Geographia Polonica
Volume 85, Issue 2, pp. 47–55
http://dx.doi.org./10.7163/GPol.2012.2.10

INSTITUTE OF GEOGRAPHY AND SPATIAL ORGANIZATION
POLISH ACADEMY OF SCIENCES
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http://www.geographiapolonica.pl/

THE BASICS OF SUSTAINABLE FOREST MANAGEMENT IN FOREST PROMOTIONAL COMPLEXES[1]

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Abstract
The intent to create Forest Promotional Complex (FPC) was introducing a new quality to Polish forestry – by taking into account social preference for forests, by embracing local community needs, by compromising forest production with nature protection and to introduce the rules of sustainable and balanced forest development. Main subject of this study is a dead wood and its ecological functions in managed forests and chosen FPC reserves. The problem of 'naturalization' or 'ecologisation' of forest management is discussed.

Key words
forest management • closed to nature forestry • dead wood • Forest Promotional Complex

Genesis and framework of the project

Forest Promotional Complexes (FPCs) were an important element of Polish forestry in the 1990s. They were established in accordance with Decree no. 30 (DGLP 1994) issued by the General Director of State Forests, and were further supported in 1997 in a government document. According to Decree no. 30 (par. 2 p. 5), one of the basic goals of the FPC is to "conduct forest research and experimental practices in order to draw conclusions about the possibility and conditions of wider employment of eco-development in all areas under State Forests' supervision". FPCs are also described in the Forest Law (MOŚZNiL 1991) as important tools when implementing a forest policy "of promoting a sustainably balanced forest economy and protection of natural forest resources" (Art. 13b p. 1). As the Forest Law states, Forest Promotional Complexes are "functional areas of ecological, educational and social importance, where all activities are defined with a unified economy-management program" (Art. 13b p. 3). A Forest Promotional Complex (FPC) means (Kapuściński 1997: 8): "a larger, possibly dense

[1] The paper is based on a publication "On the forest economy in Forest Promotional Complexes" (Rykowski 2005). It was a synthesis of research carried out within the framework of a project named "The basics of sustainable forest management in Forest Promotional Complexes", under the auspices of the Forest Research Institute in the period 1999-2003. The project consisted of 21 research tasks undertaken by independent authors, or research teams – 45 specialists in total from 8 different research units. The final full-length research reports can be found in the library of the Forest Research Institute. A team of authors supervised by Prof. Alicja Breymeyer, with Prof. Marek Degórski, Assoc. Prof. Jerzy Solon, Assoc. Prof. Ewa Roo-Zielińska, Dr. Jacek Wolski (Institute of Geography and Spatial Organization Polish Academy of Sciences, Warsaw) finalized the task: "Dead wood and its ecological function in managed forests and forests reserves within selected FPCs".

forest area, encompassing one or several forest districts, designated for promoting pro-ecological state forest management. FPCs are comprised of whole forest districts; rarely are they smaller, selected district areas. Thus FPCs are functional units, without a separate administration, which is handled (under State Forest supervision) by a regional forest directorate".

FPCs were established in order to undertake the following responsibilities (Kapuściński 1997: 8):

1. "a multi directional research on the state of forest ecological associations;
2. permanent preservation or recreation of forests' natural values;
3. integrating sustainable forest management and forest protection;
4. promoting a multifunctional and balanced forest economy using financial support from both national and foreign sources;
5. conducting forest research and experimental practices in order to draw conclusions about the possibility and conditions of the wider employment of eco-development in all areas under State Forests' supervision;
6. training the Forest Service and educating society."

"Rules for breeding-protection practice" were separately developed for each FPC, all of which focus on (Kapuściński 1997: 8):

- "preserving the whole diversity of forest nature as well as the functioning of forest ecosystems in their most natural possible state,
- restitution by active breeding and protection of the forest and natural enclaves degraded and deformed, in order to reconcile biocenosis with biotop, encouraging natural succession wherever possible,
- protecting the biological diversity of wild plants, animals and microorganisms as well as preserving their genetic diversity,
- strengthening the positive influence of forests on the natural environment and harmonizing the social and economic development of the region by rational management and renewal of forest resources, without lessening their production potential."

In the period 1995-1996 ten Forest Promotional Complexes were created; in 2001 the eleventh FPC, Lasy Birczańskie, was formed; and this was followed after the research program was completed by two more FPCs: Lasy Spalsko-Rogowskie (2002) and Lasy Mazurskie (2003). To date (2012) there are a total of 25 Forest Promotional Complexes covering a total area of over one million ha (about 10% of the total forest area under the management of State Forests).

A secondary intent behind the creation of the FPCs was to introduce a new quality to Polish forestry: by taking into account the social preference for forests, and by embracing local community needs. Furthermore, through education and the documentation of simultaneous forest production and nature protection, foresters are to break through the obvious growing isolation of the forest sector, thus responding to the pressures of widening social circles.

A pro-natural forest policy has in many places surpassed the technical abilities and technology used at the operational level – a gap has, therefore, emerged between policy and practice, which is a consequence of insufficient scientific research.

The first necessary condition to achieve success for any country willing to introduce the rules of sustainable and balanced forest development is a willingness to invest in forest research and to acquire new knowledge and operational tools.

Existing and future threats to forests, and the need to introduce new operational and technological solutions (as stated in the dispositions for forest management on an ecological basis, see: DGLP 1995), as well as insufficient knowledge, have all created a need for research and a broader knowledge of forests, especially in areas insufficiently penetrated by forest science, like the ecological-economic area and the social aspects of forestry.

With this, the necessity to monitor the aftermath of system changes, economic decisions and outcomes of forest policy appeared, in order to create the necessary expert opinions and development plans.

New *versus* previous forest management methods

The current state of knowledge concerning sustainable and balanced forest management is insufficient both in practice and theory. It is impossible to reconcile the nineteenth century concept of "permanent profit" or "permanent production", with the modern idea of a "sustainable and multifunctional forest economy". It seems that the differences between these two concepts are too

deep, and are of a structural nature; they are also derived from different moral and ethical concepts of nature, and are derived from a newly adapted methodology. In European conditions we might be able to talk about the evolutional character of the changes that have occurred in the approach towards forest management. Even here, however, it is not possible to introduce the rules of sustainable and balanced management based on the multifunctional nature of forest ecosystems, while holding on to the theoretical and instrumental base of "forest stand" oriented forestry.

None of the existing technical-management documents, such as the Forest Management Instruction or Forest Breeding Procedures, tries to elaborate on the short definition of the *sustainably balanced forest economy* which is mentioned in forest law. The legal definition is taken straight from the H1 Conference in Helsinki, where the term Sustainable Forest Management is defined in exactly these terms. What is open to discussion is whether the term *sustainably balanced forest management* stands for the same things as the English notion of Sustainable Forest Management. The Polish translation of the terms balance and sustainability as presented in the legal documents widens the range of those terms to encompass the whole of the forest economy, while the original only mentions the management of the forest itself. A forest can be managed in a sustainable and balanced way; it is, however, much harder to have a sustainably balanced forest economy, which is a much wider term than forest usage and management and is influenced by external factors, such as the market.

In the new formulation of the definition of sustainable development, the terms of sustainability and balance cannot be, in the case of forest management, limited to the continuous usage of the forest, or to continuous revenue from the balance between wood production and new growth. Neither of these terms can be reduced to the algorithm of function optimization, meaning designating levels of function fulfillment based on forest stand structure. Such an understanding of sustainability and balance was already present in the normal forest model, which pointed to the necessity of balance in surface forest age structure as a condition of forest sustainability, usage and revenue. As we know, the outcome of this particular way to balance the economy and sustain forest ecosystems was rather unappealing.

Is *sustainable and balanced forest development* a new concept for forest economy, or just a propaganda slogan?

There seems to be two main ways of understanding this problem among foresters. For some it constitutes a new challenge and an idea recently formed as a result of pressure stemming from new social expectations and sometimes heated discussion on the state of the forests (see: forest decline in the 1980s in the discussion below). This was also stated in Rio de Janeiro in 1992, and thus produced an unofficial division between "raw material" forestry and the "ecological" approach to forest management. For the second group, beneath the terminology are the hidden problems of sustainability and balance in the forest economy, which were long ago solved by the German school and put into practice when their management plans were created. This contemporary new terminology brings nothing new to the subject, with the exception of this "ecological" noise.

Such polarization is visible especially among specialists in management, economics or forest breeding, where one group follows the first notion, speaking of the sustainability and balance of forest ecosystems, and the need for spreading management practices on all possible interconnected elements of the forest ecosystem; whereas the second group would rather rely on the economic sustainability of the forest, and ensure sustainable growth and income, reducing the defined area of the forest to merely that of the forest stand and its parameters. Many of the forest breeding rules are derived explicite from the notion of constant forest coverage of a given land area (the idea of a sustainable forest area) and implicite from the notion that sustainable growth and the forest area are enough of a guarantee for the sustainability of all forest functions, both goods and services (the "water under the keel" theory).

Emerging from the traditionally understood multifunctional forest economy are three separate categories of forestry: peri-urban forestry, plantation forestry (cultivated forests, planted forests, forest plantations) and close-to-nature forestry (PRO SILVA). In Poland we talk about semi-natural forest breeding, or an ecological model of the forest economy (Bernadzki 1991), pro-ecological forestry or ecologisation of forestry (Rykowski 1989a, b, c, d, e, 1990). There have also been single attempts to form rules for closing forestry to nature (see: DGLP 1995, 1999), or "Criteria for

natural forests" (Rykowski 1995) or "Criteria and indicators for a sustainable and balanced forest economy" (Rykowski 1994). The works mentioned above, however, are mainly based on the projection of contemporary knowledge and more or less accurate deduction, and not on proper statistical analysis or field experiments. A similar level of knowledge can be observed in other countries. Forest Promotional Complexes are of special usefulness when it comes to research projects. Until now, no wide scale interdisciplinary research has been conducted in this area.

Main presumptions in the research

The overall goal of the project was to create the basis for a multifunctional forest economy in order to manage the economic, natural and social values of the forest. Among the more detailed goals were:

- ensuring the sustainability of forest ecosystems and continuity of the usage of their resources;
- learning about the range and intensity that the impact of different forest management methods have on naturally valuable elements of forest biocenosis;
- sustainable preservation, restoration and reproduction of ecological processes, including investigating the role of dead wood in the forest.

The research parameters for the study was spread across four forest sectors: management, breeding, protection and usage of the forest, and these are presented in the context of a wider set of problems concerning the role of man in the general usage and protection of nature, and the impact that such activities have on the overall environmental condition. The proposed research themes were interdisciplinary, and were further broadened to include non-forest related areas (sociology, psychology, philosophy). The project included problems that had an economic, social and environmental nature, as well as those of nature protection, breeding problems and multi-directional forest usage. These are common issues shared by all the Forest Promotional Complexes.

The short three year deadline for the goals excluded planned experiments, especially in breeding, protection and usage of the forest. Some of the tasks, as there were no other means to perform them, reached out into the natural-economic past of the forests in question, and drew conclusions from previously established research areas and accumulated knowledge, relying on expert methods. Some of the tasks required filling forms and asking questions.

There were three main methodological assumptions in the research of forest rural areas (Kołodziejski et al. 2003), that were important for the whole project:

1) In the constant and long-term process of structural transformation, the development should be sustainable, stable and balanced; this development should be self-propelled and able to thrive; it should be able to fulfill the needs of the current generation and not restrict any potential needs of future generations.
2) Every socio-economic activity of man is taking place in a given geographical area. This space can be divided into: natural (ecological) space and managed space (anthropogenic in the physical and social-economical meaning).
   In the process of the transformation of geographical space, society makes decisions in relation to the management of the entity, based on its values and goals (strategic, operational, formed at any given time) and criteria, that impacts upon both the natural space and the anthropogenic portion of the space in the given area.
3) The mainstay for sustainable and balanced forest management is forming a spatial harmony, conditioned by processes of socio-economic development and changes in the natural environment, which together create a better quality of life, effective management and improve the natural environment.

Dead wood and its ecological functions in managed forests and chosen FPC reserves

One of the most controversial problems in the forest economy, especially in view of its approach towards "ecological" forestry, is the need for the presence of dead wood in a managed forest (see: DGLP 1995). Dead wood serves many ecological functions, such as: providing conditions for the development of many life forms, e.g. bacteria, fungi, moss, etc; large dead trunks are often a great hideout and food storage for animals; it preserves moisture in the forest bed and soil and acts as a buffer for moisture conditions. The most important role it performs, however, is storing organic matter. Because of humification and

mineralization processes, it is one of the prime sources of organic carbon, and is indirectly an important link in the chain of carbon circulation in forest ecosystems. The above assumptions formed the basis for formulating methods of measurement and the qualification of dead wood and its functions in managed forests and chosen FPCs.

Four Forest Promotional Complexes were chosen for research, and this was undertaken by a team led by Prof. Alicja Bremeyer – FPC Bory Lubuskie, FPC Bory Tucholskie, FPC Puszcza Białowieska and FPC Lasy Puszczy Bukowej i Goleniowskiej. Geobotanical analysis, taxonomic diagnosis of the soil and hums layer according to Polish Soil Systematics (Polskie Towarzystwo Gleboznawcze 1989) was conducted in all the research areas, along with the physical and chemical properties of analyzed soils. The collected data were used to assess the site potential of a given FPC and its influence on dead wood decomposition processes (Breymeyer et al. 2003).

A great deal of attention was given to the methods of measuring dead wood in forests (methods of assessing the amount of dead wood in forests were developed and published as part of the project – Wolski 2003).

The problem of dead wood is closely related to the problems of "naturalization" or "ecologisation" of the forest economy. The main factor that defines a natural forest stand is that all the biomass production stays in one place. From this angle, managed forests – in other words used forests – will always be inferior to natural forests. The larger the amount of biomass left intact in the forest, the closer to its natural state this forest becomes (Breymeyer et al. 2003). Detailed solutions to this approach, however, impinge onto the grounds of forest policy and forest protection.

The presence of dead wood in the forest still causes heated emotions and mixed opinions. From one point of view, it is the single most important indicator of the forest's naturality (Brzeziecki et al. 2003), from the other, it is an important source of carbon emission in the cycle of CO_2 absorption by forest ecosystems (Galiński 2005), as well as a controversial factor in creating biotic threats (insects, fungi) to forest stands, while at the same time being a contributing factor to the buildup of environment resistance to these very threats (Gutowski et al. 2003).

The ongoing change in forest management policy rules requires the development of a new approach towards leaving dead wood in the forest. When creating new guidelines for "naturalization" or "close to nature forestry", or promoting "natural forest breeding", one has to take into account that today in managed European forests the average amount of dead wood available per ha varies between 1-5% of the amount present in natural non-managed forests. In practice, in most managed pine forests within our climate zone, the volume of the biomass does not exceed 3 m^3/ha, while on 1 ha of a natural forest it varies from 20 m^3/ha in the boreal areas of Northern Europe, through to 120 m^3/ha in more moderate climates (Puszcza Białowieska), and up to 500-1,000 m^3/ha in the beech-fir-spruce forest of eastern and central Europe. At the same time we can observe the growing acceptance for viewing dead wood as an indicator of the degree of naturalness of a forest or whole forest economy, and one of the general indicators of species diversity within forest ecosystems, along with measures like the size and shape of particular areas or type of undergrowth (Breymeyer et al. 2003).

Regardless of the origin of dead wood, its shape and quantity in the forest, we can speak of the four main functions it serves:

a) it modifies site conditions;
b) it has a direct and indirect influence on species diversity and general well-being of some animal and plant populations;
c) it has influence on site conditions and biological diversity in waterways and water reservoirs;
d) it takes part and influences the process of element circulation in a forest ecosystem.

Within dead wood, specific biocenotic ties develop, that allow for the sustained existence of many species that depend on each other. The presence of rich fungi colonies on dead wood is necessary for undisturbed matter circulation in the forest. In proper conditions, over 20% of micorrhyza fungi, which are crucial for coniferous trees' development, dwell on dead wood. Along with the bacteria absorbing nitrogen, they provide between 0.3–1.4 kg/ha/year of nitrogen in a form suitable for plants. In the early stages of dead wood decomposition, the amount of nitrogen, potassium and phosphorus in fungi fruit bodies is respectively 38, 115 and 136 times higher then in decomposing trunks. These spores are either eaten directly or fall to the soil; either way these elements are returned to circulation (Breymeyer et al. 2003).

A separate question is posed when considering the role of dead wood as a substrate for new tree growth. This function has been raised many times, and it is particularly important for coniferous forests, and even more so in pine and spruce forest stands.

Some of the interesting relationships between dead wood and the amount of seedlings are worth considering:

- the amount and success rate of seedlings correlates with the size of the gap in the forest stand, which is created when a tree falls;
- the higher amount of seedlings on dead wood trunks is explained by competition for territory versus moss and weed plants, although a positive correlation was found between the amount of moss area and the amount of seedlings on dead wood;
- the higher amount of seedlings on dead wood trunks is also derived from specific microclimatic conditions: a longer period without snow and more moisture in the substrate in comparison with soil;
- the higher amount of seedlings on dead wood trunks is also explained by the easier conditions to sprout than in undergrowth;
- the higher amount of seedlings on dead wood trunks is also related to the higher fungi presence, which on the one hand decompose the substrate, and on the other become part of the mycorrhiza complex.

Vertebrates use dead wood as:

- a place to give birth,
- shelter from weather and predators,
- a food source or food storage,
- travelling paths above dense undergrowth,
- construction material used elsewhere,
- a temporary (winter) place to live.

Among all the vertebrates, the most closely tied to dead wood in terms of their everyday environment are small mammals: rodents, insect-eaters and some predators.

Decreasing the amount of dead wood present in a managed forest by 90-98% in comparison to those that are natural, will bring a 50% decline in the variety of vertebrate species within the next couple of decades (Breymeyer et al. 2003).

Forest Promotional Complexes, being both under protection and management, ought to have a special policy regarding the amount and quality of the dead wood left in them. In order to draw guidelines for such a policy, factors like the pace of decomposition in a given climate, site, and economic conditions need to be considered.

The first stage should be to try to establish the amount of dead wood that should be left in the forest. It is a difficult task both from the scientific point of view (no interdisciplinary research has been done in Poland on the general role of dead wood), as well as mentally (to stop thinking about dead wood in terms of economical loss, the increased threat of fire and a breeding place for disease and vermin). The decision as to the exact amount of mass to be left behind should not be arbitrary, and should be derived from detailed research that concentrates on two areas: (a) what amounts of dead wood are naturally present in non-managed forests of different types and the different regions of Poland, and (b), what are the minimal requirements for the quantity of dead wood as required by the natural processes of stabilizing a forest ecosystem. These should be accompanied by research into organism dwelling on dead wood and their ties with other components of the forest ecosystem.

There are significant relationships between the quantity, spatial dispersion and the mass volume of the dead wood and forest stand age. It seems that a fundamental role is played by the development phases, which determine the forest stand life cycle.

In this research the theoretical part was developed by describing a modified method of Brown, which is used to measure dead wood in the forest (Breymeyer et al. 2003). Measurements show that the most dead wood is present in FPC Puszcza Bukowa – 86.29 m^3/ha, the second largest amount is in FPC Bory Lubuskie – 12.12 m^3/ha; FPC Puszcza Białowieska is perceived as being the most natural but only had 6.02 m^3/ha of dead wood; this was just a little more than FPC Bory Tucholskie which had 5.11 m^3/ha. This highly formalised method might form the basis for dead wood monitoring when undertaking large area forest inventories.

In addition to this dead wood evaluation, measurements in the rate of decomposition of the undergrowth, taxonomic soil diagnosis along with its physical and chemical properties, and the geobotanical characteristics of researched areas were carried out. With three of the sites having a similar rate of undergrowth decomposition (a little above 30% per year), an unusually high decomposition rate of 50% stands out, recorded in the coldest area of Poland, in Browsk (Puszcza Białowieska).

It is worth noting the warmer climate in this region in the last few years (significantly warmer winters). Differentiation in the gatherings of biomass (biomass of the undergrowth and bushes) reveal a strong patch-like differences of the researched objects, especially in the bushes layer. The biomass differences of neighbouring sites were up to ten times as much (Browsk: 22,075 g/100m^2, and those adjacent to it eight times, 526 g/100m^2) (Breymeyer et al. 2003).

Phenomena usually perceived as connected with dead wood presence, such as secondary pest activity and fire threat, are as dangerous as was commonly acknowledged in the past. Caring for the sanitary condition of the forest must not mean being blind to the positive influence of dead wood on the forest ecosystem as a whole. The fact that countries like the USA, Canada, Germany, the Scandinavian states and recently Russia are interested in this issue only confirms these notions.

The reason for the appearance of dead wood in managed forests, alongside abiotic factors (wind breaks), is the activity of insects, especially secondary pests, and fungi disease. For instance, bark beetle (*Ips typographus* (L.)) when it appears in numbers, finishes off the weakened trees, and sometimes these trees can seem perfectly healthy. Along with accompanying species, it causes increased production of standing dead trees. In recent years, the mass appearance of this species was observed in the Wigierski National Park and Puszcza Białowieska, as well as some mountain forest stands. Hastily cutting "infected" trees during the vegetation period causes much damage in other elements of forest ecosystems. And not cutting the trees at all – according to foresters – has a negative impact on the sanitary state of the forests (Gutowski et al. 2003).

According to forest administration, spruce patches within protected areas are like breeding places for bark beetles, causing damage to neighbouring forest managed forest stands. Many ecologists and entomologists have different views on this matter. Neither of those hypotheses were ever thoroughly verified.

The influence that forest reserves have on a managed forests and vice versa, as for cambio- and xylo-eating insects, and the impact of that relationship on tree development is very differentiated and rather low.

Research on insect migration between managed forests and forest reserves carried out in Primeval Puszcza Białowieska Forest and Primeval Puszcza Augustowska Forest have not proved that there has been one significant migration direction of bark beetles and other insects. The amount of insects travelling in both directions between the forests was similar in the case of both research projects. In both projects a great difference in scores was noted depending on the year that the data was collected.

The most important factor here is the tree's predisposition for settling in, and not the number of flying insects. And one should note that due to human intervention, disturbance in tree physiology happens more often in managed forests than in natural ones. Moreover, along with removing dead wood and the unwanted cambio- and xylo-eating insects, their natural enemies are also being destroyed. That is because under the bark one can find parazitoids and predators feeding on beetle bugs. Removing such trees, as one of the elements of the strategy against the bark beetle, may have the opposite effect to what was intended.

Strict forest reserves are a source of useful insects for the forests in surrounding areas because in most cases these insects translocate from natural forests towards managed ones (*Histeridae, Elateroidea, Monotomidae, Nitidulidae*). In forest reserves (in close proximity to natural forests) there are a larger number of predators and parazitoids and it has also been observed that they arrive more quickly at the feeding grounds of cambiophages than in managed forest. As an outcome, the natural resistance of the environment is more effective in a forest where there is the constant presence of dead and dying trees, which create a dwelling space for these antagonists, the bark beetle among others (Gutowski et al. 2003).

Clearing out or leaving dead wood does not significantly influence the appearance of new trees – and in some cases, as various observations and papers suggest, they may limit the amount of dried matter. Moreover, leaving active dried matter on the trunk may (when one calculates the temporary risks) improve the process of forest naturalisation (Breymeyer et al. 2003)

Another indicator of ecosystem naturalness may be the species composition of saproxylic beetles, a model group that may be used to assess forests. Keeping large dead wood chunks and protecting hollow trees increases the biological diversity of this group (Breymeyer et al. 2003; Gutowski et al. 2003).

The assessments that were carried out allow for the preparation of a model of instruction for such assessments when doing an inventory or monitoring an area. The proposed indicators may be used to assess the natural values of forest ecosystems. Forest Promotional Complexes may become the benchmark for comparison with protected areas and managed forests. Biological diversity, assessed with the proposed indicators, may be an indicator of dynamic balance and the rate of change in forest ecosystems.

Conclusions

Below are the final conclusions reached by the team lead by Prof. Alicja Bremeyer, which can be found in the final synthesis of the research, passed for presentation in newly formed technical-management document of State Forests:

1) There is a need to verify the role that dead wood plays in a managed forest. On the one hand, it is the most important structural indicator of the degree of naturalness and biological diversity of a forest ecosystem; on the other, it is a carbon emission source, and as such negatively affects the carbon dioxide absorption balance of forests, and there is some controversy over whether it is a factor that increases biotic threats (insects, fungi), while at the same time, helping to build-up environmental resistance to these very threats. We can speak of four main functions it serves:
   a) it modifies site conditions;
   b) it has a direct and indirect influence on species diversity and general well-being of some animal and plant populations;
   c) it has an influence on site conditions and biological diversity in water ways and water reservoirs;
   d) it takes part and influences the process of element circulation in a forest ecosystem.
2) Within dead wood, specific biocenotic ties develop which allow for the sustained existence of many of the species that depend on each other. Special attention must be paid to the role of dead wood as a substrate for new tree growth in the process of natural succession. This role is of much more importance in coniferous forests, and even more so in pine and spruce forest stands.
3) There is a need to undertake an inventory of all dead wood in the forests and work out a separate strategy for managing dead wood in a production forest. For this purpose, the modified through research method of Brown may be used. This method might form the basis for dead wood monitoring when doing large area forest inventories.

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Article first received • January 2012
Article accepted • June 2012