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Forest Expansion in the Swiss Alps: A Quantitative Analysis of Bio-physical and Socio-economic Causes

Waldausdehnung in den Schweizer Alpen: Eine quantitative Analyse von bio-physikalischen und sozio-ökonomischen Ursachen

By PETER BEBI and PRISKA BAUR

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Abstract

In Switzerland, the decrease in the number of farms is widely seen as the dominant reason for land abandonment and forest expansion in the Alps. Also agricultural policy, which aims to preserve open land and to ensure cultivation of marginal lands, relies on this conclusion. However, based on production and location theory, contemporary concepts of agricultural economics and empirical indications, we suggest that the relationships between forest expansion and structural change in agriculture are more complex. In 2002, we have started a three year interdisciplinary project (agricultural economics, vegetation dynamics, geoinformatics and spatial modeling) that examines the following general research question: How can we explain the pattern of land abandonment and forest expansion in the Swiss Alps during the last decades with the help of newly available large quantitative datasets? Our target is to determine the relevant bio-physical and socio-economic causes of land abandonment and forest expansion and to quantify their relative impact. We expect the findings to be significant for the understanding of land-use changes in the Swiss Alps; they may have important implications for policy design. In this contribution we review the state of knowledge on the processes of land abandonment and forest expansion in the Swiss Alps. On the basis of economic theory and vegetation dynamics we derive hypotheses and discuss the two methodical approaches planned: 1) a

total area approach where large datasets on forest expansion are investigated with multivariate statistics and 2) an approach with time series of aerial photographs in selected case study areas.

1. Introduction

The forested area in the Swiss Alps has expanded by about 30 % during the 20th century (Brändli 2000, Fig. 1). There is general agreement, that the abandonment of agricultural land is the main reason for this forest expansion. This development may not be desirable for a variety of reasons¹, for instance because of the potential loss of biodiversity (cf. Nievergelt and Hess 1984, Cernusca et al. 1996), enhanced risk of soil erosion (Cernusca 1996), soil acidification (Gisi and Oertli 1981) or degradation of esthetic landscape diversity (Krippendorf 1984).

In Switzerland, since the early 1970s several case studies have dealt with land abandonment and forest expansion in the Alps. However, up to now we lack a quantitative analysis of the relative importance of different bio-physical and socio-economic causes to explain forest expansion in the Swiss Alps, mainly because the necessary data were not available and because methodical approaches to deal with both, socio-economic and bio-physical data on different spatial and temporal scales are challenging.

After the recent completion of large data sets on forest expansion (second Swiss National Forest Inventory and second Areal Statistics), and

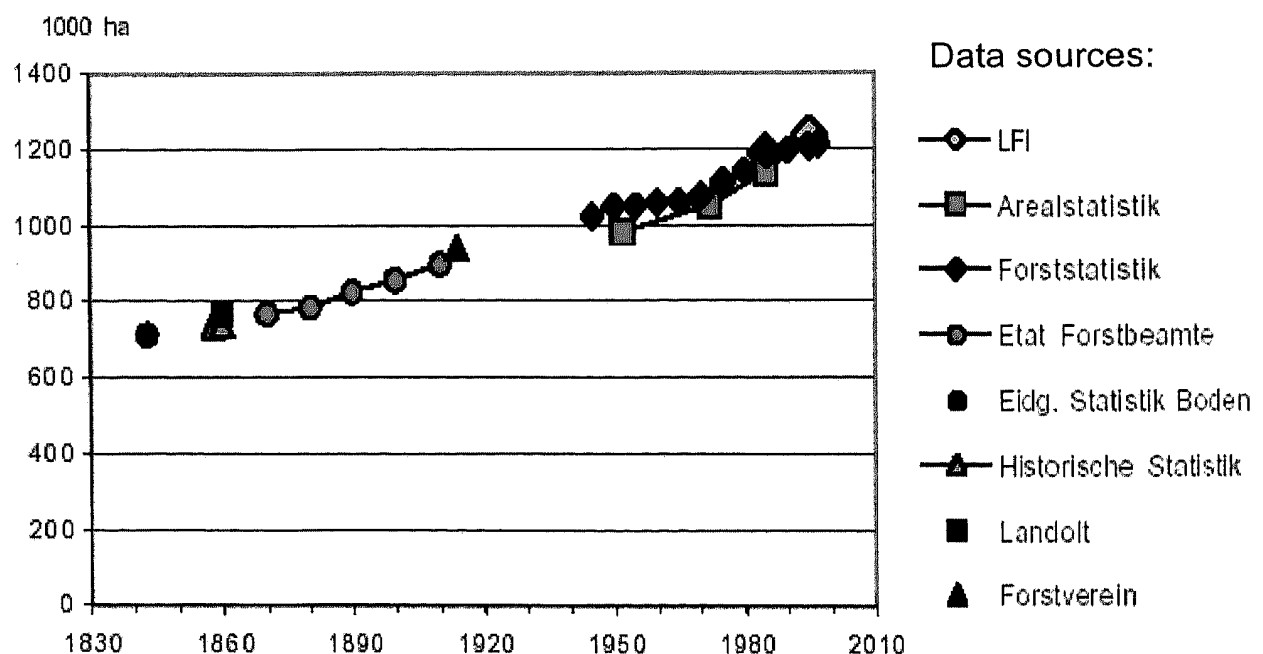


Fig. 1: Forest expansion in the Swiss Alps according to different data sources (from Brändli 2000)

¹ See also reviews in Moos and Herot (1979), MacDonald et al. (2000), or Maag et al. (2001).

with new approaches to deal with differences in quality and spatial extent of bio-physical and socio-economic data, a quantitative analysis has now become feasible. In this paper we review the current state of knowledge on land abandonment and forest expansion in the Swiss Alps and we present and discuss different theoretical and methodical approaches to explain the pattern of land abandonment and forest expansion during the last decades with the help of these newly available datasets.

2. Explaining Land Abandonment in the Swiss Alps

In the case studies on land abandonment in the Swiss Alps we distinguish two disciplinary perspectives concerning the driving factors of land abandonment: agricultural economics and social geography. In social geography, land-use change is looked at as the visible manifestation of the general social and economic development, and changes in values and preferences are identified as the relevant driving factor (Wanner 1983, Messerli 1984, Walther 1984). In contrast, in agricultural economics changes are principally explained by exogenous factors, for instance, the development of labour markets, infrastructure, mechanization, prices, etc. (Gantner 1976, Brunner 1979, Moos and Herot 1977, Rieder 1984, Rieder et al. 1990, Bernegger et al. 1990, Pezzatti 2001). The first studies (Moos and Herot 1973, Surber et al. 1973) provide mostly ad hoc explanations. Still, their reasoning about the causes of land abandonment is plausible and has basically remained unchanged by today: It is marginal land, i.e. land which supplies small yield at high costs, which is abandoned. Mainly unfavourable topography and low incomes were identified as the most relevant causes.

A comprehensive theoretical and empirical analysis on abandoned land and its causes has been conducted by Walther (1984). His investigations in 8 communities confirmed that land is more often abandoned on steep parcels which cannot be cultivated with machines. Following Rieder (1984) and Bernegger et al. (1990) land abandonment is historically correlated with mechanization. Further causes of land-abandonment for which Walther (1984) found empirical evidence are yield potential, accessibility of land, and size of parcels. He also shows that previous hereditary customs have a major influence. According to Walther's main conclusion, abandoned land is the result of a prevented modernization of land use. Thus, it occurs where the agricultural system has not been adapted to a changed social environment.

The central hypothesis in the economic way of reasoning remains that marginal land is abandoned where benefits are low and costs high. The decision to give up production is interpreted as the result of a cost-benefit reasoning concerning land use. Differences exist concerning the operationalisation of the cost-benefit model, the selection of the benefit- and cost-related variables and their relevance. Most analyses remain either qualitative (Gantner 1976, Moos and Herot 1979, Rieder 1984) or are conducted with linear programming models (Brunner 1977, Rieder et al. 1990, Bernegger et al. 1990). Empirical field analyses are rare (Pezzatti 2001).

Two significant cost-related variables are opportunity cost of labour and infrastructure development (Bernegger et al. 1990). The most recent analysis by Pezzatti (2001) confirms the decisive effect of infrastructure development which leads to a significant reduction of land-use costs: the more accessible the parcel, the more intensively they are cultivated. Labour seems to be the crucial element in explaining production, and therefore in explaining land use and land abandonment as well (Witzke 1993). Opportunity costs of labour are on the one hand determined by exogenous factors, i.e. by the economic development in general, and by the labour market (demand of labour, wages) in particular. On the other hand, opportunity costs of labour depend also on endogenous factors, such as on education or on preferences for a certain type of activity.

Some authors expect a direct relationship between farmer migration and land abandonment. Hence, they draw the conclusion that land abandonment can be stopped by a prevention of farmer migration (Messerli 1989, Bätzing 1996, Broggi et al. 1997). However, there is no empirical evidence that the decrease of the number of farms and the abandonment of land are directly correlated. Naegeli-Oertli (1986) showed for Grindelwald that despite the drastic reduction of farms almost no farmland had been abandoned. And on the aggregate level, between 1955 and 1990, the rate of farm exits in the mountain areas was not higher, but lower compared to the plain, although forest expansion is a phenomenon typical for mountain areas (Baur 1999).

Rieder (1984) and Bernegger et al. (1990) state a research gap in explaining migration of mountain farmers. From the permanent income disparities between mountain farmers and farmers on the plain one would expect the migration of mountain farmers to be higher, which apparently has not been the case. Some hints are given by Gardner's guiding paper "Changing economic perspectives on the farm problem" (1992) where he contradicts the widespread perception, that structural change in agriculture is mainly the consequence of economic pressures on farmers ("Anpassungsdruck"). Gardner (1992) postulates that in a growing economy structural change is rather driven by "pull-factors" ("Abwanderungssog") than by "push-factors" (sinking incomes in the agricultural sector). Baur (1999, 2000) found strong empirical evidence for this hypothesis for the structural change in Swiss agriculture between 1939 and 1990. She showed that agricultural policy had a strong impact on structural change. At the cost of increasing government expenditures, not only the pressure on farms was lessened, but the "pull-factors" were partly neutralized. This resulted in a highly retarded labour migration.

In summary, to explain structural change and land abandonment we need to better understand the labour allocation of Swiss mountain farmers. In our project we are going to develop a theoretical framework to explain land abandonment based on production and location theory (e.g. Brandes et al. 1997), on agricultural household models (Witzke 1993, cf. Baur 1999) and on an economic model of human behaviour (Frey 1992). The basic assumption in these models is that individuals act systematically and therefore predictably. They compare advantages (benefit) and disadvan-

tages (cost) of possible actions considering the information available to them. Thus, human behaviour is determined by expected benefits and costs, and ultimately by preferences and constraints that are mainly imposed by institutions. Institutions, i.e. laws or informal behavioural norms, can be regarded as agreements influencing expectations and therefore shaping repeated human interactions (Picot and Dietl 1990). The institutional setting is of high importance because it determines the individual's possibility set and costs of actions.

3. Research on Vegetation Dynamics on Abandoned Land

Patterns of succession or vegetation change can be asserted to some degree and at some scale for almost any natural system (McCook 1994) and there is a large body of literature on succession patterns in different forested ecosystems (cf. reviews in Kimmins 1997, Pijanowska 1985, Ellenberg 1996). Most knowledge on pattern and processes of forest expansion is based on studies about succession after human interventions or after disturbances such as fire, windthrow or snow avalanches. There is also a fast growing body of literature on tree invasion and forest succession, where a change to a more favourable climate has led to forest expansion into ecotones such as glacial meadows (Lüdi 1958), meadows near alpine timberline (Jakubos and Romme 1993) or into forest/dryland ecotones (Mast et al. 1997).

Based on such studies, we know that mechanisms and patterns of forest successions are highly site specific: Colonization of open areas varies strongly with factors such as the availability of favourable (microclimate soil, vegetation) seed beds (e.g. Schauer et al. 1998, Didier 2001) or with the seed dispersal of the invading species (Sauer 1988). In a later stage, tree invasion is often more or less inhibited by competition and allelopathic interactions with other plants (Ponge et al. 1998) or by grazing effects (e.g. Schütz et al. 2000).

Our knowledge on vegetation dynamics after agriculture abandonment is based on a sum of different case studies (c.f. Kienzle 1982, Zoller et al. 1984, Cernusca et al. 1999, Tasser et al. 1999, cf. Schütz et al. 2000). These case studies show that the speed of forest succession may vary considerably according to regional climate, former land-use and different auto-genic or allogenic factors. Due to favourable climatic conditions and due to a relatively small scaled pattern of open areas and forests, speed of forest expansion is more rapid in the Tessin and in other southern valleys of the Swiss Alps (Walther and Julien 1986). Slow pathways are most often observed where exposure to grazing or to climatic factors are extreme (Schütz et al. 2000) or where formation of dwarf shrubs build relatively stable successional stages (Zoller et al. 1984).

Changes in sites are often related to management. Various land-use methods have different effects on nutrient content, acidification of the soil, percentage of biomass in roots, C/N-ratio, or bacteria- and fungi composition in the soil (Gisi and Oertli 1981). Initially, species diversity often increases because of higher competition, which is greatest on lightly-managed areas or recent abandoned areas. Increasing succession, however, causes the

decline of species diversity which is lowest among mature dwarf shrub communities and closed forest respectively (Zoller et al. 1984, Cernusca et al. 1999). Meadows and pastures show similar changes in vegetation, but on meadows heterogeneity is decreased and the influence of parent rock is less important (Tasser et al. 1999). Grazing by cattle and by other domestic ungulates has generally an inhibitory effect on forest succession above a certain threshold, but can also accelerate forest succession by uncovering mineral soil. An abrupt cessation of cattle grazing has therefore often the effect of a strongly accelerated and often dense invasion of forests in former pastures (Dunwiddle 1977, Bebi 2000).

To a large degree, these relationships have been examined within a narrow ecological context: studies have mostly been conducted on specific valley slopes or even in individual meadows. Consequently, it is widely unclear how these mechanisms vary in importance across multiple gradients of bio-physical site factors and land use history.

4. Theoretical Framework for a Quantitative Analysis (cf. Fig. 2)

Hypotheses about the causes of forest expansion can be derived from contemporary concepts in agricultural economics (cf. chapter 2) and in vegetation dynamics (cf. chapter 3): Forests expand on abandoned land. The abandoning of land is the result of a production or rather a non-production decision. The simplified system analysis in Fig. 2 illustrates our theoretical framework to explain land abandonment and forest expansion. We distin-

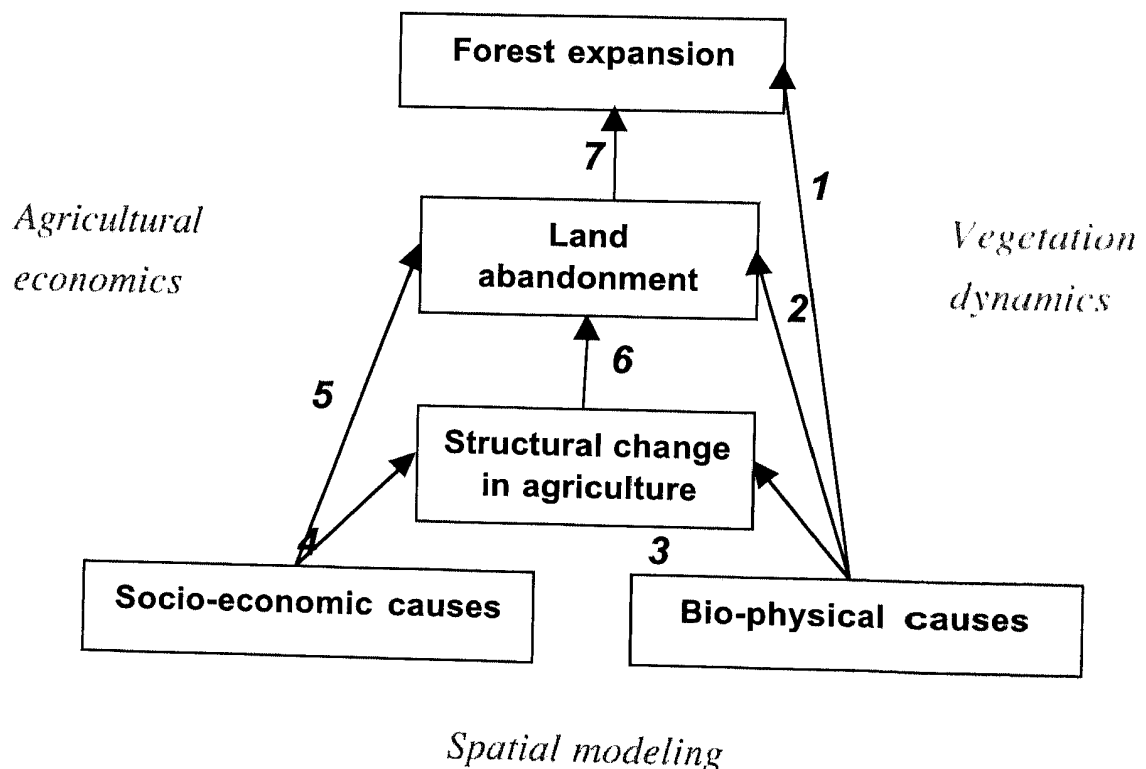


Fig. 2: Explaining land abandonment and forest expansion: Theoretical framework of the research project. Relations 1 to 7 are explained in chapter 4

guish five elements (bio-physical causes, socio-economic causes, structural change in agriculture, land abandonment, forest expansion) and seven relations. Relation 1 and 7 are based on concepts of vegetation dynamics. Reasoning about relation 2, 3, 4, 5, and 6 is based on economic models of human behavior. The following hypotheses are not complete but indicate the way of reasoning:

Relation 1: The speed of forest expansion varies significantly and in a predictable way across multiple gradients of biophysical site factors and land use history. For instance, we expect forest expansion to be faster in lower elevations, where summer precipitation is high, where snow free season is long, where ungulate grazing pressure is not extreme etc.

Relation 2: Bio-physical conditions influence benefits (yields) and costs (labour, capital) of land-use. *Ceteris paribus* (c.p.)² the probability to abandon land increases with diminishing yield, for instance with the altitude of a parcel, on poor soils, on extremely exposed parcels etc. C.p. the probability to abandon land increases with the labour and capital requirements of land use, for instance on parcels with unfavourable topography which renders use of machines difficult or demands expensive investments or even prevents mechanisation, on parcels which are not easily accessible by motor vehicles or not developed at all, on remote parcels, on small parcels etc.

Relation 3: The probability to close down a farm increases when the farm income potential is low. Since bio-physical causes have an impact on the farm income potential (benefits and costs of land use), they also influence structural change.³ C.p. the probability to close down a farm is increased with decreasing income potential, i.e. on farms where yield potential is low (e.g. high altitude) and on farms where costs are high (e.g. large percentage of unfavourable topography).

Relation 4 and relation 5: Socio-economic causes influence land abandonment directly (relation 5) and indirectly via the closure of a farm (relation 4 and 6). Therefore, two economic decisions have to be distinguished: the abandonment of a *single parcel* (relation 5) and the closure of a *whole farm business* (relation 4). The term socio-economic relates to a variety of factors, which we subdivide into causes relating to economy, infrastructure, and to the institutional setting:

Economy

- C.p. the probability to abandon a *single parcel* increases with diminishing benefit potential of this particular parcel, i.e. with sinking prices for agricultural products on the one hand, and with increasing capital and labour cost, i.e. opportunities to invest labour more profitably e.g. on nearby parcels, on parcels with a better production potential or in a part time off farm job.

² All hypotheses deduced from economic models underly the *ceteris paribus*-clause (c.p.): They postulate an effect assuming that all other conditions remain unchanged (cf. Brandes et al. 1997).

³ Structural change is defined as a decrease in the number of farms and farm labour, and as growth of the average farm size in hectares.

- C.p. the probability to close down a *whole farm business* increases with decreasing farm income potential (e.g. sinking prices, missing opportunities to extend land resources) and with increasing opportunity costs of labour, i.e. opportunities to invest labour more profitably in a full time off farm job (e.g. labour demand in a growing economy).

Infrastructure

- C.p. the probability to abandon a *single parcel* increases with sinking infrastructure quality of this particular parcel, in particular when a parcel is not developed to be accessible by motor vehicles.
- C.p. the probability to close down a *whole farm business* increases with sinking infrastructure quality on the spot and in "commuter distance" (e.g. poor accessibility of the farm, poor local road network, few shopping facilities, limited educational and recreational facilities etc.).

Institutional setting

- C.p. the probability to abandon a *single parcel* increases if improvements of marginal parcels are hindered because of a complicate and small-scale ownership structure. On the other hand, the probability that the cultivation of a parcel is maintained increases with receipt of direct income support linked to minimal land use or if holding land open is linked with benefits which eventually might be realised in the future. For instance, restrictive Swiss forest legislation is interpreted as a strong institutional barrier to prevent land abandonment.
- C.p. the probability to close down a *whole farm business* increases in an unfavourable institutional environment (e.g. missing opportunities to rent land because of restrictive regulations) and decreases in an advantageous institutional environment (e.g. security of income by guaranteed production quotas, prices and direct income support, opportunities to receive cheap credits and subsidies for renewing housing, constructing modern stables or buying machines).

Relation 6: We assume that in general a particular single parcel is abandoned in connection with the change of generation, when a farm is either taken over by the younger generation or else closed down and rented or sold. We explain this by an increase in the opportunity costs of farm labour with the change of generation: The older generation usually has low opportunity costs because of the difficulty to find an off farm job (age, no or little professional education, restricted mobility etc.). Therefore, traditional behaviour is maintained and marginal parcels often are cultivated. In contrast, the younger generation usually has high opportunity costs. The descendants are in general independent, flexible and well educated which makes it much easier for them to find an off farm job. Also people interested in renting or buying land have usually higher opportunity costs of labour. Thus, the change of generation determines the *moment* but is no ultimate reason to abandon land. Summarized, we find neither theoretical reasons nor empirical evidence for an ultimate causal correlation between the decrease in the number of farms and land abandonment.

Relation 7: Although there may be other factors contributing to the ongoing forest expansion in the Swiss Alps (e.g. afforestations, climatic induced forest expansion near tree line, recovery after natural disturbances), we expect land-abandonment to be the most significant factor of forest expansion during the last decades. However, we expect this contribution to show regional and temporal differences. For example we expect forest expansion to be fast, where grazing pressure was higher in the past, but has decreased in recent years (cf. Dunwiddle 1977). In contrast, where the cessation of mowing has been replaced by a relatively constant grazing pressure by domestic or wild ungulates, forest expansion will not occur or will be retarded (cf. Schütz et al. 2000).

5. Methodical Approaches and Database

Two complementary database-approaches addressing different spatial and temporal scales will be used to test our hypotheses and to analyse the causes of land abandonment and forest expansion: total area approach (TAA) and repeated aerial photograph-approach in selected areas (RAPAS). The main advantage of the TAA lies in the large datasets that cover the entire Swiss Alps and thus allow to disentangle the causes of land abandonment and forest expansion over multiple gradients of socio-economic and bio-physical explanatory variables. In contrast, RAPAS makes it possible to investigate forest expansion in selected case study areas with a higher spatial resolution and over a longer time frame (cf. Fig. 3). With RAPAS, it is moreover possible to combine aerial photograph time series with the analysis of terrestrial photographs and dendroecological methods.

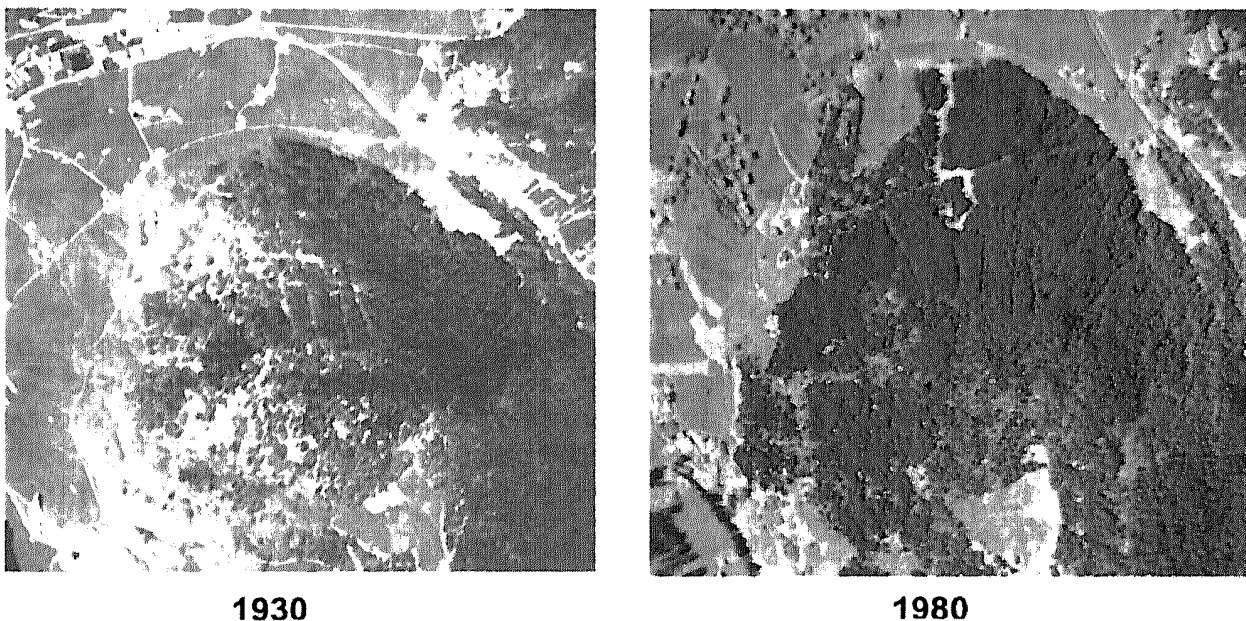


Fig. 3: Repeated aerial photograph approach (RAPAS): Comparison of aerial photographs taken in 1930 and 1980, showing a drastic expansion of forest cover after agriculture land-abandonment near Davos (Switzerland)

When operationalizing the theoretical framework for quantitative analysis, described in chapter 4, we have to consider the different foci of the TAA and the RAPAS. In the TAA we test our hypotheses by analysing regional patterns. Therefore we need only consider data which vary regionally (e.g. topography- or infrastructure-related data), but not data that are equal in all regions as for instance prices of agricultural products or direct income payments. In the RAPAS in contrast, all variables which change over time have to be included, and consequently also data on development of prices or introduction of direct income payments.

Concerning the response (dependent) variable "forest expansion" we rely in the TAA on newly available large data sets: On the one hand we have data of the first and the second Swiss Areal Statistics, completed in 1985 and in 1997: These are point data on a hectare raster which are classified into 10 categories of forested areas. On the other hand we have data of the first and the second Swiss National Forest Inventory (SNFI), completed in 1986 and in 1995: These are point data on a kilometer raster (first SNFI) and on a 1.4-kilometer raster (second SNFI) which include various attributes such as forest cover, development stage, basal area, dominant height, tree species, regeneration, etc. In the RAPAS, we use on the one hand recently completed and historical aerial photographs (e.g. since 1930) and on the other hand data of forest cover maps prepared in 1950, 1970 and 1990. Forest covers are derived by direct delineation in aerial photographs. Thus they represent a compromise between aerial photographs and inventory point in the SNFI, that are based on terrestrial point measurements (Brassel and Brändli 1999).

Data on explanatory variables of land abandonment and forest expansion are available on a large variety of spatial and temporal scales. While most bio-physical variables can be derived from a 25m-elevation model and from existing maps, socio-economic data are often only available on the aggregate level for municipalities. While in the TAA we are restricted to existing data (e.g. population census, economic surveys, agricultural census etc.) we can complement existing data with local surveys in the RAPAS, where we use spatially more detailed variables. Especially concerning the socio-economic explanatory variables we aim at choosing few but relevant indicator variables, that potentially allow international comparability. Important are data that stand for labour opportunity costs (e.g. non-farm labour opportunities, education and age of the farmer) and data on infrastructure (e.g. local network of communication).

The prepared datasets of forest-cover data (dependent variable) and of bio-physical and socio-economic explanatory variables are analysed by testing our hypotheses on land abandonment and forest expansion and by recognizing and quantifying relevant patterns and cause-effect relationships of land abandonment and forest expansion using different multivariate statistics methods.

6. Conclusions and Outlook

Land abandonment is widely explained by farm exits and by farm labour migration, leading to the political conclusion that, through preventing

farmer migration, land abandonment and forest expansion might be stopped. The argument is often stressed to legitimate general income support to the farm sector. Based on theoretical economic reflections and the review of the state of knowledge we suggest that there is no ultimate causal correlation between the decrease in the number of farms and forest expansion and that the political conclusions therefore are partly misleading.

An integrative analysis with newly available datasets allows recognition of the relevant pattern and enables a better understanding of the processes of land abandonment and forest expansion. We derive an optimum of the available information by combining different approaches, including the use of nationwide inventory datasets in a total area analysis (representativity, assessment of the general pattern) and the use of repeated aerial photographs in selected case study areas (deepened understanding). Different socio-economic and bio-physical data on various scales make multivariate analysis more difficult, but mean also a chance to profit from different disciplinary and methodical perspectives and procedures within an interdisciplinary project.

The expected findings of these integrated analyses will be significant for the understanding of land-use changes in the Alps and may have important implications for policy design: As bio-physical and socio-economic conditions vary widely within the Alps, centrally planned policy measures hardly correspond with local bio-physical and socio-economic characteristics. The necessary knowledge for designing target-oriented and efficient measures to avoid land abandonment and forest expansion might therefore rather be found at the local level. This suggests consequences for the institutional setting, in particular a shift of competences, finances, and responsibilities from the Federal level to the cantons and municipalities.

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Authors' address: Peter Bebi, Division Alpine environment; Swiss Federal Institute for Snow and Avalanche Research (SLF), CH-7260 Davos, E-mail: bebi@slf.ch; Priska Baur, Section Economics; Swiss Federal Institute WSL, CH-8903 Birmensdorf, E-mail: priska.baur@wsl.ch.