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A FIRST STEP IN APPLYING INDUSTRY 4.0 TECHNOLOGIES IN BIODIVERSITY CONSERVATION OF MACRO MUSHROOM RESOURCES: BUILDING A DATABASE FOR THE MANAGEMENT OF VALUABLE MUSHROOM SPECIES FOR SOME REGIONS IN VIETNAM

Nguyen Thanh Long[1], Le Thanh Huyen[2*]
[1]The Water Resources Institute, Vietnam
[2]Hanoi University of Natural Resources and Environment,Vietnam

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Abstract

In this era of Industry 4.0, the application of high technologies in the management of natural resources has become more popular and achieved certain successes. This paper presents the highly feasible applications of two technologies: (1) Big Data and (2) Cloud computing for the macrofungal resources biodiversity management, thereby building a pilot model for the management of some valuable macro mushroom resources in Vietnam. Technology 4.0 has facilitated the development of Big Data and Cloud computing techniques and applied them to increase efficiency in resources management (in general) and macrofungal biodiversity management (in particular). Specifically, the application of technological achievements helps managers accurately monitor the organism population's fluctuations, identify the harmful factors to this population, and promptly take remedial measures. In addition, management efficiency is also demonstrated through the identification of the distribution and conservation plan of precious mushroom genetic resources.

Keywords: Biodiversity; Conservation; Database; Macro mushroom; Fungi.

[*]**Corresponding author. Email:** lthuyen@hunre.edu.vn

1. Introduction

1.1. Industry 4.0 and its technologies

a) Characteristics of Industry 4.0

In contemporary life, everyone is familiar with The Fourth Industrial Revolution, also known as Industry 4.0 - a union of physical assets and advanced digital technologies - such as the Internet of Things (IoT), Artificial Intelligence (AI), robots, drones, autonomous vehicles, 3D printing, cloud computing, and others - that are interconnected and able to communicate, analyze, and act [1]. The term "Industry 4.0" is used within the context of a new industrial revolution that accentuates and incorporates the most recent technological advancements and facilitates both rapid and customized production.

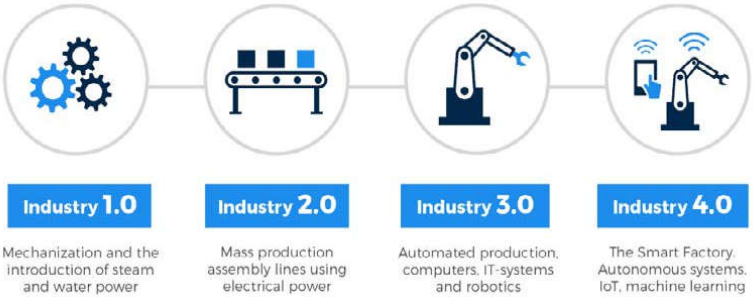


Figure 1: The Four Industrial Revolutions [1]

b) Big Data technology

The term "Big Data" has been in use since the 1990s [2]. It typically consists of data sets that are too large for commonly used software tools to capture, curate, manage, and process in a reasonable amount of time. As of 2012, the "size" of Big Data ranged from a few dozen terabytes to numerous zettabytes [3]. Big Data can be described by the following 05 main characteristics in Figure 2 below.

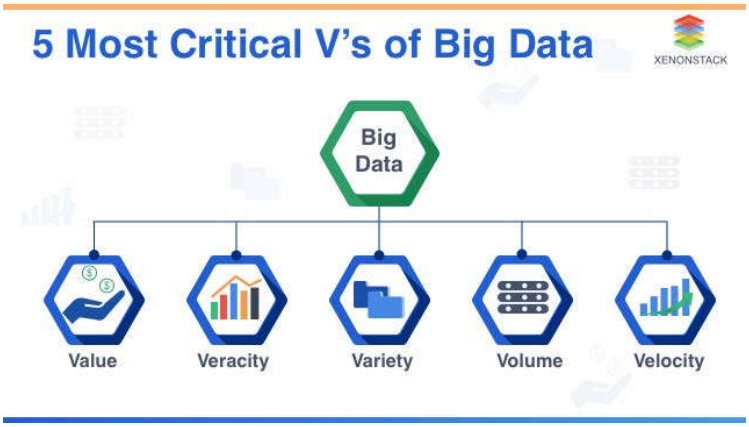


Figure 2: The characteristics of Big Data [7]

c) Cloud computing technology

Cloud computing is the on-demand availability of computer system resources, notably data storage (cloud storage) and computing power, without direct management by the user. Frequently, large clouds have their functions distributed across multiple data centers. The National Institute of Standards and Technology identifies "five essential characteristics" for cloud-based computing in its definition [8]total and daily liveweight gain (LWG and DLG: (i) Self-service on demand, (ii) Extensive network access, (iii) Combining of resources, (iv) Rapid flexibility and (v) Quantified service.

1.2. Proview of mushroom in Vietnam

a) The biodiversity of mushrooms in Vietnam

The climate in Vietnam is ideal for the growth of fungi, both in quality and quantity. Vietnam has the typical monsoon-influenced climate of mainland Southeast Asia. The varied topography, lengthy latitude, and East Sea influences result in climatic conditions that differ considerably between regions [9]. Northern Vietnam has a humid subtropical climate according to the Koppen climate

classification and is occasionally affected by cold waves from the Northeast. The North Central is also occasionally affected by cold waves, whereas the South Central and Southern Vietnam are completely tropical and hot throughout the year [10].

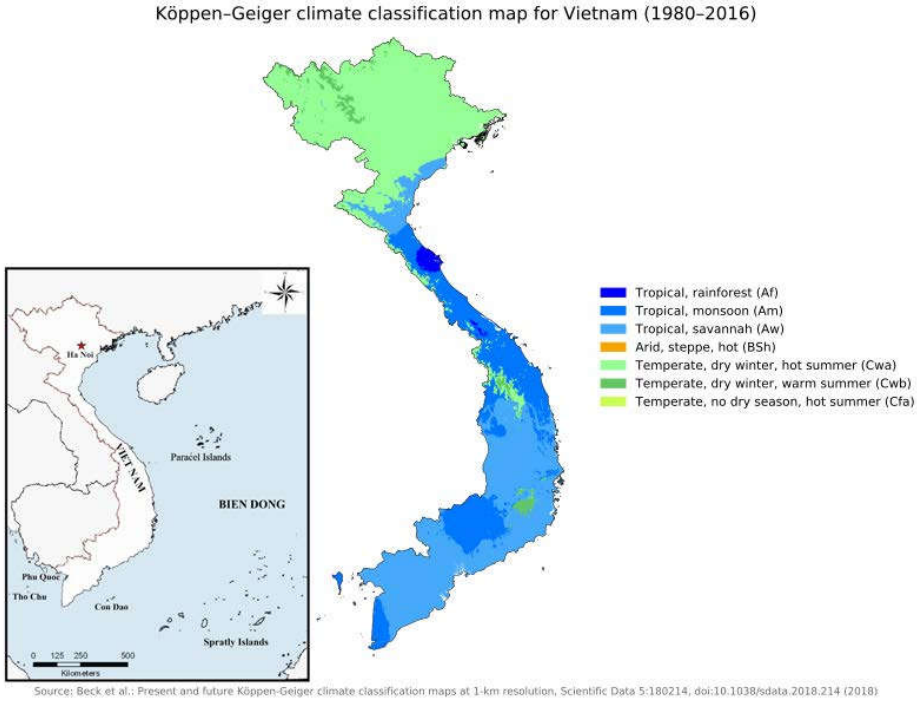


Figure 3: Climate classification map for Vietnam [11]

The diverse climate extending from the North to the South has resulted in a variety of terrain types and habitats, which is the basis for the macro mushroom's biodiversity. The catalog of Vietnamese mushrooms, which edited by Trinh Tam Kiet et al., was first published in the 2001 edition of the catalog of Vietnamese plants, contained 2,200 species [12], which includes nearly 1,000 species of macro mushroom. The catalog of Vietnamese macro mushrooms, which included 1,830 species, was later published in 2014 [13]. In 2018, nearly 2,500 new species were added, including lichens and slime molds [14]. In 2022, Le Thanh Huyen et al., revised 83 species, including macro mushrooms, slime mold, and micro mushrooms, particularly macro mushrooms belonging to 29/37 genera, 11/17 families, and 5/11 orders, including a noteworthy 33 new species [15]. This information is derived from 38 articles and the distribution of recent species groups was recorded in eleven Vietnamese provinces.

Approximately 3,700 species of mushrooms in Vietnam have thus far been described. There have been 1,380 species of micro mushroom and 2,320 species of macro mushroom, including lichens.

In recent years, most of the research on newly recorded mushroom species has taken place in Vietnam's national parks and nature reserves, such as Bidoup - Nui Ba, Chu Yang Sin, Bu Gia Map, Ngoc Linh, Phuoc Binh, Thuong Tien, etc. This demonstrates that the potential for discovering new species and new recorded species is substantial.

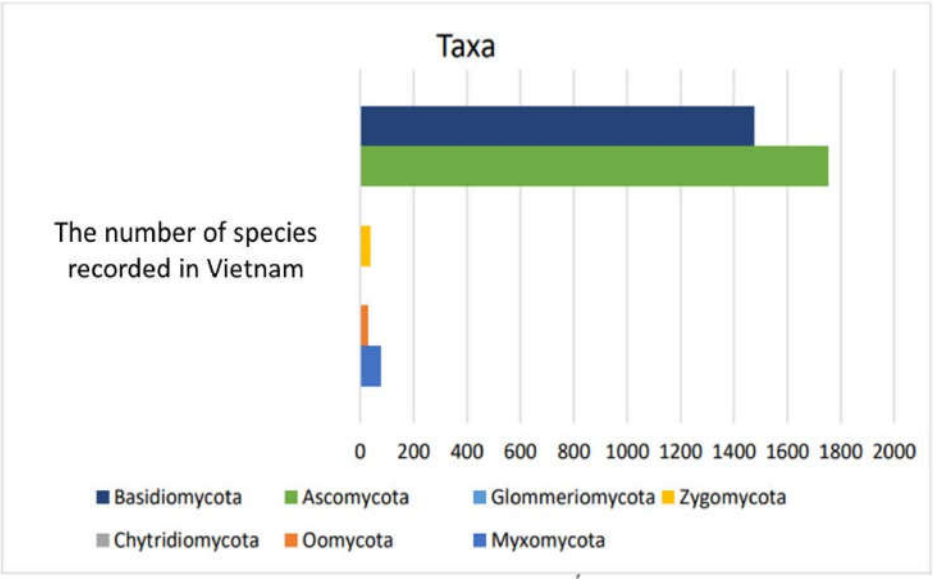


Figure 4: Diversity of fungus taxa in Vietnam [15]

b) Current mushroom utilization and management in Vietnam

Mushrooms were traditionally treated as a nutritive food source and extracted active ingredients/pharmaceuticals for the production of medications and medicinal preparations. Each species of mushroom has unique characteristics and differing levels of micronutrients, medicinal properties, and activities; consequently, the methods for consuming mushroom species are extraordinarily varied. Some species can be consumed directly, some can be steeped in tea, some require distillation or high-temperature processing, etc. The widespread use also leads to several potential risks of inefficient, unhealthy, and unsafe methods of exploitation for people during the sampling process and use, which can harm human health and the biodiversity of macro mushroom resources. The lack of information on the distribution and taxonomy, the lack of understanding of use function, or the impact of overexploitation on the habitat of the macro mushroom all contribute to these risks. All of these require extensive mushroom resources that must be cared for and managed more effectively, contributing to the conservation and development of this valuable resource's biodiversity while also facilitating the exploitation and utilization of fungi. Utilizing the beneficial properties of mushrooms is safer, healthier, and more nourishing.

2. Materials and Methods

The mushroom databases were built for each kind of mushroom and each area. The database is constructed using the primary and secondary data collected by the research team, which was summarized in one information table. This table included information on sample code, species name, sampling site location, sampling route, and sample area photographs. Since there are instances in which multiple samples appear in the same location, it is necessary to pay attention to the appropriate notes to prevent sample merging. Connecting GPS coordinates to form a comprehensive route represents the sampling route. Landscape images and field samples will be used to inform

the creation of area photographs. The information on recorded mushroom samples will be aggregated and compiled in an Excel (.xlxs) file to construct the map's source data file. The information to be gathered is displayed in Table 1.

Table 1. The gathered information for the map

Sample Code	Information of Species					Coordinates		Habitat	
	Order	Family	Genus	Specie	Area	Latitude	Longitude	Height	Host

After creating information tables regarding the location and coordinates of the occurrence of mushroom samples, the next stage is to plot the sampling lines and coordinate points on a map. There are numerous mapping tools available, such as Google Earth, Google My Maps, GIS, etc. The online distribution map is based on cloud computing, which helps researchers easily search and locate the researched mushroom species.

3. Results

3.1. Database of edible mushrooms in Tam Dao National Park, Vinh Phuc province

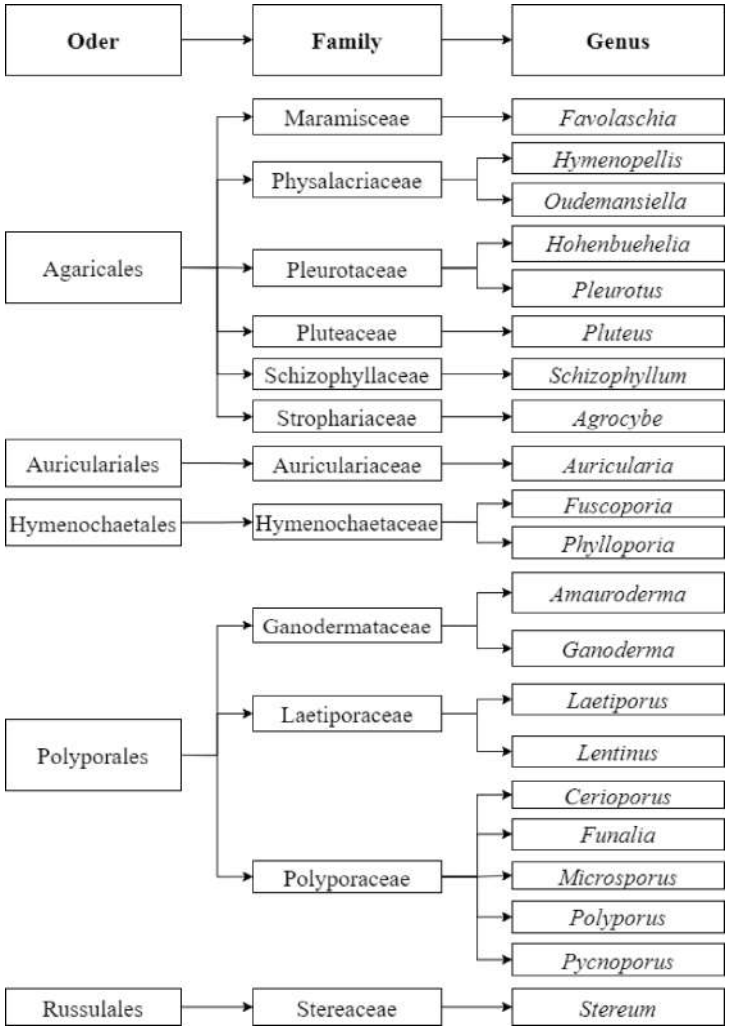
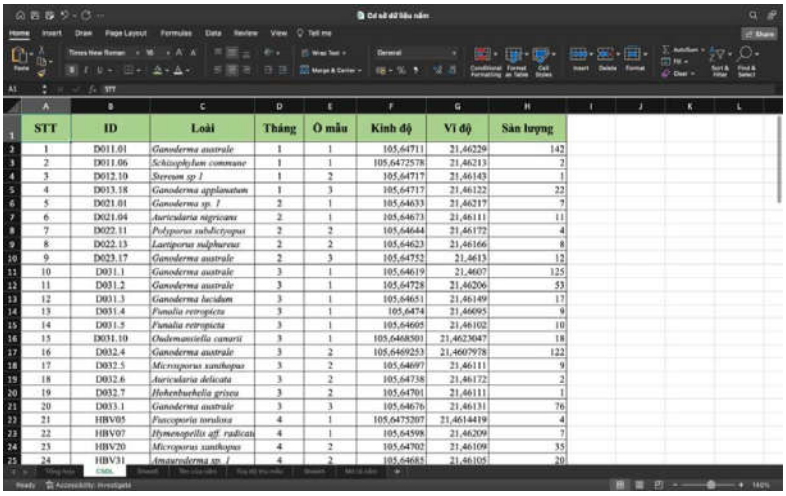


Figure 5: Diversity of edible mushrooms in Tam Dao National Park

The database of edible mushrooms in Tam Dao National Park was built in 2022 in the master thesis "Building biodiversity database of edible macro mushrooms in Tam Dao National Park" by Nguyen Thanh Long. This research aimed to synthesize and compile a comprehensive database of edible mushrooms in Tam Dao National Park, Vinh Phuc province. Survey results and sample collection in the study area uncovered 5 fungal orders, 12 families, divided into 21 genera, and 28 species, of which 25 species were identified (representing 89.28 % of the total) and 3 species were unidentified (10.72 %).

The study also created a database system for locating information on the biodiversity of edible large mushroom species in the Tam Dao National Park region by application "Tableau". This software provides users with an extensive array of interface customization options as well as superior information depiction and processing capabilities. In addition, the data will be stored on Tableau's server, making it simpler to retrieve, search, and look up. As a result of the tool's integration with too many other tools, however, it is deemed to be relatively complicated and perplexing for new users. The study has made the database available online via the link: https://public.tableau.com/app/profile/nguyen.thanh.long/viz/CSDLNmTamo/Sheet2?publish=yes.



STT	ID	Loài	Tháng	Ô mẫu	Kinh độ	Vĩ độ	Sản lượng
1	D011.01	*Ganoderma australe*	1	1	105,64711	21,46229	142
2	D011.06	*Schizophyllum commune*	1	1	105,6472578	21,46213	2
3	D012.10	*Stereum sp 1*	1	2	105,64717	21,46143	1
4	D013.18	*Ganoderma applanatum*	1	3	105,64717	21,46122	22
5	D021.01	*Ganoderma sp. 7*	2	1	105,64633	21,46217	7
6	D021.04	*Auricularia nigricans*	2	1	105,64673	21,46111	11
7	D022.11	*Polyporus subdictyopus*	2	2	105,64644	21,46172	4
8	D022.13	*Laetiporus sulphureus*	2	2	105,64623	21,46166	8
9	D023.17	*Ganoderma australe*	2	3	105,64752	21,4613	12
10	D031.1	*Ganoderma australe*	3	1	105,64619	21,4607	125
11	D031.2	*Ganoderma australe*	3	1	105,64728	21,46206	53
12	D031.3	*Ganoderma lucidum*	3	1	105,64651	21,46149	17
13	D031.4	*Funalia retropicta*	3	1	105,6474	21,46095	9
14	D031.5	*Funalia retropicta*	3	1	105,64605	21,46102	10
15	D031.10	*Oudemansiella canarii*	3	1	105,6468501	21,4623047	18
16	D032.4	*Ganoderma australe*	3	2	105,6469253	21,4607978	122
17	D032.5	*Microporus xanthopus*	3	2	105,64697	21,46111	9
18	D032.6	*Auricularia delicata*	3	2	105,64738	21,46172	2
19	D032.7	*Hohenbuehelia grisea*	3	2	105,64701	21,46111	1
20	D033.1	*Ganoderma australe*	3	3	105,64676	21,46131	76
21	HBV05	*Fuscoporia torulosa*	4	1	105,6475207	21,4614419	4
22	HBV07	*Hymenopellis aff. radicata*	4	1	105,64598	21,46209	7
23	HBV20	*Microporus xanthopus*	4	2	105,64702	21,46109	35
24	HBV31	*Amauroderma sp. 1*	4	2	105,64685	21,46105	20

Figure 6: The data frame for building the distribution map in Tam Dao

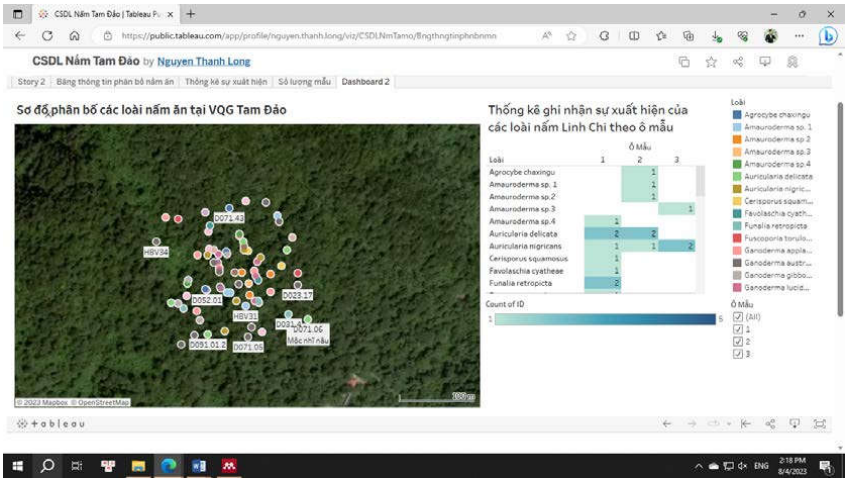


Figure 7: Online biodiversity database of edible mushrooms in Tam Dao National Park

3.2. Database of mushrooms in Thuong Tien Nature Reserve, Hoa Binh province

The database of edible mushrooms in Thuong Tien Nature Reserve was built in 2022 in "Building biodiversity database of edible macro mushrooms in Thuong Tien Nature Reserve, Hoa Binh province". After the survey and collection of samples in the study area between January and November 2022, a total of 183 samples were identified, including 02 branches, 02 classes, 06 orders, 18 families, and 33 genera. In there, 19 species have been identified as edible mushrooms.

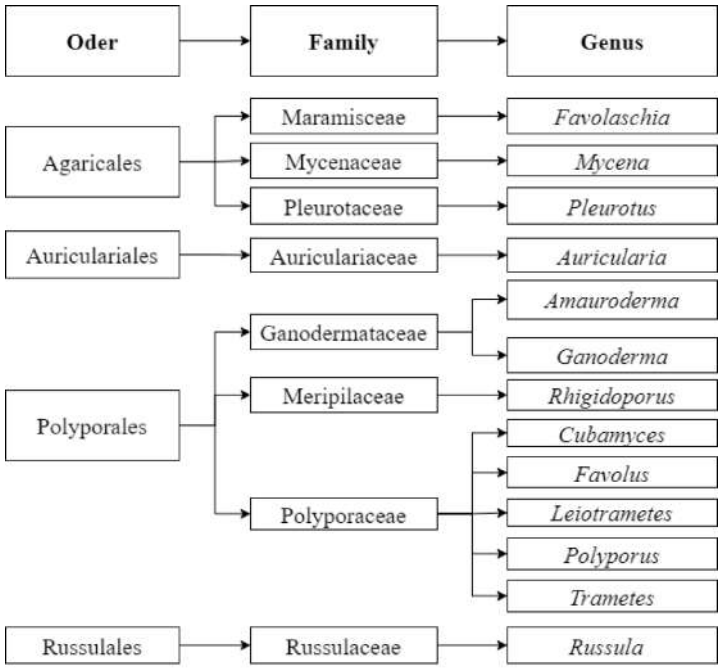


Figure 8: Diversity of edible mushrooms in Thuong Tien Nature Reserve

This study selects Google My Maps as the tool for building distribution maps and saving databases. Despite the lack of customization and simple interface, it is still a useful tool due to its easy implementation, a wide range of accessibility for most devices, and the integration of Google's ecosystem, including built-in versions of Google Maps sources and the ability to save information on Google Drive.

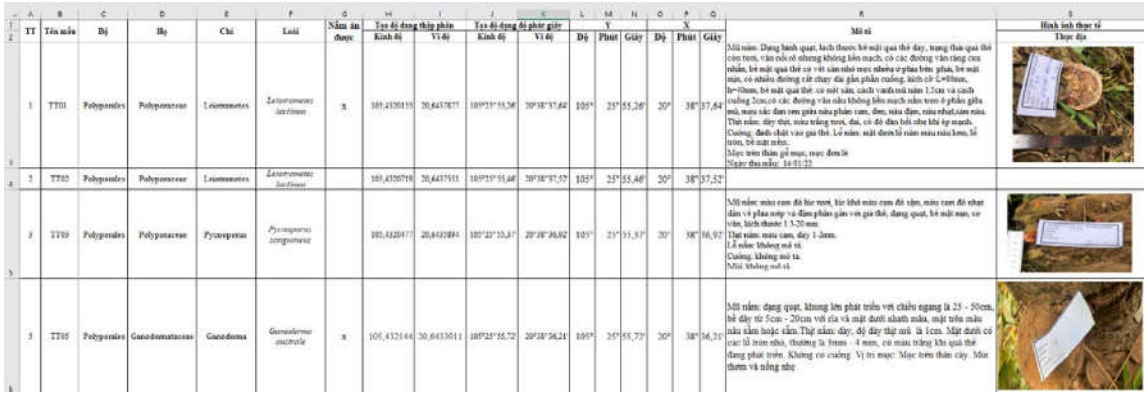


Figure 9: The data frame for building the distribution map in Thuong Tien

Figure 10: The online distribution map of edible mushrooms in Thuong Tien Nature Reserve

4. Discussion

4.1. The process of building the mushroom database

In the above-mentioned studies, 4.0 technologies were initially applied to mushroom management with remarkable results. All of these studies were processed according to the following general procedure:

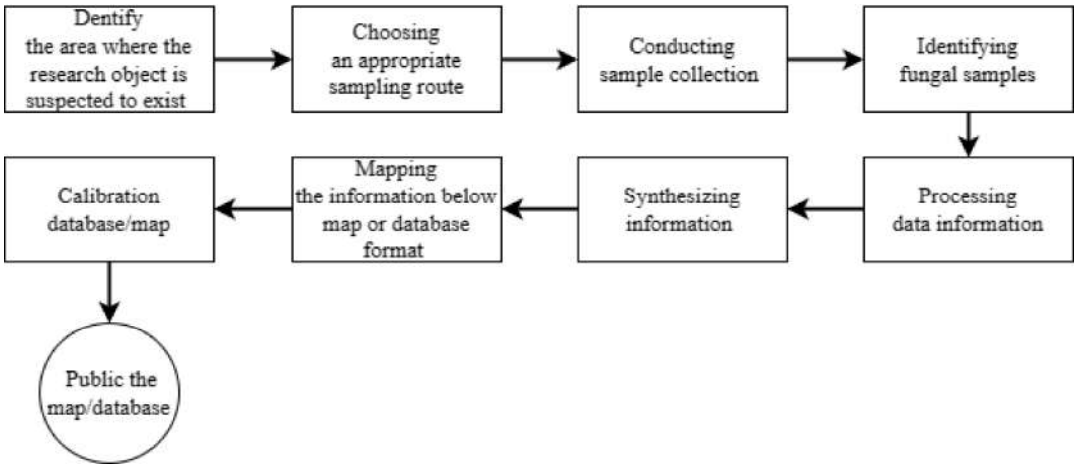


Figure 11: The 09 steps process of building the mushroom database

The successful publication of these distribution maps has resulted in favorable outcomes for both management and exploitation, including the following:

- Enhance the management effectiveness of rare and valuable mushroom specimens: Managers can monitor and identify even the tiniest changes in species populations, allowing them to make plans. To ensure the growth of this valuable mushroom population, prompt treatment is required.

- Ensure the sampling and use of macro mushrooms are healthful and sustainable: Researchers can rely on databases hosted on cloud servers that are

accessible to the public as credible sources of information and references. Creating these distribution maps not only increases the efficiency of the survey and collection but also ensures that the sampling frequency does not hinder the growth and development of the species. In addition, this database will aid inexperienced users in distinguishing specific species of medicinal mushrooms, edible mushrooms, or poisonous mushrooms through uploaded images and descriptions of all the recorded species. Thereafter, the consumption of mushrooms will become healthier, preventing their misuse from resulting in negative outcomes.

Therefore, building mushroom databases (in particular) and applying 4.0 technologies (in general) will improve the efficiency of managing precious mushroom resources. This mapping method is highly applicable to real-world situations. Utilizing the map to manage mushroom populations will serve as the foundation for the conservation of rare and valuable mushroom species. In the following section, the study will propose to construct distribution maps of two species of high-value mushrooms for sustainable management and exploitation.

4.2. Proposal of building the database for 02 precious mushroom genera: Phellinus and Phallus in Vietnam

The genera *Phellinus* and *Phallus* were selected for their high medicinal and nutritional value. The *Phellinus* mushroom genus mostly grows on ancient mulberry trees, this yellow-brown fungus is known in Korea as “Sang Hwang” (which means yellow tree). According to published studies, many species of mushrooms belonging to the genus *Phellinus* possess anti-cancer properties and are regarded internationally as the most efficient medicinal mushroom among biological cancer treatments. On the other hand, *Phallus* is a genus of edible and medicinal mushrooms that belong to the Phallaceae family. This is a saprophytic fungus that thrives on the moist roots of bamboo species found near human habitation or in tropical habitats. Due to its high nutrient, fiber, and protein content, its food and medicinal value is highly recommended for consumption. Additionally, the second cause of this selection is indifference to these fungi. Due to the dearth of attention paid to the precious species of these two genera, their status in the field has not been recorded, resulting in an inability to manage valuable resources.

5. Conclusion

This paper demonstrates the results of the application of 4.0 technologies to the management of macro mushroom resources through the databases of edible mushrooms in Tam Dao National Park and Thuong Tien Nature Reserve. These positive results provide the broad applicability of Big Data and Cloud Computing technology in the field of conserving the biodiversity of large mushrooms (in particular) and natural resources (in general).

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