# Landscape changes, traditional ecological knowledge and future scenarios in the Alps: a holistic ecological approach

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Abstract

In the last decades, a dramatic landscape change occurred in the European alpine region: open areas were naturally recolonized by forests as traditional agricultural and forest activities were reduced and reorganized. Land use changes (LUC) are generally measured through GIS and photo interpretation techniques but despite many studies focused on this phenomenon and its effects on biodiversity and on the environment in general, there is a lack of information about the transformation of human-environment connection. The study of Traditional Ecological Knowledge (TEK), such as the ability to recognize wild plants used as medicine or food, can suggest how this connection evolved through time and generations. This work investigates the relationship between the natural forest cover expansion that influences the loss of open areas and the loss of TEK. We used different data sources and approaches in order to address the topic in its complexity: a mix of questionnaire investigation, historical maps, GIS techniques and modeling were used to analyze the past land use changes and predict future scenarios. The study area, Trentino, Italy, is paradigmatic of the alpine situation and the land use change in the region is well documented from different studies, which we reviewed and compared in this paper. Our findings suggests that open area loss can be used as a good proxy to highlight the present state and to produce future scenarios of Traditional Ecological Knowledge. This could increase the awareness of the loss of TEK in other Alpine regions, where data on TEK are lacking, but where environmental trends are comparable.

## Introduction

In the last decades, a dramatic landscape change has been occurring in the European alpine region: open areas have been naturally recolonized by forests. Many studies have documented and quantified forest cover expansion in many European Alpine areas (Sitzia et al 2011). Less attention has been posed on the understanding of the dynamics and the consequences of this dramatic change both under the environmental (Scarascia-Mugnozza et al. 2000, Valle et al 2009, Schulp et al, 2008) and the social point of view (Gret Regamey et al. 2013). The loss of open areas is linked with people migration, changes in lifestyles, language and tradition, loss of economic dynamism of mountain areas, and increasing disconnection between people and natural areas (Ianni et al. 2015). In the ambit of the relation between the Land Use Change (hereafter, LUC) and the associated social processes, this study addresses the particular relationship between the loss of open areas and the decreasing intergenerational transmission of Traditional Ecological Knowledge (hereafter, TEK).

It is important to underline that the monitoring of TEK is an extremely complex and time consuming issue, since it requests hard work by committed researchers and the involvement of the interested local communities that must be convinced to actively participate to questionnaires and meetings. Therefore very few studies on Alpine TEK loss are available in literature.

The use of the word open area “loss” does not necessarily intend to give a negative connotation to the ongoing processes that can be considered as pathways of transformation to a new state. The Alpine environment is the result of a complex and millenarian interaction between man and the original alpine biomes. The anthropic intervention has irreversibly changed the natural environment (for example driving to extinction animal or plant species) and has created a different equilibrium in which man replaced at least partially the role or the habitat of the disappeared fauna or flora (Diamond 2005). The alteration of the original environment included high deforestation rates and massive LUC that stressed mountain areas and generated important phenomena of soil erosion and surface flow sediment.

If seen from another point of view, natural reafforestation could seem the best response to global concern over the rapid loss of the world’s biodiversity. In fact, at a global level, in the last decades afforestation practices and landscape restoration projects have been trying to stop or reverse the huge deforestation rates that affect in particular the tropical regions (Williams-Linera and Alvarez-Aquino 2010). Reversing the loss of environmental resources is in fact a global priority and one the targets of the millennium goals. It has been widely described that deforestation (and LUC) affects local biodiversity distribution and richness (Orlandi et al. 2016), resilience of ecosystems to climate change (Brambilla et al. 2015), water availability (Glavan et al. 2013) and carbon sequestration (Schulp et al 2008, Achard et al. 2014). Nevertheless, what is  nowadays occurring in the Alpine mountain environment - the recovery of forests at the expense of open areas and the associated impressive change in biodiversity patterns - should not be viewed only as a renaturalization process with positive consequences, not only for the mentioned TEK loss but also because the short and long term effects on fauna and flora biodiversity are debated and sometimes considered negative or doubtful at least for some groups or species (Strebel and Bühler 2015, Pornaro et al. 2013, Gilardelli et al 2013, Tattoni 2011).

Differently from TEK, the monitoring of LUC in the Alps have been extensively carried out using GIS and modelling techniques (Tappeiner 2007, Sitzia et al. 2011). The majority of these works rely on GIS analysis of cartographic material (historical maps, ortho-rectified aerial photographs, technical maps) processed combining manual and automatic techniques to extract LUC for each temporal step (Tattoni et al. 2010, Sitzia 2011). Although the techniques may vary in different studies, there is a general agreement on the way in which data are extracted, analyzed and processed (Kozak 2007, Wulf et al. 2009, Tattoni et al. 2011). The process of data preparation and analysis is especially time consuming and requires a specific expertise and background. Unfortunately, the description of this process is sometimes incomplete also in the scientific literature (Tattoni et al. 2010) and this makes cross-study comparison more difficult. Additionally it is possible to use past LUC rates to generate future scenarios, based on assumptions about key drivers such as environmental pressures and management choices. Even though the literature has debated the suitability of different methods for scenario generation based on past LUC and the associated uncertainty levels, these approaches are presently well accepted and widely used in the scientific community (Tappeiner et al. 2008, Cabral and Zamyatin 2009, Ciolli et al 2012). The same limitation mentioned before regarding the importance of the transparency of the methods applies also to scenario generation in order to allow for cross-study comparison.

The aim of this work is to enlighten the relation between LUC and the associated social processes, in particular, showing a relationship between the loss of open areas and the decreasing intergenerational transmission of ecological knowledge in a rural community. Highlighting the “inextricable link” between cultural and environmental processes can give new impulse to creative and innovative actions for the management of mountain areas that are suffering from depopulation and ageing.

To achieve this goals, in this work, the forest and open areas LUC past trends of an Alpine region (Trentino, Italy) during the last 150 years and future scenarios calculated using GIS (Geographic

Information System) aerial photographs and historical cartography are described and then combined with statistical data on migration and on traditional mountain activities that had an impact on forest patches, such as grazing. Secondly, the study is focused on a small community at a 1000 m altitude. It tries to combine LUC with field data that describe intergenerational TEK transmission using information about past TEK trends and forest LUC trends to produce future scenarios and to investigate the possible fate of LUC and TEK.

Study area

The study area is the Province of Trento, a mountain region of approximately 6,212 km² (located in the in the northeastern Italian Alps (Fig. X).

Trentino region was selected because forests cover more than 60 % of  the territory and they are expanding at the expense of open areas (Agnoletti 1998, Tattoni et al. 2010, Sitzia et al. 2009); also, the region has undergone massive migration rates and social changes during the last century and it is an important hotspot for biodiversity. In fact, the area hosts a large amount of floristic endemic species (Prosser 2001), about 19% of its surface is covered by natural parks and protected areas (ISTAT, Italian National Institute of Statistics website (http://www.istat.it/en), the Dolomites are considered a world natural heritage and Val di Ledro valley is to be declared as biosphere reserve. With its networks, the region is a corridor for macrofauna, it is the only Italian Alpine area in which the brown bear never disappeared (Tattoni et al. 2015, Mustoni 2003).

The forest varies from Mediterranean vegetation, where forests of *Quercus ilex* occur, up to alpine areas where *Pinus mugo* and alpine herbaceous vegetation represent the principal forest cover. Trentino has a long tradition of forest management and the vast majority of the forest are public (Paletto et al. 2013). Forest and agricultural activities still constitute an important part of Trentino economic resources; winter and summer tourism is the main source of income for the region. In Trentino the central valleys located along main communication routes experienced a positive population trend, while the centers located over 600 meters height experienced a clear negative trend, unless they were located in touristic areas (Turri et al. 2005, Sitzia 2009). In 1921 the 17,9 % of the total population lived in the 750-1000 m altitude range, in 1961 it has reduced to the 15,2% and in 2011 to only the 11,4% (ISPAT).

Within the whole Trentino region a sub set of study areas was utterly investigated: Paneveggio Pale di San Martino Natural Park, the Department of Montagne (Tione) and its neighbourhood, Val di Pejo, Val di Sole, Roncegno and Tesino (Valsugana), Tovel, Val di Non. In particular to investigate the connections between TEK and LUC, we selected the Montagne municipality, that is paradigmatic of the situation in Trentino and, more generally, in similar Alpine contexts. Montagne is a small village located in the Italian Alps within the boundaries of a World Heritage Site. As in many other mountainous areas of Italy, the process of rural exodus and consequent land abandonment began in the first decades of the 20th century. It continued with the transition to a global market economy initiated in the 1960s and  the process increasingly disconnected communities from agricultural and wild systems. Like other mountain communities of higher altitudes of southern Europe, Montagne suffers from depopulation and aging due to the emigration of youth caused by a lack of economic opportunities.

| **Year** | **1921** | **1931** | **1936** | **1951** | **1961** | **1971** | **1981** | **1991** | **2001** | **2011** | **2014** |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Residents** | 41,570 | 34,648 | 31,497 | 33,074 | 33,669 | 34,624 | 33,545 | 33,719 | 35,442 | 37,415 | 37,635 |

*Table 1: Residents in the Giudicarie Valley (1921-2014)*

## Materials and methods

A review of the published data regarding forest and open areas changes in Trentino region was carefully conducted. Many studies were carried out in different areas of Trentino for different purposes (see additional material). Some regions were characterized by the presence of special protection areas or Parks therefore the purpose was to highlight conservation issues, while in some other areas the forest had mainly productive o soil protection functions, so the focus was more on these issues. The focus was put only on those studies that clearly described the methodology and that provided an explicit spatial representation of the forest, i.e. used historical maps (topographic, cadastral, thematic), aerial photographs and orthophotos or other official georeferenced material. When it was possible to compare the spatial and numerical results of the different studies they were used to carry out statistical calculations. When the results were not comparable (for example because the researchers adopted different taxonomy to classify their LUC) the use of these studies was limited to check against our general results. The few studies that produced estimates for the whole Trentino area are based on historical documents. The vast majority of the cited studies are dedicated to extract detailed information about LUC change in selected regions of Trentino. Sitzia's work (2009) is particularly interesting since he quantified the natural reafforestation between 1973 and 2000 in the whole Trentino region through a sampling based on the photo-interpretation of a subset of the available orthophotos (De Natale et al. 2007). The results of this study clearly showed a general trend of forest expansion (in 2000 the forest cover was about 4,7% larger than in 1973) and provided much additional useful information especially from the historical and ecological point of view. Nevertheless, it is worth to note that 1973 orthophoto material they used is affected by a high level of uncertainties (Tattoni et al 2010) and furthermore it is not possible to extrapolate the trends of this study to periods before 1973. Since the TEK data collected for Montagne and used for the following parts of the study are referenced also to previous temporal steps, for the purposes of this study the phenomenon was investigated in the whole Trentino territory in a deeper way and with a longest temporal perspective.

Further analysis and studies were conducted integrating them with unpublished results derived from several researches carried out to study landscape change in different areas of Trentino. Since 1998 the DICAM research group was involved in many projects that covered different topics: fostering conservation actions in regions characterized by the presence of special protection areas or parks, balancing conservation and production in areas where the forest was economically exploited and assessing natural risks. The general framework of the projects can be found in Ciolli and Zatelli (1999), Ciolli et al. (1999),  Giovannini and Tomio (2006), Tattoni et al. (2010, 2011), Podetti (2012), Ciolli (2012), Pedrotti (2014), Cattani (2016). All the spatial analysis of those projects were created following the methodology described by Tattoni et al. (2010); therefore, it was not necessary to make the methodologies comparable but we had to work on different degrees of uncertainties (Kaim et al. 2014). The maps of 1859 and 1936 were digitized in vector format and their border was considered accurate. Regarding photographic material that was automatically classified, accuracy was always more than 90% for 1954, 1984 and 1994, more than 86% for 1973, more than 93% for 2000, 2006, 2010 (colour image). 1973 photographic material shows the lowest values and previous studies using the same material clearly assessed that this affects the accuracy of the results of forest surface detection (Pontius et al 2004, Tattoni et al. 2011). Therefore, to overcome the limitations in Sitzia 2009, a comparison with previous (1954) and/or successive (1984) data is needed to allow for a confirmation of the trends. Further tables and materials reporting numerical inventories of forest surfaces taken in different periods were available by Servizio Foreste of Trento Province (Provincia Autonoma di Trento 2012b) and by other sources but, since they were created with different methodologies, they were only used to check against our general patterns.

Since the main interest of the study was in the general trends, the results of forest expansion is expressed as a percent of the total investigated areas rather than on absolute values. Therefore, when necessary data were reprocessed or aggregated to harmonize the analysis.

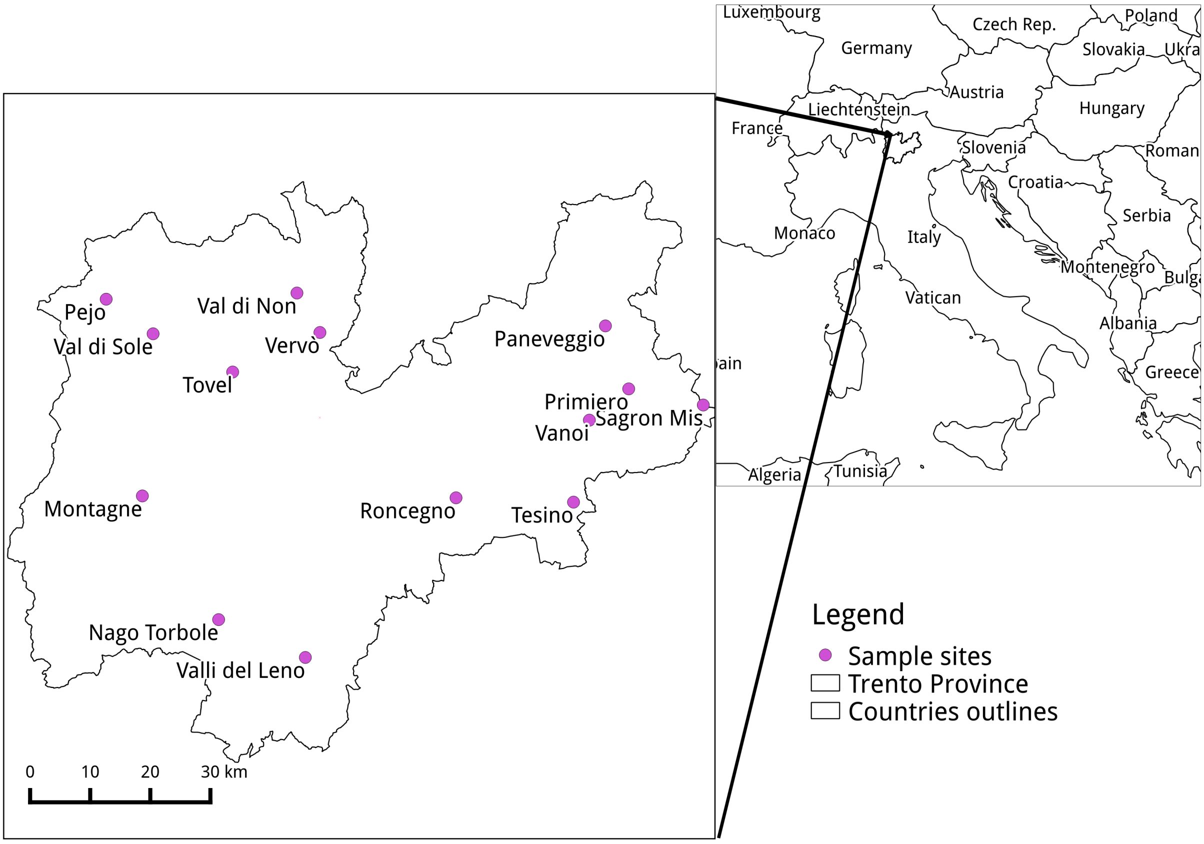


*Figure 1: The location of the areas analyzed in the reviewed studies: the total accounts for around 152.000 hectares, i.e. about 25 % of total Trentino area.*

The trends of forest coverage were analyzed over time with the linear model regression using the function (lm) available in the R base statistical package. (R Core Team 2013).

For this trend analysis, the data issuing from 9 different studies in 8 different areas (Ciolli and Zatelli 1999, Ciolli et al. 1999, Giovannini and Tomio 2006, Urbinati et al. 2006, Tattoni et al. 2010 and 2011, Podetti 2012, Pedrotti 2014, Cattani 2016) were selected, where the estimation of forest coverage derived from photo interpretation carried out with comparable method (Table 2).

For the purpose of the regression, the estimates of land cover changes were discarded when it was computed indirectly only from statistical extrapolations as not comparable with the results of direct assessment from photo interpretation. The regression analysis was run on data regarding the time frame from 1954 onwards, because older estimates were available only in few comparable datasets (Giovannini and Tomio 2005, Tattoni et al. 2010). Because in the different studies the sampled areas varied greatly in size (from 1.544 ha of the smaller to 32.400 ha of the biggest), the forest coverage estimation was converted from absolute values in hectares to percentages of coverages. Sample areas were divided in two classes for the regression analysis: study sites where most of the area fell in an average altitude of above 1200 were labeled as “High Elevation”  and those mostly located between 500 and 1500 as “Mid elevation”. The agricultural and farming practices as well as the rate of vegetation growth (Bronzini 2005, Tattoni et al. 2010, Salvador and Avanzini 2015) affecting these two elevation classes are different and we expect to observe a difference also in the invasion pattern of the forest. Forest changes were then related with the most relevant socio-economic factors for the region as identified by Sitzia (2009) and (Zanella et al. 2010) both at Trentino and at local level wherever data were available, i.e. population structure and distribution employees in agro-forest sector and cattle. In order to relate the LUC the following information about demography, economic activities related to agriculture and farming were collected: ISTAT census data, Zanella data about grazing animals, Population living at high elevation, % of population active in agro-forest sector (PAT).

The methodological steps to generate future scenarios were as follows:

TEK indicators were correlated with LUC following recent studies that highlighted that LUC trends may be connected to TEK loss in alpine rural communities. This part of the study heavily relies on Ianni et al. (2015) that investigated the intergenerational ecological transmission in a small community located in the centre south of Trentino and in an elevation range very indicative of the more critical situations. The study quantified TEK from the ability of recognizing wild plants traditionally used for food or medicine among local people in different age class and both genders.

The number of wild plants of known traditional usage are 30 of which 14 are found in forests and 16 are typical of grasslands or forest-grass ecotone area.

The ability to identify correctly the species by name or image is summarized as follows: high when the species was recognized in more then 70 % of the interviews; mid more then 30 % and less then 70 %; low in less then <30 %.

| Source | Year | Paneveggio Outside Park | Paneveggio Inside Park | Pejo Valley | Montagne Municipality | Val di Sole | Val di Non | Roncegno | Montagne and neibourhood | Tovel Malghe | Tesino |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Asburgic Cadastre** | **1859** | 40.16 | 36.72 | | | | 52.25 | | | | |
| **Italian Kingdom Forest Map** | **1936** | 45.46 | 36.5 | | | | | | | | |
| **Aerial Photograph** | **1954** | 50.43 | 38.39 | 42.77 | 38.91 | | | 42.02 | 57.72 | 46.46 | 54.08 |
| **Aerial Photograph** | **1973** | 52.78 | 37.65 | | 52.52 | 45.32 | | | 64.40 | | |
| **Aerial Photograph** | **1983** | 56.94 | 40.6 | 48.26 | | | | 54.52 | | 51.95 | |
| **Aerial Photograph** | **1994** | 59.38 | 43.51 | 54.00 | | | 70.29 | 68.42 | 74.17 | | |
| **Aerial Photograph** | **2000** | 65.6 | 46.21 | | | | 71.83 | | | 56.93 | |
| **Aerial Photograph** | **2006** | 67.4 | 46.18 | | 75.10 | 60.79 | | | 78.73 | | 80.34 |

*Table 2: Results of data harmonization from different study areas in Trentino, S.E. Alps: For each study site the forest area coverage was converted to % of the investigated area. Different authors compared different data sources in the frame time from 1859 to 2006. List of the data sources used to calculate forest land use change rates in this work (Ciolli and Zatelli 1999, Ciolli et al. 1999, Giovannini and Tomio 2006, Urbinati et al. 2006, Tattoni et al. 2010 and 2011, Podetti 2012, Pedrotti 2014, Cattani 2016).*

Finally it was tested whether the LUC trend can be used as a proxy to quantify TEK loss using past forest and open areas LUC data series, future scenarios of LUC and TEK were generated and the future perspectives TEK in alpine environment were discussed. Future scenarios of TEK were calculated by linear extrapolation while for future LUC we relied on published models (Tattoni et al. 2011, and Ciolli et al, 2012, Ianni et al. 2015). Among the different scenarios produced using Markov chain modeling, here only those with the assumption that the afforestation rate will remain unchanged were selected.

## RESULTS AND DISCUSSION

### Forest Coverage trend

Forest coverages estimates issued from the examined studies were compared and the result shows a general pattern in the trend of forest expansion. It is possible to observe a difference in the percentage of forest cover across sites, but the main trend is of a steady increase over time with a corresponding loss of open areas. The growth trend direction described by Agnoletti (2005) and Sitzia (2009) for the years 1973-2000 is in general confirmed although the the rate statistically calculated in Sitzia is probably slightly underestimated. Observation from 1954, where available, suggests that the phenomenon was already ongoing at an intensive rate before 1973. Also the comparison with the other studies (Provincia Autonoma di Trento 2012a and 2012b, Cosner & Gaio 2013, Grisotto 2015, Salvador and Avanzini 2016) generally agrees to identify a clear trend of forest expansion.

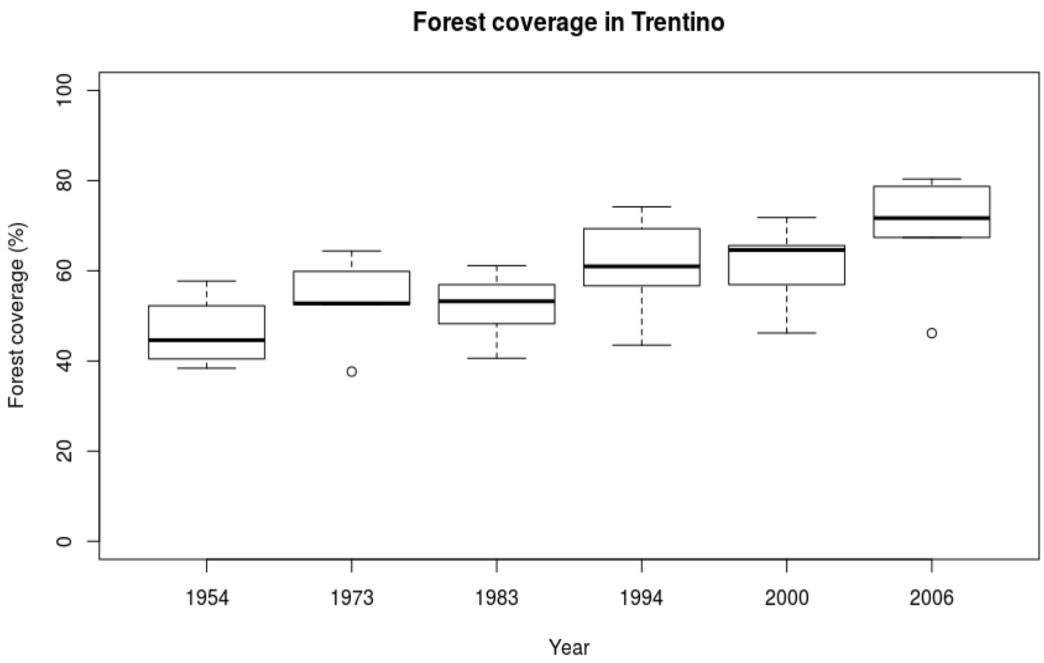


*Figure 2: Forest coverages sampled in different sites of Trentino (Italy), percentual extent was derived from aerial images interpretation.*

It seems that the phenomenon is widely spread in the whole Trentino territory with a highly recognizable pattern through time (Figure 2).

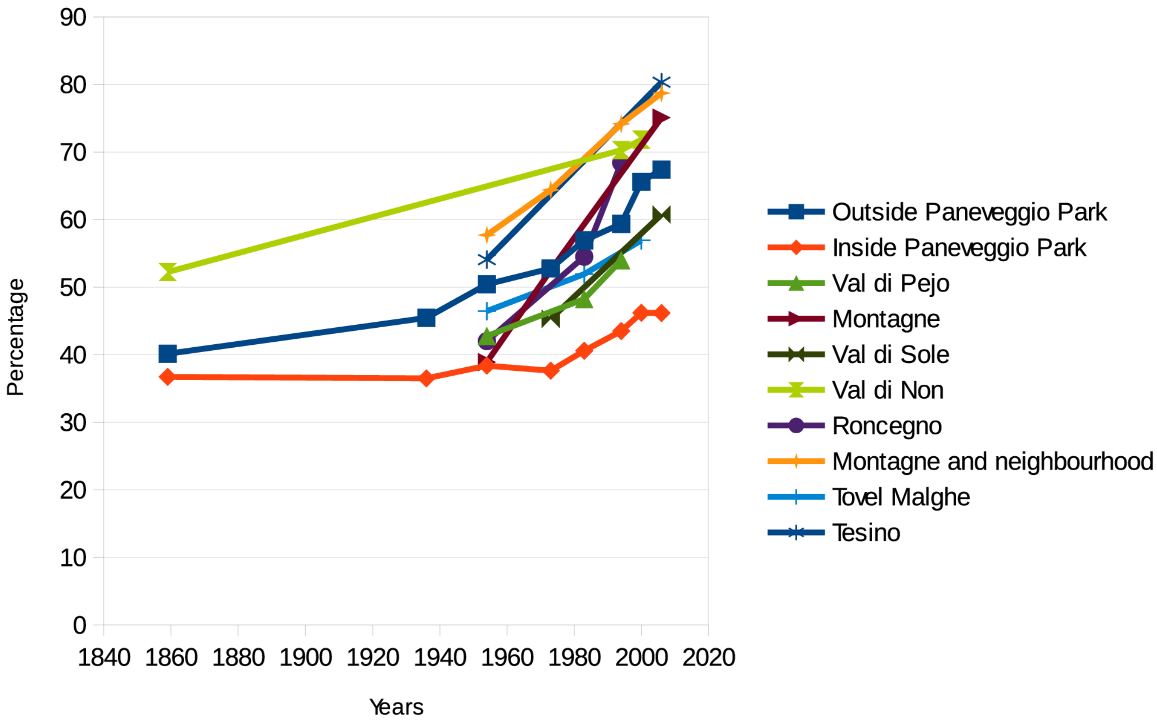


*Figure 3: Afforestation trends in 8 sample areas of S.E. Alps (Trentino)*

Anyway, some spatial variations in the region can be recognized (figure 3): on one side, the trend varies in particular situations where forest and pastures were partially replaced by highly specialized cultivations. For instance, starting from the '80s the farmers of the valley Val di Non converted most of the area into the more lucrative monocoltural (and generally with a very limited number of variety) apple cultivations (Giovannini and Tomio 2006, Chini 2010). On the other side, changes are evident along the altitudinal gradient.

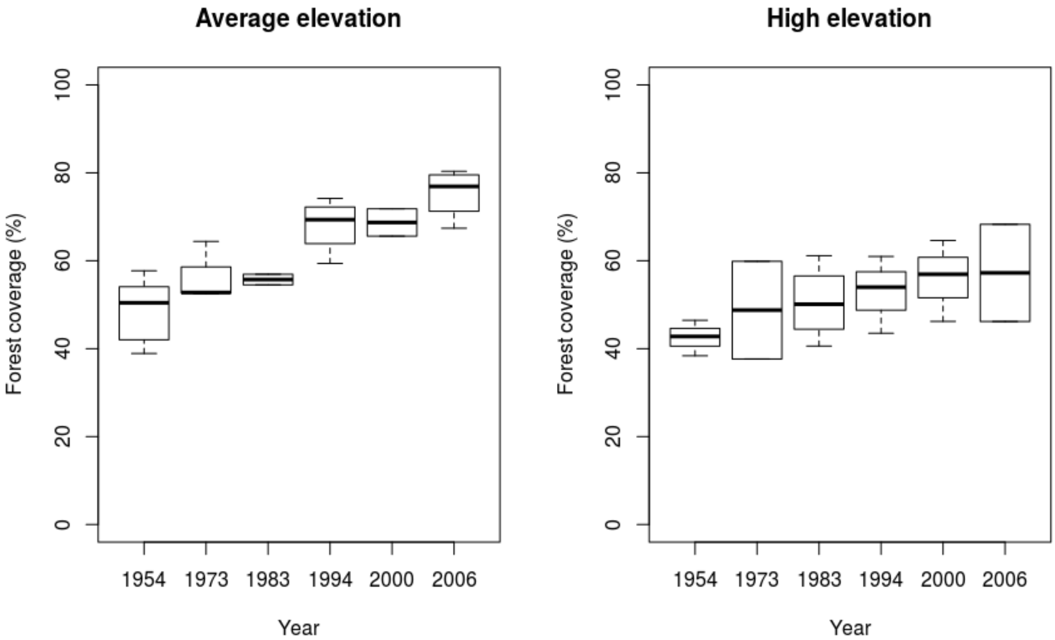


*Figure 4: Forest coverages sampled in different sites of Trentino (Italy) at average (500-1500 m) and high elevations (1200-2800 m) percentages are derived from aerial images interpretation.*

Despite a general increase in the forest coverage over time, the speed of the process is different at average and high elevations as shown in figure 4.

The linear regression model for the mid-elevations showed an increasing trend of 0.50± 0.07 points percents per year of area coverage, (Multiple $R^2$:0.73) and the effect of the year in the model is highly significant ($p<0.01$).

In the linear regression for high elevations, the effect of time was still significant ($p<0.05$) but the model fitting was poorer (Multiple $R^2=0.26$) then for the previous model. At high elevations the forest regains 0.30 ± 0.12 points percents per year of area coverage.

Furthermore, comparing the results of the whole region surrounding Montagne and the trend taken only in the Montagne municipality (that is the area interested by TEK study), the latter shows a higher expansion rate of forest cover. This is mainly due to the altitudinal range of the selected region, as it is confirmed by the results of Roncegno (Ciolli and Zatelli 1999) that had a similar dynamic and Tesino (Cattani 2016), as well as by Sitzia 2011 and by other studies in mountain European regions (Becker et al. 2007 Gellrich et al. 2007, Kozak et al, 2007).

According to Sitzia (2009), at Trentino level, the population experienced a reduction between 1869 and 1890 followed by a stabilization among 1890 and 1910 due to the first touristic fluxes. Between 1910 and 1951 the situation was quite variable with a general trend of migration. Between 1951 and 1971 population was stable while after 1971 people moved from upper elevation areas to lower elevation municipalities.

The forest change is linked also to the population distribution at different elevations and by the proportion of employees in the agricultural and forest sectors. In fact, the work force in agriculture have been decreasing by more than 50% since 1973 (De Natale et al. 2007). The trend of increasing population in lower elevation municipalities corresponds to the trend of pasture abandonment and of forest recolonization as observed in other similar cases (Chauchard et al. 2010, Zanella et al. 2010). The phenomenon caused also a reduction of the number of grazing animals, especially in disadvantaged areas (Zanella et al. 2010) (Figure 5).

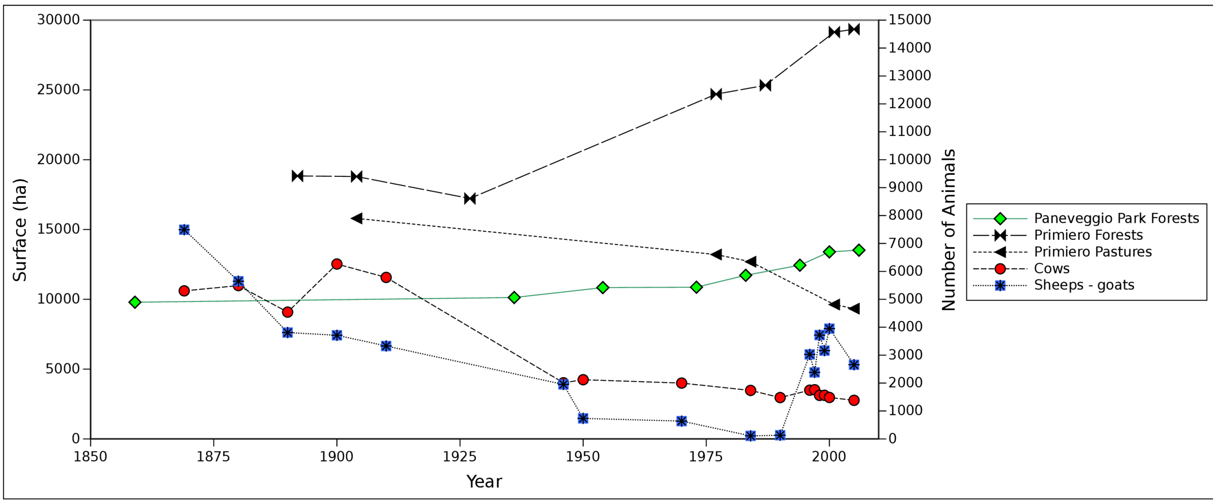


*Figure 5: Number of Cows, Sheeps and Goats (right scale), and surface of forest in Paneveggio Park, and Forests and pastures in the whole Primiero area (left scale) since 1850, modified from Zanella et al. 2010.*

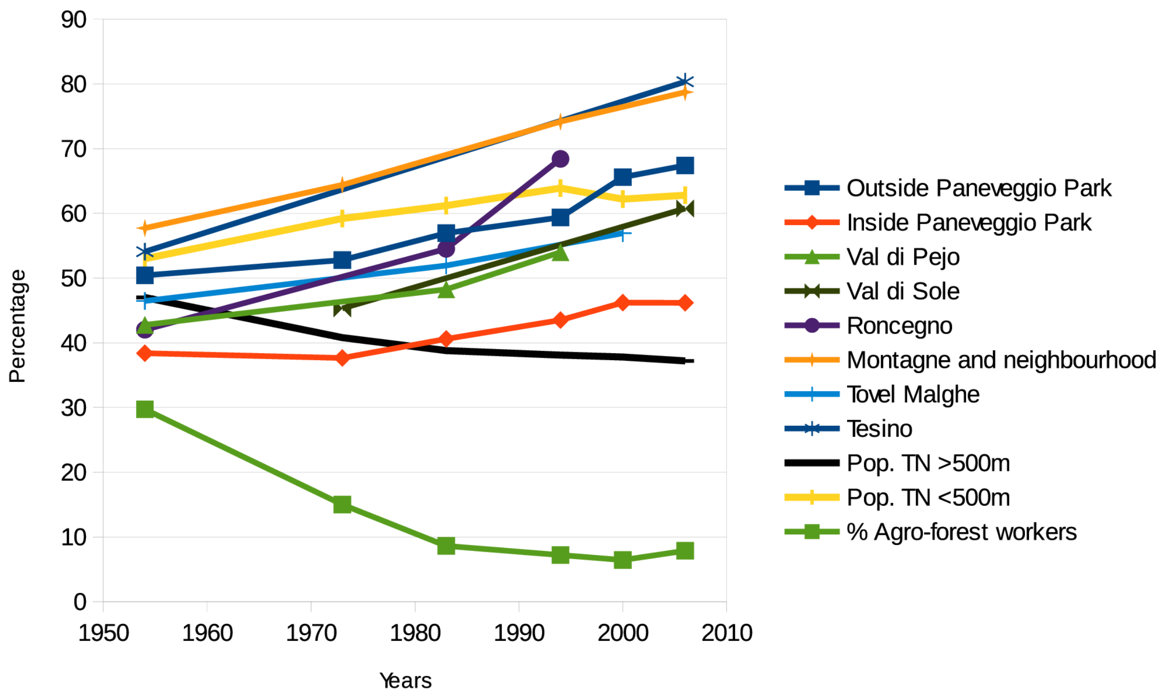


*Figure 6: Afforestation trend from 1954 in 8 sample sites in S.E. Alps (Trentino, Italy) compared to the population living at altitude > 500 m.a.s.l. (black line) and <500 m.a.s.l. (yellow line) The percent of population involved in agricultural and forest sectors is also reported in the bottom line with a steadly decreasing trend since 1951 (ISPAT)*

The comparison of the sample areas of Trentino (figure 6) highlighted a general afforestation trend that began about 40 year ago and is still ongoing at the expense of open areas, formerly used for traditional farming and agriculture. With the exception of some areas of the Non valley, whose mid elevations and bottom valley are now converted to intensive apple cultivation, the traditional economic activities led at mid and high elevations were abandoned. People lost economic advantages in maintaining alpine open areas and  moved to other economic sectors in the cities and in doing so they changed their attitude towards the mountain environment, seen more as a recreational space than as a source of incoming, food and medicine.

TEK and LUC scenarios

Data on TEK intergeneration transmission were available for Montagne municipality. The ability of recognizing wild plants, used as proxy of TEK, is still present in people aged over 30, despite the fact that only people over 65 really use those plants. Knowledge and use of plants are rapidly disappearing in the younger generation whose livelihoods do not do not depend on natural resources anymore. The loss of TEK concerns both forest and open area species: only 35% of the traditional plants are still well recognized by the residents with a marked generational difference in this ability between young (less then 30 year old) and older people. The loss of TEK follows a pattern linked to the usage of the plants: only corn is easily identified among the 9 traditionally cultivated species. Nowadays human and animal food are not coming from mountain grasslands but from more profitable low elevation fields or external markets. The ability to recognize wild flowers is still present for about 50% of the plants (6 species out of 13 fall in the high TEK class) maybe because most of the species are appreciated for their beauty other than for their medical properties such as Cyclamen (*Cyclamen purpurascens*), Edelweiss (*Leontopodium alpinum*) and Arnica (*Arnica Montana*) as reported in figure 7, and are also very common. A similar reasoning can be applied to trees, only the commonest 4 species (out of 16) are still well identified, Spruce fir (*Picea abies*), Silver fir (*Abies alba*), Beech (*Fagus sylvatica*), Hazelnut tree (*Corylus avellana*). The knowledge of species formerly cultivated and used as human or animal food is the lowest compared to the ability to recognize wild flowers and trees.

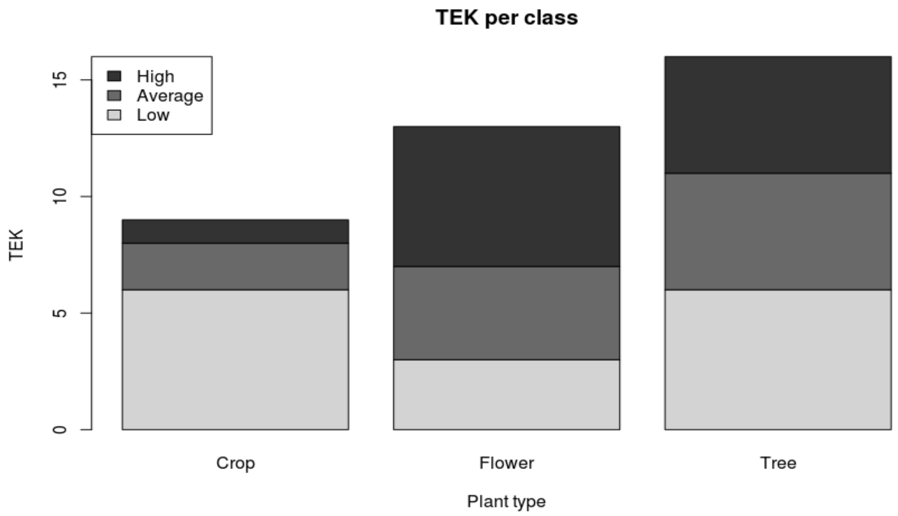


*Figure 7: Traditional ecological knowledge measured as the ability to recognize species of wild plants growing in the Italian Alps belonging*.

With the habitat changes some plants traditionally used, especially the open areas and ecotonal species, became rarer and then less recognized.

Table 3 shows the results of TEK investigation in Montagne compared with LUC data in the area. In Montagne TEK is dramatically and rapidly disappearing and the trend of TEK loss perfectly matches the one of the open areas loss.  Therefore it appears that the open areas loss could be considered as a good proxy to identify the degree of TEK loss regarding the local common species.

| Montagne | 1954 | 1973 | 2006 | 2050 |
|---|---|---|---|---|
| Open areas (% | 61.1 | 47.5 | 24.9 | 5 |
| Forest (%) | 38.9 | 52.5 | 75.1 | 95 |
| % visual Identification | 98.0 | 80.0 | 55.0 | 30 |
| % name identification | 90.0 | 70.0 | 40.0 | 10 |
| % Exploitable plants | 44.7 | 28.9 | 18.4 | 2 |
| % Exploited plants | 18.4 | 15.8 | 2.6 | 0 |
| Age class | over 65 | 30-55 | 8-25 | next gen |

*Table 3: Results of TEK investigation (Ianni et al. 2015). The percent of open area and forest are compared to the % of the knowledge of local plants by Montagne community divided by the corresponding age classes. Population was asked to recognize plants by photographs (Visual identification) by name (name identification) to tell how many plants can be used for at least one purpose (Exploitable plants) and how many plants they really use (Exploited plants)*

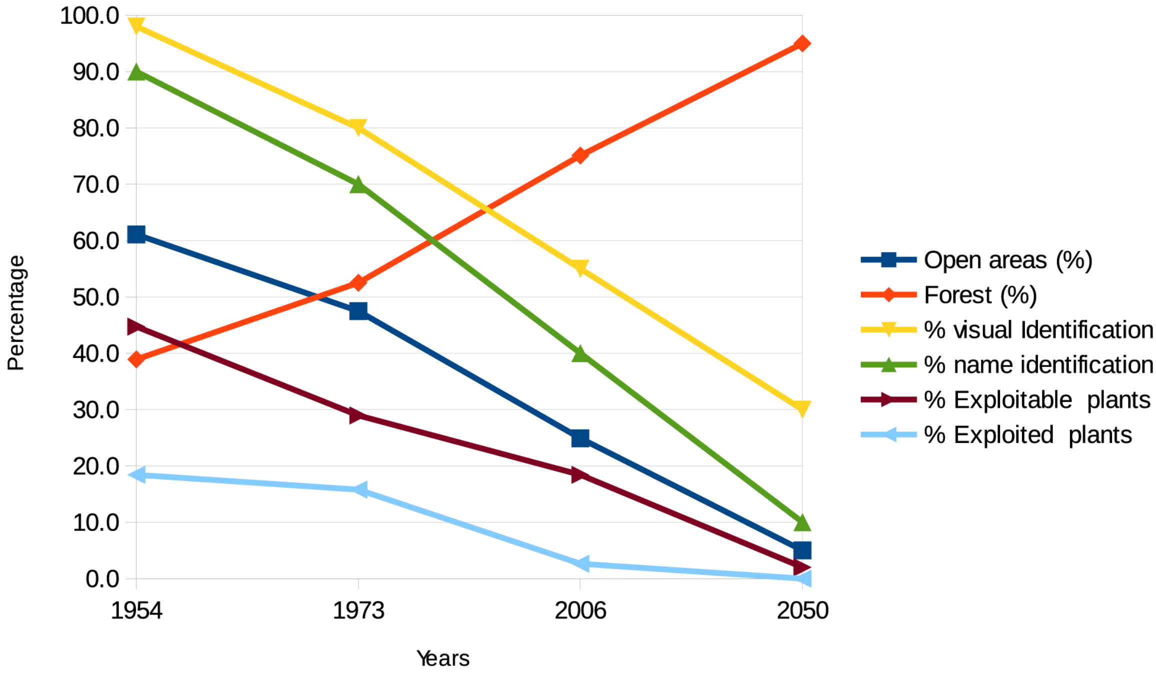


*Figure 8: Open areas loss and forest expansion in % in the community of Montagne (Italian Alps). TEK loss is described by four indicators: visual identification, name identification, exploitable and exploited plants (Ianni et al. 2015).*

Figure 8 reports the modeling of a scenario based on long term series of heterogeneous data, for the same area of Montagne starting from 1954 aerial photographs and modeling the results up to 2050.

Different scenarios were produced using Markov chain modeling using the procedures described in Tattoni et al 2011 and Ciolli et al 2012, here the one with the assumption that the afforestation rate will remain unchanged is selected. From the spatial point of view, the results show a constant loss of open areas and highlight how the phenomenon poses at risk the remnant pastures and meadows (Ianni et al 2015). The loss of TEK expressed as “% Exploitable plants” has a significant linear correlation with the loss of open areas (Multiple R-squared: 0.934, loss of adjusted R-squared: 0.912 $p < 0.01$), so it seems that it is possible to predict a loss in the usage of wild plants from the reduction of open areas, that can therefore be used as a proxy. The loss of TEK in terms of visual and name identification happened at a greater speed compared to the loss of open area. According to our prediction, it is plausible that in 2050, local people will be still able to recognize few plants, but the knowledge of their actual use will be lost forever. If can be assumed that open areas loss may be a proxy for TEK loss, reporting the results of the future modeling in graph produces a very worrying picture. TEK in Montagne will be completely lost in 2050, and this knowledge should be reconstructed from scratch, if ever.

As Salvador and Avanzini (2015) recently highlighted for the Leno Valley, according to cadastral and agriculture census the surface of the forest that is actually exploited is decreasing. This trend, confirmed for other areas (Bronzini 2005, Zanella 2010), affects the use of forest by local population and therefore both LUC and TEK. Among hay pastures, the reduction rate is highest in the period 1954-1994 in those areas that are at the highest elevation confirming that the phenomenon is in place since the 1950s. The reduction rate vary also depending on the location of the investigated area (Ciolli et al. 1999, Rauzi 2008)

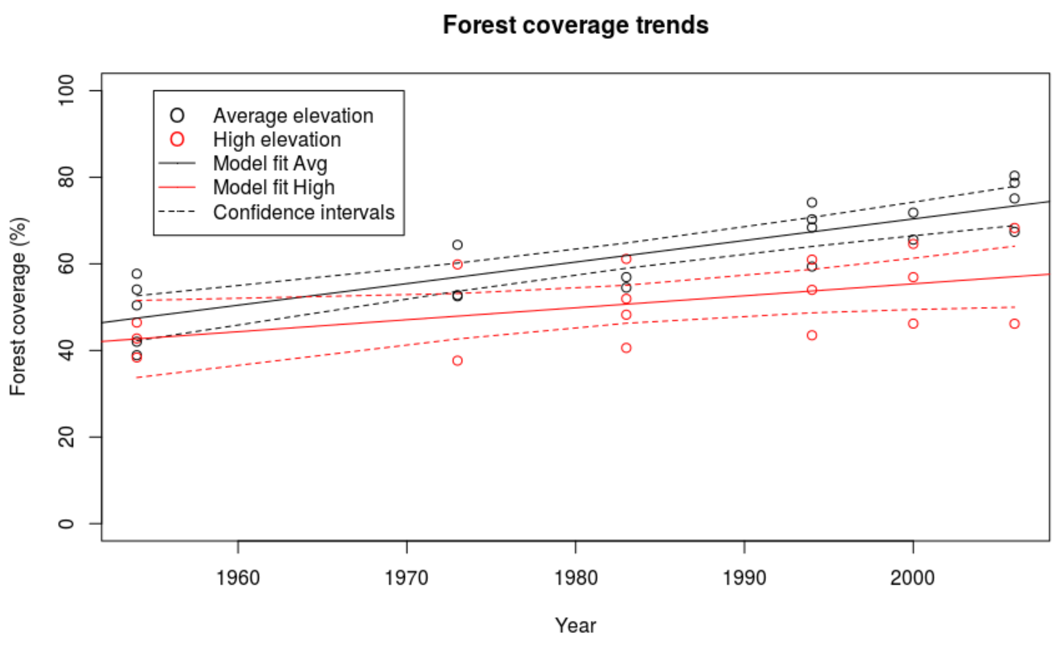


*Figure 9: Fitted linear model of forest coverages over time for two subsets sampled in different elevations in Trentino (Italy).*

The trends in “high” and “average” elevation classes are quite similar at the beginning of the investigated period (from 1954 to 1973) as shown in Figure 9 where the confidence intervals (95%) of the models overlap. From the 1970s instead the afforestation happened at different peaces: it was faster at lower elevations where the logging was abandoned reaching nearly 80% of the available area in 2006, and relatively slower at higher elevation, reaching about 50%, due also to the presence of unsuitable habitat for tree growth. An exception in this general trend are some municipalities of the Non valley, where after the 1970s, all the open areas available at suitable elevations were used to plant apple trees for intensive agriculture exploitation (Giovannini and Tomio 2006, Chini 2010).

The Markov chain modeling in other Trentino areas like Paneveggio actually follows the same pattern of Montagne, although the open area loss is slower and this is mainly due to park altitude range and vegetation distribution (Tattoni et al. 2011).

Examined all the premises, it is reasonable to think that the future scenarios trend can be plausible also for the vast majority of the areas of Trentino in which we still have not performed the calculations using Markov chain and spatially explicit techniques.

Results show a connection among population trends, TEK loss and open areas loss, but the latter can be quite easily calculated with a set of multitemporal images while the TEK loss needs specific and long field investigations and population trends need repeated inventories. Therefore, the possibility of using open areas loss as a proxy to derive this information can be very useful.

Future scenarios are extremely important in natural environment management since it is possible to incorporate other variables like climate change or forest management thus anticipating consequences and addressing management choices. Future scenarios are also important since they are a proxy of TEK loss and can be used to try to put in place measures to conserve it.

Not only the results of the modeling are relevant, but also their visual representation is important when they must be presented to stakeholders in public meetings for planning or management purposes.

These scenarios can be used also as a mean to highlight to local communities the phenomenon in order to involve local people in the revitalization of their local traditional knowledge.

To confirm this fact and check if the trend is so strictly matching in other conditions data from other alpine areas should be gathered to compare the results, but the investigation of TEK requires a huge commitment for the researchers who carry out this kind of works. They need to be accepted by the local community before to start the investigation and the whole process is generally slow and energy demanding, thus not many researches in this field are available in the Alpine environment (Ianni et al. 2015).

## Conclusions

The findings suggest that LUC can be used as a proxy for TEK loss in North Eastern Italian Alps, nevertheless further investigations are needed to confirm this on a wider scale. Using projection of future scenarios, predictive maps and/or statistics of TEK loss could be created. The method could allow to extrapolate TEK information trends from simple LUC trends, therefore helping to support environmental, political and social decisions in Alpine mountain environments.

Since the 1970s, Montagne experienced a stronger population decrease than the other municipalities nearby that are located at lower altitudes. It is reasonable to think that the population that resisted in the area was represented by those who were more interested in remaining there and more connected to their traditions. The loss of TEK registered in 2010s can be considered therefore also more serious, since those people should have retained important to pass their knowledge to their relatives and descendant but it seems that they failed.

It could be extremely interesting to investigate the state of TEK in those areas like Val di Non, where traditional mosaic diversified agriculture was mainly replaced by apple monoculture and the loss of open areas is less felt since many open areas and part of the forests were transformed in apple cultivations. Although a contact with nature was definitely maintained, the cultural transformation was profound and agriculture specialization could have lead to an important (or anyway, qualitatively different) loss of TEK as well.

The influence of the so called “extinction of experience” the loss of human-nature interactions (Soga and Gaston 2016) undermines human health and well-being as well as changes people’s emotions toward nature including their affinity to, interest in, and love of nature. Moreover, recreational play in natural environments during childhood positively influences people’s later interest in natural environments and outdoor recreation activities (Bixler et al. 2002) as well as nature conservation attitude (Collado et al. 2015).

Mountain abandon will be influenced by a lot of different issues, including climate change that may affect living conditions in the alps and therefore influence economy and biodiversity.

Historically, mountain abandonment follows a trend of expansion-contraction. The expansion trend of human activity could lead to an almost entire destruction of the original environment but northern hemisphere temperate climate and environmental conditions allow for a relatively short recovery time. In the Alps and in many mountain areas of Europe, a recovery phase is ongoing and it is possible to do something to conserve part of the former knowledge for the advantage of newer generations or it can simply be dropped and maybe rebuilt later. There is no “right” way to deal with this issue, and many things will happen independently from human intervention but a deeper comprehension of the dynamic of the phenomenon can help decision makers to take it into due consideration.

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| Year | Area | Authors | Extension (ha) | Time range | Methods |
|---|---|---|---|---|---|
| 1998 | Trentino | Agnoletti | 612000 | 1820-2001 | Historical documents |
| 1999 | Val di Pejo | Ciolli and Zatelli | 3165 | 1954-1999 | Aerial Photographs GIS, automatic classification and field campaign |
| 1999 | Roncegno | Ciolli et. al. | 2720 | 1954-1999 | Aerial Photographs GIS, automatic classification and field campaign |
| 2005 | Paneveggio malghe | Bronzini | 4977 | 1954-2000 | Aerial Photographs, manual photo interpretation, GIS and field campaign on a selection of Malghe |
| 2005 | Val di Sole | Turri et al. | 15 | 1859-2000 | Historical documents, GIS, Field campaign |
| 2006 | Tovel | Urbinati et al. | 6204 | 1860-2001 | Historical cartography, forest assessment plans, GIS, Aerial Photographs manual digitalization and field campaign |
| 2006 | Val di non | Giovannini and Tomio | 5876 | 1859-2006 | Aerial Photographs,GIS, automatic classification and field campaign |
| 2007 | Vanoi | Serafini et al. | 6423 | 1954-2006 | Aerial Photographs,GIS, automatic classification and field campaign |
| 2008 | Pejo | Rauzi | 3165 | 1954-2000 | Aerial Photographs, GIS and automatic classification |
| 2009 | Trentino | Sitzia | 612000 | 1973-2006 | Statistical estimate based on Aerial Photographs manual digitalization, GIS and field campaign on a sample of the area |
| 2010 | Paneveggio | Tattoni et al. | 32400 | 1859-2006 | Historical cartography, GIS, Aerial Photographs, automatic classification, Landscape metrics, field campaign |
| 2010 | Vervò | Chini | 1514 | 1973-2006 | Aerial Photographs,GIS, automatic classification and field campaign |
| 2010 | Nago and Torbole | Meneghetti | 5876 | 1859-2006 | Historical cartography, Aerial Photographs, GIS, automatic classification and field campaign |
| 2011 | Paneveggio | Tattoni et al. | 32400 | 1859-2010 | Markov chain Scenario production, Historical cartography, Aerial Photographs, GIS, automatic classification and field campaign |
| 2011 | Val di Pejo | Sitzia et al. | 80 | 1973-2006 | Aerial Photographs, GIS, automatic classification, Landscape metrics, field campaign |
| 2012 | Val di Sole | Podetti | 1544 | 1973-2006 | Aerial Photographs, GIS, automatic classification and field campaign |
| 2012 | Val di Sole | PAT | 38605 | 1930-2010 | Forest assessment plan data |
| 2012 | Paneveggio | Ciolli et al. | 32400 | 1859-2010 | Markov chain Scenario production, Historical cartography, Aerial Photographs, GIS, automatic classification and field campaign |
| 2012 | Trentino | PAT | 612000 | 1977-2009 | Forest assessment plan data |
| 2013 | Sagron Mis | Cosner and Gaio | 1106 | 1814-2006 | Historical cartography, Aerial Photographs, GIS, automatic classification and field campaign |
| 2014 | Montagne and neighbourhood | Pedrotti | 5620 | 1954-2006 | Historical cartography, Aerial Photographs, GIS, automatic classification and field campaign |
| 2015 | Primiero | Grisotto | 41339 | 1859-2011 | Historical cartography, Aerial Photographs, GIS, automatic classification and field campaign |
| 2015 | Montagne | Ianni et al | 5620 | 1954-2006 | Markov chain Scenario production, Historical cartography, Aerial Photographs, GIS, automatic classification and field campaign |
| 2016 | Pejo and Pesio | Orlandi et al | 4472 | 1954-2006 | Aerial photographs, GIS, manual digitalization, within a buffer of 1 km from points of interest |
| 2016 | Valli del Leno | Salvador and Avanzini | 16784 | 1859-2010 | Historical documents, Historical cartography, Aerial Photographs automatic classification, GIS, manual digitalization and field campaign |
| 2016 | Tesino | Cattani | 22500 | 1954-2006 | Aerial Photographs, GIS, automatic classification and field campaign |

*Table 4: ADDITIONAL MATERIAL List of all the research works and technical reports taken into account in the study of Trentino (Italy). Year of publication, name of the area, authors, extension (ha), time range that was investigated and methods used for the analysis are reported. Only those studies that used compatible methods and provided comparable results or allowed for results reprocessing were used to estimate Land Use Change.*