# Developing a Spatial Decision Support System for Herb Genetic Conservation in Muang Phayao, Thailand



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**Abstract**
*This research focuses on developing a data warehouse system to collect information on herbal medicinal plant type, farmer information, land information, yield maps, and farmers' income information in Muang district, Phayao province, Thailand. Moreover, the Spatial Decision Support System (SDSS) is provided by this research using the Markov Chain model. Moreover, all data analysis was used to support decision making and assessment in collaboration of herbal plant genetic conservation. Researcher has discovered several different herbs to participant in Herbal Plant Genetic Conservation. They are also used to analyze the distribution of herb conservation in different areas. As the results, the systems implementation used in the real situation, that can truly support community decision in herbal plant genetic conservation effectively.*

## 1. Introduction

In recent years, many research studies and development projects have stated using geographic information systems (GIS) and geographically-referenced data. GIS can leverage geo-location feature difference through spatial analysis which plays an important role in a decision support system (DSS) (Chi-Chung and Chia-Chi, 2013). Although GIS are characterized by many attributes that are crucial to SDSS, such as having spatial data management and analysis capabilities, they are, in general, not considered SDSS. The major deficiencies in GIS limiting their characterization as SDSS are the lack of analytical modeling capabilities and their inability to present effective scenario evaluation techniques (Segrera et al., 2003).

The SDSS provides enhanced support for decision making and management, using data that have a geographical component (Kelly et al., 2012). The proposed SDSS is the part of the Thai herb data warehouse that can be used for herb conservation by gathering all data in Muang district, Phayao province. This data can be integrated and stored as the subject oriented, which is varied by time (or time variant) without any changes (or non-volatile storage) (Inmon, 1996). Moreover, the database of the proposed system is linked to the human brain by computers to improve the best quality of decision-making (Keen and Scott Morton, 1978). By using the Simon's Model, which are intelligence, design, and choice, the proposed SDSS can reduce the decision-making processes significantly (Simon, 1960). Herb is the medicinal plant that has therapeutic properties. It also promotes our health by processing as the local medicine into many forms such as tablets, capsules, and pieces. Additionally, the herb is essential for medical and public health and is valuable in term of both economy and society. In everyday life, it can decrease the cost of medicine to improve the family economy. Most household income in the country areas comes from trading herbs, and their ecology value comes from various kinds of herbs. In the sector of agriculture, the herb can also be used to control pests and plant disease treatment. As mentioned above, we can see that the wisdom of the herbs has been beneficial to the Thai people for a long time (Buaphun, 2005).

Herbs can be classified into five general categories: (1) tree and shrub, (2) bunch, (3) head, (4) vegetables, and (5) grass. Firstly, many trees and shrubs will grow in various areas in the Thailand climate. They are very wide spreading in form from tall, narrow trees to short, and wide shrubs. Secondly, the herb bunches (or the climbing plants) can grow and crawl along the ground. Third, the head herb is categorised as the underground plants (roots, tubers, bulbs and stems), which are usually grown as annual crops. Fourth, the vegetables are parts of plants that are consumed by humans as herb as part of a medicine such as Edible Fern, Chinese Cabbage, Morning Glory and so forth. Finally, the grass herbs are the grass like plant with narrow and long leave. Most of them are located in the Euphorbiaceae family, which belongs to the Leguminosea and Caesalpinioideae sub-families. They are also used as herbs for 72 species, food for 46 species and other purposes for 10 species. Herbs can be used as medicines to cure sickness for 56

symptoms (Pattanaseree and Anantachok, 2008). Furthermore, the local villagers use components of those herbs as an ingredient in many products such as bolus, pill capsules, dried herbs, herbal balls, cleaning products, herbal water, pillow, essential oil, snack, and so on. There is a necessity to herb conservation and to improve income for farmers in Muang district, Phayao province, Thailand. This research focuses on developing a data warehouse system to collect information on herbal medicinal plant type, farmer information, land information, yield maps, and farmers' income information. Also, the GIS-based SDSS is provided by this research. As a result, Thai farmers can access useful information on herbal developments by using the proposed system. They also improve their agricultural areas to be useful and cause the most revenue.

This paper was recommended for the SDSS to assist decision makers in the complex decision-making processes. The main purpose of the current research is to find the best scenario of the DSS to improve the social, environmental, and economic sustainability. As a result, the proposed system can be used to prevent the extinction of medicinal plants and to encourage the utility of herbs continuously. It is also used to maintain consistency of the local knowledge and wisdom of herbal information resources at community scholars in Muang district, Phayao province - Thailand.

## 2. Study Area

The study area was conducted at the Muang district, Phayao province, Thailand (Figure 1). Muang district comprises 13 sub-districts. The district covers an area of 887 square kilometers with geographical location between 19 44′ N to 19 20′ N and 99 40′ E to 100 00′ E. It is mostly covered with forested mountain, with an approximate elevation of 380 meters about mean sea level (Jeefoo, 2016). In Muang district, Phayao province - Thailand, many benefits from herbs can be found in 87 plant species from 52 families by the herbal research.

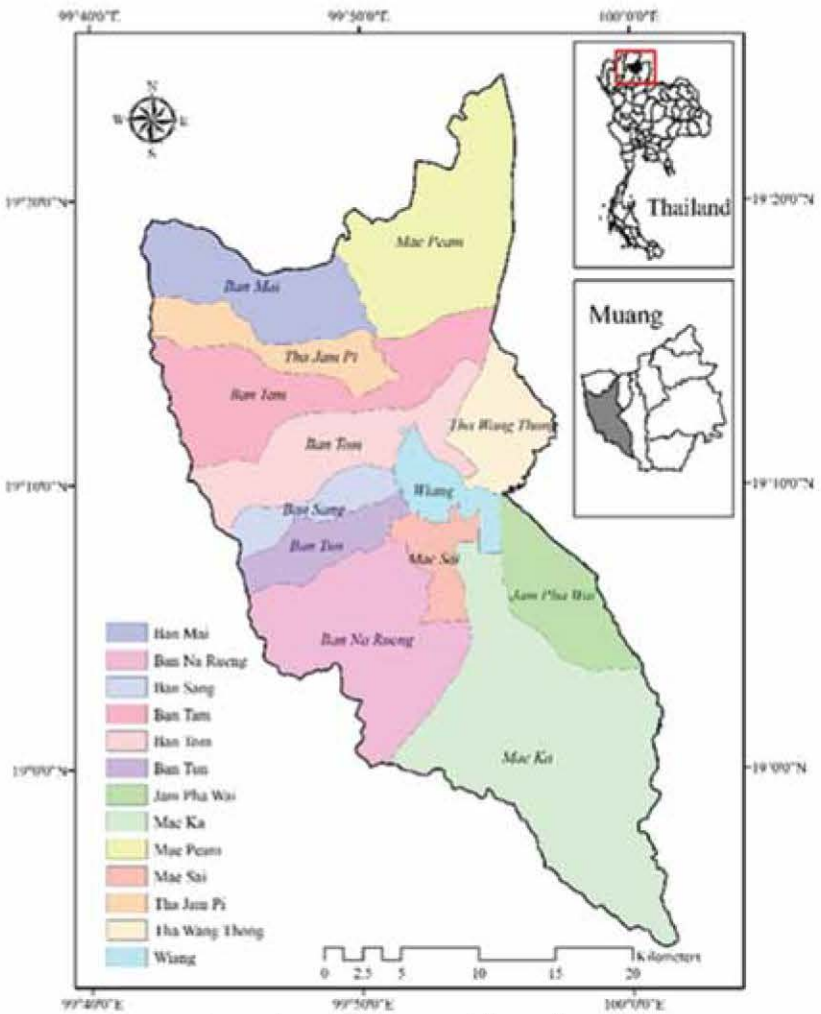


Figure 1: Location map of the study area

## 3. Methodology

This section outlines the methodology adopted in the development, of a SDSS for herbal medicinal plant type, farmer information, land information, yield maps, and farmers' income information in Muang district, Phayao province, Thailand. The research method was used in this paper consist of data collection, system analysis, system design, system development, system testing and implementation.

### *3.1 Data Collection: Questionnaires Tool*

The main purpose of this process is to gather the basic information of the herbs such as properties, types, photos, consumer demand and so on. In the term of consumer demand, the author was collected data using interviews with questionnaires the sample with the non-probability sampling method and the convenience sampling. The volunteers, who are herbal farmers, philosophers, researchers, and herbalists, totaling 157 recruits to provide information. All collecting data was built the proposed database (Figure 2).

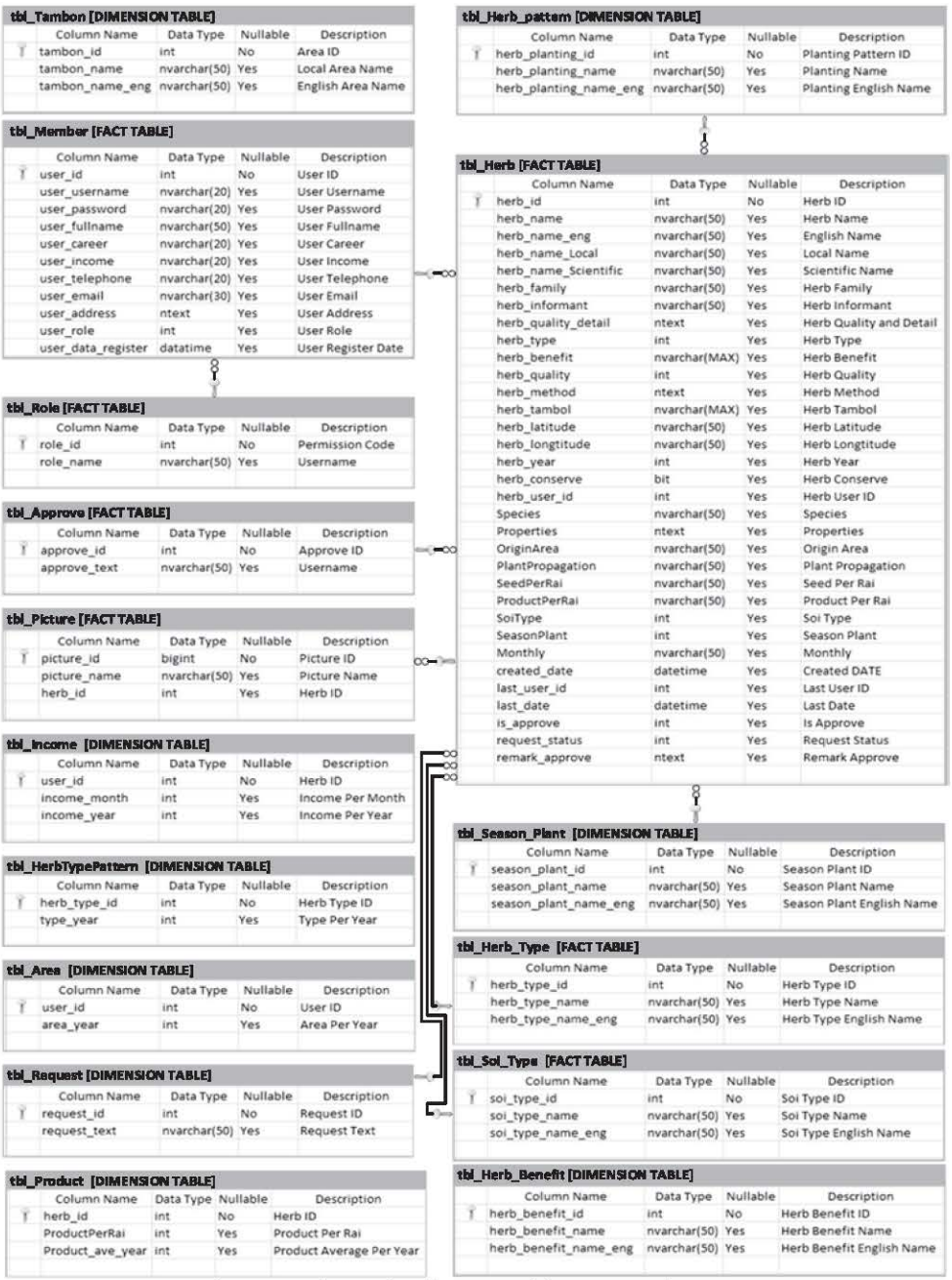


Figure 2: The entity diagram of the proposed system

*3.2 System Analysis and System Design*

The main points of these units were analyse the herbal information from various agencies and to build the herbal database respectively. The model of herbal information was created by using the Unified Modelling Language (UML). The UML is a general-purpose modelling language that graphically represents system requirements (Adamu and Zainoon, 2016). The UML is a visual modeling language dominates in object-oriented software development and this language was adopted by the Object Management Group (OMG) as its standard modeling language in 1997 (Siau, 2010). It includes the use case diagrams that were usually employed to capture the functionalities of the software system. All use case diagrams describe the typical interactions between users and the software systems. For the requirement phase, they can also be taken to the next level by providing more formal refinement inform of sequence diagrams. Each use case diagram was used to realize by one sequence diagram or more sequence diagrams. Each sequence diagram depicts how objects interact and work together to provide services. This is the reason that functional similarity relies on the information contained in sequence diagrams and class diagram to capture the static structure of the software system. Other diagrams were mostly used during the architectural and design phase to express artifacts at different design levels (Ahmed, 2011).

*3.3 System Management*

The consumer demand information and the information system management were grouped into 9 use cases consist of project data management, herb data management, soil data management, herb yield and income data management, report management, member data management, map data management, permission management, and decision report. The system analysis and modelling in the class diagram was displayed the structure of an unchanged system according to the researcher's perspective. The interrelation of each class was used to determine the data mart of the herbal data warehouse. Without a doubt, the DSS is well-known in management for supporting the multidimensional analysis (Holsapple, 2008). The multidimensional modelling and patterns were principally employed in this research (Kimball et al., 2008). It also describes the dimension of the data mart users effectively. The system design was based on the software architecture sustainability, which reflects the foundational design decisions. These decisions were used to build the system and its elements (Ali Babar et al., 2009 and Capilla et al., 2016). The use of the dimensional data model can be operated by two tables, which was the fact table and the dimension table (Brian, 2007). Firstly, according to the concept of Kimball, the information in the fact table can be defined in data mart, and then the required attributes are also built in each dimension table. In this process, the required attributes need to measure with both quantitative and qualitative in the real number. Secondly, the information in the dimension table is a data view for the measured data in the data analysis. Besides, the fact-value is the set of the data by matching between the information in the dimension table and the measured data. By this matching process, there is the fact data (Figure 2). Figure 2, It was grouped into three types of data comprise measure, dimension, and fact respectively.

*3.4 System Development*

System development was created powerful resources to access all needed information. For example, a web server can be compatible with all web browsers. All users can access existing data through a mobile application regardless of the weather or the distance. Therefore, the proposed system actually works in modern times, and it is also easy to use. Additionally, the aeronautical reconnaissance coverage GIS, it is the most common tool to do the more advanced geospatial analysis. This software was used to make an accurate analysis regarding the plan that the stakeholder was designed by using the touch table. The output was shared with the stakeholders in a report, through the web viewer, and in a revising session on the touch table. However, the parameters of the designed plan were not yet satisfactory (Hettinga et al., 2018). The Markov Chain model was used for the data analysis to improve the use of limited lands. The model also provides the choices for farmer's decision for their cultivation of herbal plants. It can be used to make the best income for farmers and to reduce the loss of land use. The set of models can be used to predict the land use change in urban regions, which are increasing in recent years. According to the Markov chain, the alternative modelling framework was described as the model of land use, which can be shown in a discrete number. It was considered to a function in the previous state only. The probability of transition between each pair of states was recorded as an element of a transition probability matrix. The model was tested for using historical data to predict recent conditions and the model was used to forecast the future distribution of land use decades into the future (Iacono et al., 2015).

*3.5 System Testing and Implementation*

The installation system, testing system, and evaluate the performance of the system were discussed in this section. The aim of this process was to make sure

the quality of the software. The software quality was the final goal of developing technology and verifying method in software development process, and it was based on the systems development life cycle, which is also necessary to build up a set of specifications (Li and Fan, 2012). Then, all users were used the ability to improve their computing choices to fulfil their requirements on-demand (Prathibhan et al., 2014). This development was divided into two test systems comprise the alpha testing and the beta testing. The alpha testing was simulated or actual operational testing by potential users or an independent test team at the developers' site. The beta testing was derived after alpha testing, and it was considered a form of external user acceptance testing (Nuraini et al., 2015). The assessment of the beta testing consists of the system functional, the system design, the system performance, the system reliability, and the system usability.

## 4. Results and Discussion

GIS provides a dynamic, user-friendly interface to explore a variety of attribute and physical information gathered from a spill, thereby facilitating in the means by which decision making is done more rapidly and with better precision (Onojeghuo et al., 2016). From the analysis of the data found that the farmers in Muang district, Phayao province – Thailand, were cooperated as a member of the herb conservation alliance for 520 people in 2015. The total land area of the herbal products industry was 6,672,000 square meters. There are 52 species of herbs analysed in this investigation. They were grouped as follows: tree and shrub for 15 species, bunch for 13 species, head for 10 species, vegetables for 21 species, and grass 4 species. This study also found that the area of the rotated crops was 2,880,000 square meters. The planted herbs in this area were Pomegranate, Mulberry, Bitter Gourd, Butterfly Pea, Ginger, Shallot, Lady's Finger, Safflower, Nut grass, and Blady grass. All 10 species of crop rotation were grouped into 5 groups: (1) tree and shrub, (2) bunch, (3) head, (4) vegetables, and (5) grass respectively.

The proposed GIS-based SDSS has provided the system features and functions to support the work of farmers to choose the type of land use for herb farming. Technically, the data in a data warehouse was organized to fulfill the needs of business analysis as a decision support instrument rather than transactional operations. Particularly, when containing a logical subset of data concerning either a specific topic or a specific business function, data mart was named. The proposed data warehouse system has basic features, which involve the extraction of data from on-line transaction processing (OLTP) systems. This synthetic data was loaded into the data staging area where cleaned and standardized were loaded to a data presentation area. After that, the data was dimensionally modelled, and data marts were created (Kimball, 1998). The proposed SDSS was showed the type and number of herbs and that grow in all areas. It also shows the type and quantity of land cultivation of herbs from 2015 to 2017.

As a result, farmers have decided to change the use of land to grow herbs to increase their income. The percentage of species of medicinal plants as shown in Figure 3 that grows in 2,880,000 square meters. Moreover, the percentage of increase and decrease of land use herbal medicine planting was compared with the increase and decrease in revenue per square meter as illustrated in Figure 4. The Markov Chain model was adapted for land-use suggestion in this research. The model was suggested annual land-use change for the farmers' decision to promote conservation of herbal plants. Herbal plants were randomly selected to test for 10 species comprised Pomegranate, Mulberry, Bitter Gourd, Butterfly Pea, Ginger, Shallot, Lady's Finger, Safflower, Nut Grass, and Blady Grass. The model was showed two different periods in Figure 5. The probability of the land-use changes between herbal species, $\gamma$, shown as:

$$\gamma = \frac{\beta}{\alpha}$$

Equation 1

Where; $\beta$ is the average income of the herb per square meter, $\alpha$ is one percentage of total land-use herbs per square meter, and $\gamma$ is the probability of the land-use change. The suggestion of the next period of land-use was expressed as:

$$\left[V_t V_b V_h V_v V_g\right]_{1st} \begin{bmatrix} \gamma_{tt} & \gamma_{tb} & \gamma_{th} & \gamma_{tv} & \gamma_{tg} \\ \gamma_{bt} & \gamma_{bb} & \gamma_{bh} & \gamma_{bv} & \gamma_{bg} \\ \gamma_{ht} & \gamma_{hb} & \gamma_{hh} & \gamma_{hv} & \gamma_{hg} \\ \gamma_{vt} & \gamma_{vb} & \gamma_{vh} & \gamma_{vv} & \gamma_{vg} \\ \gamma_{gt} & \gamma_{gb} & \gamma_{gh} & \gamma_{gv} & \gamma_{gg} \end{bmatrix} = \left[V_t V_b V_h V_v V_g\right]_{2nd}$$

Equation 2

Where; $\left[\bullet\right]_{1st}$ and $\left[\bullet\right]_{2nd}$ are the vector of land use of the first year and the second year respectively. $V_t$, $V_b, V_h, V_v$, and $V_g$ are the land-use area of tree and shrub, bunch, head, vegetables, and grass respectively.

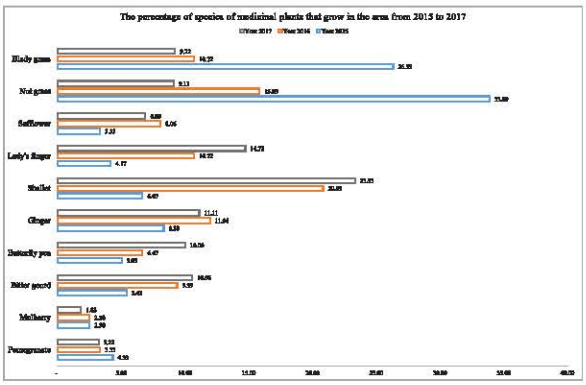


Figure 3: The percentage of species of medicinal plants that grow in the area from 2015 to 2017

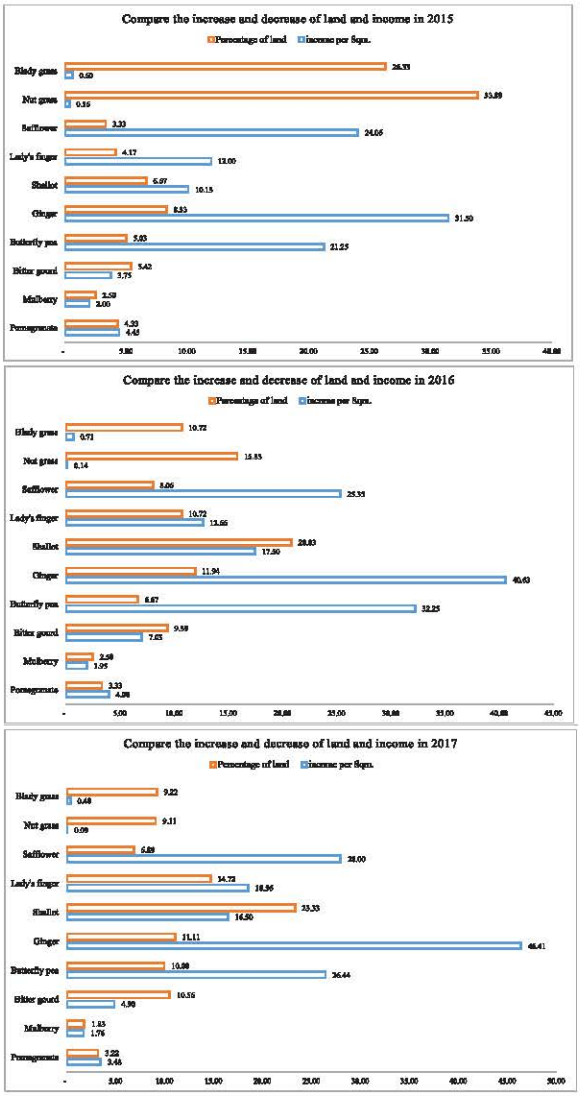


Figure 4: The percentage of increase and decrease of land use herbal medicine planting for 5 types, compared with the increase and decrease in revenue per square meter

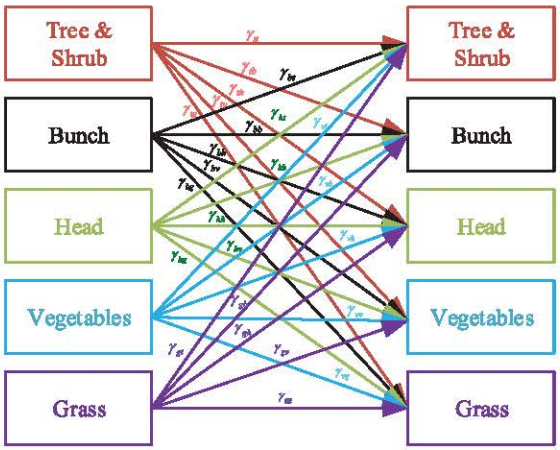


Figure 5: The general form of the model to suggest the land-use change

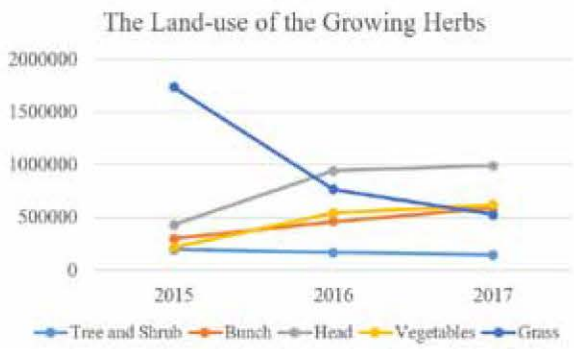


Figure 6: The land-use of the growing herbs from 2015 to 2017

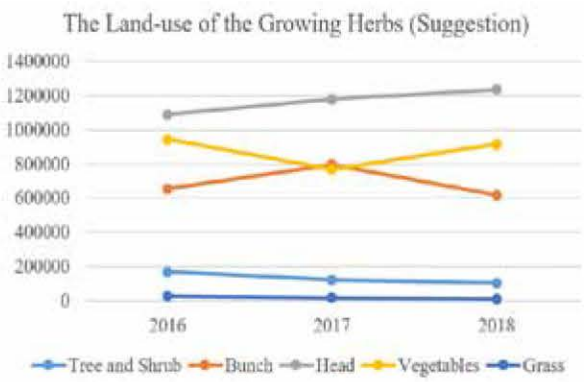


Figure 7: The suggestion of the land-use changes from 2016 to 2018

**Pie graph showing income per year, 2015, 2016, 2017**
**Classification, District in Muang Phayao**

| Type | Herb name | Cultivated area (Sqm.) | yield per year (Kg.) | Average price (Baht:Kg.) | Income per year (Baht) | Average income (per Sqm.) |
|---|---|---|---|---|---|---|
| tree and shrub | Pomegranate | 92,800.00 | 9,500.00 | 34.00 | 323,000.00 | 3.48 |
| tree and shrub | Mulberry | 52,800.00 | 11,600.00 | 8.00 | 92,800.00 | 1.76 |
| bunch | Bitter gourd | 304,000.00 | 53,200.00 | 28.00 | 1,489,600.00 | 4.90 |
| bunch | Butterfly pea | 288,000.00 | 16,920.00 | 450.00 | 7,614,000.00 | 26.44 |
| head | Ginger | 320,000.00 | 550,000.00 | 27.00 | 14,850,000.00 | 46.41 |
| head | Shallot | 672,000.00 | 504,000.00 | 22.00 | 11,088,000.00 | 16.50 |
| vegetables | Lady's finger | 424,000.00 | 437,250.00 | 18.00 | 7,870,500.00 | 18.56 |
| vegetables | Safflower | 198,400.00 | 9,920.00 | 560.00 | 5,555,200.00 | 28.00 |
| grass | Nut grass | 262,400.00 | 5,800.00 | 4.00 | 23,200.00 | 0.09 |
| grass | Blady grass | 265,600.00 | 21,000.00 | 5.00 | 105,000.00 | 0.40 |

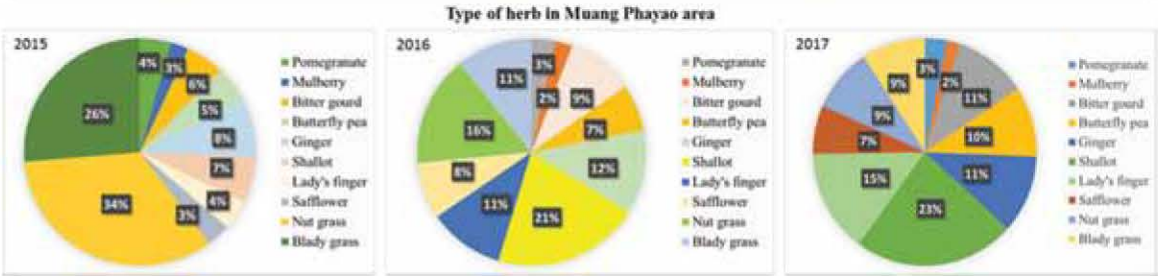


**Figure 8: The report on types and number of herbs that participate conservation**

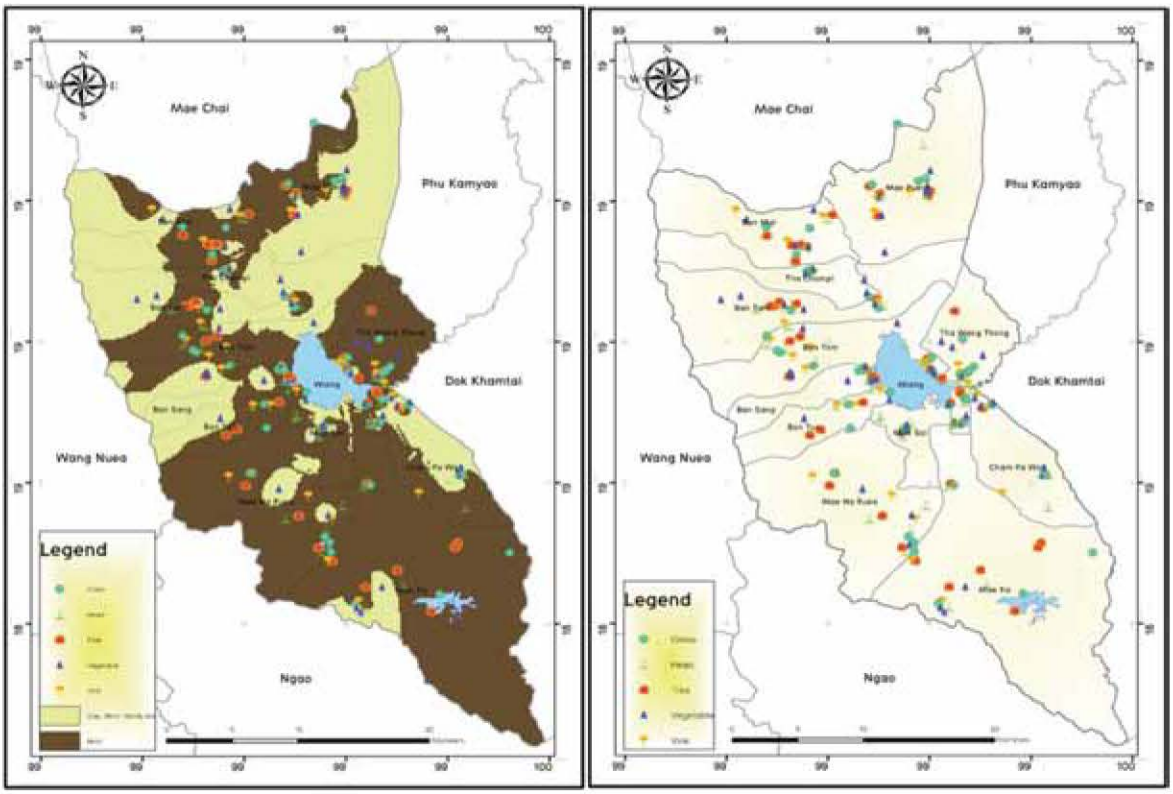


**Figure 9: The comparison of herbal cultivation areas and density**

The Figures 6 and 7 illustrated that the comparison of area between the real growing herbs and the suggestion. The three herbal types, which were bunch, head and vegetables, that nearly the same as their suggestion. However, there was one essential point wherein the rate of tree and shrub (up or down) was quite low. The reason shown that the tree and shrub type was difficult to replace or to plant with the new type of herbs. With the complicated processes and high cost, most farmers were still to have to steady the rate of tree and shrub unavoidably. Although its price was higher or lower, farmers do not prefer to change it. As a result, the tree and shrub cannot be replaced with another type of herbs were planted or destroyed. The proposed system shown all information in the term of data, graphs, maps, and decision support reports respectively. The changes of the area for herbal agricultures were shown in Figures 8 and 9.

The analysis of the data found that there has been a change in farmland related to income from the sale of herbs. In 2015, the local farmers have areas of natural grasses, which are Nut Grass and Blady Grass, for 1,734,400 square meters (60.22% of the total area). They also have areas of head herbs such as Ginger and Shallot for 432,000 square meters (15% of the total area). The bunch herbs, which are Bitter Gourd and Butterfly Pea, have been planted for 300,800 square meters (10.44% of the total area). In addition, the vegetables, which are Lady's Finger and Safflower, have been cultivated for 216,000 square meters (7.5% of the total area). Finally, the tree and shrub, Pomegranate and Mulberry, have been grown for 196,800 square meters (6.83 % of the total area).

In the year of 2016, the head herbs were the most popular for farmers to plant for their income. The total area of the head herbs is 944,000 square meters (32.78% of the total area). The second most popular herb is the grass type. The total area of grass is 764,800 square meters (26.56% of the total area). The third one is the vegetables. Its area is 540,800 square meters (18.78% of the total area). The fourth most popular herb is the bunch type. Its total area is 462,400 square meters (16.06% of the total area). Finally, the least popular herb in 2016 is the tree and shrub type.

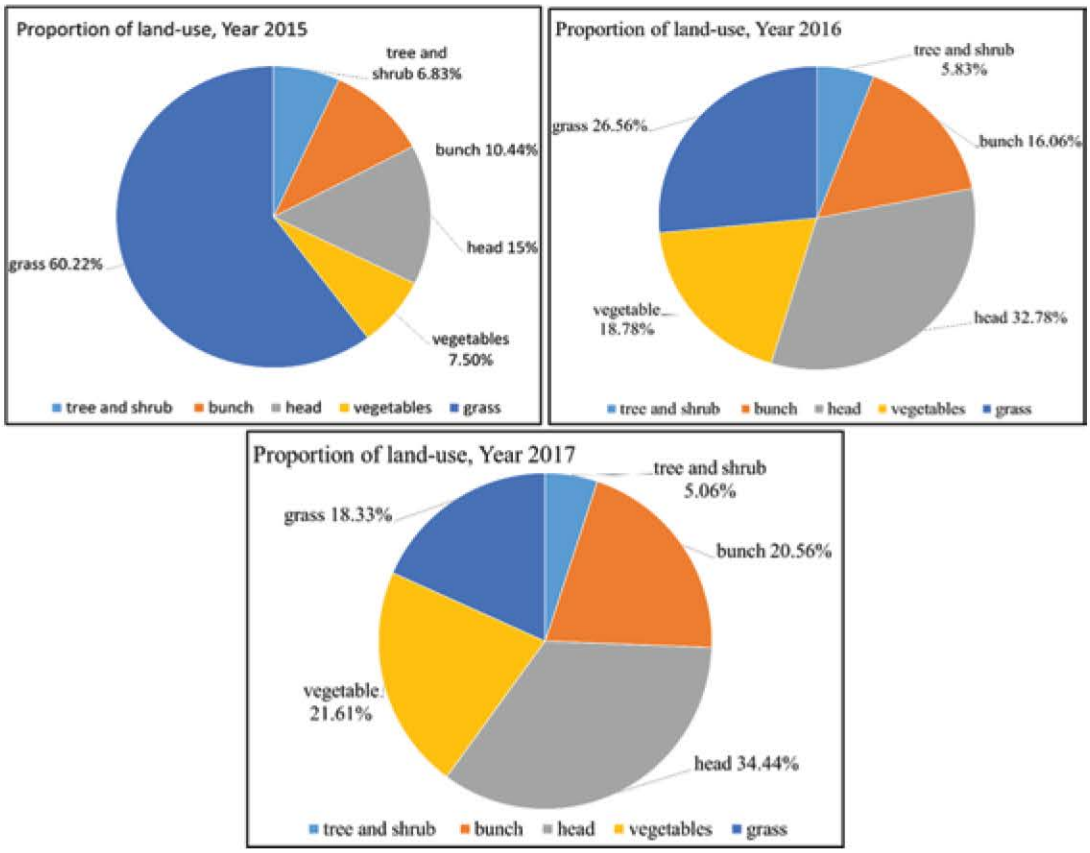


Figure 10: The comparison of herbal cultivation areas and density

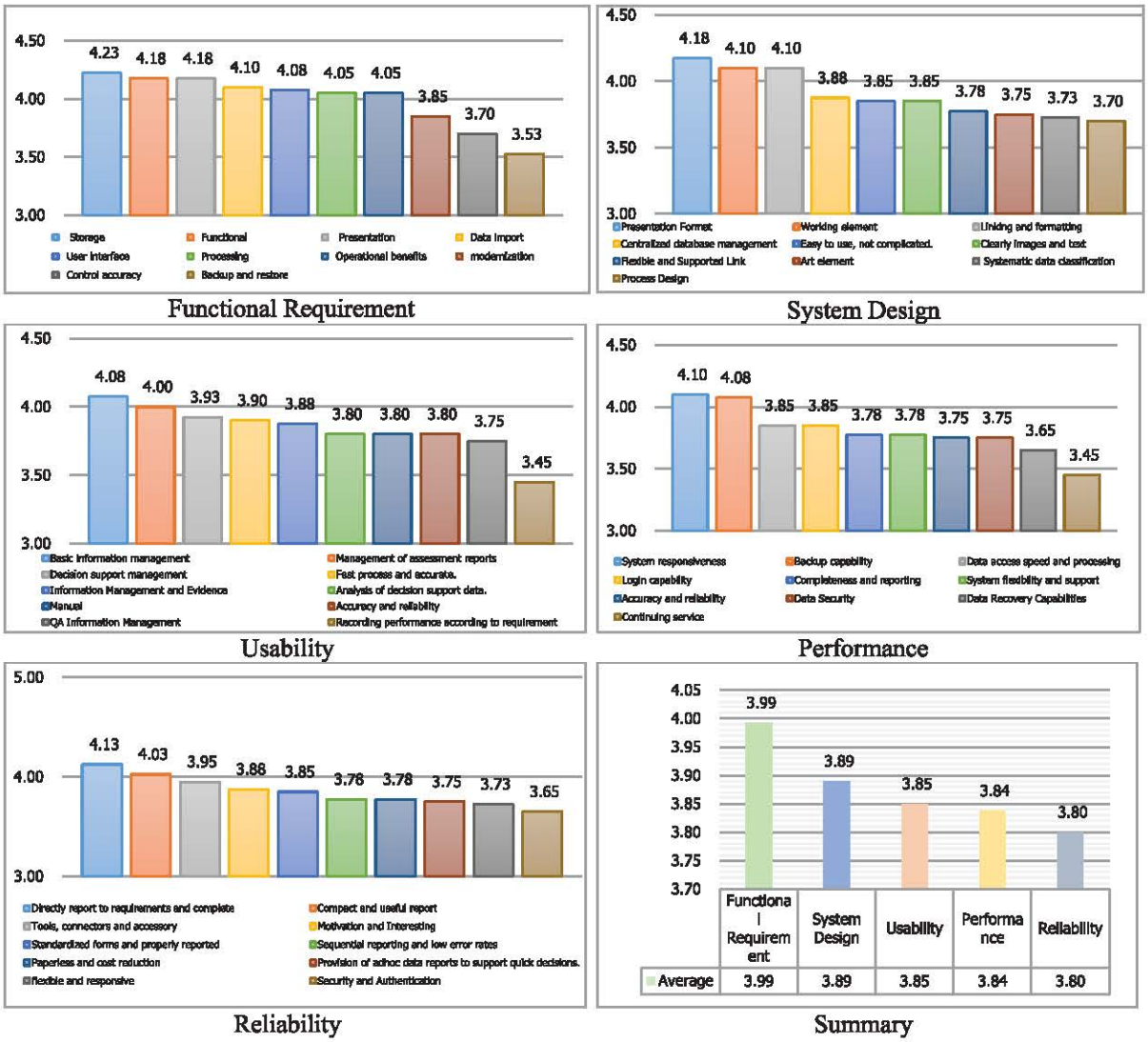


Figure 11: The results of the system performance assessment from research sample

The total area of them is 168,000 square meters (5.83% of the total area) respectively. In the year of 2017, the most popular herb is the head herbs. Their total areas are 992,000 square meters (34.44% of the total area). The second one is the vegetables. Their total areas are 622,400 square meters (21.61% of the total area). The third most popular herb is the bunch. Their total areas are 592,000 square meters (20.56% of the total area). The grass is the fourth most popular one and the total area is 528,000 square meters (18.33% of the total area). Finally, the least in 2017 is the tree and shrub. The total area is 145,600 square meters (5.06% of the total area).

All the results show that both the grass herbs and the tree and shrub herbs have continually decreased. The reason is a long growing period. Moreover, their price is lower than the others. On the other hand, the herbs planting trends were head, vegetables, and bunch. Their area was increased continuously because of the high price of herb in the market (Figure 10). The system is tested by the alpha testing with three experts in software development (Nuraini et al., 2015). This testing was based on the application quality assurance checklist (AQAC) by the Strong Quality Assurance Ltd., (2016). They were business requirements, development framework, development IDE, concurrent users, passwords, code comments, error handling, error logging, field validations, system testing, source code, and database design. The test results have shown the proposed system has passed in every aspect. All results were showed in Figure 11. Furthermore, the beta testing was used to evaluate the system effectiveness. Participants were chosen from herbal conservation consisting of 520 people: 470 herbal farmers 15 herbal experts and local scholars,

and 35 village health volunteers. Then, all participants were randomly selected by Taro Yamane's (1973) rule for 226 people (Yamane, 1973). As a result, the evaluation results are at a good level in every assessment: 3.87 ( $\overline{X}$ = 0.03) for overall system, 3.99 ( $\overline{X}$ = 0.25) for functional requirement, 3.89 ( $\overline{X}$ = 0.19) for system design and 3.85 ( $\overline{X}$ = 0.20) for usability (Figure 11).

## 4. Conclusion

The data warehouse system and decision support system for conservation of herbal plants were proposed in this paper. The proposed system has already been put to practical use in Muang district, Phayao province, Thailand. As a result, the evaluation scores from international standard for testing were at a good level. This research purposes to develop a database for the herbal preservation. Therefore, all users have used the proposed system to support the decision to conserve medicinal plants in their own areas. However, the conservation of herbal plant genetic need to get cooperation from the community continuously. This paper can justifiably be proud of our many achievements and successes in plant conservation though the past years. The proposed system can be used to help slow the loss rate of herbal species. So, it is a tool to help conserve medicinal plants of Muang district, Phayao province, Thailand, concretely. So, GIS can also be used as an effective tool to manage and visualization herbal cultivation areas and density.


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