以地理資訊系統為基礎之林分結構與材積推估之空間分析**

馮豊隆*

[摘要]
本研究以台灣第三次資源調查 4002 個地面樣區的調查資料，進行各種林型、群衆的樹種組成、林分結構與蓄積量的分析由 96 篇本省各主要樹種的生長收穫的論文報告，探討林分結構，樹種組成的基本模式。吾人以主要樹種的百分比、樹種的重要值來表示樹種組成；坡度、坡向、海拔高和地理位置為林分結構與蓄積推估模式的獨立變數。以韋伯機率密度函數來描述直徑分布，表示其林分結構，性態值分布狀況。韋伯機率密度函數的定位、尺度和形狀母數，可用來說明其林分結構。由直徑分布法推估單位面積之蓄積用 DDM 表示：由單位面積內單株林木蓄積量之累積以求單位面積之蓄積量的方法謂之 SUV。由單位面積之蓄積樣本樣區之地理因子結合發展出空間林分結構模式與空間林分蓄積量的推估模式。由地理資訊系統展現出各林型多邊形及可查詢出其面積，由比例推估法與迴歸推估法可將樣區之資料推估整個族群。本研究中，以比例推估法，由某林型單位面積之蓄積量，乘上該林型之面積，以求得某範圍內某林型的總蓄積量。數位地形模型（DTM）可切割成 200 m × 200 m 的地理單元，迴歸推估法，則用來推估各地理單元的林分蓄積，再累加某林型所涵蓋的地理單元內，經迴歸推估出蓄積量即得整個族群蓄積量。台灣的森林資源調查與分析於文中亦有詳細的說明。

關鍵字：空間模式、數位地形模型、森林資源調查、韋伯機率密度函數。

**GIS MODEL-BASED SPATIAL ANALYSIS OF FOREST STAND STRUCTURE AND VOLUME ESTIMATION**

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[Abstract]
In this study, a 4,002 ground plots data set of the 3rd Taiwan Forest Inventory are used to study the stand composition, stand structure, growing stock of forest types and forest

**本文於 1995 年 3 月 27 日－30 日於加拿大舉氏省(British Columbia, BC) 維多里亞(Vancouver)舉行的GIS 95 會上發表，目前已收錄於 GIS World Inc. 出版之“GIS Application in National Resource 2”書內

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communities in Taiwan. From 96 published papers of growth and yield, we reviewed the analytical techniques of stand composition and stand structure of Taiwan forest types. In the analysis of stand composition, we try to get the information of main species percentage and important value (IV) of species. Aspect, slope, elevation and geographic locations are used as the input variables to the stand structure and growth stocking estimating function. Weibull probability density function (pdf) is used to describe the diameter of breast height (dbh) distribution for stand structure. The parameters of Weibull pdf are used to explain the location, scale and shape of dbh distribution. Two methods are used to obtain the growth stocking per hectare. The first one is to sum all the individual volume in the plot (SUV), the second one is the diameter distribution method (DDM). The growing stock per hectare is then integrated with the geographic factors to develop spatial stand structure models and growth stock estimating models. In forest inventory and analysis, how to develop estimating models from plot sampling data is a very important work. We used the developed spatial stand structure models and growth stock estimating models to get the whole characteristics of population. The geographical information system (GIS) are used to store, overlay, analyze and display the stand structure and growing stock of any forest types in the area of interest. From forest type map in GIS, we can get the location and area information of any forest types. Ratio estimation and regression estimation are the methods used in estimating characteristics of population from samples. Ratio estimation was used to calculate the growing stock of any forest types by multiplying area with growing stock per hectare of the type. Digital terrestrial model (DTM) in GIS is used to extract characteristics of any geographic units (200m × 200m) of interested area. Regression estimation was used to obtain growing stock of all the geographic units in the forest types interested, separately. Then, sum up the amount of units to get the population information. The spatial distribution of growing stock and stand distribution are showed in GIS clearly. Detail description of forest inventory and analysis are also provided in the paper.

(Key Words): spatial models, DTM, forest inventory, Weibull pdf

1. Introduction

(1) Decision Support System (DSS)

When we want to do relational forest ecosystem management under conservation concepts of alpha, beta, gamma biodiversity, we need to know the stand composition, stand structure, growing stock of forest types and forest communities. To make a decision
making in forest ecosystem management wisely, we had to get sufficient information. The information derived from 3 subsystems—(a) resource simulation modeling system, (b) GIS, and (c) economical evaluation system. Modeling is necessary in the estimation and evaluation, especially in integrating the information of forest inventory into GIS.

(2) Forest Inventory and Analysis (FIA)

Forest measurement, inventory and survey are very important components in forest resource conservation and management. Sampling design, data acquisition, data management and data analysis are main steps in the forest inventory. If there are no good sampling design, data collection techniques and skillful persons, we couldn't get data with representative precisely. Without efficient data management system, we can not get data into useful as a whole. Data analyzing and modeling is the last steps to make data into information for supporting decision-making. There is 3rd Land Use and Forest Inventory in Taiwan proceeded from 1989-1993 by Taiwan Forest Bureau. The information of land use types distribution and growing stock are key factors in forest policy making and practicing decision making. For all the data of plots have their own coordinates and tree, their own spatial location, we want to know where the forest types and their growing stock, so we try to put all the data in geographic information system (GIS). GIS was selected to be a spatial database management.

(3) Geographical information system (GIS)

There are many kinds of data which came from different data acquisition system and existing data files. For forest resource have their own position, coordinates which we can use GIS to connect all the data in a common spatial database management system.

The GIS is used to store, overlay, analyze and display the information of stand structure and growing stock of any forest types in the area of interest. GIS is a tool for integrating map layers and spatial attribute tables which came from different resources, types, formats and scales. We can use it to retrieve, overlay, iterated processing the point, line and polygon data, and then, to display and query the products of it. GIS could use to(1) integrate, storage and query the data of attribute and many layers (2)data overlay (3)to integrate simulation model to get simulate and analysis capability (4) display the results.(Jeffrey & John, 1990). It will be an efficient tools in the decision making of natural resource conservation and management. We have to digitize the base map and theme maps such as watershed map, plot location map, tree location map, forest management
administration system map. For getting slope maps, aspect maps and contour, we have to use digital terrestrial model(DTM) to do analysis. Data of photo interpretation and field surveyed are key in database, then linking to GIS with spatial coordinates. After analysis sampling data and modeling the stand characteristics, we can display the result in the map. From overlaying the map layers, we can get to know what the stand status we interested.

(4) Spatial model

GIS model-base spatial analysis of forest stand structure and volume estimation data are analyzed to be an rich, accurate and efficient information, which information can be used for explaining, estimating and predicting. If there are appropriate statistical sampling, analyzed and interpreted in forest inventory, we can (1) estimating the timber volume where we wanted, (2) use data to verify the model which we developed, and (3) get the error interval we estimated. For estimating the stand structure and stand growing stock, we have to build estimating models. If we want to use samples to estimate the whole population, ratio estimation and regression estimation are the two important methods. There must have assumption of homogeneous population in estimating. It makes sense to estimate stand composition, stand structure and stand growing stock by forest types separately. There are many different definitions to indicate stand composition, stand structure and stand growing stock, which derived diverse methods to create, such as (A) stand composition: species composition, (B) stand structure: size distribution of tree characteristics in sample plots, tree characteristics such as: dbh, height, basal area(BA), volume diameter of breast height (dbh) distribution is the common one, and (C) stand growing stock: stand volume per ha. This is derived variables we can (i) sum up all individual tree volume (estimating by volume equation)in the plot, this is what we called Sum of Volume(SUV), and (ii) sum up volumes by dbh classes which estimated from stand structure, this is what we called Diameter Distribution Method(DDM).

Environmental hierarchical concept showed us that climate, soil, vegetation are deemed by topography (Kellman, 1980). We can promote that topography factors are location, aspect, slope and elevation which affect the composition, distribution and structure of biological species. From mathematical viewpoint, we can indicate that solar energy, water content and mental in soil are elements of photosynthesis. Solar energy and water content are synthetic environmental index which could be derived from aspect, slope and elevation.

(5) Motive
In consideration of (A) integrating data acquisition data, management data, analysis, and information application under ecosystem management, and (B) getting to know where and how much the growing stock and stand structure for each forest types from data of the 3th Taiwan Forest Inventory, we try to develop spatial models from data of FIA into GIS. Topographic factors, synthetic environmental index are used for variables in growth stocking and stand structure of different species community and forest types. Stand composition, stand structure and growth stocking are the key stand characteristics in decision-making. To estimate the area and the growth stocking of timber resources are also the main objectives of the 3rd Forest Inventory of Taiwan. If we want to achieve the objective, integrating FIA and GIS is the indispensable way to do. FIA and GIS are the most important techniques in supplying information for decision-making. Developing spatial model to combine the two tools is the main aim of this paper.

2. Material and Method

(1) Material-
   
a. Ground sample plots
   
The survey area of the forest inventory covers the whole island (36,000 squared km). We get the plot distribution map with 4,002 ground survey plots shown as the figure 1. There is one ground survey plot in each cross-section per 3 km. Working circles are the managerial unit of forest. There are 37 working circles in Taiwan forest management system. If we zoom out and cut the Da-Pu working circle from the whole island, the distribution of the 280,000 interpreted points and the 4,002 ground survey plots could be shown as following. (Figure 2)
   
b. Individual tree data
   
There are 66,979 individual trees in 4,002 plots (excluding supplement plots remind 56,267 stocks).

c. Contents of surveyed data and what we used in the study
   
The items of the ground surveyed data tables are showed as the table 1. "x" stands for the items recorded in surveyed table. The "☐" items are used for data files connected. The upper items of "☐" belong to stands in "Plot1.dbf", and the lower items are individuals in "Plot2.dbf".
Figure 1. Ground survey plots in the 3rd forest inventory of Taiwan (courtership from Taiwan Forestry Bureau 1993)

Figure 2. The distribution of interpreted points and ground survey plots of Ta-Pu working circle (courtership from Taiwan Forestry Bureau 1993)
Table 1. Item comparisons between ground survey and aero-photo interpretation

<table>
<thead>
<tr>
<th>Survey items</th>
<th>Field survey</th>
<th>Photo plot</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Stand- plot1.dbf)</td>
<td>(Individual- plot2.dbf)</td>
<td></td>
</tr>
<tr>
<td>Map no.</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>Plot no.</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>Date</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>Abscissa</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>Ordinate</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>Recorder</td>
<td>x</td>
<td></td>
</tr>
<tr>
<td>Surveyer</td>
<td>x</td>
<td></td>
</tr>
<tr>
<td>Plot area</td>
<td>x</td>
<td></td>
</tr>
<tr>
<td>Elevation</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>Slope</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>Aspect</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>Land use</td>
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<td>x</td>
</tr>
<tr>
<td>Land form</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>Age class</td>
<td>x</td>
<td></td>
</tr>
<tr>
<td>Crown closure</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>Stand class</td>
<td>x</td>
<td></td>
</tr>
<tr>
<td>Major lesser plant</td>
<td>x</td>
<td></td>
</tr>
<tr>
<td>Minor lesser plant</td>
<td>x</td>
<td></td>
</tr>
<tr>
<td>Density of lesser plant</td>
<td>x</td>
<td></td>
</tr>
<tr>
<td>Height of lesser plant</td>
<td>x</td>
<td></td>
</tr>
<tr>
<td>Tree no.</td>
<td></td>
<td>x</td>
</tr>
<tr>
<td>L/R</td>
<td></td>
<td>x</td>
</tr>
<tr>
<td>Location distance</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tree to line</td>
<td></td>
<td>x</td>
</tr>
<tr>
<td>Growth status</td>
<td></td>
<td>x</td>
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<tr>
<td>Species</td>
<td></td>
<td>x</td>
</tr>
<tr>
<td>DBH</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Height</td>
<td></td>
<td>x</td>
</tr>
<tr>
<td>Branch height</td>
<td></td>
<td>x</td>
</tr>
<tr>
<td>Crown class</td>
<td></td>
<td>x</td>
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<tr>
<td>Decayed rate</td>
<td></td>
<td>x</td>
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<tr>
<td>Decay reason</td>
<td></td>
<td>x</td>
</tr>
<tr>
<td>Utilization</td>
<td></td>
<td>x</td>
</tr>
<tr>
<td>Used rate</td>
<td></td>
<td>x</td>
</tr>
</tbody>
</table>

There are two parts of the files. One is GIS spatial map files, and the other is spatial data-based estimating models and numeral database.

a. The variables of estimating stand characteristics models are derived from Plot2.dbf (individuals' characteristics in sampling plot).

b. Stand composition, stand structure and growing stock are the main stand characteristics we are interested. Stand composition is calculated from the percentage of tree species. Stand structure is shown in distribution of dbh with Weibull probability density function. Growing stock is described in summing individual tree volume and with diameter distribution method. Growing stock per unit is what we used in the paper.

c. Land-use-types maps are got from photo interpreting and digitizing. Stand characteristics distribution maps are generated from spatial estimating models a land characteristics of topographic units. To overlay with administration layer, watershed layer or other classified layers etc. which we are interested separately, we can get information clearly. Area of each land-used-type and any classified units are easy to be calculated and located from GIS.
Figure 3. Flow chart of data procedure in the 3rd Taiwan Forest Inventory

Note — plot2.DBF: sample trees database
plot1.DBF: sample plots database

DDV: diameter distribution Method
SUV: sum of individual tree volume
Figure 4. Getting the relationship of stand characteristics and environment factors

Working circle GIS

Figure 5. Decision Support System in working circle
(2) Methods- Data analysis

We use tree individuals of each plot to get stand composition, stand structure and stand volume, then put the results in the stand database. a. There are 4 field data-plot data(Plot1.txt), individual tree data(Plot2.txt), photo data and soil survey. b. To combine Plot1, Plot2, and Photo. c. To gather volume equations, equations of tree height and dbh relationship. From 96 published papers of growth and yield, we reviewed the analytical techniques of stand composition and stand structure of Taiwan forest types.

4. Results and Discussion

To know the species composition, stand structure, and growing stock of the whole island is an important objective in the 3rd Taiwan forest inventory. For huge area, tally is not suitable method, sampling survey is adopted to practice. It's necessary for us to develop models with samples to estimate the stand characteristics of the whole island.

(1) Modeling

We try to use aspect, slope, elevation, topographic position, aspect, water gradient, and solar energy as the input variables to build models to estimate the stand structure and growth stocking.

We can get the model into two parts, one is dependent variable, the other is independent variable.

A. Dependent variables

(A) Stand composition-- main species percentage and important value index (IVI) of species.

i. From aero-photo interpreting, we know what forest types (or land-use types) of field plots are. We calculate the stock percentage of species in the plot. If the stock percentage of the species is more than 30%, we name after the “main species” of plot by it's code.

ii. IVI is stand for the relative importance of some species in a stand or forest type. There are 3 components--relative frequency, relative density and relative dominance. (Liu and Shu, 1983)

\[
\text{relative frequency} \% = \frac{\text{frequency of some species}}{\text{sum of frequency}} \times 100 \quad (1)
\]
stocks of some species
relative density % = 
all stocks in plots

x 100..........................(2)

dominant(coverage) of some species
relative dominance% = 
sum of dominant(or coverage) in plot

x 100.......................... (3)

Important value index (IVI) = relative frequency + relative density + relative dominance ...(4)

(B) Stand structure

The size distribution of stand characteristics is called stand structure. The status of stand structure is integrated results of growing merits, environmental condition and management practices. (Husch, Miller and Beer, 1972)

Individual trees are the components of stand. Diameter of breast height (dbh) and tree height are the major scale in tree measurements. For estimating and predicting the size distribution of stand characteristics, we need to model the distribution. Probability density function (pdf) is the generally used to model. For many merits, Weibull probability density function (pdf) is used to describe the diameter of breast height (dbh) distribution for stand structure. The parameters of Weibull pdf are used to explain the location, scale and shape of dbh distribution. Weibull can describe dbh distribution very well (Feng, 1988).

Weibull function f(x,θ) is shown as following:

\[ f(x, \theta) = \left(\frac{c}{b}\right)\left(\frac{x-a}{b}\right)\exp\left[-\left(\frac{x-a}{b}\right)^c\right] \]

\[ \left(\frac{x-a}{b}\right)\exp\left[-\left(\frac{x-a}{b}\right)^c\right] \] ........................(5)

where \( a \geq 0, \ b > 0, \ c > 0 \)

\( x \) : dbh

exp : exponential

There are many methods to estimate the parameters (θ) of Weibull function. We adopted the 5 methods --Hater Wingo, Fillter, Dagostino which are arranged by Bailey(1973). In the mean time, we use Kolmogorov-Simirov test(K-S test) to check the goodness of fit and from D value of K-S test to get the best one of it.
(C) Growing stock

Two methods are used to obtain the growth stocking per hectare of sampling plots. The first one is to sum all the individual volume in the plot (SUV), the second one is diameter distribution method (DDM). Volume equations of different species and species groups are used to estimate the volume of individual tree.

i. Basic tree equations

From 96 published papers of growth and yield, we reviewed the individual volume equations and D-H relationship curves by species.

ii. Sum individual tree volume: To sum up all the estimated tree volume in the plot, then, derived by plot area we can get growing stock per ha (SUV/ha).

\[ \text{SUV/ha} = \Sigma \text{Vi/ha}, \text{Vi} = f(D,H) \] ..........................(6)

where Vi: the volume of tree i

D : dbh
H : tree height

iii. Diameter distribution method (DDM): To get the whole volume of plot by DDM, we can get the whole stand growing stock per ha. (DDV/ha).

\[ \text{DDM/ha} = Nt \cdot g(x)f(x, \theta) \] ..........................(7)

where Nt : stems per ha. which calculated from plot
g(x) : function of dbh (x), such as H = f(D)V = f(D,H)
f(x, \theta) : Weibull function
\theta : parameters a, b, c of Weibull

(D) Estimating models of the whole island

The growing stock per hectare is then integrated with the geographic factors and derived variables to develop spatial stand structure models and growing stock estimating models.

B. Independent variables
Light and water are the main elements in plant photosynthesis. Slope and elevation affect solar energy, slope and aspect affect solar radiation, water gradient and soil.

(A) Slope: The azimuth of direction which is vertical to the contour which we are interested.

\[ B \cos(a-\theta) \] ..................................................(8)

where \( B \) : extension factor

\( a \) : azimuth

\( \theta \) : assumed 45°(Trimble and Weizman 1956),(Stage, 1976)

(B) Aspect: Gradient or degree of arc we are interested.

From azimuth, we can calculate the water gradient. South-west is the driest and north-east is humidest in North-hemisphere(Day & Monk 1974).

(C) Elevation: The calculating height from average sea level of Keelung in the south-east of Taiwan.

The relationship of ambient energy levels and elevation are following:

\[ \text{energy} = a - b(\text{elevation}) \] ...........................................(9)

The higher energy, the lower the moisture

\[ \text{water content} = a - b(\text{energy}) \]

(D) Solar energy

\[ \tan(\text{slope})(\%) \times \sin(\text{azimuth}) \] .................(10)

\[ \tan(\text{slope}) \times \cos(\text{azimuth}) \] .................(11)

\[ \sin 360 = \sin 0 = 0 \]

\[ \cos 360 = \cos 0 = 1 \]

(E) Water gradient

The water gradient could derive from aspect as following:
(2) Building estimating models

From 2, we know there are 2 approaches - diameter distribution method, and sum individual tree volume - to estimate the growing stock per hectare. However, if we want to estimate some area which we are interested in or the whole population, we need to build stand structure models and growing stock models. Stand structure and growing stock are the function of species, age, site index, stand density and management treatment. For it is not easy to identify the age of natural forest and there are not any management treatment in Taiwan, we have to get out of those affected factors. Site index are used to indicate the productivity of forest land with the name of average tree height of dominant and codominant trees in pure forest. If we try to estimate the stand characteristics of mixed natural forest with site index may be not suitable. There are hierarchical correctional effects of environmental factors to forest composition, structure, and growing stock. Topographic position and aspect are the upper layer factors to explain the characteristics diversity of plant community, it called it "environmental hierarchical concept"(Kellman, 1980). Slope, aspect, elevation, coordinate are the key factors of environmental factors, so we use them to be indicators of site productivity. Density is the other important factors of growing stock. The growing stock per hectare is then integrated with the geographic factors and derived variables to develop spatial stand structure models and growing stock estimating models. We have to check the relationship of stand characteristics and environmental factors before models are built. To draw the graphs of relationship between stand characteristics and environmental factors, we could
get a profile of it. The latter are slope, aspect, elevation, solar energy, water gradient and density. The front are stand structure (Weibull a, b, c), and growing stock (SUV/ha, DDV/ha). From the graphs, we can know the tendency of the relationship, and do more detail in the analysis of cause-effect. In the mean time, we use principal component analysis (PCA) method to gain the main environmental factors, too. Regression estimation and ratio estimation are the major methods to estimate the stand characteristics of population. We need regression models to do regression estimating, mean and stand deviation to do ratio estimating. In the step, we have to prepare regressions and characteristics distribution of different range in some land-use and species classification.

The models are:

- growing stock estimated model:
  \[
  V/ha = f1(\text{slope, aspect, elevation, solar energy, water gradient}) \ldots \quad (12)
  \]

- stand structure model:
  \[
  b = f2(\text{slope, aspect, elevation, solar energy, water gradient}) \ldots \quad (13)
  \]

  \[
  c = f3(\text{slope, aspect, elevation, solar energy, water gradient}) \ldots \quad (14)
  \]

(3) Estimating the population

We used the developed spatial stand structure models and growing stock models to estimate the whole characteristics of population. The geographical information system (GIS) are used to store, overlay, analyze and display the stand structure and growing stock of any forest types in the area of interest. From forest type map in GIS, we can get the location and area information of any forest types. Ratio estimation and regression estimation are the methods used in estimating characteristics of population from samples. Ratio estimation was used to calculate the growing stock of any forest types by multiplying area with growing stock per hectare of the type. Digital terrestrial model (DTM) in GIS was used to get characteristics (such as slope, aspect, elevation, solar energy, and water gradient) of any geographic units (200m x 200m) of interested area. Regression estimation was used to obtain growing stock of all the geographic units in the forest types interested, separately. Then, sum up the amount of units to get the population information. The spatial distribution of growing stock and stand distribution are shown in GIS clearly. We will show the results of some working circles in the presentation.

(4) Detail description of forest inventory analysis
Detail description of forest inventory analysis is provided as following:

A. To get the stand characteristics—species composition, stand structure, and growing stock
   --from tree individuals of plots.
B. Put the calculated stand characteristics into stand files.
C. To do some transformation and estimation of the geographical variables to environmental factors.
D. To do cause-effect analysis of characteristics and environmental factors, and get the principal environmental factors.
E. Use the principal environmental factors to classify the plots into several ranges, and then calculate the mean and stand deviation of stand characteristics in each ranges.
   For ratio estimation.
F. Doing regression analysis with stand characteristics and environmental factors, we get stand structure estimated models and stand growing stock models.
G. From aero-photo interpretation and base map, we get land-use maps(including vegetation maps) with coordinates in GIS. Overlaying the land-use map with plot location map, we can get plot numbers and coverage of different types of land-uses.
H. We use DTM to do spatial analysis for getting average geographical characteristics, such as slope, aspect and elevation of each units.
I. If there are regression models of some species, we could use land-use specific model separately. If there are none, we would use ratio estimating to get the stand structure and growing stock of whole area we are interested.
J. From the upper processing, we can make stand structure distribution maps, and stand growing stock maps.
K. We can use administration map, watershed map to overlay land-use maps, stand structure map and stand growing stock map to get what stand characteristics which we are interested.

5. Conclusion

To get to know "how about the stand structure? and how much and where the growing stock of forest in Taiwan?" is the main objective of 3rd Taiwan forest inventory. There are tree, stand and soil field survey, photo interpretation and measurement in the forest inventory. We got attribute data with coordinate and geographical factors items. Spatial map
layers are other kind of data. The former data are describing the characteristics of stand plot and tree, which are supplied for developing estimated models. The latter data are supplied some maps (such as: plot distribution maps, land-used maps etc.) for digitizing into GIS. We analysis and develop models from sampling data to estimate forest resource. Developing characteristics estimated models with spatial or geographic variables, we can integrate spatial estimated model with GIS. The stand characteristics are stand composition, stand structure and stand growing stock. The geographic variables are slope, aspect, elevation, solar energy and water gradient. Before model built, we have to check the relationship between stand characteristics and geographic factors. PCA is an efficient method in simplifying the models. If there are enough information to certificate we can develop an efficient model, we estimate the stand characteristics of whole island with regression estimation or ratio estimation with mean value of each environment range. The method to sum up the amount of units to get the population information is better than estimating with mean value multiply area of each forest types. The spatial distribution of growing stock and stand distribution are shown in GIS clearly. The results could be estimated and displayed in GIS.

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