

【附件三】 成果報告（此為格式範例，詳情請見格式說明；請於系統端上傳 PDF 檔）

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教育部教學實踐研究計畫成果報告
Project Report for MOE Teaching Practice Research Program

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Forest Fungi and Carbon Sequestration

Forest Fungi

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National Taiwan University/ School of Forestry & Resource Conservation

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本文與附件 Content & Appendix

計畫名稱 (Title of the Project) **Forest Fungi and Carbon Sequestration**

Forest Fungi

一、本文 (Content)

1. 研究動機與目的 (Research Motive and Purpose)

Biodiversity

Through theoretical and practical learning, students will obtain and create insights into the importance of biodiversity for ecological functioning of forests such as carbon sequestration. Examples will be different systematic and ecological groups of fungi. Diversity is exemplified by the high specialization of different fungi on different substrates. Biodiversity is also conveyed as a value of itself.

Interdisciplinarity

In the examples of forest fungi, students realize that there are complex interactions between living and non-living factors of environment, such as carbon sequestration by forest trees enhanced by mycorrhiza fungi and release of carbon through wood decay by saprobic fungi. Global warming also influences the fruiting of macroscopic fungi in the forest. Different systematic groups and species of fungi have interactions with very specific plants and animals which highlights the importance of biodiversity knowledge not only in fungi, but also botany and zoology. These specificities are further specialized with respect to specific organs and tissues of the involved organisms.

Digital competence

Young people have high technical digital competence, but this needs to be complemented by analog experience and skills. In the virtual representation e.g. of species on a screen, the real size of objects cannot be as clearly recognized as in the direct perception (八, Fig. 1). Through these very simple examples, students realize that there is a difference between digital and analog reality and may be able to transfer this experience also to social and political interaction.

Appreciation of Science

The increasing dangers of people through manipulation by faked virtual “realities” need to be counteracted by establishing contrary values. The scientifically predicted global warming now cannot be any more ignored and is a good example for the value of Science. Scientific values such as reproducibility and crediting priority of new discoveries may contribute to balancing virtual manipulation. Preserving physical specimens, documentation of data in the field and in the lab all enhance reproducibility and objectivity. Since students have to follow basic scientific standards through the practical part of the course, they implicitly realize the importance of scientific values and of Science in general.

Urban society and forests

Urban forests may play lesser roles in carbon sequestration than rural forests, but are more easily accessible to people and, therefore, provide great opportunities to outdoor education about mitigating by forests of environmental stress and loss of biodiversity. Urban forests differ from rural ones by a higher proportion of introduced species. Furthermore, tree health and safety is more important in urban than in rural forests. Students in the course may choose by themselves whether they want to select an exemplary forest fungus for research and presentation from the urban or rural environment.

English and teamwork competence

Since the course is an EMI course, most likely foreign students may join it. The Taiwanese students profit from the additional explanations in Chinese so that they can train their English listening abilities more effectively than in a purely English course. Taiwanese and foreign students have to collaborate in small teams for a small research project on a selected forest fungus and for their oral repetition report in the term and particularly for the final oral report of the research outcome.

2. 研究問題 (Research Question)

Managing carbon sequestration and storage is becoming an important tool towards environment-friendly and global-warming neutral economy and society. Sensibilizing the population to the importance of forest protection is necessary for successful protection policies, but scientific understanding of how forests sequester carbon is important for distinguishing between forests with good and poor sequestration

performance. Forests are the major habitat for macrofungi compared to arable land (Griffith & Roderick 2008). The functions of fungi in forests are diverse. Mycorrhiza fungi in symbiotic interactions in the roots enhance stress resilience of the plant by enhanced or stabilized uptake of soil nutrients and water as well as by protection against pathogens and pollutants. Saprobic fungi which degrade wood and litter, however, have the potential to transform a forest with poor ecological functioning into a carbon source in the short term, but in the longer term recycling by these fungi may lead to better growth of newly developing forests. In addition to these above mentioned macroscopically visible fungi, many other fungi which are rather microscopic also play important roles in forest ecosystems, such as pathogens on trees and understory plants or on animals, in plant growth promotion, or as symbionts of forest animals or in lichens. Having an impression of the diversity of species and functions of fungi in forests may prevent us from too simplified estimates of the role of fungi in carbon sequestration and from failing forest management policies. Protecting biodiversity as a value of itself, independent from positive or negative ratios in carbon sequestration is also a rationale of this course.

In fungi, lack of knowledge about the diversity and distribution of fungi is the largest challenge in mycology, which can be resolved only step by step by detailed observation of their morphology and association with other microbes, plants, and animals, in nature and culture, comparison with previous publications and specimens from other mycologists, and molecular analyses. The ecological roles include endophytic, saprobic and parasitic fungi on plants, and parasitic and symbiotic fungi in animals. The global distribution of fungi and lack of knowledge require more international collaboration in research and teaching than in many other disciplines. For the present digitalization, the newly created data are carefully curated, brought into unified formats and distributed for perusal by other researchers.

3. 文献探討 (Literature Review)

In terrestrial ecosystems, forests have the greatest potential of carbon sequestration (Canadell & Raupach 2008). Just planting trees does not inevitably lead to carbon sequestration (Lefebvre et al. 2021). For example, 25% of the land area of Germany is covered by forest, but due to climate change, the carbon sequestration function has been heavily damaged, which since 2017 has led to a shift from carbon sink to a carbon source by releasing 3% more carbon than fixing carbon from the atmosphere (Bundeswaldinventur 2022). Mycorrhiza fungi are considered enhancing carbon sequestration indirectly by supporting their symbiotic trees. Several mycorrhiza fungi of trees produce edible fruit-bodies that could serve as human food in a more sustainable and carbon-reducing way than food from agriculture, but this potential has

not yet been explored in forestry (Thomas & Jump 2023). The role of mycorrhiza fungi, however, changes with climate warming which may increase mushroom production without increased tree growth and may rather reduce carbon sequestration (Büntgen et al. 2013). These complex processes have been poorly investigated and are now difficult to assess, because they overlap with climate warming (Büntgen et al. 2013). Wood decay fungi are the single organisms that produce large amounts of wood-degrading enzymes, while insects rather mechanically degrade wood and enhance the surface of dead wood through which fungal enzymes can enter. Different species of wood-decay fungi do not have only diverse enzymes for degrading wood, but also show divergent growth and degradation of specific cells and tissues in wood (Schwarze et al. 2006). The same fungus depending on the tree species or the type of wood can also switch from one type of wood decay to another one (Schwarze et al. 2006). These specific ways of wood degradation are only known from a few species in few countries; almost nothing is known about such specificities in the wood-decay fungi in Taiwan. An addition to the poor knowledge about the fungal species known to science, the majority of fungi still awaits scientific discovery and description (Hawksworth & Lücking 2017).

4. 教學設計與規劃 (Teaching Planning)

The course is composed of traditional lectures, students' own oral presentations in English, written tests, a field trip, and lab work, as explained below. The students form teams of 2-3; each team has to give one repetition report during the term, conduct own field collection and lab work, and a final oral presentation.

- Weekly lectures: The course is composed of weekly lectures throughout 13 weeks of the term (3 academic hours each) with Powerpoint Presentations which are uploaded in the electronical system of NTU (NTUCool) and serve as teaching material.
- Weekly oral brief repetition report: Each team (mostly 2 students) provides one oral repetition report in English with PowerPoint at the beginning of a course. The content is a summary of the last week's 3-hours lecture within ca. 10 minutes.
- Weekly written self-tests: The test sheets (1-3 pages) are prepared in English about the content of the last week. The student with the "open-book" option can check how much they remember from the last week's course, and whether they understand the English and content of the test questions, and write down their answers in English or Chinese. The answers of the self-tests are exposed after collecting the test sheets. The sheets of the self-tests are collected and stored as proof of attendance, but the self-tests are not graded individually. The empty self-

tests are uploaded in the NTU system for the students' own reference.

- Mid term exam: The mid term exam is a traditional written exam about the lectures before. The self-tests serve as preparation for the written exam which is not "open-book" and serves for 50% of the final grading.
- Field trip: A field trip is arranged for demonstrating the content of the course in nature. It is also an opportunity for the students to collect specimens which serve for each team's small research project.
- Small research projects (lab work): Major part of this lab research by the students takes place after the mid term exam. Each team documents and collects a specimen in the field and provide a fresh fragment for our lab for molecular species identification based on DNA sequences. The results are communicated to each respective team. Time slots are arranged individually for each team for microscopical characterization with measurements and photographs in the lab. These materials created by the student serve as basis for the final oral presentation.
- Final oral presentation: Each team presents a species collected by the students in the field themselves, assisted by us by molecular species identification and guidance through the microscopy in the lab. The students have to amplify and discuss the available knowledge about this species and its potential ecological role in the forest, implicitly also whether it is rather contributing to carbon sequestration or carbon release. The oral presentations are given in English along PPT slides, are ranked and then serve for another 50% of the final grading.

5. 研究設計與執行方法 (Research Methodology)

1. Sample collection:

Observation of fungi is done throughout the year in an urban or rural forest according to the students' preference with the opportunistic strategy (Mueller et al. 2011) during the term. Fresh samples are photographed directly in their habitat or occasionally in the lab. GPS data have to be noted. Samples are dried on an electrical drier and preserved in our lab. Prior to drying of some specimens, strains can be isolated and cultivated if necessary.

2. Morphology:

Mushrooms (macrofungi) are identified with color guides such as Chou & Chang (2005), and Wu et al. (2002), followed by consulting more specialized books and special articles in international and local scientific journals. Fungal material is sectioned by hand or squashed for light microscopy. Light microscopic

mountings are made in water or 5–10% (w/v) aqueous KOH solution, with or without staining with phloxine or cotton blue and observed at 1000x magnification (oil immersion). Most photographs will represent the fungus in its habitat in the forest; microscopic photographs made with a dissecting or light microscope are added, particularly for microscopic fungi and slime molds with small fruit-bodies. Preferably, different stages of development are shown in the photographs for indicating the intraspecific variability.

3. Molecular identification of fungi:

For molecular identification of fungi, genomic DNA is extracted and subjected to polymerase chain reaction (PCR). The PCR products are amplified with different primers to identify species was based on published phylogenetic analyses of specific genera or species complexes of fungi. DNA sequences of the internal transcribed spacer regions (ITS) and/or the ribosomal large subunit RNA gene (LSU rDNA) are generated for a preliminary identification. For most Basidiomycota, these two regions are sufficient for species identification. Occasionally, an additional barcode is required for better species resolution. For example, the primer pair TUB2Fd/TUB4Rd is used for amplification of the beta tubulin gene, particularly for the identification of Xylariales.

DNA sequencing is performed by Mission Biotech (Nankang, Taipei) with the same primers used for the PCR. The DNA sequences are edited and submitted to BLAST searches at GenBank (<https://blast.ncbi.nlm.nih.gov/>). Depending on the similarities of the used barcode and verifiability by morphology, the strains are identified to species or genus. For reproducibility by published vouchers and scientific quality, only sequences cited in publications are considered for identification. The scientific names retrieved from GenBank are updated with Index Fungorum (<http://www.indexfungorum.org>).

4. Sources suggested to students for identification and assessing distribution of the forest fungi in the project:

- ✓ color guides of Taiwanese mushrooms (e.g. Chou & Chang 2005, Mycobiota Taiwanica 2015, Wu et al. 2002)
- ✓ online database with illustrations and descriptions of fungi from Taiwan hosted by the Bioresource Collection & Research Center
<http://www.bcrc.firdi.org.tw/fungi/index.jsp>
- ✓ Species of fungi of Taiwan:
<http://web2.nmns.edu.tw/TFungi/chinese/fungi1.php>

- ✓ Biodiversity database of Taiwan - TaiBif: <http://taibif.tw/en/node/140>
- ✓ Plant parasitic fungi worldwide with search options for Taiwan: <https://nt.ars-grin.gov/fungalatabases/fungushost/fungushost.cfm>
- ✓ Didactically carefully prepared classification of fungi: Piepenbring (2015)
- ✓ Catalogue of living strains: BCRC <https://catalog.bcrc.firdi.org.tw/>
- ✓ Catalogue of fungal specimens at the National Museum of Natural Science, Taichung: <http://collection.nmns.edu.tw/scripts/fungi.dll>
- ✓ DNA sequences: <http://www.mycobank.org/BioLoMICSSequences.aspx>, GenBank <https://www.ncbi.nlm.nih.gov/nucleotide/>
- ✓ Scientific fungus names: Index Fungorum <http://www.indexfungorum.org/names/names.asp>
- ✓ Scientific plant names: TROPICOS <http://www.tropicos.org/>

5. 教學暨研究成果 (Teaching and Research Outcomes)

(1) 教學過程與成果

The aim of the course “Forest Fungi and Carbon Sequestration — Forest Fungi” was to sensitize the participants to the complexity of these questions, but also provide primary theoretical and practical tools to access this complexity. 26 students (21 undergraduate, 3 from other departments than Forestry Department, 1 from another university, 1 from Myanmar) formed teams of 2 or 3 members. Each group was responsible for a repetition report during the course and an own small research project on a selected forest fungus with final oral presentation in the last week. The course was bilingual: written teaching materials, weekly written self-tests and mid-term exam, and students’ oral presentations in English, oral teaching presentation in Mandarin. The written teaching materials were deposited in an online repository of the university. A field trip to the forest of Fuyang Eco Park in Daan, Taipei City, revealed surprisingly important for the connection of teaching and research, because 5 of 9 student teams chose their research object from this excursion, including a mushroom hitherto not yet published for Taiwan, and the supervisor himself discovered a new genus and species on this field trip. These findings enhanced the message from the course that

poorly known fungal biodiversity is the major challenge in research of fungal ecology so that data-based quantification of carbon sequestration by fungi is not yet possible. From the field trip the students learnt that urban forests can be the first address for research. In addition to this intellectually complex course content, students trained their English abilities, teamwork and digital competences.

(2) 教師教學反思

Teaching methods and contents:

The combination of theoretical and practical learning as well as the methods for self-testing and grading based on written and oral performance seemed well-balanced. I was surprised myself that in the Fu Yang Eco Park of Taipei the students identified a mushroom hitherto not published for Taiwan and I found a new genus and species. While the specific course content was demanding, the main messages such as of potential roles of fungi in carbon sequestration in the forest, the lack of quantitative data and the extremely low proportion of described species compared to the unknown species should have been more repeatedly emphasized as conclusion at the end of the lecture and “take-home” messages. The effects of climate change already interfere with the original functioning of forests in Europe more strongly than in Taiwan. This effect but also regional differences should be explained in more detail in future courses.

Digital competence:

During the students’ oral reports, I encountered at least two times where the students by relying on AI obviously presented mistakes. For me, it was the first experience of using AI by students, which I principally encourage, but I was not prepared to discuss how to balance the usage of AI with fact checks. Providing reliable specialized databases and also demonstrating their limitations to students is still an important task of the instructor, because only few students discover the important databases themselves and do not yet have the background to recognize the pitfalls of using such databases. The field trip and practical lab elements in the course were important countermeasures for balancing undesired side effects of PPT and digital representations of “reality”.

Student English proficiency

The students had to give their oral presentations in English, which was a successful encouragement of preparing and reading English texts, but most students depended on reading the pre-prepared English text from the cell phone

instead of freer speech. This may indicate the limitation of the present overfinancing of promoting English as medium of instruction, but the next step of training should go to more confident English speaking. 學生學習回饋

Among 26 participants, 22 students sent online feedback on the course, with an average rating of 4.69.

Personal comments were given by the students as below:

請寫下您修習這門課程對你自身學習收穫最多的地方?

1. 英文的口頭報告能提升自己的口說能力
2. 對真菌的了解越來越多，更了解他們的分類
3. 認識很多菌
4. 初步認識真菌，現在在野外看到後大概能分真菌的大方向。
5. 老師中文好好喔！非常厲害、很專業~雖然複習測驗分數不算成績，但能有效讓我複習到上次的内容、輕鬆抓到重點！
6. 老師人很好 很有教學熱忱 還會帶我們去野外採菇
7. 了解很多森林真菌有趣的事情，有吸收了很多關於真菌詳細的研究內容。
8. 對於真菌有更進一步的認識，無論是類型、與他種生物的互動及裡頭的形態，都很有趣。老師自我風格幽默也是覺得很棒的部份
9. 認識許多冷門的微型真菌，包含其生活史、型態等等，例如 Laboulbeniales，一種生長在活體步行蟲的子囊菌

請寫下這門課在教學上您覺得最需要改善之處?

1. 無
2. 沒有，老師超棒，可以看見他對真菌德熱愛
3. 沒有 老師令人滿意
4. 不用
5. 每週的複習報告用英文最後都變成在看稿照唸，其實台下的同

學大多聽不太懂或沒在聽，不知道如果報告也改用中文會不會比較有複習的效果？但確實英文報告可以練英文啦，但不知道能練到多少，感覺用中文也沒關係呀！

6. 無

7. 我覺得這堂課的學習非常完整，不需要改善！

8.

A. 校外教學後有一個小複習會更好，可能在戶外聽到的不太夠正確

B. 老師的 ppt 檔 有時候字型或圖會跑掉，再看怎麼修正好

6. 建議與省思 (Recommendations and Reflections)

Dealing with courses in blocks of 3 or more hours:

If courses with 3 or more credits cannot be separated on 3 or more days, but have to be given as block, using the first hour for repetition report and repetition self-tests may help students to allow the content to “sink in” and avoid overloading their attention with too many details.

Appreciation of complexity:

The example of carbon sequestration by forest fungi showed that this is a topic that is too complex even in science. Climate change is already interfering with the “normal” carbon sequestration in forests. A didactic reduction or simplification is not yet possible. While on the one hand the urgent need of reduction of carbon release is supported by science and the public, the scientific mechanisms behind carbon cycling are still poorly known and hard to communicate. Maybe we need to accept the idea that we have to take action without knowing the scientific details. Dealing with this social and psychological uncertainty seems to need also some kind of training and resilience, which is yet to be developed.

Critical usage of AI:

Usage of AI by the students can be recognized in oral presentations, which may be a better occasion to interact with students and discuss how to improve the

usage of AI than in written reports. While the teacher has the special knowledge to recognize mistakes of the AI-generated elements, as teachers we may not have the knowledge how students use AI and how to provide them tools for critical usage.

English as medium as expression by students:

The present activities in promoting English as medium of instruction by teachers in the meanwhile seem to too numerous and overfinanced, while it is now realistic and more important to encourage students to write and talk in English. They are able to manage the first step by preparing an English text and reading it aloud. The next step of instruction for them should be that they are encouraged and trained to talk more freely based on a few written keywords. This need was also identified by the students themselves (see above).

二、參考文獻 (References)

- Balmford A, Clegg L, Coulson T, Taylor J (2002). Why Conservationists Should Heed Pokémon. *Science Magazine* 295(5564): 2367.
- Bundeswaldinventur (2022) Bundesministerium für Ernährung und Landwirtschaft (BMEL) = Federal Ministry of Agriculture and Food, Bonn, Germany.
- Chou W-N, Chang T-T (2005). *Mushrooms of Taiwan*. Yuanliu Press, Taipei, Taiwan.
- Dai Y-C, Cui B-K, Si J, He S-H, Hyde KD, Yuan H-S, Liu X-Y, Zhou L-W (2015). Dynamics of the worldwide number of fungi with emphasis on fungal diversity in China. *Mycol. Progress* 14: 62 DOI 10.1007/s11557-015-1084-5
- Griffith GW, Roderick K (2008). Saprotrophic Basidiomycetes in Grasslands: Distribution and Function. In Boddy L et al.: *Ecology of Saprotrophic Basidiomycetes*. British Mycological Society Symposia Series 28: 277–299.
- Hawksworth DL, Lücking R (2017). Fungal Diversity Revisited: 2.2 to 3.8 Million Species. *Microbiol Spectr.* 5(4): 1–17. doi: 10.1128/microbiolspec.FUNK-0052-2016
- Hsu ST, Chang TT, Chang CA, Tsai JL, Tsay TT (2002). *List of Plant Diseases in Taiwan*, 4th edn. Taiwan Phytopathological Society, Taichung, Taiwan.
- Lefebvre D, Williams AG, Kirk GJD, Paul BJ, Meersmans J, Silman MR, Román-Dañobeytia F, Farfan Jh, Smith P (2021). Assessing the carbon capture potential of a reforestation project. *Scientific Reports* 11 (1): 19907. doi:10.1038/s41598-

021-99395-6

Mueller GM, Schmit JP, Huhndorf SM, Ryvardeen L, O'Donnell ThE, Lodge DJ, Leacock PR, Mata M, Umaña L, Wu Q, Czederpiltz DL (2011). Recommended protocols for sampling macrofungi. In G.M. Mueller, M. S. Foster, & G. F. Bills (Eds.). *Biodiversity of fungi: inventory and monitoring methods* Academic Press, pp. 169–172.

Mycobiota Taiwanica, 3rd ed. 2015. CD-ROM, Department of Plant Pathology and Microbiology, National Taiwan University, Taipei.

Piepenbring M (2015). *Introduction into mycology in the Tropics*. American Phytopathological Society Press, St Paul, MN, USA.

Schwarze, F.W.M.R., Engels, J. & Mattheck, C. 2006. *Fungal Strategies of Wood Decay in Trees*. Springer

Thomas PW, Jump AS (2023). Edible fungi crops through mycoforestry, potential for carbon negative food production and mitigation of food and forestry conflicts". *Proceedings of the National Academy of Sciences*. 120 (12): e2220079120.

Wu S-H, Chou W-N, Wang Y-Z (2002). *Higher fungi from Taiwan. Knowledge of Asco- and Basidiomycota*. National Museum of Natural Science, Taichung. 吳聲華，周文能，王也珍。2002。臺灣高等真菌。子囊菌與擔子菌的認識。國立自然科學博物館，台中。

三、附件 (Appendix)