock numbers, which has resulted in a polarisation of grazing intensity. In particular, cattle herding has been concentrated at easily accessible, flat, more productive sites around the huts, where poorly structured pasture land has been essentially maintained. Steeper, less accessible areas have been gradually extensified and lay now fallow. The high share of scattered tree areas with more than 70% young trees (tab. 24) shows that natural succession is already on its way. This evolution might be attributed to less favourable geo-morphologic conditions, geographic perifericity (15 km from valley floor), and the absence of additional income sources through on-farm tourism.

5.5 Landscape change in the other landscape regions

As to the remaining landscape regions, namely the submontane, the montane, the subalpine, and the alpine landscape regions, no relevant land use and landscape structure changes could be observed. This is mainly due to the fact that these areas, except for the alpine zone, are traditionally dominated by commonly owned forests, and rarely include usable agricultural land. However, following directions of change were identified.

- Existing open spaces almost completely disappeared over the period 1954-2006 in forest-dominated landscape regions. In particular, forest re-growth affected isolated ‘grassland islands’ such as malga Poia in Lomaso and Pian del Lares and malga Gulva in Terragnolo. The ecologic value of these ecosystems is particularly high, given that the open areas most important for the flora und fauna diversity are those which interrupt the continuity of woodlands (Giupponi et al., 2007). Hunters have an interest in the maintenance of such open spaces, as they are a fundamental fodder source for ruminant wildlife (Unterhofer, 2005).
- In the Giasinozza valley (Transacqua), the montane and subalpine forest belts experienced an extensive process of forest thickening between 1954 and 2006, resulting in a reduction of light forest stands at the advantage of thick ones. This development is attributable to the abandonment of traditional silvo-pastoral practices in the area, where forests were used for wood production and summer grazing of minor livestock such as goats and sheep. Similar findings have been reported in the Italian Eastern Alps (Rieder, 2004) and in Carintia (Bogner, 2008).

The alpine zone occurs only in the community of Transacqua and covers the Cimonega Range as well as the top of the Monte Dalaibol. As it predominantly consists of unproductive rock outcrops, it was not affected by significant land use and landscape structure changes.

5.6 Overview of landscape change by landscape region

The analysis performed so far shows that rates and patterns of landscape change in Lomaso, Terragnolo, and Transacqua have been substantially different. In the following, the salient directions of change are summarized in order to allow a direct comparison between the three case study communities (tab. 25, 26, 27, and 28).

Tab. 25. Overview of landscape changes in the cultivated valley floor of Lomaso, Terragnolo, and Transacqua

	Lomaso	Terragnolo	Transacqua
valley floor	• arable land remained the dominant land use (48,9% in 2006) • shift from policultural systems to monocultural cropping (maize) • moderate reduction of UAA through forest re-growth • moderate urban development • strong simplification of landscape structures through agricultural intensification (45% classified as structure-less and poorly structured in 2006)	• total collapse of arable farming (from 72,4% in 1954 to 0,0% in 2006) • arable land fully converted to grassland • conspicuous loss of UAA through forest re-growth (nearly 1/3) • no remarkable urban development • loss of structural complexity through forest re-growth	• total collapse of arable farming (from 23,0% in 1954 to 0,0% in 2006) • almost no reduction of UAA through forest re-growth • massive urban development/urban sprawl (from 10,8% in 1954 to 41,1% in 2006) • persistence of structural richness in the remaining open landscape

Tab. 26. Overview of landscape changes in the cultivated lower slope region of Lomaso, Terragnolo, and Transacqua

	Lomaso	Terragnolo	Transacqua
cultivated lower slope region	• strong reduction of arable land • remarkable increase of forest cover (from 15,6% in 1954 to 44,8% in 2006) • introduction of fruit plantations (2,9% in 2006) • simplification of landscape structures both through forest re-growth and intensification of grassland	• total collapse of arable farming • almost total collapse of viticulture (from 26,7% in 1954 to 1,3% in 2006) • massive increase of forested area (from 18,4% in 1954 to 85,0% in 2006) • increase of unproductive area through landslides on abandoned terraces • monotonisation of landscape structures through extensive 're-wildering' and ubiquitary forest expansion	• remarkable increase of forest cover at the expenses of grassland (from 42,0% in 1954 to 68,5% in 2006) • persistence of structural richness in the remaining open landscape

Tab. 27. Overview of landscape changes in the high altitude pasture region of Lomaso, Terragnolo, and Transacqua

	Lomaso	Terragnolo	Transacqua
high altitude pasture region	• massive increase of forested area through natural forest re-growth and active afforestation (from 46,7% in 1954 to 85,5% in 2006) • thickening of existing thin forest stands • persistence of structural richness in the remaining landscape	• massive increase of forested are through natural forest re-growth (from 36,5% in 1954 to 71,3% in 2006) • increasing share of grassland in mixed use with forest • persistent high share of scattered tree areas with more than 70% young trees (high landscape instability)	• very moderate increase of forested area through natural forest re-growth (from 37,9% in 1954 to 49,5% in 2006) • strong thickening of existing thin forests • persisting high share of structure-less land pieces (8,8% in 2006) • increasing share of scattered tree areas with more than 70% young trees (local phenomena of extensification)

Tab. 28. Overview of landscape changes in the landscape regions dominated by forests in Lomaso, Terragnolo, and Transacqua

	Lomaso	Terragnolo	Transacqua
landscape regions dominated by forest	• disappearance/strong reduction of small grassland islands	• disappearance/strong reduction of small grassland islands	• disappearance/strong reduction of small grassland islands • extensive phenomena of vegetation thickening in existing thin forest stands

5.7 Agricultural land abandonment and forest re-growth

The present section addresses the topic of agricultural land abandonment and forest re-growth in Lomaso, Terragnolo, and Transacqua over the period 1954-2006. As discussed in the chapter ‘Materials and Methods’, forest expansion on formerly used agricultural land – both natural (spontaneous succession) and artificial (active afforestation) – was taken as proxy indicator for land abandonment.

The section is subdivided into two parts. In the first part, the spatial patterns of forest re-growth are extensively documented and compared with the help of descriptive statistics. The second part focuses on the drivers of agricultural land abandonment and is based on a modelling exercise involving monovariate and multivariate linear regression models.

5.7.1 Spatial patterns of agricultural land abandonment and forest re-growth

The physical characteristics of the locations where land abandonment occurs are typically referred to as the 'spatial patterns of land abandonment' (Pontius et al., 2001). For the purpose of the present analysis, the patterns of land abandonment were assumed to depend on the cost/benefit decisions of the landowner, who abandons (at least tendentially) agricultural land with high cultivation costs and low yield potential (Gellrich et al., 2007; Giupponi et al., 2007). Hence, cost-related and yield-related variables were selected to describe the spatial patterns of land abandonment. In particular, altitude, aspect, and distance to forest edges were chosen as proxies for the yield potential of agricultural land, while cultivation costs were considered using the variables slope, distance to roads, distance to buildings, and distance to inhabited areas.

Tab. 29. Mean and median values of slope, altitude, aspect, distance to forest edges, distance to roads, distance to buildings, and distance to inhabited areas for absence (no forest re-growth) and presence (forest re-growth) observations in Lomaso, Terragnolo, and Transacqua

	Lomaso		**Terragnolo**		**Transacqua**	
	absence n = 85.724	**presence** n = 53.686	**absence** n = 28.859	**presence** n = 54.435	**absence** n = 50.144	**presence** n = 27.178
explanatory variable	**mean**					
slope (degrees)	8,9	17,8	21,3	27,4	15,9	23,5
altitude (m asl)	626,8	1.007,4	1.190,7	995,4	1.221,4	1.254,9
aspect (degrees)	201,5 (SSW)	244,9 (WSW)	179,0 (S)	186,4 (S)	212,6 (SSW)	204,1 (SSW)
distance to forest edges (m)	265,4	122,3	130,3	105,8	164,1	78,2
distance to roads (m)	63,6	193,6	130,8	161,9	131,2	201,1
distance to buildings (m)	216,5	358,4	276,2	380,2	174,0	285,1
distance to inhabited areas (m)	725,3	1.570,5	1.316,7	1.210,6	2.747,0	2.551,9
explanatory variable	**median**					
slope (degrees)	8,0	17,4	20,2	27,8	13,0	23,3
altitude (m asl)	518,0	1.173,0	1.206,0	828,0	1162,0	1.207,0
aspect (degrees)	261,9 (W)	270,0 (W)	194,0 (S)	190,0 (S)	231,3 (WSW)	197,6 (S)
distance to forest edges (m)	214,5	70,1	105,4	69,6	91,4	43,6
distance to roads (m)	42,5	111,8	80,2	113,9	60,1	128,5
distance to buildings (m)	179,8	311,6	158,0	222,7	75,3	176,7
distance to inhabited areas (m)	397,6	1.782,7	1.139,3	774,6	2088,3	2.842,0

Table 29 reports descriptive statistics (means and medians) about agricultural land where farming practices were maintained (absence) and where forest re-growth was observed (presence) in the three case study communities over the period 1954-2006. The number of observations (*n*) refers to the number of 10x10m raster cells considered and gives an idea of the proportions of land abandonment in each community. In relative terms, Terragnolo was affected the most by land abandonment, as it lost 63,7% of its open spaces through forest re-growth between 1954 and 2006. Lomaso's forest free agricultural land dropped by 37,7% due to forest expansion, while Transacqua experienced a more moderate reduction (18,3%). In Transacqua, however, the loss of agricultural land through urban development was more marked than in the other communities (3,0% against 2,4% in Lomaso and 0,16% in Terragnolo). In absolute terms, Terragnolo and Lomaso lost double as much open spaces as Transacqua in the same period. In order to achieve a higher degree of precision, the means and medians are now integrated by the frequency of presence and absence observations along the gradient of each variable.

Slope steepness

Slope steepness is a fundamental cost factor of agricultural land use (Tasser et al., 2001; Bogner, 2008). In fact, cultivation costs increase overproportionally with increasing slope steepness, as labour costs increase with decreasing use of machines. Additionally, the yield potential of steep slopes is generally lower than that of flat areas (Buchgraber & Gindl, 2004). Hence, steep agricultural land is particularly susceptible to marginalisation and abandonment (MacDonald et al., 2000).

Figure 54 shows the distribution of presence and absence observations along a slope gradient in the three case study communities. In the main, absence of forest re-growth was observed at lower values of slope steepness than presence. However, community-specific trends could be highlighted. In particular,

- Lomaso's agriculture has almost completely retreated from areas with a slope steepness higher than 20°, and has progressively concentrated on flat areas (mean slope of absence observations 8,9°). Besides the exceptionally favourable geo-morphologic conditions of the territory, the evolution of local agricultural structures fully explains this trend. In fact, intensive livestock farming has been oriented to cultivating maize fields in the valley floor and managing the most easily mechanisable grassland in the lower slope region (Loose, 1983). Hence, the high degree of mechanisation achieved has not allow to utilise less favourable meadows. Additionally, the introduction of permanent stabulation and the consequent decline of cattle pasturing have caused the abandonment of steeper pasture land both in the lower slope region and in the high altitude pasture region.

- In Terragnolo, the distribution of presence and absence observations along a slope gradient is markedly humped-shaped. However, while open agricultural land still occurs at intermediate values of steepness (mean value 21,3°), steeper surfaces have been extensively abandoned. (mean value 27,4°). Hence, there is a tendency to maintain less steep areas open, even though the generally unfavourable geo-morphologic conditions make the territory unsuitable for intensification and mechanisation of farming practices. Note that the values of steepness were derived from the isoipses, and do not consider the presence of terraces on the soils. Therefore, the actual steepness of agricultural land is expected to be lower than the one observed.

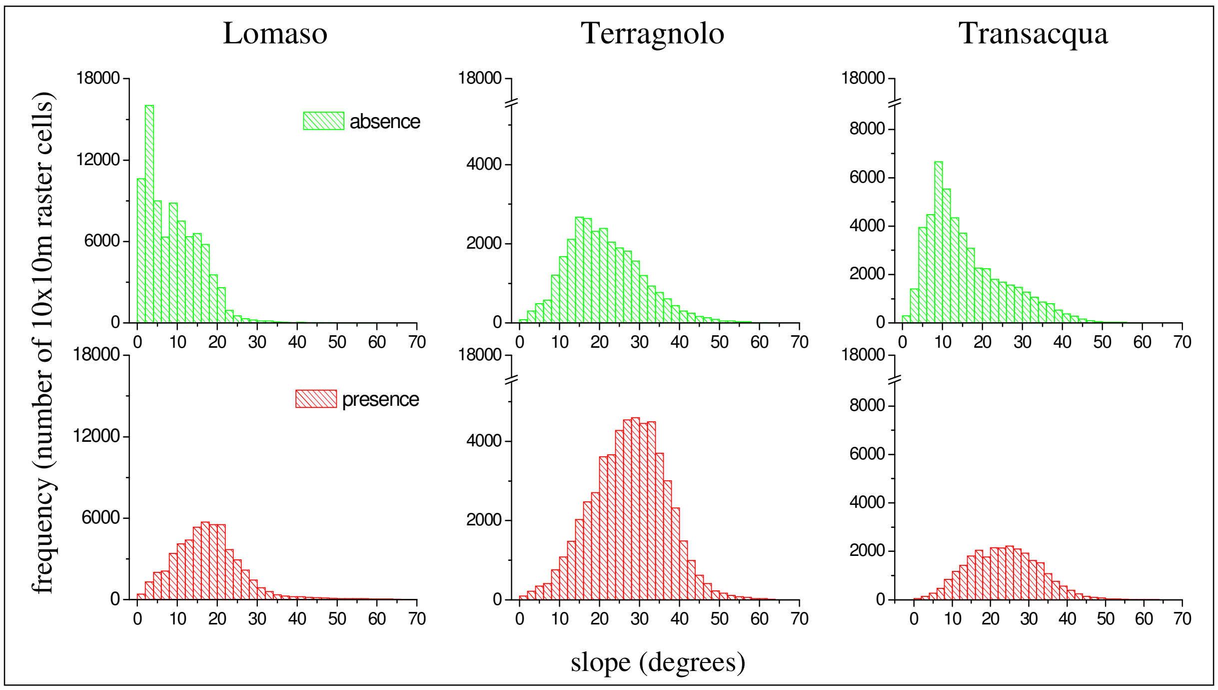


Fig. 54. Frequency of absence (no forest re-growth) and presence (forest re-growth) observations along a slope gradient in Lomaso, Terragnolo, and Transacqua.

- In Transacqua, forest re-growth has occurred more frequently on land pieces with intermediate measures of steepness (mean value 23,5°), while agriculture has been maintained at low and (at least partly) at high values of slope inclination. This might be explained by the comparatively low labour costs of mechanical mowing in the valley floor and of extensive pasturing at higher altitudes (Gellrich et al., 2007). On one hand, less steep land has been further cultivated due to its suitability for mechanisation and rational agricultural production. On the other, very steep land close to the tree-line has been maintained for extensive cattle, sheep, and goat pasturing. Furthermore, the dynamics of spontaneous succession are slower on very steep slopes due to unfavourable growing conditions for trees and shrubs (e.g. shallow soils, low nutrient availability, avalanches; Ellenberg, 1996). In sum, the combination of pasturing and limited plant growth have slowed down forest re-growth on Transacqua's steeper agricultural land.

Altitude

Altitude is one of the major physio-geographic determinants of yield potential on agricultural land, as it strongly influences the length of the vegetation period as well as the water and temperature regimes of the soil and of the athmosphere (Körner, 1999). According to Dietl & Lehmann (2006), the vegetation period on cultural grassland shortens by 3-4 days every 100 m altitude increase, resulting in a yield reduction of approximately 5% per 100m altitude (base 500 m asl). Therefore, high altitude grassland has a lower yield potential and was expected to be more prone to abandonment than low altitude agricultural land.

Figure 55 shows the distribution of presence and absence observations along an altitudinal gradient in the three case study communities. The altitudinal patterns of forest re-growth are non-linear and quite idiosyncratic, as they depend on community-specific conditions. In particular,

- In Lomaso, forest re-growth has occurred with the same frequency at lower and higher altitudes. However, while absence observations are particularly frequent in the valley floor, they are more rare in the high altitude pasture region. This reflects the almost complete abandonment of high altitude pasture land and the consequent concentration of farming activities at more favourable sites. Similar developments have been observed in Belluno's mountain areas by Aguanno (2006) and in the Carnia by Krismer (2005).
- In Terragnolo, forest re-growth is more evident at lower altitudes than in the high altitude pasture region. In fact, the mean altitude of absence observations is higher than that of presence observations (1.190,7 and 995,4 m asl respectively). This trend is not attributable to lower rates of land abandonment in the uplands, as the process of land desertion was generalized throughout the territory. Rather, it is due to the different speed of spontaneous succession along an altitudinal gradient. Forest re-growth is assumed to be faster at lower altitudes due to more favourable growing conditions for trees and shrubs (Lasanta-Martìnez et al., 2005). Additionally, the extensive presence of terraces in Terragnolo's lower slope region has accelerated natural forest re-growth, as terrace walls represent an optimal starting point for the expansion of border and nemoral cenosis on the fertile terrace floors (Sarzo, 2006).
- In Transacqua, the distribution of presence observations along the altitudinal gradient is almost unimodal, as forest re-growth was more frequent at intermediate values of altitude,

between 1.000 and 1.300 m asl. As previously discussed, land abandonment was particularly accentuated in the lower slope region due to the simplification of traditional transhumance practices in livestock farming. Nevertheless, the '3-step' character of Transacqua's cultural landscape is still evident in the distribution of the presence observations, which peak in correspondence to the valley floor, the mid-altitude meadow region, and the high altitude pasture region. This reveals the persistence of decentralized agricultural land use in the community.

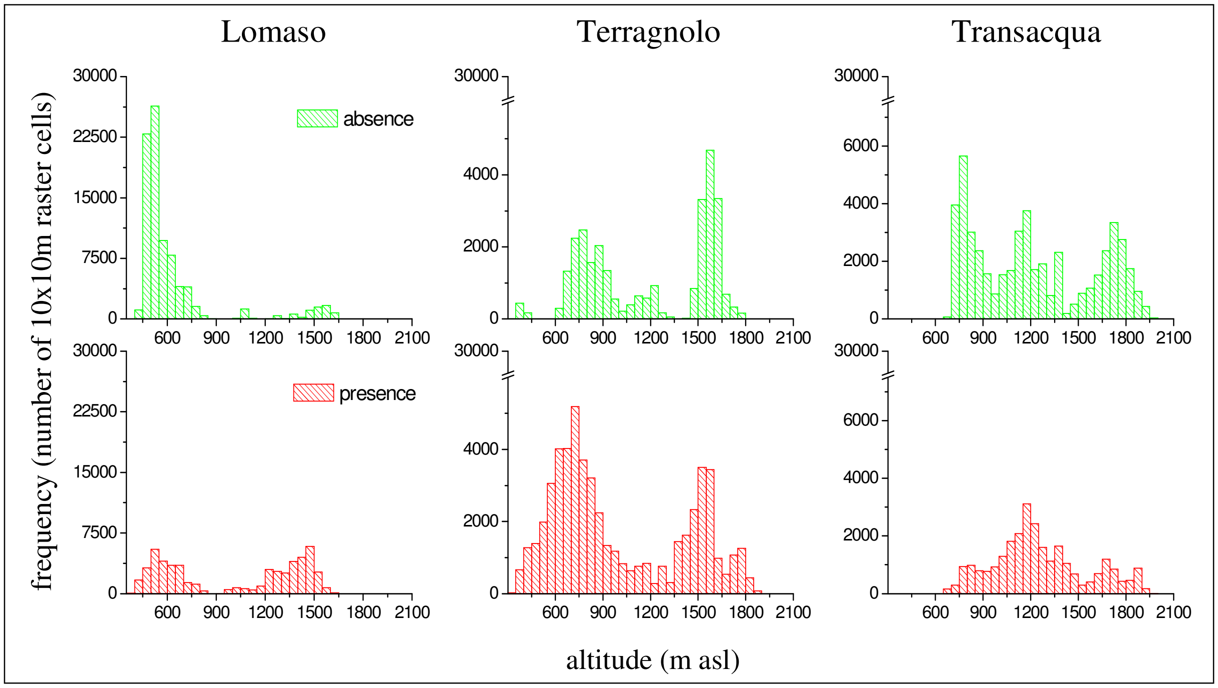


Fig. 55. Frequency of absence (no forest re-growth) and presence (forest re-growth) observations along an altitudinal gradient in Lomaso, Terragnolo, and Transacqua.

Aspect

The influence of different aspects on the yield potential of agricultural land is mainly related to the different intensity of solar radiation, which determines the water and temperature regimes of an agro-ecosystem (Tischler, 1993). Among other factors (crop type, soil type, etc.), a certain aspect may be advantageous or not to agricultural production depending on the meso-climatic context. For instance, if the limiting factor to plant growth is scarcity of water rather than low temperature, then a shady aspect is probably more productive then a sunny one. Contrarily, in areas where low temperature limits plant growth more than the scarcity of water, a sunny aspect may be preferable to a shady one. These differences increase with increasing altitude (Reisigl & Keller, 1994).

Data on the distribution of presence and absence observations along an aspect gradient do not show any clear relationship between forest re-growth and aspect, the more so as agricultural land is characterized by a dominant aspects in each case study community (WSW in Lomaso, S in Terragnolo, SSW in Transacqua). Similar findings have been reported by Schellenberg (2002), Lasanta-Martìnez et al. (2005), and Bogner (2008).

Distance to forest edges

Distance to forest edges affects natural forest re-growth on agricultural land in a twofold way. On one side, agricultural land close to forest edges has less favourable cultivation conditions than land remote from forest edges due to shade, wildlife damages, etc. On the other side, land close to forest edges is more susceptible to woody plant seed rain and young tree colonisation than land remote from forest edges (Gellrich et al., 2007). Hence, forest re-growth was expected to decrease with increasing distance from forest edges.

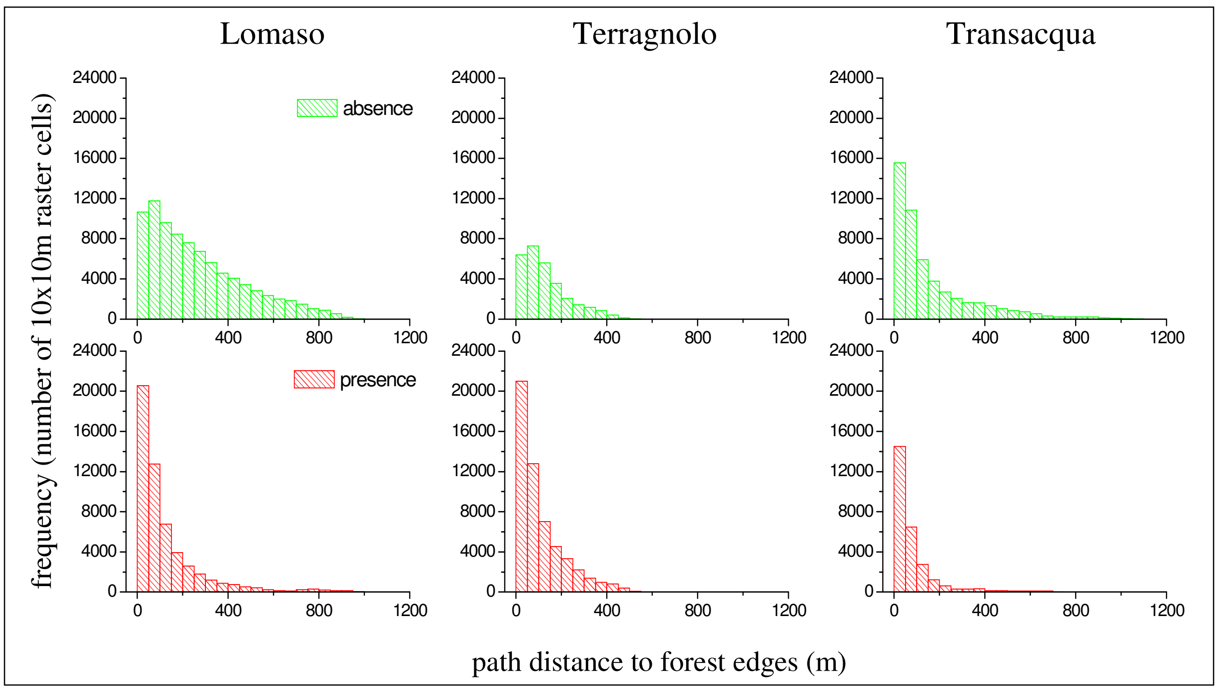


Fig. 56. Frequency of absence (no forest re-growth) and presence (forest re-growth) observations along a distance-to-forest-edges gradient in Lomaso, Terragnolo, and Transacqua.

Figure 56 shows the distribution of presence and absence observations along a distance-to-forest-edges gradient in the three case study communities. On average, agricultural land on which forest re-growth was observed was closer to forest edges than agricultural land where farming practices were maintained. In particular, land pieces at a distance between 0 and 200 m from forest edges were most affected by forest re-growth. However, while in Lomaso and Terragnolo the maximum frequency of absence observations was registered at a distance between 100 and 200 m from forest edges, in Transacqua it was recorded at a distance between 0 and 100 m. This may be explained as follows. In Lomaso and Terragnolo, large scale land abandonment has polarised landscape structures, resulting in a sharp spatial contraposition between large open areas and large forested areas. In Transacqua, the maintenance of decentralised and extensive agricultural land use systems has preserved structurally rich landscape mosaics, where forested areas are alternated with scattered grassland islands. Though, the comparatively low mean distance of open agricultural land from forest edges in Transacqua (91,4m) makes its cultural landscape more vulnerable to natural forest re-growth in the case of further land abandonment, as the pressure of forest on the open landscape is particularly high.

Distance to roads

Land accessibility appears to be an important pre-condition for maintaining land use and preventing land abandonment (Mottet et al., 2006). According to Antrop (2005), difficult access to land plots is one of the main factors that distinguishes abandonment from all other land uses and can be therefore considered as a proximate cause of land use decision making. Accessibility is a function of different variables, including slope steepness, distance to roads, and the spatial arrangement of farmland at the farm level. The presence or absence of road infrastructure, however, is the most important aspect of accessibility. Pezzati (2001) found a direct relationship between road infrastructure development and land use intensity: parcels in the vicinity of roads are less likely to be used extensively and to be abandoned than areas which are located at a greater distance. In fact, the development of roads leads to a modification of the optimal combination of labour and capital and, consequently, to the adaptation of technical progress on the farm. Roads reduce the transport costs incurred, lower the expenditure of labour, and ease mechanisation, thus allowing (when possible) a certain degree of intensification.

Figure 57 shows the distribution of presence and absence observations along a distance-to-roads gradient in the three case study communities. On average, the distance to roads of land pieces where forest re-growth was observed is higher than that of land pieces where farming practices were maintained. However, community specific trends could be identified. In particular,

- Lomaso is provided with an exceptionally good road network, as almost all absence observations are located at a distance lower than 150 m from roads (mean value 63,6 m). This is attributable to the fact that most agricultural land is concentrated in the valley floor and in the lower slope region, where land accessibility is normally better thanks to more favourable geo-morphologic conditions and the vicinity to inhabited areas. Additionally, the development of highly mechanised farming systems in the lowlands (arable farming in particular) has been necessarily accompanied by the development of a capillary road network (Gorfer, 1987). On the other hand, presence observations show a markedly higher mean distance to roads (193,6 m) and range from 0 m to over 1.000 m: virtually all land with a distance higher than 200 m from roads has been affected by forest re-growth. Specifically, land far away from roads occurs to a large extent in the uplands, where traditional summer herding practices have been abandoned.

- In Terragnolo, no significant difference in the distribution of absence and presence observations could be identified. Forest re-growth occurred almost independent of the distance from road infrastructure due to the generalized phenomenon of land use desertion in the community. The high mean value of absence observations (130,8 m) is partly attributable to the relative weight of uplands, where road infrastructure is generally poor, partly to the lack of a road network on the terraced slopes of the lowlands. As Sarzo (2006) notes, insufficient land accessibility has been one of the major constraints to the modernisation and mechanisation of Terragnolo's agriculture. In fact, the steep terraces did not allow the use of any machine, not even of pack and draft animals for transportation and ploughing (Mattevi, 1957).

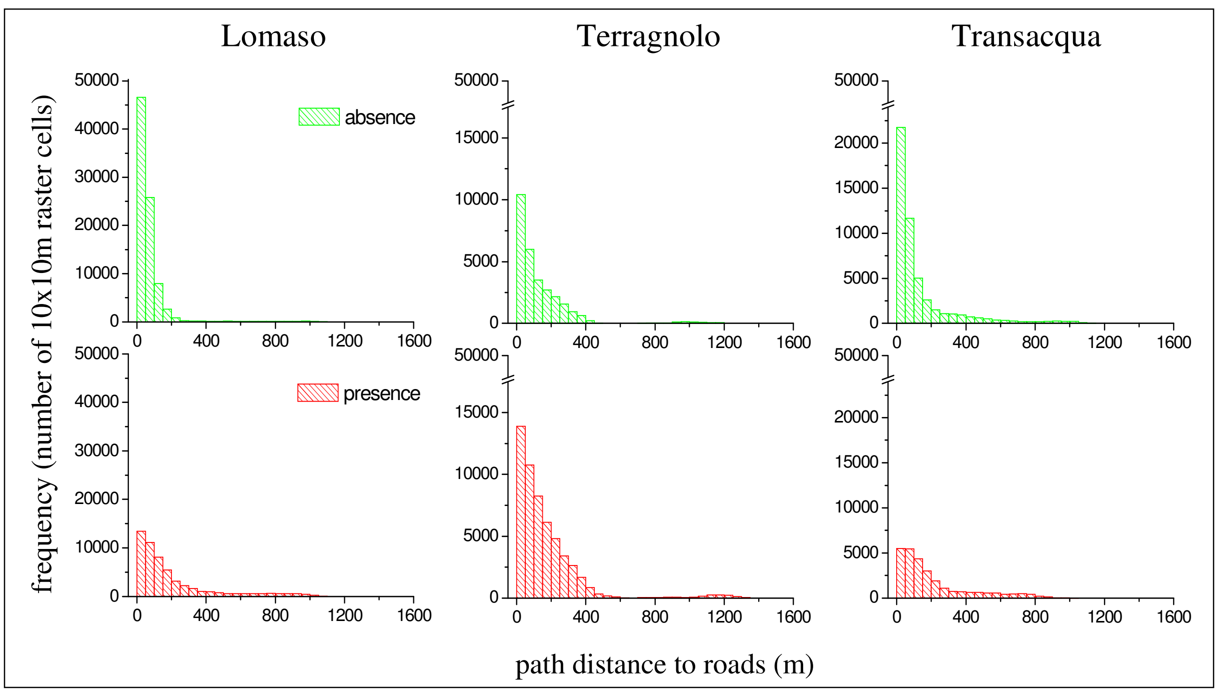


Fig. 57. Frequency of absence (no forest re-growth) and presence (forest re-growth) observations along a distance-to-roads gradient in Lomaso, Terragnolo, and Transacqua.

- In Transacqua, absence observations show a distribution similar to the one occurring in Lomaso, with the only difference that a consistent share of agricultural land situated at a longer distance from roads has been maintained. This reflects the preservation of high altitude pastures in the region through the prosecution of traditional summer herding practices. As Gellrich et al. (2007) note, remoteness from road infrastructure is less relevant for land use decisions in the uplands than in the mechanically cultivated valley floor, as direct accessibility to pasture land by vehicles is often not necessary. However, Transacqua is provided with a good road network throughout the territory. Extensive road infrastructure is of relevance not only for decentralized land management systems as they occur in Transacqua, but also for the accessibility and fruibility of cultural landscapes by tourists and guests. In fact, tourism requires direct access to landscapes, thus positively affecting road development in rural areas (Bätzing, 2005).

Distance to buildings

The spatial layout of farmland with respect to infrastructure has been recognized to be a highly significant factor in land use decision making (Thenail & Baudry, 2004; Mottet et al., 2006; Van Doorn & Bakker, 2007; Bogner, 2008). Besides land accessibility via road networks, the distance to farmsteads or other buildings such as haylofts or houses may influence the intensity of land use and the presence or absence of land abandonment. The basic assumption was that land abandonment and forest re-growth are more likely to occur far away from buildings than in their vicinity.

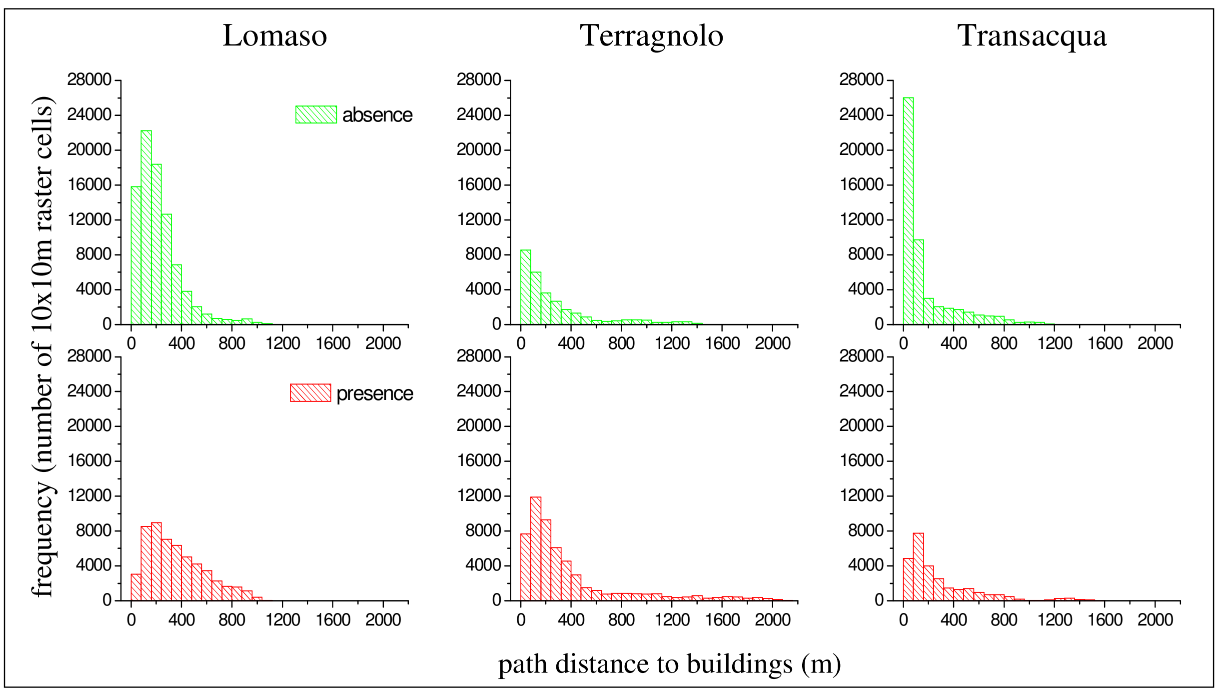


Fig. 58. Frequency of absence (no forest re-growth) and presence (forest re-growth) observations along a distance-to-buildings gradient in Lomaso, Terragnolo, and Transacqua.

Figure 58 shows the distribution of presence and absence observations along a distance-to-buildings gradient in the three case study communities. In the main, the frequency of presence observations follows a hump-shaped curve from shorter to longer distance from buildings. This means that land abandonment and forest re-growth were less frequent in the immediate surroundings of buildings (between 0 and 80 m in particular). However, community-specific trends could be highlighted. In particular,

- Lomaso is characterized by a low density of single buildings in the open landscape, as most buildings are concentrated in and around the hamlets of the valley floor. Therefore, agricultural land in the immediate vicinity of buildings (0-80 m) is comparatively less than agricultural land at higher distances (more than 80 m). Both the frequency of absence observations and the frequency of presence observations have a unimodal shape, but the former decreases faster than the latter with increasing distance to buildings. In particular, land pieces at a distance longer than 600 m from buildings were almost completely abandoned over the period 1954-2006. Again, extensive land desertion and forest re-growth in the uplands explain this trend, as the density of single buildings in the high altitude pasture region is extremely low .
- In Terragnolo, the presence of single buildings does not appear to significantly influence the intensity of land use. The number of absence observations in the immediate vicinity of buildings (0-80 m) is only slightly higher than the number of absence observations in the same class, and forest re-growth exceeds open landscape for all other distance classes. Note that the mean distances to buildings of presence and absence observations do not differ noteworthily (276,2 m vs. 380,2 m).
- Transacqua is characterized by a very high density of single buildings in the landscape. This is attributable to more recent urban sprawl in the valley floor, and to the presence of a myriad of traditional haylofts and small farm buildings in the lower slope region. Not surprisingly, 51,9,% of presence observations were recorded at a distance from buildings lower than 80 m. On the contrary, only 17,8% of presence observations fell into this category. Note that the presence of single buildings in the lower slope region represents an important incentive for landowners to maintain a minimum degree of land use. In fact, many landowners, both locals and tourists, have converted their haylofts and small buildings to cottages or holiday homes, as they do not run any professional farming activity. They have an interest in keeping the surrounding landscape open primarily for aesthetic/recreative purposes. In the case of large plots, the land is normally rented to local farmers, while smaller plots are generally mown by the owners themselves. Since they have no livestock, they don’t need the cut grass and often let it decompose on the next compost heap (picture 14).

Picture 14. On the left, an old farm building has been converted to a cottage in the surroundings of Transacqua. On the right, the cut grass lies on the compost heap in the vicinity of a small holiday home (picture by the author).

Distance to inhabited areas

The variable 'distance to inhabited areas' expresses the spatial remoteness of a land plot from the built-up areas. Remoteness is an important cost factor of farming practices, as production costs increase with increasing distance from the centre of socio-economic activities (Mottet et al., 2006). Hence, land plots far away from villages or hamlets were expected to be more susceptible to land abandonment that land plots around the built-up areas.

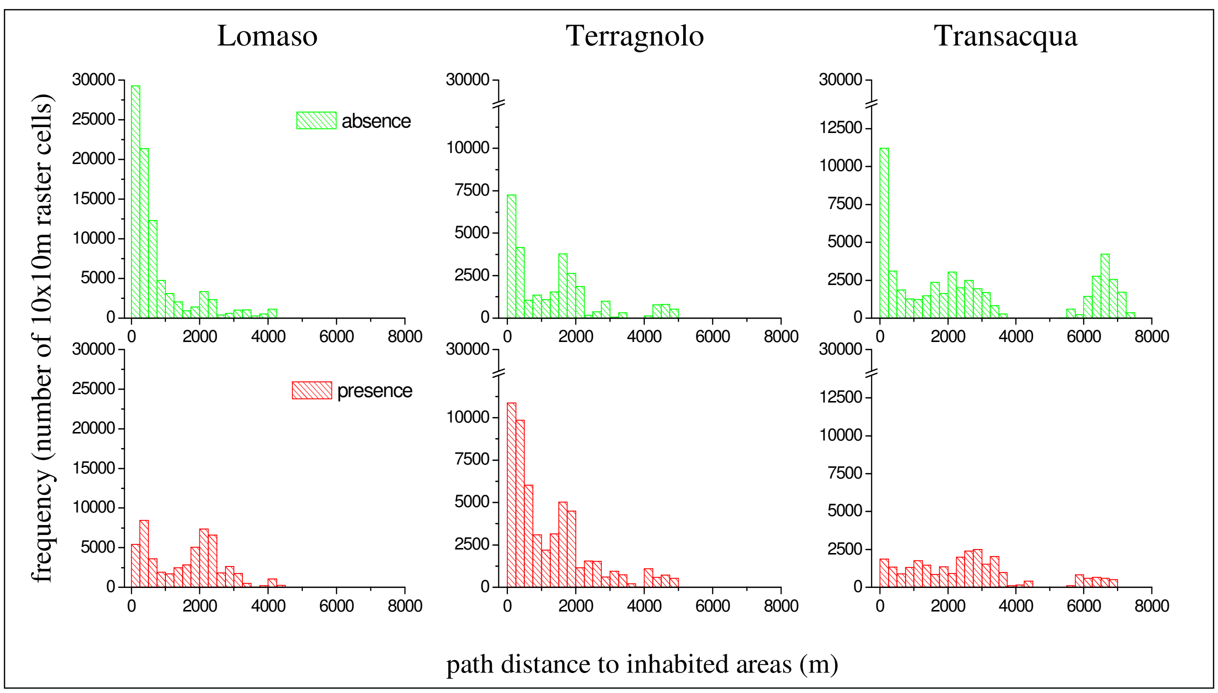


Fig. 59. Frequency of absence (no forest re-growth) and presence (forest re-growth) observations along a distance-to-inhabited-areas gradient in Lomaso, Terragnolo, and Transacqua.

Figure 59 shows the distribution of presence and absence observations along a distance-to-inhabited-areas gradient in the three case study communities. The graphs are to a large extent redundant with the altitudinal patterns observed above, as the built-up areas are normally concentrated in the valley floor or in the lower slope region. In Lomaso, the gap between the mean value of absence observations (397,6 m) and the mean value of presence observations (1.782,7 m) indicates higher rates of forest re-growth in the more peripheral regions of the Monte Casale, where most high altitude pasture land is concentrated. In Terragnolo, no relationship could be observed between land abandonment and distance to inhabited areas. The mean value of absence observations was even higher than that of absence observations (1.139,3 m vs. 774,9 m) due to faster forest re-growth at lower altitudes. In particular, forest re-growth was very high even in the immediate vicinity of hamlets. This reveals a very low level of human disturbance and a high degree of landscape degradation. Finally, in Transacqua forest re-growth was more frequent at intermediate values of perifericity (lower slope region), while it was particularly low at high distances from inhabited areas, in correspondence to the high altitude pasture region (malga Neva Prima and malga Neva Seconda in particular).

5.7.2 Drivers of agricultural land abandonment

The drivers of land abandonment selected for the purpose of the present analysis have been extensively described in the previous section. These drivers were utilised as explanatory variables in monovariate and multivariate linear regressions. In particular, the former allowed to quantify what fraction of the observed abandonment can be explained by each single variable (R-squared) and to define the sign and strength (regression coefficient) of the correlation. The latter allowed to quantify what fraction of the observed abandonment can be explained by the set of selected variables (R-squared) and to define the relative contribution of each variable to the explanatory power of the model (F-Ratio).

Tables 30, 31, and 32 report the salient results of monovariate linear regression in the three case study communities. In the main, all variables are statistically significant at the 99% confidence level, as their p-value is always smaller than 0,01. As to the coefficient of determinations and the regression coefficients, following aspects could be highlighted in each case study community:

- In Lomaso, the physio-geographic variables slope and altitude strongly correlate with land abandonment: they explain alone 23,6% and 24,0% of forest re-growth respectively. As expected, the correlation is positive, i.e. the probability of land abandonment increases with increasing slope steepness and increasing altitude. The comparatively high regression coefficient of slope steepness indicates a high susceptibility of the dependent variable to changes in slope inclination. Except for aspect, the other explanatory variables show a good correlation with land abandonment, ranging from 11,1% to 15,7%. As assumed, distance to forest edges and land abandonment are inversely proportional, while distance to roads, distance to buildings, and distance to inhabited areas are positively related to the dependent variable. In general, Lomaso's agriculture shows a high sensitiveness to cost-related and yield-related variables in land use decision making.

Tab. 30. Results of monovariate linear regression between the explanatory variables and land abandonment in Lomaso

explanatory variable	p-value	R-squared (%)	regression coefficient	constant
slope	0,0000	23,6	+ 0,026607	1,05516
altitude	0,0000	24,0	+ 0,000634	0,89425
aspect	0,0000	3,8	+ 0,000892	1,19026
distance to forest edges	0,0000	11,8	- 0,000826	1,55987
distance to roads	0,0000	13,0	+ 0,001000	1,26981
distance to buildings	0,0000	11,1	+ 0,000788	1,17051
distance to inhabited areas	0,0000	15,7	+ 0,000187	1,18817

- In Terragnolo, the coefficients of determination of the selected variables are fairly low. Slope steepness and altitude explain alone only 8,6% and 4,9% of the variability in land abandonment, and the other variables show an even weaker correlation. Except for slope steepness, the regression coefficients are extremely low. Additionally, the sigh of the relationship between some explanatory variables and land abandonment does not reflect the expectations. Specifically, the likelihood of land abandonment decreases with increasing altitude and with increasing distance to inhabited areas. This is mainly due to the fact that forest re-growth has occurred much more rapidly at lower altitudes (where the villages are located) than in the uplands thanks to more favourable growing conditions for shrubs and trees. In the main, the process of land abandonment in Terragnolo has not been particularly sensitive to cost-related and yield-related variables.

Tab. 31. Results of monovariate linear regression between the explanatory variables and land abandonment in Terragnolo

explanatory variable	p-value	R-squared (%)	regression coefficient	constant
slope	0,0000	8,6	+ 0,014175	1,29421
altitude	0,0000	4,9	- 0,000254	1,92329
aspect	0,0000	0,2	+ 0,000276	1,60271
distance to forest edges	0,0000	1,3	- 0,000521	1,71347
distance to roads	0,0000	0,6	+ 0,000208	1,62179
distance to buildings	0,0000	1,6	+ 0,000154	1,60003
distance to inhabited areas	0,0000	0,2	- 0,000017	1,67461

- In Transacqua, the selected variables do not show any strong correlation with land abandonment, apart from slope steepness, which explains 12,2% of observed forest re-growth. Remarkably, distance to forest edges and distance to buildings reach a coefficient of determination of 6,1% and 4,5% respectively. As mentioned above, this trend is ascribable to the high structural complexity of Transacqua's landscape (small grassland island surrounded by forest) and to the maintenance of open spaces around single buildings in the lower slope region. The regression coefficient between distance to inhabited areas and land abandonment is extremely low but negative, as land desertion was comparatively limited in very peripheral areas (high altitude pasture region). In comparison to Lomaso and Terragnolo, land abandonment in Transacqua shows an intermediate to low level of sensitiveness to the selected variables.

Tab. 32. Results of monovariate linear regression between the explanatory variables and land abandonment in Transacqua

explanatory variable	p-value	R-squared (%)	regression coefficient	constant
slope	0,0000	12,2	+ 0,016174	1,05032
altitude	0,0000	0,2	+ 0,000061	1,27580
aspect	0,0000	0,2	+ 0,000229	1,39953
distance to forest edges	0,0000	6,1	- 0,000708	1,44717
distance to roads	0,0000	2,7	+ 0,000396	1,28930
distance to buildings	0,0000	4,5	+ 0,000402	1,26527
distance to inhabited areas	0,0000	0,2	- 0,000008	1,37371

The results of multivariate linear regression basically confirm the findings illustrated above (tables 33, 34, 35, figures 60, 61, 62). In particular, following aspects could be highlighted in each case study community:

- In Lomaso, the explanatory power of the model is comparatively good. In fact, the set of selected variables explains 41,3% of land abandonment and forest re-growth in the community. The independent variable 'slope' contributes the most to the explanatory power of the model, as it has the highest F-Ratio. Its regression coefficient (positive) is the highest as well. The remaining variables show moderate to low F-Ratios. Specifically, the variable 'altitude', which had the highest coefficient of determination in the monovariate linear regression, does not significantly contribute to this model. All variables are statistically significant at the 99% confidence level, as their p-value is always smaller than 0,01. The variance inflation factor (V.I.F), which measures the extent to which the predictor variables are correlated among themselves, is always lower than 10. Hence, no serious multicollaterality is given.

Tab. 33. Results of multivariate linear regression between the explanatory variables and land abandonment in Lomaso

explanatory variable	p-value	R-squared (%)	regression coefficient (constant = 0,87636)	F-Ratio	V.I.F.
slope	0,0000	41,3	+ 0,018677	19664,7	1,4
altitude	0,0000		+ 0,000184	1773,2	2,7
aspect	0,0000		+ 0,000151	226,3	1,2
distance to forest edges	0,0000		- 0,000333	3551,8	1,3
distance to roads	0,0000		+ 0,000364	2646,7	1,5
distance to buildings	0,0000		+ 0,000362	3690,0	1,5
distance to inhabited areas	0,0000		+ 0,000030	377,4	2,6

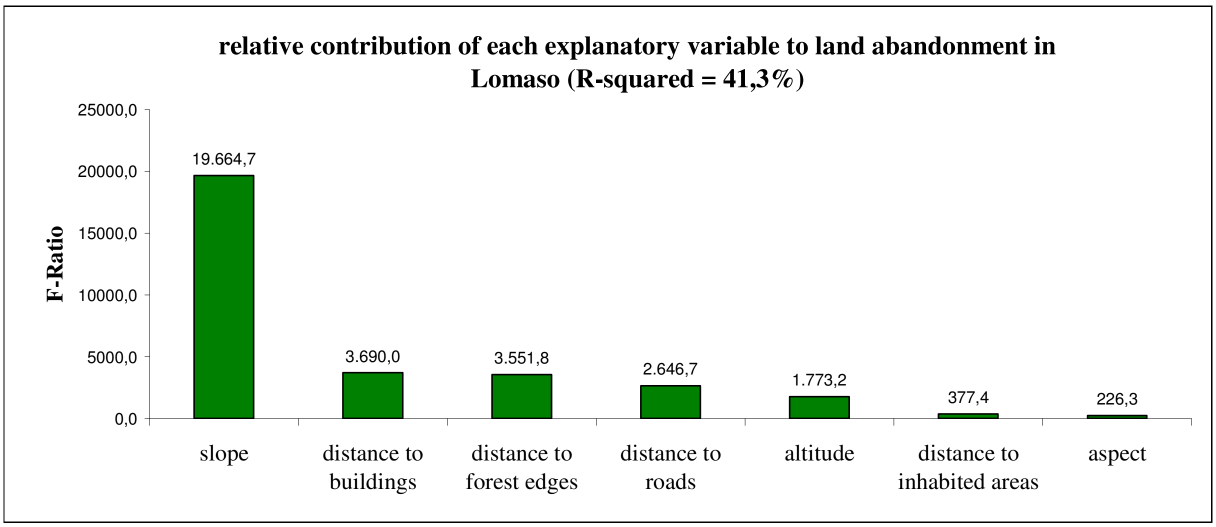


Fig. 60. Relative contribution of each explanatory variable to the land abandonment model in Lomaso.

- In Terragnolo, the multivariate linear model shows a very poor performance, as the coefficient of determination reaches only 19,1%. Altitude and distance to buildings contribute the most to the model, but the sign of their relationship with land abandonment is not in line with the assumptions adopted. This could be observed for the variables 'distance to roads' and 'distance to inhabited areas' as well. The only predictor variable responding to the expectations is slope steepness, which is positively related to land abandonment and significantly contributes to the explanatory power of the model. 'Distance to forest edges' has a lower statistical significance than the other variables (it is statistically significant at the 90% confidence level), and has the lowest F-Ratio. No relevant redundance between variables was detected.

Tab. 34. Results of multivariate linear regression between the explanatory variables and land abandonment in Terragnolo

explanatory variable	p-value	R-squared (%)	regression coefficient (constant = 1,72274)	F-Ratio	V.I.F.
slope	0,0000	19,1	+ 0,010111	4059,7	1,1
altitude	0,0000		- 0,000466	7923,6	2,2
aspect	0,0000		- 0,000108	29,1	1,1
distance to forest edges	0,0729		- 0,000027	3,2	1,1
distance to roads	0,0000		- 0,000146	202,2	1,6
distance to buildings	0,0000		- 0,000424	5645,8	2,2
distance to inhabited areas	0,0000		- 0,000023	189,3	1,8

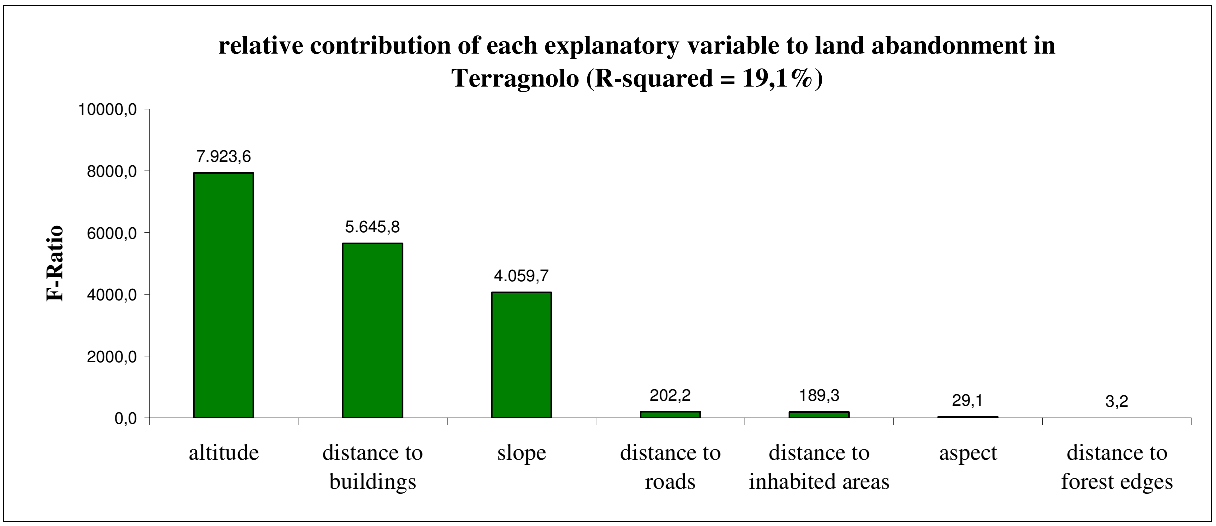


Fig. 61. Relative contribution of each explanatory variable to the land abandonment model in Terragnolo.

- In Transacqua, the overall explanatory power of the model is fairly low, as the set of selected variables justifies only 24,4% of forest re-growth in the community. Slope steepness is the variable most affecting land abandonment, followed by distance to forest edges. The variable 'distance to inhabited areas' in inversely proportional to the dependent variable, as observed in the monovariate regression. The relationship of the remaining variables with land abandonment is in line with the expectations, but their explanatory power is very weak. The high variance inflation factor of the variables 'altitude' and 'distance to inhabited areas' indicates a certain redundance, i.e. land pieces at higher altitudes are to a large extent located far away from the built-up areas.

Tab. 35. Results of multivariate linear regression between the explanatory variables and land abandonment in Transacqua

explanatory variable	p-value	R-squared (%)	regression coefficient (constant = 1,06432)	F-Ratio	V.I.F.
slope	0,0000	24,4	+ 0,017364	7894,9	1,8
altitude	0,0000		+ 0,000105	57,3	10,7
aspect	0,0000		+ 0,000175	103,6	1,1
distance to forest edges	0,0000		- 0,000768	4570,7	1,6
distance to roads	0,0000		+ 0,000378	668,3	3,8
distance to buildings	0,0000		+ 0,000051	18,5	3,9
distance to inhabited areas	0,0000		- 0,000063	1110,3	8,6

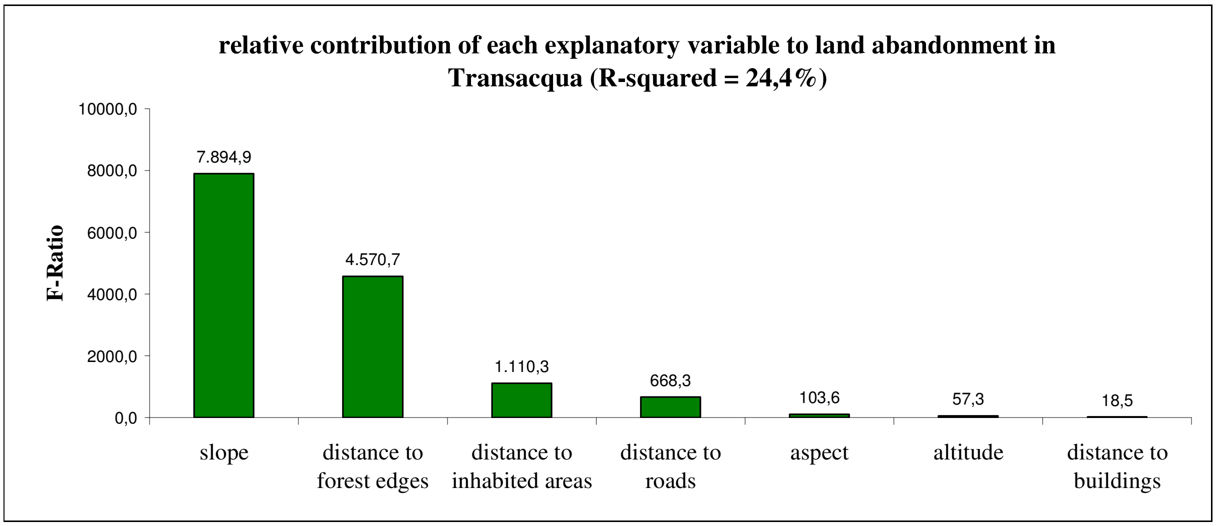


Fig. 62. Relative contribution of each explanatory variable to the land abandonment model in Transacqua.

Which conclusions can be drawn from these results? In absolute terms, the coefficients of determination of both the monovariate and the multivariate relationships show that the explanatory power of the proposed models is rather low. This may be attributed to three main causes:

- omittance of variables related to undetected local characteristics such as water availability, intensity of solar radiation, soil quality, small-scaled topographic peculiarieties, etc. (Schellenberg, 2002; Gellrich et al., 2007);
- omittance of socio-economic variables such as property fragmentation, farm income, farm size, age and education of farmers, labour markets, local agricultural policies, etc. (Baldock e al., 1996; MacDonald et al., 2000; Bell et al., 2004; Bürgi et al., 2004; Van Doorn & Bakker, 2007);
- non-consideration of the motivations of individual farmers to abandon and maintain agricultural land use.

These variables could not be included in the model either because data were not available or because available figures could not be geo-referenced due to their aggregate nature (e.g. one value of average farm size for the entire community). Collecting individual level and farm level information would have probably helped to improve the understanding of land use changes in the study areas.

However, the results obtained from geo-statistical analysis allow a general conclusion about the drivers of land abandonment in Lomaso, Terragnolo, and Transacqua. The selected cost-related and yield related factors, which represent the major bio-physical and spatial constraints to farmers' land use practices, had fundamentally different weights in land use decision making in the three case study communities, in response to the different environmental conditions and the different evolution of agricultural and socio-economic structures. In Lomaso, the relationship between land abandonment and the predictor variables (slope in particular) was strong, as intensive and highly mechanized farming systems are very cost and yield sensitive. The assumption that farmers cease to use a piece of land as soon as its cultivations costs become too high and/or its yield potential too low could explain nearly half of the observed land abandonment in this community. On the contrary, the influence of bio-physical constraints on farmers' land use decisions appeared to be much weaker in Terragnolo and Transacqua. In Terragnolo, land abandonment occurred almost independent of cost related and yield related variables because it was a generalized phenomenon, arising from the structural collapse of local agriculture. In Transacqua, land use decisions were not much sensitive to bio-physical constraints due to the (at least partial) persistence of traditional land management practices (hay making, summer grazing) and the landscape conservation incentives associated with a moderate degree of tourism development.

6. Conclusions

The diachronic landscape analysis performed shows that rates and patterns of landscape change in Lomaso, Terragnolo, and Transacqua have been extremely context-dependent. In fact, a landscape changes through time in response to changes in the interaction of its natural and anthropic components. Since the three case study communities profoundly differ from each other both in their natural conditions and in their recent socio-economic evolution, their cultural landscapes have experienced diametrically opposed developments. In particular:

- In **Lomaso**, landscape changes have been basically driven by favourable environmental conditions and a progressive specialisation of local agriculture in intensive livestock farming. The high pressure on farms to maintain incomes has resulted not only in the replacement of mixed farming with monoculture cropping (maize or grass), but also in a strong polarisation of agricultural land use at the community level. Highly productive arable land in the valley floor and easily mechanisable grassland in the lower slope region have been intensified through increased inputs and higher stocking rates, while poor quality grassland as well as pasture land at higher altitudes have been extensively abandoned due to high cultivation costs and low yield potential. Both intensification and abandonment have been detrimental to the structural heterogeneity of traditional low-intensity landscapes. On one side, intensively utilized land pieces have been drastically simplified through the elimination of structural elements such as hedges or single trees. On the other, the extensive conversion of grassland areas to scrub and forest has implied increasing rarity of open space and loss of landscape mosaics. <u>It can be concluded that agricultural intensification is disruptive to traditional cultural landscapes and ineffective in limiting land abandonment and forest re-growth.</u>
- In **Terragnolo**, landscape dynamics have been driven by unfavourable geo-morphologic conditions and a generalized process of marginalisation and decline affecting the entire socio-economic system of the community. The structural collapse of local agriculture has compromised the precarious balance between human activity and natural processes, resulting in massive land abandonment throughout the territory independently of cost and yield related variables. As a consequence, uncontrolled scrub and vegetation development has irremediably ‘erased’ the old cultural landscape and transformed Terragnolo in a wilderness area with a forest cover exceeding 90% of surface area. <u>It can be concluded that the retreat of agriculture from cultural landscapes inevitably leads to their disappearance.</u>

- In **Transacqua**, landscape changes have been strongly influenced by tourism development and the associated economic growth. Even though tourism has increased the opportunity costs of agricultural employment and agricultural land use (pull-factors), it has created off-farm income opportunities as well as local demands for high-quality agricultural products (milk derivates) and related by-products (biodiversity, aesthetic and didactic values, cultural heritage, etc.). Hence, its impacts on traditional cultural landscapes have been contradictory. On one side, tourism development has accelerated the 'exodus' from agriculture and boosted urban development, thus contributing to land desertion in the lower slope region and agricultural land consumption through soil sealing in the valley floor. On the other, it has maintained small farm sizes and generated incentives to prosecute traditional farming practices such as mowing and high altitude summer grazing, thus slowing down the process of land abandonment and forest re-growth. In the main, it can be concluded that small farm scales and the dynamic economic integration of agriculture with the tourism industry guarantee the (at least partial) maintenance of decentralised agricultural land use and structure-rich landscape mosaics.

In spite of essentially different rates and patterns of landscape change, the increase of forested areas at the expenses of open landscapes and the resulting simplification of landscape structures represent the *trait d'union* between Lomaso, Terragnolo, and Transacqua. The persisting high degree of landscape dynamic makes a further forest expansion foreseeable, with detrimental impacts on the environmental quality and socio-economic potential of the region. Wilderness is becoming a reality in Trentino as well.

7. Outlook

The present research work shows that Trentino's cultural landscapes are changing in a direction and with a rate which can be considered unsustainable. If no meaningful strategies to counteract current landscape change are undertaken, the loss of traditional landscapes will be irremediable. This creates a growing need for action at both the policy making and the landscape planning level in the Province.

The definition of long-term objectives for the conservation and the sustainable use of landscape resources is the first imperative for policy and planning. Questions about the desired state of future landscapes are fundamental and unavoidable, as they represent the starting point for the design of instruments, measures, and intervention strategies. While landscape concepts and guiding principles for landscape development have been extensively formulated in neighbouring Alpine regions (e.g. *Landschaftsleitbild* in South Tyrol or *Landschaft 2020* in Switzerland), the Province of Trento still lacks a comprehensive vision for the integrated conservation and management of its cultural landscapes. Covering this deficit should become a priority of the Province.

However, objectives alone do not suffice. A set of institutional tools and implementation strategies are needed to achieve the wanted outcome. In designing them, three main principles should be considered:

- <u>spatial heterogeneity</u>: every sub-region or even every community is characterized by peculiar environmental conditions and socio-economic structures, and has specific potentials and assets. Therefore, general approaches should be integrated by local objectives and strategies responding to local priorities and needs.
- <u>participation</u>: bottom-up processes and involvement of local actors from the definition of objectives to the implementation of measures are necessary to guarantee the acceptance and effectiveness of interventions.
- <u>cooperation</u>: integrated concepts and strategies require cooperation not only between different institutional levels (Province, Districts, Municipalities), but also between different economic sectors (e.g. tourism and agriculture) and interest groups (e.g. hunters and nature conservationalists).

In the field of policy making, the preservation of cultural landscapes by the maintenance of agricultural activities is to be acknowledge as the primary strategy of intervention. In this respect, the rural development programme is a powerful tool, as it allows influencing farming practices through financial support mechanisms. In order to effectively contribute to the conservation of cultural landscapes, Provincial support schemes should fulfil following criteria:

- They have to be more tailored to local peculiarities and specificities. For instance, fundamentally different subsidisation strategies are necessary in the three case study communities Lomaso, Terragnolo, and Transacqua, due to their diametrically different agricultural production systems and natural conditions. Surprisingly, they are all classified as 'disadvantaged areas' in the rural development plan. This reflects the persisting horizontal approach of subsidisation policies.
- They have to set landscape quality objectives. For each landscape type, typical landscape qualities should be identified, which are worthy of preservation or further development. Subsequently, direct payments should be at least partly dependent on the contribution of agricultural practices to the maintenance or enhancement of these landscape qualities (result-oriented approach).
- They have to mobilize local resources. The valorisation of local assets has the potential to add value to agricultural production, thus creating incentives to maintain the extensive use of landscape resources. Increased added value can be reached through cooperatives, agro-tourism, agro-cultural events, product labelling, direct marketing, service provision (e.g. bioenergy), nature conservation contracts, etc. Volunteer work programmes on farms represent a way to mobilise local resources as well (see e.g. the *Bergbauernhilfe* in South Tyrol or the *Sensenvereine* in Austria). The rural development programme should more strongly support these initiatives, as they prevent rural depopulation and landscape degradation through decentralized income opportunities.
- They have to include hobby farmers. In Trentino's mountain areas, the maintenance of traditional landscape mosaics is to a significant extent dependent on a myriad of small land owners, who do not run any professional farming activity but cultivate their land in their spare time (hobby-farming). Valuable landscape elements such as small vegetable gardens, meadows with scattered fruit trees, and forest pastures still survive thanks to the prosecution of farming practices by hobby-farmers. Hence, it is necessary to create a set of incentives (both financial and non-financial) to preserve these small-scaled landscape mosaics from abandonment or disruption.

As to landscape planning, most planning instruments at the Provincial, District, and Municipality levels refer to urban and infrastructure development. The protection of cultural landscapes is basically conceived as the preservation of agricultural land from urban sprawl or inappropriate construction activities. Proactive planning involving local institutions and land users in the maintenance and sustainable development of cultural landscapes is still lacking. Hence, it appears necessary to develop new landscape planning instruments at the local level besides the already existing urban and zoning plans. We suggest the introduction of Municipality landscape plans, in which local landscape patterns are inventoried and evaluated, a local landscape concept is elabrated, and local intervention measures for landscape conservation and development are designed. These plans should be drawn following bottom-up and participatory approaches, and should entail comprehensive strategies to guarantee acceptable rates of landscape change.

The need for an integrated and effective landscape conservation approach in Trentino is urgent. The present research work intends not only to attract the interest of policy and planning on the magnitude of recent landscape change in the Province, but also to provide a first information base for the definition of long-term objectives, measures, and strategies for the sustainable development of (remaining) traditional landscapes.

9. Summary

The present degree thesis addresses recent structural changes in Trentino's agriculture (Italian Alps) and its impacts on traditional cultural landscapes. For the purpose of simplicity, three case study communities were selected which represent the three major directions of agricultural change in Trentino's mountain areas. Specifically,

- the community of Lomaso has experienced a process of agricultural intensification and specialisation in cattle farming thanks to the favourable climatic and geomorphologic conditions of its territory;
- the community of Terragnolo has faced massive farm abandonment and a generalized collapse of agriculture due to insurmountable geo-morphologic constraints as well as geographic and socio-economic marginality;
- the community of Transacqua has maintained small scaled livestock farms and developed a strong economic integration between local agriculture and tourism.

A diachrocnic landscape analysis over the period 1954-2006 was performed on the entire territory of each case study community following the aerial photograph interpretation model proposed by Tasser et al. (in print). Present landscape patterns and their change over the last 50 years were described by means of two indicators: land use and structural richness. Both indicators were digitalized as vector data with the help of GIS-technology, starting backwards from the 2006 orthophotograph to the 1973 and 1954 aerial photographs. Subsequently, the spatial and temporal patterns of land use and landscape structure change in Lomaso, Terragnolo, and Transacqua were extensively examined and compared. As the dynamics of landscape change were extremely heterogeneous within each community, the community area was subdivided into homogeneous landscape regions (cultivated valley floor, cultivated lower slope region, high-altitude pasture region, landscape regions dominated by forest, alpine elevation zone). Finally, forest re-growth on formerly cultivated agricultural land was quantified and its natural and spatial drivers investigated. This methodological approach has been already implemented in several parts of the Alpine bow. In Trentino, it finds its first application through the present degree thesis.

Results show that **Lomaso** has experienced a strong polarisation of agricultural land use between the lowlands (intensification) and the uplands (abandonment). In the valley floor, policultural arable systems have been transformed into intensive monocultures, resulting in a strong simplification of landscape structures. In the lower slope region, arable land has been converted to intensive grassland, while less favourable land pieces have been abandoned and re-conquered by forest. Peculiar landscape features such as areas with scattered fruit trees and mulberry tree plantations have fully disappeared. In the uplands, the abandonment of traditional summer herding practices

through permanent stabulation in the lowlands has caused extensive forest re-growth and the (almost complete) loss of landscape mosaics. Agricultural land desertion has been fairly sensitive to cost and yield related variables (slope steepness and altitude in particular).

In **Terragnolo**, the structural collapse of local agriculture has been accompained by massive farmland desertion throughout the territory independent of cost and yield related variables. In the valley floor, arable land has been fully converted to grassland, and forest re-growth has occurred even in the immediate vicinity of the built-up areas. In the extensively terraced lower slope region, policultural crop systems (grassland, arable, vineyards) have been completely substituted by natural scrub vegetation. Besides the loss of traditional landscape mosaics, the extensive neglect of terracces has negatively affected slope stability, resulting in augmented soil erosion and landslides. In the uplands, forest re-growth has been less marked due to the different speed of spontaneous succession along an altitudinal gradient. However, a further increase of forested area is foreseeable, as Terragnolo's high altitude pasture region is situated under the potential tree line and lies to a large extent fallow.

In **Transacqua**, the traditional decentralised use of landscape resources has been basically maintained thanks to small scales in livestock farming and the landscape conservation incentives arising from tourism. In the grassland dominated valley floor, tourism development has boosted urban and infrastructure expansion, causing considerable losses of agricultural land through soil sealing. However, a high degree of structural complexity has been preserved in the open landscape and almost no forest re-growth has occurred. Complex landscape mosaics still persist in the lower slope region, even if agricultural land abandonment has been substantial due to the simplification of livestock transhumance practices. In the uplands, the prosecution of traditional summer herding has slowed down forest re-growth: forested area has only slightly increased through localised phenomena of land desertion and thickening of existing light forest stands (forest pastures). Agricultural land desertion has been poorly sensitive to cost and yield related variables.

It could be concluded that an agricultural system based on small farm scales and the economic integration with tourism is more effective in maintaining traditional cultural landscapes and limiting forest re-growth than intensive or marginalised agricultural systems.

Trentino's cultural landscapes are changing in a direction and with a rate which can be considered unsustainable. The need for an integrated and effective landscape conservation approach is urgent. The present research work intends not only to attract the interest of policy and planning on the magnitude of recent landscape change in the region, but also to provide a first information base for the definition of long-term objectives, measures, and strategies for the sustainable development of (remaining) traditional landscapes.

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