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## The interdependence between biodiversity and socioeconomic variables on a local level: Evidence for german counties

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# JENA ECONOMIC RESEARCH PAPERS



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by

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# THE INTERDEPENDENCE BETWEEN BIODIVERSITY AND SOCIOECONOMIC VARIABLES ON A LOCAL LEVEL: EVIDENCE FOR GERMAN COUNTIES

Angela Münch<sup>1</sup> & Wolfgang Völkl<sup>2</sup>

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## Abstract:

*This paper explores possible interdependence of biodiversity and several socioeconomic and political factors at the county level. It is aimed at the empirical identification of direct and indirect effects between biodiversity (loss) and their theoretical major impact factors. To date, research shows that in addition to geography, agriculture is one major determinant of biodiversity status. However, the impact of regional socioeconomic structures on biodiversity should not be underestimated. Specifically, in regard to biodiversity loss, the socioeconomic structure counteracts political measures instituted to protect biodiversity and change agricultural practice.*

**Keywords:** biodiversity socioeconomic interdependence Bavaria Thuringia

**JEL:** Q15, Q57, R14

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## **1. Introduction**

Biodiversity research is a dynamic field, of interest to a wide variety of researchers as well as potential stakeholders. To date, application-oriented research either explores the impact on biodiversity of different land-use regimes in field studies, or concentrates on surveys intended to anticipate the demand for biodiversity and ecosystem services within a population, or models the dynamics between ecological and economic systems. This study takes a different perspective and investigates possible interdependencies between biodiversity and socioeconomic/political aspects simultaneously. Moreover, the level of analysis is neither fields nor particular communities; instead, general interdependences are identified at the regional level (administrative counties). The core research questions to be addressed are:

1. What influence do socioeconomic and political variables have on grassland biodiversity in a local framework?
2. Which kind of interdependence links changes in local land use, biodiversity loss in grassland, and socioeconomic/political alterations?

To find answers to these questions, an empirical analysis for the counties of Thuringia and Bavaria, Germany, is conducted that examines direct and indirect relations at the same time so as to identify interactions between biodiversity, land use, socioeconomic factors, and political interference.

The paper is organized as follows. The next section gives the background for the empirical analysis in form of hypotheses. This is followed by a description of the data (Section 3) and method used (Section 4). Results are set out in Section 5; conclusions are drawn in Section 6.

## **2. Theoretical Background/State of Research**

### **2.1. Land Use and Biodiversity**

In recent years, agricultural production has intensified (see, e.g., Concepcion et al. 2008). Moreover, as early as the last century, it was realized that the increasing human population and its economic activities pressure is set on nature, which, in turn, has negative implications for the mere existence of mankind. Therefore, it is not surprising that mankind's land usage leads to reduced biodiversity. However, research conducted to date is still not definitive as to which kind of land use diminishes biodiversity. The following section contains an overview

of current discussion on the question of which potential factors of agricultural land use diminish biodiversity. The ecological theories “single-large-or-several-small” (SLOSS) (see, e.g., Quinn/Harrison 1988) and “island biogeography” (see, e.g., MacArthur/Wilson 1967) have attracted some attention in empirical research on nature conservation. The *optimal size* of nature reserves in regard to agricultural landscapes is also a topic of interest in this field. Boyce (2004) emphasizes the importance of small-scale farming for biodiversity preservation. Additionally, in their specific consideration of machinery efficiency, Rodríguez and Wiegand (2009) argue that larger fields do not necessarily increase production efficiency. They propose, instead, small-scale farming, assuming that it will enhance biodiversity in arable landscapes. However, extant field research provides no clear evidence of positive effects of small-scale farming on species richness (similar to discussion on SLOSS). For example, in the case of spider populations, differences in species abundance are more due to intensity and mode of usage (i.e., ecological vs. conventional farming) than to isolation or size of grassland (see Horvath et al. 2009). Also, ground beetle species seem to react more to habitat characterization (e.g., type of soil, climate) or long-term land management than to field size (Irmeler 2003). As small-scale farming is often also connected with *fragmentation* of the landscape, Tschardt et al. (2002) argue that the higher abundance of butterfly species they found on small grassland fragments is due to surrounding habitat fragments. They strengthen this argument by pointing out that species numbers of parasitoids, but not of herbivores, on legumes increased with area. This so-called matrix effect is also found by Devictor and Jiguet (2007) for bird assemblages and by Dauber et al. (2003) for wild bees and ants, but not for plant richness in grassland. Hence, the impact of surrounding landscape fragmentation seems to depend on the taxonomic group under observation. However, because in this empirical analysis fragmentation cannot be measured, the following hypothesis regarding farm size is tested:

*Hypothesis 1: Small-scale farming yields higher biodiversity.*

Apart from scale or fragmentation of agricultural land use, the *intensity* of land-management practice may be decisive for biodiversity. Brose (2003) stresses the importance of cultivation intensity for the reduction in arthropod communities; Wehn (2009) emphasizes the negative impact of grazing pressure on grassland vegetation. Moreover, it is found that the usage of fertilizer significantly increases the risk of biodiversity loss (Mozumder/Berrens 2007). However, in field studies, exclusion of fertilizer inputs barely changes plant or invertebrate diversity; instead, it is soil treatment (e.g., rotavation or natural regeneration) (Sheridan et al.

2008) or species' tolerance of fertilizer and landscape patterns (Aavik/Liira 2009) that appear to explain alterations in species composition. Considering landscape patterns, for example, side stripes, Smart et al. (2002) find a higher biodiversity in the field than in the field boundaries, in a low-intensity usage scenario. However, with a rising intensity of usage, species richness declined in the fields faster than in the adjacent areas. This resulted in higher species richness in the boundaries than in the fields. Also, compositional similarity between fields and their boundaries declined with increased intensity of use. Smart et al. (2002) therefore claim that grassland field boundaries may function as a refuge for some species, but not for all. In contrast to these findings, Smith, Firbank, and Macdonald (1999) find no connection between species abundance on side stripes and species occurrence in the field. Here, again, results on intensity are driven by the taxonomic group under examination and adjacent landscape characteristics (Jeanneret/Schüpbach/Luka 2003). Regarding agricultural intensity, the following hypothesis is investigated empirically:

*Hypothesis 2: The intensity of farming affects biodiversity negatively.*

The influence of *organic farming* on species abundance is often the focus of field research. Measuring biodiversity by examining, e.g., carabid or centipede populations has so far revealed neither short-term (Döring et al. 2003; Blackburn/Wallace 2001) nor long-term significant difference in species richness or diversity (Irmeler 2003) when organic field management is compared to conventional practice. If disparity in species abundance is found, habitat preferences (e.g., for open fields) (Döring/Kromp 2003), species mobility (Merckx et al. 2009), or landscape context (Diekötter et al. 2010) explain it in most instances. However, complementarity of land-management practice (patchwork of conventional and organic) may enhance species abundance in the case of soil arthropods or plants (Diekötter et al. 2010; Fédoroff et al. 2005). The impact of the mode of farming (conventional vs. ecological) is examined in this paper. It is assumed that organic farming changes species composition. Species abundance is measured with empirical results analyzed in light of the following hypothesis:

*Hypothesis 3: Organic farming practice does not change species abundance.*

Overall, it seems that it is land-use practice that is determinative of the survival of one species over another. That is, some species appear to react positively to a particular land-management measure (e.g., early mowing, applying fertilizer), whereas others may be disturbed by the very same practice, resulting in reduced prevalence. Due to fragmentation of the landscape and

heterogeneity in land management, such effects may be balanced out by providing niches for several species (Benton/Vickery/Wilson 2003). Hence, as Perrings and Walker (1997) state, there is no such thing as an optimal strategy to conserve biodiversity. The outcome is sensitive to the choice of parameter values for, e.g., livestock, grasses, and woody plants. Thus, in their model, ecological and economic usage over time does not converge to a steady state if not at least one parameter is removed neglected from the system. This implies that if humankind is the decision maker in the system, land will be used strictly for economic purposes, with devastating effects on nature (Eichner & Pethig 2006a, 2006b). However, when the concept of risk aversion is introduced, even the most myopic farmer will choose a strategy that reduces income variability and so leads to sustainable farming (Quaas et al. 2007). These arguments are discussed in more detail below.

## **2.2. Socioeconomic Influence, Agriculture, and Biodiversity**

Related to agricultural land use and environmental issues are the socioeconomic characteristics of regions. Indeed, agricultural land use can even be viewed as a subsystem of the ecological and socioeconomic systems (Saifi/Drake 2008) in that agriculture serves as a food supplier as well as providing (and using) ecosystem services for mankind (Dale/Polasky 2007). Hence, a relatively high percentage of variance in land use can be explained by agricultural and socioeconomic factors such as population density and employment structure (Hietel/Waldhardt/Otte 2007). Moreover, agriculture and the socioeconomic system can be seen as co-evolutionary processes. Environmental and agro-ecological problems lead to changes in policy measures, consumer preferences, citizen involvement, and technological development (Saifi/Drake 2008). Saifi and Drake (2008) strengthen this argument by illustrating with the case of Sweden that the lack of social embeddedness of agriculture leads to unsustainable land-management practices. Dwindling interaction and interconnectedness between agriculture and the surrounding ecological and socioeconomic systems in recent years has separated agriculture from the socioeconomic system. When agriculture is moved into the international arena, the production process becomes separated from local ecological and socioeconomic constraints, thus making it possible to pursue, because it is not obvious, an unsustainable path of agricultural development. The neglect of social relationships within common property management is also criticized by Sick (2008) and Bertacchini (2008). Sick (2008) claims that historically-, culturally-, politically-, and economically-shaped social relationships and structures play a fundamental role in the setting of institutions. Although institutions also, in turn, shape these structures, institutions should not be ignored when

evaluating the effectiveness of collaborative resource management. Bertacchini (2008) points out that the efficiency of classical institutional solutions (tax/property rights) in the case of agriculture will not be reached unless the traditional farming process is taken into consideration in their design. As this process—traditional farming—tends to be based on reciprocity and cooperation, it is further argued that conservation activities should seek to get closer to peer organizations.

Using social pressure to achieve cooperation for conservation seems to be another feasible strategy (see Suzuki/Iwasa 2009). Social pressure promotes cooperation when more players in the society are cooperative (conformist tendency) and when the problem at hand is of greater concern to society. Thus, increasing the conformist tendency tends to be the most effective way to minimize differences in cooperation levels (Suzuki/Iwasa 2009). This, however, requires a common socially-desired level of nature conservation or environmentally-friendly behavior, which needs to be created externally and reinforced permanently (see Buenstorf/Cordes 2008). Moreover, as Sethi and Somanathan (1996) demonstrate, social norms may break down if changes in prices or technology occur. Thus, social behavior or moral intentions do not guarantee long-term sustainable resource extraction (for evidence without external change, see also Chaudhuri/Paichayontvijit 2010).

Moreover, economic growth leads to an increased demand for environmental quality (Bimonte 2009). In general, higher incomes are accompanied by higher education and greater awareness of environmental degradation, often leading to a stronger tendency toward “green” consumption behaviors (Bimonte 2002). Duroy (2008), in a cross-country study, empirically finds that income inequality, education, and subjective well-being raise the level of environmental concern. Examining this effect at a local level, Bornstein and Lanz (2008) show for Switzerland that demand for environmental quality is in general driven by income, but that by incorporating structural attributes (such as notions of ideology), the explained variance increased significantly. However, these structural attributes can again be traced back to education. For example, Wheeler (2008) argues that education is the factor that determines attitudes of farmers; she provides evidence that farmers’ decisions about land-management practice (conventional or ecological farming) depend on their attitude, which, in turn, is dependent on their level of education. Deacon and Schläpfer (2009) observe a strong local bias in a referendum vote for river restoration in Bern (Switzerland). They argue that public approval of the restoration would be significantly reduced if the scope of the project was larger (e.g., river restoration across the whole canton). Thus, in addition to income and



education, ideology and local embeddedness seem to drive the demand for environmental quality. Therefore, constructing a conceptual framework that involves environmental issues needs to incorporate, at the least, ecological, economic, and social aspects (see White et al. 2009).

Regarding the geographic area studied in this paper, Bavaria and Thuringia are classified as “developed” in economic terms. Thus, the loss of biodiversity prevalent in early periods of development has already occurred in these areas, and it is income and education that drive local demand for environmental quality. To test the influence of socioeconomic characteristics in our empirical analysis, the following hypothesis is derived (in respect to biodiversity occurrence):

*Hypothesis 4: Education and income level enhances the demand for biodiversity conservation.*

### **2.3. Political Interference, Land Use, and Biodiversity**

As increasing income and education boost the demand for biodiversity conservation, it seems rational for politicians to engage in biodiversity protection programs in order to gain public support. Indeed, Dietz and Adger (2003) argue that the demand for environmental quality leads to an extension of governmental environmental policy. Magnani (2000) asserts that it is actually income distribution patterns that determine the outcome of environmental policy decisions and with this the virtuous path of sustainable growth. Once politicians have garnered public support by championing environmental protection, they next need to come up with a plan for actually doing so. That intervention is necessary to “save nature” appears to be widely accepted “fact” within environmental economics research (see, e.g., Eichner/Pethig 2006c). However, the optimal instrument of salvation is still to be identified. For example, it is argued that general direct payments for nature conservation are more cost effective than promoting specific environmentally-friendly activities (Ferraro/Simpson 2002). In particular, the information asymmetry between politicians/bureaucrats and farmers in contract negotiation (Ferraro 2008) (which is how, e.g., nature conservation is organized in Bavaria) or the costs involved in appropriately designing each single instrument may result in severe loss of efficiency. In contrast, general programs, although less costly and time consuming to effectuate, are also less specific and reliable in outcome (Albrecht 2003). Hence, the answer to which is best—a general program or several specific ones—is not obvious. Considering the general approach, results from modeling research show that spatial differentiation in the

targeting mechanism increases efficiency regarding the allocation of a given budget. This differentiation is to be either aligned according to environmental service potential or to landowners' heterogeneity in participation costs, including opportunity, transaction, and direct costs of protection (Wünscher/Engel/Wunder 2008). Additionally, the given budget should be allocated as evenly as possible across time periods to reduce uncertainty for landowners, thus enhancing the efficiency of subsidies (Drechsler/Wätzold 2001). Specific programs have their own problems to overcome, one of which is the problem of information asymmetry. A suitable incentive scheme may help not only reveal relevant information to the social planner, but also coordinate the participating farmers. Coordination may even permit decentralized decision making and thus reduce the cost for the social planner. Within the framework of an experiment, Parkhurst and Shogren (2007) show that introduction of an agglomeration bonus leads to spatial coordination of private actors. If participants have enough experience with the game structure, coordination is successful, and the objective, a corridor-style reserve, is achieved.

Pascual and Perrings (2007) note that reduced biodiversity in agricultural landscape is due to the incentive structure offered by current markets and other institutions. Thus, institutional failure seems to be a chief factor in hampering biodiversity conservation. For example, in the Schraden/Brandenburg water-management system, an inadequate assignment of property rights yielded misallocation and improper land use (Schleyer 2004). Theories from the field of political economy postulate that money is transferred toward the section with the strongest or most efficient interest group (see Mueller 1976, 2003). In the field of biodiversity conservation, these interest or lobby groups take various forms and can be NGOs (e.g., Birdwatch, Greenpeace), farmers and their associations, or bureaucrats, to name just a few. Thus, although democratic systems in general seem to have lower levels of air pollution, Bernauer and Koubi (2009) find higher air pollution levels in areas where trade unions are more dominant than in areas where the Green Party has a strong influence. Regarding parliamentary configuration, Rawls and Laband (2004) discover for the U.S. House of Representatives that listings under the Endangered Species Act are significantly lower in states with greater representation on the U.S. Fish and Wildlife Service's budgetary oversight subcommittee. Examining stakeholder groups within the Biodiversity Conservation Network, on the other hand, Mahanty and Russel (2002) point out that charismatic individuals and local elite interests dominate biodiversity conservation groups, thus making these groups less than representative of the public at large.

To summarize, although political interference to conserve biodiversity appears justified, there is a lack of knowledge as to the optimal institutional design for doing so and intervention by interest groups may lead to an inefficient allocation of resources (see also Freytag/Muench 2010). However, considering the empirical findings in regard to agricultural impact on biodiversity, an effective conservation strategy would appear to involve a combination of highly intensive agriculture use paired with low-intensity managed areas on the landscape scale (Pascual/Perrings 2007) and/or the creation of a heterogeneous landscape that may counterbalance the loss of farmland biodiversity in intensified agricultural areas (Benton/Vickery/Wilson 2003). It must be kept in mind, however, regardless of which instrument is chosen (e.g., introduction of nature protection area), that a change in land use may increase biodiversity in some respect, but will inevitably lead to biodiversity loss in another (Herrmann/Dabbert/Schwarz-von Raumer 2003). Furthermore, public policy interventions may crowd out voluntary private contributions toward environmental conservation (see Brekke/Kverndokk/Nyborg 2003). Thus, when several policy programs are looked at in the same empirical analysis, it is assumed that the effects of any one scheme may not be distinctive enough to be discovered. The influence of interest groups, though, and their embeddedness in socioeconomic features seem feasible to analyze at the county level. Hence, the hypothesis to be proved considering alterations of the system is:

*Hypothesis 5: Increasing demand for environmental conservation is transferred into extended political activities.*

#### **2.4. Geography, Land Use, and Biodiversity**

There is evidence that (bio-) geography influences economic development (see, e.g., Olsson/Hibbs 2005; Norton et al. 2009) as well as agricultural practice (see, e.g., Deffontaine/Thenail/Baudry 1995; Llausas et al. 2009). In particular, climate and the feedback between rainfall, crop growth, soil type, slope, and land cover determine agricultural production, diversification, and the income structure of the farm (Bithell/Brasington 2009; Valbuena/Verburg/Bregt 2008). Moreover, ecological farming practices tend to occur in spatial clusters, the location of which is determined by geographic features (Parker/Munroe 2007).

In addition to shaping socioeconomic and agricultural characteristics, geography also affects biodiversity. It is argued that topography, soil, and landscape elements determine biodiversity (e.g., Marini et al. 2007). This argument goes so far as to claim that landscape can even serve

as a biodiversity indicator (e.g., Hoffmann-Krol/Schäfer/Seibel 2003; Piorr 2003). This claim finds support in the work of Aviron et al. (2005), who use carabid assemblages to show that landscapes characteristics explain very well the variance in communities' composition, followed by habitat type, and, to a lesser extent, by landscape context characteristics. This may be because landscapes remain stable over time. Changes in biodiversity are observable only in the long-run (Burel 1993) and thus the age of grassland (Waesch/Becker 2009; Waldhardt/Otte 2003) and yearly climate conditions (Irmeler 2003) tend to have significant influence on species abundance. Regarding soil quality, Dahms et al. (2010) observe that low-yield land (i.e., low agricultural value) is richer in ant, springtail, and cursorial spider populations (particularly the rarer species) than is high-yield land. Moreover, the microbial nitrogen turnover in soil (which is related to bacterial and fungal diversity) is affected significantly only in low-yield areas where conventional farming is practiced (Schloter et al. 2003).

As both agricultural land use and biodiversity are determined by geography, the question is: What causes what? Eriksson, Cousins, and Bruun (2002) claim that the distribution of plant species in the present-day landscape dates back to land use during the Iron Age. The fragmentation of landscape that occurred with the onset of agricultural usage at that time resulted in grassland-forest mosaics with plant communities with exceptionally high species densities. However, Heikkinen et al. (2004), in the case of birds, find that they are not per se dependent on landscape fragmentation, but on the availability of diverse preferred habitats. Here, again, effects seem to depend on species' characterization. Steiner and Köhler (2003) model the effect of landscape fragmentation on biodiversity. Their results show that effects of landscape patterns depend on the species' community structure. The higher the rate of generalists in the species pool, the greater the species richness at the local and regional scale, whereas in landscapes in which only specialists live, biodiversity is always lower.

Summing up, geography, in all its different aspects—landscape, soil, and climate—influences socioeconomic development, agricultural practices, and biodiversity, and each of these areas interacts with each other. As geography remains relatively stable over time, the hypothesis to be tested focuses on biodiversity occurrence, rather than on change in biodiversity:

*Hypothesis 6: Geographic conditions affect species abundance positively.*

The works discussed above obtained their results mainly by field work, cross-country analysis, or modeling. However, those findings should be reevaluated in light of the

hypotheses set out in this paper, which will be investigated on the basis of data collected from the counties of Bavaria and Thuringia (excluding cities).<sup>3</sup> A comprehensive list of all variables (including descriptive statistics and source of data) can be found in Table 2 (Appendix).

### 3. Data

#### 3.1. Biodiversity

Generally, measuring biodiversity involves different practices in the fields of economy and ecology. Ecologists tend to measure biodiversity as observed frequency; economists concentrate on the properties of biodiversity. In our study, we strike a balance between these two methods by using the number of species occurring (see also Baumgärtner 2003, 2006). Biodiversity is not only species abundance, but also the interaction between species, and results are often driven by the specific species under consideration. To avoid species-dependent effects, the following taxonomic groups are chosen to instrumentalize biodiversity for the empirical analysis (following Hansson 1997): (1) number of grassland *bird* species out of a sample of 35 typical grassland bird species per hectare grassland; (2) number of *butterfly* species out of a sample of 98 common species per hectare grassland; (3) number of *grasshopper* species out of a sample of 51 common species per hectare grassland; (4) number of *orchid* species out of a sample of 34 common grassland orchid species per hectare grassland; (5) number of common grassland *plants* out of a sample of 162 typical grassland plant species per hectare grassland. Thus, biodiversity is here approximated by the occurrence of taxonomic groups indicating “typical” grassland ecosystem characteristics. However, these variables are displaying only the present status of biodiversity in the county. To examine the effects of land-use changes on biodiversity, the number of species of our sample that are listed in the regional *Red Lists* for Thuringia and Bavaria are used as indicators. In cases of extinction, the former prevalence (before 1945) is used to account for the loss of the species in the county. Due to a lack of alternatives, this measure is incorporated in the empirical analysis even though the *Red Lists* have several drawbacks, one of which is that they only show

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<sup>3</sup> The exclusion of cities from this analysis is intentional, as cities normally score higher species abundance and therefore may distort the results (Wania/Kühn/Klotz 2006).

biodiversity status and do not indicate the driving forces behind that status (van Strien et al. 2009).

### 3.2. Agricultural Structure

As the agricultural structure of a county might be quite heterogeneous, several measures are used to account for different dimensions within the agricultural structure. The fraction of grassland used under *ecological* standards of the Council Regulation (EEC) 2092/91 in 2007 are incorporated into the empirical analysis, as well as the change in that fraction between 2003 and 2007, as stated in the “Agrarstrukturerhebung 2007” (and 2003, respectively).<sup>4</sup> This figure indicates the mode of farming. To measure the intensity of grassland usage, a *grazing intensity* indicator is constructed, irrespective of the mode of land use. Therefore, the number of sheep, sucker cows, and horses (in livestock units) per hectare grazing area in 2007 as listed in the “Agrarstrukturerhebung 2007” is calculated at the farm level. Areas (ha) scoring an intensity measure above *1.4 and 2.0 LU/ha*, respectively, are then assessed at the county level as a fraction of total grazing area. The total forage consumed by grazing animals on a rangeland is actually a random variable (Batabyal 2007). However, the thresholds of 1.4 LU/ha and 2.0 LU/ha are generally used as guidelines for subsidies for extensive land use and therefore are implemented here. The difference between the grazing intensity in 2003 and 2007 is applied to proxy the alteration of land use across these years.

Regarding the *scale* of farming, data on the relative number of farms per county in 2007 using between *5–20 hectares of grassland* and *more than 50 hectares of grassland*, respectively, are incorporated. It is assumed that farms operating on a high number of hectares bundle them together into larger areas to achieve scale effects. Thus, in areas where the majority of farms manage a larger amount of grassland (more than 50 hectares), large-scale farming may be the dominant mode of farming. Due to historical reasons, e.g., agriculture in the former GDR, large-scale farming is more common in Thuringia than in Bavaria. The difference between the fraction of farms per scale category in 2003 and 2007 is used as an alteration measure within the respective years.

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<sup>4</sup> “Agrarstrukturerhebung” is a survey of the German Federal Statistical Office conducted every four years in which all German farms are obliged to answer questions about, e.g., cultivation, employment, and asset structure.

### 3.3. Socioeconomic Structure

The socio-economic structure is here approximated by *GDP per capita* in 2007, *population density* in 2007, fraction of *settlement and traffic area* in 2008, and the *available income* of private households in 2007. Additionally, data are implemented to identify social demand for environmental service. Based on the notion of Hirschman (1970), individuals may use their voice (vote/engagement) to make known their preferences. Here, the *votes* for the “Green” party for the regional parliament (2008/2009), the fraction of population that belongs to the Society for the Protection of Nature (*BUND* in 2008 Thuringia or 2010 in Bavaria) or to the Society for Nature Conservation (*NABU*) in Thuringia (2009) and BirdLife (*LBV*) in Bavaria (2009) serves as proxy for preferences for nature conservation. The proportion of the population with an *academic* degree (in 2006) is integrated into the analysis as a measure for education. As the use of formal education is often criticized for not revealing awareness or preferences of any kind, an alternative is to use figures on occupation. In particular, people in highly creative professions may seek biodiverse recreational space as a means to cultivate inspiration. Thus, an alternative measure here applied is the fraction of *creative professionals* in the population in 2004 (as defined by Florida 2002).

Difference indicators are calculated on the basis of available data. These indicators include the difference in GDP per capita between 2003 and 2007, in population density between 2003 and 2007, in available income between 2003 and 2007, in the number of votes between the last regional elections (difference between 2004/2005 and 2008/2009), and changes in the amount of area classified as settlement and traffic area between 2004 and 2008.

### 3.4. Political Measures

As policy interference may crowd out or replace social demand, it is integrated as a separate variable in the analysis. Due to data constraints, only regulations of the EU with respect to agricultural production and nature conservation are incorporated in the empirical analysis. Thus, the Agri-Environmental Schemes targeting agricultural production are included in terms of subsidies paid (in Euros) in 2006 to farmers under the schemes KULAP A/B for Bavaria and Thuringia (*AES-P*). Additionally, subsidies paid (in Euros) under the schemes KULAP C in Thuringia and VNP/EA-FFH in Bavaria in 2006 (*AES-N*) are included as agricultural nature conservation schemes. These data are comparable to the nature conservation measures that were supported in Bavaria under the guidelines of VNP and EA-FFH and those in Thuringia at this time under KULAP C. However, measures specifically aimed at grassland

cannot be disentangled from measures for, e.g., cropland, hedgerows, or domestic animals as the available figures include the total amount of subsidies paid under the respective general scheme. However, one opportunity to analyze the effect of grassland measures directly is provided by using the number of grassland hectares under KULAP C in Thuringia and under VNP/EA-FFH in Bavaria in 2006 (*AES-G*). Thus *AES-G* is the part of the *AES-N* program that is applicable only to grassland. However, the same is not possible for KULAP A/B due to data constraints.

In addition to the three *AES* schemes, farmers are paid subsidies to remain in rural areas, irrespective of their production mode, to compensate them for operating in “Less-Favored Areas” (*BENA*). This scheme is considered to be related to compensation schemes for nature conservation because it is paid under the same subsidy framework of the EU. Criteria for this compensation scheme are low-yield agricultural production area, low population density, and a high fraction of grassland. The aim of the subsidy is to prevent emigration from remote areas. In the empirical analysis, the number of hectares of grassland under this scheme in 2007 is included.

In addition to subsidies for farmers, other political interference in the realm of nature conservation includes protection of areas under Council Directive 92/43/EEC on the Conservation of Natural Habitats and of Wild Fauna and Flora (*FFH*). The fraction of protected area per county under this directive is included here, as well as the fraction devoted to bird sanctuaries (*SPA*) per county in 2010.

### **3.5. Landscape/Geography**

To account for the natural characteristics of the area that may influence land use and biodiversity, severable variables are employed. The average long-term yearly *precipitation* for each county as well as the average long-term yearly *temperature* are used as climate indicators, as it is expected that some climates are more favorable for grassland biodiversity. Furthermore, the average *altitude* of the county is used to account for differences in biodiversity due to mountainous or flat landscapes. Climate and altitude are strongly connected to each other as well as to soil quality, which in turn influences biodiversity. To proxy soil quality, the “Ertragsmesszahlen” (*EMZ*) as used for taxation purposes is applied. This figure measures the potential agricultural yield based on soil quality. However, this measurement is composed of indicators for grassland and cropland; to entangle this indicator for grassland alone was not possible due to data constraints.



An additional variable is the fraction of protected “*biotopes*” as registered by the respective state offices. This figure indicates the heterogeneity of the area regarding environmental characteristics. It can be expected that some counties display a high degree of biodiversity due to the fact that they possess a high number of biotopes, or habitats. This variable shows only low correlation with the one of biotopes registered under FFH Directives or Bird Directives used above, which may be due to the small size and the patchiness of most protected biotopes. Furthermore, protected biotopes in Bavaria are restricted to open areas and do not include forest habitats, while FFH and SPA sanctuaries are predominantly situated in forests.

#### 4. Analysis

Our data make it clear that there is a high correlation between variables, and impacts are sometimes not only direct but might occur through a third variable. As it is believed that every variable reveals some factor integral to the analysis, reduction of variables does not seem optimal. Thus, a partial least square regression (PLS) approach is chosen to discover direct and indirect effects at the same time and thus reveal possible interdependencies by displaying a structure of effects. As this approach is not common in either economic or natural science research, we provide a brief explanation of it here.<sup>5</sup> To use this approach, all variables need to be standardized (mean = 0, standard deviation = 1).

The PLS approach we use is related to structural or simultaneous equation models (SEMs). However, instead of basing calculations on maximum likelihood (ML) estimations, regression analysis is the dominant approach here. Hence, a linear relationship between the created latent variables is assumed in general by:

$$(2.1) \quad \xi_{(m)} = \sum_{l \in C_{(m)}^P} \xi_{(l)} \gamma_{(ml)} + \varepsilon_{(m)}, \quad m = 1, \dots, M.^6$$

An inner model of latent variables is calculated with the help of observed (manifest) variables, which create the outer model. The outer model (or measurement model) determines the weights (or loadings) by applying regression analysis (or factor analysis), depending on the definition of the data structure. Thus, if the observed data reflect the characteristics of the

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<sup>5</sup> For a detailed description of the PLS approach, see Bliemel et al. (2005) or Huber (2007).

<sup>6</sup>  $X$  denotes manifest variables,  $\xi$  latent variables,  $\gamma_{(ml)}$  path coefficients,  $\varepsilon_{(m)}$  error term with expected value 0, and  $M$  are the constructed blocks  $J_{(m)}$  of observed variables  $m = 1, \dots, M$ , (based on Bliemel 2005).

latent variables (all observed variables describing approximately the same characteristic of the latent variable), a *reflective measurement model* is constructed as follows:

$$(2.2a) \quad x_{(m)j} = \xi_m \lambda_{(m)j} + \theta_{(m)j}, \quad m = 1, \dots, M; j = 1, \dots, J_{(m)}.$$

This factor-analytical approach is used here for construction of the latent variables “biodiversity” and “geography.” However, as the indicators obtained to construct the variable “policy” (AES-P, AES-N, etc.), for example, describe different facets of this latent variable, a *formative measurement model*<sup>7</sup> is defined, based on regression analysis in the following form:

$$(2.2b) \quad \xi_{(m)} = \sum_{j=1}^{J_{(m)}} x_{(m)j} \omega_{(m)j} + \theta_{(m)}, \quad m = 1, \dots, M.$$

Based on the background presented in Section 2.3, an *inner model* is created in the following form:

$$(2.3) \quad \xi_{(m)} = X_{(m)} \omega_{(m)}, \quad m = 1, \dots, M.$$

In contrast to SEM, here the latent variables are weighted aggregates of the outer models. The therefore necessary weighting coefficients

$$(2.4) \quad \Omega_{(m)} = (w_{(m)1}, w_{(m)2}, \dots, w_{(m)J_{(m)}})', \quad m = 1, \dots, M, j = 1, \dots, J_{(m)}.$$

are constructed with the help of an iteration process that includes the paths between the latent variables. To integrate these path weights, instrument variables are created according to the following formula:

$$(2.5) \quad \xi_{(m)}^* = \sum_{l \in C_m} \xi_{(l)} \rho_{(ml)}, \quad m = 1, \dots, M.^8$$

The iteration process applied here is based on alternating least square (ALS) algorithms in order to find weights that minimize the informational loss. In other words, the constructed variables will explain, as far as possible, the variance of the observed variables (similar to least square regression) by considering at the same time neighboring latent variables. So, for example, the weight of the latent variable “agriculture” is computed by considering the

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<sup>7</sup> A detailed discussion of the differences between reflective and formative models and their practical implications can be found in Jarvis, MacKenzie, and Podsakoff (2003) and Collier and Bienstock (2009).

<sup>8</sup>  $\rho_{(ml)}$  denotes weighting coefficients.

observed variables in a reflective model as well as the latent variables “policy,” “geography,” and “socioeconomy.” As long as there are more observations than variables to calculate from, there should always be a solution to the iteration process.

After the first values for the latent variables are computed based on the iteration process described above, the inner model is calculated in three steps:

1. Computing the surrounding variables as weighted sums of neighboring latent variables:

$$(2.6) \quad \xi_{(m)(k)}^* = \frac{1}{|C|} \sum_{l \in C_m} \xi_{(l)(k)} \rho_{(ml)(k)},$$

2. Determination of the weighting vectors:

$$(2.7a) \quad X_{(m)} = \xi_{(m)(k)}^* \omega'_{(m)(k+1)} + U_{(m)} \text{ (reflective measurement model), or}$$

$$(2.7b) \quad \xi_{(m)(k)}^* = X_{(m)} \omega_{(m)(k+1)} + u_{(m)} \text{ (formative measurement model)}$$

3. Recalculation of the latent variables:

(2.8)  $\xi_{(m)(k+1)} = X_{(m)} \omega_{(m)(k+1)} + c_{(m)(k+1)}$ , whereby  $c_{(m)(k+1)}$  is a standardization factor intended to ensure computation of  $\xi_{(m)(k+1)}$ . The iteration process stops as soon as convergence criteria are met:

$$(2.9) \quad \sum_{m=1}^M \left\| \xi_{(m)(k+1)} - \xi_{(m)(k)} \right\|^2 < \varepsilon^9$$

The above-described regression model is implemented with the SmartPLS 2.0 software<sup>10</sup> (see Ringle/Wende/Will 2005). The advantage of this method, and the reason for choosing it over SEM, is that PLS provides robust results with a small sample size. As estimations of the structure are based on least square estimation, neither a large sample size nor normally distributed data are preconditions for robust results. However, heteroskedasticity of the error term and the manifest variables and multicollinearity within the outer model may lead to underestimation of the inner model (Huber 2007). Additionally, as structure is calculated

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<sup>9</sup> As this estimation is an alternating procedure, the convergence criteria may already be reached at the local optimum. In contrast to PLS, SEM always yields the global optima.

<sup>10</sup> A comparison of PLS implementation software can be found in Temme, Kreis, and Hildebrandt (2006).

partially by alternating least square (ALS) estimation, this method lacks global quality criteria; instead, the model has to be split up and its parts evaluated separately. For example, one requirement for robust results is the uni-dimensionality of latent variables. This requirement is met with a Cronbach’s alpha higher 0.7 (Tenenhaus et al. 2005). Moreover, cross-correlation of the observed variables (and the variance inflation factor) needs to remain low if estimation is to be efficient (Bliemel et al. 2005). Table 1 presents an overview of further quality criteria as stated by Jahn (2007) and Ringle (2004).

	Jahn (2007)	Ringle (2004)
R <sup>2</sup>	> 0.4	> 0.67 substantial > 0.33 average > 0.19 low < 0.1 to be excluded
AVE	> 0.5	> 0.5
Reliability	> 0.7	> 0.6
Redundancy	> 0	> 0
Path coefficient	> 0.2 & significant (two-side t-test)	> 0.1 or 0.2 depending on source & significant (two-side t-test)

**Table 1: Overview of Quality Criteria for PLS (Selection)**

Before the PLS model is constructed, factor analysis is conducted based on Backhaus et al. (2006). This is done to reduce observed variables and the consequent risk of underestimation due to multicollinearity, as well as to control for data suitability in the reflective measurement model.

## 5. Results

### 5.1. Biodiversity Status

In a first step, we set up a full basic model that incorporates most of the variables of the established dataset that were found to be suitable. Results of the PLS can be seen in Figure 1. Regarding the cross-correlation matrix (see Table 3 and Table 5, Appendix), possible inefficiencies in the estimation may arise from high correlation between, e.g., FFH and SPA. Furthermore, findings in the cross-correlation matrix already hint at issues such as that diverse subsidy schemes favor geographic characteristics. So, a high correlation of –0.64 between “policy” and “EMZ” indicates that the subsidy schemes considered here are predominantly provided to counties with an average amount of low-yield arable land (EMZ). Furthermore,

“AES-P” is highly (0.87) correlated with the latent variable “geography,” which points to the fact that counties at higher altitudes, with lower temperatures, and poorer soil quality (among others) pay more subsidies to their farmers under the Agri-Environmental Schemes. Moreover, the scale of agricultural production regarding grassland is also affected by socioeconomic characteristics of the county. Thus, a higher agricultural intensity (grazing intensity measures weights are positive) is predominantly found in counties with higher available income (cross-correlation of “agriculture” and “available income” is 0.66). “Large-scale” grassland farming (above 50 hectares grassland per farm) seems to be prevalent in rural areas (low settlement and traffic area, low available income, etc.; cross-correlation with “socioeconomy” of  $-0.7$ ), while “small-scale” grassland farming (between 5 and 20 hectares grassland per farm) can be found in rather urban areas (cross-correlation with “socioeconomy” is 0.62). These cross-correlations, however, may lead to underestimation of the model. Therefore, a second model is constructed by eliminating the most severe cross-correlations. Results remain generally the same. Only one change in sign is observed, that between geography and agriculture. After reducing cross-correlations, the model was further reduced based on the quality criteria displayed in Table 1. The reduced model is shown in Figure 2. Due to low explained variance, the latent variable “policy” needs to be removed.

Regarding the *direct effects*, we find that counties at higher elevations (and with lower average temperatures and higher average rainfall) tend to be farmed in smaller patterns than in larger patterns. Ecological farming and grazing intensity cannot be significantly related to either geographic/socioeconomic conditions or biodiversity occurrence and are removed from the regression model. Therefore, no effect of the intensity or the mode of farming is measured. Hypothesis 2, which states that intensity of farming reduces species abundance, is rejected based on these results. Hypothesis 3, under which it was expected that ecological farming would have no effect on species abundance but, instead, on species composition (which cannot be detected here), is supported by our analysis. As the lack of empirical evidence is found for species abundance only, not for species composition, how ecological agriculture affects species composition would be a good subject for future research.

Considering the biodiversity indicators applied here, a negative effect of small-scale farming and a positive effect of large scale-farming on biodiversity are observed. This is in contrast to the finding of landscape ecology, which emphasizes the important role of fragmentation for biodiversity. Small-scale farming should actually create fragmented landscapes. However, considering Hypothesis 1, which proposed a positive relationship between small-scale

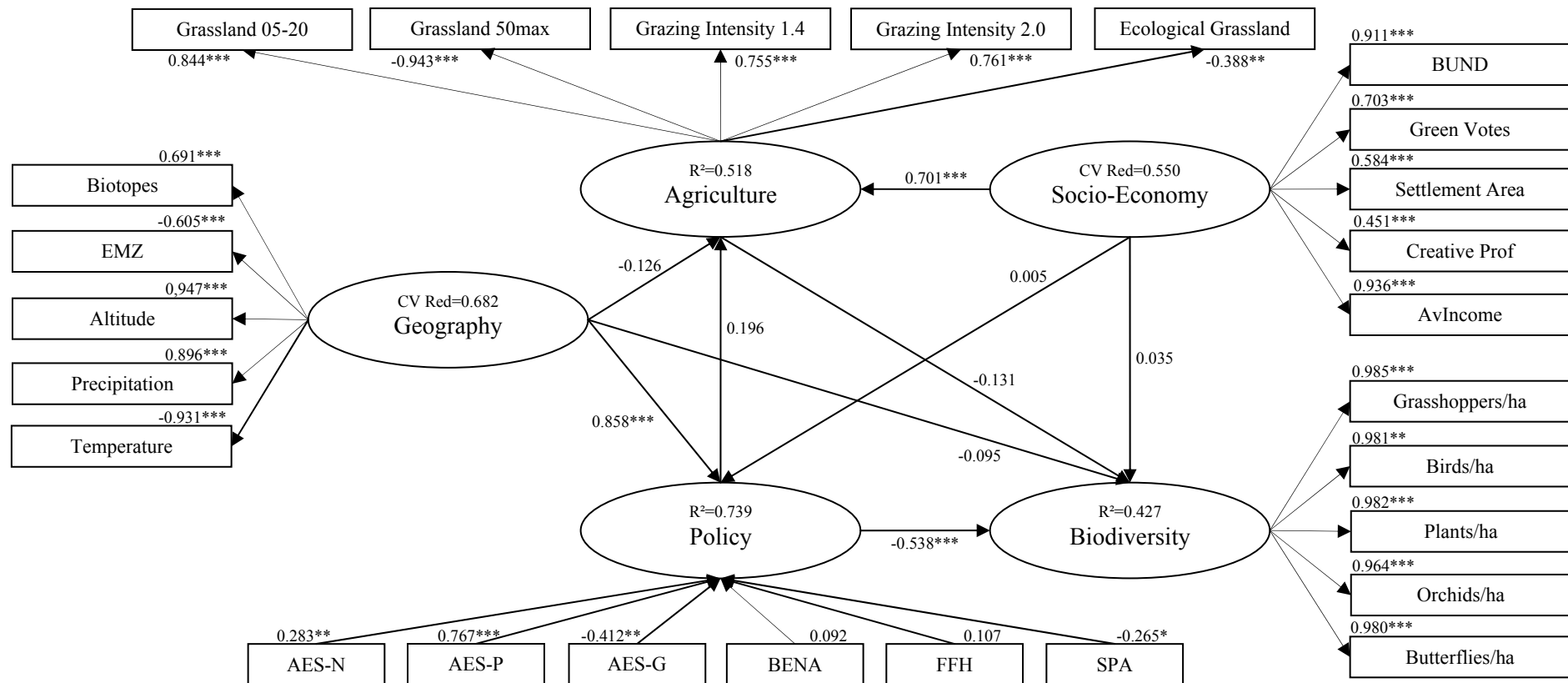


Figure 1: Full Basic Model for Bavarian and Thuringian Counties

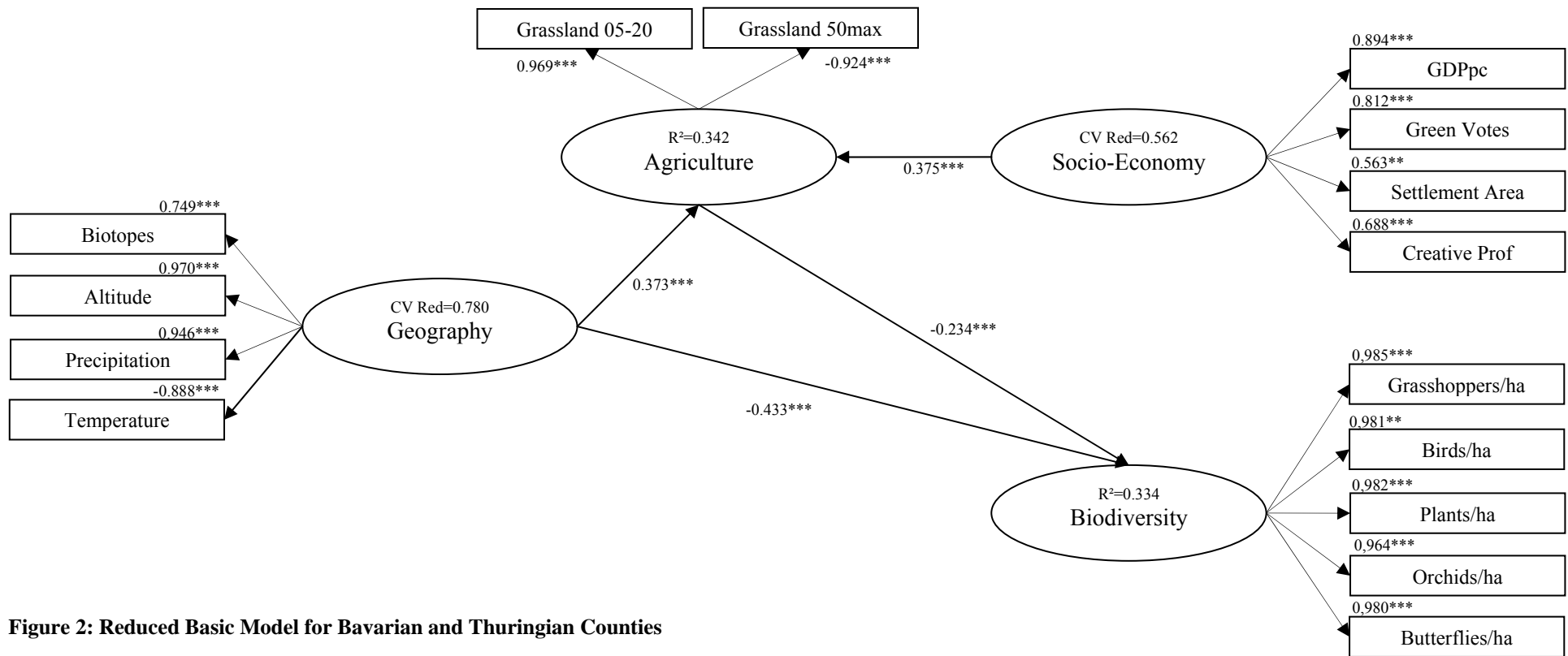


Figure 2: Reduced Basic Model for Bavarian and Thuringian Counties

farming and biodiversity, no support can be found in our analysis.

Unfavorable geographic conditions (here, high altitude, high precipitation, low temperature, high number of biotopes) further reduce species abundance as proposed by Hypothesis 6. The result, which contradicts the assumptions above, is due to the positive weighting of biotopes within the latent variable “geography.” This result can be explained by the high correlation of biotope area with altitude and the Alps dummy. Thus, with increasing altitude, more areas are classified as biotopes. Because in our dataset upland biotopes and species specific to the Alps are excluded explicitly, this correlation still seems to hold for open lands and lowland biotopes, respectively.

Socioeconomic factors (high GDP per capita, high settlement area, etc.), in contrast, seem to reduce the predominant scale of agricultural (grassland) farming, but show no significant impact on the status of biodiversity in this regional context. Hence, Hypothesis 5, which proposes that increasing demand for nature conservation leads to the extension of policy intervention, is not supported regarding the occurrence of species abundance.

In addition to the direct effects, *total effects* are also calculated by incorporating all linkages (direct and indirect) between the latent variables (see Table 6-Table 7, Appendix). In respect to total effects for biodiversity, unfavorable geographic attributes seem to reduce the scale of farming. The negative impact of small-scale farming (and positive effect of large-scale farming) on biodiversity remains. The influence of socioeconomic factors disappears once the overall structure is considered.

As results might be driven by Bavarian-specific features, the same models are calculated for the counties of Bavaria in order to test for the robustness of the findings. Hence, the number of observations is reduced to 71 counties (excluding Bavarian cities), which may reduce the explanatory power of the estimations. Furthermore, as only Bavarian counties are subject to analysis, the biodiversity indicator is extended so that all acknowledged butterfly species (143) and grasshopper species (75) are incorporated instead of the sample of common species. Results can be found in Figure 3 (as well as in Table 9-Table 14, Appendix). As the latent variable “geography” could not be separated from the variable “agriculture” in order to meet the unique identification criteria, both latent variables are bundled together. Also, in the reduced model for Bavaria, the latent variable “policy” shows no significant effect and thus needs to be excluded. Despite the fact that in the Bavarian model, agricultural practice is not just intertwined with geographic conditions, both variables together are interdependent with



species richness. Ecological grassland usage in Bavaria tends to be not only more common at higher altitudes, but also in areas with lower levels biodiversity. In contrast, grazing intensity is negatively related to altitude (as well as to precipitation). Hence, grassland usage incorporating more intense methods is more prevalent in lower-altitude areas, the same regions that tend to have a higher degree of biodiversity.

As geography changes very little over time and agricultural practices tend to be “sticky,” it seems that both together lay the foundation for socioeconomic development (see also Olsson/Hibbs 2005). The causality of the positive effect between biodiversity and socioeconomic structure is here defined to mean that biodiversity may lead to a socioeconomic selection effect, based on the grounds that the time period considered for the socioeconomic structure is more up-to-date than the one for biodiversity. This line of argumentation is supported by the outer model. Thus, it is shown in this reduced model that areas that are home to a high number of individuals who are highly educated and engaged in nature conservation issues (membership in the Party Bündnis 90/Die Grünen) are also more likely to be rich in biodiversity. In other words, it appears that people tend to self-select into areas with a high degree of natural amenities if they have the income to do so.

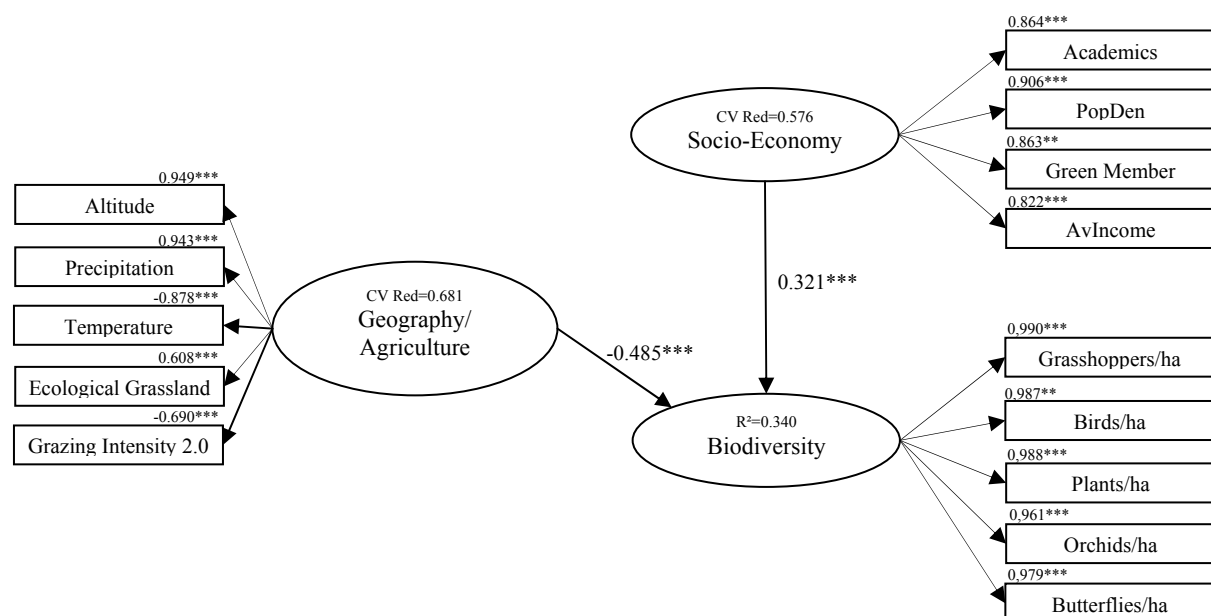


Figure 3: Reduced Basic Model for Bavarian Counties

## 5.2. Change in Biodiversity

A procedure similar to that detailed above is followed to compile a PLS model to examine change in biodiversity. The loss of biodiversity is here approximated by *Red List* data. After factor analysis to assure compatibility of the data, a PLS structure is set up. The full model for explaining loss of biodiversity is shown in Figure 4 (and Table 15-Table 20, Appendix). To meet the quality criteria discussed earlier, this model needs to be substantially reduced. For example, the *Red List* data is highly cross-correlated with geographic characteristics (e.g., precipitation:  $-0.62$ ) (see Table 15, Appendix). Hence, geographic attributes are removed so to achieve robust results. Furthermore, changes in agricultural practice cannot be significantly *directly* related to the biodiversity loss indicated by *Red List* data.

In general, the remaining constructs explain the variance in number of species to be found in the Red List by reference to political instruments and the socioeconomic characteristics of the counties. The model shows that increases in socioeconomic characteristics (such as growth in GDP per capita, available income of private households, or population density) directly reduce the number of subsidies granted for nature conservation purposes as well as those awarded to support agricultural production.<sup>11</sup> Moreover, political interference is higher in areas with a high proportion of species listed on the *Red List*.

In respect to *direct effects* and our hypotheses, no support is found for Hypothesis 2. Also, regarding the *Red List* data, intensity of farming has no impact on the species on the *Red List* and organic farming does not cause alterations (Hypothesis 3). While at the cross-national level, as well as in surveys, a rising demand for biodiversity accompanies increasing income, this relationship can be found here only within the positive relationship between income and votes for the Green Party/membership in BUND, which is exploited in setting up the latent variable “socioeconomy.” However, regarding the PLS estimation for changes and biodiversity loss, no evidence in support of Hypothesis 4 is found. Thus, rising income and education are related to increased awareness of environmental issues, but do not seem have any direct effect on measures found in the *Red List* data (as pointed out by Farzin/Bond 2006). However, political interference seems to counterbalance the negative relationship of income and biodiversity loss by transferring more resources into areas with large number of species

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<sup>11</sup> Subsidies are measured as Euro per hectare arable land.

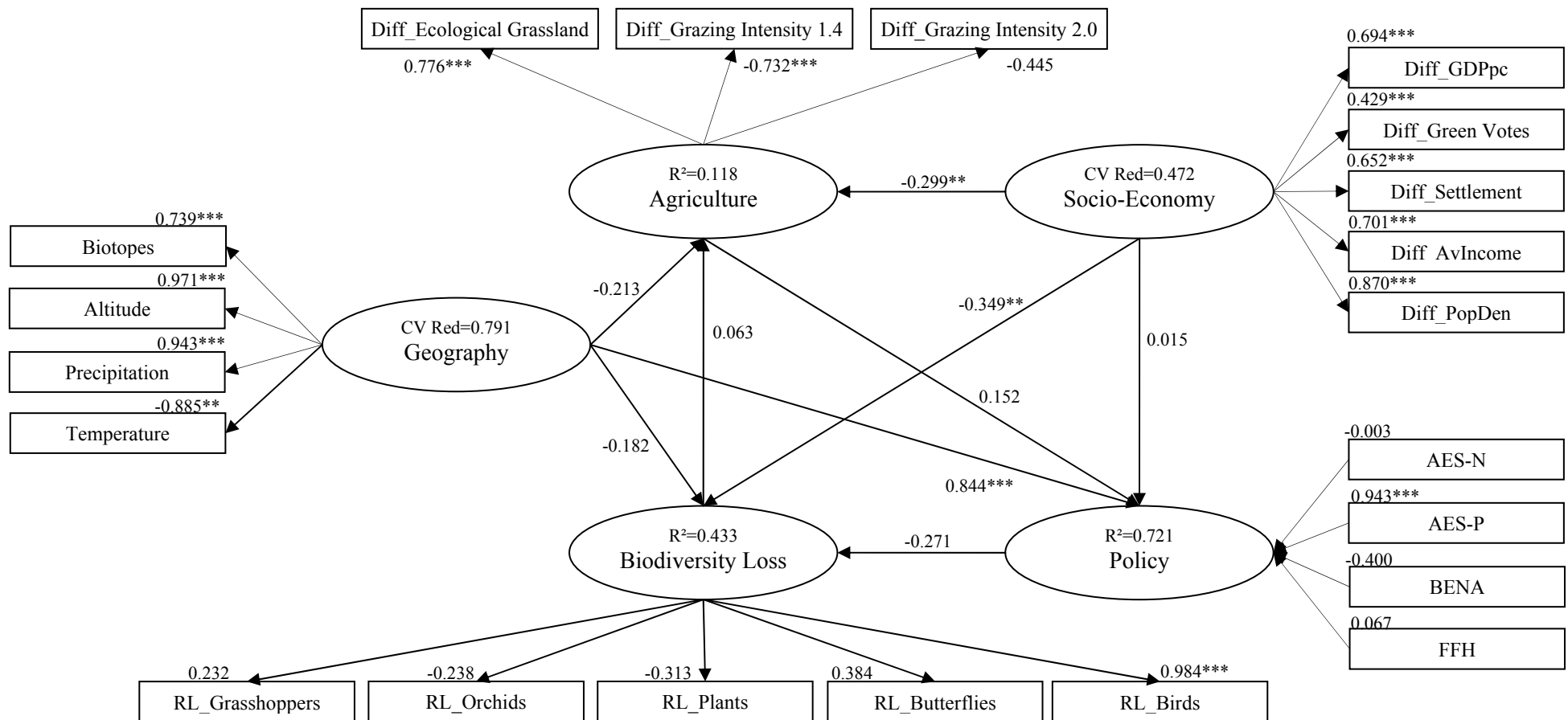


Figure 4: Full Change Model for Bavarian and Thuringian Counties

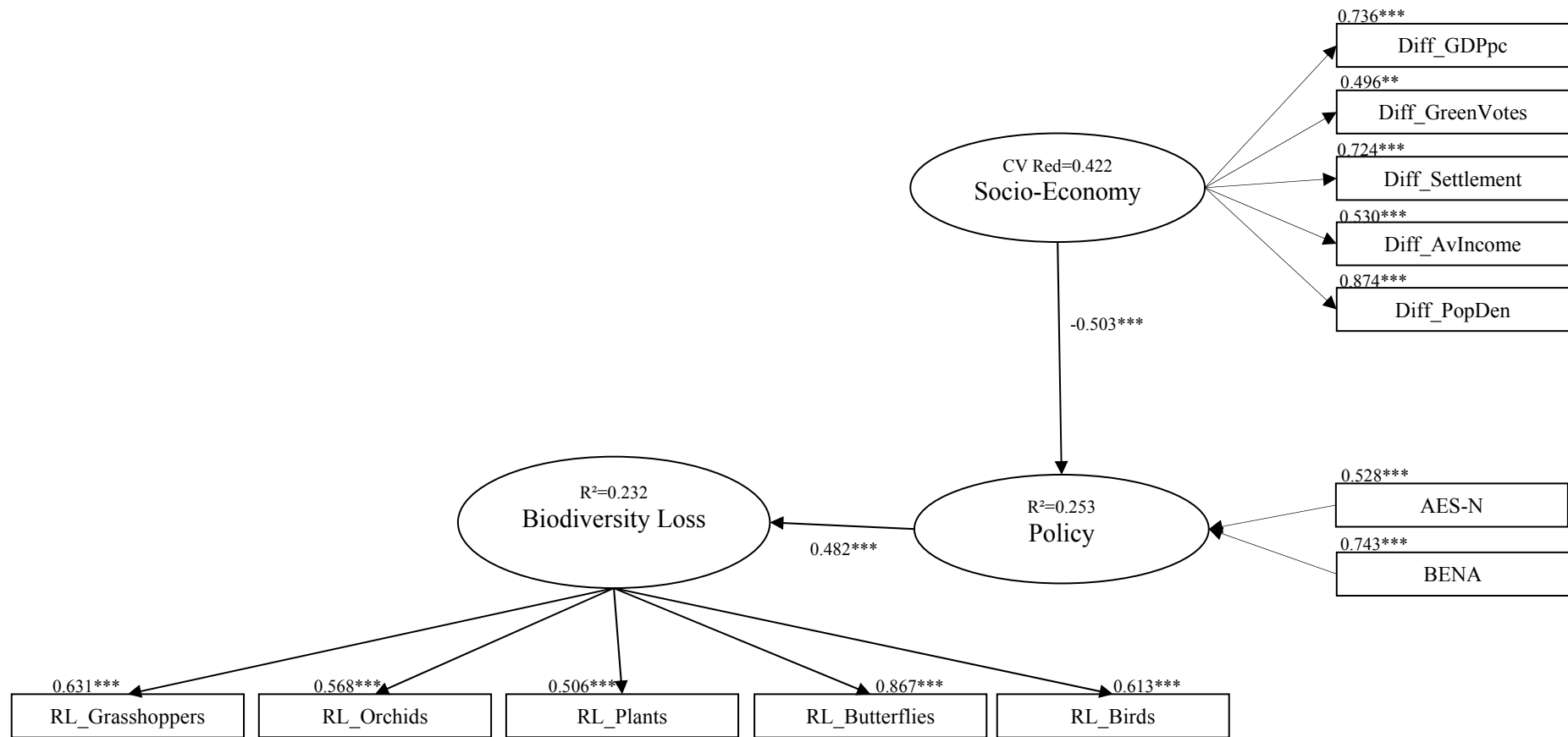


Figure 5: Reduced Change Model for Bavarian and Thuringian Counties

on the *Red List*. Therefore, Hypothesis 5 is partly supported. Although no increasing demand for environmental conservation can be observed, extended political activities in areas with high biodiversity loss can be found in the data on changes between 2003 and 2007.

Regarding *total effects*, there is a negative effect of socioeconomic development on the number of species on the *Red List*. Thus, biodiversity loss accelerates with rising income. On the other hand, rising income is also connected to more votes for the Green Party. That this growth in the relative strength of the Green Party actually reduces payments for nature conservation is counterintuitive at first sight. However, when looking at the weightings within the latent variable “socioeconomic,” it becomes obvious that one of the variables, “Difference Green Votes,” is relatively small compared to “Difference in Population Density” or “Difference in GDPpc.” Thus, the effect of socioeconomic features on the *Red List* and allocation of subsidies seems to be rather driven by changes in the economy. In particular, economically strong counties (high GDP per capita, high settlement and traffic areas) seem to have a higher growth rate in GDP per capita as well as in settlement and traffic areas (see Table 19, Appendix). Thus, these counties will not be eligible for subsidies intended for rural areas (BENA) or nature conservation (AES-N), a situation observable in this analysis.

We again test the robustness of this model by implementing only data for the Bavarian counties; findings remain generally the same for this revised and reduced model based on *Red List* data (see Figure 6, as well as Table 21-Table 26, Appendix). Hence, the socioeconomic structure can be related negatively toward the loss of biodiversity. Regions with higher growth rates in population density, GDP per capital, and settlement area also tend to accommodate a higher number of species listed in the local *Red List*. In this model, also, political interference proves to be targeted at areas with higher rates of rare species. However, overall, effects are reduced and some changes are made to the final model. For example, the variable “Birds in the Red List” must be excluded from the model due to insignificance. The latent variable “policy” is here described only by the observed variable “FFH” area in the county, and no longer by the subsidies paid under BENA and AES-G. As AES-G encompasses compensation payments for restricted agricultural usage of FFH areas, it is puzzling that only the FFH area as such seems to be connected with the loss of biodiversity.

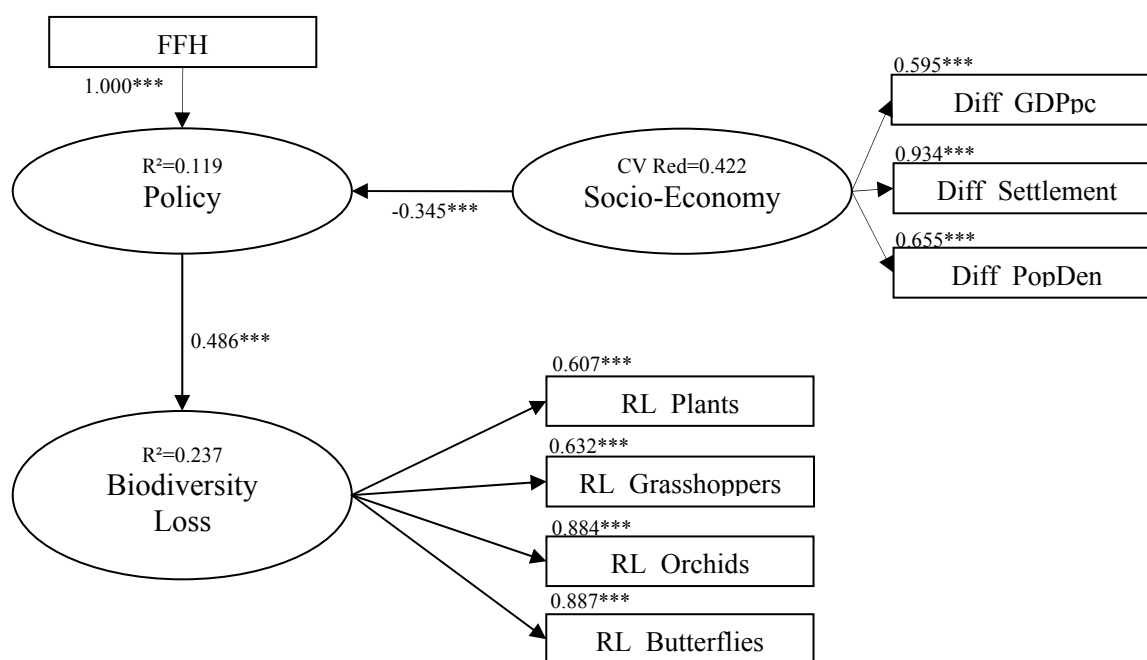


Figure 6: Reduced Change Model for Bavarian Counties

## 6. Conclusion

The aim of the analysis presented in this paper is to empirically examine, at the regional and local level, the influence of socioeconomic and political variables on biodiversity and change in biodiversity in grassland. To this end, a wide variety of research methods are introduced, ranging from field research to cross-country analysis to modeling and experiments. Most of the results obtained complement each other; some contradict each other. To identify direct and indirect influences on the status and loss of biodiversity at the county level, PLS estimations are conducted with the goal of identifying the most important interdependencies between biodiversity and socioeconomic variables as well as the major drivers of biodiversity loss. We show that in addition to its dependence on geographic features, biodiversity is also shaped by agricultural modes. The effect of these modes is found to be significant (size and mode of practice in Bavaria), and they, in turn, are dependent to some degree on geographical features and are quite stable over time. Moreover, the embeddedness of agricultural structures within socioeconomic features is emphasized by this study. Thus, a change in agriculture practice intended to preserve biodiversity needs to take into consideration the extant socioeconomic and geographic conditions. A regulation based purely on the size of farms seems inadvisable, particularly since small-scale farming appears to enhance, instead of reduce, biodiversity by creating heterogeneous fragments in landscapes. As in this paper a negative relationship is found between farm size and diversity for both Thuringia and Bavaria,

the question arises at to what is the optimal size of landscape fragments or agricultural production. Moreover, as to the intensity of farming, in general, intensive farming reduces species abundance; however, the specific measure of grazing intensity displayed no such effect. Excluding Thuringia from the analysis, grazing intensity even has a positive relationship with species abundance. Also, ecological farming does not appear to have any effect on biodiversity abundance or biodiversity loss. Fragmentation and heterogeneity within landscape and land management seem to be the main drivers of species abundance.

Regarding policy programs, we observe that there is a focus on areas with a high number of species on the *Red List*. However, as the empirical results show no significant relation between biodiversity in situ and the allocation of subsidies, it must be assumed that subsidy schemes are aimed more at socioeconomic issues than at biodiversity conservation. Moreover, an additional significant driver of agricultural structure is found in the socioeconomic structure of the county (GDP per capita, education, settlement and traffic areas, etc.). These socioeconomic features also form a significant basis for the allocation of subsidies. Indeed, in our reduced change model, the allocation criteria for socioeconomic-based subsidies (BENA) appear to be very similar to those for nature conservation funds (AES-G). Nature reserve nets (FFH area) or bird sanctuaries (SPA) do not seem to make a significant contribution to biodiversity or biodiversity conservation (*Red List* data) in either of the Federal States studied. Areas under FFH regulation in Bavaria, however, tend to be a relevant policy tool in respect to the *Red List* data.

This paper draws a general outline of the interdependence between biodiversity and socioeconomic variables. We show that agricultural practice is interdependent with geographic features. Thus, the spatial clustering of agricultural practice (as already demonstrated for the case of ecological agriculture) may be due to geographic influences as landscapes seldom stop at administrative borders. As to policy measures, we cannot provide a definitive answer as to the effectiveness of any one specific policy as, in this paper, all policy measures were bundled together into one latent variable and significant weights changed with the models.

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### **Conventions, Laws & Regulations**

Council Directive 92/43/EEC of 21<sup>st</sup> May 1992 on the conservation of natural habitats and of wild fauna and flora; OJ L 206, 22.07.1992, 7-50.

Council Directive 75/268/EEC of 28<sup>th</sup> April 1975 on mountain and hill farming and farming in certain less-favoured areas; OJ L 128, 19.05.1975, 7-25; repealed by Council Regulation (EC) No 950/97 of 20<sup>th</sup> May 1997 on improving the efficiency of agricultural structures; OJ L 142, 02.06.1997, 1-21.

Directive 2009/147/EC of the European Parliament and of the Council of 30<sup>th</sup> November 2009 on the conservation of wild birds; OJ L 20, 26.01.2010, 7-25.

Council Regulation (EEC) No 2092/91 of 24<sup>th</sup> June 1991 on organic production of agricultural products and indications referring thereto on agricultural products and foodstuffs; OJ L 198, 22.07.1991, 1-15; repealed by Council Regulation (EC) No 834/2007 of 28<sup>th</sup> June 2007 on organic production and labelling of organic products; OJ L 189, 20.07.2007, 1-23.

## APPENDIX

Table 2: Overview of Variables

Abbreviation	Description / Source	Descriptive statistics
Academics	Fraction of employed people within population with an tertiary degree in 2006 <i>Initiative NeueSozialeMarktwirtschaft</i>	Min: 0.0250 Max: 0.1840 Mean: 0.0566 Std.Dev. 0.0259 N: 88
AES-G	Fraction of grassland (hectares) subsidized under the EU-Scheme of KULAP C in Thuringia and VNP/EA-FFH in Bavaria in 2006 <i>Bavarian Ministry for Environment; Thuringian Ministry for Administration</i>	Min: 0.0000 Max: 0.4965 Mean: 0.0955 Std.Dev. 0.1050 N: 88
AES-N	Subsidies paid under the EU-Scheme of KULAP C in Thuringia and VNP/EA-FFH in Bavaria in 2006 per hectare arable land in the county (in Euros/hectare) <i>Bavarian Ministry for Nutrition, Agriculture &amp; Forestry; Thuringian Ministry for Administration</i>	Min: 0.0738 Max: 66.4813 Mean: 7.4365 Std.Dev. 10.4619 N: 88
AES-P	Subsidies paid under the EU-Scheme of KULAP AB in Thuringia and Bavaria in 2006 per hectare arable land in the county (in Euros/hectare) <i>Bavarian Ministry for Nutrition, Agriculture &amp; Forestry; Thuringian Ministry for Administration</i>	Min: 11.2807 Max: 198.6867 Mean: 61.3996 Std.Dev. 39.5170 N: 88
Alps	Dummy with value of 1 for counties dominated by the Alps (10) and 0 for counties not dominated by the Alps (78)	
Altitude	Mean altitude of the county in 2009 (in meters) <i>Bavarian State Office for Environment; Thuringian State Office for Environment and Geology</i>	Min: 183.42 Max: 1122.60 Mean: 479.12 Std.Dev. 174.71 N: 88
AvIncome	Available income of private households in 2007 <i>Federal Statistical Office</i>	Min: 13681.00 Max: 28764.00 Mean: 18338.01 Std.Dev. 2471.57 N: 88
Bavaria	Dummy variable with value of 1 for county in Bavaria and 0 for county in Thuringia	
BENA	Grassland (in hectares) subsidized under the EU-Scheme Less-Favoured Areas– Agrarian zone as fraction of total grassland in the county <i>Agrarstrukturhebung 2007</i>	Min: 0.00000 Max: 1.00000 Mean: 0.63690 Std.Dev. 0.36 N: 85
Biotopes	Fraction of counties area listed as lowland biotope (Bavaria, Status 12.12.2007) or as open land biotope (Thuringia, Status 31.12.2005, not finished – missing data is substituted by data on protected landscapes) <i>Bavarian State Office for Environment; Thuringian State Office for Environment and Geology</i>	Min: 0.1300 Max: 28.5000 Mean: 3.9391 Std.Dev. 3.5800 N: 87

Birds/ha	Number of grassland bird species out of a sample of 35 typical grassland bird species, i.e., birds breeding in grassland or nourishing crucially in grassland to be found in the county relative to the county's grassland <i>Bavaria: Bezzel et al (2005), Status 1996-1999;</i> <i>Thuringia: Nicolai (1993), Status 1978-1982</i>	Min: 0.0003 Max: 0.0147 Mean: 0.0032 Std.Dev. 0.0026 N: 88
BUND	Fraction of population engaged in the Society for the Protection of Nature (Bund fuerUmwelt und Naturschutz) <i>Bavarian Society for the Protection of Nature 2010;</i> <i>Thuringian Society for the Protection of Nature 2008</i>	Min: 0.0009 Max: 2.5500 Mean: 1.1331 Std.Dev. 0.6620 N: 88
Butterflies/ha	Number of butterfly species to be found in the county out of a sample of 98 common species relative to the county's grassland (if only Bavaria is considered: full sample of 143 species) <i>Bavaria: Voith/Bolz/Wolf (2007); Status up from 1971;</i> <i>Thuringia: Thust/Kuna/Rommel (2006), Status 1991-2002</i>	Min: 0.0011 Max: 0.0361 Mean: 0.0079 Std.Dev. 0.0060 N: 88
CreativeProf	Fraction of population whose occupation encompasses knowledge intensive work, whereby the major task is to solve problems creatively and self-dependent rather than to create new things. Members of this occupational group are e.g. lawyers, manager, physicians as defined by Florida 2002) <i>IAB; Artists and Social Security Fund 2004</i>	Min: 0.0437 Max: 0.2137 Mean: 0.0780 Std.Dev. 0.0215 N: 88
Cutting Area	Fraction of grassland used predominantly as cutting area (grass is cutted for forage production) <i>Agrarstrukturenerhebung 2007</i>	Min: 0.51074 Max: 0.98997 Mean: 0.90344 Std.Dev. 0.10 N: 88
Diff_Arable Land	Difference of arable land (in ha) in 2007 & 2003 <i>Agrarstrukturenerhebung 2003 and 2007</i>	Min: -4339.00 Max: 4188.00 Mean: -520.71 Std.Dev. 956.19 N: 88
Diff_AvIncome	Difference of available income of private households in 2007 and 2003 <i>Federal Statistical Office</i>	Min: 516.00 Max: 2847.00 Mean: 1658.97 Std.Dev. 473.48 N: 88
Diff_CuttingArea	Difference between fraction used as cutting area in 2003 and 2007 <i>Agrarstrukturenerhebung 2003 and 2007</i>	Min: -0.07417 Max: 0.11564 Mean: 0.00120 Std.Dev. 0.02 N: 88
Diff_Ecological Grassland	Difference between fraction of grassland used ecologically in 2007 to fraction of grassland used ecologically in 2003 <i>Agrarstrukturenerhebung 2003 and 2007</i>	Min: -0.0378 Max: 0.2636 Mean: 0.0100 Std.Dev. 0.0326 N: 88
Diff_GDPpc	Difference in Average Gross Domestic Product per capita between 2007 and 2003 <i>Federal Statistical Office</i>	Min: 35.10 Max: 1487.41 Mean: 367.58 Std.Dev. 259.27 N: 88



Diff_Grassland	Difference between fraction of arable land used as grassland in 2007 & 2003 <i>Agrarstrukturenerhebung 2003 and 2007</i>	Min: -0.0567 Max: 0.0338 Mean: -0.0021 Std.Dev. 0.0115 N: 88
Diff_GrazingArea	Difference between grassland fractions used as grazing area in 2007 and 2003 <i>Agrarstrukturenerhebung 2003 and 2007</i>	Min: -2858.93 Max: 1543.37 Mean: -70.67 Std.Dev. 452.78 N: 88
Diff_GrazingIntensity 1.4	Difference between fraction of grazing area used with a grazing intensity above 1.4 livestock units (sucker cows older than 2 years, horses, and sheep) per hectare grazing land per farm in 2007 to fraction of grazing area used in 2003 with grazing intensity above 1.4 LU/ha <i>Agrarstrukturenerhebung 2003 and 2007</i>	Min: -0.3404 Max: 0.4358 Mean: 0.0162 Std.Dev. 0.1098 N: 88
Diff_GrazingIntensity 2.0	Difference between fraction of grazing area used with a grazing intensity above 2 livestock units (sucker cows older than 2 years, horses, and sheep) per hectare grazing land per farm in 2007 to fraction of grazing area used in 2003 with grazing intensity above 2 LU/ha <i>Agrarstrukturenerhebung 2003 and 2007</i>	Min: -0.1404 Max: 0.2512 Mean: 0.0095 Std.Dev. 0.0851 N: 88
Diff_Green Votes	Fraction of valid votes for the Green Party in county parliament elections (Bavaria 2003-2008, Thuringia 2004-2009) <i>Federal Statistical Office</i>	Min: -0.0146 Max: 0.1016 Mean: 0.0162 Std.Dev. 0.0194 N: 88
Diff_LU/ha	Difference between total livestock in the county per ha grassland in 2007 in livestock units/hectare and the same in 2003 <i>Agrarstrukturenerhebung 2003 and 2007</i>	Min: -0.1657 Max: 0.0229 Mean: -0.0533 Std.Dev. 0.0328 N: 88
Diff_PopDen	Difference in average population density between 2007 and 2003 <i>Federal Statistical Office</i>	Min: -10.6242 Max: 12.5488 Mean: -0.7592 Std.Dev. 3.4152 N: 88
Diff_Settlement	Fraction of settlement and traffic area of total county area on 31.12.2008 compared to the one on 31.12.2004 <i>Federal Statistical Office</i>	Min: 0.0006 Max: 0.0113 Mean: 0.0031 Std.Dev. 0.0016 N: 88
Ecological Grassland	Fraction of grassland used under ecological standards of the EWG regulation 2092/91 in 2007 <i>Agrarstrukturenerhebung 2007</i>	Min: 0.0015 Max: 0.2702 Mean: 0.0645 Std.Dev. 0.0480 N: 88
EMZ	Ertragsmesszahl—number given by tax authority in evaluating the potential quality (profit) of the soil in 2007 <i>Bavarian Treasury Ministry;</i> <i>Thuringian Ministry of Finance</i>	Min: 28.51 Max: 63.39 Mean: 42.96 Std.Dev. 8.36 N: 88

FFH	Fraction of area registered under Council Directive 92/43/EEC on the Conservation of natural habitats and of wild fauna and florain 2010 <i>Federal Agency for Nature Conservation</i>	Min: 0.0019 Max: 0.4686 Mean: 0.1012 Std.Dev. 0.0896 N: 88
GDPpc	Average Gross Domestic Product per capita in 2007 <i>Federal Statistical Office</i>	Min: 1204.00 Max: 26344.50 Mean: 3208.67 Std.Dev. 2751.92 N: 88
Grasshoppers/ha	Number of grasshopper species to be found in the county out of a sample of 51 common species relative to the county's grassland (if only Bavaria is considered: full sample of 75 species) <i>Bavaria: Schlumprecht/Waerber (2003), Status up from 1986; Thuringia: Köhler (2001), Status 1980–2000</i>	Min: 0.0005 Max: 0.0208 Mean: 0.0044 Std.Dev. 0.0036 N: 88
Grassland	Area used as grassland as percentage of arable land in 2007 <i>Source: Agrarstrukturerhebung 2007</i>	Min: 0.0353 Max: 0.9829 Mean: 0.3374 Std.Dev. 0.2371 N: 88
Grassland 05-20	Proportion of farms in the county operating more than 5hectares and less than 20 hectares grassland <i>Agrarstrukturerhebung 2007</i>	Min: 0.1193 Max: 0.6060 Mean: 0.3762 Std.Dev. 0.0968 N: 88
Grassland 20-50	Proportion of farms in the county operating between 20 hectares and 50 hectares grassland <i>Agrarstrukturerhebung 2007</i>	Min: 0.04814 Max: 0.46020 Mean: 0.16483 Std.Dev. 0.09 N: 88
Grassland 50max	Proportion of farms in the county operating more than 50 hectares grassland <i>Agrarstrukturerhebung 2007</i>	Min: 0.0014 Max: 0.3235 Mean: 0.0748 Std.Dev. 0.0899 N: 63
Grazing Area	Fraction of grassland used predominantly as meadow/pasture etc. <i>Agrarstrukturerhebung 2007</i>	Min: 0.01003 Max: 0.48926 Mean: 0.09656 Std.Dev. 0.10 N: 88
Grazing Intensity 1.4	Fraction of grazing area used with a grazing intensity above 1.4 livestock units (sucker cows older than 2 years, horses, and sheep) per hectare grazing land per farm in 2007 <i>Agrarstrukturerhebung 2007</i>	Min: 0.0139 Max: 0.6801 Mean: 0.3540 Std.Dev. 0.1869 N: 88
Grazing Intensity 2.0	Fraction of grazing area used with a grazing intensity above 2 livestock units (sucker cows older than 2 years, horses, and sheep) per hectare grazing land per farm in 2007 <i>Agrarstrukturerhebung 2007</i>	Min: 0.0098 Max: 0.5910 Mean: 0.2619 Std.Dev. 0.1664 N: 88

Green Members	Fraction of the population listed as member of the Green Party (31.12.2007) <i>Federal Office of the Green Party</i>	Min: 0.0005 Max: 0.0226 Mean: 0.0037 Std.Dev. 0.0035 N: 87
Green Votes	Fraction of valid votes for the Green Party in county parliament elections (Bavaria 2008, Thuringia 2009) <i>Federal Statistical Office</i>	Min: 0.0272 Max: 0.2352 Mean: 0.0738 Std.Dev. 0.0387 N: 88
NABU/LBV	Fraction of population engaged in the Society for Nature Conservation (NABU) in Thuringia and BirdLife(LBV) in Bavaria <i>Bavarian BirdLife 2009;</i> <i>Thuringian Society for Nature Conservation 2009</i>	Min: 0.0010 Max: 0.1965 Mean: 0.0418 Std.Dev. 0.0370 N: 88
Orchids/ha	Number of orchid species to be found in the county out of a sample of 34 common orchid species relative to the county's grassland <i>Bavaria: Schönfelder/Bresinsky/Ahlmer (1990), Status 1945-1986;</i> <i>Thuringia: Korsch/Westhus/Zündorf (2002), Status 1990-2001</i>	Min: 0.0003 Max: 0.0096 Mean: 0.0020 Std.Dev. 0.0016 N: 88
Plants/ha	Number of common grassland plants to be found in the county out of a sample of 162 typical grassland plant species relative to the county's grassland <i>Bavaria: Schönfelder/Bresinsky/Ahlmer (1990), Status 1945-1986;</i> <i>Thuringia: Korsch/Westhus/Zündorf (2002), Status 1990-2001</i>	Min: 0.0023 Max: 0.0683 Mean: 0.0171 Std.Dev. 0.0127 N: 88
PopDen	Average population density (inhabitants per sqm) in 2007 <i>Federal Statistical Office</i>	Min: 69 Max: 469 Mean: 141.9130 Std.Dev. 74.2295 N: 88
Precipitation	Average of monthly mean of precipitation in millimeters for the years 1961–1990 for Bavaria and 1971–2000 for Thuringia <i>DWD (German Weather Service)</i>	Min: 519.69 Max: 1890.13 Mean: 894.99 Std.Dev. 280.61 N: 88
RL_Birds	Number of bird species of the sample in the regional Red List as fraction of total species in the sample <i>Red List of Bavaria 2005;</i> <i>Red List of Thuringia 2001</i>	Min: 0.1143 Max: 0.5143 Mean: 0.3308 Std.Dev. 0.0989 N: 88
RL_Butterflies	Number of butterfly species of the sample in the regional Red List as fraction of total species in the sample <i>Red List of Bavaria 2005;</i> <i>Red List of Thuringia 2001</i>	Min: 0.0510 Max: 0.4082 Mean: 0.2250 Std.Dev. 0.0853 N: 88
RL_Grasshoppers	Number of grasshopper species of the sample in the regional Red List as fraction of total species in the sample <i>Red List of Bavaria 2005;</i> <i>Red List of Thuringia 2001</i>	Min: 0.0784 Max: 0.4118 Mean: 0.2718 Std.Dev. 0.0810 N: 88

RL_Orchids	Number of orchid species of the sample in the regional Red List as fraction of total species in the sample <i>Red List of Bavaria 2005;</i> <i>Red List of Thuringia 2001</i>	Min: 0.0882 Max: 0.6176 Mean: 0.3379 Std.Dev. 0.1217 N: 88
RL_Plants	Number of grassland plant species of the sample in the regional Red List as fraction of total species in the sample <i>Red List of Bavaria 2005;</i> <i>Red List of Thuringia 2001</i>	Min: 0.0185 Max: 0.1049 Mean: 0.0712 Std.Dev. 0.0181 N: 88
Settlement Area	Fraction of settlement and traffic area of total county area on 31.12.2008. <i>Federal Statistical Office</i>	Min: 0.0451 Max: 0.1865 Mean: 0.1019 Std.Dev. 0.0256 N: 88
SHDI	Shannon Diversity Index for orchids <i>Based on data provided by: Schönfelder/Bresinsky/Ahlmer (1990) for Bavaria (Status 1945-1983); Korsch/Westhus/Zündorf (2002) for Thuringia (Status 1990-2001)</i>	Min: 1.6582 Max: 2.9866 Mean: 2.4501 Std.Dev. 0.3390 N: 88
SPA	Fraction of area classified as Bird Sanctuary area in 2010 in the Framework of FFH/Natura 2000 <i>Federal Agency for Nature Conservation</i>	Min: 0.0000 Max: 0.5844 Mean: 0.1147 Std.Dev. 0.1371 N: 88
Temperature	Average of monthly mean of the daily temperature in degrees Celsius for the years 1961–1990 for Bavaria and 1971–2000 for Thuringia <i>DWD (German Weather Service)</i>	Min: 5.2323 Max: 8.8372 Mean: 7.5747 Std.Dev. 0.7157 N: 88

*a) Full Basic Model for Thuringia & Bavaria*

**Table 3: Full Basic Model - Latent Variable Correlations (Bavaria/Thuringia)**

	Agriculture	Biodiversity	Geography	Policy	Socio-Economy
Agriculture	1				
Biodiversity	-0.255180	1			
Geography	0.214512	-0.576675	1		
Policy	0.238657	<b>-0.643065</b>	<b>0.859504</b>	1	
Socio-Economy	<b>0.711469</b>	-0.199579	0.248959	0.218442	1

**Table 4: Full Basic Model - Cross Loadings (Bavaria/Thuringia)**

	Agriculture	Biodiversity	Geography	Policy	Socio-Economy
AES-G	-0.51990	0.256832	-0.191451	-0.376780	-0.435539
AES-N	-0.417513	-0.030312	0.045093	-0.035863	-0.40645
AES-P	0.107840	-0.553190	<b>0.876173</b>	<b>0.938020</b>	0.167454
Altitude	0.303280	-0.553162	<b>0.946766</b>	<b>0.782299</b>	0.362773
AvIncome	<b>0.662481</b>	-0.197274	0.293881	0.239410	<b>0.935560</b>
BENA	-0.002786	-0.312481	0.182798	0.294146	-0.312788
Biotores	0.076461	-0.345847	<b>0.69111</b>	0.505654	0.365468
Birds/ha	-0.291080	<b>0.980862</b>	<b>-0.601835</b>	<b>-0.642337</b>	-0.253297
BUND	<b>0.770168</b>	-0.236183	0.256303	0.293580	<b>0.910583</b>
Butterflies/ha	-0.257467	<b>0.979563</b>	-0.577577	<b>-0.651909</b>	-0.197964
CreativeProf	0.154087	-0.226416	0.170132	0.124150	0.450851
Ecological Grassland	-0.387925	-0.117182	0.081453	0.074706	-0.147647
EMZ	-0.039309	0.454516	<b>-0.605113</b>	<b>-0.644613</b>	0.157479
FFH	-0.372528	-0.123616	0.289630	0.197099	-0.177914
Grasshoppers/ha	-0.192275	<b>0.984666</b>	-0.540914	-0.596057	-0.187504
Grassland 05-20	<b>0.843559</b>	-0.521329	0.511056	0.512259	<b>0.626874</b>
Grassland 50max	<b>-0.942881</b>	0.235495	-0.244145	-0.297757	<b>-0.708024</b>
Grazing Intensity 1.4	<b>0.755294</b>	0.109393	-0.190212	-0.182539	0.435349
Grazing Intensity 2.0	<b>0.761212</b>	0.054827	-0.17756	-0.168757	0.536203
Green Votes	0.306573	-0.123816	0.31994	0.175120	<b>0.702959</b>
Orchids/ha	-0.344561	<b>0.963545</b>	-0.536238	<b>-0.624325</b>	-0.223011
Plants/ha	-0.152937	<b>0.981863</b>	-0.560381	<b>-0.626504</b>	-0.108803
Precipitation	0.192777	-0.466183	<b>0.896070</b>	<b>0.753931</b>	0.380637
Settlement Area	0.443135	0.174292	-0.347489	-0.307917	0.584186
SPA	-0.378016	0.236978	-0.183142	-0.331703	-0.277406
Temperature	-0.214162	0.525661	<b>-0.931402</b>	<b>-0.803994</b>	-0.081003

**Table 5: Full Basic Model - Overview Quality Criteria (Bavaria/Thuringia)**

	AVE	Composite Reliability	R <sup>2</sup>	Cronbachs Alpha	Communality	Redundancy
Agriculture	0.580203	0.335419	0.517695	-0.564823	0.580202	0.010459
Biodiversity	0.956735	0.991036	0.427107	0.988683	0.956735	0.384136
Geography	0.682122	0.384973		-0.000507	0.682122	
Policy			0.738769		0.209755	0.149885
Socio-Economy	0.548625	0.850567		0.789610	0.548625	

**b) Reduced Basic Model for Thuringia & Bavaria**

**Table 6: Reduced Basic Model - Total Effects Inner Model (Bavaria/Thuringia)**

	Agriculture	Biodiversity	Geography	Socio-Economy
Agriculture		-0.233631***		
Biodiversity				
Geography	0.37315***	-0.519962***		
Socio-Economy	0.374636	-0.087527		

\*\*\* p<0.01, \*\* p<0.05, \* p<0.1

**Table 7: Reduced Basic Model - Total Effects Outer Model (Bavaria/Thuringia)**

	Agriculture	Biodiversity	Geography	Socio-Economy
Altitude			0.969692***	
Biotopes			0.748858***	
Birds/ha		0.981042***		
Butterflies/ha		0.979618***		
CreativeProf				0.688341***
GDPpc				0.893878***
Grasshoppers/ha		0.984598***		
Grassland 05-20	0.969275***			
Grassland 50max	-0.924137***			
Green Votes				0.811991***
Orchids/ha		0.963622***		
Plants/ha		0.981589***		
Precipitation			0.946441***	
Settlement Area				0.563014***
Temperature			-0.888006***	

(Weights or Loadings); \*\*\* p<0.01, \*\* p<0.05, \* p<0.1

**Table 8: Reduced Basic Model - Overview Quality Criteria (Bavaria/Thuringia)**

	AVE	Composite Reliability	R <sup>2</sup>	Cronbachs Alpha	Communality	Redundancy
Agriculture	0.896762	0.009771	0.342085	-8.089003	0.896762	0.165689
Biodiversity	0.956722	0.991034	0.334277	0.988683	0.956722	0.139065
Geography	0.796349	0.794928		0.100943	0.796349	
Socio-Economy	0.562287	0.833189		0.731022	0.562286	

*c) Full Basic Model for Bavaria*

**Table 9: Full Basic Model - Overview Quality Criteria (Bavaria)**

	AVE	Composite Reliability	R <sup>2</sup>	Cronbachs Alpha	Communality	Redundancy
Agriculture	0.538813	0.018737	0.641855	-0.338448	0.538813	0.271155
Biodiversity	0.962578	0.992284	0.406024	0.990278	0.962578	0.223723
Geography	0.662649	0.410650		-0.042311	0.662649	
Policy			0.785556		0.338405	0.306994
Socio-Economy	0.681716	0.913649		0.885428	0.681716	

**Table 10: Full Basic Model - Latent Variable Correlations (Bavaria)**

	Agriculture	Biodiversity	Geography	Policy	Socio-Economy
Agriculture	1				
Biodiversity	-0.506452	1			
Geography	<b>0.780016</b>	-0.485955	1		
Policy	<b>0.755818</b>	-0.533724	<b>0.88456</b>	1	
Socio-Economy	0.091031	0.302659	-0.009544	-0.064209	1

**Table 11: Full Basic Model - Cross Loadings (Bavaria)**

	Agriculture	Biodiversity	Geography	Policy	Socio-Economy
Academics	0.15427	0.20178	0.07801	0.00431	<b>0.90049</b>
AES-G	-0.21934	0.38484	-0.01195	-0.22992	-0.07669
AES-N	-0.04563	-0.02845	0.33602	0.17511	-0.17434
AES-P	<b>0.75785</b>	-0.47506	<b>0.87794</b>	<b>0.97893</b>	-0.08275
Altitude	<b>0.77141</b>	-0.47612	<b>0.94816</b>	<b>0.81670</b>	0.08726
AvIncome	0.19567	0.18473	0.09535	0.03730	<b>0.82552</b>
BENA	0.50635	-0.42981	<b>0.81841</b>	<b>0.82431</b>	-0.31646
Biotopes	0.49017	-0.12814	<b>0.69169</b>	0.48659	0.02053
Birds/ha	-0.53365	<b>0.98621</b>	-0.51958	-0.55599	0.29818
Butterflies/ha	-0.45940	<b>0.98002</b>	-0.40741	-0.48827	0.30111
creativeProf	0.20956	0.09703	0.11177	0.05377	<b>0.64606</b>
Ecological Grassland	<b>0.70989</b>	-0.15791	0.50845	0.49467	0.30937
EMZ	-0.27496	0.37232	-0.52088	-0.55750	0.24841
FFH	0.42173	-0.09715	<b>0.60638</b>	0.55258	-0.00902
Grasshoppers/ha	-0.53455	<b>0.98958</b>	-0.50820	-0.53727	0.23020
Grassland 20-50	<b>0.76025</b>	-0.48149	<b>0.66179</b>	<b>0.71795</b>	0.07231
Grassland 5-20	0.42932	-0.52808	0.42335	0.28841	0.07816
Grazing Intensity 1.4	-0.85881	0.29902	-0.61822	-0.58419	-0.01143
Grazing Intensity 2.0	-0.83082	0.31764	-0.56741	-0.57686	0.10462
Green Member	0.13375	0.22447	0.04367	-0.00948	<b>0.86462</b>
Orchids/ha	-0.41142	<b>0.96177</b>	-0.42231	-0.46691	0.31075
Plants/ha	-0.53188	<b>0.98771</b>	-0.51381	-0.55913	0.34186
PopDen	-0.12468	0.40253	-0.19660	-0.20970	<b>0.86675</b>
Precipitation	<b>0.83846</b>	-0.41434	<b>0.89468</b>	<b>0.82275</b>	0.17416
SPA	0.04891	0.11243	0.13952	0.06135	-0.00758
Temperature	-0.64955	0.50861	-0.92954	-0.82777	0.17474

*d) Reduced Basic Model for Bavaria*

**Table 12: Reduced Basic Model - Overview Quality Criteria (Bavaria)**

	AVE	Composite Reliability	R <sup>2</sup>	Cronbachs Alpha	Communality	Redundancy
Biodiversity	0.962186	0.992200	0.340441	0.990186	0.962186	0.225245
Geography/Agriculture	0.681183	0.353245		-0.984696	0.681184	
Socio-Economy	0.747002	0.921852		0.893401	0.747001	

**Table 13: Reduced Basic Model - Total Effects Outer Model (Bavaria)**

	Biodiversity	Geography/Agriculture	Socio-Economy
Academics			0.863801***
Altitude		0.948733***	
AvIncome			0.821671***
Birds/ha	0.986520***		
Butterflies/ha	0.979324***		
Ecological Grassland		0.608397***	
Grasshoppers/ha	0.989721***		
Grazing Intensity 2.0		-0.689667***	
Green Members			0.863254***
Orchids/ha	0.960861***		
Plants/ha	0.987842***		
PopDen			0.906369***
Precipitation		0.943276***	
Temperature		-0.877648***	

(Weights or Loadings); \*\*\* p<0.01, \*\* p<0.05, \* p<0.1

**Table 14: Reduced Basic Model - Total Effects Inner Model (Bavaria)**

	Biodiversity	Geography/Agriculture	Socio-Economy
Biodiversity			
Geography/Agriculture	-0.484836***		
Socio-Economy	0.320870***		

\*\*\* p<0.01, \*\* p<0.05, \* p<0.1



e) *Full Change Model for Thuringia & Bavaria*

**Table 15: Full Change Model - Cross Loadings (Bavaria/Thuringia)**

	Agriculture	Biodiversity Loss	Geography	Policy	Socio-Economy
AES-N	0.177012	0.193929	0.106565	-0.038019	-0.349942
AES-P	-0.054369	-0.411996	<b>0.829897</b>	<b>0.912792</b>	0.144437
Altitude	-0.210432	-0.567880	<b>0.970884</b>	<b>0.835156</b>	0.360965
BENA	0.153807	0.339897	-0.084955	-0.271341	-0.385989
Biotopes	-0.069782	-0.310397	<b>0.739182</b>	0.544876	0.194028
Diff_AvIncome	-0.304660	-0.395154	0.295025	0.279714	<b>0.701355</b>
Diff_Ecological Grassland	<b>0.775693</b>	0.225295	-0.204117	-0.142019	-0.250131
Diff_GDPpc	-0.070411	-0.302054	0.054070	0.060494	<b>0.694257</b>
Diff_Grazing Intensity 1.4	<b>-0.732061</b>	-0.038299	0.056281	-0.001949	0.069539
Diff_Grazing Intensity 2.0	-0.444989	-0.104382	0.008399	0.002133	0.221503
Diff_Green Votes	-0.140909	-0.237177	0.349756	0.256058	0.426363
Diff_PopDen	-0.253523	-0.463531	0.276504	0.262798	<b>0.870406</b>
Diff_Settlement	-0.269353	-0.212503	-0.043705	-0.049585	<b>0.651870</b>
FFH	-0.006804	-0.101724	0.478226	0.449306	-0.114820
Precipitation	-0.204939	<b>-0.621352</b>	<b>0.942599</b>	<b>0.871815</b>	0.410985
RL_Birds	0.288718	<b>0.947790</b>	-0.528098	-0.531251	-0.478654
RL_Butterflies	0.244864	0.384467	0.018753	-0.001563	-0.302028
RL_Grasshoppers	0.103741	0.231595	-0.151361	-0.206539	0.056321
RL_Orchids	0.132010	-0.238472	0.232146	0.251453	0.011340
RL_Plants	0.118905	-0.313125	0.198035	0.120295	0.234099
Temperature	0.110695	0.311357	<b>-0.885176</b>	<b>-0.702156</b>	-0.090350

**Table 16: Full Change Model - Latent Variable Correlations (Bavaria/Thuringia)**

	Agriculture	Biodiversity Loss	Geography	Policy	Socio-Economy
Agriculture	1				
Biodiversity Loss	0.239288	1			
Geography	-0.179374	-0.534780	1		
Policy	-0.113796	-0.532086	<b>0.848738</b>	1	
Socio-Economy	-0.323483	-0.504636	0.318738	0.283996	1

**Table 17: Full Change Model - Overview Quality Criteria (Bavaria/Thuringia)**

	AVE	Composite Reliability	R <sup>2</sup>	Cronbachs Alpha	Communality	Redundancy
Agriculture	0.445209	0.088245	0.117561	0.28816	0.445209	0.008662
Biodiversity Loss	0.250935	0.214814	0.432944	0.658921	0.250934	0.007127
Geography	0.790259	0.788299		0.008727	0.790259	
Policy			0.720559		0.277536	0.220669
Socio-Economy	0.467644	0.807755		0.70534	0.467643	

*f) Reduced Change Model for Thuringia & Bavaria*

**Table 18: Reduced Change Model - Overview Quality Criteria**

	AVE	Composite Reliability	R <sup>2</sup>	Cronbachs Alpha	Communality	Redundancy
Biodiversity Loss	0.420855	0.777920	0.232293	0.669146	0.420855	0.088426
Policy			0.252653		0.604149	0.152454
Socio-Economy	0.471413	0.810339		0.705499	0.471413	

**Table 19: Reduced Change Model - Total Effects Outer Model (Bavaria/Thuringia)**

	Biodiversity Loss	Policy	Socio-Economy
AES-N		0.52772***	
BENA		0.742977***	
Diff_AvIncome			0.530345***
Diff_GDPpc			0.736445***
Diff_Green Votes			0.495907***
Diff_PopDen			0.873819***
Diff_Settlement			0.723855***
RL_Butterflies	0.867204***		
RL_Grasshoppers	0.630687***		
RL_Orchids	0.568403***		
RL_Orchids	0.613034***		
RL_Plants	0.505544***		

(Weights or Loadings); \*\*\* p<0.01, \*\* p<0.05, \* p<0.1

**Table 20: Reduced Change Model - Total Effects Inner Model (Bavaria/Thuringia)**

	Biodiversity Loss	Policy	Socio-Economy
Biodiversity Loss			
Policy	0.481968***		
Socio-Economy	-0.24226***	-0.502646***	

\*\*\* p<0.01, \*\* p<0.05, \* p<0.1

*g) Full Change Model for Bavaria*

**Table 21: Full Change Model - Cross Loadings (Bavaria)**

	Agriculture	Biodiversity Loss	Geography	Policy	Socio-Economy
AES-G	-0.261719	0.429733	0.028034	0.246849	-0.186181
AES-N	0.026221	0.297822	0.380252	0.492091	-0.294855
AES-P	0.106125	0.274994	<b>0.867823</b>	<b>0.868207</b>	-0.331547
Altitude	0.320225	0.206455	<b>0.932373</b>	<b>0.754127</b>	-0.132244
BENA	0.086165	0.288509	<b>0.833696</b>	<b>0.889796</b>	-0.535920
Biotopes	0.146418	0.440806	<b>0.734096</b>	<b>0.674751</b>	-0.268004
Diff_Ecological G.	<b>-0.837359</b>	-0.004247	-0.392608	-0.225480	-0.088842
Diff_GDPpc	0.121052	-0.007462	-0.141570	-0.243687	0.580368
Diff_Grazing I. 1.4	0.593254	-0.086356	0.048943	-0.012835	0.040473
Diff_Grazing I. 2.0	0.507438	-0.053164	-0.011642	-0.072984	0.253298
Diff_Green Votes	0.244076	0.085112	0.294089	0.083971	0.202776
Diff_LU/ha	-0.409504	0.180788	0.119622	0.268166	-0.092802
Diff_Settlement	0.165448	-0.474603	-0.339850	-0.473710	<b>0.930093</b>
EMZ	-0.017263	-0.155194	-0.535050	-0.578641	0.469952
FFH	0.096645	0.431201	<b>0.615726</b>	<b>0.747195</b>	-0.340821
PopDen	0.121943	-0.040767	-0.024684	-0.207570	<b>0.674755</b>
Precipitation	0.219576	0.238348	<b>0.875946</b>	<b>0.710852</b>	-0.090820
RL_Birds	-0.331602	0.129856	-0.352662	-0.192656	-0.131529
RL_Butterflies	0.032116	<b>0.834203</b>	0.407594	0.491987	-0.252593
RL_Grasshoppers	-0.147444	<b>0.755495</b>	0.167050	0.384004	-0.413205
RL_Orchids	-0.065349	<b>0.805459</b>	0.257318	0.363919	-0.218298
RL_Plants	-0.064325	<b>0.621938</b>	0.009755	0.073189	-0.159583
SPA	0.031391	0.094192	0.156642	0.210053	-0.215604
Temperature	-0.231721	-0.192760	<b>-0.923053</b>	<b>-0.830502</b>	0.375420

**Table 22: Full Change Model - Latent Variable Correlations (Bavaria)**

	Agriculture	Biodiversity Loss	Geography	Policy	Socio-Economy
Agriculture	1.000000				
Biodiversity Loss	-0.093343	1.000000			
Geography	0.242676	0.305590	1.000000		
Policy	0.043105	0.483035	<b>0.879790</b>	1.000000	
Socio-Economy	0.171700	-0.377398	-0.314911	-0.474183	1.000000

**Table 23: Full Change Model - Overview Quality Criteria (Bavaria)**

	AVE	Composite Reliability	R <sup>2</sup>	Cronbachs Alpha	Communality	Redundancy
Agriculture	0.369577	0.008402	0.200962	0.242364	0.369576	-0.135602
Biodiversity	0.463820	0.786963	0.308656	0.681043	0.463820	-0.000793
Geography	0.662760	0.410818		-0.042311	0.662760	
Policy			0.817167		0.408505	0.321252
Socio-Economy	0.424578	0.712439		0.672548	0.424576	

*h) Reduced Change Model for Bavaria*

**Table 24: Reduced Change Model - Overview Quality Criteria (Bavaria)**

	AVE	Composite Reliability	R <sup>2</sup>	Cronbachs Alpha	Communality	Redundancy
Biodiversity Loss	0.584281	0.844993	0.236576	0.776262	0.584281	0.110826
Policy			0.118892		1	0.118892
Socio-Economy	0.551645	0.779967		0.686037	0.551645	

**Table 25: Reduced Change Model - Total Effects Inner Model (Bavaria)**

	Biodiversity Loss	Policy	Socio-Economy
Biodiversity Loss			
Policy	0.486391***		
Socio-Economy	-0.167711***	-0.344807***	

\*\*\* p<0.01, \*\* p<0.05, \* p<0.1

**Table 26: Reduced Change Model - Total Effects Outer Model (Bavaria)**

	Biodiversity Loss	Policy	Socio-Economy
Diff_GDPpc			0.594857***
Diff_Settlement			0.934151***
FFH		1.000000***	
RL_Grasshoppers	0.632487***		
RL_Orchids	0.884249***		
RL_Plants	0.607216***		
RL_Butterflies	0.886836***		
Diff_PopDen			0.654555***

(Weights or Loadings); \*\*\* p<0.01, \*\* p<0.05, \* p<0.1