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ORIGINAL PAPER

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Concept and feasibility study for the integrated evaluation of environmental monitoring data in forests

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Abstract In the 1970s unexpected forest damages, called "new type of forest damage" or "forest decline", were observed in Germany and other European countries. The Federal Republic of Germany and the German Federal States implemented a forest monitoring system in the early 1980s, in order to monitor and assess the forest condition. Due to the growing public awareness of possible adverse effects of air pollution on forests, in 1985 the ICP Forests was launched under the convention on long-range transboundary air pollution (CLRTAP) of the United Nations Economic Commission for Europe (UN-ECE). The German experience in forest monitoring was a base for the implementation of the European monitoring system. In 2001 the interdisciplinary case study "concept and feasibility study for the integrated evaluation of environmental monitoring data in forests", funded by the German Federal Ministry of Education and Research, concentrated on in-depths evaluations of the German data of forest monitoring. The objectives of the study were: (a) a reliable assessment of the vitality and functioning of forest ecosystems, (b) the identification and quantification of factors influencing forest vitality, and (c) the clarification of cause-effect-relationships leading to leaf/needle loss. For these purposes additional data from external sources were acquired: climate and deposition, for selected level I plots tree growth data, as well as data on groundwater quality. The results show that in particular time series analysis (crown condition, tree growth, and tree ring analysis), in combination with climate and deposition are valuable and informative, as well as integrated evaluation of soil, tree nutrition and crown condition data. Methods to combine

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information from the extensive and the intensive monitoring, and to transfer process information to the large scale should be elaborated in future.

Keywords Environmental monitoring · Data management · Forest growth · Critical loads · Regionalization · Integrated evaluation · Modelling · Forest vitality · Crown condition

Introduction

In the 1970s unexpected forest damages were observed in Germany, but also in other European countries. Conventional theories failed to explain the new combination of the symptoms ‘‘yellowing of leaves/needles’’ and ‘‘needle loss’’, particularly their occurrence on the large scale. Thus, the syndrome was called ‘‘new type of forest damage’’ or ‘‘forest decline’’. First, mainly conifers, but later also deciduous trees were affected. Other unusual changes in the environment were water acidification, first reported for Scandinavia in the early 1960s (i.e. Overrein et al. 1980), and reduced or accelerated growth of forest trees (i.e. Utschig 1989; Spiecker et al. 1996). Thus, acidifying and eutrophying deposition were very early supposed to be important factors leading to the observed phenomena (Ulrich et al. 1979).

The results of many studies and research programmes on forest damage led to the conclusion that the damages are the effect of a complex forest disease and an expression of impaired functioning of the whole forest ecosystem (Ellenberg et al. 1986; Matzner 1988; Schulze 1989; Ulrich 1989; Innes 1992; Matschullat et al. 1994; Wright et al. 1995; Müller-Edzard et al. 1997; Lükewille et al. 1997; Augustin and Andreae 1998; De Vries et al. 2000). Possible causes were seen in both abiotic and biotic factors, acting sequentially, concurrently, synergistically, or cumulatively on the forest ecosystem. However, to distinguish between triggering, accompanying and/or inciting factors has found to be very difficult, due to the complexity of forest ecosystems and regional varying affecting factors.

In order to monitor and assess the forest condition, the Federal Republic of Germany and the German federal states implemented a forest monitoring system in the early 1980s. In 1985 the ICP Forests was launched under the convention on long-range transboundary air pollution (CLRTAP) of the United Nations Economic Commission for Europe (UN-ECE) due to the growing public awareness of possible adverse effects of air pollution on forests. ICP Forests monitors the forest condition in Europe in close co-operation with the European Union (Lorenz 1995). The German experience in monitoring forest condition was one basis for the implementation of the European forest monitoring system.

Essential component of the environmental monitoring in forests is the extensive assessments on the large scale, the systematic level I grid, which for the ICP Forests and EU consists of the 16 km×16 km net, whereas for Germany a 8 km×8 km grid was proven to be the minimum density for national evaluations. Several German federal states performed more intensive investigations at denser grids, in order to derive information also at the regional scale. The crown condition has been assessed annually since 1984. One national survey of the forest soil condition was carried out (1989–1992), as well as one national assessment of the tree nutrition status (Wolff and Riek 1997). At present 1846 level I plots are implemented in Germany, among them 450 on the 16 km×16 km grid of ICP forests/EU (Fig. 1).

On the background of increasing evidence that forest damages are an expression of ecosystem dysfunction, an intensive monitoring net (level II) was installed since 1995 to study intensively forest ecosystem key processes under the impact of changing environmental conditions. The plots were selected to be representative for a particular geographic region. In Germany 89 sites were currently intensively monitored. At most of these plots element fluxes were measured to document changes of the environmental quality in forests and to study cause-effect-relationships regarding leaf/needle loss of trees (Fig. 1).

The overall goal of the 2-stage monitoring on level II and I plots is the scientific support of political decisions (air pollution control measures, e.g. the 2. sulphur protocol), by means of the identification and quantification of indicators for forest condition and its change (Lorenz 1995; Wellbrock et al. 2005). The programme was successful in the derivation of recommendations for forest measures, as well as for their control, the development of hypotheses, and the calculation of critical loads (Bolte et al. 2001; Wellbrock et al. 2004).

Both levels of the monitoring system are designed to answer different questions. In Table 1 the spatial representation and the temporal and spatial resolution of large-scale extensive monitoring/inventories and intensive monitoring/ecosystem research are given to illustrate the possibilities and limitations of the individual monitoring levels.

Individual processes can be studied in case studies and on the scale of level II plots, but the spatial scale for which the results are valid is small. On the other hand, large-scale inventories give information on geographical patterns of parameters and, in the case of periodically repeated assessments, also on changes over time. No underlying processes are studied, but the results can serve to deduce hypotheses on possible causes. For both monitoring levels the precision of process information and the spatial representation of the results are complementary to each other.

The missing links between the various spatial scales and process levels are one reason for the two ‘‘classical dilemmas’’ of the monitoring in forests: It is only possible to come to conclusions for those monitoring plots were the data are assessed, but (a) information are needed for the ‘‘white space’’ between or (b) detailed process information is required for areas, where only extensive measurements of simple indicators are

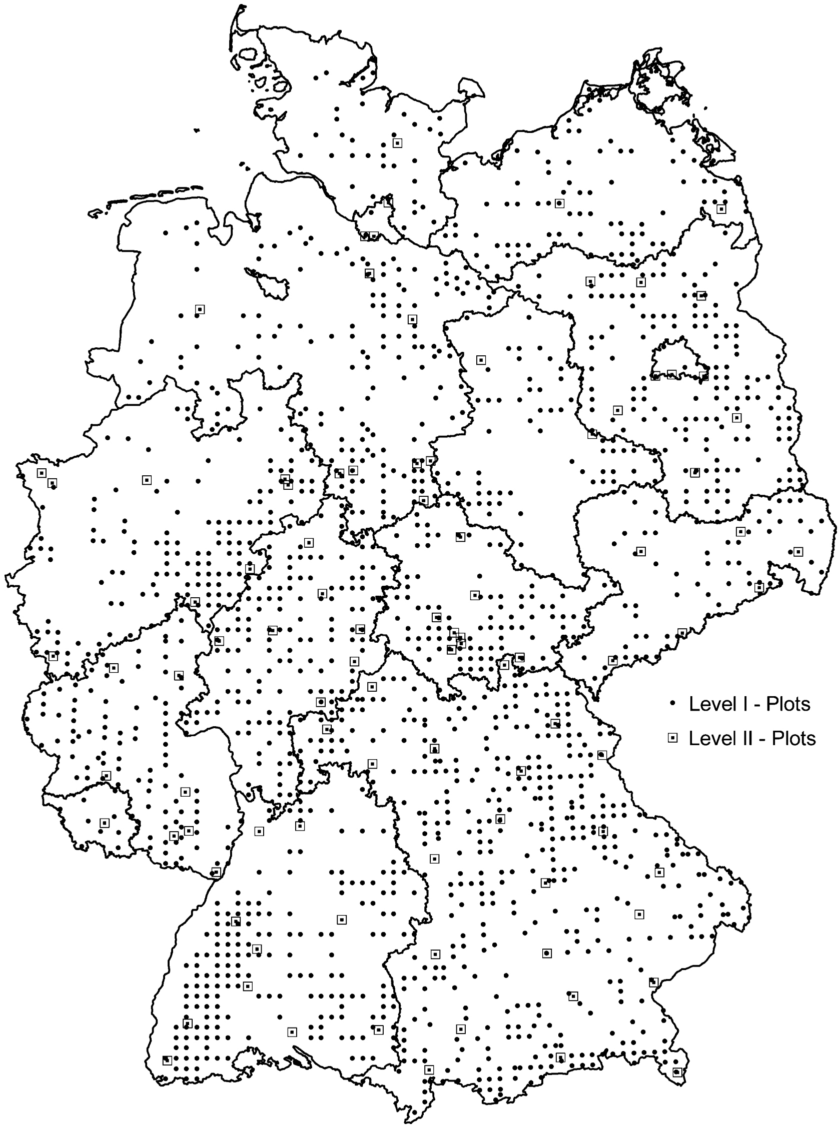

Fig. 1 The level I- and level II-plots of the environmental monitoring in Germany (level I ●, level II ⊡)

Table 1 Spatial and temporal resolution of environmental monitoring and ecosystem research (according to Hildebrand et al. 1996)

Tool (monitoring/research)	Representation		Resolution	
	Processes	Spatial scale	Space (km^2)	Time
Large scale monitoring/inventories (level I)	Element pools, growth	Region/state		Years–decades
Intensive monitoring/case studies (level II)	Ecosystem budget, flux type	Stand/catchment	Tree group/stand	Days–years

measured. To fill these gaps and to come to a more comprehensive picture of patterns and processes in forests, is the main objective of the German case study on integrated evaluation of forest monitoring data.

Background and objectives of the German integrated evaluation project

In 1997 the German government appointed an expert group to evaluate the existing crown condition surveys. The experts stated that the data of the environmental monitoring in forests contain a high information potential, and the continuation of the monitoring was recommended. A great chance to detect cause-effect relations and to formulate data based hypotheses was seen in the analysis of time series, and the integrated evaluation of the different data describing the forest condition, i.e. crown condition, forest growth and increment, soil condition and the nutritional status of trees (Eichhorn et al. 1998). It was suggested to enforce the development of regionalization methods for forest

Table 2 Hierarchical organisation of forest ecosystems (according to O'Neill et al. 1986 and Ulrich 1994)

<table>
<tr><th></th><th>Process unit</th><th>Process duration</th><th>Spatial compartment</th><th>Pattern / indicator</th></tr>
<tr><td>+2</td><td colspan="4">System regeneration in centuries (ecosystem)</td></tr>
<tr><td>+1</td><td>Stand development (changes of pools in biomass/humus)</td><td>decades</td><td>Forest stand (ecosystem section)</td><td>Age class / matter budget of the soil</td></tr>
<tr><td>0</td><td>Element cycle</td><td>year</td><td>Tree / tree groups</td><td>Matter budget of the ecosystem</td></tr>
<tr><td>-1</td><td>Development of plant organs (leafs, fine roots, fruits, wood)</td><td rowspan="2">weeks - month</td><td>Tree + forest floor vegetation</td><td>Tree foliation</td></tr>
<tr><td>-1</td><td>Decomposition</td><td>Soil horizon</td><td>Humus form</td></tr>
<tr><td>-2</td><td>Assimilation / matter uptake</td><td rowspan="2">hours - weeks</td><td>Leaf / root</td><td>Carbon and ion allocation</td></tr>
<tr><td>-2</td><td>Mineralisation</td><td>Soil aggregate</td><td>Soil solution chemistry</td></tr>
<tr><td>-3</td><td colspan="4">Fast reacting biochemical processes on cell or mineral level</td></tr>
</table>

monitoring data, because up to present no standard methods were available.[1]

The main objectives of the study are:

(1) A reliable assessment of the vitality and functioning of forest ecosystems.
(2) The identification and quantification of factors influencing forest vitality.
(3) The clarification of cause-effect-relationships leading to leaf/needle loss.

Based on this, recommendations for the further development and the enhancement of the environmental monitoring in forests are to be deduced.

All objectives should be achieved by the analysis of already existing forest monitoring data. The acquisition of additional data or the use of data from external sources should be reduced to a minimum. As indispensable for integrated evaluations additional large-scale information on climate and deposition were considered and therefore "assessed" within the project. Climate data were provided by the Potsdam Institute for Climate Impact Research (Potsdam) and by the German weather service, deposition data by the Institute of Navigation, University of Stuttgart. For selected level I plots also tree growth data were assessed (see Schröder and Riek 2005). Data on groundwater quality were provided by the German federal states Saxony, Thuringia, and Baden-Wuerttemberg.

Synthesis

For the synthesis of the project, the results achieved with various methods at various spatial and temporal scales, are linked here on the background of the hierarchical structure of forest ecosystems (O'Neill et al 1986). For the detailed results the reader is referred to Augustin et al. 2005a, b; Eichhorn et al. 2005; Evers and Schulze 2005; Musio et al. 2006; Rötzer et al. 2005; Schröder and Riek 2005; Seidling 2004; Wellbrock et al. 2005.

Forest ecosystems as hierarchically ordered systems

Forest ecosystems are open systems, which exchange matter and energy with their environment. The processes in forest ecosystems can be ordered hierarchically. The classifying criteria for the functional or process units are (a) the process duration, which is the time span needed to complete one process and (b) the spatial compartment in which the process occur (Table 2, according to O'Neill et al. 1986, modified after Ulrich 1994).

For example, all processes belonging to the functional unit "development of plant organs" (−1) take place in the surrounding area of one tree. They are of seasonal significance (the process duration is weeks to month) and do result in the indicator "foliation" (Table 2). On each functional level disturbances, due to external influences and/or impacts from other hierarchical levels are possible. In order to neutralize the potential negative impact and to avoid impairments of the process functioning, each functional unit possesses filtering mechanisms. Permanent pressure on the filter mechanisms will diminish or even exhaust their capacity. This can be detected in the indicative pattern of the respective spatial compartment. For example, a permanent input of nitrogen leads—in the long term—to an enrichment of all ecosystem storages, which can be detected by the indicators C/N ratio of the forest floor humus, or in the nitrogen content of the leaves/needles. A permanent exceedance of the filter capacity in one process unit will give a "signal" to the unit above, for example in a changed supply of nutrients, which in turn exert "constraints" on the process unit below. This possibly means stress for those units which are subjected to these alterations.

Whether a shift to changed growth conditions actually occurs or not is visible in the patterns of the respective spatial compartment, which were mostly the indicators of the monitoring systems.

[1]With the project "Concept and Feasibility Study for the Integrated Evaluation of Environmental Monitoring Data in Forests" (IFOM) this postulation was taken up by the German Federal Ministry of Education and Research.

The most common target variables used in the analysis of forest monitoring data are parameters, which describe crown condition. Thus, most of the studies within the framework of the ''concept and feasibility study for the integrated evaluation of environmental monitoring data in forests (IFOM)'' deal with the process unit on the −2 hierarchical level (assimilation or matter uptake) and −1 (development of plant organs/wood).

Synthesis of the project results

In dependence of the factors climate, stand structure, immissions and nutrient level the process oriented tree growth model BALANCE reproduced the growth and vitality of forest stands realistically (Rötzer et al. 2005). The particular advantage of physiologically based, individual tree models such as BALANCE is that a number of different physiological processes are described separately in response to environmental parameters and that the interaction of these parameters leads to integrated results for growth and vitality. Thus, also new combinations of environmental conditions can be investigated. Simulating growth responses on the single tree level enables to assess also the influence of competition, stand structure, species mixture, and management impacts because tree development is described as response to individual environmental conditions and environmental conditions change with individual tree development. In general, the responses of the forest stands were quite different depending on the environmental changes, and ''defoliation'' and ''growth'' react non-congruent to environmental influences. This was plausible, since between the process units ''assimilation'' (−2 level) and ''tree development'' (−1 level) one filtering level is situated, in terms of the hierarchy theory, which attenuate the signal ''loss of foliage'' and adhere the growth of a tree. Accordingly, in lower saxony time series (1985–1995) of beech crown condition reveal an increase in defoliation, accompanied by reduced growth. The basal annual increment decreased 20% while average defoliation increased from 25 to 35% (Evers and Schulze 2005).

Including additional potential impact parameters, like fructification and deposition, to explain higher degrees of defoliation is meaningful, especially since these factors are known to have a significant physiological effect on foliation (Paar et al. 2000; Seidling 2004). The effect of fruiting on crown condition of beeches could be verified in time series analysis on level I plots (Eichhorn et al. 2005), where beeches with frequently fruiting events show higher defoliation percentages (−1 level). Additionally, the defoliation of beech was more pronounced for older individuals, for trees with a larger distance to the next tree and in pure beech stands compared to mixed stands (Eichhorn et al. 2005). This points to the fact that information on forest structure is important for the evaluation of trends in crown condition.

Studies on the influence of nutritional status of trees show that low contents of magnesium in Norway spruce needles are combined with higher defoliation (Musio et al. 2006) and reduced shoot growth (Seidling 2004). With increasing aluminium contents in the rooting zone, as well as with an imbalanced tree nutrition (high N/K ratios), the defoliation in conifers increases (process unit −2) (Musio et al. 2006). These results are in agreement with those reported by Augustin and Schmieden (1997) on the basis of forest decline research. In Lower Saxony, the discolouration of trees decreased from 1985 to 2003 (Evers and Schulze 2005). This can be traced back to the lowering of the sulphur deposition in the past 25 years (i.a. Meesenburg et al. 2002), as well as to the improvement of Mg nutrition of trees by forest liming with dolomite, which was demonstrated on the large scale (NML 2004). Studies with Scots pine (*Pinus sylvestris* L.) on German level I plots show that especially on sites with high deposition load a relation between tree nutrition and deposition exists (Wellbrock et al. 2005). It is plausible that after the reduction of element inputs the importance of element supply through the soil will increase.

A correlation between growth and nitrogen supply was exemplary shown for Scots pine (*P. sylvestris* L.) on level I plots: The higher the nitrogen input the higher the positive deviation of the growth rate from the expected values (Schröder and Riek 2005). Common beech (*Fagus sylvatica* L.) on level II sites shows lower defoliation with increasing nitrogen concentration in leaves (Seidling 2004). Obviously, nitrogen has a stimulating effect on leaf development. The annual fluctuations in the defoliation of all tree species on level II could be explained to a high degree with the element contents in leaves and needles, the remaining variation of foliation was best explained with the annual fluctuations in weather conditions (Seidling 2004).

However, the results have to be seen in an ecosystem context. On the long term high nitrogen inputs are detrimental for forests (i.a. Wright et al. 1995; Nadelhoffer et al. 1999; Magill et al. 2004; Venterea et al. 2004). On the basis of element budgets on level II plots it could be shown that C/N ratios <25 in the forest floor humus layer indicate an increased risk of nitrogen output from the soil (Augustin et al. 2005b). Elementary functions of the forests are impaired and the signal from the −1 process unit ''decomposition/humusform'' has an effect on the indicator ''matter budget'' on the process unit ''element cycle'' (0 level). In this respect an enhanced tree growth is not a sign for ecosystem stability, but rather a sign for ongoing changes in the system, with unknown end. The knowledge regarding the long-term fate of nitrogen is incomplete, as modelling results reveal (Schultze et al. 2005). One explanation could be the gaseous export of nitrogen as the missing sink in forest soils (Butterbach-Bahl et al. 2001).

For Norway spruce on level I sites a deep reaching debasing of the mineral soil (base saturation $<15\%$ in 10–60 cm) was combined with higher percentages of trees with defoliation $>25\%$ in the years 1991–1999, indicating a confined scope of trees to counteract stress (Augustin et al. 2005b), whereas the influence of nitrogen saturation (low C/N ratios) was less pronounced.

Schröder and Riek (2005) found for "beech under stress", defined by deposition and climate, a clear relationship between defoliation and reduced growth. For "beeches without stress" the foliation is still an unspecific indicator and probably the result of fluctuations in natural conditions like climate. The plots for the study were selected according to forest condition types, which represent areas with similar deposition rates, climate as well as soil condition (Wellbrock et al. 2002). Obviously, the relation between climatical variables and tree growth has changed in the last decades (Nellemann and Thomsen 2001; Webster et al. 2004). Tree ring analysis of Scots pine on level I plots show that the growth response to the natural factor climate becomes more severe (Schröder and Riek 2005). It seems that the long-term effects of deposition alter the reactions of trees to climatical stress (−2 to 0 process level). This is in accordance with results of Dittmar and Zech (1994), which reported variations in growth as an effect of climate fluctuations for beeches on sites with environmental stress. On level II plots in Bavaria the relation between radial increment and climate stress was investigated retrospectively by means of tree core analysis (Schultze et al. 2005). Until the 1970s the relation between growth and temperature follow the expectations, but after ca. 1980 this relation becomes increasingly weak.

The knowledge of key processes and "filtering mechanisms" in forests is a prerequisite to regionalise results from the plot level to forest stands or landscapes. A test of regionalization methods by Musio et al. (2006) in Baden-Wuerttemberg reveal that a monitoring grid density of 4 km×4 km is adequate for the transfer of process information, whereas lower densities led to increasing prediction errors. One successful regionalization approach was performed on soil chemical data, using characteristics of landscape morphology, geology, and stand parameters as predictors in multiple regression models (Zirlewagen 2003). Another way is the use of statistical upscaling with forest condition types (Wellbrock et al. 2002), which represent areas with similar deposition rates, climate as well as soil condition. However, there are no standard methods available for regionalization of monitoring data.

Resume

The results of the different approaches applied can be combined to an explanatory model for the observed changes in forests, which is also compatible with the theory of hierarchical levels in ecosystems, and with stress theories (i.a. Manion 1981; Godbold 1998). In principle, the results of the German monitoring of forest ecosystems are adequate to come to a more comprehensive picture of status and change of forest ecosystems.

The integration of the results into the hierarchical organisation of forest ecosystems clarifies, that scientific (evaluation and statistics) and technical (monitoring and sampling design) recommendations are complementary to each other. For example, the necessity to complete the data sets of the level I monitoring with accompanying data like climate and deposition, arise directly from theoretical and statistical requirements. The non-observance of this and insufficient long-term evaluation capacities are often the reason, why the interpretations of findings remain speculative.

Recommendations

Evaluations: principles

Evaluations should be based on the present knowledge of forest ecosystem functioning. The parameters assessed in the monitoring nets are seemingly "simple", but their significance in the ecosystem, their indicative value, their relations and interactions in processes and cycles should be known and taken into account by the evaluator. Otherwise a meaningfull evaluation strategy and interpretation of results is not possible. The fact is trivial, but often disregarded.

Evaluations: statistics

Forest condition is the result of many interacting site factors and processes, evaluations should therefore include at least the most important information on the site and external data. Future integrative evaluations should comprise digital landscape models, data on climate and deposition, but also information on soil- and groundwater quality for some purposes. Qualified indicators are to be defined in the development of the level II monitoring programme.

The classical tool to assess the multiple interacting effects in forests are multivariate statistics: the data sets consists of a lot of variables, which are known to interact, and the constellation of the parameters within a set of variates provides an access for assessing process relations. The structure within the data set lead to conclusions on the causes of observed phenomenons. Multivariate statistics, and their combination with geostatistics, were successfully applied in the combined project and they are further recommended.

Evaluations: modelling

Simulation models are tools to approximate reality and to test hypotheses on cause-effect-relations. They are also tools for the prognosis of ecosystem development under the influence of changing environmental conditions or management strategies. In this sense they are technological models and represent an important link between science and practice (Hauhs 1990). To some extent they have also the characteristic of ‘‘communication tools’’ between science and practice.

Model results are only as good as the available input data. Model results indicate that the fate of nitrogen in the ecosystem is still an important factor, and an unsolved problem. The fact that the comparison ‘‘modelled versus measured’’ nitrogen data is often insufficient, indicates that the regulation of some processes is not fully understood, and/or certain nitrogen fluxes (e.g. in the gas phase) were overlooked. In this respect, further measurements on intensive plots and research are needed, but also more communication between modellers and ecologists regarding model structure and interpretation of the results. The further development and improvements of simulation models is a permanent task. The recommendations of van Grinsven et al. (1995) are still valid: (a) the representation of hydrology, biogeochemistry and forest growth should be balanced, (b) long-term integrated field monitoring programmes should be continued, and (c) models and field data sets need better documentation.

Parameters assessed

The course in time and the pattern on the large geographical scale reveal information on causes for observed changes. It could be proven, that the results of dendroecological analyses, if available, have a high conclusiveness for some lines of arguments (e.g. the tree growth and climate, element analyses in tree rings and site history). This holds also true for other time series analyses (leaf/needle loss). Regarding the pattern of development on the large scale there are too much ‘‘missing areas’’ and completion seems meaningfull.

Obstacles for evaluations arise further from:

(1) The temporal non-integration of the explaining variables: if the monitoring data like element concentrations, and explainig variables like weather are not sampled annually or in the same time step, their potential value is greatly reduced.
(2) The non-compatibility of data between the monitoring systems: the application of transfer functions from level II to I is reduced, if the relevant parameters in both systems are sampled and analysed with different methods. This concerns e.g. the forest floor humic layer, which is a simple basic parameter with indicative value. Harmonization of methods and synchronization of assessments are urgently needed.
(3) Differences in assessment methods between the German federal states (e.g. forest floor vegetation and humus layer stratification) reduce the comparability of results and hinder large scale analyses.

Regionalization

The two ‘‘classical dilemmas’’ of the two-stage-monitoring system are the transfer problems between scales. To overcome these shortcomings regionalization efforts are necessary, but no standard methods for ecological purposes are available. For different aims different methods are necessary. Tests were successfull, and promising results on regional scales are available.

The main hinderances for regionalization arise from the non-compatibility of the ‘‘common denominator’’ data between the levels I and II data sets, e.g. soil solid phase characteristics, element contents in leaves/needles, in terms of: different assessment methods, different sampling (e.g. depths in soil layers), and unsynchronously sample intervals (see above).

Data management

One aim of the environmental monitoring in forests is the provision of environmental information. These information are needed for scientific evaluations, the support of political decisions, and increasingly for reporting duties in the framework of international agreements. An important prerequisite of this tasks is the permanent availability of adequate data.

The experiences of the combined project shows, that due to heterogeneous data bases and improper data management in the past for each project considerable additional work arose. On the other hand, it could be shown that it is possible to establish and implement a unified data management system, which is able to store level I and II data and provide the scientists with all data used for the evaluations. For frequently occuring evaluations algorithms were implemented. This means not only a saving of labour, but also an enhancement of the resulting quality. The data management system was sucessfully tested in three German federal states and other federal states indicate interest in the system.

In future a long term strategy is required to guarantee the availability, interpretability and security of data. This includes the cooperation of data management experts with scientists, and a joint investment in the data management in common activities of the German federal states.

Outlook

The environmental monitoring in forests provides an important infrastructure and possesses a high information potential. It is the basis for manifold evaluations and it is flexible and upgradable. It is possible to assess still lacking information for these plots, which is needed in future. This enables the adoption of new tasks. In general, the monitoring systems provides information on the present state of the forests as well as basic data for prognosis of ecosystem behaviour and forest planning under the influence of changing environmental conditions. Such ‘‘multiple usage’’ of the monitoring system is only realistic under the precondition of an open monitoring scheme (Wolff 2002).

However, it must be taken into account where the core competence of the forest monitoring is: It is not possible and not necessary to measure all parameters, which perhaps become important in future. Co-operation with relevant services, environmental authorities and with research institutions becomes increasingly important, in order to fulfill new and more tasks.

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Appendix

The structure of the German case study

Participating institutions in the IFOM project are (a) the federal research centre for forestry and forest products (BFH), (b) forest research institutions of the German federal states, as well as (c) university institutes, and (d) the German environmental agency. In the sub projects (SP) various forestry disciplines closely cooperated. In Fig. 2 the sub projects and their position in the whole project are presented. The evaluations can be divided into the fields "cause-effect-relations" and "regionalization", but there are many transitions and overlapping tasks. All sub projects are assigned to at least one thematically item.

The coordinating institution is the Institute for Forest Ecology and Forest Inventory of the Federal Research Centre for Forestry and Forest Products, located in Eberswalde. The task of the project coordination (SP 1) is the acquiring, documentation and distribution of external data, the organisation of status seminars and reporting. Together with the other project partners, the synthesis of the results, and the formulation of the recommendations is the final task of SP 1. In the project "data management" (SP 2) a unified data management system for the storage of all environmental monitoring data was developed, including the implementation of algorithms for frequently occuring evaluations. The permanent cooperation with forest scientists from the other projects is essential for this.

In SP 3b the suitability of the inclusion of growth data in the large scale monitoring (level I) was tested. The subject of the associated project 6b, funded by the "Federal Agency for Agriculture and Food", was the simulation of growth and vitality. Using the model BALANCE growth and vitality of single trees of different level II plots were calculated on the base of physiological processes. The evaluation of nutritional development types was in the focus of the SP 7b, with the aim to bridge gaps in time series and to transfer the results to the large scale. The special focus of SP 4 was the test of various geostatistic and multivariate methods for the regionalization of environmental data. The—in some aspects—more dense monitoring net in Baden-Wuerttemberg, compared to entire Germany, provides the opportunity for this. The associated project "Integrated evaluation of forest monitoring data with multivariate methods" (financed by the "Federal Agency for Agriculture and Food") deals also with the calculation of regionalization basing on the forest condition types or deposition. In SP 5 data from the level II monitoring were screened and evaluated in order to elaborate a strategy for integrated evaluation based on potential stress for forest trees.

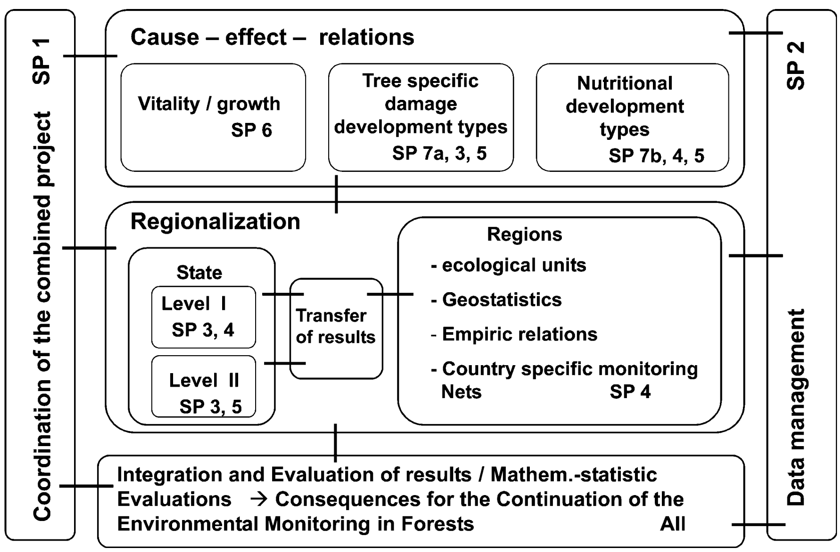

Fig. 2 The position of the sub-projects (SP) in the combined project "concept and feasibility study for the integrated evaluation of environmental monitoring data in forests (IFOM)"

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