Sino-German Symposium 2006

The Sustainable Harvest of Non-Timber Forest Products in China

Strategies to balance economic benefits and biodiversity conservation

Symposium Proceedings

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PREFACE

Non-timber forest products, or NTFPs, include a large variety of products. In different regions different products are relevant. In China, most prominent are medicinal plants; several thousand plant species form the basis for the traditional Chinese medicine. Many other products are important, for subsistence of the rural poor or even for high value and high revenue export, such as the Matsutake mushroom which is exported mainly to Japan. Only few products, though, like rattan and bamboo, have a huge industry behind them, and have correspondingly been researched intensively. That research lead also to domestication and the establishment of plantations which has taken away to some extent the pressure on the natural resource. Other NTFPs, however, are being over-harvested, some are even regionally extinct. Given the huge number of species harvested, utilized and traded, NTFP management becomes also a biodiversity conservation issue.

The state of knowledge of and research about different NTFPs is extremely unbalanced: much is known about some, and close to nothing about others. NTFPs and their sustainable management for biodiversity conservation constitute a multi-facetted complex system. The challenges are manifold. We are convinced that they can be tackled best by efficient and trustful cooperation of experts from different disciplines and different regions. That was the reason why we convened a first Sino-German Symposium at Georg-August-Universität Göttingen, Germany, 13-17 March 2006, inviting about 10 experts from different research institutions in China and 10 from Germany.

This Symposium was an excellent opportunity to bring together research groups from different institutions of China and Germany – and it is expected that it was the starting point for promising future cooperative activities.

Figure 1: Participants of the Sino- German Symposium 2006 in Göttingen

In this proceedings volume, the presentations given at the Symposium are compiled together with a summary of the final discussions outlining promising future paths of joint research.

An International Symposium like this one can only be organized with the active and proactive support by many. We are indebted to Mr. Haijun Yang, Ms. Marion Hergarten and Mr. Torsten Sprenger for their excellent role in facilitating the smooth flow of the Symposium. Mr Sprenger deserves particular thanks for his efforts in putting together the manuscripts for this Proceedings Volume.

The Sino-German Center for Research Promotion in Beijing, a cooperation between the German (DFG) and the Chinese Science Foundation (NSFC), made the Symposium possible through its financial support. We express our sincere thanks for this support and also for the fact that a high ranking staff of the Center, Dr. Zhao, gave us the honor to deliver the opening address for the Symposium.

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Compiled by: Christoph Kleinn, Marco Stark, Yang Yongping, Horst Weyerhäuser:

The overall goal of the envisioned research cooperation between Chinese and German research institutions is to improve the knowledge base on the sustainable harvest and utilization of NTFPs for the benefit of the rural poor. We argue that the potential of the NTFP resources for this purpose is not yet fully realized and the respective strategies and policies not yet effectively implemented, or, that appropriate policies are lacking.

Truly trans- and interdisciplinary research is required. The large variety of NTFPs and their different characteristics and uses opens up a wide field of research covering various disciplines from natural to social sciences. Figure 1 illustrates the process' of policy formulation, starting with the assessment of existing data and the formulation of information needs; the provision of information and knowledge is an important research issue. The figure also shows the various disciplines involved.

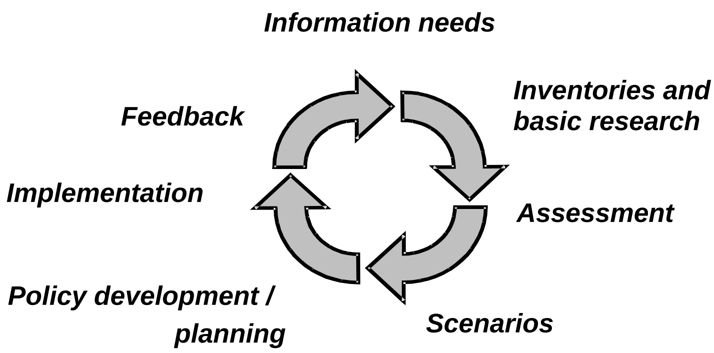

Figure 1. Illustration of the process of policy formulation for the sustainable management of the natural renewable resource "forest" (FAO 2000[1]) – which is directly applicable to the management of NTFPs. In each of the depicted steps, research questions from different disciplines arise.

The overall goal of the Sino-German research cooperation, as stated above, can only be attained by formulating regional or national policies that guide the sustainable management of NTFPs in an overall framework focusing on the sustainable use of the natural renewable

[1] FAO. 2000. Global forest survey concept paper. FRA Working Paper No 28. 41p.

resource "forest". Working towards this goal requires a long-term interdisciplinary research cooperation. During the symposium it was agreed that such a collaborative and integrated research project is the mid-term goal, and that the grounds for such an undertaking must be laid step by step in a preparation phase.

Such a preparation phase would include, above all:

1. the identification of specific research topics, as well as conducting smaller collaborative research projects of two to five years duration to answer some of these, and
2. the identification of more partners from relevant research institutions in both countries.

It was agreed during the symposium that specific projects will be proposed to donors in Germany and China (for example the DFG – NSFC program of joint specific research projects) in this year. Such smaller and more focused projects will have a number of advantages, such as;

- specific results can be achieved in a relatively short period of time,
- new hypotheses can be formulated that prepare the framework of a bigger collaborative project (i.e. not only pre-formulated research questions can be addressed), and
- the responsibility for preparing project proposals is distributed among many researchers from both China and Germany, thus exercising cooperative research in an efficient manner.

About one year after the first symposium, we intend to conduct a second workshop that marks the start of the preparation of a larger collaborative Sino-German research project. Designing a proposal for such an international and interdisciplinary research project is a complex undertaking, from a technical and from an organizational point of view. While we expect the research topics and associated methodologies to be well-defined after the initial one-year preparation phase, closer cooperation and direct interaction between Chinese and German scientists is required to bring the project proposal development forward. Therefore, a number of "bi-lateral" exchange visits within the working groups (by research topic) are envisioned before and after the second workshop.

TOPICS FOR SPECIFIC JOINT RESEARCH PROJECTS

During the workshop sessions, participants suggested potential project activities, including corresponding consortia. Potential sources of funding were also discussed. It was stressed that other instruments (i.e. other than focussed joint research projects) should also be used to foster collaboration and the development of joint research ideas. Among these instruments are short or medium term exchange visits of scientists, the exchange of students for internships and theses preparation, and summer schools. Specific plans have yet to be devised for these activities. InWENT, a German organization for education and international development expressed interest in cooperation with regards to longer-term visits of Chinese scientist to Germany.

In the following, specific research topics are presented for which the Chinese and German symposium participants expressed their interest in and commitment to developing more detailed project profiles over the next few months.

Topics are listed in the order as they were proposed during the symposium workshop:

TOPIC 1: DEVELOPING BIOMETRIC METHODS FOR THE INVENTORY OF MUSHROOMS

Various mushroom species are collected in Yunnan. Some of them have a high commercial value and are even exported overseas such as the Matsutake mushroom. While traditional knowledge exists about the productivity of selected mushroom species for specific sites and under specific overall conditions, there is no technique available yet allowing the sound estimation of the existing growing stock and potential yield. This research will focus on statistical techniques on a theoretical basis, but also on the applicability of such a method and its relevance in the context of developing guidelines for the sustainable harvesting of this resource.

Among the tentative research topics are: identification of relevant species and relevant research areas in general, the establishment of a link between plant communities and mushroom abundance as a starting point for modelling, and the identification of the general spatial distribution pattern of mushrooms as a function of different site factors.

Potential partners in this research topic are: Prof. Yang Yongping (KIB, CAS), Dr. Yang Xuefei (KIB, CAS) and Prof. Kleinn (Goettingen). More scientists at the Forestry Faculty of Georg-August-Universität Göttingen are potential partners, as there is a rich expertise on fungi research.

TOPIC 2: MULTI-PURPOSE TREES / MULTI-FUNCTIONAL TREES

Many tree species are a resource for more products and functions than just timber. Bark, leaves, fruits, root parts, etc. are tree products for which specific uses are known for a great variety of species. In addition, relating to topic 1, mushrooms are linked to tree species (mycorhiza).

Therefore, further developing forest management towards fostering and integrating multi-purpose tree species is an important research field. Specific topics include the identification of promising species and corresponding production types, the development of diversified production mechanisms in multi-species ecosystems and of optimal production types for simultaneous production of several products (e.g. fruit and timber), the development of inventory techniques for multi-purpose trees in the remaining natural stands (distribution, species composition, characteristics), the adaptation of silvi-cultural treatments in the context of close-to-nature forest management in those stands, and of harvesting techniques.

Potential partners are: Prof. Lu Yuanchang (CAF), Prof. Yang Yongping (KIB, CAS), Dr. Marco Stark (CMES, KIB/ICRAF), Prof. Dohrenbusch (Göttingen), Prof. Mussong (Eberswalde) and Prof. Phoris (Dresden).

TOPIC 3: SETTING UP A NTFP INFORMATION SYSTEM

NTFPs are a large and diverse group of products. An extremely valuable basis for all research and development work in this context would be a comprehensive information system in which the available relevant information is stored, amended and made available to interested researchers.

Each one of the project topics presented here will produce data inputs for this information system. Even though it is not a generic research project, it is nonetheless of utmost importance and requires a systematic approach to creating a comprehensive and useful knowledge base. Funding for this activity probably needs to be sourced from other agencies than those supporting research projects.

The Kunming Institute of Botany (CAS) might be the best host of such an information system.

TOPIC 4: PRODUCT LINE DEVELOPMENT

For most of the NTFPs not much is known about the product line (commodity/supply chain), i.e. from the harvest in the forest up to the end user. Detailed knowledge about transport channels, value adding, distribution of benefits, final uses etc. will enable the resource planners to improve NTFP management and harvest and identify improved and/or alternative market channels (including organic and fair-trade certification).

Research topics include the analysis and optimisation of the product lines for selected NTFPs, the analysis of the resource management (above all the evaluation of sustainable harvesting techniques) and the analysis of the “social resources” (market and income studies, cost-benefit-analysis). Particular interest in that context has been expressed for the products bamboo, pine-resin, nuts, mushroom and medicinal plants. This topic links to Topic 5.

We still need to identify more partners in the field of socio-economic research and market studies. Potential partners from among the symposium participants include: Dr. Lou Yiping (INBAR), Prof. Phoris (Dresden), Prof. Höfle (Göttingen) and Dr. Marco Stark (CMES, KIB/ICRAF).

TOPIC 5: SOCIAL SCIENCE ASPECTS OF NTFP HARVESTING

While much research on NTFP focuses on natural science research questions of growing stock and production potential, there are also very relevant social science implications which refer mainly to market issues, but also to policy issues when it comes, for example, to the regulation of user rights.

Research topics include conflict management (for example when collection habits conflict with regulations in protected areas), legal frameworks for endangered species (how are they implemented and enforced, and what are the driving forces in policy making), market analysis (commodity chain, who benefits most, the role of local collectors and middlemen, what institutions are concerned with benefit sharing? CB-analysis – this links to Topic 4), policy impacts on forest resource management and livelihoods of local communities, property rights concerned with NTFPs (in nature reserves for example). In this context, though not a research topic, also capacity building for local communities and government is an important issue (how does policy implementation differ from policy intention?)

Among the potential partners are all researchers among the participants who work in economics and policy, including Dr. Zheng Baohua (CDS, YASS), Mr. He Jun (CMES, KIB/ICRAF), Dr. Sikor (Berlin), Dr. Grossmann (Freiburg) and Dr. Krott (Göttingen). More partners among the Chinese scientists need to be identified and should possibly come from governmental and national level research institutions in China.

TOPIC 6: BAMBOO

Although bamboo is probably the most extensively researched NTFP (it is commonly considered a NTFP – although this may be challenged since commercial bamboo comes predominantly from pure bamboo stands), there are still many research questions, in particular with respect to determining the growing stock, sustainable yield regulations and optimizing silvicultural management practices.

Research issues include: the refinement of specific inventory techniques, in particular for tropical bamboo (Note: a link to ongoing INBAR activities is envisaged), monitoring and assessment of bamboo management strategies (including human impacts on biodiversity, and plantation vs. indigenous management), and management and sustainable harvesting schemes for bamboo from natural forests. The last issue refers to an integrated management approach (major challenge: replacement of forest for bamboo plantation) which includes the definition of criteria and indicators for sustainable bamboo management for natural stands and plantations and the development of monitoring mechanisms.

Interested research partners from the symposium include: Dr. Luo Yiping (INBAR), NN (KIB and Southwest Forestry College, China), Dr. Horst Weyerhaesuer (ICRAF). Prof Kleinn (Göttingen) and Prof. Phoris (Dresden).

TOPCIC 7: RELATIONSHIP BETWEEN MUSHROOMS AND MULTIPURPOSE TREES (*FAGACEAE* ETC.)

Given the high economic value of some mushroom species, one of the goals is domestication. While this has been successful for some species, it continues being a problem for others. Basic information for any domestication attempts are the site requirements. This research aims at the identification of these site requirements with a particular focus on the interaction between tree species and mushroom species.

This is a research topic which is combining aspects of Topics 1 and 2 and requires the matching of expertise in mycology, ecology and forestry. Mycology experts are to be identified, possibly from the corresponding research group in Göttingen.

TOPIC 8: HONEY BEES

Honey is an NTFP with large local importance. Compared to plant resources it has different attributes in terms of seasonality, spatial distribution and productivity. Information procurement will depend largely on interviews with honey seekers. Very little systematic research has been done so far on honey as a NTFP. Therefore, research needs to address basic issues, such as an inventory of the abundance of honey bee hives (habitat, abundance, status), the relationship between honey bees and plant communities (maize, barley, *Castanopsis* and other forest species) and the production of bee products (honey, propolis etc.), including their medical and nutritional properties.

Interested research partners from the symposium include: Ms. Jie Dong (IAR, CAS) and researchers from the Chinese Academy of Agricultural Sciences (CAAS); further partners need to be identified.

TOPIC 9: TREE LINE AND ELEVATION RANGE OF NTFPS

The spatial distribution of NTFPs with respect to eco-regions and elevation gradients is another open research question. Basic research would include the establishment of transects along an eco-region gradient and the identification of changes in biodiversity and diversity of NTFPs. This research would also include rural appraisals and interviews with the communities that harvest NTFPs. It will contribute in a very relevant manner to topic 3, the information system. Another important question that can be addressed by this research is how global change possibly affects the productivity and availability of NTFPs, i.e. this research topic does not only have a natural science, but also a strong socio-economic dimension.

Interested research partners from the symposium include: Prof. Yang Yongping (KIB, CAS), Dr. Horst Weyerhaeuser (ICRAF), and Prof. Dohrenbusch (Göttingen); additional scientists with expertise in vegetation sciences, ecology and socio-economy will need to be identified.

TOPIC 10: TRANSITION ZONES BETWEEN FOREST AND OTHER LAND USE TYPES

Although it seems contradictory to the definition of the term "NTFP" – these non-timber forest products are also found outside the forest. For example, tree bark and wild fruits harvested from non-forest trees are also considered NTFP. It is a general trend in forestry research to also recognize the tree resource outside the forest ('forest landscapes' or 'land use mosaics' at a landscape level) as a resource that is relevant from a forest and ecosystem utilization and management point of view.

The research questions include how the species composition changes along a transect that starts from the forest and extends into the open land, and whether a specific niche can be identified (with respect to various site factors) where the latter is an important issue also for domestication attempts.

Interested research partners from the symposium include: Prof. Lu Yuanchang (CAF), Dr. Horst Weyerhauser (ICRAF) and Prof. Kleinn (Göttingen).

CONCLUSION

The symposium achieved its goal of forming research partnerships and identifying specific research topics in the field of sustainable management of non-timber forest products. While a relatively great number of different institutions actively involved in research and development initiatives on the management of natural renewable resources, including NTFPs, were present at the symposium, more partners need to be identified in the process of developing the envisaged larger Sino-German research project. The symposium has been a gratifying opportunity to start the process of establishing and further developing the Sino-German cooperation in a field of research that has not only local and national importance, but is also of great regional and global value. We envision this partnership to develop into a long-term joint research initiative with the next two to three years.

RESEARCH ON NON-TIMBER FOREST PRODUCTS: A REWARDING SUBJECT FOR JOINT PROJECTS BETWEEN CHINESE AND GERMAN RESEARCH INSTITUTIONS

- A background paper -

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Non-timber (or Non-wood) forest products (NTFPs) are defined as goods of biological origin other than wood, derived from forests, other wooded land and trees outside forests (FAO, 1999); they include products used as food and food additives (edible nuts, mushrooms, fruits, herbs, spices and condiments, aromatic plants, game), fibers (used in construction, furniture, clothing or utensils), resins, gums, and plant and animal products used for medicinal, cosmetic or cultural purposes. Non-timber forest products have long been an important component of the livelihood strategies of people living in or adjacent to forest areas. Several million households world-wide depend heavily on these renewable resources for subsistence and/or income, and the FAO estimated that eighty percent of the population of the "developing" world use NTFPs to meet some of their health and nutritional needs (FAO 1997). However, NTFPs are seldom the primary source of household income, since their supply is largely seasonal.

A study by Jansen *et al.*, (1991) showed that nearly 6000 species of rain forest plants in Southeast Asia have economic uses. While over 150 NTFPs worldwide have been identified as significant commodity in international trade (the most important tropical products are rattan, brazil nuts, gum arabic, bamboo and spices) it is more difficult to quantify national trade, which may be very substantial (Tropenbos International (2005)).

NTFPs have attracted considerable interest as a component of sustainable development initiatives in recent years due to their ability to support and improve rural livelihoods while contributing to environmental objectives, including biodiversity conservation. The eco-friendly and people-friendly connotations associated with NTFPs have supported some products to fill in a niche in international trade: the small, but rapidly growing fair-trade market. However, despite this positive image, there is no guarantee of a beneficial outcome and the utilization of NTFPs requires the same measure of planning and control that is required for timber in order to be sustainable. Decisive factors in the sustainable use of NTFPs include government involvement, the ability of local people to claim and enforce use rights (NTFPs are in most cases openly accessible), market transparency and access, and pressure on the resource (Tropenbos International (2005). Higher value is often associated with higher harvest levels and more intensive management. Unlike the larger number of less valuable NTFPs, those with a high market value are often not harvested in a benign way, and many are lost to the poor as other stakeholders take over control.

Domestication of NTFPs can be a way to intensify production (through higher yields, improved and/or more consistent quality, and control over timing of harvest), secure producer rights and reduce pressure on wild resources. Its risk are that domestication of wild-harvested products can lead to genetic homogenization, reduce the economic value of wild systems (up to the point where natural forest land is being cleared to grow domesticated NTFPs on a larger scale) and lead to transfer of benefits from one group of stakeholders to another (Belcher, 2003).

Despite more than a decade of research and targeted development projects, systematic understanding of the role and potential of NTFPs in conservation and development (i.e. how to enlarge its benefits for rural communities and the environment) remains weak. This is especially true for China where research and development efforts have only recently addressed the issue of sustainable utilization of NTFPs. The rich variety of non-timber forest products in Southwest China, many of which have been used by people for centuries, has been well-documented by Pei (Pei, 1985; 1996), and Zu and Jiang (2001) to name just a few. Zu and Jiang (2001) point out that more than 6000 plant species growing in China are being used for medical purpose, among which more than eighty percent grow wild in the forest. However, the fast process of modernization, urbanization and globalization not only increasingly adds more entries to the list of extinct species (i.e. rapidly reduces biodiversity), but also leads to the gradual and irretrievable loss of indigenous knowledge on the uses of medicinal plants and other NTFPs.

Despite the rich knowledge on medicinal plants, past research and development efforts have rarely thought of setting up an inventory and monitoring system, nor have they addressed management issues related to these and other NTFPs in China. Only the Matsutake mushroom (*Tricholoma matsutake*) has gained considerable research and development attention due to the fact that its economic value has rapidly increased in recent years as a result of rising demand in Japan. This mushroom grows wild in the Northeast and Southwest of China and is sold fresh and dried in local and the domestic market, but the largest portion is exported to Japan.

Among the many non-timber forest products that are being extracted by rural households from natural and planted forests and plantations in the mountains of Yunnan province, mushrooms and medicinal plants (both in many species and varieties), as well as walnuts, pine nuts, wild vegetables, eucalyptus oil and honey play an important role in the household economy. Examples exist for institutional arrangements aimed at the sustainable utilization of NTFPs in communal forests for those products that are valuable (and thus threatened by over-exploitation), such as Matsutake. These are good examples to learn from and improve upon and as emphasized in FAO's State of the World's Forests (2003): "*if benefits are to be provided on a sustainable basis to local communities and to countries at large, more effective controls may be required to maintain populations of NTFPs at productive levels. The means to accomplish this will vary, but they must be built on sound economic and ecological principles, and often on traditional institutions*".

Since enacting a logging ban in all natural forests in China under the Natural Forest Protection Program (NFPP) in 2000, people that traditionally use forest products (i.e. wood and non-timber products) for subsistence and income needs, have seen their resource base diminish substantially. The Sloping Land Conversion Program (SCLC; enacted in 1998) has further reduced upland farmers' production options as SLCP land cannot be used to grow other crops in-between the trees, even when trees are young and leave plenty of space for intercrops. However, the use of NTFPs in natural or planted forests is normally not restricted so that they have been increasingly exploited without a long-term view towards their sustainable use. The World Agroforestry Centre (ICRAF) and the Forestry Department in Baoshan prefecture, Yunnan province have started a pilot project to assist smallholder upland farmers to domesticate selected medicinal forest plants with high commercial value. Since they are not considered as crop species, they can be grown on SLCP land. Increased household income and reduced pressure on wild resources are the prime benefits of such an agroforestry system.

ICRAF has been working closely with the Department of Ethnobotany at the Kunming Institute of Botany (KIB) since it started to build research ties with China in 1995. In 2004, ICRAF and KIB jointly founded the Center for Mountain Ecosystem Studies (CMES) to collectively work towards understanding the causes and effects of past and current landuse changes in biologically and culturally diverse mountain areas in Southwest China. Joint research has been conducted in Northwest Yunnan that aims to generate concrete recommendations for development and policy on improved community-centered natural resource management.

Northwestern Yunnan has become of particular research interest in recent years because the mountain watersheds harbor great biological and cultural diversity, and are one of just a few places on earth recognized as both a Global Biodiversity Hotspot and Global 200 Priority Ecoregion. The area has recently been declared a World Natural and Cultural Heritage site by the United Nations Educational, Scientific, and Cultural Organization (UNESCO). Northwest Yunnan (an area covering almost 70 000 km2) is home to more than 15 officially-recognized ethnic groups. These groups pursue complex livelihoods, based on a wealth of knowledge, beliefs, and institutions for maintaining the region's diverse landscapes. Forests account for more than 60 percent of the land area of northwest Yunnan, and provide crucial ecological and economic services, such as wildlife habitat, water retention and regulation, and soil erosion control. Forest ecosystems are also an important grazing habitat for livestock, and provide local populations with food, fuel, medicines, building materials, and valuable non-timber forest products (NTFPs).

Based on case studies conducted in Northwestern Yunnan, Xu and Wilkes (2004) conclude that biodiversity loss in the region is mainly driven by land use and land cover change and that market driven loss is currently a major threat, especially for NTFPs. Cross-border trade with the Southeast Asian neighbors plays a significant role. Xu and Wilkes (2004) observe this as indicative of what is occurring in many global biodiversity hotspots. They point out that market information is primarily supplied by outsiders who engage in collection or procurement of local produce and who are unconcerned about sustainability of harvesting. However, buyers and traders are in many cases the only link for rural communities (especially in remote areas) to the market. Xu and Wilkes (2004) also point out that NTFPs are liable to agricultural product tax, but enforcement is difficult.

The studies conducted by KIB and ICRAF point to important knowledge gaps that may lead to serious exploitation and unsustainable use of the natural resource "NTFP", among them the following five:

1. lack of basic knowledge on germplasm and non-existing or incomplete inventory;
2. no in-depth and long-term monitoring and institutional arrangements to ascertain sustainable extraction levels of major NTFPs;
3. insufficient market transparency for communities' (in terms of quality, price, markets for NTFPs);
4. only general, superficial knowledge of NTFP domestication and little understanding of the effects of domestication on product quality and price and the conservation of wild sources; and
5. no existing research on the full length of the commodity chain for major non-timber forest products and the various actors in the chain.

Based on the current state of knowledge on the use and management of NTFPs in Yunnan, Southwest China, and other parts of the world, answers to the following research questions are being sought:

- What are the most important NTFPs in terms of market value, their abundance (or scarcity) and their ecologically importance for the ecosystems in which they grow?
- Have they and the environments they grow in been delineated, inventoried and monitored? (Note: this is a crucial base for developing sustainable management techniques, particularly for those species that are in danger of over-exploitation).
- What are current management regimes (amount, frequency and methods of collection) for these NTFPs, what are/were the traditional practices, how have these changed over the past decade, and what have been the effects on their abundance or scarcity and on biodiversity in general? Are there indications that harvest levels are decreasing and is there a link to changes in forest area/structure? Are local communities aware of these processes and associated effects?
- What are the economic benefits obtained at household, local and provincial level from selected NTFPs (in absolute terms and in relation to other forest); how are they being processed (i.e. which value added processes are being done) and traded (commodity chain assessment)?
- What role do NTFPs play at domestic and regional (Southeast Asian) level? What product and amounts go into border trade and into the international market?
- How can smallholder upland dwellers benefit more from the use of NTFPs, i.e. what value-added measures can they take at household and community level, such as processing, labeling, packaging and trading? How can ownership, control over resources, market knowledge and access be improved for the benefit of poor upland communities?
- Which species are suitable for domestication; what agroforestry systems provide productive models for growing NTFPs on-farm; what are the effects of on-farm production of NTFPs on quality, price and on existing wild sources?
- What are the existing institutional arrangements to sustainably manage NTFPs; do they provide a model to learn from and improve upon? What recommendations can be drawn from these and other experiences that can feed into applied research projects and policy recommendations?

To initiate a Sino-German research cooperation appears particularly promising at this point in time, because research and development on NTFPs in Southwest China has recently gained significant attention from the Chinese government and donor organizations. The State Forest Administration (SFA) of China with support from the Ford Foundation and the World Agroforestry Centre is currently planning a national conference and workshop on the sustainable use of NTFPs in China. The conference will review China's NTFP policy within the National Forestry Management Framework and identify innovative approaches for sustainable community-based NTFP management. The proposed Sino-German research initiative can be linked to this significant event that will not only guide future research & development work in China, but also lay the ground for international research cooperation.

OBJECTIVES OF SYMPOSIUM

The symposium aimed to assess and review the state of knowledge on the use of non-timber forest products in terms of their importance for rural livelihoods and the effects of NTFP extraction on biodiversity in Southwest China. Symposium outputs will form a base for future Sino-German research that intends to focus on the sustainable management of NTFPs as part of a holistic natural resource management concept in one of the important biodiversity hotspots of the world.

Specific symposium objectives included:

1. To create an up-to-date knowledge base on past and current research and development work on NTFPs, including a list of major species and products according to their utilization and their importance for rural livelihoods (for both subsistence and cash economy);
2. To understand the threats of NTFP use on the maintenance of local and global biodiversity and identify those species that are rare and under threat of extinction;
3. To assess the importance of selected NTFPs for domestic and cross-border trade and identify key enabling and restricting market characteristics;
4. To appraise the potential for sustainable management of the resource, domestication and improved marketing of NTFPs (including institutional arrangement for communities' shared use and trade of products, as well as value-added processing, labeling, packaging and transport);
5. To develop a set of recommendations for future research on the sustainable utilization of NTFPs that not only support targeted development action, but also translate into policy recommendations in a holistic natural resource management context.

The symposium is viewed as the initial crucial step in laying the base for a long-term research collaboration and scientific exchange between German and Chinese institutions. The symposium in Germany has provided scientists from the Chinese Academy of Sciences at the Kunming Institute of Botany and its Chinese partner institutions an opportunity to interact with a large number of German scientists who are experts in the same field of research, and to visit and get to know relevant institutions and field projects in Germany.

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FOREST INVENTORIES: RESOURCE DATA PROVISION AS BASIC COMPONENT OF SUSTAINABLE MANAGEMENT OF THE FOREST RESOURCE, INCLUDING NON-WOOD FOREST PRODUCTS

by

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1 ABSTRACT

An overview of basic technical characteristics of forest inventories with reference to designing inventories for non-wood forest products is given in this paper, and challenges and research issues addressed. In conclusion, many of the basic principles of forest inventories can be applied to the inventory of many non-wood forest products; There are, however, obviously some special characteristics of NWFPs that need particular attention in inventory planning, field measurements and analysis. Probably, for many non-wood forest products, an efficient integration of local knowledge is required to make inventories workable and efficient.

2 INTRODUCTION

Data and information are a basic element in decision making, in particular when the manager is dealing with a complex production system, such as forests. Inventories of renewable natural resource are tools to collect data that are being converted to information to support the sustainable management and sustainable utilization of the target resource. However, an inventory of a renewable natural resource is a complex undertaking, and provision of information is a considerable investment that should pay off. It is always an optimization process because resources (time and budget) are limited and must be optimally allocated. This is true for timber inventories, but it is much more so for the inventory of non-wood forest products (NWFPs) many of which are relatively rare and unevenly distributed over the area of interest which makes them a difficult object for inventory.

In the optimization process of an inventory, the usefulness of all possible information sources needs to be considered, among them maps, prior inventory reports, satellite imagery, aerial photographs, expert knowledge, interviews with owners and users of the resource are among these information sources. The most comprehensive information source about the biophysical status of the resource, however, is direct field observations, wherever possible. It is only there in the field, that direct observations of many of the attributes of interest can be done.

Forest inventories do usually refer to larger areas and field observations can not be done over the entire area of interest. Field inventories, therefore, base on sampling: observations take place only at a specifically selected subset of the population of interest. From these sample observations, extrapolations are calculated to produce estimations of the attributes of interest for the entire population.

It has often been discussed what a “good forest inventory” is. However, there is no such thing yet like a “good practice guide for forest resource inventory”. There are so many possibilities to carry out a “good inventory” that it is probably impossible to set up such a guide (it is probably much better to list bad practices that are to be avoided!). However, there is one criterion which is some times referred to as the overall goal of each inventory, and this is credibility: an inventory should be carried out, justified and reported in such a way that the results are credible. To achieve credibility, a number of sub-criteria need to be fulfilled like transparency of methods, complete and illustrative reporting, but, above all, methodological soundness. If the methods used are not sound and consistent, then it is practically impossible to achieve credibility.

In this paper, basic principles of forest inventory in general and of statistical sampling applied to the inventory of forest and renewable natural resources are presented and discussed. Then, specific challenges of inventories for NWFPs and for research in that field are identified and discussed.

3 BASIC CHARACTERISTICS OF FOREST INVENTORIES

When a natural renewable resource is to be managed the general objective is to do that in a sustainable manner so that, also on the long run, the resource base is maintained or even improved in quantitative and qualitative terms. Sustainability is one of the most modern concepts which in the meantime is being discussed in many sectors, in particular known in the context of sustainable development. In fact, the principle of sustainability had been invented and first described in the forestry context, where early in the 18th century a mining engineer, Carl von Carlowitz, recognized that the rapidly growing mining industry threatened the forest resource through over-utilization – which would have meant on the long run that the survival of the mining industry was threatened, as well. That was one of the reasons to introduce a more reasonable approach to wood harvesting and the term "sustainability" was coined ("Nachhaltigkeit" in German).

Information is considered one of the vital pillars of sustainable management. Only when the basic characteristics of the natural renewable resource are known to a sufficient degree it can be guaranteed that harvesting does not exploit the resource. Major components of that information are the answers to the questions

- how much is out there at a given point in time (growing stock)?
- what is the quality?
- where is it?
- what is the growth (including all components of natural dynamics like mortality and regeneration)?
- how much can be harvested (accessibility, detection functions, ownership restrictions)?

A great part of that information can be produced by sample based inventories, be it temporal ones of permanent ones.

Information requirements are there on various geographical levels. A forest owner is interested in stand-wise information to plan for silvicultural treatments, harvesting operations and selling forest products; he or she requires information on a local basis. The government of a country or province wishes to know about the development of the forest resource, for example to guarantee the livelihoods of rural communities or to attract investors to establish a wood based industry. The government needs then large area information which has many commonalities to the local information but is different in a number of aspects.

Forest information is also produced on a global level: since the Earth Summit in 1992, various international conventions are in place which require the governments to report to the international community on various aspects that do also have to do with the forest resource; we refer here, for example, to the Convention on Biological Diversity CBD, to the Convention to Combat Desertification CCD and the Framework Convention on Climate Change UNFCCC. The signatory countries are obliged to report to these international processes on a regular basis and that requires that they do permanently generate up-to-date information also about their forest resource; that requires a national forest inventory. Then, international organizations such as the Food and Agriculture Organization of the UN (FAO) compile information and publish results on the state of the world´s forests.

While NWPFs are now included as "Special Study" into the reports of the global Forest Resource Assessment (FRA) of FAO, it is mostly on a local level where information on that resource is required and where the question of an NWFP-inventory may come up.

4 FOREST INVENTORIES AS COMPLEX PROJECTS

Forests are complex ecosystems and complex production systems. While the early forest inventories were exclusively about guiding and optimizing wood production, focused on wood volume in terms of quantity and quality, the objectives are much wider nowadays. While wood production does still play an important role, forests are seen as a resource in a much more comprehensive manner: it is not only wood which is produced but a long list of other tangible products, the NWFPs, including fruits, mushrooms, bamboo, rattan, ornamental plants, and bush meat. In many regions medicinal plants play an economically much more important role than timber! But it is also the services that forests offer which are of interest for monitoring and for sustainability issues: forests, for example, help maintaining water clear, they serve as recreation area, they filter the air, produce oxygen, they prevent and control erosion, and they are home to many plants and animals such conserving biodiversity.

This certainly incomplete list of forest functions makes clear that an inventory which intends to provide information on some of these features is bound to result in a complex project.

The overall complexity arises from the complexity of the target object "forest" itself, and from the conflicting interests in the forest as resource or ecosystem, but also from the mere size of many of the inventory projects: when a forest inventory is to cover a larger area by sample plots, then a high degree of complexity comes in from an organizational and logistical point of view: a sampling protocol needs to be devised, appropriate staff needs to be found, field teams put together, training given, transport organized, supervision, data entry and data management need to be organized. As in any complex undertaking, errors will come in at different stages, which should be accounted for when reporting the results.

5 WHERE DOES THE INFORMATION COME FROM: INFORMATION SOURCES USED IN FOREST INVENTORIES

When information on a complex object is needed, the planners will naturally resort to all available sources of information. In a one-shot forest inventory, one is interested in the current status quo, so that only up-to-date data are of interest. The most up-to-date data come from field measurements and recent remote sensing imagery (aerial photographs of satellite imagery) – and these two are, in fact, the most important sources of information that are being evaluated and analyzed in forest inventory studies. However, the usefulness of remote sensing for NWFP inventories is still to be verified, maybe it can serve as a proxy in modeling approaches.

Field measurements and remote sensing both have their specific strengths and problems: while remote sensing imagery allows for a synoptic view and provides an immediate impression of forest area distribution and fragmentation over a larger area, it does not offer the possibility to make observations of many of the core variables in forest inventories such as species composition, diameter distribution, density of regeneration, or signs of utilization of wood and non-wood products, indicators of biodiversity. Field measurements allow for all these measurements but are more tedious and less precise when it comes to the estimation of areas. It is commonly accepted, though, among forest inventory experts, that a forest inventory requires field observations. A solely remote sensing based study may actually be caked a forest mapping exercise – and not a forest inventory. This is some times causing severe confusions.

There are many other information sources that are being used as ancillary information and as planning tool; among them, maps are most indispensable. Without useful maps, any inventory faces severe problems and the generation of a work-map will be the first step to be undertaken. In cases where maps are outdated or of limited accuracy for the area of interest, the maps must be adjusted and updated.

For many NWFPs, however, the most valuable source of information for inventory planning is probably local knowledge and experiences of experts or staff who participated in former inventories. It is those people who have the specific knowledge of the region of interest and may help to efficiently guide an inventory exercise. The integration of local knowledge and sample based NWFP-inventories is certainly a field worth to be closer looked at.

6 SAMPLING: AN IMPORTANT STATISTICAL TOOL IN FOREST INVENTORIES

Sampling is an important and essential methodological element of natural resources inventories. Soundness of sampling is an important component of overall credibility, where we refer exclusively to statistical sampling, not to other approaches like purposive or subjective sampling. Statistical sampling follows strict rules. Not-observing these rules means that the data can not, in a strict sense, be analyzed along statistical procedures but produce case-study results without the possibility of extrapolation.

If we wish to produce scientifically defendable results, we need to adhere to the principles of statistical sampling. However, cost does obviously also play also a role and there might be situations in which the decision maker is happy with information which is not backed by statistical soundness.

Sampling studies can be broken down into three major technical design elements: (I) sampling design, (II) response design and (III) estimation design. In addition to that, a number of organizational and logistical issues need to be addressed like in any other project. This refers mainly to practical implementation and dissemination of results.

The sampling design defines the technique that is being used to select the sample elements. The very basic sampling design is simple random sampling. However, this is practically not used in natural resources inventories, because more efficient designs are available, such as stratified sampling, cluster sampling, systematic sampling. Sampling technique and sample size are important factors for statistical precision. It is, therefore, worthwhile to do a detailed and proper planning. Most forest inventories base on systematic sampling, both for reasons of statistical precision and for practicality. The detail planning, however (referring mainly to size and type of the systematic grid applied) needs to be adjusted to the particular situation and conditions of the specific inventory and there is not one single optimal sampling design for all situations.

The response design defines the sample elements themselves and the observations/measure-ments that are to be taken there. Usually, in natural resources inventories, sample plots are used that have some spatial extension, such as circles of a defined radius or squares of defined side length. On these sample plots, observations are made on the target attributes such as trees dimensions, forest structure, dead wood, soil and also NWFPs. Definition of plot type and size depends on statistical and practical considerations. Experiences from forest inventories are very useful in this context for inventories of NWFPs as well. From a statistical point of view, it is best to design the sample plots such, that a maximum of variability is present within each single plot. By that, a maximum of variability is captured per plot which leads to a reduction of the standard error, because the variability between plots is kept small.

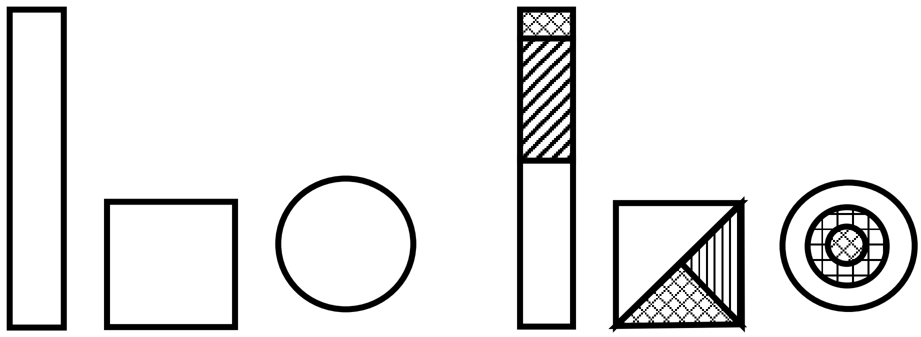

Figure 1: Illustration of fixed area sample plots. Left: typical plot shapes. Right: the same plot shapes as nested plots where several sizes of sub-plots are nested; in each one of the sub-plots, specific dimension ranges (for example tree diameters) are observed.

Given the typical spatial structure of plant communities, we may assume that objects (trees, plants) that are close to each other exhibit more similar characteristics than those at farther distance. The consequence is then, that, from a statistical point of view an elongated plot design that covers various different conditions is to be preferred over a compact plot like a circle or square plot. The latter, however, are more practical in terms of implementation under many conditions.

The definition of the response (i.e. plot-) design is a compromise between statistical considerations and considerations of practical implementation. Typical plot shapes as used in forest inventory are the rectangle, the square and the circle (see Figure 3). A variation are nested plots, where several sub-plot sizes are nested; then, on each one of the sub-plots different diameter classes of trees are observed (see Figure 3). That principle of using sub-plots may also be applied when inventorying NWFPs where the more abundant objects (like trees) are observed on a smaller plot and rarer plant species NWFPs are searched on larger plots. Such an approach had been followed by Kleinn et al. (1995) in a forest inventory project in Nepal where medicinal plants were also to be inventoried.

Besides these fixed area plots there are other plot types which are also called variable area plots, because the respective plot area varies from sample point to sample point depending on particular characteristics of the stand. Examples of these techniques are distance methods such as k-tree sampling (where, from a sample point the k nearest trees/plants are measured) and the so called relascope sampling where trees around the sample point are included with a probability proportional to their basal area (see Figure 4). While k-tree sampling (or k-object sampling) is appealing because there is always the same number of objects per sample point, it is problematic for rare objects, because the distance to the k-th object may be large and nearer objects may be overlooked.

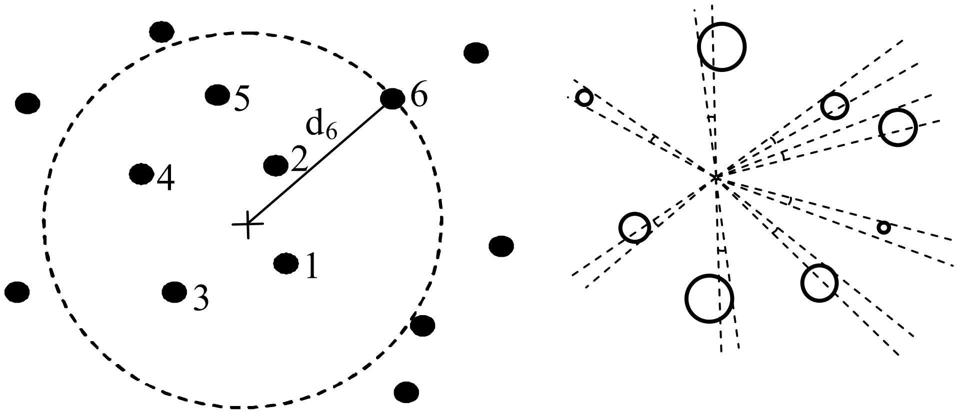

Figure 2: Further plot types used in forest inventories and ecological surveys. Left: point-to-tree distance sampling where the size of the circular plot is determined by the distance to the kth tree, in this example k=6). Right: relascope sampling (or Bitterlich sampling or angle count sampling), where, from a sampling point, all trees are observed which appear wider than a pre-defined observation angle.

Spatial cluster plots area widely used in forest inventory. There, one cluster plot consists of several sub-plots, each one being one plot as described above. By that, a larger area per plot is covered causing more variability to be collected. A plot design that has been proposed for rare and clustered elements is adaptive cluster sampling, where the clusters adapt to the occurrence of the target objects. That design has been repeatedly applied to NWFP inventories.

Finally, the estimation design defines the analysis procedure and consists of the appropriate estimators that allow making unbiased estimations. One is not free in the choice of the estimator but the estimators need to be exactly conforming to the sampling and response design where, in some cases, estimation is a complex issue, for example when using k-tree sampling as plot design (Kleinn and Vilcko 2006). The estimators for mean and variance from simple random sampling are well known. However, there are sampling designs for which more than just one estimator is available. Then, one needs to choose between them; each one is likely to produce different estimations. One would choose the estimator for which the estimated standard error is smallest, i.e. precision highest.

Results from forest inventories are usually reported on a per-hectare basis – while observations are made on a per-plot basis. That means that the per-plot observations need to be converted to per-hectare values. This is done for fixed area plot designs by so-called expansion factors.

7 MODELS

Forest inventories utilize and depend on models. This has to do with the fact that various variables need to be observed which can not be directly measured. The most typical example is timber volume or biomass which are usually predicted by models that have easily measureable attributes like species, diameter and height as input variables, called volume functions or biomass functions. Also the observation of basal area makes a model assumption, namely that the stem is a perfect circle (which it is not). While we know that the models are not perfect and carry certain errors, we depend on them until better approaches are being developed.

There is a long history of development of basic models for forest inventory. Volume functions, for example, are there for many regions and many species and species groups where building such a model is a laborious undertaking.

It is assumed that inventories of many NWFP will also require adequate modeling, also for the more simpler exercises like the inventory of tree-related NWFPs: for bark harvesting, bark volume models need to be known (depending also on the harvesting technique), for fruit harvesting models are needed that allow predicting fruit load as a function of, for example, tree diameter, crown diameter, crown length and tree height. And in the case of fruits, the accessibility is also a point: growing stock is not the same like the stock available / technically accessible for harvesting. Of course, the fruit load of a tree can also be estimated by sampling techniques, but this is too tedious for an inventory.

8 SPECIFIC ASPECTS OF NWFP INVENTORIES

It is neither easy nor straightforward to talk about NWFP inventories in general, because different products obviously require different inventory techniques. An overall optimal technique does definitively not exist and the planning must be essentially done on a specific NWFP by NWFP basis (Kleinn et al. 1995).

For NWFPs which are tree parts – such as bark, roots, fruits, leaves – standard forest inventory techniques can directly be applied to estimate number of stems per area unit. Additional models or sampling techniques are then required and need to be applied to estimate the per-tree amount of resource. So this is fairly straightforward.

For all other (non-directly-tree-related) NWFP (such as medicinal plants, tubers, ornamental ferns and palms, bee honey, wildlife/bushmeat), there are some special characteristics which make sample based inventories difficult, among them

- scarcity,
- seasonality and
- detectability.

Because of the complex nature of NWFPs, the first question to ask is whether a biophysical inventory of the sampling-type is required – implying high cost and efforts and considerable planning and evaluation efforts -, whether a stand-alone NWFP inventory pays off or whether it should be combined with a default forest inventory.

It is probably local knowledge that plays a crucial role in any NWFP resource inventory study. The local collectors have the knowledge to identify the target species and have an idea of its distribution, can therefore support and guide the inventory planners. Also, market survey type of studies will provide (at least some) insight in the resource base and its development over time; again, it is not only the observation what there is on the market, but above all the interviews with the collectors and traders about their experiences over the past period.

9 RESEARCH TOPICS

From the above description of the characteristics of forest inventories and, in particular, NWFP inventories, it becomes clear that there are various research topics to be addressed. In the following, some are listed – where the selection may have some personal bias.

Some of the issues are of a more technical nature, such as

- Integration of data sources. While field observations are indispensable in all forest resource inventories, available ancillary information in reach need to be used. In forest inventories, this refers mainly to remote sensing, for NWFP inventory it refers mainly to the integration of local knowledge; because local knowledge does not occur in standardized formats and because forest inventory experts are usually not experts in interviewing techniques, this integration is a challenge.
- For field observations, efficient sampling techniques for the estimation of the growing stock of rare events need to be devised; it is somewhat open to the author, whether this is a feasible undertaking at all. Some techniques, like adaptive cluster sampling, have been proposed – but the practical problems are still unresolved and the experiences not overly convincing yet.
- Sampling techniques must also become simpler in implementation and estimation. Rural communities, for example, that are responsible for the sustainable management of a forest area and its products will have to give evidence of the sustainability of their resource management, they urgently need inventory techniques that are easily understood and implemented. This is a wide field.
- Assessment and evaluation of error sources. In resource inventories, many error sources exist. They are usually not duly taken into account and the standard error remains commonly the only error quantity given.

Forest inventory research, however, does not only have its technical side, but many more aspects worth to be researched into:

- The interdisciplinary implementation of forest resource inventories at a landscape level is still in its early stages. In addition to the technical issues, many organizational and balancing efforts are required.
- Capacity building and, above all, capacity maintenance is another serious issue. This is, of course, not only a research issue; but research is directly linked to that problem: If forest and natural resource inventory courses at universities are schematic and do not focus on problem solving and the whole range of issues touched upon in a forest inventory, we'll fail on the long run to educated capable experts.
- Maybe the most crucial issue, and an extremely difficult one at the same time, is that of a smooth integration of forest inventory into the policy process and the clear definition of information requirements that shall be served by a resource inventory. It is not clear at all that there is a direct relation between information quality and quality of decisions. It is, therefore, very difficult to define what minimum / optimum information is required for decision makers to make optimal decisions. Surprising enough, this very basic question crucial for any inventory of renewable natural resources is still largely unanswered.

10 CONCLUSION

This paper gives a brief introduction into the technical and research field of forest inventories with special reference to their application for data collection on non-wood forest products. It is certainly incomplete in terms of description and in terms of the list of research topics. However, it is hoped that it shows that forest inventory is not a merely technical issue but has many more aspects to be considered. If it is not a very specific timber inventory for a plantation company, for example, a forest inventory is a truly interdisciplinary exercise in which the lead planners and researchers need to have a good command of a variety of skills, among them statistical sampling techniques, human resource management, planning of logistics, presentation of results and communication skills when it comes to defending the inventory and its results before unjustified (and also justified) criticism. Of course, all these skills are also required in many other types of projects.

Baseline information is the starting point of many natural resource management projects. The author expects that forest data provision, notably forest inventories and the know-how about it, will be in increasing demand, also when it comes to feed the great international processes with hard data (such as the Convention on Biodiversity, the Convention to Combat Desertification and the UN Framework Convention on Climate Change).

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FOREST MANAGEMENT SYSTEMS AND DIVERSIFIED PRODUCTION - PRINCIPLES OF SUSTAINABLE MANAGEMENT OF RENEWABLE RESOURCES

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ABSTRACT

Since the UN conference in Rio 1992 the term ”sustainability” seems to have developed to a world-wide buzzword. But recognizing the fact that we are about to reach our limits not only with respect to non-renewable resources, but increasingly also towards renewable resources, leads to the necessity to apply sustainable development to all economic development planning’s. Sustainability is not a new thought: In forest land use (of central and Western Europe), the principle of a sustainable management has been used since the beginning of the 18th century and has been applied more or less consistently for at least 200 years. Many centuries of uncontrolled ”plenter forestry” which was oriented only at the need of the users but not at the production capacity of the forest lead to a considerable forest degradation. The result was the development of different sustainable management systems in European silviculture of which many are still in use today. An essential condition for sustainable management is a thorough inventory that quantifies the potential increment and thus prevents overexploitation. This is also valid for non-timber forest products (NTFPs), which range from woody plant species such as bamboo or rattan to products that only have certain relationships to forest ecosystems, e.g. resins, mushrooms, spices, medical plants. Due to the diversity of NTFPs and types of use there are no general rules for controlling their sustainable management. Moreover the rules must be adjusted for each single product group. Today's understanding suggests that sustainability criteria should not only be reduced to the relationship of growth and yield. Sustainable management also includes soil fertility, biodiversity and ecosystem stability. Certification systems, which have been proved as positive control tools for forest management, also need to be developed for and applied on the different ways of utilizations of NTFPs.

INTRODUCTION

Since the 1990s, the concept of sustainability or sustainable development became an important task of all political and economic programs. This new way of thinking lead to the UN conference in Rio de Janeiro / Brazil in 1992 where 180 nations signed the “Convention of Biological Diversity” to make sustainability to a general principle of human activities. Nowadays, we define sustainability as the effort for the compatible integration of all activities of an enterprise into its ecological, social, cultural, ethnical, and religious surrounding.

But Rio was – in a global perspective – not the first shock for mankind in terms of fear for unsuccessful sustainability. Exactly 20 years ago, in 1972, Dennis Meadows and his co-workers from the Massachusetts Institute for Technology (MIT) published an impressing study. At that time all thoughts were focussed on non-renewable resources, such as iron ore, natural gas or coal. It was clear to everybody that these resources are limited. The new message, however, was that the commonly used way to calculate the availability, was completely wrong. The calculation was mostly based on the current average consumption: When we calculate this for example for coal, the stock of estimated 5000 billion metric tons will last for about 2300 years. But as in many relations growth is not developing proportionally (linear), but exponential like the world population. When we take these realistic growth rates for our forecast into account, the coal supply will not be enough for the next 2000 years, but only 111. This is just an example; the situation can be even more severe for other resources.

The awareness that the limits of non- renewable resources are predictable was im important signal for a more sustainable use of resources in principle. Apparently sustainable management can only be applied on renewable resources. Hence this is not applicable on iron, gas or coal, but on forests and timber. After all, a forester was the first in Europe who used the term "sustainable" and demanded a sustainable forest management to guarantee unlimited harvest for the future. Carl von Carlowitz wrote the book Silvicultura oeconomica after he had seen the good results of the French forest inventory in the 17th century. And he wrote this book in a period, when many forests in central Europe were devastated and in bad condition. Timber in the forest was mostly used according to the uncontrolled so-called plenter system, harvesting primarily the biggest trees. As a consequence, people used the timber that they needed without caring for renewing the production base. In connection with intensive grazing activities, the results in large areas of Central Europe were destroyed forests and devastated landscapes. Foreseeable

The most successful strategy to avoid uncontrolled use and overuse was the knowledge about the growth potential of the forests. If people know the growth they can use renewable resources sustainably. The precondition for this knowledge is a good inventory, and this was already the conviction of v. Carlowitz when he saw the large inventory programs in France.

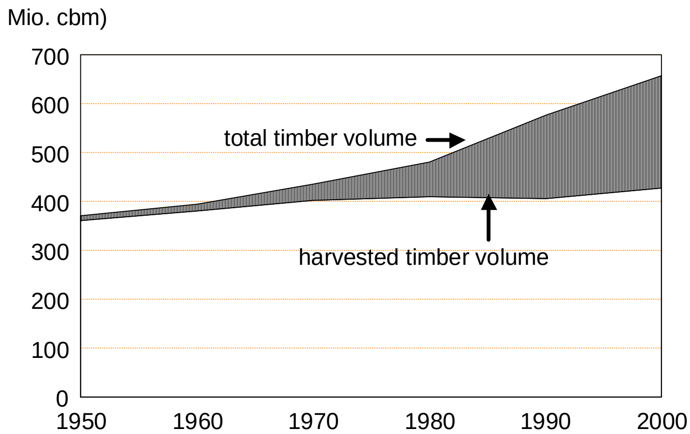

Figure 1 Wood increment and harvest in Europe 1950-2000

The impression arises, that sustainability was mainly a result of scarcity. But even at that time thoughts on sustainable management in context with forest inventory was not a new discovery. Already in the late middle age, there are examples of pre-industrial enterprises like saltworks with a tremendous demand for fire wood which had a fundamental interest in a sustainable supply of the raw material. Some enterprises used the forest in a very responsible way and despite great demand of firewood the timber stock in the forests increased, others harvested careless with the result of overused and devastated forests. The first simple methods of a sustainable forest use were dividing the total available forest area into patches of same size. The number of patches depended on the rotation period. The typical form of forest management in former times, coppice, had an average rotation period of 15 to 20 years. Hence, it was necessary to have 15 to 20 patches in order to harvest just one patch every year. Later on, sophisticated and better methods of forest inventory were developed and applied. Nowadays, in Central Europe we have the highest forest stock volume we ever had for the last centuries.

According to an international assessment (UNECE/FAO 2003), the development of total timber volume increment in the forests and the harvested timber volume is more and more drifting apart (Fig. 1). While the harvest of about 400 Mio. m³ remains on the same level for more then three decades, the timber increment has increased from 450 Mio. m³ in the middle of the 1970s to about 660 Mio. m³ today. Only about 60% of the total wood increment is currently used according to this assessment. Therefore, in Europe we observe an increasing over-fulfilment of sustainability principles in the forest. After the comparison of two very detailed forest inventories in Germany from 1987 and 2002 it could be shown that this European trend of restrained harvest intensity has reached significant extents particularly in Germany: the degree of wood mobilization is not higher than 55%.

THE QUALITY OF FOREST INVENTORIES

The comparison of the two national forest inventories did not only deliver surprising results in terms of mobilisation degrees. Unexpected high was the calculated average annual increment of 12 m³ per hectare and year. Even if there are some methodical reasons within the assessment for the great wood increment, the growth potential of the European forests has changed due to ecological changes during the last decades. In spite of the so called forest decline that could explain a decreasing growth trend we have a strong increase due to higher carbon dioxide concentration in the atmosphere along with increasing inputs of nitrogen. Additionally, we observe longer vegetation periods and higher average temperature which increases photosynthesis activity. The expected negative impact of drought due to reduced precipitation und warmer summers has not yet influenced the growth dynamic in most parts of Central Europe. Hence, in short and middle term perspectives, foresters see the principle of sustainability for the renewable resource timber in Central Europe not at risk.

To sum it up it can be said that the sustainable management of renewable resources

3. is not a new idea
4. needs adequate inventory and
5. is influenced by environmental changes.

WHAT DOES SUSTAINABLE FOREST MANAGEMENT INCLUDE?

In the first chapter all aspects on sustainable forest management were focused on the timber production with regard to of timber volume and in a wider sense carbon sequestration. Sustainability however, means more and should relate also to timber quality and ecosystem stability. This includes health and vitality for the forest stand as well as long-term soil fertility. Under these conditions, the principles of sustainable forest management should include the following objectives:

6. Ecologically adapted silviculture (conservation or increase of forest area, harvest adapted to growth potential)
7. Effective forest protection
8. Improvement of long-term stability
9. (Attractive forest-landscape scenery)

THE FOUR PRINCIPLES OF A SUSTAINABLE FOREST MANAGEMENT

PRINCIPLE 1: ECOLOGICALLY ADAPTED SILVICULTURE

This indicates the conservation and the support of natural processes of the forest ecosystem. In detail this principle does not allow a direct disturbance of nutrient cycles, thus clearcuts should generally not be applied. Instead, a promotion of natural regeneration concepts should be favoured. Furthermore, only a very limited application of chemicals, such as herbicides and insecticides should be accepted. In order to improve the biological vigours, more ecological niches, i.e. a higher portion of dead wood, should be created. Finally, an ecologically based game management is an essential condition for a sustainable forest management, at least in Central Europe.

PRINCIPLE 2: EFFECTIVE FOREST PROTECTION

This goal can be approached on different levels: First of all a minimum area of forest reserves such as nature reserves, biosphere reserves or national parks should exist. These areas may have different levels of protection. The portions of completely protected area in countries with multifunctional forest management system can me much lower compared to countries with a segregation system. That means a clear separation between areas with 100% production function and others which are entirely protected.

On the operational level within a forest management the trend towards more mixed stands is obviously the most effective concept in order to stabilize our forests and to create good conditions for an effective forest protection. It is expected that a higher diversity in tree species will support a higher diversity of the other components of a forest ecosystem which will improve resisting power against biological (insects), chemical (air pollution) and physical (climate) stresses. Furthermore mixed stands might have a higher stability against mechanical (storm) hazard.

PRINCIPLE 3: IMPROVEMENT OF LONG-TERM STABILITY

This goal is linked with principle No. 2, the effective forest protection, but is more focused on long term stability. According to our current knowledge it should be approached by the already mentioned concepts of a higher level of biodiversity. Diversity of species, particularly tree species, a higher genetic variety of stand structures shall reduce the risk for forest ecosystems which are faced with significant environmental changes. Tree species with different ecological demands and stress tolerance will statistically reduce the risk to lose complete ecosystems.

PRINCIPLE 4: ATTRACTIVE FOREST-LANDSCAPE SCENERY

The demand to include also aesthetic aspects on landscape level into the principles of a sustainable management is certainly the most controversial thought. Here we should distinguish between countries with a high population density and high expectations of the public toward the recreation function of forest land. In Germany, there are big expectations in terms of landscape aesthetic and recreational functions which need to be respected in sustainable management plans. On the operational level, this implies an improvement of forest margins and a special focus on an attractive landscape, i.e. a balanced and reasonable mixture of forests, intensively used agricultural land and other areas such as settlements and streets.

NON-TIMBER FOREST PRODUCTS

All explanations above were related to the sustainable management of forests. Can we simply apply these principles to non-timber forest products? NTFPs are commonly defined as ‘all products derived from biological resources found on forest land but not including timber, fuelwood or medicinal plants harvested as whole plants’. NTFPs include

Table 1: Overview about different kind of NTFP

• Edible plants	• Edible animal products
• Food	• Terrestrial animals
• Edible oils	• Animal products
• Spices	• Fish and aquatic invertebrates
• Fodder	• Insect products
• Medicinal products	• Wildlife products and live animals
• Rattan	
• Bamboo	
• Cork	
• Ornamental plants	
• Chemical components	

According to estimations from the European Tropical Forest Research Network, up to 2000 non-timber forest products can be listed today and there is still an increasing trend for more products (Gopalakrishnan et al. 2005). In terms of the economic value the importance of NTFPs is concentrated on a few products only, mainly bamboo and rattan (Paudel and Chowdhary 2005). Nevertheless, NTFP experts see urgent need for adequate NTFP inventory methods. During the conference of the European Tropical Forest Research Network (ETFRN) at FAO, in Rome / Italy from May 4-5th, 2000, Wong presented a review of NTFP inventories (Wong, 2000).

She concluded that

- the variety of life forms and distributions represented by NTFPs mean that traditional forest inventory techniques cannot be adapted easily for NTFPs.
- there is a lack of properly researched NTFP-specific sampling designs and measurement techniques.
- lack of theoretical models means that it is difficult to determine the sustainability of NTFP harvesting.
- there has been little cross-disciplinary exchange of ideas and methods suitable for use with NTFPs.
- There is no service that provides effective communication of advice to field workers and communities

Summarized, there are some aspects which can and should be improved in order to come closer to a more sustainable management of these products with a promising future. An adequate inventory is without doubt an essential precondition for a sustainable management of non timber forest products, but there are still other problems.

CONFLICT POTENTIALS WITH NTFPS

In Central Europe non-timber forest products were very important for livelihood and the economy for more than 1000 years. In the middle ages, the economic value of grazing in forests (pigs, sheep, goats, cattle, horses) was much higher than the revenue for timber production. Already at that time, the promotion of a certain NTFP was automatically a decision against other functions and products of the forest. High grazing intensities in the woods destroyed the forests for many generations. In the Mediterranean countries this experience was already made some thousand years ago.

Nowadays, this conflict does not exist any more in Germany. But we still have the internal conflict of a diversified production with changed actors. Today it is not cattle, pig, and sheep, but red deer, roe deer and hare. Game has developed to the most important non-timber forest product in Germany and at the same time has a negative impact on the regeneration and healthy development of forests. High deer populations will not be able to destroy the forest as for example goats did in the past, but they can harm the stand and timber quality. This is also a big economic problem because a main goal of German forestry is the production of quality wood. Even though this conflict between silviculture and hunting has been calmed down in recent times due to a more ecologically adapted wildlife management, we have to consider that the promotion of NTFPs can produce conflicts with other objectives of a forest management. There are several examples from all parts of the world where comparatively severe conflicts exist between the use of timber and non-timber forest products (Ndoye and Tieguhong 2004, Trauernicht and Ticktin 2005, Pulido and Caballero 2006). But there are also examples where even in bioreserves the sustainable use of NTFPs can be compatible with nature protection goals (Kiehn 2004).

OUTLOOK

Non-timber forest products are of increasing importance for the economy of many countries, particularly in the tropics and subtropics. The most important sector for non-timber forest products is Asia (Mahapatra 2005), followed by Africa (Obebode 2005) and South- and Central-America. Interest in non-timber forest products (NTFPs) is increasing rapidly; internet-based search engines find more than 350000 entries for NTFP. On a simple level the prognosis for the sustainable development of this highly diverse product group is not too difficult: NTFPs are according to the definition closely linked with forests. Therefore, sustainability for NTFPs can only be ensured if there is a long-term stability and sustainability of forests. On a world-wide level, however, the forecast is not very optimistic. The world's population follows an exponential growth curve and at the same time we have dramatic losses of forest area with an annual net loss of about 10 Mio. hectares. Consequently, the average forest area per capita is decreasing dramatically: in 1960 t 1.2 ha/capita were calculated; 35 years later this ratio has decreased to only 0.6! According to a model of Gardner-Outlaw and Engelman (1999), we expect only 0.4 ha forest / capita in 2025. With respect to these data, the prognosis for a sustainable management of non-timber forest products for the next decades cannot be too optimistic. The big advantage of non-timber forest products in comparison with timber production, however, is the expectation of annual income due to short(er) production periods. While the conventional products require many years to produce, it is possible to develop annual income from many non-timber forest products. Common sense management can produce NTFPs sustainably to make them a permanent part of forest productivity (Jones 2004). This is without doubt an important factor for the great interest in NTFPs.

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SECONDARY METABOLITES AND THEIR BIOLOGICAL ACTIVITIES FROM MUSHROOMS UNDER FOREST IN CHINA

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ABSTRACT

As a part of our search for naturally occurring bioactive metabolites from higher fungi, we investigated the chemical constituents of the basidiomycetes and ascomycetes fungi (Albatrellus confluens, Albatrellus dispansus, Boletus edulis, Boletopsis grisea, Cortinarius tenuipes, Cortinarius vibratilis, Daldinia concentrica, Engleromyces gotzii, Hydnum repandum, Hygrophorus eburnesus, Lactarius deliciosus, Lactarius hirtipes, Lactarius rufus, Polyporus ellisii, Russula cyanoxantha, Russula foetens, Russula lepida, Russula nigricans, Sarcodon leavagatum, Sarcodon scabrosus, Shiraia bambusicola, Thelephora aurantiotincta, Thelephora ganbajun, Tremella aurantilba, Tricholomopsis rutilans, Tylopilus plumbeoviolaceus, Xylaria euglossa), and isolated a number of novel terpenoids, phenolics and nitrogen-containing compounds. The isolation, structural elucidation and biologically activity of the new compounds are discussed.

1 INTRODUCTION

China is extraordinary rich in higher fungi. To date about 10,000 species of fungi have been reported from the vast territory of China. Among them, nearly 6000 species, belonging to about 1200 genera, are higher fungi (excluding lichens). Higher fungi in bio-resources belong to the very productive biologically sources which produce a large and diverse variety of secondary metabolites. We have been interested in the biologically active substances present in untapped and diverse source of higher fungi from China. The isolation, structural elucidation and biologically activity of the new compounds before 2002 have been reviewed previously.[1,2]

Recently several dozen new natural products and bioactive compounds were found in selected mushrooms on the basis of using our knowledge on the collection of fruiting bodies, strain preservation, fermentation, biologically screening and chemical investigation of higher fungi. The isolation, structural elucidation and biologically activity of the novel terpenoids, phenolics and nitrogen-containing compounds from basidiomycetes and ascomycetes fungi (*Albatrellus confluens, Albatrellus dispansus, Boletus edulis, Boletopsis grisea, Cortinarius tenuipes, Cortinarius vibratilis, Daldinia concentrica, Engleromyces gotzii, Hydnum repandum, Hygrophorus eburnesus, Lactarius deliciosus, Lactarius hirtipes, Lactarius rufus, Polyporus ellisii, Russula cyanoxantha, Russula foetens, Russula lepida, Russula nigricans, Sarcodon leavagatum, Sarcodon scabrosus, Shiraia bambusicola, Thelephora aurantiotincta, Thelephora ganbajun, Tremella aurantilba, Tricholomopsis rutilans, Tylopilus plumbeoviolaceus, Xylaria euglossa*) will be reviewed.

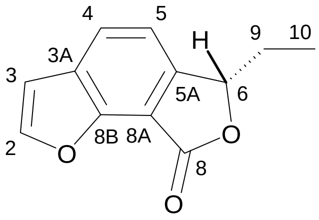
2 CONCENTRICOLIDE, AN ANTI-HIV AGENT AND OTHER COMPOUNDS FROM THE ASCOMYCETE DALDINIA CONCENTRICA

Although anti-HIV-1 drugs now available have improved the quality of the lives of HIV/AIDS patients, the rapid evolution of new HIV clades and drug resistant variants in AIDS patients urged the search for new anti-HIV-1 agents and targets. A large variety of natural products including alkaloids, flavonoids, coumarines, lignans, phenolics, triterpenoids, saponins, sulfated polysaccharides, phospholipids, quinines and peptides with anti-HIV-1 effect have been described, and for a portion thereof the target of interaction has been identified.[3] Natural products provide a large reservoir for screening of anti-HIV-1 agents with novel structure and anti-viral mechanisms.

A novel benzofuran lactone, named concentricolide (**1**), was isolated along with the four known compounds (friedelin, cytochalasin L-696,474, armillaramide, russulamide) from the fruiting bodies of the xylariaceous ascomycete *Daldinia concentrica*. The structure of concentricolide was established by spectroscopic methods and X-ray crystallographic analysis. Its anti-HIV-1 activity was tested. Results showed that concentricolide inhibited HIV-1 induced cytopathic effects. The EC_{50} value was 0.31 μg/ml. The therapeutic index (TI) was 247. Concentricolide exhibited the blockage (EC_{50} 0.83 μg/ml) on syncytium formation between HIV-1 infected cells and normal cells.[4]

Except concentricolide (**1**), a new homologous series of 3-alkyl-5-methoxy-2-methyl-1,4-benzoquinones (**2-4**) with chain length C_{21} to C_{23} were isolated from the fruiting bodies of *Daldinia concentrica* [5] A pair of novel heptentriol stereoisomers, hep-6-ene-2,4,5-triols 6 and 7, were isolated from the culture broth of *D. concentrica*, besides three known compounds, i.e., 2,3-dihydro-5-hydroxy-2-methyl-4H-1-benzo-pyran-4-one (**5**), 3,5-dihydroxy-2-(1-oxobutyl)-cyclohex-2-en-1one (**8**), and pyroglutamic acid (=5-oxo-L-proline; **9**). [6] Compound **5** was reported as a metabolite from the rice culture solution of the fungus *Phialophora gregata* and shown to have biological activity against soybean cells.[7] Compound **8** has also previously been isolated from the culture broth of the fungus *Nodulisporium sp.* and found to have chlorosis activity, which was stronger against monocotyledons than against dicotyledons.[8]

The identification of aromatic steroid hydrocarbons bearing a methyl group at positions 1, 2, 3, 4, or 6 in sediments and petroleum has been puzzling since possible steroidal precursors have not yet been reported in living organisms. Two new aromatic steroids (**10** and **11**) were isolated from the fruiting bodies of *D. concentrica*, of which compound **11** bears an unusual methyl group at position 1. We propose that the origin of these compounds is derived from the transformation undergone by their precursor due to microbial action. Compounds **10** and **11** could be the long-sought, biological precursor steroids for organic matter in Earth's subsurface. [9] Another two new compounds, 1-isopropyl- 2, 7-dimethylnaphthalene (**12**) and 21-acetyloxyl-16, 18-dimethyl-10-phenyl-6,13,14-trihydroxyl-[11]-cyto-chalasa-7,19-diene-1-one (**13**), were also isolated from the fruiting bodies of *D. concentrica* [10].



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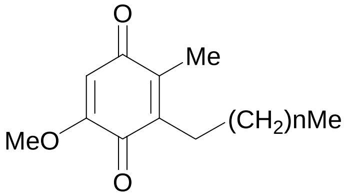
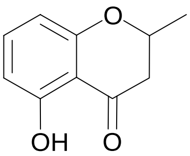


2 *n*=19
3 *n*=20
4 *n*=21



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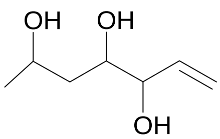

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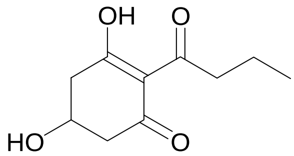

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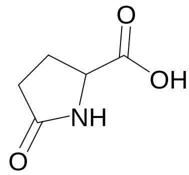

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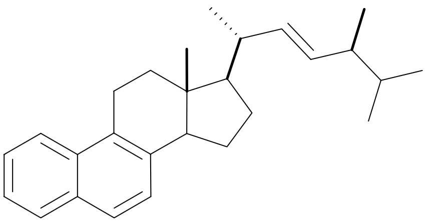

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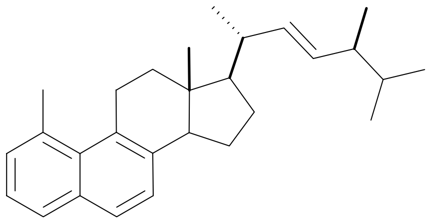

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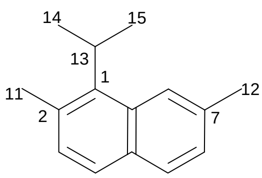

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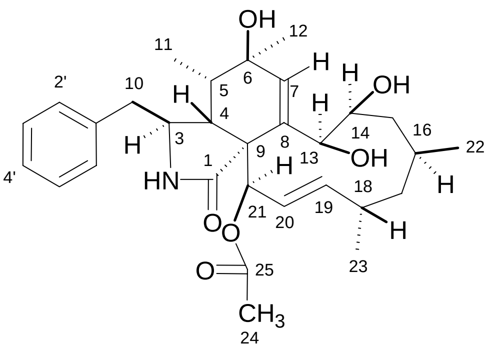

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Figures 1 to 13: Different compounds of the ascomycete *Daldinia concentrica*

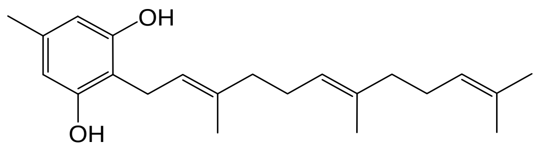
3 GRIFOLIN, A POTENTIAL ANTITUMOR NATURAL PRODUCT BY INDUCING APOPTOSIS IN VITRO FROM ALBATRELLUS CONFLUENS, AND OTHER RELATED COMPOUNDS FROM SAME GENUS

Grifolin (**14**) is a natural biologically active substance isolated from the fruiting bodies of *Albatrellus confluens*. We, for the first time, have described a novel activity grifolin, namely its ability to inhibit the growth of tumor cells by the induction of apoptosis. Grifolin strongly inhibited of tumor cells lines: CNE1, HeLa, MCF7, SW480, K562, Raji and B95-8. Analysis of acridine orange (AO)/ethidium bromide (EB) staining and flow cytometry showed that grifolin possessed apoptosis induction activity to CNE1, HeLa, MCF7 and SW480. Furthermore, the cytochrome *c* release from mitochondria was detected by confocal microscopy in CNE1 cells after a 12 h treatment with grifolin. The increase of caspase-8, 9, 3 activities revealed that caspase was a key mediator of the apoptotic pathway induced by grifolin, and the under-expression of Bcl-2 and up-regulation of Bax resulted in the increase of Bax: Bcl-2 ratio, suggesting that Bcl-2 family involved in the control of apoptosis. Owing to the combination of the significant antitumor activity by inducing apoptosis and natural abundance of the compound, grifolin holds the promise of being an interesting antitumor agent that deserves further laboratory and in vivo exploration.[11]

In the course of screening for novel naturally occurring fungicides from mushrooms in Yunnan province of China, the ethanol extract of the fruiting bodies of *Albatrellus dispansus* was found to show antifungal activity against plant pathogenic fungi. The active compound was isolated from the fruiting bodies of *A. dispansus* by bioassay-guided fractionation of the extract and identified as grifolin (**14**) by IR, 1H- and 13C-NMR and mass spectral analysis. Its antifungal activities were evaluated in vitro against 9 plant pathogenic fungi and *in vivo* against the plant disease of *Erysiphe graminis*. *In vitro, Sclerotinina sclerotiorum* and *Fusarium graminearum* were the most sensitive to grifolin, and their mycelial growth inhibition were 86.43 and 80.90% at 0.1 μg/ml, respectively. Spore germination of *F. graminearum*, *Gloeosporium fructigenum* and *Pyricularia oryzae* were almost completely inhibited by 12.5 μg/ml of grifolin. The curative effect of grifolin (**14**) against *Erysiphe graminis in vivo* were 65.52% at 100 μg/ml.12

In the previous report, the effects of albaconol (**15**) from *Albatrellus confluens* on *vanilloid* receptors were studied electrophysiologically on rat ganglion neutrons as well as on recombinant cell lines expressing rat VR1 receptor.[13] Lately, the effect of albaconol (15) on the growth inhibition of human tumor cell, DNA topoisomerase (topo)-mediated DNA cleavage and direct DNA break was investigated. Albaconol (**15**) inhibited significantly the growth of human chronic myelogenous leukemia K562, lung adenocarcinoma A 549, gastric adenocarcinoma BGC-823 and breast carcinoma Bcap-37 cell line, the IC_{50} values were 2.77±0.14□2.58±0.88□1.45±0.05□1.10±0.31 μg/mL, respectively. Albaconol (**15**) stabilized and increased the topo II-mediated DNA cleavable complex and inhibited the religation activity of topo II in a dose-dependent manner, but it failed to affect the activity of topo I. Albaconol (**15**) has the break activity on pBR322 DNA at relatively high concentration, but no effect on macromolecule DNA of K562 cells. These results strongly suggested that albaconol (**15**) targeted specifically to DNA topo II and that this is one of the mechanisms of antitumor action of albaconol; the direct action of albaconol (**15**) on DNA may partly contributed to its antitumor activity at high concentration.[14]

The contraction and desensitization induced by albaconol (**15**) and the influence of capsazepine, capsaicin and extracellular Ca^{2+} were investigated to see whether the actions were mediated via a specific VR receptor in guinea pig trachea spiral strips *in vitro*. Both albaconol (**15**) and capsaicin were contractors of tracheal smooth muscle, but albaconol (**15**) was not so potent as capsaicin, with –log (M) EC_{50} values of 4.23±0.18 (n=10) and 7.33±0.21 (n=10) respectively. 2.5, 5.0 μM capsazepine competitively antagonized the contractile response to albaconol (15), with -log (M) pK_B values of 6.60±0.39 (n=10) and 7.36□0.45 (n=10) respectively. Albaconol (**15**) increased the contraction induced by a low dose of capsaicin (10^{-10}-10^{-9}M), but non-competitively antagonized the contraction induced by a high dose of capsaicin (10^{-8}-10^{-3} M). Either albaconol (1, 100 mM) or capsaicin (3.0, 10 μM) was able to desensitize the isolated guinea pig bronchi to subsequent addition of albaconol. Capsazepine (5.0 μM) significantly prevented the desensitization induced by either albaconol (1, 100 μM) or capsaicin (3, 10 μM). Extracellular Ca^{2+} was essential for albaconol to induce excitation, but it unaffected albaconol- or capsaicin-induced desensitization. The results suggested that albaconol (**15**) induce contraction and desensitization of guinea pig trachea *in vitro* as a partial agonist for VR.[15]



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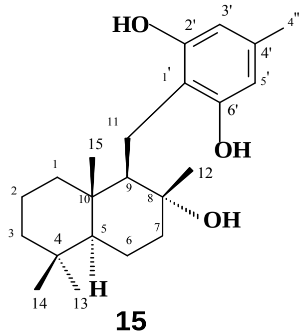

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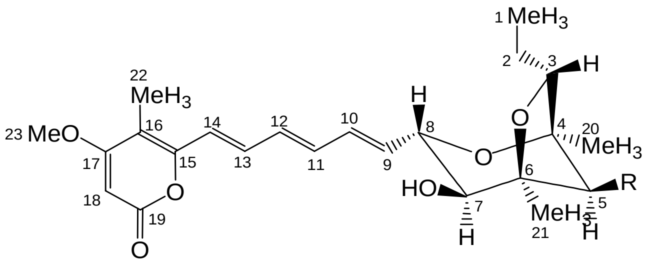


16 R = OAc
17 R = OH

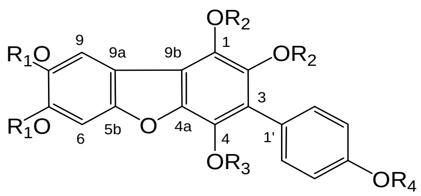
Figures 14 – 17: potential antitumor natural products

Albaconol (**15**) inhibited lipid peroxidation in rat liver homogenate with IC_{50} value of 104.2 μg/ml compared with butylated hydroxyanisole (BHA, IC_{50} 40.4 μg/ml) and vitamin E (IC_{50} 127.2 μg/ml). Albaconol increased SOD activity with EC_{50} value of 106.3 μg/ml, and BHA (EC_{50} 19.9 μg/ml).[16]

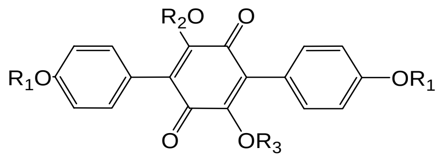
The basidiomycete *Albatrellus confluens* when grown in culture produces a polyene pyrone mycotoxin, aurovertin E (**17**), along with aurovertin B (**16**). This was the first example of the occurrence of aurovertins in macromycetes.[17] The aurovertins, metabolites from the fungus (anamorphic ascomycetes) *Calcarisporium arbuscula*, are a group of acute neurotoxic substances which act as potent inhibitors of ATP synthesis and ATP hydrolysis catalyzed by mitochondrial enzyme systems.[18-21]

4 RADICAL SCAVENGING ACTIVITY OF NATURAL P-TERPHENYLS OBTAINED FROM THREE EDIBLE MUSHROOMS INDIGENOUS TO CHINA AND OTHER NATURAL P-TERPHENYLS

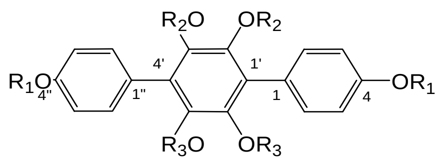
Ten natural *p*-terphenyl derivatives (**18-27**) obtained from the fruiting bodies of three edible mushrooms (*Thelephora ganbajun, Thelephora aurantiotincta, Boletopsis grisea*) indigenous to China were assessed on the DPPH (1,1-diphenyl-2-picrylhydrazyl) radical scavenging activity. The compounds **18-20** showed potent DPPH radical scavenging activities comparison with the well known strong activitor BHA (butylated hydroxyanisol) and α-tocopheral. It was found that the free radical scavenging activities of **19** (EC_{50}=0.07) was stronger than BHA (EC_{50}=0.09) and α -tocopherol (EC_{50}=0.25), that of **18** (EC_{50}=0.12), **20** (EC_{50}=0.13) were similar to BHA and stronger than α-tocopherol. The formation of furan rings and the numbers and position of hydroxy groups in the molecular structure of *p*-terphenyls are found to be important for modulating free radical scavenging activity.[22]



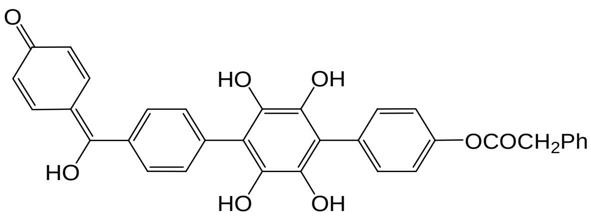
18 R_1=R_2=Ac, R_3=R_4=H
19 R_1=R_3=R_4=H, R_2=Ac
20 R_1=R_4=H, R_2=R_3=CH_2COPh
25 R_1=R_2=R_3=R_4=Ac



21 R_1=R_3=CH_2COPh
22 R_1=R_3=H, R_2=Me
24 R_1=R_2=R_3=H



23 R_1=CH_2COPh, R_2=R_3=H
26 R_1=R_2=Ac , R_3=H

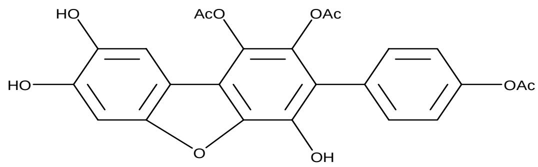


27

Figures 18 – 27: Ten natural *p*-terphenyl derivatives

A metabolite with *p*-terphenyl core, named sarcodan (**28**), was isolated from the fruiting bodies of the basidiomycete *Sarcodon leavagatum*.[23] Another nitrogenous metabolite with p-terphenyl core, sarcodonin δ (**29**), together with two known *p*-terphenyl metabolites (**7** **8**), was isolated from the fruiting bodies of the basidiomycete *Sarcodon scabrosus*.[24]

Terphenyls are aromatic hydrocarbons consisting of a chain of three benzene rings. There are three isomers, in which the terminal rings are *ortho-*, *meta*-, or *para*-substituents of the central ring. Most of the natural terphenyls are *p*-terphenyl derivatives. The chemical investigation of *p*-terphenyls as one class of the pigments of mushrooms began in 1877.[25] In recent years, it has been reported that some terphenyls exhibit significant biological activities, e.g., potent immunosuppressants, neuroprotective, antithrombotic, anticoagulant, specific 5-lipoxygenase inhibitory, and cytotoxic activities (see section 5). In addition, by comparison with other types of complex natural products, terphenyls are easily synthesized since they contain fewer (or no) chiral centers. It is also interesting to note that some popular edible mushrooms are rich in *p*-terphenyls; this is a sign that the toxicity of at least some *p*-terphenyls is low. Because of their promising biological activities and important properties, terphenyls have generated increasing research interest.[25]



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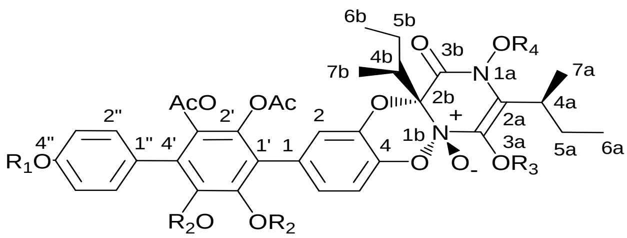


29 R_1=H R_2=H R_3=H R_4=Me

Figures 28, 29: sarcodan (28) and sarcodonin δ (29)

5 ANTIFUNGAL SESQUITERPENOID FROM LACTARIUS NECATAR AND OTHER COMPOUNDS FROM GENERA LACTARIUS AND RUSSULA

The mushrooms belonging to the genus Lactarius (family Russulaceae, Basidiomycotina) form a milky juice when the fruiting bodies are injured. In the great majority of *Lactarius* species, different kinds of sesquiterpenes play an important biological role, being responsible for the pungency and bitterness of the milky juice, the change in the air of the color of the latex, and constituting a chemical defense system against various predators such as bacteria, fungi, animals, insects.[26] Most of *Lactarius sesquiterpenes* belonging to the classes of lactaranes, secolactaranes, marasmanes, isolactaranes, norlactaranes, and caryophyllanes were believed to be biosynthesized from humulene.[27-30]

Rufuslactone (**30**) is an isomer of a previously described lactarane 3, 8-oxa-13-hydroxylactar-6-en-5-oic acid γ-lactone (**31**) from *Lactarius rufus*. Its structure was elucidated on the basis of spectroscopic means. Rufuslactone (**30**) showed the antifungal properties against plant pathogenic fungi.[31] *Alternaria brassicae* was the most sensitive to Rufuslactone (**30**), and its mycelial growth inhibition was 68.3 at 100 µg/ml.

A sesquiterpene of humulene type, named 2β,3α-epoxy-6Z, 9Z-humuladien-8 α-ol (**32**) together with a known compound lactarinic acid was isolated from the fruiting bodies of *Lactarius hirtipes*. For the subdivision Basidiomycotina, fungal sesquiterpenes formed via the humulane-protoilludane biosynthetic pathway are also characteristic. However, no representative of humulene type of sesquiterpenes has ever been isolated so far from higher fungi. Compound **32** was found as the first humulene-type sesquiterpene in higher fungi.[32] Five new humulane-type sesquiterpenes, mitissimols A (**33**), B (**34**), and C (**35**), and a mixture of mitissimyl A oleate (**36**) and mitissimyl B oleate (**37**), were isolated from the fruiting bodies of *Lactarius mitissimus*.[33] Their structures were elucidated on the basis of comprehensive spectroscopic techniques and necessary chemical methods. The relative stereochemistry of **33** was determined by single crystal X-ray diffraction analysis.

Two new red azulene pigments (**38, 39)** were isolated from the fruiting bodies of the basidiomycete *Lactarius deliciosus* together with one known pigment (**40**).[34] Other two new azulene pigments, 1-formyl-4-methyl-7-(11-hydroxyl) isopropylazulene (**41**) and 4-methyl-7-isopropylazulene-1-carboxylic acid (**42**), were isolated from the fruiting bodies of the basidiomycete Lactarius hatsudake.[35]

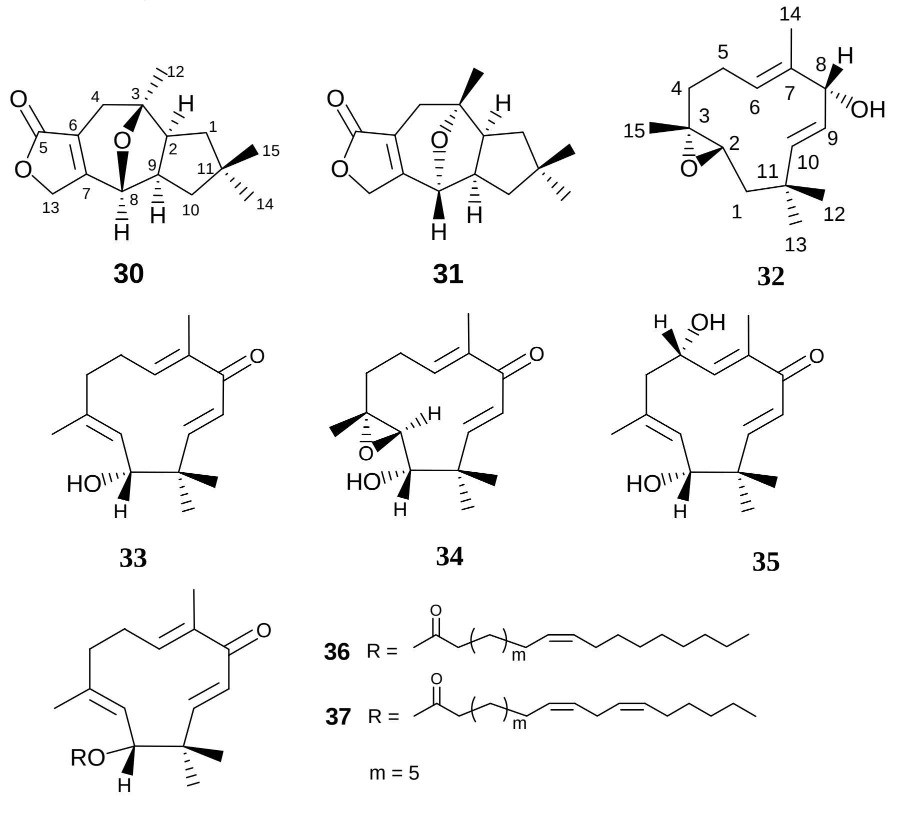


Figure 30 – 37: described chemical compounds

A new marasmane sesquiterpene, named lactapiperanol E (**43**), was isolated from the fruiting bodies of *Russula foetens* together with a known sesquiterpene lactapiperanol A (**44**).[36] Sesquiterpenes possessing the marasmane skeleton are known for more than 50 years.[37] Marasmic acid was found as an antibacterial substance in *Marasmius conigenus*,[38] and its 9-hydroxy derivative, detected in another basidiomycete, displayed antifungal, cytotoxic and phytotoxic activity.[39]

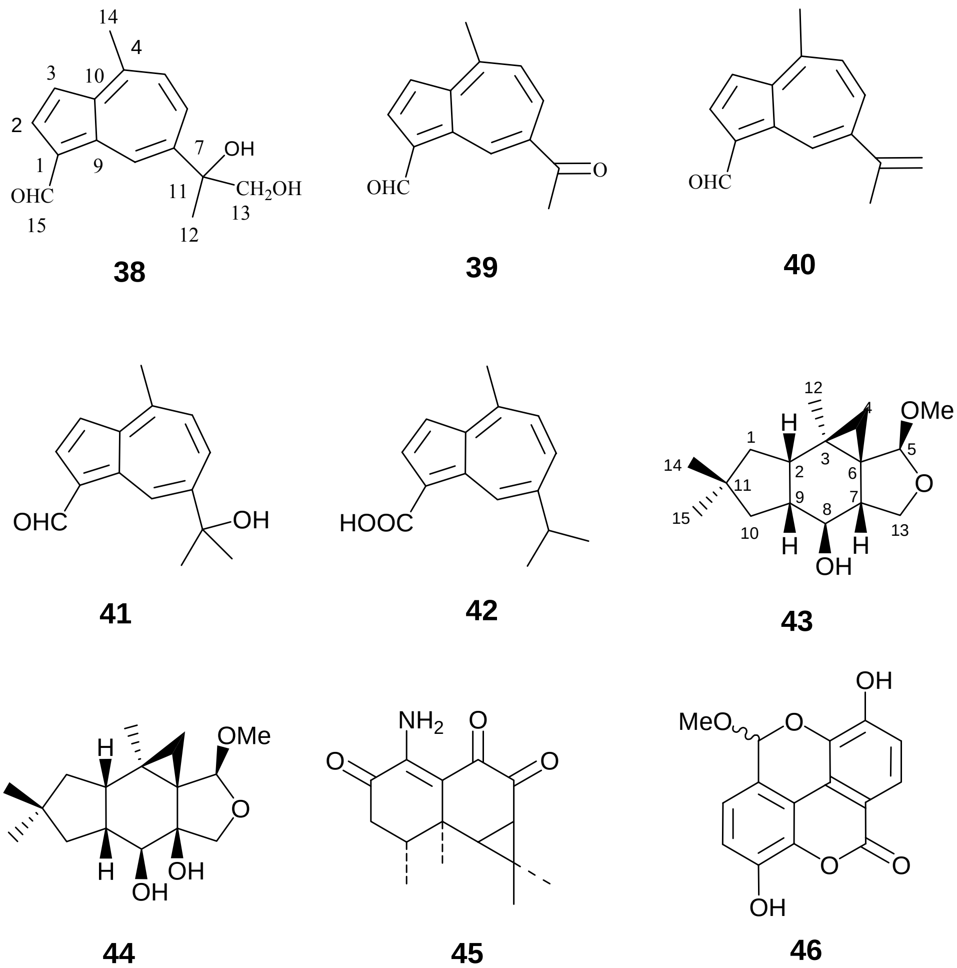
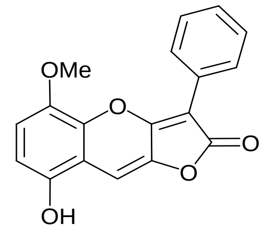


Figure 38 – 46: described chemical compounds

Velutinal and its fatty acid esters represent interesting examples of prodrug.[40-41] In most fungi only the esters are present which are cleaved to velutinal in case of injuries at the fruiting bodies.[42] Pilatin is an antibiotically active marasmane derivative from the culture of *Flagelloscypha pilatii*. It is a higher oxidized derivative of marasmic acid, cause frameshift mutations in *Salmonella typhimurium*, inhibits the growth of bacteria and fungi and is highly cytotoxic.[43] The Russulaceae family is one of the largest in the subdivision Basidiomycotina in Witthaker's kindom of Fungi and comprises hundreds of species.[44] While secondary metabolites occurring in the fruiting bodies of European *Lactarius* species have well been investigated, the *Russula* mushrooms have received less attention, notwithstanding the larger number of existing species.[45] Our recent chemical constituent investigation on *Russula lepida* led to the identification of some new terpenoids.[46-48] The minor constituent of *Russula lepida* was further investigated. A novel nitrogen-containing aristolane sesquiterpenoid compound, lepidamine **45**, was isolated from the fruiting bodies of Basidiomycete Russula lepida. It is the first aristolane-type sesquiterpene alkaloid isolated from nature.[49] It is also interesting that nigricanin (**46**), the first ellagic acid related derivative from higher fungi, has been isolated from the fruiting bodies of the basidiomycete *Russula nigricans*.[50] Ellagic acid and its derivatives are widely distributed in plants, but are rare in fungi. Ellagic acid and its derivatives are known to display multiple biological activities such as DNA damaging[51] or acting as antioxidants.[52] In the case of actinomycete, e.g., *Streptomyces chartreuses,* only the antibiotics D 329C, chartreusin, and elsamicin have been isolated; and these compounds have been reported to display antibacterial, antineoplastic, and antileukaemia activities.[53-55]

6 PIGMENTS FROM *PULVEROBOLETUS RAVENELII* AND *XYLARIA EUGLOSSA*

A new butenolide-type fungal pigment, pulverolide (**47**) was isolated from the fresh fruiting bodies of *Pulveroboletus ravenelii*.[56] *Xylaria euglossa* is a rot-wood-inhibiting ascomycete, mainly occurring on stumps and fallen branches of forested areas in the Southwest of China.



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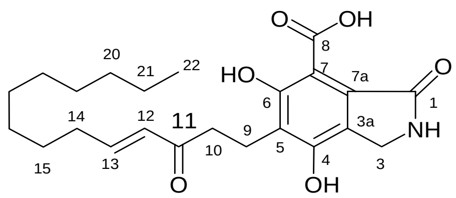

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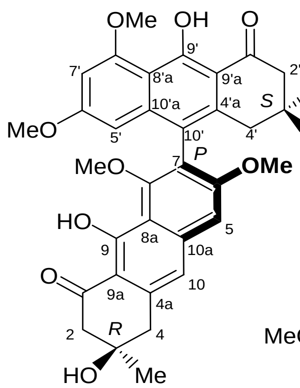
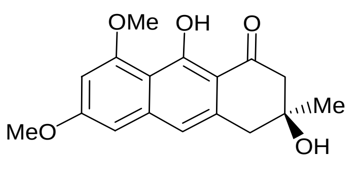
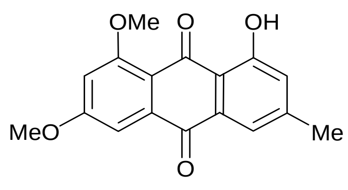






49 **50** **51**

Figure 47 - 51: described chemical compounds

Many unique secondary metabolites have been found in the fungi of this genus. During the study of *Xylaria* sp., various new metabolites had been discovered, including cytochalasins, globoscin, lactones, maldoxin, sesquiterpenoids, xylaramide, xylarin, and xyloketals.[57] We have carried out a detailed chemical investigation on the fungus Xylaria euglossa and isolated a new nitrogen-containing compound, xylactam (**48**), along with two known alkaloids, penochalasin B 2 and neoechinulin A from extracts of the fruiting bodies.[57]

A new pigment, 8,8'-O,O-dimethylphlegmacin A (**49**), was isolated from the fruiting bodies of ascomycete *Xylaria euglossa* along with two known fungi pigments (**50**) and (**51**). The structure of compound **49** was established as (3R, 3'S, P)-2,2',3,3'-tetrahydro-3,3',9,9'-tetrahydroxy-6,6',8,8'-tetramethoxy-3,3'-dimethyl-[7,10'-bianthracene]-,4'(1H,1'H)-dione on the basis of spectroscopic means. Its absolute configuration was deduced from the CD and ^{1}H-NMR spectra. It is the first isolation of a phlegmacin type pigment from an ascomycete.[58]

7 DITERPENOIDS FROM SARCODON SP. AND HYDNUM SP.

Novel cyathane-type diterpenoids, scabronines G, H and sarcodonin I (**52-54**) were isolated from the fruiting bodies of the basidiomycete *Sarcodon scabrosus* together with four known diterpenoids: allocyathin B_2, sarcodonin A, sarcodonin G and scabronine F.[59,60] *Sarcodon scabrosus* is a mushroom belonging to the family *Thelephoraceae* and has a bitter taste.

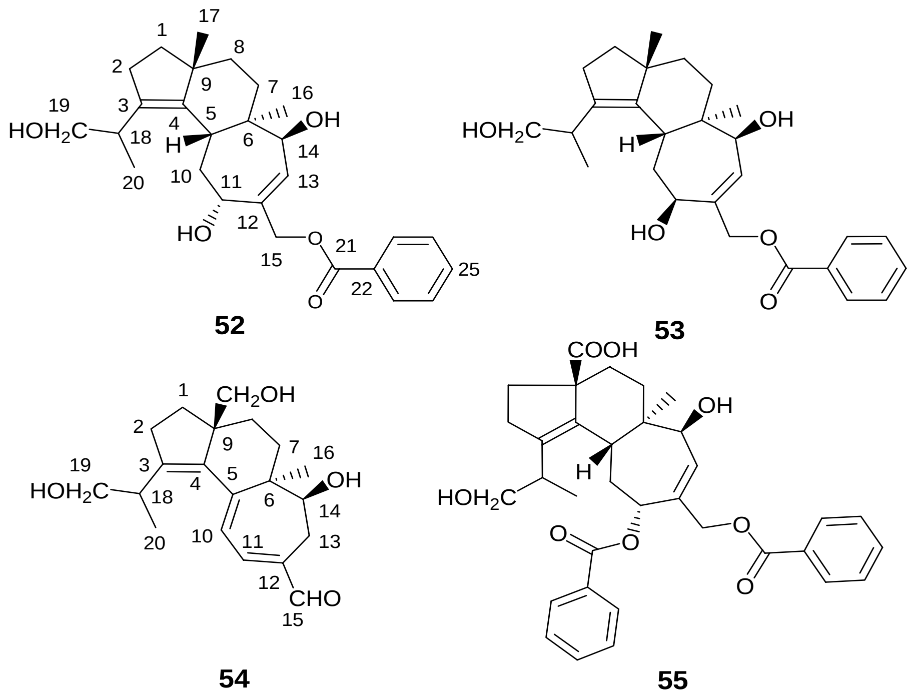


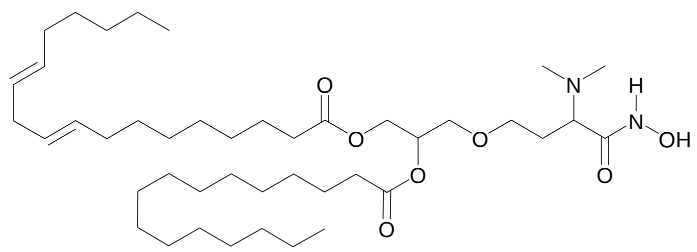
Figure 52 - 55: described chemical compounds

Diterpenoids, including sardonins A-H, scabronines A-F and scabronines L and M have previously been isolated from this mushroom as the bitter principles.[61-63] All thses diterpenoids posses a cyathane skeleton consisting of angularly condensed five-, six and seven-membered rings and show stimulating activity of nerve growth factor (NGF)-synthesis *in vitro*.

Eleven compounds have been isolated from the fruiting bodies of the basidiomycete Hydnum repandum. Their structures were established as sarcodonin A, scabronine B (**55**), 3 β-hydroxy-5α, 8α-epidioxyergosta-6, 22-dien , (22E, 24R) -ergosta-7, 22-diene-3β, 5α, 6β-triol, (22E, 24R)-ergosta-7, 22-diene-3 β-ol, benzoic acid, 4-hydroxylbenzaldehyde, 4-monopropanoylbenzenediol, ethyl-β-D-glucopyranoside, thioacetic anhydrid , (2S, 2'R, 3S, 4R)-2-(2-hydroxytricosanoylamino) hexadecane-1, 3,4-triol by spectral methods. Among them, sarcodonin A and scabronine B were reported firstly from *Hydnum* genus, and the other compounds were isolated from this fungus for the first time.[64]

8 MISCELLANEOUS

A novel N-containing compound, vibratilicin (**56**), was isolated from the fruiting bodies of the basidiomycete *Cortinarius vibratilis*.[65] Compound **56** is a representative of the rare natural products containing hydroxamic acid moieties, and can be viewed as a derivative of neoengleromycin from the fungus *Engleromyces goetzii*.[66]



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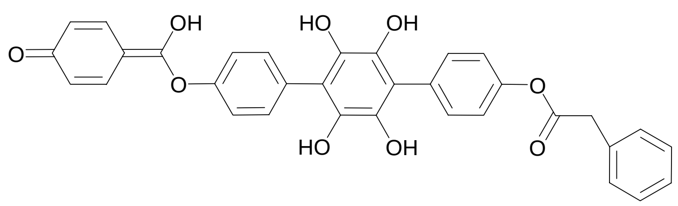

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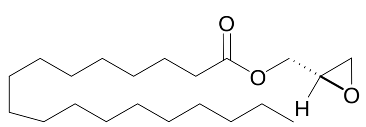

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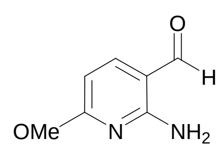

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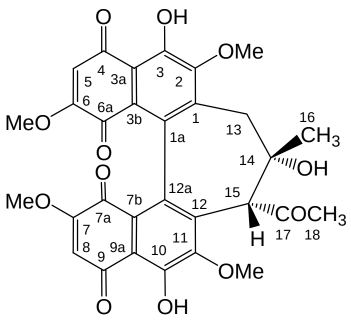
Figure 56 - 59: described chemical compounds

Fruiting bodies of the basidiomycete *Thelephora aurantiotincta* contain a *p*-terphenyl, named aurantiotinin A (**57**), together with ganbajunin C and atromentin.[67] Fruiting bodies of the basidiomycete Cortinarius umidicola contain a natural pyridine derivative (3-aldehyde-2-amino-6-methoxypyridine, **59**), together with (R)-glycidyl octadecanoate (**58**).[68]

An unique fungal pigment, hypocrellin D (**60**), together with three known perylenequinone derivatives hypocrellin A (**61**), B, C, was isolated from the fruiting bodies of *Shiraia bambusicola*.[69] The ROESY experiment and CD of hypocrellin D required that the absolute configuration of the asymmetric carbons of the alicyclic ring of **60** be the same as those of hypocrellin A; i.e. 14S and 15R. *Shiraia bambusicola* (Hypocreaceae), an ascomycete parasitic on bamboo twigs, is recorded only in China and Japan.



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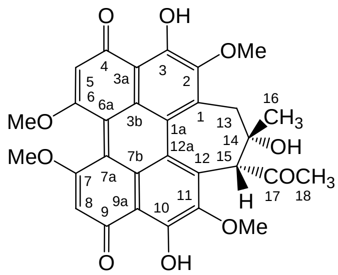

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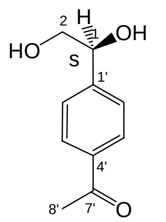

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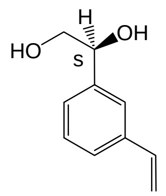

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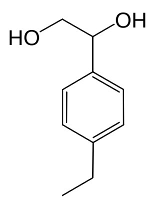

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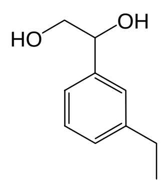

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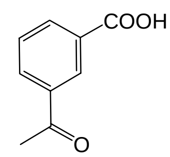


66

Figure 60 - 66: described chemical compounds

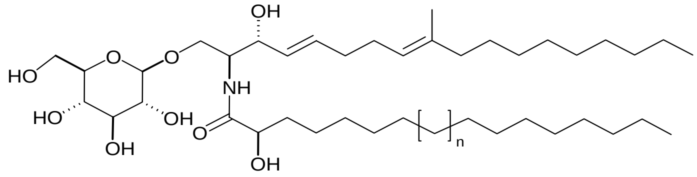
It has been commonly used as medicinal fungi under the name of "Zhu Huang" in China for treatment of rheumatism and pneusomia in traditional Chinese medicine (TCM). Previously new perylenequinone pigments hypocrellin A-C and shiraiachrome A-C have been isolated from *S. bambusicola* as fungal metabolites which exert photodynamic activity towards bacteria and fungi.[70,71] Lately the methanolic extract of the mycelium of the fungus *S. bambusicola* was found to show significant cytotoxicity in the A-549 and HCT-8 solid tumor cells. Subsequent bioassay-guided fractionation in HCT-8 in vitro led to the isolation and characterization of shiraiachromes A and B as two major cytotoxic principles.[72] A series of new perylene derivatives related to shiraiachrome-A and -B as well as calphostin-C have been synthesized and evaluated for their cytotoxicities, antiviral activities, and inhibitory activities against protein kinase C.[72]

The basidiomycete *Boletus edulis* when grown in culture produces two phenyl-ethanediols, 1-(3-ethenylphenyl)-1, 2-ethanediol **62** and 1-(4-acetylphenyl)-1, 2-ethanediol **63**, together with three known compounds 1-(3-formylphenyl)-ethanone **64**, 1-(3-ethylphenyl)-1, 2-ethanediol **65** and 1-(4-ethylphenyl)-1, 2-ethanediol **66**.[73] Compound **62** was usually used as a kind of rubber composition, and was isolated for the first time as a new natural product.

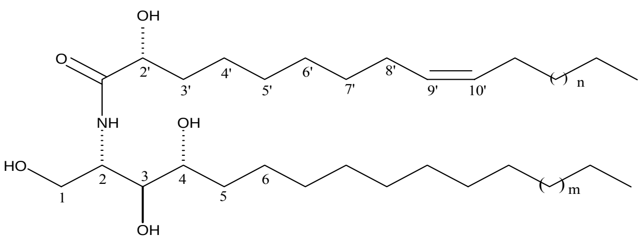
Five cerebrosides, including three new ones named cortenuamide A (**67**), cortenuamide B (**68**) and cortenuamide C (**69**), were isolated from the fruiting bodies of the Basidiomycetes *Cortinarius tenuipes*. The structures of those compounds were elucidated as (4E,8E)-N-D-2′- hydroxytetracosanoyl-1-O-β-D-glycopyranosyl-9-methyl-4, 8-sphinga-dienine (**67**), (4E, 8E)-N-D-2′-hydroxytricosanoyl-1-O-β-D-glyco- pyranosyl-9-methyl-4,8-sphingadienine (**68**), (4E, 8E)-N-D-2′-hydroxyl- docosanoyl-1-O-β-D-glycopyranosyl-9-methyl-4,8-sphingadienine (**69**), (4E, 8E)-N-D- 2′-hydroxyoctasanoyl-1-O-β-D-glycopyranosyl-9-methyl-4, 8-sphingadienine and (4E, 8E)-N-D-2′-hydroxypalmitoyl-1-O-β-D-glyco-pyranosyl-9-methyl-4,8-sphingadienine by spectral and chemical methods.[74] A new ceramide, named hygrophamide (70), was isolated from the fruiting bodies of the Basidiomycetes Hygrophorus eburnesus. The structure of the compound was elucidated as (2S, 3R, 4R, 2’R)-2-(2’-hydroxy-9’Z-ene-tetracosanoylamino)-octadecane-1, 3, 4-triol (**70**) by spectral and chemical methods.[75]

The ceramide fractions were isolated from the fruiting bodies of Tuber indicum and separated into three kinds of molecular species **71**, **72**, and **73** by normal and reverse phase silica gel-column chromatography. By means of NMR spectroscopy, FAB-MS, and chemical degradation experiment, their component sphingoid base for **71** and **72** was uniformly (2S, 3S, 4R)-2-amino-1, 3, 4-octadecantriol, while the sphingoid of **73** was D-*erythro*-sphingosine, and their structures have been determined unequivocally to be (2S, 2’R, 3S, 4R)-2-(2’-D-hydroxyalkanoylamino) octadecane-1, 3, 4-triol, the fatty acid composition of which consists of 2-hydroxydocosanoic, 2-hydroxytetracosanoic, and 2-hydroxytricosanoic acids; (2S, 3S, 4R)-2-(alkanoyl-amino) octadecane-1, 3, 4-triol, the fatty acid composition of which is unusual and consists of docosanoic, hexadecanoic, tricosanoic, octadecanoic and nonadecanoic acids; and (2S, 3R, 4E)-2-(alkanoylamino)-4-octadecene-1, 3-diol, the component fatty acids of which were hexadecanoic (predominant) and octadecanoic acids, respectively.[76] The new phytosphingosine-type ceramide **74**, named paxillamide, was isolated from the fruiting bodies of the basidiomycete *Paxillus panuoides*.[77]

From the fruiting bodies of ascomycete *Tuber indicum*, a new steroidal glucoside with polyhydrxy ergosterol nucleus, tuberoside (**75**), has been isolated. This is the first example of isolation of a polyhydroxylated ergosterol glucoside from higher fungi in nature.[78] Two new oleate esters of polyhydroxylated ergostane-type nucleus, 3β, 5α -dihydroxy-(22E,24R)-ergosta-7,22-dien-6β -oleate (**76**) and 3β, 5α -dihydroxy-(22E,24R)-ergosta-22-en-7-one-6β -oleate (**77**), were isolated from the fruiting bodies of the basidiomycete Tricholomopsis rutilans along with three known sterols.[79] A new cytotoxic lanostane triterpenoid (**78**) was isolated from the basidiomycete *Hebeloma versipelle*.[80] **78** exhibited to possess cytotoxic activities against tumor cell lines, HL60, A549, SGC-7900 and Bel-7402, with IC_{50} values, 11.2, 20.9, 22.6, and 25.0 µg/ml, respectively. A new ergostane-type glycoside, named tylopiloside (**79**), was isolated from the fruiting bodies of the basidiomycete *Tylopilus virens*. Its structure was elucidated as (22E, 24R)-ergosta-7, 22-dien-5α , 6β -diol-3β -O-[3-(3-phenylpropanoyloxy)]- β -D-glucopyranoside.[81]

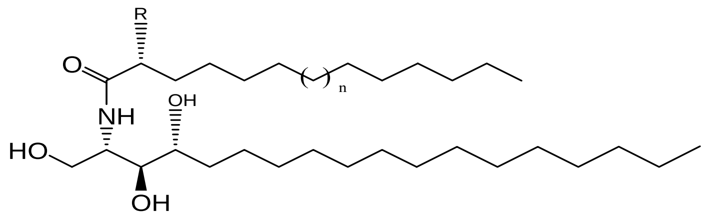


67 n=9, **68** n=8, **69** n=7

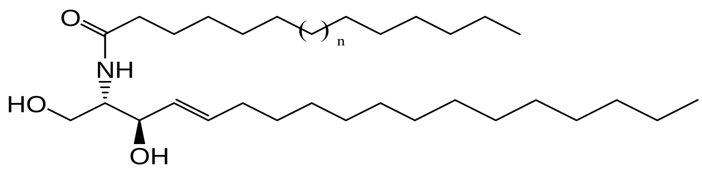


70 n=11, m=4

Figure 67 - 70: described chemical compounds



71 R=H (n=10, 11, 12)
72 R=H (n=4, 6, 7, 10, 11)



73 n=4, 6

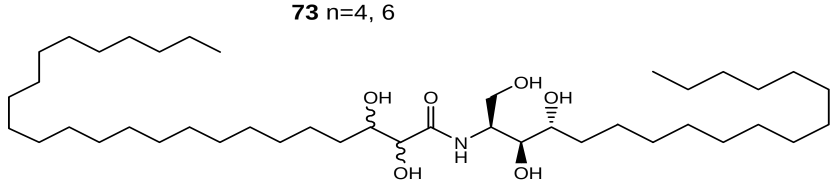


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Figure 71 - 74: described chemical compounds

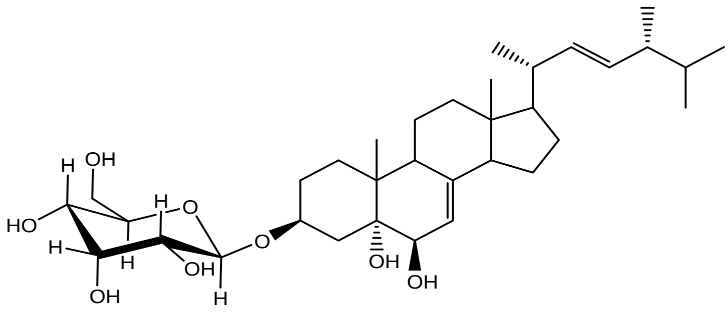

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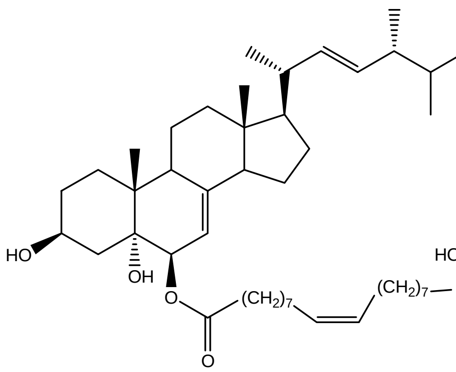
Figure 75: described chemical compound



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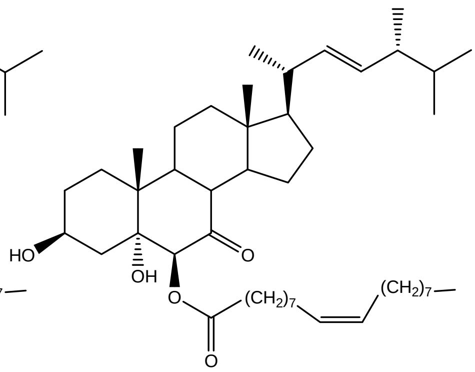

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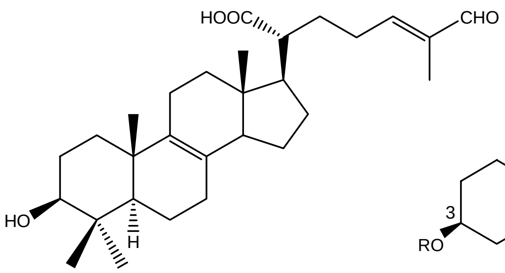
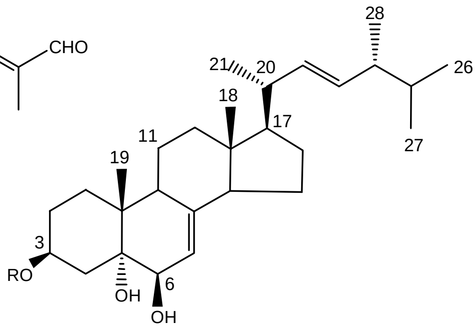


78



79 R =

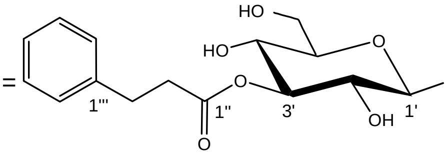


Figure 76 - 79: described chemical compounds

The fungus *Bondarzewia berkeleyi* (Fr.) Bond. et Singer of the family Bondarzewiaceae (Basidiomycota) grows at the base or roots of *Abies* and other conifers of the family

Fagaceae. There are no any reports on its chemical constituents in literature. Steglich and Anke reported a cytotoxic metabolite, montadial A, isolated from the polypore *B. montana*.[82] They pointed that treatment of these mycelial roots with aqueous KOH causes an intense yellow color. Taxonomically the genus *Bondarzewia* has been placed in the order Russulales, which is supported by the occurrence of stearoyl-velutinal, the chemotaxonomic marker compound for this order.[82]

9 SUMMARY

Higher fungi, among the many diverse organisms, are a major source of biologically active natural products. They have often been found to contain biologically active compounds, and they provide a rich variety of active secondary metabolites. There are potentially many compounds still to be discovered in higher fungi since until now only a relatively small number of higher fungi have been chemically investigated, and many of the remaining species are involved in interesting biological phenomena. These as yet unstudied species hold the promise of providing new natural products. That these fungi are often involved in interesting biological processes indicates not only that the new metabolites involved will be chemically interesting but also that the new metabolites may be biologically interesting and significant. The large biodiversity of higher fungi provides a huge resource for extending the chemodiversity of natural products and for finding new lead structures for medicinal chemistry.

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