A multi-model approach predicts agricultural land abandonment and forest re-growth in an alpine region: a tool for biodiversity conservation

Maruska Anzini

Departement of Ecology and Evolution; University of Lausanne, Biophore, 1015 Lausanne, Switzerland.

Abstract

Land abandonment followed by forest re-growth could have a negative impact on biodiversity by reducing the species-rich habitats. In previous studies land abandonment is mostly explained by the recent social and economic development. Particularly agricultural land are abandoned where the profitability is loss and the cost of management increase. The objective of this study was to predict land abandonment and biodiversity threat to improve land management and better conservation practices in an alpine region. We predicted forest re-growth by considering many explanatory variables comprising climatic, topographic, distance and demographic variables. A multi-model approach was tested with two different land-cover transition. This permitted us to calibrate the model on the data set of the first transition and validate it on the data set of second transition. Our results showed that the model build in the first transition could explain the second transition indicating that the factors explaining the land abandonment remained constant throughout the time. We made a projection for the future land abandonment. Additionally we modeled the species richness over the study areas. Uniting this information with the projected land abandonment probability we obtained an index of threat to biodiversity loss. Predicting a level of threat for each agricultural areas gives the possibility to plan some intervention to favour the maintenance of biodiversity.

Keywords: Agricultural land abandonment, forest re-growth, biodiversity conservation, multi-model approach.

INTRODUCTION

Among the three main threats to biodiversity, i.e. climate changes, habitats destructions and biological invasions, land use change might be the one where conservation planning could bring the most notorious improvements. Land use change can be the consequence of intensification of human activities, but also of land abandonment. Reported changes in land use concern both intensification of agriculture through fertilization and urbanisation, which drastically reduces the biodiversity or land abandonment that also have a negative impact on biodiversity. If the intensive use could represent a threat to biodiversity the effect of agriculture is not always negative. For example in the case of extensive agriculture by limiting forest recolonization. Recently, large surfaces of agriculture have been abandoned, particularly in mountain areas, causing a recolonization of the forest (Gellrich et al., 2007(c), MacDonald et al., 2000).

Land abandonment can have some positive impacts, but has mostly a negative impact on biodiversity. Among the positive consequences, forests permits the stabilization of soil, carbon sequestration and a temporary increase of biodiversity (Gellrich et al., 2007(c)). However, a main negative consequence is the long-term loss of open species-rich habitats through competition with trees (Anthelme et al., 2001). Species richness of all groups (plants, insects) decreases with increasing cover of trees and shrubs (Öckinger et al., 2006(a)). After abandonment, new species begin to co-exist with the earlier ones. This cause a temporary increase in species richness and a negative effect is recorded only after a few years. As many insects groups are depending on the vegetation, and in particular they are favored by a heterogeneous vegetation structure, they will be influenced by the cover change. As for the richness of plant species, the abundance and richness of many animal species increase immediately after an abandonment, but decrease when a forest begins to establish (Öckinger et al., 2006(a)).

The land abandonment observed during the last years in many industrialized countries can be explained by socio-economic constraints and are useful to understand the increase of the forest cover occurred in many countries since the mid 19th century (MacDonald et al., 2000). The decline in traditional agricultural practices causing land abandonment has been intensely studied and was mostly explained by the recent social and economic development. Particularly the loss of profitability and the increasing cost of agricultural management (Walter 1986; Gellrich et al., 2007(b)) influenced the abandonment in more remote and less accessible places. As a consequence, land abandonment occurs primarily in areas where the conditions are less favorable for agricultural production (higher management cost, more difficult accessibility, lower productivity caused by unfavorable environmental and geo-physical conditions) (Gellrich et al., 2007(c)).

The ability to predict the change from agricultural land to forest land cover can be very useful to improve land management and better conservation practices. Many studies were conducted in Switzerland to model these changes (Gellrich et al., 2007(a); Gellrich et al. 2007(c); Rutherford et al., 2008). These studies were realized by analyzing land-use data from two different time periods only. With the release this year of a new land-use coverage for the period 2004/09, we were able to compare land-use changes between three time periods, allowing to analyze two different transitions. The new second transition permitted to verify if a model built on the transition between the first and second periods could successfully explain land abandonment and forest re-growth between the second and third periods.

The aim of this study was thus to build a model that could explain and predict the transition between agricultural patch into forest patch. In particular we wanted know where the transition had a higher probability to occur. We used geo-physical and socio-economics variables to explain the forest re-growth in the Alps of the Canton de Vaud and make a predictions of future changes within the current agricultural surfaces. Additionally we combine the areas with a high level of biodiversity and a high probability of change in forest to determine the areas with the higher threat to biodiversity and in need of conservation.

1. We expected that the model made on the first transition could predict accurately and without loss of predictive power the changes within the second transition.
2. Second, we expected that the agricultural land where management was costly had a higher probability to be abandoned and undergo a forest re-growth. We expected to find forest re-growth principally in areas far from roads and settlement, where agricultural management costs more energy. Agricultural areas far to forest were expected to have a lower probability to transit into forest areas in reason of the dispersal capacity of plants (Rickebusch et al., 2007). Additionally we supposed that forest re-growth occurred in municipality with a higher emigration and lower economic importance in the primary sector.
3. Because species richness is higher in extensive agricultural land (that represent habitats with better quality of nutriments) (Öckinger et al., 2006(b)). the third main hypothesis was that the land with a higher probability to transit into forest were the areas that had also a higher biodiversity. We expected to find a concomitance between the areas most supposed to be abandoned and the areas with a high level of biodiversity.

METHODS

Study area

The study area is situated in the Western Alps of the Canton the Vaud in Western Switzerland. The area (of ca. 700km2) is composed of several valleys ranging from 372 to 3210m at the top of Diablerets mountains. The land cover is very heterogeneous with several types of open surfaces, forested surfaces and urban surfaces. Vegetation types are characteristic of the calcareous Alps, but changes along the altitudinal gradient. The colline belt is covered with deciduous forests (mainly *Fagus sylvatica*), the montane belt with mixed forests (mainly *Fagus sylvatica, Abies alba*); and the subalpine belt with coniferous forest (*Picea abies*). In the alpine belt, above tree line, the vegetation consist principally in heath, meadow and grassland vegetation; in the nival belt there is only a sparse vegetation cover and still important glaciers are found there (Randin et al., 2006).

Land use transition

The response variable used in the statistical model refers to the occurrence or not of a natural forest re-growth following agricultural land abandonment. Pixels having transited from open agriculture area to forest were identified by comparing Land-use data (ASCH) available from the Swiss Federal Office of Statistics for different time periods (SFOS, 2009). The ASCH is a nationwide aerial photography aiming at categorizing the land use with a 100m lattice. It is available for three periods 1979/1985, 1992/1997 and 2004/2009. Among these periods the land use for our study area were determined at the years 1979, 1992 and 2004. Many studies were conducted in Switzerland to model the transition of agricultural land to forest land (Gellrich et al., 2007(a); Gellrich et al., 2007(c); Rutherford et al., 2008) analyzing the GEOSTAT land-use data for the periods, 1979/85 and 1992/97. Recently the new land-use data available for the period 2004/09 permitted to analyze two different transitions (transition 1 between data of the period 1979/85 and 1992/97, transition 2 between data of the period 1992/97 and 2004/09). In all survey, 72 land cover classes were distinguished according to the Standard Nomenclature NOAS04 (data from 1979/1985 and 1992/1997 was re-classed in order to be comparables with the new one). For this study we grouped the land-use classes that interest us in two major groups, “forest” and “agriculture”. The definition of “forest” and “agriculture” was the same as in the work of Gellrich et al., (2007)(c). The forest category included: closed forest, open forest, brush forest and wood (classes: 50-60). The agriculture category include: orchard, vineyard, horticulture, arable land, meadows, farm pastures, alpine meadows and alpine pasture (classes: 37-49). This category included only the agricultural classes founded below the tree line. The land-use layers were reclassified into these two categories.

The response variables used in the statistical model was a binary variable referred to the presence or absence of a land-use change. Presence or absence of change was determined by comparing the classification made for the raster layers. Raster's pixels that changed from "agriculture" to "forest" were labelled as "presence" observations (1), while those that remained "agriculture" were labelled as "absence" observations (0). We obtained three dataset of response variables: one for the first transition (1979/85-1992/97), one for the second transition (1992/97-2004/09) and one for the global transition (1979/85-2004/09). In analyzing the transition 1 and 2 we determined also which among the agriculture classes had the higher probability to undergo a forest re-growth.

Explanatory variables

The explanatory variables were chosen to explain the study hypothesis (Table 1). Reforestation was supposed to have occurred where the conditions were unfavourable to the agricultural maintenance. Based on findings from other studies (Gellrich et al., 2007(a); Gellrich et al., 2007(b); Gellrich et al., 2007(c); Gellrich and Zimmermann, 2007; Rutherford et al., 2008) we used the variables E*levation, Degree days, Precipitation sum, Potential radiation* and *Slope* as climatic and topographic variables available for Switzerland (Zimmermann and Kienast 1999). These variables were supposed to have an influence on the productivity of the agricultural land. The decision of abandoning a land can derive, for example, from a lower accessibility to the site, e.g. caused by too steep slopes.

We used *Distance to roads, Distance to forest, Distance to settlement* and *Distance to agricultural settlement* as distance variables. These variables were used as indicators of management cost. Agricultural management was considered costly in areas less easily reachable, i.e. areas far to roads or settlement. The distance to road was calculated as an Euclidian distance from a digitized network of roads in Switzerland. The distance to forest and settlement (agricultural and not) was calculated as an Euclidian distance from each corresponding class. The forest category was the same as for the responses variables, agricultural settlement correspond at class no. 11 from the NOAS04 Nomenclature, settlement correspond at classes 1-14.

Because land abandonment have been linked to rural depopulation and a decrease in farm employment (MacDonald et al., 2000), we used *Rate of population change, Proportion of primary employers* and *Proportion of primary industry* as demographic variables. Data were obtained from the SFSO and were based on population census undertaken in the years 1968 and 2009. Rate of population change was calculated as the averaged population change over the twelve years previous to the determination of land-use for the canton Vaud (1967-79 for period 1, 1980-92 for period 2). Proportion of primary employers and primary establishment were determined for each commune of the study area using data from 2001 for the first transition and from 2008 for the second transition.

Data on employers and industry correspond at the percent of employers/industry of primary sectors to the total number of employers/establishment.

Statistical analysis

We modelled the occurrence of the transition of interest (i.e. agriculture to forest) using the BIOMOD package (Thuiller et al., 2009) in R (R Development Core Team 2009) 2.10.0. Explanatory variables were used to model the transition from agricultural area into forested area. Data of first transition (independent data) were used to calibrate the model, while those of second transition (dependent data) were used to evaluate it. We used eight different modelling techniques: Artificial Neural Networks (ANN), Classification Trees Analysis (CAT), Generalised Boosting Models (GBM), Generalised Additive Models (GAM), Generalised Linear Model (GLM), Multivariate Adaptive Regression Spline (MARS), Mixture Discriminant Analysis (MDA) and Breiman and Cutler's random forest for classification and regression (RF). Each of these has different proprieties and analyses data in a different way. They were all performed at once in BIOMOD (using the *model* function).

For the eight modelling techniques, we compared the importance of the explanatory variables in explaining the transition between agricultural and forest surfaces.

Final model and projections

A final ensemble model was computed in BIOMOD. To do this, for each modelling technique we projected the predicted probability for a transition to occur in the open agricultural land of the study area. Using the function *Projection*, at each pixel classified as agriculture in 2009 was given a probability of making a transition during the future years. As each modelling technique possesses its own strengths and weaknesses, we used the Ensemble modelling approach to combine the single projections of each models to obtain a single values for each pixel (Araujo and New, 2007). Probability values range from 0 (estimated probability of 0% to transit into forest) to 1 (estimated probability of 100% to transit into forest). We obtained a final map that displays the probability of each pixel classified as agricultural surface in the ASCH 2009 to transform into forest.

Biodiversity modelling and assessment

During the years 2002 to 2009, 912 vegetation plots were sampled throughout the study area. The diversity of species has been modelled across the entire study area using a generalized linear model (GLM) with a Poisson distribution. For each pixel of the study area, the model predicted the diversity of species. The explanatory variables taken into consideration were: *Degree-days*, M*oisture index* (average of values of June-August months), *Solar radiation*, *Topographic position* and *Slope*. We then transformed species richness in a number between 0 and 1 (1 corresponded at the pixel with the highest biodiversity value) We done this transformation in order to have a value easily comparable to the value of probability transition.

For the agricultural pixels correspondent at the vegetations plot we extract the probability to undergo a change calculate with the final model. We than test if a correlation existed between the two variables. In order to give at each pixel in the study area an index of its condition (at risk vs. non-at risk) we combined the information about land-use transition with those about biodiversity. We multiplied the transition probability and the biodiversity level to obtain a value between 0 and 1. Values close to 0 correspond to areas with a low biodiversity and a low probability to undergo a transition to forest. Values tending to one correspond to areas with a high biodiversity level and a high probability to undergo a transition to forest.

RESULTS

Model performance

Our model successfully predicted forest re-growth for transition 1 (dependent sample) and could also largely explain forest re-growth occurring in the second transition (independent data). Prediction accuracy measured by the area under the ROC curve (AUC) measured on the dependent data set ranged from 0.70 to 0.79. The same AUC measured for the independent data set (range: 0.61-0.76) were almost always slightly lower than those measured on the calibration data (Table 1). According to De Leo (1993), AUC value can be translated in the probability that the model could correctly explain the transition. This means that our model could distinguish between presence and absence of forest re-growth with a probability of 0.76% and 0.75% (mean of the respective AUC range) (Figure 1). These values indicated that the model was useful to make a projection.

Explanatory variables importance

The different explanatory variables had varying importance in the model (Figure 2). Modelling techniques analysed the data in different ways, it is why the importance value could have a great variance. Here we chose to consider the importance mean as an indicator of the importance of the variables in explaining the forest re-growth. The importance mean corresponds to the mean of the value that the variable of interest took across models fitted with the different modelling techniques. *Degree day* is the only one with a importance mean greater than 0.5. *Elevation* (mean=0.32) and *Distance to forest* (mean= 0.33) were also important in the model, and to a lesser extent *Slope* (mean=0.17) and *Precipitation* (mean=0.15). *Radiation*, *distance to settlement*, *Distance to agricultural settlement, Distance to roads, Demographic change, Employers I and Industry I* showed only very little or no significant relationship to the response variable.

Looking at graphs of the variable response curves, *Elevation* shows a positively relationship, suggesting that forest re-growth occurs principally at high elevations. *Distance to forest* shows, as expected, a negative relationship suggesting that forest re-growth occurs only in areas far from forests. The most important variable, *Degree day*, shows a positive relationship, suggesting that forest re-growth has a major probability to occur in areas with a value greater than 2000 KJ/day. *Slope* and *Precipitation* both show a similar trend, with a greater probability of forest re-growth in areas with intermediate values of slope and precipitation (an average between 30°-60° and 1400-1900 [1/10mm/mounth]). As Precipitation is correlated with elevation, a similar trend was found for these two variables. Although the other variables did not show any important relationship to the response variable, we noticed a slight tendency for forest re-growth to occur in areas far to agricultural settlements. Demographic variables did not show any importance in any modelling technique.

Projection

The representativity of the model permitted us to make a prediction for the future years. With the 'Projection' function, we obtained a probability of change for each pixel classified as agricultural land in 2009 (Figure 3). The probability obtained refers to a possible transition in the futures years and thus the resulting maps reveal those agricultural areas most exposed to suffer a transition to forest. These are principally located in the middle of large forests.

In analysing the transitions occurring between 1979/85 – 1992/97 and 1992/97 – 2004/09, we determined which agricultural classes had undergone a transition to forest. We found that a change was observed mainly in the classes "Favourable alpine pastures"(class 46) and "Brush alpine pastures"(class 47). This permitted us to additionally predict that agricultural areas with low direct use will have the highest probabilities of conversion to forest (Annex 1). The analysis of transition also permitted to note that most pixels that underwent a transition had changed to "open forest (on agricultural areas)" (class 55) and to "Clusters of tree (on agricultural areas)" (class 59). We remark that they were mainly forest surfaces developed on formerly agricultural surfaces, which confirms that the forest re-growth happened generally to the detriment of agricultural land (Annex 2). This observation confirmed previous findings by Rutherford and co-workers (2008).

Conservation of Biodiversity

Biodiversity level and transition probability were positively correlated (cor = 0.259, $p < 0.001$), (Figure 4). This confirmed the hypothesis that the areas with a higher probability to be abandoned are also the areas with a high level of biodiversity. The biodiversity map showed that species richness was higher principally in mid altitude areas near to forest. Particularly endangered areas - i.e. those with high biodiversity level and a high probability of transition to forest – may correspond to land loosing a great part of its current species richness. We founded that these areas were mainly localized in the middle of larges forest surfaces at intermediate elevations. They were rarely found at higher or lower elevation (Figure 5).

DISCUSSION

Forest re-growth is an important threat to biodiversity. Its increase cause the disappearance of many grassland species and animals. Several studies (Gellrich et al., 2007(a); Gellrich et al., 2007(b); Gellrich et al., 2007(c); Gellrich and Zimmermann, 2007; Rutherford et al. 2008) had modelled the increase of forest linked to agricultural land abandonment to better explain the phenomenon. The results obtained showed that agricultural land abandonment cold be explaining in considering some climatic, topographic, economic and demographic variables among a period of time. In our study we founded that the phenomenon of forest increase could be modelled but also predicted by a model. This is a very important point that permit to better understand and monitoring this phenomenon.

More in particular the results of our model showed that the mean of AUC values were similar for the dependent data (0.76) and the independent data (0.75). These values did not correspond to a very high explanatory power, but they were better than the AUC values found in other studies, i.e Gellrich et al., 2007(c). Despite, these difference values obtained are not totally comparables because of the different approach used in this two study (different model, different study area size). Anyway the values obtained from the two data sets were very similar and quite high, so that the results obtained confirmed our first hypothesis. The model calibrated with the first transition could be applied to the second transition data keeping a useful AUC. This suggested that the factors explaining the first transition remain quite stables over the years. This stability is an important factor that permitted us to make a model over the total transition, apply it to the present and make a projection for the futures years. The possibility to make a projection is an important tool to predict the future development of the forest re-growth. The multi model approach used in this study is a recent methods that permit to better analyse the data. In particular the niche based model permitted to analyse the data with several methods and so have a stronger approach using the Ensemble. Making an ensemble permitted to make a better projection of the probability to a forest re-growth. However, there were some important factors explaining the land cover change that could not be considered in this study, such the individual motivation of a land abandon and the local characteristics of land.

The second hypothesis was partially confirmed by the results that suggested that forest re-growth took place where the cultivation costs were high and yield potential was low. Some of the explanatory variables showed a high importance in the model and the results gave precise indication about the occurrence of forest re-growth. This occurrence was found principally in favourable alpine pastures, brush alpine pastures or in areas at mid to high altitudes with a higher temperature sum, mid- steep slopes, mid-high level of precipitation. Most of the overgrown areas have been found in areas closer to the forest and, with a slightly effect, farther to agricultural settlement.

Variable elevation showed a positive relationship with forest re-growth indicating that the transitions were most frequent on high altitudes. This agree with the expectation that surfaces in the bottom of valley were more exploited because more easily accessible and economically exploited (Gellrich et al., 2007(b)). Interesting was the contraposition between the influence of the altitude and those of the temperature. The variable degree days showed in fact a positive relationship with the frequency of forest re-growth, indicating that a forest re-growth occurred at high altitudes (not too high altitude), but only where the temperatures were sufficiently high too permit the development of forest (Gehrig-Fasel et al., 2007).

Forest re-growth occurred more frequently on land with intermediate measures of steepness. Slightly and steep measures of slope undergone a transition less frequently. Probably this is due to the different characteristic of these surfaces. Slightly slopes are generally located on the bottom of valley these surfaces are intensively exploited for agricultural production, land cultivation is maintained due to the high suitability, an abandon is very improbable. Mid-steep slope are generally located at mid-higher altitudes and used for pasturing (Netting, 1972). This land use is related to low cost but, in case of abandon, these surfaces could change into forest land. Steeper slope are located at higher altitudes near the tree line, if abandoned the land forest re-growth is limited because of unfavourable growing conditions for trees causing by the high elevations, the lower water holding capacity and the snow avalanches (Gellrich et al., 2007(a),(c)). When we chose the agricultural categories to analyze we tried to have only grassland areas below the tree line. But, the past intensive cutting had down-shift this limit so the position of the tree line is unclear and we had to consider all the subalpine surface. This can explain why the surfaces abandoned were principally the "Favour alpine pastures" and why at steeper slope the frequencies of forest re-growth is reduced.

The variable distance to forest was significant in the model and showed the expected trend. Forest re-growth decreases with increasing distance to forest. The negative relationship can be explained in consider the dispersal capacity of the plants (Rickebusch et al., 2007). Land far to forest will be more difficultly and slowly colonised by plant. Another explanation is more related at the decision of abandonment. We can suppose that agricultural areas nearer to forest are also the areas with smaller size. It is costly manage a great number of small and separated areas than a few but higher areas (Gellrich et al., 2007(a),(c)). When a farmer want reduces his territories is more probably that he will abandon first the smaller areas. This mechanism is know as gap filling.

Distance to road was not significant in the model. The effective influence of this variable is still unclear. Some studies found that distance to road was negatively correlated with the forest re-growth (Pezzati, 2000). Oppositely, other found that the land use decrease with the increasing distance to roads (Gellrich et al., 2007(c)). These variations were supposed to be due at the different use of these surfaces. On remote mechanically exploited meadow the harder accessibility with agricultural vehicles can cause the abandon of the land. On pastures land the remoteness has minor importance and the abandon is less probable. This means that the importance of this variable in the model can vary depending of the frequency of these two different land-uses in the area considered. Another aspect determining the influence of this variable on the model is the precision of the road network used. The routs map was too precisely and sometimes contained also very small roads and impassable roads that they could influence the result.

Surprisingly, we found no influence in forest re-growth of the proportion of industry and employees in the primary sector. This could be due at the origin of data used in the model. Demographic data from 2001 used to explain the transition were not sufficient pertinent and precise. However the number of industry was not closely related to the level of agricultural land exploitation. Recent innovations and technologies permit to exploit large areas employing few workers so that it was not possible explain the agricultural abandonment using the proportion of primary industry and primary employers in the municipalities.

Rate of population change was also not relevant in the model. The variation in population change (increase or decrease) between the last 20 years did not show a precise trend and probably they could not have a strong influence on land abandonment phenomenon. Additionally the limited extension of the study area did not permit to have a strong association between the number of habitant par commune and the rate of forest re-growth. Rate of population change was an indicator of emigration/immigration but the value was not corrected with the municipality surface or the total number of habitants. A municipality could show a decrease of population in keeping a high proportion of people in confront of the area surface. The others study showed also any relation between emigration and forest increase (Gellrich et al., 2007(d)), although the rural depopulation was consider as the cause of land abandonment in many European mountain regions (MacDonald et al., 2000).

Distance to settlement was insignificant in the model, while distance to agricultural settlement was slightly important and had an influence according with our initials expectations. This suggests that to consider all the construction was probably less informative and could not explain the transition. However consider only the distance to agricultural settlement had a higher influence despite it remain quite insignificant. Higher distances to settlement represent a higher cost of management but, as suggest for the influence of demographic variables, the technology could have minimized this negative effect.

Because the forest re-growth had a negative impact on biodiversity, predicting the land abandonment could be very useful and important to make a conservation planning. An increasing cover of tree and shrubs decrease the species richness of all groups in the concerned areas. Species richness of many groups such plants, birds and insects are favoured by an heterogeneous vegetation, so many times it first increase when management and grazing are stopped. However, as the reforestation continues the number of grassland species strongly decrease (Öckinger et al., 2006(a)). The biodiversity conservation is a main theme among the ecological biology. The maintenance of a high specific richness is the purpose of many studies. In this study we used the results of our model as a possible point of start of a conservation planning. Because our model could predict the transition from agricultural land to forest land, we combined the projection for the future land cover transitions with an index of biodiversity to highlight the areas with a higher threat of biodiversity loss. As we predicted the result showed that the most threat areas were located in correspondence of the areas most subject to undergo a transition. A logical explanation exists for the positive relationship between the probability of a transition and the level of biodiversity. A first step of an abandonment generally occurs when a land intensively used is transformed in an extensively-used surface. An extensively used, such a pasture land, has less or no economic investment so that this transition could be an alternative of a total abandonment. Therefore, total abandon occurs principally in extensively used land. These areas have a higher probability to be abandoned but they have also a higher level of biodiversity in reason of their less-invasive use (Öckinger et al., 2006(b)).

Predicting a level of threat for each pixel gives the possibility to plan some intervention to favour the maintenance of biodiversity. In particular the map of threat level permits to determine the areas with the most urgent need of protection. In function of the resources at disposal we could determine an adequate number of areas that could be subject of a conservation planning.

In conclusion our results represent a tool to predict the loss of biodiversity and the species range shift on open areas. But the forest increase and the reduced habitats of mountain grassland species are not only the consequence of the agricultural land abandonment. Other factors as the progressive climate warming is shifting the species range on open areas and the effect of climate is often used to model the plants distribution (Randin et al., 2009; Engler et al., 2009). An approach including both land abandonment and climate change could be useful to better understand the land cover change and its effect on the species richness and distribution.

Acknowledgments

I thank Loïc Pellissier and Antoine Guisan for their precious help and advices, The Swiss Federal Office of Statistic for supplying data and Federico Tettamanti for his help to start this work.

REFERENCES

Anthelme, F., Grossi, J.L., Brun, J.J., Didier, L., 2001. Consequences of green alder expansion on vegetation changes and arthropod communities removal in the northern French Alps. Forest **Ecol**. Manage. 145: 57–65.

Araujo, M.B., New, M. 2007. Ensemble forecasting of species distributions. Trends in Ecology & Evolution, 22(1): 42-47.

DeLeo, J. 1993. Receiver operating characteristic laboratory ROCLAB: Software for developing decision strategies that account for uncertainty, Proceeding of the 2nd International Symposium on uncertainty Modelling and Analysis, IEEE Computer Society Press, College Park, MD, pp. 318-325.

Engler, R., Randin, C.F., Vittoz, P., Czáka, T., Beniston, M., Zimmermann, N.E., Guisan, A. 2009. Predicting future distribution of mountain plants under climate change:does dispersal capacity matter? Ecography, 32: 34-45.

Gehrig-Fasel, J., Guisan, A., Zimmermann, N.E. 2007. Tree line shifts in the Swiss Alps: Climate change or land abandonment? Journal of Vegetation Science, 18: 571-582.

(a)Gellrich, M., Baur, P., Koch, B., Zimmermann, N.E. 2007. Agricultural land abandonment and natural forest re-growth in the Swiss mountains: A spatially explicit economic analysis. Agriculture, Ecosystem and Environment, 118: 93-108.

(b)Gellrich, M., Baur, P., Robinson, B.H., Bebi, P. 2007. Combining classification tree analyses with interviews to study why sub-alpine grasslands sometimes revert to forest: A case study from the Swiss Alps. Agricultural Systems, 96: 124-138.

(c)Gellrich, M., Baur, P., Zimmermann, N.E. 2007. Natural forest regrowth as a proxy variable for agricultural land abandonment in the Swiss mountains: a spatial statistical model based on geophysical statistical model based on socio-economic variables. Environmental Modeling Assessment, 12: 269-278.

Gellrich, M., Zimmermann, N.E. 2007. Investigating the regional-scale pattern of agricultural land abandonment in the Swiss mountains: A spatial statistical modelling approach. Landscape and urban planning, 79: 65-76.

MacDonald, D., Crabtree, J.R., Wiesinger, G., Dax, T., Stamou, N., Fleury, P., et al. 2000. Agricultural abandonment in mountain areas of Europe: Environmental consequences and policy reponse. Journal of Environmental Management, 59: 47-69.

Mather, A.S., Fairbairn, J., 2000. From floods to reforestation: the forest transition in Switzerland. Environment and History, 6: 399-421.

Motta and Nola, 2001 growth trend and dynamics in sub –alpine forest stands in the Varaita Valley (Piedmont, Italy) and their relationship with human activities and global change. Journal Vegetation Science, 12: 219-230.

Netting, R. 1972. Of Men and Meadows: Strategies of Alpine Land Use. Anthropological Quarterly, 45(3): 132-144.

(a)Öckinger, E., Eriksonn, A.K., Smith, H.G. 2006. Effects of grassland abandonment, restoration and management on butterflies and vascular plants. Biological conservation, 133:291-300.

(b)Öckinger, E., Hammarsted, O., Nilsson, S.G., Smith, H.G. 2006. The relationship between local extinctions of grassland butterflies and increased soil nitrogen leves. Biological conservation, 128:564-573.

Pezzatti, M. 2001. Einfluss der Erschliessung auf die Agrarstrukturen im Alpenraum, Schriftenreihe nachhaltige Land- und Forstwirtschaft im Alpenraum, Vauk KG, Kiel.

Randin, C.F., Dimböck, T., Dullinger S., Zimmermann, N.E., Zappa, M., Guisan, A. 2006. Are niche-based species distribution models transferable in space? Journal of Biogeography, 33:1689-1703.

Randin, C.F., Engler, R., Normand, S., Zappa, M., Zimmermann, N.E., Pearman, B.P., Vittoz, P., Thuiller, W., Guisan A. 2009. Climate change and plant distribution: local models predict high-elevation persistence. Global change Biology, 15: 1557-1569.

Rickebusch, S., Gellrich, M., Lischke, H., Guisan, A., Zimmermann, N.E., 2007. Combining probabilistic land-use change and tree population dynamics modelling to simulate responses in mountain forest. Ecological modelling, 209: 157-168.

Rutherford, G.N., Bebi, P., Edwards, P.J., Zimmermann, N.E. 2008. Assessing land-use statisting to model land cover change in a mountainous landscape in the European Alps. Ecological modelling, 212: 460-471.

SFSO, 2009. *contrôl demographique.* Swiss Federal Statistical Office, Neuchâtel.

Thuiller, W., Lafourcade, B., Engler, R., Araújo, M.B. 2009. BIOMOD-a platform for ensemble forecasting of species distributions. Ecography, 32: 369-373.

Walther, P. 1986. Land abandonment in the Swiss Alps: a new understanding of a land-use problem. Mountain Research and Development, 6: 305–314.

Zimmermann, N.E., Kienast, F. 1999. Mapping of Alpine Grasslands in Switzerland: Species versus Community Approach. Journal of Vegetation Science, 10(4): 469-482.

Table-1 Potential explanatory variables

Variable names	Unit	Exp. Sign [a]
Climatic and topographic variables		
Elevation (E)	m	+
Degree days (DD)	(day °C)	+
Slope (S)	(°)	+
Radiation (R)	(KJ/day)	?
Precipitations (years) (PR)	(1/10mm/mounth)	?
Distance variables		
Distance to forest (d_F)	m)	-
Distance to settlements (d_S)	(m)	+
Distance to agricultural settle (d_SA)	(m)	+
Distance to road (d_R)	(m)	+
Demographic variables		
Demographic change (POP)	(mean/10 years)	-
Industry I (I_I)	(%)	-
Employers I (E_I)	(%)	-

a the expected sign represent the influence that we expected to find according to other studies.

Table 2 – AUC of each modelling methods with an Evaluation Roc

	Calibration data [a]	Validation data [b]
ANN	0.703	0.605
CTA	0.745	0.738
GAM	0.784	0.757
GBM	0.785	0.760
GLM	0.787	0.753
MARS	0.780	0.736
MDA	0.752	0.699
RF	0.776	0.743

a calibration made with variable response from transition1 (1979/85-1992/97).
b validation made with variable response from transition2 (1992/97-2004/09).

LEGEND

Figure 1: Boxplot of AUC of the model. The calibration model (data from transition1) shows an accuracy above 0.7. The validation model has an accuracy range between 0.61 and 0.76.

Figure 2: Importance of the explanatory variables in the models. The climatic and topographic variables have the greater importance, particularly elevation, degree day slope and precipitation contribute in main part to explain the transition. The distance variables contributed with the distance to forest and in minor way with the distance to agricultural settlement. The demographic variables don't contribute at the model.

Figure 3: Representation of the probability to undergo a change into forest surface for each pixel of the study area classified as agricultural in 2009.

Figure 4: Probability of a change reported in function of the level of biodiversity. In red is reported the linear regression. The two variables are positively correlated.

Figure 5: Representation of the level of threat to biodiversity of the study areas. In red there are areas with a high value of threat that correspond at a high value of biodiversity and a high probability to undergo a change into forest land. In blue there are areas with low value of threat.

Figure 1.

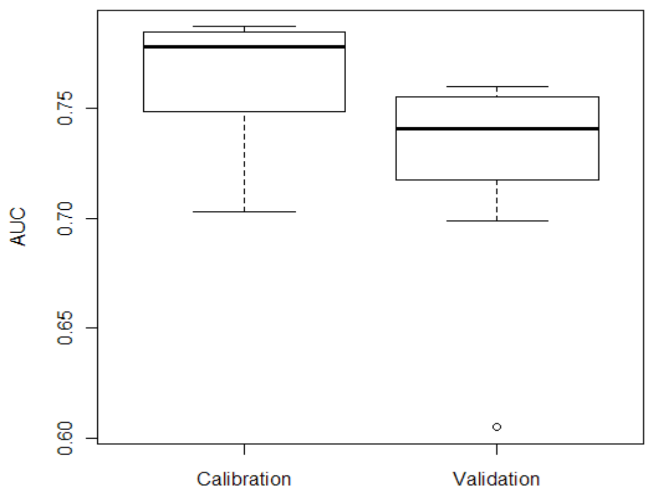


Figure 2.

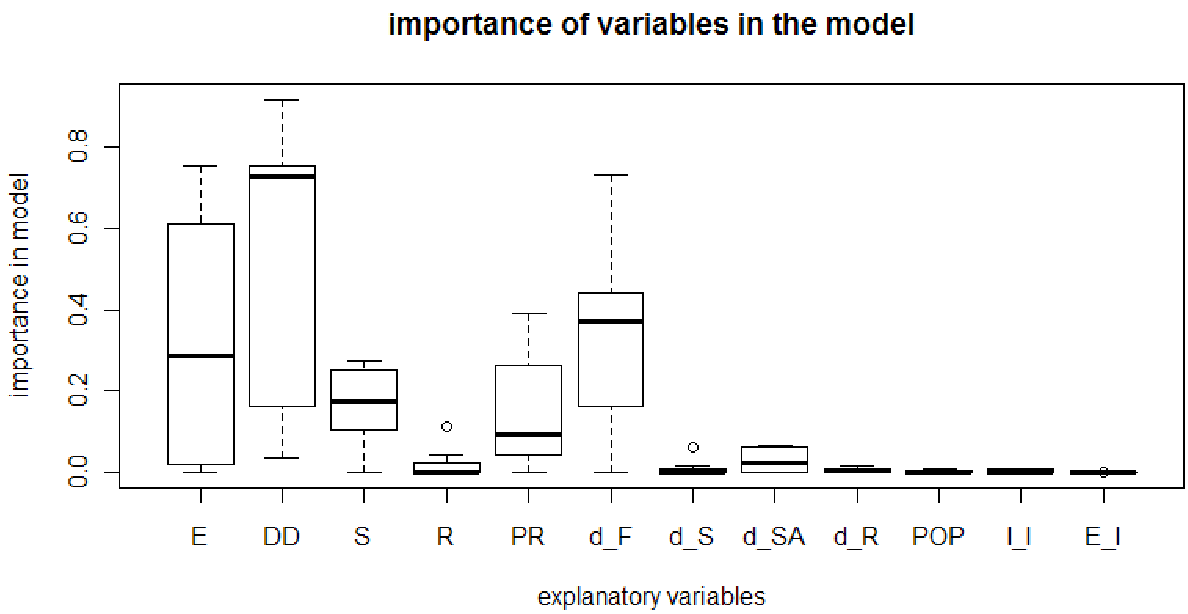

importance of variables in the model
importance in model
0.0
0.2
0.4
0.6
0.8
E
DD
S
R
PR
d_F
d_S
d_SA
d_R
POP
I_I
E_I
explanatory variables

Figure 3.

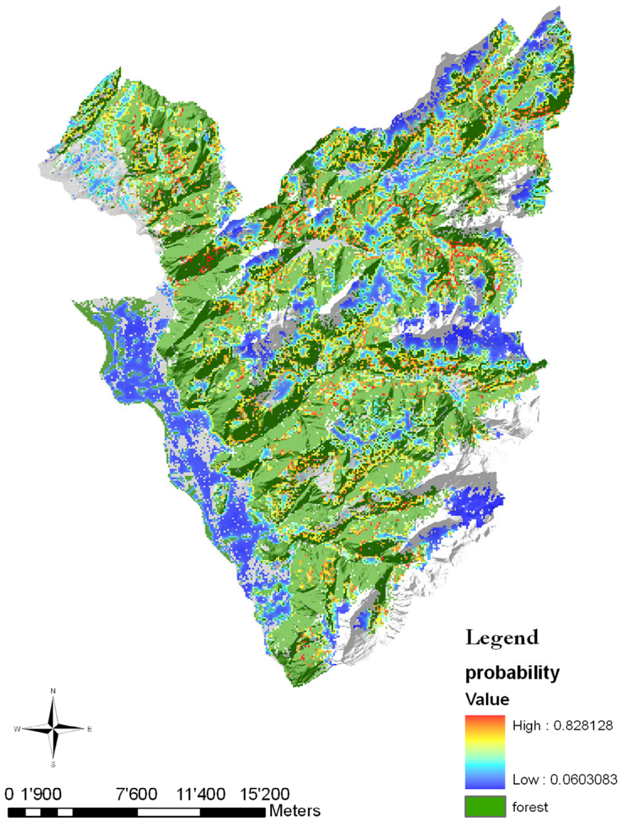

Legend
probability
Value
High : 0.828128
Low : 0.0603083
forest
0 1'900 7'600 11'400 15'200
Meters

Figure 4.

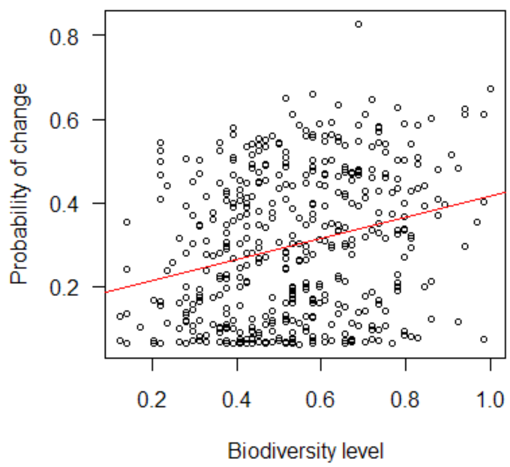
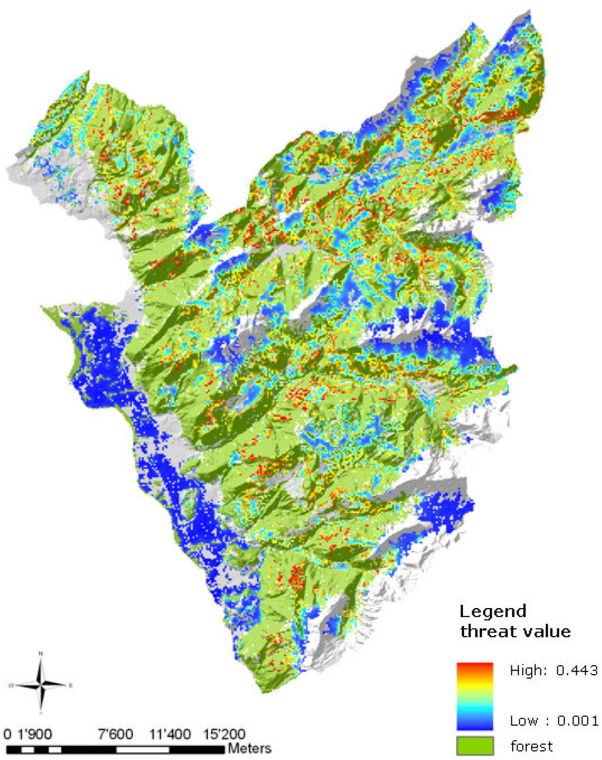
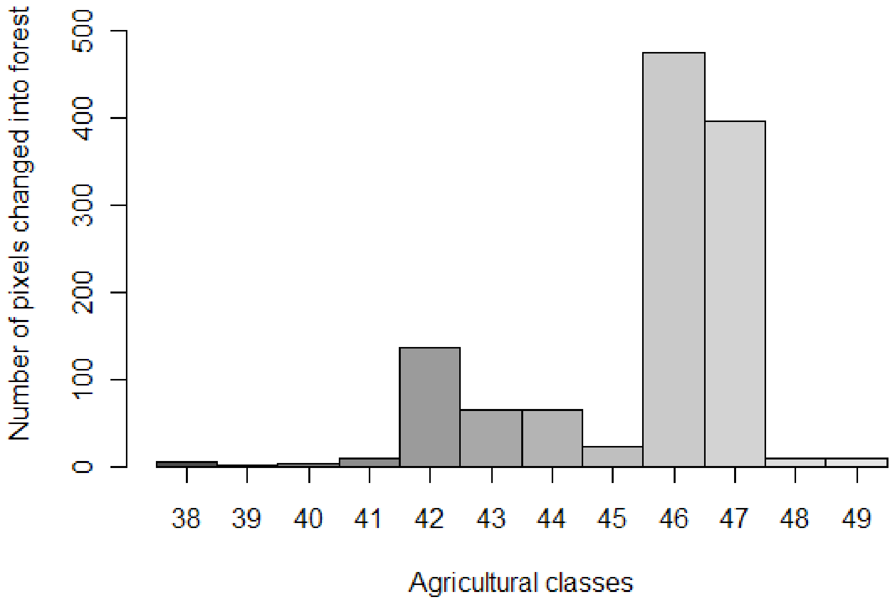

0.8
0.6
0.4
0.2
Probability of change
0.2
0.4
0.6
0.8
1.0
Biodiversity level

Figure 5.

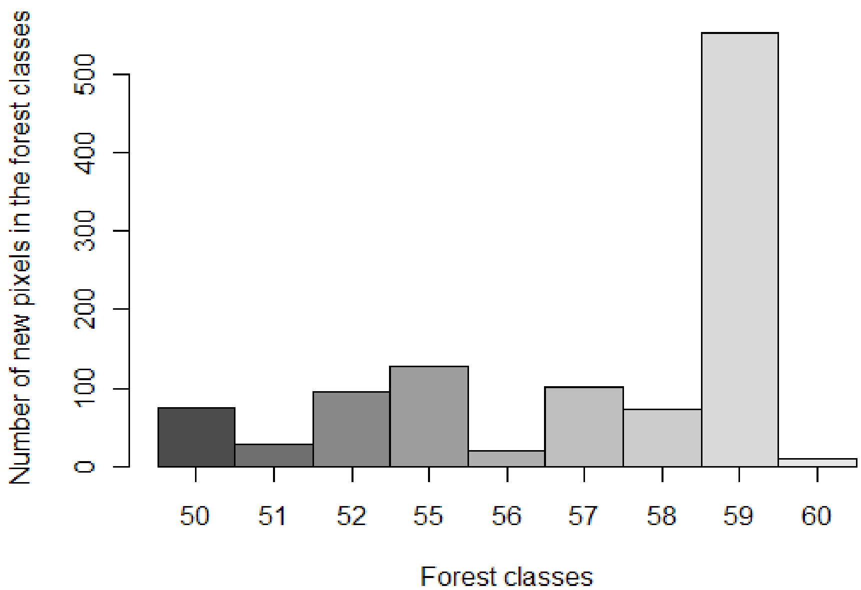

Legend
threat value
High: 0.443
Low : 0.001
forest
0 1'900 7'600 11'400 15'200
Meters

Annex 1.



Annex 1: Total number of agricultural pixels that had undergo a transition into forest from 1979 to 2009. The x axis represent the agricultural classes numbered in accord with the NOAS04. The classes 46 and 47 correspondent at “Favourable alpine pastures” and “Brush alpine pasture”. A transitions occurred mostly in these to classes.

Annex 2.



Annex 2: Total number of new forest pixels that had recorded from 1979 to 2009. The x axis represent the forest classes numbered in accord with the NOAS04. Agricultural pixels that undergone a change became mostly classified as “Cluster of trees (on agricultural areas) that correspond at the class 59.