Development of the Yarding and Harvesting Cost Estimation System

Koji Shimasaki

ABSTRACT

It is indispensable for sustainable forest management to make an economically efficient operation plan based on the detailed information of the site.

For developing economically efficient operation plan, the Yamaguchi Agricultural Public Corporation integrated the results of their conducted field survey into the database, and built a Yarding and Harvesting Cost Estimation System using ArcGIS. This system can estimate the income and expenditure of timber production on each site by calculating yarding and harvesting cost based on the database and additional knowledge of the operators. The database reflects the actual situation of the site by means of frequency modification using ArcPAD and GPS.

This system made it possible to select the most efficient plan based on the actual situation. Furthermore, this is also useful for the utilization of our biomass resources derived from timber production in estimating the supply cost.

KEYWORD: ArcPAD, ArcMap, present condition of forest, estimation of cost, field survey

INTRODUCTION

Since liberalization of the forest products trade came into effect in 1964, the demand for domestic timber products has been declined because of mass import of the timber products. On the other hand, the labor cost of forest operation has been increasing gradually with domestic economic growth and caused drastic deterioration of the economy of domestic forestry. Furthermore, expansion of income gap between a city and a country side has caused serious problem of provincial depopulation and shortage of hands in forestry. Such type of condition has indicated that the multiple function of forest has been declined because of the neglected artificial forests has been increased, and this results occurrence of the landslide in different parts of the country.

In such a demanding situation, the first thing we must do is to put the information of the present condition of forest together, accumulate and share the information required for sustainable management of forest, and then develop a system to conduct the planning of a most cost-effective forest operation. GIS is expected to serve as a very useful tool capable to support the unification of the information and determination in planning of the forest operation.

Yamaguchi Agricultural Public Corporation, located in the Yamaguchi Prefecture, Japan, is the organization responsible for the forest operation on contracts for sharing the harvesting profit with forest owner. They are planning to improve economical efficiency of forest operation and they need to form the logging plan to minimize the yarding and harvesting cost by intensive forest operation.

In forming the plan, they had troubles to gather the information of present condition of the forest. And also they must conduct the field survey to update the information because the present condition of forest is considerably changing. Conducting field survey frequently is desirable for forming the harvesting plan based on present condition of the forest.

We tried to build the database integrated with materials of the information of present condition of forest, and develop the system to enable us to extract the information of forest and estimate easily yarding and harvesting cost using ArcMap. In addition, we tried to develop the system to support the integration of field survey and updating the database by using ArcPAD.

METHODOLOGY

The position of logging target area affects yarding and harvesting cost strongly while operating intensive logging. Because the shorter the time of walking and setting cables for yarding is, the shorter the total time for logging to take place. Furthermore, to form an efficient logging plan, we should select the most efficient one from more than one plan based on estimation of yarding and harvesting cost (F. Nakayama, 2001). And also, the timber volume is changed by the history of forest operation, so the existing information of present condition of forest has to be updated by the result of field survey.

We defined the subjects as below by getting the problems.
1）Interaction of the maps and the ledger recorded with the information of forest condition.
2）Supporting field survey and updating the forest map.
3）Supporting estimation of yarding and harvesting cost.

We designed three subsystems as below based on the subjects mentioned above.
1) Database management system of the present condition of forest
2) Survey map importing system
3) Yarding and harvesting estimation system
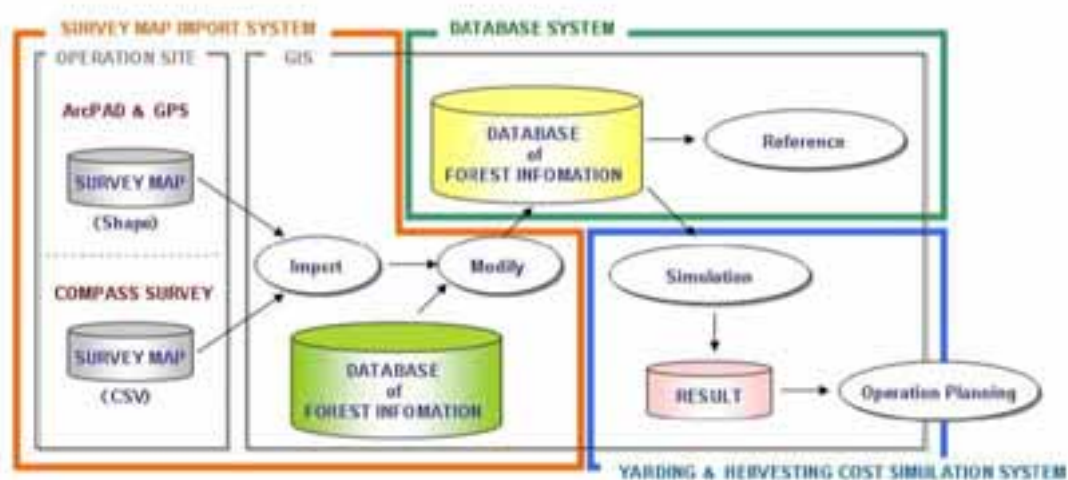
Figure.1 shows the conceptual roles of the subsystems.

Fig.1 Conceptual Diagram

1）Database management system of the present condition of forest
　The information below is stored in the database.
・　map showing the borders of forest operation unit
・　ledger recorded with the information of forest condition such as species, age and owner of forest and so on in forest operation unit
・　survey map of forest operation conducted area
　By unifying the information above as the database, the users can easily extract the information of forest on demand. And also users can extract the information required to form logging plan quickly.

2）Survey map importing system
　In the field survey, conductors investigate species, average height and diameter, content of operation and result of area survey of forest. The area survey is conducted by using GPS or compass. If GPS receiving condition is available, the area survey is conducted by using GPS and ArcPAD, otherwise the survey is done with compass. Table.1 shows data format of the result of area survey under each GPS receiving condition.

Table.1 Data Type of Survey Map

GPS condition	Method	Data format
Available	ArcPAD & GPS Connector	Shape file
Not Available	Compass	CSV

3）Yarding and harvesting cost estimation system

User can estimate yarding and harvesting cost on ArcMap in order to observe the position of forest into account. This system automatically estimates yarding and harvesting cost and extract the information required to do estimation from the database. And also, user gets more than two results of the estimation by setting different condition, so they can compare the results to select the most efficient one.

Table.2 shows the software utilized to develop the system.
ArcGIS is suitable as the database management tool because it has rich standard functions and various data format are available. And also it can interact easily with ArcPad, therefore we decided to adopt ArcGIS.

Table.2 Software

Software	Products
GIS Software	ESRI ArcGIS9.1 （ArcView）
GIS Database	ESRI Personal Geo Data Base
Server-Side Database Software	Microsoft SQL Server 6.5
Client-Side Database Software	Microsoft Access2003
Mobile GIS Software	ArcPAD6.0.3

The detailed methods of development of the systems are mentioned as followings;

1）Database management system of the present condition of forest

The database was created by digitizing the map with displayed borders of the minimum unit of forest operation in polygon layer. The ledgers recorded with the information of present condition of forest had already been digitized and stored in another database.

Figure.2 shows the method of interaction with the map and ledgers. We added the common primary key which identified forest operation unit to both the polygon layer and the table data. We realized the interaction by searching the features which have same primary keys from the polygon layer or the table data as features are selected from another using query in SQL.
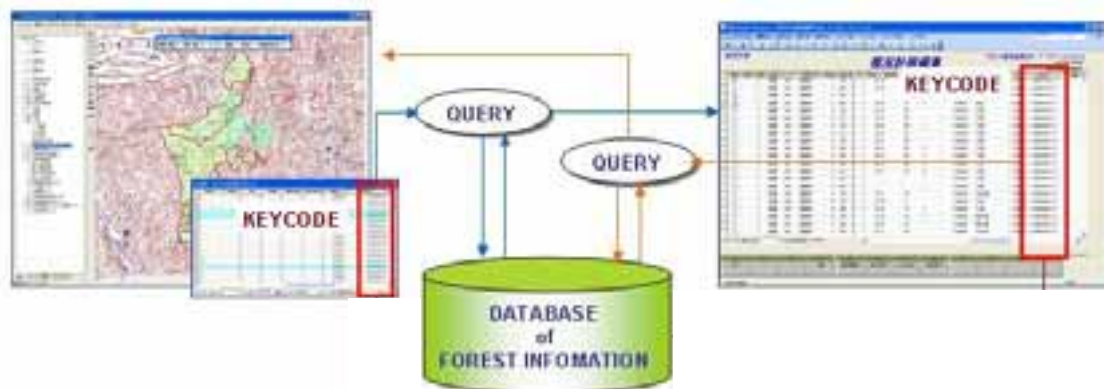
Fig.2 Interactive Connection of Maps and Ledger

２）Survey map importing system

ArcPAD has rich standard functions so we did not perform any customization on it.

In our developed system, users can input the attribute layers of the survey map on ArcMap during import of the layer to the database. The result of survey is automatically appended to the layer specified by user. Geometry type of the survey map which is available for appending the database is point, poly line and polygon.

The raster of topographical map is used as background map on ArcPAD. We had to convert the raster into 8bit data to use on ArcPAD, because commonly used forest base map is of 1bit data in Japan.

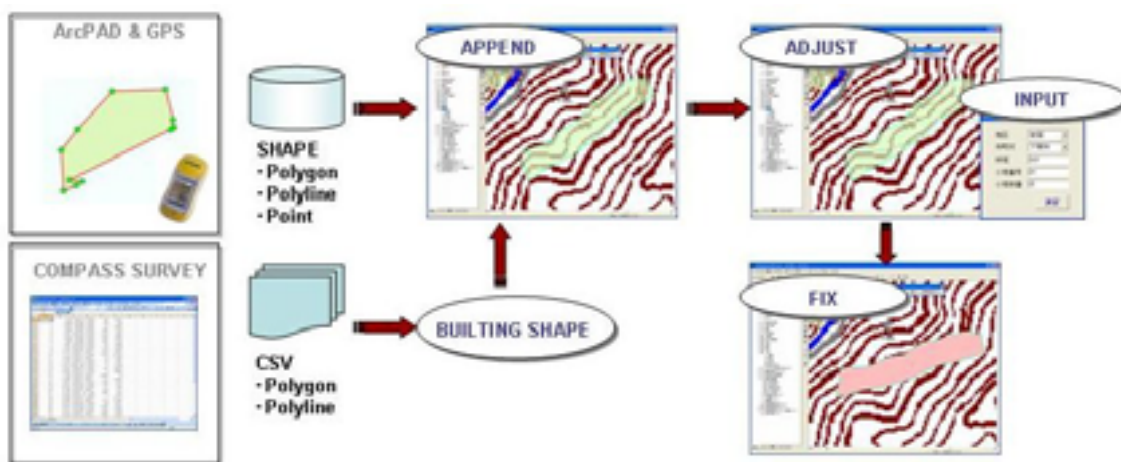Figure.3 shows the flow diagram of the survey map importing system.

Fig.3 Flow Diagram of Importing Survey Maps

３）Yarding and harvesting cost estimation system

The processes of the yarding and harvesting cost estimation are described as bellow;

- Select the target features of the estimation from the polygon layer which shows borders of the minimum unit of forest operation on ArcMap and get the primary keys features.
- Get species, age of forest, the potential ability of timber production from the table data recorded with the information of current condition of forest by using query in SQL. And also get area of features on ArcMap.
- Calculate log volume expected to be harvested.
- Estimate the selling price of log by calculating the volume that can be used as squared timber.
- Set some selection sets from the target area, and get the area, average angle of slope inclination, average distance from the nearest logging road, log volume and the parameters of unit cost of each selection set.
- Estimate yarding and harvesting cost and income on each selection set.
- Estimate the profit of logging on each selection set by deducting the cost from the income.

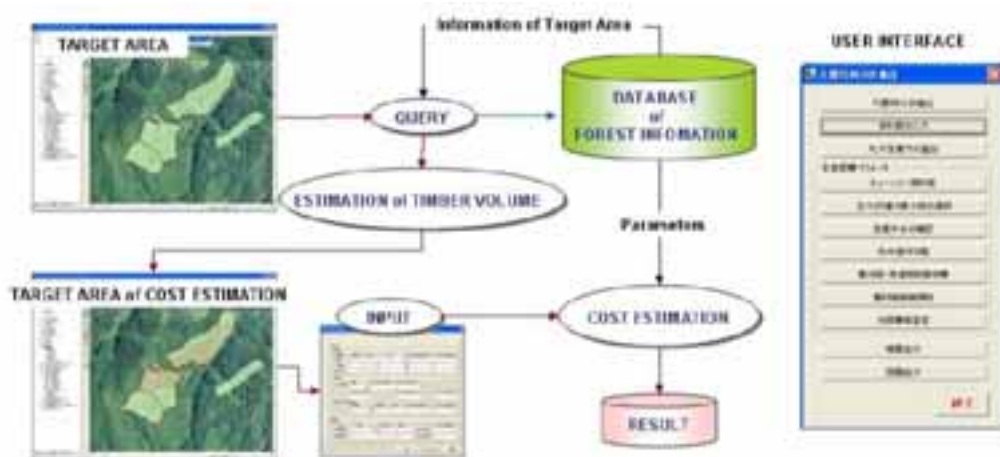Figure.4 shows the flow diagram of the cost estimation.

Fig.4 Flow Diagram of Cost Estimation

The result of the estimation on each selection set is temporarily stored in work table. So users can compare the results of each selection set outputting in account books. And also, logging road and yarding cable setting route is able to be inputted as poly line on ArcMap. And the setting cost of logging road and yarding cable is considered for the estimation of each selection set.

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RESULTS

We verified the results after introducing this system by the following methods;

1）Output of the maps illustrating the quarter of owner's forest and required for several contracts with owners.

Users were able to prepare the maps and the ledgers required for contracts with owners by unifying the information once managed separately as the database and realizing the interaction of the maps and the ledgers. So we succeeded to shorten the time required to gather the information.

2）Obtaining the result of the field survey as shapefile using GPS（Geo-XT built by Trimble） with ArcPAD and then importing the shapefile into the database.

In conducting compass survey, at least two persons are required. By using GPS with ArcPAD, it was possible to conduct the field survey by a single person. And also, it was useful to use ArcPAD as a navigation tool for the field survey target area. In this case, it is also useful to cut out the data required as background from ArcMap.

The shapefiles obtained by GPS often had positioning errors because of condition of GPS receiver availability. So the device was required for editing the layer to append the result of the field survey after importing the shapefile into the database.

3）Comparison of the results of yarding and harvesting cost estimation obtained by our developed system and previous methodology.

The result of yarding and harvesting cost estimation by our developed system was completely same as by the previous methodology. This system enables to estimate on several selection sets of logging target area on ArcMap, so users were able to obtain more than two results of the estimation with ease. And also, results of the estimation can be output as a map illustrating logging plan, users are able to visualize the logging plan.
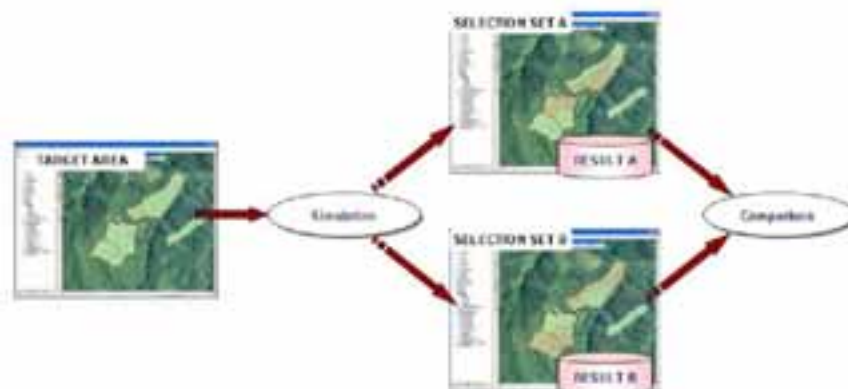

Fig.5 Comparison of the Results

DISCUSSION

Thanks to standard function of ArcGIS, we could easily develop the database management system for the current forest condition

Compared with conducting compass survey, we can expect to reduce cost of field survey by using ArcPAD. However, in putting ArcPad to practical use, below three problems remain to be solved;

1）Compass survey is still required in zone where GPS receiver is unavailable.
2）It is troublesome to coordinate the results of compass survey in projection after importing into the database.
3）It is difficult to edit the result of GPS survey after importing into the database caused by unevenness of precision of GPS.

Compass survey is indispensable for the moment because of above mentioned problems. It is practical to use GPS in coordination of the results of compass survey.

It is also desirable to input the attribute of the field survey area promptly on ArcPAD in order to prevent the discrepancy of the information. A device which supports inputting attribute on ArcPAD without keypad is required for improving field survey efficiency.

In estimating yarding and harvesting cost, bird's-eye view simulation is very effective because the topographical features influence a lot to determine the route of logging roads and setting cables. By using 3D Analyst, we can create a perspective model, but the process is difficult for end users. The bird's-eye view simulation and the cross section of the route of logging roads are in demand, so a device is required which can enable to make it easier from ArcMap. For example, the function is very useful that can load the layers which currently reading on ArcMap to ArcScene in the same way of submitting the data out to ArcPad. And also, aerial photo on the 3D view is very useful for forming logging plan. So the device is also required which shorten the rendering time of raster data.

In this system, distance from logging area to market, which is using as parameter in the estimation system, is configured by users. By building network data set of the route of transportation, we can estimate the cost based on the time of transportation. Actual time of work influences a lot on the cost because of the wages in forest operation is usually paid on the daily basis. Therefore, to analyze the time required for transporting is important to estimate the cost.

In this system, we developed a cost estimation system for harvesting timber. The resource of forest is not only logs used as squared timber, but also the part of tree

which is not used as squared timber like tree top, branches and leaves is expected to put in practical use as biomass energy. It is said that one of major problems to put this biomass energy in practical use is the cost of gathering it. The present developed system can be diverted to a system that can estimate the cost of gathering the biomass resources. And also, the logs left in forest after thinning is expected to be used as the biomass resource. ArcPAD can be a powerful tool to investigate the volume of the logs leftover in forest. It is expected that this system will be applicable to the tool which forms efficient plan for gathering biomass resources.

CONCLUSION

In this paper, using ArcPAD and ArcMap, we can demonstrate a model of the system which enables to easily estimate the yarading and harvesting cost based on present condition of the forests. This system enables users to evaluate logging plan visibly by selecting the target area of logging on ArcMap. And also, this system enables user to compare with more than two logging plans by estimating yarding and harvesting cost automatically. Further, this system should be developed to be able to estimate the cost of operation using high-capacity machine of forestry which is now spreading gradually in Japan.

Field survey using ArcPAD is easier than compass survey, thus users can update the database of present condition of forest frequently. However, some problems remain to put ArcPAD in practical use because GPS is not always available in the forest areas, and also it is troublesome to edit the survey map on ArcMap after importing into the database.

In our future development, we need to develop this system to be more practical by improving the system of updating the database based on the obtained results of field survey.

REFERENCE

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About the author

Name: Koji shimasaki
Organization: PASCO Corporation,
                    Consultant Division, Department of Environmental Information
TEL: +81-3-6412-2501
FAX: +81-3-6412-2561
E-mail: koji_shimasaki@pasco.co.jp