Please leave blank
Nr.

Proposal form

Project funding: Division IV NFP/SPP

Scientific details

Main applicant Surname, first name	Baur Priska
Project title (English)	Forest expansion in the Swiss Alps: A quantitative analysis of bio-physical and socio-economic causes with an emphasis on structural change in agriculture

Contents

1. Summary [36]

In Switzerland, the closing down 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. This can be illustrated already on the aggregate level: In Switzerland, forest expansion is a phenomenon typical for mountain areas, whereas the rate of farm exits in the mountain areas between 1955 and 1990 was not higher, but lower compared to the plain.

Our general research question that will be examined during the span of the proposed project is: *How can we explain the pattern of land abandonment and forest expansion during the last decades with the help of newly available large quantitative datasets*? To address this question, we will first deduce hypotheses from economic theory and from vegetation dynamics to explain forest expansion and, second, conduct spatial statistical analyses to investigate these hypotheses. 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. The analyses are carried out on different spatial and temporal scales, both with the help of extensive, recently completed data of forest inventories and areal statistics, and with aerial photograph time series.

The expected findings 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.

2. Research plan

2.1 Account of the state of research in the field [37]

2.1.1 A short history of the interest of the Swiss research community in land abandonment and forest expansion

In the last 150 years, forests in Switzerland expanded significantly, most of all in the Alps. Although exact statistics are not available, it is estimated that forest surfaces have increased by about a third (Brändli 2000). The dominant direct cause of this development is the giving up of agricultural cultivation. Although land abandonment is going on since more than one hundred years, according to Surber *et al* (1973) and Walther (1984), it has become a research topic only in the sixties of the 20th century.

First investigations have been undertaken by agricultural scientists (Moos and Herot 1973, Gantner 1976, Brunner 1977, Moos and Herot 1979) and by forest scientists (Surber *et al* 1973). An important reason for the forester's interest in land abandonment was the fear of a further deterioriation of the rentability of timber production as a consequence of forest expansion on marginal land. The approach of Surber *et al* (1973) is based on systematic field studies in typical municipalities all over Switzerland. The investigation showed that abandoned land was yet the exception, but a significant increase was expected. The political reaction was rather fast: In 1979, direct income payments per hectare and per alped animal as incentives to promote minimal cultivation of land in regions with unfavourable production conditions were introduced (Schweizerischer Bundesrat 1979). Potential risks resulting from abandoned land and expected positive income effects for mountain farmers served as legitimation for the new policy.

These first investigations were followed on the one hand by research projects focusing exclusively on land abandonment, in particular the projects on abandoned land conducted at the Institute of Geography at the University of Zurich (Walther 1984, Julen 1984, Haefner and Guenter 1984, Haefner and Hugentobler 1985). On the other hand, land abandonment and its driving forces were of interest in the Swiss Man and Biosphere (MAB) Programme (1979-1985) (Brugger *et al* 1984, Messerli 1989).[1] The central starting point for the MAB-Programme was that land-use is the "meeting point" that brings together the natural and the socio-economic system (Messerli 1986). The first of the four research leading questions in the MAB-programme was: "Which socio-economic processes induce relevant changes in land-use patterns?" (Messerli 1986). In this sense, our project means a continuation of the MAB research tradition.

In the following years, there was no specific interest in land abandonment but more general in land-use change: in particular in the National Research Programme „Land use in Switzerland“ (Bernegger *et al* 1990, Rieder *et al* 1990), in the European research project ECOMONT – Ecology of European Mountain Ecosystems (Cernusca *et al* 1999) or in the ETH Polyproject PRIMALP – Sustainable Primary Production in the Alpine Region (http://www.primalp.ethz.ch/). One reason for the diminished interest might be that land abandonment in the Swiss Alps was judged by some experts as a problem of little quantitative importance (Rieder 1984b, Rieder and Anwander Phan-huy 1994). Only recently, basically as a consequence of the results of the second Swiss National Forest Inventory 1993-95 (Brassel and Brändli 1999), there is a new interest for land abandonment or rather forest expansion in the Swiss Alps (Brändli 2000, Ghiggi 2000).

We distinguish three fields of research which are relevant for our project:
- Research on explaining land abandonment in the Swiss Alps
- Research on vegetation dynamics on abandoned land
- Spatial modeling with bio-physical and socio-economic data

The account of the state of research is given for each field separately.

2.1.2 Research on explaining land abandonment in the Swiss Alps and research gaps

Explaining land abandonment

The first studies (Moos and Herot 1973, Surber *et al* 1973) provide mostly ad hoc explanations of the causes of land abandonment. Still, the reasoning about the causes is plausible and has basically remained unchanged by today: It is marginal land, *ie* land which supplies small yield at high costs, which is abandoned. This view is compatible with the trivial outcome of production and location theory that production decisions depend on marginal yields and costs (*cf* Henrichsmeyer and Witzke 1991). Further, in these first investigations it was distinguished between some kinds of natural or ecological factors on the one hand, and socio-economic and political factors on the other hand. Mainly unfavourable topography and low incomes were identified as the most relevant causes (Grubinger 1975, Gantner 1976, Brunner 1977, Moos and Herot 1979).

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 (1984a,b) 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. In regions where farms used to be divided among heirs ("Realteilung"), land abandonment is more spread. According to Walter's main conclusion, abandoned land is the result

[1] For a general overview on MAB reseach in European Mountain regions see Price (1995).

of a prevented modernization of land-use. Thus, it occurs where the agricultural system has not been adapted to a changed social environment. This seems particular the case in regions where “Realteilung” was practised.

In the Swiss literature we distinguish two disciplinary perspectives concerning the driving factors of land abandonment: social geography and agricultural economics. 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). By contrast, in agricultural economics changes are principally explained by exogenous factors, for instance, the development of labour markets, infrastructure, mechanization, prices, *etc*. Moreover, in economic models it is postulated that preferences will remain unchanged while we observe the behaviour (Varian 1996). This fundamental economic hypothesis is relevant for empirical economic analysis, because changes in individual behaviour are attributed to observable modifications of constraints. Consequently, the hypotheses deduced from this model are empirically testable. A further important difference is that economics is based on the postulate of methodological individualism: Any event that can be observed on the aggregate level is the result of individual actions. The individual agent is taken as the fundamental building block for all economic analysis (Frey 1992). By contrast, concepts in geography are rather based on the idea of aggregate social development. Following the leading hypothesis of Messerli and Brugger (1984: 77) the development of the mountain areas follows general and superior energy fields (“Kraftlinien”) which are steered by the centers. A further difference relates to the methodological position. Economics adheres rather to deductive, and social geography to inductive reasoning.

The economic way of reasoning is taken up by Gantner (1976), Brunner (1979), Moos and Herot (1979), Rieder (1984b), Rieder *et al* (1990), Bernegger *et al* (1990) or Pezzatti (2001). The central hypothesis remains that marginal land is abandoned where benefits are low and costs high. To summarise, 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 analysis remain either qualitative (Gantner 1976, Moos and Herot 1979, Rieder 1984b) or are conducted with Linear Programming models (Brunner 1977, Rieder *et al* 1990, Bernegger *et al* 1990). Empirical field analyses are the exception (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 better parcels are accessible, the more intensively they are cultivated. Labour seems the crucial element in explaining production, and therefore in explaining land-use and land abandonment as well (Witzke 1993). The more labour intensive an activity and the higher labour costs, the more probable it becomes that marginal land is abandoned. Opportunity costs of labour are on the one hand determined by exogenous factors, *ie* 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.

Structural change and land abandonment

Some authors expect a direct relationship between farmer migration and land abandonment. Hence, they draw implicitly or explicitly the conclusion that land abandonment can be stopped by a prevention of farmer migration (Messerli 1989, Bätzing 1996, Broggi *et al* 1997). This view is persistent, although by now 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).

Although there is no evidence for a general direct correlation between farmer migration and land abandonment, one special case has to be discussed. It is the case of complete land abandonment, because no farmers are left at all. To clarify this special case, we need to know more about farmer migration and structural change in agriculture. From the vast literature on this topic (for an overview see Baur 1999), we concentrate on an issue which did not arise from theory but from observation, and which is relevant for the proposed project. It is the question of the minimum size of viable villages (Gantner 1976, Rieder 1984a, Bernegger *et al* 1990). In Switzerland, population decline is restricted to peripheral agricultural villages (Wanner 1983). According to Rieder (1984a), pure agricultural villages have no chance of survival because they are too small. Villages can only survive, if non-farmer population and non-farmer employment remains or rather increases (Bernegger *et al* 1990). By supporting agricultural income total migration cannot be prevented. Agriculture cannot create enough employment to help villages survive. The conclusion is that the survival and development of non-farm employment is a necessary condition to prevent total migration and also total land abandonment. As a whole this conclusion is of high relevance because it turns a common political argument upside down: Prevention of migration is less the result of a maintained farm sector but rather on the contrary. The basic argument is that a minimal farm sector can only be kept alive, if local infrastructure is preserved, and this needs a minimum size non-farmer population. This conclusion is also supported by Naegeli-Oertli (1986) who found that in Grindelwald, on average, 70% of the farm income resulted from non-farm labour.

Rieder (1984b) 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 in the plain one would expect the migration of mountain farmers to be higher, which apparently has not been the case by now. 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"). This perception is supported by well-known theoretical concepts. Famous is Cochranes "technological treadmill thesis" which explains decreasing prices for agricultural products by a fast diffusion of technological innovation (Rieder and Anwander Phan-huy 1994). According to Gardner (1992) the farm problem model has persisted although it is theoretically not consistent and empirically not evident. Gardner shows for the US that migration of farm labour after the war can be explained primarily by an increase of wages and labour demand and not by sinking or instable agricultural incomes. He postulates that in a growing economy structural change is rather driven by "pull-factors" ("Abwanderungssog"; better income opportunities in the non-agricultural sector) than by "push-factors" (sinking incomes in the agricultural sector). Baur (1999, 2000a) found strong empirical evidence for this hypothesis for the structural change in Swiss agriculture between 1939 and 1990. She could show 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. After 50 years, the average size of Swiss farms had only doubled (from 5.8 to 12.2 ha), labour intensity remained extraordinarily high (1996: ca. 7 ha per labour unit) and there was almost no development of large farms (1996: 1% of farms > 50 ha).

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, 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 disadvantages (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, *ie* 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 important because it determines the individual's possibility set and costs of actions as the following two examples illustrate:

1. Previous hereditary customs are the main reason for small and dispersed parcels which makes cultivation very expensive and thus increases probability of land abandonment.

2. The restrictive Swiss forest legislation (Federal Forest Act), wherupon forests expanding on abandoned land cannot be removed, leads to an increased interest in preventing land abandonment, independent of agricultural benefits. Minimal cultivation is maintained because of eventual benefits expected in the future. Eventual high future benefits mean high opportunity costs of land abandonment for the landowner and thus decrease the probability of land abandonment.

Political conclusions

How can land abandonment be prevented? According to Brunner (1977) this aim can be achieved the cheapest by maintaining family farms and giving compensation payments in regions with unfavourable natural conditions. The latter was realised in 1979, when the Federal government introduced direct income payments ("Flächenbeiträge"). Also Rieder (1984a) expects direct income payments to be effective instruments to prevent land abandonment. Simulations with Linear Programming models (Bernegger *et al* 1990) and a survey in selected communities of the canton Graubünden (Anwander *et al* 1990, Rieder *et al* 1990) confirmed allocative effects of these income payments. However, the analyses and investigations provide also evidence of the importance of infrastructure development which allows accessibility of parcels and mechanisation. According to Bernegger *et al* (1990) and Rieder and Anwander Phan-huy (1994), the existence of development is even more important than income payments.

Since land abandonment seems a local problem, Rieder and Anwander Phan huy (1994) suggest local solutions instead of increasing payments. Concerning political implications, land abandonment shows many similarities with the problem of designing effective and efficient measures to promote biodiversity in agricultural landscapes, where a regionalization of policy seems promising (Baur 1998). This basic idea that problem solving has to take place on the local or at least regional level is not new neither in the problem-oriented literature (Brugger 1984, Rieder and Häfliger 1995) nor in economic theory (Theory of Fiscal Federalism, Public Finance, Political Economics *etc*; *cf* Feld and Kirchgässner 1998). Nevertheless, despite the federalistic tradition in Switzerland, such ideas have not influenced (agricultural) policy by now. After all, if land abandonment is a major and wide-spread problem, it cannot be resolved within traditional concepts of centrally designed agricultural policy. In particular in regions menaced by total migration, we need policies going beyond the sectoral approach (*cf* Baur *et al* 1999). There is a research gap concerning the design of effective and efficient policies to handle land abandonment.

Research gaps

- Consistent explanation of land abandonment founded on contemporary concepts of agricultural economics.
- Quantitative analysis of land abandonment/forest expansion between ca. 1950 and 2000 on the basis of a sound theoretical framework.
- Allocative effects of direct income payments, introduced in 1979, for regions with unfavourable production conditions, and in particular in the mountain regions.
- First allocative effects of the significant raise of direct income payments within the new agricultural policy (since 1993).
- Policies to handle land abandonment.

2.1.3 Research on vegetation dynamics on abandoned land and research gaps

Patterns of succession or vegetational change can be asserted to some degree and at some scale for almost any natural system (Mc Cook 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, blowdown or snow avalanches. And there is also a fast growing body of literature on tree invasion and forest succession, where a change to a more favourable climate has lead to forest expansion into ecotones such as glacial meadows (Lüdi 1958), meadows near alpine timberline (Franklin *et al* 1971, Jakubos and Romme 1993, Hessl and Baker 1997) 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 (*eg* Schauer *et al* 1998, Dider 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 (*eg* Gessamann and Mc Mahonn 1984, Schütz *et al* 2000a).

Forest succession patterns after agricultural land use change is much less investigated than forest succession after natural disturbances. However, some case studies let us already draw some conclusions and hypotheses about the effect of land use changes, and various case studies in or near the Alps show, which pathway succession from hay meadows or pastures to forests are likely to follow in specific regions:

- In the Swiss National Park vegetation surveys since 1917 (Braun Blanquet *et al* 1931, Stüssi 1970, Schütz *et al* 1998, Ackermann *et al* 2000) enabled different studies about succession pathways after abandonment of agriculture and under the influence of changing grazing pressure. On the basis of these studies, Schütz *et al* (2000b) developed successional models, which show the expected change in vegetation over a period of 580 years from tall herb communities (species group *Aconitum*) to pine forests (*Pinus montana*).
- In the Jura, Kienzle (1979) described pathways from *Mesobromium* (drier sites) or *Cynosurium* (more mesic sites) to different types of beech-forests (*Fagion*). Dependent on the site conditions (humid *vs* xeric) the pathway goes over different intermediary stages.
- In the central Alps (Urserental, Obergoms, Bedretto) Zoller *et al* (1984) described pathways from *Festucion variae* (South facing) or *Nardion* (North facing) to different staged of abandoned land. Dependent on site conditions and in particular on different expositions (North *vs* South facing slopes), these intermediate stages include different dwarf shrub formations *(Vaccinium, Calluna)* and deciduous trees. Dwarf shrub formations or stages of *Alnus viridis* may keep for several decades until they change to spruce-forests *(Picetum)* or mixed larch-spruce forests *(Larici-piceetum)*.
- In the Napfgebiet (Kienzle 1985) described succession pathways on an altitudinal gradient from mown meadows to different types of beech, beech-fir or spruce-forests.
- In 3 different sites along an east-alpine transect from North Tyrol (Stubai Valley), South Tyrol (Passeier Valley) to Trento (Monte Bondone) land-use determined changes of the vegetation were investigated. In general on heavily managed hay meadows (annual fertilisation and mowing *Geranio silvatici-Trisetum* or *Festuco-Agrostietum*) decline of land use (moving every 1-2 years) first leads often to the development of a *Nardetum*. With a further decline of land use, different dwarf shrubs (*Calluna, Vaccinium*) begin to colonize and initiate, with a complete absence of management, the vegetation into a secondary forest according to the site related succession (Tasser *et al* 1999).
- In the Malcantone in the canton Tessin (Lischer 1998) and in the lower Engadin (Schöne 1999) dendroecological methods in combination with aerial photographs enabled to reconstruct invasion of different tree species and forest expansion.

Although the main characteristics of these studies is that succession is very different according to different sites there is also some similarity in the succession pattern of most of these case studies: Heavily managed areas show a high frequency of hemikryptophytes, which declines with less cultivation. After abandonment, the number of lignified chamaephytes and herbaceous species (herbs and grasses) increases. Finally, tree species begin to invade abandoned areas and gradually lead to forest cover conditions (Zoller *et al* 1984, Cernusca *et al* 1999). Changes in sites are often related to management. Depending on the various land-use method, light intensity decreases, as well as nutrient content, which leads to an acidification of the soil. Percentage of biomass in roots and root depth gradually increases. While pH-values generally decrease, C/N-ratio often increase in abandoned land leading also to a change of bacteria and fungi composition in the soil and to a slower mineralisation process (Gisi and Oertli 1981). Initially, species diversity 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, Cernusa *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 (Franklin *et al* 1971, Veblen 1986, Bebi 2000). Based on a study in the Wind River Mountains, Dunwiddle (1977) suggests that grazing, combined with other factors can produce changes in meadows condition that enhance tree invasion for 20 to 25 years once intense grazing pressure is reduced.

The speed of forest succession may vary considerably according to regional climate, former land-use and different autogenic or allogenic factors. Due to favourable climatic conditions and due to a relatively small scaled pattern of open areas (Montis) and forests, speed of forest expansion is more rapid in the Tessin and in other southern valleys of the Swiss Alps (Walther and Julen 1986). Slow pathways are most often observed where exposure to grazing or to climatic factors are extreme (Schütz *et al* 2000a) or where formation of dwarf shrubs build relatively stabile successional stages (Zoller *et al* 1986).

Our knowledge on vegetation dynamics after agriculture abandonment is based on a sum of different case studies. These case studies give some insight on the mechanisms of succession from meadows to forest in different regions. To a large degree, however, 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.

Research gaps

- Tree invasion pattern across multiple gradients of biophysical site factors and land use history.
- Time between land abandonment and measured forest expansion, dependent on land use history and site conditions (topography, soil, climate, *etc*).
- Consistent time series on forest expansion with reliable data sets.

2.1.4 Spatial modeling with bio-physical and socio-economic data

Spatial modeling is a fast growing research field in the natural sciences as well as in economics (*eg* regional economics, Reggiani 2000). Geographical information systems (GIS) of varying complexity have emerged during the last 20 years as useful tools in addressing landscape research questions (Turner 1990, Fischer *et al* 1996). Many current ecological problems can be addressed more easily by overlaying various bio-physical or socio-economic data-layers, and the combination of GIS with multivariate statistical methods is increasingly used to analyse and disentangle the driving forces of the current landscape pattern and to explain and predict ecological or socio-economic processes. Traditionally, GIS modeling has mostly been used in combination with either only bio-physical or only socio-economic data.

GIS-models with bio-physical data

There is a large body of literature on predictive vegetation modeling (see review in Franklin 1995). Predictive vegetation modeling is founded in ecological niche theory and vegetation gradient analysis, and rests on the premises that vegetation distribution can be predicted from the spatial distribution of environmental variables that correlate with or control plant growth. The availability of digital maps of topography and other environmental variables such as soils, geology and climate has allowed in many studies of predictive vegetation mapping to successfully identify and quantify explanatory variables (*eg* Guisan *et al* 1998, Franklin 1998). Similar approaches have also been conducted in risk assessment analysis, where the risk of certain disturbances is explained and predicted with the help of a large sets of bio-physical data (Robothom and Dudycha 1998, Bebi *et al* 2001) or in habitat analysis, where the suitability for certain species is spatially modelled dependent on ecological and topographical factors (*eg* Mladenoff and Sickley 1998, Brito *et al* 1999).

Depending on the sets of available data, different multivariate modeling approaches are preferred. Mutiple linear regression models are generally used for the modeling of continuous dependent variables (*eg* density of forest cover). Alternatively, categorical or binary dependent variables (*eg* classification of forest types, forest *vs* non-forested area) can be explained with logistic models, General Linear Models (GLM), General Additiv Models (GAM) or discriminant analysis (canonical variation analysis). Beside these techniques, tree based models (Classification and Regression trees) have been increasingly used during the last years to explain vegetation pattern or to assess disturbance potential (Reynolds 1993). The advantage of classification trees is that, in contrast to regression models, they can determine relationships between the response variable and a predictor, where the relationship is conditional on the values of other predictors (Franklin 1995).

GIS modeling procedures with bio-physical data are mostly carried out on a raster based GIS-format and raise the question of spatial autocorrelation. Extended forest stands are ecosystems which are on a broad spatial scale implicitly correlated biological processes. But autocorrelation has also to be considered on a temporal scale (Legendre 1993). The effect of spatial autocorrelation can be limited with an appropriate sample technique and thus using only non adjacent information (Pereira and Itami 1991, Brito *et al* 1999).

GIS-models with socio-economic data

Socio-economic spatial data have some properties that distinguish them from bio-physical data (*cf* Bohnet 1995). In contrast to bio-physical data, the position and the boundaries of socio-economic phenomena cannot be directly determined through observation or measurement on the earth's surface. Usually, they are produced indirectly by aggregation of data of enumeration districts or statistical analysis of data of representative areal units describing features of individuals or groups. As socio-economic phenomena are linked to people and their activities, their distribution over space is often extremely uneven and heterogeneous. In most studies with socio-economic data, the information is collected at the point level (individual, household, house, community) and almost always aggregated to existing spatial entities such as administrative units to allow tabulations according to various data attributes. Many of the GIS modeling procedures, described for bio-physical data are also used for socio-economic data (*cf* Arlinghaus 1996). However, data for socio-economic models are more often aggregated on a broader scale (*eg* on the level of administrative units with known census data) and the problem of autocorrelation is often addressed with autoregressive models (*eg* Brown *et al* 1996).

Data integration issues

GIS modeling approaches with both bio-physical and socio-economic data often face the problem of integrating data of different types and scales. There are several ways of addressing this issue: Interdisciplinary land-use modeling approaches, which are biased more to the bio-physical sciences, tend to integrate different data layers into raster data and perform statistical analysis with samples of such raster data (*eg* Tappeiner *et al* 1998, Verburg and Chen 2000). Alternatively, studies with population census data show awareness of the often arbitrary nature of the spatial data variability (Goodchild *et al* 1993), and different techniques to integrating social and environmental data have been developed (*eg* Brown 1996). Conversion between areal units or the creation of new areal units, which represents the intersection of two sets of units, provide mechanisms for comparing disparate data. Data collected and aggregated to some spatial aggregation units can be converted to other spatial units through a variety of techniques outlined by Tobler (1979), Flowerdew and Green (1989), and Goodchild *et al* (1993). A common assumption for many of these methods is that the density of the count variable, or the value of the density variable, is constant throughout each of the units, what is of course not always a good approximation. Thus before data integration, it is important to inve stigate the intern heterogeneity of socio-economic units and to consider remedial measures (Wong 1995, Hung and Yasuoka 2000).

2.2 Account of own research in the field [38]

The project is carried by an interdisciplinary research team at the Swiss Federal Research Institute WSL.

Priska Baur, main applicant

In the last decade, Priska Baur's topics in research and teaching have been *environmental economics of land-use in agriculture* (teaching: Baur 1992, Baur 1996, Baur 1997, Baur and Rieder 1997; research: Baur 1995, Baur 1998, Baur 1999b, Baur 2000d), *structural change in agriculture* (Baur *et al* 1995, Baur 1996, Baur *et al* 1999, Baur 1999, Baur 1999c, Baur 2000a, Baur 2000b, Baur 2000c) and *political economics* of agricultural policy (Baur *et al* 1994) and forest policy (Baur 2001, in review).

Her research so far is important for the proposed project concerning the theoretical framework, the empirical results, the methodical approach in the quantitative analyses and the design of policies:

<u>Theoretical framework</u>: In her PhD thesis, Priska Baur discussed different theoretical economic approaches to understand and explain structural change in agriculture. Her problem-oriented synthesis of theories serves as a starting point.

<u>Empirical results</u>: A crucial result of Priska Baur's thesis is that structural change in Switzerland between 1939 and 1990 was highly retarded mainly because of the significant financial support of agriculture. In the mountain area, the retarding effect of agricultural policy was eventually of even greater importance. The reasons identified are:

- Economy in the peripher regions is generally weaker, and hence, opportunity costs of farm labour are lower.
- Morevoer, there are empirical indications that progress in education of farmers was retarded in mountain areas, which also contributes to lower opportunity costs of farm labour.
- According to economic theory, direct income payments tend to retard structural change even more than price support. In the mountain area, direct income payments were already introduced in 1959 (Baur 1999c).
- Significant financial support to improve working conditions and housing quality contributed to a neutralization of pull-factors from the non-farm sector and from the economic centers.

<u>Methodical approach in the quantitative analysis</u>: Between 1994 and 1999, Priska Baur acquired experiences in analysing individual farm data from the Swiss farm census. In Switzerland, she was the first person to combine data from two and more census to analyse the deve lopment of farms in time. She developed her methodical approach in the canton Zurich and in Sudtirol. In particular, she studied farm exit patterns and participation of farmers in the ecological programmes of the Swiss government. In her methodical approach she relies on the theory of complex phenomena (Hayek 1961/1972), which emphasizes the great relevance of pattern statements with respect to understanding and predicting of social and economic change. As in her thesis, the objectives of the quantitative analyses in the proposed project are pattern recognition and pattern prediction.

<u>Design of policies</u>: By today, in Switzerland, agricultural policy has basically remained income policy. Overall political objectives, such as preserving cultivation of land, promoting environmentally sound production or ensuring the production potential are primarily pursued in an indirect way, *ie* by maintaining farms and by designing measures without relation to the local context. Problems arising from conflicting goals have been addressed by a continuous increase of governmental expenditures. Priska Baur's principal interest in research is how political

measures can be developed to mitigate conflicts between different user interests and thus to better reach overall objectives at less costs.

Peter Bebi, co-applicant

Peter Bebi has already as an undergraduate student (Environmental Natural Science ETHZ) elaborated a contribution to ecological and socio-economic causes and effects of abandoned land in the Alps (Bebi and Häberli 1992). In his PhD project 'Structures in mountain forests as a basis for the assessment of different forest functions', which was advised by Prof. P. Bachmann, PD. F. Kienast and Dr. W. Schönenberger (Bebi 1999, Bebi 2000, Bebi *et al* 2001) Peter Bebi elaborated tools for the assessment of different relevant structure types in mountain forests with the help of aerial photo-interpretation and with a newly developed GIS-based automated image processing approach. On the basis of these methods, Peter Bebi mapped small scaled structure types on aerial photographs from 1930 and from 1997 and studied, with the help of GIS-based overlay procedures, forest dynamics under the effects of different site and management factors. With two GIS-based examples of application Bebi showed the functionality of the elaborated methods in combination with a 25m-digital elevation and statistical models.

The postdoc project 'Evaluation of newer GIS modeling approaches to study disturbance interactions in a Rocky Mountain subalpine forest landscape', advised by Professor T.T. Veblen (Department of Geography, University of Colorado), enabled him to increase his knowledge in forest dynamics, in GIS-based modeling techniques and spatial statistics. With the help of different GIS modeling approaches (logistic models, tree based models, autologistic models) and an overlay of historical maps, field checked aerial photographs, topographical data and different existing GIS layers, Peter Bebi analysed and modelled the risk of subsequent fires and spruce beetle outbreaks in a complex mountainous study area (Bebi *et al* 2001b, Bebi *et al* in review).

Ruedi Boesch, co-applicant

Ruedi Boesch has a solid background from his geography study at the university of Zurich concerning spatial analysis and image processing. In the last years, he has been working in the section „Landscape inventories“ at the Swiss Federal Research Institute WSL as a specialist for spatial analysis, image processing, pattern recognition and analysis within several projects and expertises. He successfully conducted a project for the extraction from vegetation data from scanned topographic maps and designed and developed a large software-based application framework for the detection and analysis of bioacoustic signals. Currently, he works in the project „retrospective analysis of forest development from forest cover maps“ and the project „recognition of spatial structures for the next generation of landscape and forest inventories“.

2.3 Detailed research plan [39]

2.3.1 Problem and objectives

The forested area in the Swiss Alps has expanded by about 30% during the 20th century. There is general agreement, that the abandonment of agriculture land is the main reason for this forest expansion. This development may not be desirable because of a variety of reasons [1], for instance because of the potential loss of biodiversity (*cf* Nievergelt and Hess 1984, Cernusca *et al* 1996), eventually enhanced risk of soil erosion (Ruf 1982, Cernusca 1996), soil acidification (Gisi 1981) or degradation of esthetic landscape diversity (Krippendorf 1984).

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 might be stopped. The argument is often stressed to legitimate general income support to the farm sector. Based on theoretical reasoning and on empirical indications we suggest that this widely accepted hypothesis, which postulates a direct relation between number and size

[1] See also reviews in Moos and Herot 1979, Häberli and Bebi 1992 or in MacDonald *et al* 2000.

of farms and land abandonment, is over-simplifying and the political conclusions are therefore partly misleading. This can be illustrated already on the aggregate level:

- In Switzerland, forest expansion is a phenomenon typical for mountain areas, whereas the rate of farm exits in the mountain areas between 1955 and 1990 was not higher, but lower compared to the plain (Baur 1999).
- In the canton Jura we find few and on average large farms (JU: 29,7 ha, CH: 13,8 ha; 1997). Still, according to the Swiss National Forest Inventory (SNFI) the forest area increased only slightly (+1,6% between 1982/86 and 1993/95), and following the Areal Statistics (AS) the forested area even decreased (-1% between 1979/85 and 1992/97).
- In the canton Valais we find many and on average small farms (VS: 5,8 ha; 1997). Nevertheless, the forest area clearly increased (+5,6% according to the SNFI and 2,2% according to AS).

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. Since the data base significantly improved during the last decade (recent completion of the second Swiss National Forest Inventory and of the second Areal Statistics), a quantitative analysis has become feasible.

Given the political aim to maintain a high percentage of open landscapes in the Alps, it is important to improve our understanding of the bio-physical and socio-economic reasons of forest expansion. Our general research question that will be examined during the span of the proposed project is:

How can we explain the pattern of land abandonment and forest expansion during the last decades with the help of newly available large quantitative datasets?

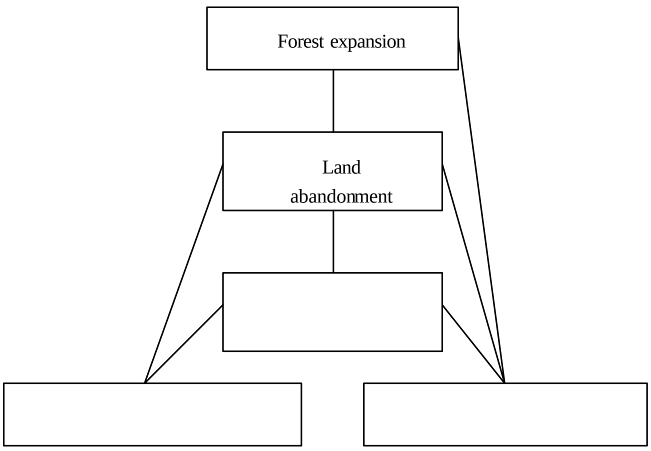
The objective of this project is thus to identify, to disentangle and to quantify the relevant patterns and cause-effect relationships of land abandonment and forest expansion and to interpret and evaluate them from an economic perspective.

In detail, we distinguish the following partial aims:

1. Theoretical deduction of hypotheses to explain forest expansion with an emphasis on structural change in agriculture.
2. Spatial statistical analysis of extensive existing data bases and of aerial photo series.
3. Empirical estimation of models to explain forest expansion (testing hypotheses, pattern recognition and quantification) based on the same data bases.
4. Economic interpretation and evaluation of the results.
5. Political conclusions concerning the institutional setting and the design of measures to maintain open landscapes.

2.3.2 Explaining land abandonment and forest expansion

Hypotheses about the causes of forest expansion are derived from contemporary concepts in agricultural economics and in vegetation dynamics: Forests expands on abandoned land (vegetation dynamics) and abandoned land is the result of a production or rather a non-production decision (agricultural economics). Figure 1 illustrates our theoretical framework to explain land abandonment and forest expansion.



Agricultural economics **7** ***1*** *Vegetation dynamics*

5 **2**

6

4 **3**

Figure 1 Explaining land abandonment and forest expansion (explanation in the text)

In our simplified system analysis, we distinguish five elements (bio-physical causes, socio-economic causes, structural change in agriculture, land abandonment, forest expansion) and seven relations. Relation 1 and 7 are discussed on the basis of concepts of vegetation dynamics. Reasoning about relation 2, 3, 4, 5, and 6 is based on production and location theory (*eg* Henrichsmeyer and Witzke 1991, Brandes *et al* 1997), on agricultural household models (Witzke 1993, *cf* Baur 1999), and on a general economic model of human behaviour (Frey 1992). Every relation corresponds to a research question. The following working hypotheses are not complete but they illustrate the theoretical framework.

Relation 1: How do bio-physical causes influence forest expansion?

Forest expansion and most of all the speed of forest expansion varies significantly and in a predictable way across multiple gradients of biophysical site factors and land use history. For example we expect forest expansion to be faster:

- in lower elevations
- where summer precipitation is high
- where snow free season is long
- where soil humidity is intermediary
- within a certain distance (depending of tree species) of mature trees
- where ungulate grazing pressure is not extreme
- where no stable, intermediary vegetation stage (e.g. dwarf shrubs) develop.

Relation 2: How do bio-physical causes influence land abandonment?

Bio-physical conditions influence benefits (yields) and costs (labour, capital) of land-use. The expected benefit of land-use depends on the yield potential. *Ceteris paribus* (*c.p.*)[2] the probability of land abandonment increases with diminishing yield potential:

- with the altitude of a parcel

[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).

- on parcels with unfavourable soils (poor soils, wet soils)
- on extremly exposed parcels (south facing slopes, shadow)
- in extreme climates (irregular precipitation) or where natural hazards return regularly (snow avalanches, mudslides).

The expected costs of land-use depend on the labour and capital requirements. Thus, *c.p.* the probability of land abandonment increases with the labour and capital requirements of land use:

- on parcels with unfavourable topography (steep slopes, irregular terrain) 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 developped at all
- on distant parcels
- on small parcels.

⇒ In summary, we expect land abandonment on parcels where bio-physical conditions, in particular topography, are unfavourable.

Relation 3: How do bio-physical causes influence structural change in agriculture?

The probability to close down the farm increases when the farm income potential is low. Since bio-physical causes have an impact on the income potential (benefits and costs of land use), they also influence structural change.[3] *C.p.* the probability to close down the farm is increased with decreasing income potential,
on farms where yield potential is low:

- high altitude a.s.l.
- large percentage of unfavourable soils (see above)
- large percentage of extremly exposed parcels (see above)
- sites with extreme climates (irregular precipitation) or where natural hazards return regularly (see above)

and on farms where costs are high:

- large percentage of unfavourable topography
- large percentage of parcels which are not easily accessible by motovehicles or not developed at all
- large percentage of distant parcels
- large percentage of small and scattered parcels

⇒ In summary, we expect less and larger farms where income potential is restricted because of unfavourable bio-physical conditions.

Relation 4: How do socio-economic causes influence structural change in agriculture?

The term socio-economic relates to a variety of factors, which we subdivide into causes relating to economy, infrastructure, and to the institutional setting.

<u>Economical causes</u>

We take the same starting point as in the preceding section. With increasing farm income potential the probability to close down the farm decreases. Since socio-economic causes have an impact on the income potential (benefits and costs of land use), they influence structural change as well. *C.p.* the probability to close down the farm increases with decreasing income potential:

- with sinking prices for agricultural products
- with increasing opportunity costs of labour (when opportunities are at hand to invest labour more profitably in an off farm job, opportunity costs of labour are high).

[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.

On the one hand, opportunity costs depend on exogenous factors. They increase with a positive economic development:
- with growth of wages
- with growth of employment possibilities.

On the other hand, opportunity costs are also dependent on endogenous factors.
- They increase with education and
- decrease with age.

<u>Infrastructure</u>

The probability to give up farming depends not only on the income but also on other factors relevant for the general well being. The quality of infrastructure contributes significantly to the quality of life. Our hypothesis says that the probability to close down the farm increases with sinking infrastructure quality on the spot and in "commuter distance":
- with a bad accessibility of the farm
- with insufficient local road network and public transport facilities (distance to and accessibility of nearby economic and cultural centers)
- with few shopping facilities
- with insufficient or missing schools
- with missing opportunities for additional off farm income
- with bad quality of housing (no modern installations).

<u>Institutional setting</u>

The institutional setting determines the individual's possibility set and costs of actions, and therefore also influences the decision to give up farming. *C.p.* the probability to close down a farm increases with
- missing opportunities to rent land, for instance because of restrictive regulations (Land-lease Act)
- impediments for land improvements because of a complicate and small-scale ownership structure.

On the other hand, *c.p.* the probability that a farm is maintained increases with
- security of income by guaranteed production quotas and prices, and by getting direct income support linked to production and land-use activities
- getting cheap credits and subsidies for renewing housing, constructing modern stables or buying machines.

Combining economic, infrastructural and institutional factors we get different cases, which is illustrated by the following three examples:

1. We expect less and larger farms where
   - agriculture income potential is low and
   - off farm income potential is high

   and where at the same time
   - local infrastructure is sufficient and
   - institutional setting facilitates the development of conditions which allow a rational cultivation of land.

2. We expect more and smaller farms where
   - agriculture income potential is low and
   - off farm income potential is not high but exists

   and where at the same time
   - local infrastructure is sufficient and
   - institutional setting gives income guarantees.

3. We expect total migration where
   - agriculture income potential is low and

- off farm income potential is high

and where at the same time

- local infrastructure is insufficient and
- institutional setting hinders the development of conditions which allow a rational cultivation of land.

Relation 5: How do socio-economic causes influence land abandonment?

We take the same starting point as in relation 2; socio-economic causes influence benefits and costs of land-use.

Economical causes

The probability of land abandonment increases with diminishing benefit potential, *ie* with sinking prices for agricultural products on the one hand, and with increasing labour and capital costs on the other hand. The most relevant are the opportunity costs of labour: The probability of land abandonment increases the better the opportunities at hand to invest labour more profitably, *eg* on nearby parcels, on parcels with a better production potential or in an off farm job.

Infrastructure

Land-use costs are significantly influenced by infrastructure. The probability of land abandonment increases with sinking infrastructure quality, in particular when a parcel is not developed to be accessible by motor vehicles.

<u>Institutional setting</u>

The probability of land abandonment 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 getting direct income support linked to minimal land-use
- if holding land open is linked with benefits which eventually might be realised in the future. For instance benefits from selling land for construction or infrastructure of leisure industrie (skiing *etc*). Through maintaining minimal land-use, the irreversible loss of land, due to restrictive Swiss forest legislation, is prevented. Forest legislation is interpreted as a strong institutional barrier to prevent land abandonment.

⇒ In summary, we expect land abandonment on parcels where opportunity costs of farm labour are high (better income opportunities on other parcels or off farm), where parcels are not easily accessible, and where the realisation of future benefits is unlikely.

Relation 6: How does structural change in agriculture influence land abandonment?

We do not find theoretical reasons nor empirical evidence for an ultimate causal correlation between the decrease in the number of farms and land abandonment. We postulate that land abandonment can be explained by the factors discussed above, and in particular by the labour related variables topography, accessibility of parcels, and by opportunity costs of labour, which depend primarily on local or regional development of employment and wages. Consequently, land abandonment cannot be prevented by maintaining the number of farms.

⇒ In summary, we do not expect an ultimate cause-effect relationship between the number of farms and land abandonment.

Relation 7: How does land abandonment influence forest expansion?

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.

There are different possible pathways of land abandonment, and we expect the speed of forest expansion to be different according to these pathways: 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* 2000a).

2.3.3 Methods

Two complementary database-approaches for different spatial and temporal scales will be used to test our hypotheses and to analyze and model the causes of land abandonment and forest expansion: total area approach (TAA; section 2.3.3.1) and repeated aerial photograph-approach in selected areas (RAPAS; section 2.3.3.2). While the main advantage of the TAA lies in the large representative datasets covering the whole Alps, RAPAS allows us to investigate forest expansion in selected case study areas with a higher spatial resolution and over a longer time period.

When operationalizing the theoretical framework for quantitative analysis, described in the previous section 2.3.2, 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 considering data which vary regionally (*eg* 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 by 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.

Further, we have to take into account considerable time lags between the causes of land abandonment and effective land abandonment, as well as between land abandonment and measured forest expansion.

2.3.3.1 Total area approach (TAA)

In this approach we use data sets covering the complete area of the Swiss Alps. These data sets include spatially extended data on forest expansion (dependent variables), as well as spatially explicit socio-economic and bio-physical explanatory variables. The following list is not complete but it illustrates the methodical approach.

Available databases

The *response (dependent) variable* "forest expansion" is available in three different entities, allowing three different approaches to derive the dependent variable:

1. Data of the first and the second Swiss Areal Statistics (AS), completed in 1979/85 and in 1992/97: These are point data on a hectare raster which are classified into 10 categories of forested areas.
2. Data of the first and the second Swiss National Forest Inventory (SNFI), completed in 1982/86 and in 1993/95: 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*.
3. Data of forest cover maps (FCM) prepared in 1950, 1970 and 1990: These data are taken from topographic maps and from the digital landscape model of Switzerland (Vector25, Swiss Federal Office of Topography).

The explanatory (independent) variables are derived from the following sources:

Bio-physical explanatory variables

- 25m-digital elevation model (DHM25, Swiss Federal Office of Topography).
- Maps of climatic variables are generated by using data from meteorological recordings and the DHM25 to spatially interpolate the climatic data (*cf* Zimmermann and Kienast 1999)
- Edaphic data (soil type, nutrient availability, soil water capacity) are taken from hydrogeological and geotechnical maps (Swiss Geotechnical Commission, Institute of Cartography ETHZ).

Socio-economic explanatory variables

We aim at choosing few but relevant indicator variables, that potentially allow international comparability, *eg*:

- From annual labour statistics we draw conclusions about the local labour market development and non-farm labour opportunities.
- From commuter statistics we derive labour mobility (decennial population census).
- Development of population informs about the per saldo migration (decennial population census).
- The network of communications is an important aspect of infrastructure (digital since 1970).
- From farm census data (1955, 1965, 1969, 1975, 1980, 1985, 1990, 1996, 2000) we can derive structure of the farm sector and dynamics of change.

In selecting socio-economic variables, we rely as far as possible on existing analyses of socio-economic development in Switzerland, and in particular in the Swiss Alps (*eg* NRP "Regional problems in Switzerland", Bätzing *et al* 1995, ORL 1995, ORL 1998).

Among the socio-economic explanatory variables we also list data about former cultivation, such as

- Data about land use in 1951 ("Kulturlandkarte Schweiz 1951"; mentionned by Haefner and Günter 1984) or
- Data about the development and suitability of sites for agricultural production ("Zonen Viehwirtschaftskataster")

Previous prognoses of land abandonment

Further, we intend to compare previous prognoses of land abandonment with recent data on forest expansion:

- Map with grouping of mountain regions with respect to the tendency of land abandonment (Moos and Herot 1973)
- Map with 5 classes of land menaced by land abandonment (Surber *et al* 1978).

Preparation of the datasets

The first two datasets of the dependent variable (SNFI- and AS inventory data) are point data. We use a Geographical Information System (GIS) to intersect these inventory point data with polygon data layers (*eg* edaphic data, socio-economic data per municipality) and with raster based data (*eg* DHM25, climatical data). All relevant variable-attributes of the intersected polygon and raster-data are then added to the inventory data sets of forest cover.

In the last approach, where we intend to use data of forest cover maps (FCM) to calculate area changes within the Swiss Alps since 1950, the forest area will be extracted with vectorizing techniques from scanned topographic maps, delivering vectorised forest data for three time slices since 1950. Polygon comparisons based on graph representation will allow to model the forest expansion over time. This is the most promising approach in terms of length of the time span of forest expansion and of available spatial accuracy, but methodically also the most challenging approach, in particular concerning automatic extraction of data.

Using the FCM datasets and other bio-physical data (*eg* soil type maps), rather different delineation techniques can be applied (Alesheikh 1996, Devine 1994). Forest covers are derived by direct delineation in aerial photographs, whereas data from the first and second SNFI are based on terrestrial point measurements (Brassel and Brändli1999). The Swiss AS uses another classification method based on photointerpretation (BSF 1999).

When comparing digital forest data, the problem of emerging sliver polygon arises (Edwards 1994). The traditional visual comparison of transparency prints allowed a slight disagreement between similar boundaries. Within the GIS, we need accuracy criterias to discriminate between fuzzy area oscillations and real forest expansion. The idea of boundary fuzziness has been developed by several authors (Goodchild 1989, Openshaw 1989) for characterizing digitizing errors. The older epsilon-band method assumes a single global bandwidth, whereas other authors suggest variable bandwith methods (Edwards 1994).

A buffered line accuracy for each dataset is necessary to properly model the unsharpness of the data. Comparing polygon accuracy will be an important aspect in our total area approach (Caspary 1992, Dutton 1992, Power

2001), because inhomogeneous spatial and time resolutions have to be normalized. The point-in-polygon problem has been addressed by several algorithms. One of the newer approaches uses a probabilistic model with two different phases during comparison. In the first phase, it is decided if the point is inside, outside or on the boundary; in the second phase, it is determined in which uncertainty range the point falls (Alesheikh 1996). This boundary model is assumed to be appropriate for all point and vector data which are used in the project.

Modeling approaches

The prepared datasets of forest-cover data (dependent variable) and of bio-physical and socio-economic explanatory variables are analysed:

- by testing and empirically estimating our hypotheses on land abandonment and forest expansion (chapter 2.3.2.).
- by recognizing and quantifying relevant patterns and cause-effect relationships of land abandonment and forest expansion using different multivariate modeling approaches.

In our modeling approach we rely on the theory of complex phenomena (Hayek 1961/1972, *cf* Baur 1999). The starting point of Hayek's reflections is the realistion of the omnipresence of incomplete information. With increasing complexity of a phenomenon, also uncertainty grows. From this correlation results the postulate to explicitly consider uncertainty in building theories and in empirical research. Scientific theories have to be adapted to the phenomenon investigated. According to Hayek, social pheonomena are always complex and thus, general patterns are all we can expect to find. Acknowledging the complexity of land abandonment and forest expansion, where bio-physical and socio-economic factors are involved, means that in our project we are primarily interested to recognize patterns of land abandonment and forest expansion.

To test our hypotheses we select a sample set of inventory points where forest expansion has occurred between two inventories and compare them with an appropriate control sample (no forest in both inventories). The approach to test our hypothesis depends on the operationalisation of the theoretical framework. However, as the dependent variable (forest expansion – no forest expansion) is binary in most cases, we will mainly use multivariate logistic models (*cf* Franklin 1995). To test the effect of single explanatory variables we will use univariate logistic models for continuous explanatory variables and chi-square contingency tables for binary or categorical explanatory variables. Depending on the hypothesis, we will for some analysis stratify the study area before (*eg* different geographical regions (Elsasser 1994), different elevation strata).

Beside these modeling procedures to test our specific hypotheses, we will explore the data with further multivariate statistical analyses to find relevant patterns and cause-effect relationships between variables which might not have been fully considered in the hypotheses. To this end we enlarge the set of explanatory variables and perform univariate statistical analysis with all available explanatory variables. The explanatory variables with a significant effect on forest expansion in the univariate tests will then be considered for multivariate analysis. Beside logistic models we will also use classification and regression trees (CART), an exploratory, machine-learning approach to identify patterns of forest expansion. The advantage of classification trees is that, in contrast to logistic models, they can determine relationships between forest expansion and explanatory variables, where the relationships is dependent on other explanatory variables (Franklin 1995).

The datasets of the inventory data (SNFI and AS) provide spatially separated sampling points and are relatively easy to handle, because the underlying statistical assumptions fit to the proposed modeling techniques. By contrast, the data acquired from forest cover maps and overlayed with explanatory polygon- or raster data (*eg* topographic maps) require rather different techniques. We will consider different approaches for data analysis with vectorized forest cover data:

- Changes in forest cover are analyzed for each time step on the aggregation level, the socio-economic explanatory variable is available (*eg* municipality). We then summarise forest expansion (or decrease) for each aggregated unit, using regression models to analyse the effect of different explanatory variables (*cf* Brown *et al* 1996).

– We plot forest cover expansion *vs* different explanatory variables and use overlay techniques (*eg* Brito *et al* 1999) and Cole' s coefficient (*eg* Rebertus *et al* 1997) to quantify the level of association.

– Forest cover polygons of each time step will be converted into a raster based format and overlayed with explanatory bio-physical and socio-economic raster data (*eg* DHM25). We will then choose an appropriate sample of non adjacent raster cells (to reduce the effect of spatial autocorrelation) and perform the statistical analysis on the level of these sample cells (*cf* Pereira et Itami 1991, Brito *et al* 1999).

The modeling procedures described in this section will be validated with the help of a sample set, which has not been previously used for the model development.

2.3.3.2 Repeated aerial photograph-approach in selected areas (RAPAS)

Study areas and database

In coordination with other NFP 48 projects and with other ongoing partner projects, we select two or three well documented areas for the repeated aerial photograph-approach. The main condition for these potential study areas will be the availability of high quality aerial photographs and/or additional terrestrial photographs.

Potential study areas for RAPAS are:

- The landscape Davos, where high quality aerial photographs time series exists since 1930 (time serie includes at least 1930, 1956, 1960, 1981, 1989, 1997) and have already been analysed and/or georectified for different research projects (Haefner 1963, Günther 1985, Bebi 2001). Beside these aerial photographs, for the Landscape Davos exists a large amount of terrestrial photos originating from about 1870 to 1930, which served already for long time series of forest change (Bebi 2000). Case study area in the Landschaft Davos would also provide synergies with available data on land-use history (MAB6-project Günther, 1985) and with other NRP 48-projects (*eg* the project "Vulnerability of the Alpine Habitat and Landscape"; project leader Peter Bebi).
- Areas where in previous studies in the 1970s and 1980s land abandonment and its underlying causes have already been mapped and discussed. Examples of such areas are the lower Engadin, the Schanfigg, the area around Trun (Vorderrheintal), the Centovally, Chandolin, Ayent and the Val d'Hérens, which have all been investigated by Surber *et al* (1979) and Walther and Julen (1986). First of all, the latter study which investigated forest expansion between 1950 and 1980 would provide a favorable basis for longer time series with more comprehensive analysis techniques.
- The Malcantone (Ticino) where repeated aerial photograph exist and have already been used to study forest succession in combination with dendroecological methods (Lischer 1998).
- Study areas, which will be investigated during our partner WSL-projects "Forest structures in Swiss forests since 1880" and "The pine-forests in the canton Wallis – a landscape element changes". Both projects have just started and only a pilot study area in the canton Wallis has yet been determined.

Data survey and analysis

Changes in forest cover will be surveyed with interpretation of repeated aerial photographs and with additional old terrestrial photographs. Photointerpetation and georectification of aerial photographs since 1930 will be made similar to the approach of Bebi (2000), except that the focus will be less on the differentiation of different structure types, but more on a comprehensible assessement of forest – non-forest categories (*cf* Mast *et al* 1997). Dependent on the quality of the aerial photographs and the differences in different time steps, we will also consider automated methods to increase the objectivity of the forest – non-forest determination (*cf* Bebi *et al* 2001, Mast *et al* 1997). We aim at surveying the aerial photographs for three different time steps (old survey before 1940, intermediate survey in the 1960s and a modern survey after 1995). While a verification of the modern aerial photographs will be made by field surveys, a verification of earlier time steps is more difficult but will be made with the help of old terrestrial photographs (*cf* Bebi 2000) and (in some specific reference plots) with dendroecological field methods (*eg* Veblen *et al* 1994, Lischer 1998).

Old terrestrial photographs since 1880 will also be used to expand the time series of aerial photographs beyond the 1930s. Here, we will closely co-operate with Christian Ginzler (remote sensing, WSL; see letter of intent), who is currently developing methods for a spatially accurate interpretation of terrestrial photos. Methods to geo-rectify terrestrial photos have already been developed for modern time series and successfully applied in landscape development studies (*eg* Aschenwald *et al* 2001), and adaptations of such methods for historical photographs are currently in progress within the above mentioned WSL projects.

We will eventually verify and complement the interpretation of terrestrial photos with dendroecological techniques: In selected reference plots, where forest expansion has occurred and where the database requires a closer analysis of tree growth pattern, we extract increment core samples at a coring height of less then 20 cm and reconstruct age structure and growth pattern of the invaded trees using standard dendroecological techniques (*cf* Stokes and Smiley 1968, Veblen *et al* 1994, Schweingruber 1996).

To derive the bio-physical and socio-economic explanatory variables we take advantage of the same sources as in the total area approach. But here, we also use spatially more detailed variables on the level of individual farms. Where necessary, we complement these data with local surveys. In preparing and conducting the survey, we will work together with social scientists (see letter of intent by Dr. Marcel Hunziker/WSL). Further, following the approach of Wear and Bolstad (1998) we will also create appropriate distance dependent variables (for instance distance to closest road, distance to correspondent farm buildings, distance to closest village center) and add them to the data base. In contrast to the study of Wear and Bolstad (1998), most of these data have not to be digitized from aerial photo interpretation because they are already available in a digitized format (BSF 1993).

The approach of data analysis and modeling will be comparable to the total area approach for vectorised data. The data layers used in this approach will be implemented in a raster based GIS and an appropriate sample of raster-cells will be used to develop statistical analysis and models (*cf* Chapter 2.3.3.1). The RAPAS-approach will thus enable us to analyse and discuss models of forest expansions on a more detailed spatial and temporal scale. For instance, models and validated hypothesis to explain forest expansion from TAA will be tested and discussed in the case study areas of the RAPAS under consideration of a larger variety of possible explanatory variables. The combination of statistical analysis with a detailed reconstruction of socio-economic boundary conditions (*eg* derived from local surveys) and ecological data (derived from long term photo series and tree ring analysis) will enable us to explain land abandonment and forest expanision and its underlying causes in a more holistic way.

The RAPAS-approach will also allow us to address additional questions of political relevance.

- In contrast to the TAA, RAPAS enables us to investigate not only forest expansion but also land abandonment.
- Consequently, the impacts of the direct income payments, introduced in 1979, on abandonment of land can be analysed.
- Further, an assessment of the first effects of the new Swiss agricultural policy, that started in 1993, becomes feasible.[4] Through this policy reform the value of marginal land has been significantly increased, and we expect an impact on land abandonment (recultivation of abandoned land, prevention of land abandonment).

[4] The primary focus of the reforms has been to partially decouple price and income policies. To this end, general direct income payments were introduced which are designed as factor subsidies for land or animals and are subject to farmer's compliance with environmental regulations.

2.3.4 Structure of the project: Workpackages and tasks

The project is structured in 5 workpackages (WP) and 12 tasks:

Workpackage 1: Theoretical framework, hypotheses and conception for operationalization

- Task 1: theoretical framework and hypotheses to explain land abandonment and elaboration of a conception for operationalization of the model (selection of variables)
- Task 2: theoretical framework and hypotheses to explain vegetation dynamics on abandoned land and elaboration of a conception for operationalization of the model (selection of variables)

Workpackage 2: Total area approach (TAA)

- Task 3: preparation of forest expansion data (dependent variable)
- Task 4: preparation of database of explanatory data (secondary data)
- Task 5: quantitative analysis

Workpackage 3: Repeated aerial photograph approach in selected areas (RAPAS)

- Task 6: preparation of land abandonment and of forest expansion data (dependent variable)
- Task 7: preparation of database of explanatory data (secondary and primary data/survey)
- Task 8: quantitative analysis

Workpackage 4: Implementation

- Task 9: journalistic accompaniment of the research project
- Task 10: publishing activities

Workpackage 5: Synthesis

- Task 11: discussion and interpretation of the results
- Task 12: political conclusions

2.4 Timetable for the main project [40]

Table 1 gives a provisional timeframe for the project organization, and table 2 an overview of the responsibilities and the asssignment of labour force.

Table 1 Timeframe and project organization

Workpackages (WP), tasks (T)	Year 1				Year 2				Year 3			
and products (P)	I	II	III	IV	I	II	III	IV	I	II	III	IV
WP1: Theoretical framework *etc*												
– T1: explaining land abandonment	■	■	■									
– T2: explaining forest expansion	■	■	■									
→ P1: Hypotheses, concept for operational.			■	■								
WP2: Total area approach (TAA)												
– T3: forest expansion data		■	■	■	■	■						
– T4: explanatory variables			■	■	■	■						
– T5: quantitative analysis					■	■	■	■	■			
→ P2: Final database								■	■			
→ P3: relevant patterns/cause-effect rel.								■	■	■		
WP3: Selected area approach (RAPAS)												
– T6: forest expansion data		■	■	■	■	■						
– T7: explanatory variables/survey			■	■	■	■						
– T8: quantitative analysis					■	■	■	■	■			
→ P4: Selection of areas	■											
→ P5: Final database								■	■			
→ P6: relevant patterns/cause-effect rel.								■	■	■		
WP4: Implementation												
– T9: journalistic accompaniment			■	■	■	■	■	■	■	■	■	■
– T10: publishing activities					■	■	■	■	■	■	■	■
→ P7: brochure for inst.bodies,stakeholders												■
→ P8: scientific publications					■	■	■	■	■	■	■	■
WP5: Synthesis												
– T11: discussion and interpretation									■	■	■	
– T12: political conclusions									■	■	■	
→ P9: provisional results (for workshop)						■	■					
→ P10: workshop with network platform							■					
→ P11: final report											■	■

Table 2 Responsibilities and assignment of labour force

Applicant / PhD student	WP1: Hypotheses			WP2: TAA			WP3: RAPAS		WP4: Implement.		WP5: Synthesis	
	T1	T2	T3	T4	T5	T6	T7	T8	T9	T10	T11	T12
Dr. P. Baur (20%)	R			R	A		R	A	R	R	R	R
Dr. P. Bebi (20%)		R				R	R	R		R	A	A
Dr. R. Boesch (20%)			R	R	R					R	A	A
Dipl. Ing.ETH C. Schreiber (500h)							A		CA			
PhD student (NN) (100%)	CA		CA	CA	CA		CA		A	CA	CA	CA

PhD student (NN) (100%)		CA			CA	CA	CA	A	CA	CA	CA

R Responsible A Assistance CA Conducting analysis

3. Implementation plan

3.1 Previous attainments in the field of the transfer of knowledge and technology [41]

Priska Baur, main applicant

Priska Baur has acquired experiences in research on mandate, such as a study on economy and ecology of agriculture in the canton Zurich (Baur *et al* 1995) or a study about the longterm development of agriculture in Sudtirol (Baur *et al* 1999). The Zurich-study was used as basis for the cantonal strategy in agricultural policy ("Leitbild Zürcher Landwirtschaft"). The Sudtirol-study was presented in January 2000 at a press conference and incited vivid discussions among the stakeholders.

Further, she has been a member of advisory groups, such as the "Committee on Economics" of the Swiss Association for Environment (1994-1997) or the committee "Modeling participation in governmental programmes to promote biodiversity in agriculture" (1999-2001) which resulted in products (a publication on trade and ecology, Minsch and Baur *et al* 1995; a model to simulate different political strategies to promote biodiversity, http://www.ag.ch/natur2001).

She published the results of her research on structural change and on ecological-economic analyses of Swiss agricultural policy in agricultural journals in Switzerland (Baur 1995, Baur 1998, Baur 1999, Baur 2000a, Baur 2000b) and presented them in national and international (Baur 2000c, Baur 2000d, Baur 2001) colloques and conferences.

On initiative of her PhD advisor Prof. Dr. Peter Rieder, she sent her thesis to a broad public, such as the Federal Office of Agriculture (FOA), the Swiss Association of Farmers, and other NGOs and stakeholders in agriculture. As a result, in 2000, she was invited by the director of the FOA to present her results about the structural effects of Swiss agricultural policy.

Finally, Priska Baur discussed her research with her students (1992-1998, lectures on environmental economics, Department of Food and Agricultural Sciences, ETH Zurich), and between 1989 and 1998, she accompanied and initiated numerous seminar, semester and diploma works.

Peter Bebi, co-applicant

Peter Bebi grew up on a mountain farm in the Swiss Alps on an altitude of 1700 m. a. s. l. The practical dealing with questions of land abandonment and its consequences is thus a part of his life since his youth. In his professional life, Peter Bebi has written several articles in management- and implementation orientated regional, national and international journals (*eg* Bebi, 2000, Bebi 2001, Bebi *et al* 2001, Frey and Bebi 2000, Mayer and Bebi 1999). He was also actively involved in implementation projects of the SLF Davos (*eg* Amman *et al* 2000) as well as in the preparation and realisation of conferences (Bebi and Stöckli 2000, Bebi and Brang 2000) and of field courses in alpine ecology.

Ruedi Boesch, co-applicant

Ruedi Boesch has contributed several articles in the fields of bioacoustics, image processing and feature extraction (Boesch 1996, Boesch 1998, Obrist and Boesch *et al* 1998), which also have been implemented successfully as software packages: 1. Batit, a software package for recording, filtering and pattern matching of ultrasonic signals (Bioacoustic Taxon Identification Tool, http://www.wsl.ch/land/biodiversity/PRODUCTS/batit/acoustbatid.html). 2. Stapler, an image extraction tool for ArcINFO image catalogs (http://www.wsl.ch/relics/ rauminf/data/ GIS/raster/pixelkarten/stapler.html).

3.2 Planned activities [42]

Addressing institutional bodies and stakeholders at the local and the national level

We want to contribute to an improved decision basis for judging the necessity of political intervention to maintain open landscapes, for the appropriate institutional setting and for designing target oriented measures. Consequently, the adressates of our research are institutional bodies on all three political levels, the Federation, the cantons and the municipalities. Important addressates on the Federal level are the Federal Office of Environment, Forest and landscape and the Federal Office of agriculture. Further interested stakeholders are NGOs in the fields of nature- and landscape, agriculture, *etc*.

In particular we plan three activities (see offer of Dipl. Ing. ETH C. Schreiber in Appendix 5):

- In the case study regions, where we conduct the repeated aerial photograph-analysis, we intend to inform regularly about the progress of the project in local print medias.
- Additionally, the final result will be worked up in selected print medias with national dissemination. The preparation contains further local investigations from a journalistic perspective (interviews with landowners, tourism responsibles, farmers, foresters, administrators, *etc*).
- As final product a brochure will be prepared, which contains the most important results relevant for action, and which is written explicitly for a non-scientific public.

Transdisciplinary moduls

There are two transdisciplinary moduls in the project:

- The survey of socio-economic data for the repeated aerial photograph-approach requires local knowledge and therefore a close cooperation with local stakeholders. Local stakeholders shall be informed in advance, who is going to conduct a research project in their municipality/region and with which intentions. Hence, motivated individuals get the chance to participate in the project by bringing in their knowledge and opinion.
- We are going to organize a workshop with the NRP 48 network platform and other stakeholders from different institutional levels and NGOs to discuss the provisional results of the project, in particular the economic interpretation and political conclusions. The results of this workshop will influence the second round of model estimations and simulations and will be included in the final report.

Making results available on the Web

We plan to publish the results of the project in a Web-based extension similar to other packages, which have been implemented at the Swiss Federal Research Institute WSL (http:// www.wsl.ch/products/welcome-en.ehtml).

Scientific publications

We intend to publish in national and international, disciplinary and interdisciplinary journals (in english as well as german), such as:

- German journals: Agrarwirtschaft, GAIA, Zeitschrift für Umweltpolitik, *etc*
- English: Ecosystems, Mountain Research and Development, European Review of Agricultural Economics, Land Economics, Journal of Environmental Economics and Management, International Journal of Geographic Informations Systems, Photogrammetric Engineering and Remote Sensing, *etc*

International policy level

The results may also be of international relevance (*eg* Convention of the Alps, Rio 1992 / Index 13 on Sustainable Development of Mountain Areas) and will be presented at international conferences.

In the implementation activities the project will be supported by the WSL extension service (Dr. W. Spillmann, Dr. M. Roux).

3.3 Timetable [43]

The implementation activities will be continued after finishing the project. Table 3 gives a provisional timetable.

Table 3 Timetable for the implementation activities during the projects and after the official end of the project (year 4)

	Year 1				Year 2				Year 3				Year 4			
	I	II	III	IV	I	II	III	IV	I	II	III	IV	I	II	III	IV
Addressing institutional bodies and stakeholders at the local and national level																
– Information about the research progress																
– Journalistic working up of final results																
– Brochure for stakeholder																
Transdisciplinary moduls																
– Information of local stakeholders, survey																
– Workshop with NRP 48 network platform																
Making results available on the Web																
– publishing project results (maps, data, *etc*)																
Contributions to the scientific community																
– publications in div. journals																
– presentations at international conferences																

4. Significance of the planned work

4.1 Scientific significance [44]

In a highly interdisciplinary project we link the disciplines agricultural economics, vegetation dynamics, and spatial modeling to explain and model land abandonment and forest expansion. The scientific significance concerns empirical findings, methodical experiences and potential use for future applications:

- The combined use of newly available large data sources and recent developed analyse techniques will provide new insights into the relevant driving forces of forest expansion and will improve our knowledge about structural change of agriculture in the Swiss Alps. The extended time series of forest expansion for the last 50 years will supply a valuable complement to the two existing national forest inventories.
- While former studies on land use history and forest expansion are mainly based on single case studies in geographically limited areas, the large datasets on forest expansion will provide insights in vegetation dynamic patterns across multiple gradients of bio-physical site factors and land use history.
- Prognoses of land abandonment and forest expansion which have already been developed in the 1970s (Moos and Herot 1973, Surber *et al* 1973, 1978) can be empirically tested for the first time.
- Our modeling approaches, which combine socio-economic and bio-physical data on different spatial and temporal scales, will contribute to the field of applied spatial statistical modeling, and in particular to data integration issues which are of growing importance in many fields of interdisciplinary ecosystem research.
- Our models, derived and estimated in this study with extensive data sets of the last decades build a basis for spatial forecasting models of forest expansion and to simulate spatially explicit scenarios of future land-use

(*cf* Wear and Bolstad 1998). The project may thus provide contributions to other NFP 48 projects, where future landscape scenarios are developed. The quantitative models on forest expansion could be directly implemented for instance in the modeling framework of the NRP 48 project "Vulnerability of Alpine Landscape and Habitat: Simulation of future landscapes and development of support tools for regional decision making" (project Bebi), and would also provide a solid empirical base for NRP 48 projects where scenarios of future landscapes are visualized (*eg* Project Schmid) or used for further analysis (*eg* project Hunziker).

4.2 Social and economic significance [45]

The project will give further evidence if forest expansion because of land abandonment is relevant in Switzerland. Further, the project will enable us to localise sites in the Swiss Alps where land abandonment and forest expansion could be a problem. In addition, it enhances the understanding of the underlying cause-effect relationships between forest expansion and its bio-physical and socio-economic causes. By making these drivers transparent, the project contri-butes to an improved decision basis for a rational policy. Assessing the relevance of structural change in agriculture allows to evaluate effectiveness and efficiency of agricultural policy with respect to maintain open landscapes in the Alps. In addition, the project gives first empirical indications about the impact of the new agricultural policy in Switzerland (since 1993) on the cultivation of marginal lands.

The expected findings 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, where it might be indicated (natural hazards, biodiversity, tourism, *etc*), is to be found at the local level. This would suggest a shift of competences, finances and responsibilities from the Federal level to the cantons and municipalities. Such consequences for the institutional setting in direction of a partial regionalisation of agricultural policy show many similarities with the problem of designing effective and efficient measures to promote biodiversity in agricultural landscapes (Baur 1998). The latter might serve as a model for policy design to prevent land abandonment.

5. References

Ackermann, G. 2000. The influence of red deer (Cervus elaphus L.) upon a subalpine grassland ecosystem in the Swiss National Park. Diss ETH 13479. Zürich.

Alesheikh, A., R. Li. 1996. Rigorous Uncertainty Models of Line and Polygon Objects in GIS, GIS/LIS `96 Annual Conference and Exposition, Denver, Co., pp. 906-920.

Ammann, W. P. Bebi, M. Bründel, S. Margreth, T. Wiesinger, and C. Wilhelm et a.. 2000. Der Lawinenwinter 1999. Eidg. Institut für Schnee und Lawinenforschung (SLF). Davos. 588 pp.

Anwander, S., St. Buergi, G. Cavegn, L. Meyer, P. Rieder, J. Salmini. 1990. Direktzahlungen an die Berg-landwirtschaft: eine Gesetzesevaluation. ETH Zürich: Verlag der Fachvereine. 195pp.

Arlinghaus. S. Practical handbook of spatial statistic. CRC Press Boca Raton. 307 pp.

Bätzing, W. (Schriftleitung). 1996. Landwirtschaft im Alpenraum – unverzichtbar aber zukunftslos? Eine alpenweite Bilanz der aktuellen Probleme und möglichen Lösungen. Hrsg. Europäische Akademie Bozen, Fachbereich "Alpine Umwelt". Berlin/Wien: Blackwell. 242 pp.

Bätzing, W., P. Messerli, M. Perlik. 1995. Regionale Entwicklungstypen, Analyse und Gliederung des schweizerischen Berggebietes. Zentralstelle für regionale Wirtschaftsförderung, BIGA Bern. 98 pp.

Baur, P. 1992. Einführung in die Umweltökonomie. Vorlesungsunterlage. Institut für Agrarwirtschaft, ETH Zürich. 101 pp.

Baur, P. 1995. Ökologische Direktzahlungen - Ein Diskussionsbeitrag. Agrarwirtschaft und Agrarsoziologie 2: 88-115.

Baur, P. 1996. Veränderungen in der Zürcher Landwirtschaft zwischen 1990 und 1995. Schriftenreihe des Instituts für Agrarwirtschaft, ETH Zürich 4. 127 pp.

Baur, P. 1996. Wohlfahrtstheoretische Grundlagen der Umwelt- und Ressourcenökonomie. Vorlesungs-unterlage. Institut für Agrarwirtschaft, ETH Zürich. 20 pp.

Baur, P. 1997. Ökonomische Ursachen der Umweltbelastung durch die Landwirtschaft und Massnahmen zur Lenkung der Umwelt- und Ressourcennutzung. Vorlesungsunterlage. Institut für Agrarwirtschaft, ETH Zürich. 41 pp.

Baur, P. 1998. Ökologischer Ausgleich durch Direktzahlungen: Denkanstösse für eine zielgerechte Weiterentwicklung. Schriftenreihe Institut für Agrarwirtschaft ETH Zürich 5. 45 pp.

Baur, P. 1999. Agrarstrukturwandel in der Schweiz – Eine theoretische und empirische agrarökonomische Analyse anhand von aggregierten Daten für die Schweizer Landwirtschaft 1939-1990 und von einzelbetrieblichen Daten für die Zürcher Landwirtschaft 1990-1996. Dissertation 13240 , ETH Zürich. 331 pp.

Baur, P. 1999b. Öko-Ausgleich – vom Zufallsprodukt zur ökologischen Leistung, AgrarForschung 6 (1): 5-8.

Baur, P. 1999c. Strukturwirkungen von Direktzahlungen. Unveröff. Diskussionspapier. Institut für Agrarwirtschaft, ETH Zürich.

Baur, P. 2000a. Strukturwirkungen der neuen Agrarpolitik - erste Thesen. AgrarForschung 7 (5): 230-235.

Baur, P. 2000b. Agrarstrukturwandel - das Ergebnis von Druck oder Sog? AgrarForschung 7 (2): 76-81.

Baur, P. 2000c. The magic growth barrier for Swiss farms. Rev. paper presented at the XXIV International Conference of Agricultural Economists, August 13-18 2000, Berlin. 8 pp.

Baur, P. 2000d. Participation in governmental programs for organic agriculture in Switzerland, presentation at the 13th International IFOAM Scientific Conference, August 28-31, 2000, Basel. (IFOAM: The International Federation of Organic Agriculture Movements).

Baur, P. 2001 (submitted). Preconditions and driving factors in (non)developing financial instruments in Swiss forest policy – A tentative politico-economic analysis. Proceedings Financial Instruments of Forest Policy, 17-20 June 2001, Rovaniemi, Finland. 15pp.

Baur, P., L. Meyer, P. Rieder. 1994. Politökonomische Analyse der Getreidepolitik. Nationales Forschungs-programm 27, Wirksamkeit staatlicher Massnahmen. Reihe Schlussberichte. Bern. 69 pp.

Baur, P., M.-G. Pezzatti, P. Rieder, I. Schluep. 1999. Langfristige Entwicklung der Agrarstrukturen in Südtirol. Hrsg. Europäische Akademie Bozen, Fachbereich "Alpine Umwelt". Fachbericht 15. 363 pp.

Baur, P., P. Rieder. 1997. Quantitative Bewertung der Summe der positiven und negativen externen Effekte ökonomischer, ökologischer und sozialer Art der Schweizer Landwirtschaft. Vorlestungsunterlage auf der Basis eine Projektskizze mit ausführlichem Theorieteil. Institut für Agrarwirtschaft, ETH Zürich. 24 pp.

Baur, P., S. Anwander, P. Rieder. 1995. Ökonomie und Ökologie in der Zürcher Landwirtschaft, Institut für Agrarwirtschaft, ETH Zürich, vdf Hochschulverlag AG. 243 pp.

Bebi, P. 1999. Erfassung von Strukturen im Gebirgswald als Beurteilungsgrundlage ausgewählter Waldwirkungen. Dissertation ETHZ. Nr. 13 192.

Bebi, P. 2000. Waldveränderung im 20. Jh. Davoser Revue 75 (1): 51-57.

Kommentar:

Kommentar:

Bebi, P. and A. Mayer, 1999. Alpwirtschaft im Dischmatal – gestern und heute. Davoser Revue 74 (3) 34-43.

Bebi, P. and P. Brang. 1999. Excursion guide for the post-workshop excursions. International Workshop 'Structures of Mountain Forests', September 6-10, 1999, Davos, Switzerland, Birmensdorf, Swiss Federal Institute for Forest, Snow and Landscape Research, 10 pp.

Bebi, P. and V. Stöckli. 1999. Excursion guide for the mid-workshop excursion. International Workshop 'Structures of Mountain Forests', September 6-10, 1999, Davos, Switzerland, Birmensdorf, Swiss Federal Institute for Forest, Snow and Landscape Research, 12 pp.

Bebi, P. D. Kulakowski, and T.T. Veblen. (in review) Disturbance interactions in a Rocky Mountain Subalpine forest landscape. Submitted to *Ecology*

Bebi, P. D. Kulakowski, and T.T. Veblen. 2001b. Disturbance interactions in a Rocky Mountain Subalpine forest landscape. Tree Ring and People. Conference Proceedings. 22-26.9.2001. Davos.

Bebi, P. F. Kienast and W. Schönenberger. 2001a. Assessing structures in mountain forests as a basis for investigating the forests' dynamics and protective function. Forest Ecology and Management 145: 3-14.

Bernegger, U., G. Cavegn, L. Meyer, P. Rieder. 1990. Existenzfähige Bergbauernbetriebe in nicht-touristischen Bergdörfern. Bericht 34 des NFP 22 "Nutzung des Bodens in der Schweiz". 110 pp.

Boesch R. 1996. Detection and extraction of complex map symbols, Proceedings XVIIIth. ISPRS Congress, Vienna, Vol 31(B3), pp. 65-69.

Boesch R. 1998. Framework for feature extraction of natural objects, International Geoscience and Remote Sensing Symposium, Vol 4, pp. 2062-4.

Bohnet, D. 1995. Integration of Socio-economic data into GIS – a case study of the CRDA Bizerte GTZ, Bonn, F.R. Germany. Paper presented at UNITAR / CNTGI / OSS /UNSO. Published in AfricaGIS'95 Travaux/Documents. Abidjan, 6-10 March 1995.

Brandes, W., G. Recke, T. Berger. 1997. Produktions- und Umweltökonomik, Stuttgart: Eugen Ulmer. 534 pp.

Brändli, U.-B. 2000. Waldzunahme in der Schweiz – gestern und morgen. Informationsblatt Forschungsbereich Landschaft. Eidg. Forschungsanstalt WSL. 45: 1-4.

Brassel, P., U.-B. Brändli (Red.) 1999. Schweizerisches Landesforstinventar. Ergebnisse der Zweitaufnahme 1993-1995. Birmensdorf, Eidg. Forschungsanstalt WSL. Bern, Bundesamt für Umwelt, Wald und Landschaft. Bern/Stuttgart/Wien: Haupt. 442 pp.

Braun-Blanquet, J., S. Brunies, E. Campell, E. Frey, H. Jenny, C. Meylan, and H. Pallmann. 1931. Vegetationsentwicklung im Schweizerischen Nationalpark. Ergebnisse der Untersuchung von Dauerflächen. Jahresber. Naturf. Ges. Graubünden 13: 3-82

Brito, J. C., E.G. Crespo, and O.S. Paulo. 1999. Modeling wildlife distribution: Logistic regression vs overlap analysis. Ecography 22: 251-260.

Broggi, M.F., K. Kusstatscher, R. Sutter. 1997. Ökologisch motivierte Direktzahlungen in der Berglandwirtschaft des Alpenbogens. Hrsg. Europäische Akademie Bozen, Fachbereich "Alpine Umwelt". Berlin/Wien: Blackwell. 223 pp.

Brown, D.G. Spatial statistics and GIS applied to internal migration in Rwanda, Central Africa. In: Arlinghaus. S. Practical handbook of spatial statistic. CRC Press Boca Raton. 149-174.

Brugger, E.A. 1984. Folgerungen und Überleitung. In: Brugger, E.A. *et al* Hrsg. Umbruch im Berggebiet: Die Entwicklung des schweizerischen Berggebietes zwischen Eigenständigkeit und Abhängigkeit aus ökonomischer und ökologischer Sicht. Stuttgart: Haupt. 917-921.

Brugger, E.A., F. Furrer, B. Messerli, P. Messerli. Hrsg. 1984. Umbruch im Berggebiet: Die Entwicklung des schweizerischen Berggebietes zwischen Eigenständigkeit und Abhängigkeit aus ökonomischer und ökologischer Sicht. Stuttgart: Haupt. 1097 pp.

Brunner, G. 1977. Möglichkeiten zur Sicherstellung der Flächennutzung in landwirtschaftlichen Problemgebieten. Dissertation 6065 ETH Zürich. 149 pp.

Bundesamt für Statistik (BFS). 1999. Geostat Benützerhandbuch, 428 pp.

Caspary, W., R. Scheuring. 1992. Error-bands as Measures of Geometrical Accuracy, Proceedings of the Third European Conference on GIS (EGIS 92), Munich, Germany, pp. 227-233.

Cernusca, A., U. Tappeiner and N. Bayfield. 1999. Land-use changes in European Mountain Ecosystems. Ecomont – concepts and results. Blackwell. Berlin. 368 pp.

Chrisman, N.R. 1989. Modeling error in overlaid categorical maps, The Accuracy of Spatial Databases, Taylor & Francis, pp. 21-34.

Christensen, R. 1991. Linear models for multivariate, time series, and spatial data, Springer Time Series, New York.

Der Lawinenwinter 1999. Eidg. Institut für Schnee und Lawinenforschung (SLF). Davos. 588 pp.

Devine, HA. Styron JB. 1994. Boundary blur issues in vegetative mapping, Proceedings International Symposium on Spatial Accuracy of Natural Resource Data Bases „Unlocking the Puzzle“, American Soc. Photogrammetry & Remote Sensing, Bethesda, MD, USA, pp. 249-266.

Didier, L. 2001. Invasion patterns of European larch and Swiss stone pine in subalpine pastures in the French Alps. For. Ecol. Manage. 145: 67-77.

Dunwiddle, P.W. 1977. Recent tree invasion of subalpine meadows in the wind river mountains, Wyoming. Arct. Alp. Res. 9: 393-398.

Edwards, G. 1994. Characterising spatial uncertainty and variability in forestry data bases Proceedings International Symposium on Spatial Accuracy of Natural Resource Data Bases „Unlocking the Puzzle“, American Soc. Photogrammetry & Remote Sensing, Bethesda, MD, USA, pp. 88-97.

Ellenberg, H.1996. Vegetation Mitteleuropas mit den Alpen. 5. Auflage. Ulmer. Stuttgart. 1095 pp.

Elsasser, H. 1994. Regionalisierung im Alpenraum, AlpenForum '94, Disentis, 71 pp.

Feld, L.P., G. Kirchgässner. 1998. Fiskalischer Föderalismus. WiSt Heft 2: 65-70.

Fischer, M., H.J. Scholten, and D. Unwin. 1996. Spatial analytical perspectives on GIS. Taylor andFrancis. London. 256 pp.

Flowerdew, R., and M. Green. 1989. Statistical methods for inference between incompatible zonal systems. In: M.F. Goodchild and S. Gopal. Accuracy of spatial databases. London: Taylor and Francis, pp. 239-247.

Franklin, J. 1995. Predictive vegetation mapping: geographic modeling of biospatial patterns in relation to environmental gradients. Progress in Physical Geography. 19: 474-499.

Franklin, J. 1998. Predicting the distribution of shrub species in southern California from climate and terrain-derived variables. Journal of vegetaion science 9: 733-748.

Franklin, J.F. , W.H. Moir, G.W. Douglas, and C. Wiberg. 1971. Invasion of subalpine meadows by trees in the Cascade Range, Washington and Oregon. Arct. Alp. Res. 3: 215-224.

Frey, B.S. 1992. Economics as a science of human behaviour: Towards a new social science paradigm. Kluwer Academic Publishers, Boston/Dordrecht/London. 254 pp.

Frey, W. and P. Bebi. 2000. Der Schutzwald im Lawinenwinter 1999 aus Forschers Sicht. Specht . pp. 2-3.

Gantner, U. 1976. Das Brachlandproblem: Eine eingehende Behandlung desselben in einer Berggemeinde, Aufzeigen von Lösungen technischer und organisatorischer Art innerhalb der Gemeinde. Diplomarbeit. ETH Zürich.

Gardner, B.L. 1992. Changing Economic Perspectives on the Farm Problem. Journal of Economic Literature Vol.XXX: 62-101.

Gessamann, J.A and J.A. Mc Mahon. 1984. Mammals in ecosystem: their effects on the composition and production of vegetation. Acta Zoo Fennica 172: 11-18.

Ghiggi, D. 2000. Waldentwicklung im Val Colla nach der Aufgabe der Landwirtschaft. Diplomarbeit Universität Basel. 101 pp.

Gisi, U. and J.J. Oertli. 1981. Oekologische Entwicklung in Brachland verglichen mit Kulturwiesen,. In: Acta Oecologica Vol 2(16), no. 1-3.

Glenn-Levin, D.C., R.K. Peet and T.T. Veblen (eds.) 1992. Plant succession – theory and prediction, Chapman and Hall, 352 pp.

Goodchild, M.F., L. Anselin, and U. Deichmann. 1993. A framework for the aerial interpolation of socio-economic data. Environment and Planning. A, Vol. 25, pp. 383-397.

Goodchild, M.F., O.Gopal. 1989. Accuracy of Spatial Databases, Taylor and Francis, New York, 290 pp.

Gopal, S., Woodcock C. 1996. Remote sensing of forest change using artificial neural networks, IEEE Trans. on Geoscience and Remote Sensing, Vol 34(2), pp. 398-404.

Grubinger, J. 1975. Technische und wirtschaftliche Aspekte der Nutzung von Böden im Grenzertragsbereich. In: FAT-Schriftenreihe 5. Tänikon.

Guisan, A. Theurillat, J. P, and F. Kienast. 1998. Predicting the potential distribution of plant species in an Alpine environment. Journal of vegetation science 9: 65-74.

Günter, T.F. 1985. Landnutzungsänderungen in einem alpinen Tourismusort. Schlussbericht zum Schweizerischen MaB-Programm. Bern.

Häberli, K. and P. Bebi. 1992. Brachland im Kanton Uri – ein Problem? Semesterarbeit der Abteilung für Umweltnaturwissenschaften am Institut für Agrarwissenschaften ETHZ.

Haefner, H. 1963. Vegetation und Wirtschaft der oberen subalpinen und alpinen Stufe im Luftbild. Dargestellt am Beispiel des Dischmatales und weiteren Teilen der Landschaft Davos, Schweiz. Dissertation Universität Zürich. 87 pp.

Haefner, H., F. Hugentobler. 1985. Assessment and monitoring of abandoned agricultural land in the Swiss Alps: Methods and examples. Remote Sensing Serie Vol. 9. Department of Geography, University of Zurich. 21 pp.

Haefner, H., T. Günter. 1984. Landnutzungswandel und ökologische Veränderungen im Schweizer Berggebiet. In: Brugger, E.A., F. Furrer, B. Messerli, P. Messerli. Hrsg. 1984. Umbruch im Berggebiet: Die Entwicklung des schweizerischen Berggebietes zwischen Eigenständigkeit und Abhängigkeit aus ökonomischer und ökologischer Sicht. Stuttgart: Haupt: 139-164.

Häfliger, H., P. Rieder. 1996. Optimale Regelungsebene: Fallbeispiel Kulturlandschaft. Nationales Forschungsprogram 28, Synthese 27.

Hayek, F.A. 1961/1972. Die Theorie komplexer Phänomene. Walter Eucken Institut. Vorträge und Aufsätze. Tübingen: J.C.B. Mohr.

He, F., P. Legendre, C. Bellehumeur, J.V. LaFrankie. 1994. Diversity pattern and spatial scale: a study of tropical rain forest of Malaysia, Environ. Ecol. Stat., Vol 1, pp. 265-286.

Henrichsmeyer, W., H.P. Witzke. 1991. Agrarpolitik Band 1: Agrarökonomische Grundlagen. UTB Wissenschaft. 463 pp.

Hessl, A. E., Baker, W. L. 1997. Spruce and fir regeneration and climate in the forest-tundra ecotone of Rocky Mountain National Park, Colorado, U.S.A. Arctic and Alpine Research. 29 (2): 173-183.

Hung, T and Y. Yasuoka. 2000. Integration and application of socio-economic and environmental data within GIS for development study in Thailand. Proceedings ARCS. Asian Conference on Remote sensing 2000.

Jakubos, B. and W.H. Romme. 1993. Invasion of subalpine meadow by lodgepole pine in Yellowstone National Park, Wyoming, U.S.A. Arctic and Alpine Research. 25: 382-390.

Julen, St. 1984. Brachland in touristisch entwickelten Gebieten des Kanton Wallis. Diss. Universität Zürich.

Kienzle, U. 1979. Sukzession in brachliegenden Magerwiesen des Jura und des Napfgebietes. Dissertation Universität Basel. 104 pp.

Kienzle, U. 1982. Vegetationswechsel (Sukzession) in brachliegenden Streuwiesen und Magerwiesen des Napfgebietes. Mittg. Naturf. Ges. Luzern, Bd.27:113-166.

Kimmins, J.P. 1997. Forest ecology. A foundation for sustainable management. 2nd ed. Prentice-Hall. London. 595 pp.

Legendre, P. 1993. Spatial autocorrelation: Trouble or new paradigm, Ecology, Vol 74, pp. 1659-1673.

Legendre, P., Legendre L. 1998. Numerical Ecology, Developments in Environmental Modelling, Elsevier, Vol 20, 853 pp.

Lemmens, M.J.P.M. 1999. Uncertainty in Automatically Sampled Digital Elevation Models, Spatial Accuracy Assessment, Land Information Uncertainty in Natural Resources, Ann Arbor Press, pp. 399-407.

Lischer, C. 1998. Dynamik der Wiederbewaldung in nicht mehr bewirtschafteten Kastanienselven im Malcantone / Tessin. Diplomarbeit am botanischen Institut der Universität Basel. 116 pp.

Lowell, K., Jaton A. 1999. Spatial accuracy assessment: land information uncertainty in natural resources, Ann Arbor Press, 455 pp.

Lüdi, 1958. Beobachtungen über die Besiedlung von Gletschervorfeldern in den Schweizeralpen. Flora 146: 386-407.

Mas, J.F. 1999. Monitoring land-cover changes: a comparison of change detection techniques, International Journal of Remote Sensing, Vol 20(1), pp. 139-152.

Mast, J. N., T.T. Veblen, and M.E. Hodgson.1997. Tree invasion within a pine/grassland ecotone: An approach with historic aerial photography and GIS modeling. Forest Ecology and Management. 93: 181-194.

McCook, L.J. 1994. Understanding ecological community succession. Causal models and theories, a review. Vegetatio 110: 115-147.

Messerli, P. 1984. Auf die Landwirtschaft einwirkende und von der Landwirtschaft ausgehende Belastungen: Versuch einer Bilanz. In: Die Berglandwirtschaft im Spannungsfeld zwischen Oekonomie und Oekologie, Kolloquium MAB, 23. November 1984, Bern: 103-123.

Messerli, P. 1986. Modelle und Methoden zur Analyse der Mensch – Umwelt – Beziehungen im alpinen Lebens- und Erholungsraum: Erkenntnisse und Folgerungen aus dem schweizerischen MAB-Programm 1979-1985. Schlussbericht 21 zum schweizerischen MAB-Programm NFP "Sozio-ökonomische Entwicklung und ökologische Belastbarkeit im Berggebiet". Bern. 172 pp.

Messerli, P. 1989. Mensch und Natur im alpinen Lebensraum: Risiken, Chancen, Perspektiven. Stuttgart: Haupt. 366 pp.

Mladenoff, D.J. and Sickley, T.A. 1998. Assessing potential gray restoration in the northeastern United States: A spatial prediction of favorable habitat and potential population levels. Journal of wildlife management. 62: 1-10.

Minsch, J., P. Baur, P. Giannini, L. Rigendinger. 1995. Schritte zur Ökologisierung des Welthandels. Fachausschuss Ökonomie der Schweizerischen Gesellschaft für Umweltschutz (SGU). SGU Schriften, Diskussionsbeitrag Nr. 1. 27 pp.

Moos, F., S. Herot. 1973. Gruppierung der Bergregionen nach der Tendenz der Brachlegung. Karte 1:2000000. 16.1.73. Neue Zürcher Zeitung.

Moos, F., S. Herot. 1979. Möglichkeiten zur Verhinderung oder Beseitigung der Brachlegung von landwirtschaftlichen Grenzertragsstandorten. Hrsg. AGBA AG, Ebikon. 66 pp.

Naegeli-Oertle, R. 1986. Die Berglandwirtschaft und Alpwirtschaft in Grindelwald. Schlussbericht 21 zum schweizerischen MAB-Programm NFP "Sozio-ökonomische Entwicklung und ökkologische Belastbarkeit im Berggebiet". Bern. 278 pp.

Obrist, M.K., R. Boesch, P. Flückiger, U. Dieckmann. 1998. Who's calling ? Acoustic Bat Species Identification Revised, Biosonar Conference, Portugal.

Openshaw, S. 1989. Learning to Live with Errors in Spatial Databases, The Accuracy of Spatial Databases, Taylor & Francis, pp. 263-276.

ORL 1995. Der wirtschaftliche Strukturwandel und die Regionen: Am Beispiel der Schweiz und der angrenzenden Länder, ORL-Bericht 93. Institut für Orts-, Regional- und Landesplanung, ETH Zürich.

ORL 1998. Regional Unemployment Disparities: The Case of the Swiss Cantons, ORL-Bericht 103. Institut für Orts-, Regional- und Landesplanung, ETH Zürich.

Pereira, J.M.C. and R.C. Itami. 1991. GIS-based habitat modeling using logistic multiple regression: a case study of the Mt. Graham Red Squirrel. Photogrammetric engineering & remote sensing. 57: 1475-1486.

Pezzatti, M. 2001. Einfluss der Erschliessung auf die Agrarstrukturen im Alpenraum. Schriftenreihe Nachhaltige Land- und Forstwirtschaft im Alpenraum, Bd.1. Kiel: Vauk KG. 205 pp.

Picot, A., H. Dietl. 1990. Transaktionskostentheorie. Wirtschaftswissenschaftliches Studium 4: 178-183.

Pijanowska, B. 1985. Selected bibliography on forest succession on the northern temperate zone. Rapport nr. 406. Research Institute for Forestry and Landscape Planning, Wageningen. 232 pp.

Pinz, A.J. 1991. A computer vision system for the recognition of trees in aerial photographs, Multisource Data Integration in Remote Sensing, Vol 3099, pp. 111-124.

Ponge, J. F., A.J. Zackrisson,.O.Bernier, N.Nilsson, and M.C.Gallet. 1998. The forest regeneration puzzle. Bioscience 48: 523-530.

Power, C., Simms A., White R. (2001): Hierarchical fuzzy pattern matching for the regional comparison of land use maps, International Journal of Geographic Information Systems, Vol 15(1), pp. 77-100.

Price, M. 1995. Mountain Research in Europe: An Overwiew of MAB Research from the Pyrenees to Siberia. Man and the Biosphere Series Vol. 14. Paris: Parthenon Pub. Group. 230 pp.

Reggiani, A. (ed.). 2000. Spatial Economic Science – New Frontiers in Theory and Methodology. Springer Advances in Spatial Science. 457 pp.

Reynolds, K.M. 1993. Classification of spruce-beetle hazard n Lutz spruce (Picea lutzii) stands on the Kenai Peninsula, Alaska. Can. J. For. Res. 24. 1015- 1021.

Rieder, P. 1984a. Das sozio-ökonomische und agrarpolitische Umfeld der Berglandwirtschaft: Rückblick und Ausblick mit forschungspolitischen Forderungen. In: Die Berglandwirtschaft im Spannungsfeld zwischen Oekonomie und Oekologie, Kolloquium MAB, 23. November 1984, Bern: 87-102.

Rieder, P. 1984b. Werte und Wertschöpfung der Berglandwirtschaft. In: Brugger, E.A. *et al* Hrsg. Umbruch im Berggebiet: Die Entwicklung des schweizerischen Berggebietes zwischen Eigenständigkeit und Abhängigkeit aus ökonomischer und ökologischer Sicht. Stuttgart: Haupt. 631-643.

Rieder, P., S. Anwander Phan-huy. 1994. Grundlagen der Agrarmarktpolitik. 4. vollständig überarbeitete Auflage. ETH Zürich: vdf Hochschulverlag.

Rieder, P., S. Caneve, U. Bernegger. 1990. Der Einfluss agrarwirtschaftlicher Massnahmen auf die Nutzung landwirtschaftlichen Bodens. Bericht 44 des NFP 22 "Nutzung des Bodens in der Schweiz". 128 pp.

Rowbotham, D.N. and D. Dudycha. 1998. GIS modelling of slope stability in Phewa Tal watershed, Nepal. Geomorphology 26: 151 – 170.

Sapiro, G., Tannenbaum A. 1995. Area and length preserving geometric invariant scale-spaces, IEEE Trans. on Pattern Analysis and Machine Intelligence, Vol 17(1), pp. 67-72.

Sauer, Jonathan D. 1988. Plant Migration. The dynamics of geographic patterning in seed plant species. Berkley, CA: University of California Press.

Schauer, A.J., Wade, B.K. and J.B. Sowell. 1998. Persistence of subalpine forest-meadow ecotones in the Gunnison Basin, Colorado. Great-Basin-Naturalist 58: 273-281.

Schöne, B.R. 1999. Rekonstruktion der Wiederbewaldungsdynamik der Alpen mit dendroökologischen Methoden, dargestellt am einem inneralpinen Trockental bei Ramosch im Unterengadin. Abschlussbericht zum DAAD-Projekt. 62 pp.

Schütz, M. B.O. Krüsi and P.J. Edwards. 2000a. Succession research in the Swiss National Park. Nationalpark-Forschung in der Schweiz. 259 pp.

Schütz, M. O. Wildi, G. Ackermann, B.O. Krüsi, and B. Nievergelt. 2000b. Predicting the development of subalpine grassland in the Swiss National Park: how to build a successional model based on data from long-term permanent plots. In: Schütz, M. B.O. Krüsi and P.J. Edwards.Succession research in the Swiss National Park. Nationalpark-Forschung in der Schweiz. 259 pp.

Schütz, M., B.O. Krüsi, G. Ackermann, G. Gräminger. 1998. Zeitreihenanalyse in der Vegetationskunde: Analyse und Interpretation von Einzelflächen am Beispiel von Daten aus dem Schweizerischen Nationalpark. Bot Helv. 108: 105-124.

Schweizerischer Bundesrat. 1979. Botschaft zu einem Bundesgesetz über Bewirtschaftungsbeiträge an die Landwirtschaft. BBl 131 Bd. 11: 1309-1351.

Shi W. 1994. Modeling Positional and Thematic Uncertainties in Integration of Remote Sensing and GIS, Ph.D. Thesis, ITC, The Nederlands, Vol 22, 200 pp.

Stehman S.V. 1999. Alternative measures for Comparing Thematic Map Accuracy, Spatial Accuracy Assessment, Land Information Uncertainty in Natural Resources, Ann Arbor Press, pp. 45-51.

Stüssi, B. 1970. Naturbedingte Entwicklung subalpiner Weiderasen auf Alp La Schera im Schweizerischen Nationalpark während der Reservatsperiode 1939 – 1965. Ergebnisse wiss. Untersuch. Schweiz. Nat. park 61: 1-385.

Surber, E., P. Gresch, F. Pfister. 1978. Die Kartierung von Brachland. Bericht 199 der Eidg. Forschungsanstalt für das forstliche Versuchswesen. Birmensdorf. 32 pp.

Surber, E., R. Amiet, H. Kobert. 1974. Das Brachlandproblem in der Schweiz. 2. Auflage mit erw. Literaturverzeichnis. Bericht 112 der Eidg. Forschungsanstalt für das forstliche Versuchswesen. Birmensdorf. 140 pp.

Tappeiner, U., E. Tasser, and G. Tappeiner. 1998. Modelling vegetation patterns using natural and anthropogenic influence factors: preliminary experience with a GIS based model applied to an Alpine area. Ecological Modelling 113: 225-237.

Tasser, E., S. Prock and J. Mulser. 1999. The impact of land-use on vegetation along the Eastern Alpine transect. In: Cernusca, A., Tappeiner, U and N. Bayfield (eds.): Land use changes in European Mountain Ecosystems. 235-246.

Thierry, B., K.E. Lowell. 1999. New Method of Photointerpretation to Increase the Overall Reliability of Forest Maps, Spatial Accuracy Assessment, Land Information Uncertainty in Natural Resources, Ann Arbor Press, pp. 273-279.

Tobler, W. 1979. Smooth pycnophylactic interpolation for geographical regions. Journal of the American Statistical Association. 74: 519-536.

Tomita, F., Shiray Y., Tsuji S. 1982. Description of textures by a structural analysis, IEEE Trans. on Pattern Analysis and Machine Intelligence, Vol 4(2), pp. 183-191.

Turner, M.G. 1990. Spatial and temporal analysis of landscape pattern. Landscape ecology 4: 21-30.

Varian, H.R. 1996. Intermediate Microeconomics: A Modern Approach. Fourth edition. W New York, London: W. Norton & Company. 650 pp.

Veblen, 1986. Anthropogenic disturbance and recovery pattern in montane forests, Colorado Front Range. Physical Geography. 7: 1-24.

Walther, P. 1984. Die Brachlandentwicklung im Schweizer Alpenraum 1950-1980. Diss. Universität Zürich. 181 pp.

Walther, P. and S. Julen. 1986. Unkontrollierte Waldflächenvermehrung im Schweizer Alpenraum. Ber. Eidgenöss. Forsch.anst. Wald Schnee Landsch. 282. 83 pp.

Wanner, H. 1983. Aspekte sozialen Wandels in peripheren Agrarräumen eines Industrielandes. Kurzbericht einer sozialgeographischen Untersuchung im Berggebiet. Fachbeitrag 17 zur schweizerischen MAB-Information. 60 pp.

Wear, D.N and Bolstad P. 1998. Land-use changes in southern appalachian landscapes: spatial analysis and forecast evaluation, Ecosystems 1: 575-594.

Weih, R.C. Jr. 1994. The effect of slope on area calculations in a geographic information system, Proceedings International Symposium on Spatial Accuracy of Natural Resource Data Bases „Unlocking the Puzzle“, American Soc. Photogrammetry & Remote Sensing, Bethesda, MD, USA, pp. 132-140.

Witzke, H.P. 1993. Mikrotheorie in der Agrarsektoranalyse – neoklassischer Standard, Konflikte mit der Realität und Versöhnungsversuche mit Komplikationen. Volkswirtschaftliche Schriften Heft 431. Berlin: Duncker&Humblot.

Wong, D. 1995. Aggregation effects in geo-referenced data. In Arlinghaus. S. Practical handbook of spatial statistic. CRC Press Boca Raton. pp. 83-105.

Zimmermann, N.E. and F. Kienast. 1999. Predictive mapping of alpine grasslands in Switzerland: species vs. community approach. Journal of vegetation science. 10: 469-482.

Zoller, H., N. Bischof, A. Erhard, and U. Kienzle. 1984. Biocönosen von Grenzertragsflächen und Brachland in den Berggebieten der Schweiz. In: Brugger, A., Furrer, G. Messerli, B and P. Messerli. Umbruch im Berggebiet. pp. 523 – 548.