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Abstract: Vietnam is one of the countries with high biological diversity in the world but also greatly influenced by climate change. Therefore, it is necessary to have a solution for sustainable forest management through field surveys in permanent plots to study forest ecology, combining advanced GIS (Geographic Information System) technologies such as Google Earth, Global Mapper, etc. to monitor changes in forest structure and dynamics. The paper is based on the inheritance of the first measurement data in 2012 and directly measures in the second time after 5 years in 2017 at a 10-ha plot with ten 1-ha subplots. The results show that the number of trees is the highest at the diameter class of 10-20 cm (< 20 cm), accounting for about 60% of the total number of trees of each 1-ha sub-plot and the study site and at the height of < 20 m, respectively 8,402 out of 10,261 in 2012 and 8,189 out of 10,013 in 2017 were measured. In addition, the result of this paper indicates that Google Earth software is one of the most effective GIS tools in planning biodiversity conservation strategies and natural resource management.

Key words: Forest structure, GIS, permanent plot, Bidoup-Nui Ba.

1. Introduction

In Vietnam, the total forest area is 14,773,000 ha, the proportion of forest coverage of 47.6% [1]. Vietnam is one of the countries with high biological diversity in the world but also greatly influenced by climate change. In fact, the natural forest area in general and the quality of forest ecosystems along with the biodiversity in our country have been severely reduced in recent years [2]. Reducing greenhouse gas emissions from deforestation and forest degradation (REDD) in developing countries is a global initiative that has been the 13th Conference of the Parties (COP13) of the United Nations Change Framework Convention on Climate

(UNFCCC) and Kyoto Protocol adopted in Bali, Indonesia in 2007 [3].

Therefore, sustainable forest management requires monitoring and evaluating structure and dynamics of the forest ecosystem, finding out the causes of dynamics to predict the development in the future and to plan strategies to protect, develop and sustain use of forest resources. In the last decade of the 20th century, the FAO (Food and Agriculture Organization) of the United Nations implemented a project to assess the global forest resources in order to gather information about the area and quality of forests as well as ecological indicators, thereby, define changes in forest resources periodically every 5 years to 10 years in each country. Countries have been using advanced technologies such as remote sensing and GIS (Geographic Information System) to monitor forest areas. However, the monitoring of forest quality and

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forest ecological factors requires a lot of efforts through field surveys in permanent plots to study forest ecology [4].

A GIS is a system designed to capture, store, manipulate, analyze, manage and present spatial or geographic data. GIS applications are tools that allow users to create interactive queries (user-created searches), analyze spatial information, edit data in maps, and present the results of all these operations [5]. With the development of GIS, environmental and natural resources managers have information systems at their disposal, data of which are readily accessible, easily combined and flexibly modified for decision making in environmental and natural resources management [6]. Google's freely available Google Earth software provides many functions that can be used as GIS tools to support natural resources management activities. Google Earth, which lets you view and work with satellite imagery, maps, aerial photos, and other imagery, is available in three versions: the free version, Google Earth Pro., and Google Earth Enterprise [7].

This study uses the Google Earth Pro. tool to manage forest resources at the permanent plot in Bidoup, Nui Ba National Park scientifically, easily updated, accurately and effectively.

2. Methodology

The study area in the permanent plot at Bidoup-Nui Ba National Park was established by the SIE (Southern Institute of Ecology) since 2012 under the State's key science-technology program "Science and Technology for Serving Tay Nguyen Region's Social-Economic Development" KHCN-TN3/11-15 Project (Tay Nguyen 3) "Establishing a forest dynamics plot in Bidoup-Nui Ba National Park as foundation for studies in forest succession". Bidoup-Nui Ba National Park with a total area of 65,188 hectares in the Northeast of Da Lat Highland, has coordinates 12°00' N to 12°19' N and 108°21' E to 108°44' E. The 25-ha plot is designed with 25 small plots of 1 ha, size 20 m \times 500 m. Each tree is labeled, positioned, dimensioned and identified. The limit of this study only measures the woody plants with the diameter $(D_{1,3}) > 10$ cm, carried out in 10 sub-plots (10 ha) with each sub-plot having an area of 1 ha (see Figs. 1 and 2).

2.1 Data Collection

The field trip was carried out in 2012 and 2017. Data in 2012 were inherited from the study of Southern Institute of Ecology [8]. The data in 2017 are made by the research team from March-May 2017.



Fig. 1 Study site 10 ha at the permanent plot.



Fig. 2 Design the permanent plots.

DBH (Diameter at Breast Height) and H (Tree Height) were measured according to FIPI [9], in which all woody trees were measured with DBH > 10 cm, and about 40 sample trees were measured in each

sub-plot of 1 ha to establish an allometric equation between DBH and H.

2.2 Data Analysis

Collected data were analyzed by using Excel software and Statgraphics Centuriron XV [10] to determine the allometric equation between the tree height (H) and diameter (DBH), thereby to calculate the tree height of the entire study site, the basal area $(G: m^2)$ and the stem volume $(V: m^3)$ [9].

GIS softwares, such as Global Mapper v19.0, Google Earth Pro. were used to manage forest data at the permanent plot in Bidoup-Nui Ba National Park.

The study process is shown in Fig. 3.

3. Results and Discussions

3.1 Allometric Equation between DBH and H

The tree height of individuals (H) is one of the important indicators to calculate the volume of trees as



Fig. 3 The process of study.

Subplata	Allomatria aquations		Statistical coefficient							
Subplots	Anometric equations	R^2	SEE	SSR	MAE					
S1	$H_1 = 1/(0.0321601 + 0.712002/DBH)$	83.22%	0.008	0.003	0.006					
S2	$H_2 = \exp(3.61461 - 15.279/DBH)$	80.58%	0.17	1.13	0.14					
S3	$H_3 = \exp(1.24739 + 0.561466*\ln(DBH))$	75.37%	0.19	1.44	0.15					
S4	$H_4 = \exp(1.85681 + .0535684*DBH)$	80.67%	0.120	0.570	0.08					
S5	$H_5 = 1/(0.040294 + 0.292272/DBH)$	90.80%	0.002	0.0002	0.002					
S6	$H_6 = \exp(1.15259 + 0.529132*\ln(DBH))$	78.50%	0.140	0.880	0.10					
S7	$H_7 = \exp(3.58204 - 15.5687/DBH)$	78.73%	0.190	1.360	0.15					
S8	$H_8 = 1/(0.0147037 + 0.780262/DBH)$	79.80%	0.007	0.002	0.006					
S9	H ₉ = 1/(0.036996 + 0.539281/DBH)	98.00%	0.002	0.0001	0.001					
S10	$H_{10} = 1/(0.025532 + 0.782251/DBH)$	90.30%	0.005	0.0009	0.004					

Table 1 Allometric equations between DBH and H of ten subplots of 1 ha area (8.9 cm $< D_{1,3} < 140.7$ cm).

well as the tree volume. We can identify the tree height by many different methods such as direct measurement with height measuring instruments but the difference will be relatively large and time consuming; or based on the available height table from previous research, but the area must be relatively similar in terms of climate, soil, terrain, etc. with the previous study area; or create the allometric equation between H and a more easily identifiable factor. During the growth of the trees, the tree height and DBH have a direct ratio and close relationship, so we determine the tree height through DBH. Here, finding out the relationship between tree height and DBH is significant in determining the relative tree height quickly and inexpensively. That relationship is expressed through the allometric equations made from the data of the sample trees as shown in Table 1. After analyzing the allometric equations, the selected equation is most suitable for the relationship between H and DBH with a high correlation coefficient (R^2) (not necessarily the

highest) but SEE (Standard Error of Estimate), SSR (Sum of Squared Residuals) and MAE (Mean Absolute Error) has the smallest value.

3.2 Forest Structure

3.2.1 Distribution of Tree Diameter Class

Diameter frequency distributions provide a useful substitute for development trends of the stands [11] and help to evaluate potential forest sustainability [12].

According to Fig. 4, the graph of distribution of trees by diameter class (N-DBH) in 2012 and 2015 is an inversed J-shape, so the observed data are inclined to be less than the average value. The number of trees is the highest at the diameter class of 10-20 cm (< 20 cm), accounting for about 60% of the total number of trees of each 1-ha sub-plot and the study site (6,780 trees measured in 2012 and 6,593 trees measured in 2017), the diameter class which has the lowest number of trees was > 90 cm in diameter. The larger the diameter is, the smaller the number of trees is. This



Fig. 4 Distribution of tree diameter class in 2012 and 2017.





Fig. 5 Distribution of tree height class in 2012 and 2017.

indicates that the density of smaller trees in a stand is sufficient to replace the current population of larger tree. According to Aye, et al. [13], tree density is generally higher in small DBH classes compared to large DBH classes, this is a secondary forest characteristic.

3.2.2 Distribution of Tree Height Class

The woody tree height is also an important indicators in forest classification. Primary tropical rainforest is vertically divided into at least five layers: the overstory, the canopy, the understory, the shrub layer and the forest floor. As for woody tree stratification, there are 03 layers, including the overstory (A1: 30-40 m), the canopy (A2: 20-30 m) and the understory (A3: 8-20 m) [14].

According to Fig. 5, the graph of distribution of trees by the height (N-H) is an inversed J-shape and the number of trees tends to decrease when the height class increased. In both surveys, the highest number of trees is at the height of < 20 m, respectively 8,402 out of 10,261 in 2012 and 8,189 out of 10,013 in 2017 were measured. In addition, the number of trees under 20 cm at the second measurement is lower than the first, thus ensuring the lower trees in a stand are sufficient to replace the



current population of higher tree.

3.3 Using Google Earth for Forest Management

3.3.1 Create Study Area Boundaries

Firstly, determine 4 points of the rectangular plot on GE (Google Earth) based on coordinates Long (X) and Lat (Y) as Table 2 using the Add Placemark (\checkmark) tool.

Then, use the Polygon (\bigcirc^+) tool to set the boundary of the study area from 4 identified points (see Fig. 6).

3.3.2 Create DEM and Contour Line Maps

A DEM (Digital Elevation Model) is a digital model or three dimensional (3D) representation of a terrain's surface created from elevation data. DEMs can be derived through a variety of techniques, such as digitizing contours from existing topographic maps, topographic levelling, EDM (Electronic Distance Measurement), differential GPS measurements, (digital) photogrammetry, Radar remote sensing (InSAR) and Light Detection and Ranging (LiDAR). Many derivate maps can be produced from DEMs using fairly simple GIS operations. These days a wide range of data sources can be selected for the generation of DEMs. The selection depends on the data availability for a

Table 2 Coordinates of Long (X) and Lat (Y) of 4 points of the rectangular plot.

Points	Long (X)	Lat (Y)
D1	108.686175°	12.172295°
D2	108.686175°	12.176795°
D3	108.688012°	12.176792°
D4	108.688012°	12.172292°





Fig. 6 Create study area points and boundaries.



Fig. 7 Create DEM and Contour maps.

specific area, the price and the application [15, 16]. Derivatives from DEMs can be used in heuristic analysis at small scales (e.g. hill-shading images for display as backdrop image, physiographic classification, internal relief, drainage density), in statistical analysis at regional scales (e.g. altitude zones, slope gradient, slope direction, contributing area, plan curvature, profile curvature, slope length), in physically-based modelling at local scales (local drain direction, flow path, slope gradient) and in spread modelling (detailed slope morphology, flow path) [17].

Global Mapper software helps create DEM and contour line maps from the boundaries of study area created on Google Earth to derive the characteristics of the terrain which can be applied to study the correlation relationship between the above topographic factors with species distribution, forest volume and carbon stocks in the study area (Fig. 7).

3.3.3 Forest Management

Characteristics and location of tree individuals measured in 2012 and 2017 are managed on Google Earth Pro. software in the following steps:

Step 1: Enter all measurement data into Excel (*: xls), calculate the diameter (DBH: cm), tree height (H: m), basal area (G: m²), tree volume (V: m³), latitude (Y) and longitude (X) coordinates (see Fig. 8);

Step 2: Save Excel file * xls to * kml or * csv to open on Google Earth Pro. (Fig. 9);

Step 3:

—Open Google Earth Pro. software: File \rightarrow Open \rightarrow Saved Folder \rightarrow the converted file O1-GE.csv (Fig. 10);

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2	1	1	1	2.015	7.979	01.0034	Adinandra micr	ocarpa	Hồng đạm quả nhỏ	Adimic	Adinandra	Theaceae	Chè	220	22.0	15.5	0.038	0.265	70	22.3	1
3	1	1	2	19.925	5.718	01.0344	Calophyllum de	ongnaiense	Công nước	Caldon	Calophyllum	Calophyllaceae	Công	306	30.6	18.0	0.074	0.599	98	31.2	1
4	1	1	4	9.344	9.946	01.0104	Craibiodendron	sp.	Cáp mộc	Crasp.	Craibiodendron	Ericaceae	Đố quyên	124	12.4	11.2	0.012	0.060	40	12.7	1
5	1	1	5	17.097	13.748	01.0340	Craibiodendron	sp.	Cáp mộc	Crasp.	Craibiodendron	Ericaceae	Đô quyên	231	23.1	15.9	0.042	0.301	77	24.5	1
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0		1	5	13.384	1.381	01.0235	Elaeocarpus fio	ribundus	Com noa nnieu	Elano	Elaeocarpus	Elaeocarpaceae	Lom	107	10.7	10.1	0.055	0.239	40	14.5	
10	1	1	6	1.222	14.1	01.0139	Diospuros latis	enala	Thi đài rông	Diolat	Diospuros	Fhenaceae	Thi	222	22.2	15.6	0.039	0.041	59.5	18.9	-
11	1	1	6	18 371	0.416	01 0373	Elaeocarrous flo	ribundus	Côm họa nhiều	Elaflo	Elaeocarpus	Elaeocarpaceae	Côm	203	20.3	14.9	0.032	0.215	71	22.6	
12	1	1	6	10,789	12.422	01.0280	Elaeocarpus flo	ribundus	Côm hoa nhiều	Elaflo	Elaeocarpus	Elaeocarpaceae	Côm	289	28.9	17.6	0.066	0.523	70	22.3	
13	1	1	6	2.362	19.225	01.0151	Elaeocarpus flo	ribundus	Côm hoa nhiều	Elaflo	Elaeocarpus	Elaeocarpaceae	Côm	640	64.0	23.1	0.322	3.347	66	21.0	

Fig. 8 Input data on Excel file.

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Fig. 10 Open Google Earth Pro. software.



Fig. 11 Change icons in properties.



(a) Tree distribution at the 1 ha subplots (S1)

(b) Tree distribution at the study site



(c) Characteristics of tree individuals

Fig. 12 Forest management on GE.

Contents	Example					
Subplot 1 ha	S1					
Code	01.3265					
Name	Polnha					
Latin name	Polyosma nhatrangensis					
Vietnamese name	Đa hương Nha Trang					
Genus	Polyosma					
Family	Escalloniaceae					
DBH_cm 2012	9.7					
H_m 2012	9.5					
$G_m^2 2012$	0.007					
DBH_cm 2017	12.4					
H_m 2017	11.2					
$G_m^2 2017$	0.012					
Tinh trang (Status)	Good					
Longitude (X)	108.686168°					
Latitute (Y)	12.1739°					

Table 3Information of tree individuals on GE.

-Change the icon of individual trees icon into tree images in Properties (Fig. 11);

Step 4: All data information was shown on GE for forest management (Fig. 12).

Information of tree individuals on GE is shown in Table 3.

Thus, the whole characteristics of the measured individual trees are fully represented on Google Earth for the management and inventory of natural resources and biodiversity scientifically, easily updated, accurately and effectively.

4. Conclusion

current years, facing climate In changes, environment pollutions, habitat loss and biodiveristy decline, the development of GIS technology has been the optimal solution for researchers, policy makers and government to find the causes of natural resources loss and establish solutions in adaption and mitigation of harmful environement changes. The results of this paper show that Google Earth software is one of the most effective GIS tools in planning biodiversity and conservation strategies natural resource management. In addition, further studies will be conducted to assess forest dynamics in relation to other factors of the ecosystem, find the cause and predict the future changes, thereby have plans and strategies in protection of natural resources and environment in general and forest in particular.

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