Vietnam Journal of Earth Sciences 36 (2014) 504-514

(VAST)

Vietnam Academy of Science and Technology

Vietnam Journal of Earth Sciences

Website: http://www.vjs.ac.vn/index.php/jse

Bioclimatic map of Tay Nguyen at scale 1:250,000 for setting up sustainable ecological economic models

Nguyen Khanh Van[1*], Pham Thi Ly[1], Nguyen Thi Hong[2]

[1]*Institute of Geography, Vietnam Academy of Science and Technology, Hanoi, Vietnam*

[2]*College of Education, Thai Nguyen University*

Received 15 November 2014

ABSTRACT

A study on development of a system for bioclimatic classification criteria and construction of a bioclimatic map of Tay Nguyen region at scale of 1/250,000 was conducted, based on statistical analysis of bioclimatic characteristics of Tay Nguyen, comparing with those of other regions of Vietnam. The system of classification criteria was developed based on 4 factors, namely: mean annual temperature (T_N), total annual rainfall (R_N), length of cold season (N) and length of dry season length (n). The thermal-humid indicators, featuring seasonal constraints (for tropical plants) as well as the thresholds for their division, were selected based on the ecological characteristics of vegetation and their role for the formulation, structure, appearance of the natural vegetation types of Tay Nguyen region. Results showed bioclimatic resources of Tay Nguyen territory is rich and diverse reflecting in 23 different bioclimatic units of a total of 57 separate polygons. That partly explains the diversity of vegetation types of Tay Nguyen. Study of bioclimatic classification has both a scientific and practical significance. Bioclimatic classification provides an important information for mapping ecological landscape of Tay Nguyen; A bioclimatic resource assessment of a specific territory is a necessary scientific basis for proposing the development orientation of economic sectors and establishment of sample sustainable economic models in Tay Nguyen territory.

Keywords: Bioclimatic classification, bioclimatic criteria, vegetation ecology.

1. Introduction

Climate is one of the essential factors determining the formation and development of natural vegetation (on genesis base), affecting classification and diversity of the landscape of a territory. To recommend the orientation of appropriate use for territory and sustainable ecological economic development, we need to establish the divided rule of natural landscapes and typical ecologies. From the perspective of ecological view, bioclimatology plays an important role as one of the factors in formation of the natural landscape. Monsoonal, humid tropical climatic regime associated with geographical location and topography have created diversified segmentation of bioclimatic conditions in different regions of our country. This report presents the findings of the study on climatic characteristics, construction of a bioclimatic map for Tay Nguyen, in order to assess its bioclimatic resources toward an establishment of ecological economic models, an appropriate agricultural and forestry production, plant layout, crop seasons in accordance with natural rules of the territory, contributing to environmental protection of the rich and beautiful Tay Nguyen territory.

2. Study area, methodology and databases

Tay Nguyen is a plateau to the west of Nam Truong Son mountain, with geographical

*Corresponding author, Email: ngkhvan@gmail.com

coordinates in the range of 11º12'N - 15º25'N; 107º12'E - 108º00'E.

Tay Nguyen has 5 provinces arranged from north to south including Kon Tum, Gia Lai, DakLak, DakNong and Lam Dong. Total area of Tay Nguyen is 54,474 km², accounted for 16.6% of the national area.

The following research methods were used in this study: Statistical methods in meteorological - climatological data processing; Climate classification method. General survey methodology; Fieldwork methods; Mapping and geographic information systems (GIS).

Database of bioclimatic map of Tay Nguyen at 1:250,000 scale includes yearly climate data of 15 meteorological stations, 12 hydrological stations and 29 rain gauge sites of 5 provinces of Tay Nguyen, topographic map at the scale of 1:250,000 (Characteristics of meteorological, hydrological stations and rain gauge sites in Tay Nguyen region are shown in Appendix 1).

3. Results and discussion

Bioclimatology is the interdisciplinary science of climatology and ecology, studying the effects of climate, weather on living organisms in the ecosystem/natural synthetic ecology (Nguyen Khanh Van, 2006). Bioclimatic researching is also studying the suitability of bioclimatic conditions for organisms in the ecosystems, improving the productivity of the crops and livestock in agro-forestry ecosystems. Thus, the concept of bioclimatic conditions of organisms in ecosystems or natural synthetic system is rather broad, this report just focused on investigating and classifying bioclimatic conditions of natural vegetation (based on the genetic source), for the establishment of ecological economic models, proposal of development orientation for sustainable agricultural and forestry production; and in some specific cases, sample plant layouts, crop seasons areproposed in accordance with the laws of nature, contributing to the protection of natural resources and environment inTay Nguyen.

3.1. Classification systems of bioclimate in Vietnam

Contributions to bioclimate classifications in Vietnam notably include the classification system of bioclimate by Vu Tu Lap (Vu Tu Lap, 2002) landscape research in Northern Vietnam; the system by Thai Van Trung is providing classification of forest vegetation in Vietnam (Thai Van Trung, 1978). Other works have found application in forestry (Lam Cong Dinh, 1992) and in studying tropical monsoon landscape of Vietnam (Nguyen Khanh Van et al., 1999).

Bioclimatic research has become increasingly useful in providing a scientific basis, proposing direction for a rational use of natural resources. To study bioclimate of different geographic regions in Vietnam, the authors in Institute of Geography have conducted the following projects: bioclimatic classification of Tay Nguyen (1987), bioclimatic classification of 9 mountainous provinces in Northern Viet Nam (1995), bioclimatic classification of Southeast (Viet Nam) region (1996), bioclimatic classification of the North-Central region (1997) (Nguyen Khanh Van et al., 1999). Bioclimatic characteristics used in the classification are: annual average temperature (T_N), totalannual rainfall (R_N), the length of the cold season (N), the length of the dry season (n) / or mean rainfall of dry period (for Tay Nguyen - 1987). Threshold values of these indexes depend on specific climate characteristics of each region as well as the ecological characteristics of the living organisms that are the subject of the study.

3.2. Criteria system of bioclimatic classification in Tay Nguyenat scale 1: 250,000

Based on experience from construction of bioclimatic maps for different regions and at different scales, in this report, criteria systems of bioclimatic classification in Tay Nguyen have been set up taking into account the following specific features of climatic conditions and vegetation ecology of the study area such as:

- Climate of Tay Nguyen is tropical monsoon climate of plateau with temperature change in accordance with the rule of elevations, large diurnal temperature amplitude, humidity conditions in a sharp contrast between two seasons - the rainy season and dry seasons.

- Connecting to the presence of vegetation in this territory, climatic conditions as quoted in (Thai Van Trung, 1978) showed that from low to

high altitudes of the region, the following natural vegetation types exist: : (i) The tropical evergreen closed forest (in Blao, Di Linh, DakLak, southwestern of Pleiku); (ii) The tropical deciduous closed forest (in Pleiku, DakLak); (iii) The tropical broad-leaved deciduous semiarid woodland forest (in Ea Sup, DakLak, Di Linh); (iv) The tropical coniferous (needle leaves) semiarid woodland forest (in DakLak); (v) The tropical coniferous semiarid woodland forest at low mountain (in Da Lat, DakLak, Di Linh); (vi) The tropical woodland, shrub, savanna (in Cheo Reo, Buon Ma Thuot), (vii) The tropical evergreen closed forest at low mountain (in Kon Tum, DakLak), (viii) The tropical mixing broadleaf and needle leaves forest at low mountain (in Ngoc Linh, Chu Yang Sin); (ix) The tropical coniferous closed forest at medium mountain (in Ngoc Linh, Chu Yang Sin).

Requirements of criteria selection for Tay Nguyen bioclimate are:

- Selected criteria must be representative, reflecting the nature and seasonal distribution characteristics (thermal and moisture) over space, time and altitude.

- Selected criteria must represent the nature of ecoclimate, reflecting the law of distribution, the growth and development of the natural vegetation types existed on the territory of study.

To assess the bioclimatic conditions of thestudy area, factors reflecting thermal - moisture basic conditions are selected such as: mean annual air temperature and total annual rainfall.

3.2.1. Thermal criteria system

Analysis of observed data at stations in Tay Nguyen showed that on the whole territory, surface temperatures ranging between 18 and 24°C are differentiated with space, latitude and elevation. In the lowlands, annual average temperatures fluctuate from 20°C to 23°C. In the mountainous areas, the higher altitude the lower temperature is, the longer the coldseason is in accordance with the laws that temperatures decrease with height.

- Mean annual temperature

Thermal resource in the territory is evaluated through mean annual air temperature of Tay Nguyen T_N, corresponding to the total accumulated temperature - a very valuable factor in agro-climatology research and widely used in planning for farming practice. Temperature $T_N$is classified into the following levels (Table 1):

Table 1. Classification of annual average temperature T_N

Sign, name	Temperature levels		Elevations		Characteristics of vegetation and plant
	T_N	Total temperature	North of Tay Nguyen	South of Tay Nguyen	
I- Very hot	$T_N > 24°C$	> 8,800°C	<200m	<300m	Tropical vegetation and plant with adequate heat
II- Hot	$22°C < T_N \leq 24°C$	8,000°C - 8,800°C	200-600m	300 - 700m	Tropical vegetation and plant with adequate heat
III- Warm	$20°C < T_N \leq 22°C$	7,300°C - 8,000°C	600-1,000m	700 - 1,100m	Tropical vegetation exist and may have some of temperature plant and sub-tropical plants
IV– Cool	$18°C < T_N \leq 20°C$	6,500- 7,300°C	1,000 - 1,400m	1,100-1,500m	Tropical vegetation exist. Sub-tropical plants and temperature plants are diverse in types
V- Cold	$T_N \leq 18°C$	<6500°C	>1,400m	> 1,500m	Tropical plants may exist but temperate plants are dominant, especially vegetables and flower plants of cold areas; the conifers are grown.

(I) Very hot, $T_N > 24°C$, equivalent to the total operating temperature more than 8,800°C. For Tay Nguyen, where the elevation is less than 200m in Ea Sup, Ban Don, Ayun Pa, Krong Pa, or less than 300m in Da Teh, both T_N and total operating temperatures satisfy conditions above. In overall, very hot temperature conditions are favorable for tropical plants to flourish.

(II) Hot, $22°C < T_N \leq 24°C$ equivalent to the total annual temperature from 8,000 - 8,800°C. The areas with elevations from 200 to 600m in North of Tay Nguyen and from 300 to 700m in South of Tay Nguyen are guaranteed with such conditions of heat. This thermal belt is very favorable for vegetation and tropical plants to grow all over the year.

(III) Warm, 20°C $<T_N \leq$ 22ºC, equivalent to the total annual temperature: 7,300-8,000ºC. The areas with height from 600-1,000 m in North of Tay Nguyen and from 700-1,100 m in South of Tay Nguyen. This thermal belt is favorable for the development of tropical plants and some plants of temperate or subtropical origin.

(IV) Cool, 18ºC $<T_N \leq$ 20°C, equivalent to the total annual temperature: 6,500-7,300ºC: Available in mountainous areas of Northern Kon Tum at elevation: 1,000-1,400 m. In South of Tay Nguyen, this temperature appears in mountainous region of Lam Dong and a part of DakLak with height: 1,100-1,500 m. Sub-tropical and temperate plants are more dominant than tropical plants in this temperature belt.

(V) Cold, $T_N \leq$ 18º C is equivalent to the total annual temperature below 6,500°C: Available in Kon Tum - the area around Ngoc Linh (with altitudes above 1,400 m); in Da Lat and mountainous region of northern Da Lat (with altitudes above 1,500m). Temperature conditions are suitable for the development of temperate plants, flowers and vegetables originated from cold areas and coniferous forest. Therefore, this region has become famous of cultivation and exportation of flowers and vegetables all over the country.

- Length of the cold season

The change in length of the cold season in a given region is closely related to its geographic location and altitude (Houérou H.N. et al., 1993). The length of the cold season is determined by the number of cold months with a monthly verage temperatures below 18ºC (Vu Tu Lap, 2002; Nguyen Khanh Van, 1993), sign "N". For Tay Nguyen, cold season length is divided into the following levels (Table 2):

Table 2. Classification of cold season length

Sign	Name	Number of coldmonths(N)	Altitude
0	No cold season	0	< 600-700m
1	Short cold season	1	600/700-1000/1100m
2	Average cold season	2-3	1000/1100m-1400/1500m
3	Long cold season	≥ 4	> 1400/1500m

The data on annual average temperature, the number of cold months of stations in Tay Nguyen are presented in Appendix 2.

3.2.2. Criteria system of humid regime

It is believed that temperature affects the distribution of plant species, while wet - dry condition affects the appearance, shaping and status of vegetation (Legris P. et al., 1989; Nguyen Khanh Van, 2006). Thai Van Trung studied the genetic ecology of forest vegetation in Vietnam proved that dry-wet mode is a dominant factor, determining the formation of climate types of primitive natural vegetation in a large area in monsoon tropical climate, such as Vietnam.

Among the climatic - hydrological factors forming genetic vegetation, wet-dry regime in this study is described as a complex combination consisting of the total of annual rainfall and the number of dry month.

- Criteria of rainfall

As an indicator of the humid potential supply for an area, rainfall-humidity indicator was chosen as the totalannual rainfall (R_N). By studying the rainfall regime throughout the territory in relation to natural genetic vegetation (Legris et al., 1989; Thai Van Trung, 1978; Nguyen Khanh Van, 1993) suggests the following levels of the total annual rainfall inTay Nguyen:

(A) Excessive rain, $R_N >$ 2,500mm, indicating excess moisture conditions, to ensure dense evergreen forests with broadleaf trees exist in any circumstances.

(B) Abundant rain, 2,000mm $<R_N \leq$ 2,500mm, enough moisture, corresponding to the existence of closed evergreen vegetation.

(C) Moderate rain, 1,500mm $<R_N \leq$ 2,000 mm, corresponding to evergreen or semi-deciduous forests (depending on dry season).

(D) Little rain, 1200mm $<R_N \leq$ 1500mm, corresponding to the type of vegetation in dry deciduous forests.

(E) Very little rain, $R_N \leq$ 1,200mm, corresponding to dry deciduous forest and scrub.

- Criteria of dry season length

Looking at the distribution of total yearly rainfall in a territory, the number of dry months has a great influence on the structure, external appearance of the vegetation (dry month is the month with total of rainfall ≤ 50 mm (Houérou et

al.,1993; Vu Tu Lap, 2002; Thai Van Trung, 1978), so beside the total annual rainfall, rainy-humid criteria, the number of dry months is added as an indicator for climate constraints to plant species in particular or tropical vegetation in general.

Based on the results of studies (Nguyen DucNgu, 1988; Thai Van Trung, 1978; Nguyen Khanh Van, 1993) the dryness in Tay Nguyen is divided into the following levels (Table 3):

Table 3. Classification of dry season length

Sign	Name	Number of dry months (n)	Present of vegetation
a	Short dry season	a ≤ 2 months	Type of tropical rain forest, closed evergreen forest with broad leaves.
b	Medium dry season	n = 3–4 months	Type of rain season evergreen closed forest or type of mid-decidous forest depend on total annual rainfall and ability of maintaining water of the ground
c	Long dry season	n≥ 5 months	Type of mid- deciduous broad leaves sparse forest or deciduous broad leaves sparse forest in dry season.

The data on annual average rainfall, the number of dry, arid and desert dry months of stations in Tay Nguyen are presented in Appendix 3.

3.3. Building bioclimatic map of Tay Nguyen, scale 1:250,000

Criteria system of bioclimatic division in study area is shown in matrix Table 4. Based on analysis, overlaying the information of selected bioclimatic factors (T_N, R_N, N, n), the bioclimatic map of TayNguyen was built (Fig.1).

- Bioclimaticunits of Tay Nguyen

There are 23 bioclimatic units in the bioclimatic map of Tay Nguyen, scale 1: 250,000 in which bioclimatic unit IIIC1b appears the most with 11 times, VA3a appears 5 times, IIIB1a appears 4 times; and 5 types of bio-climate No 12, 14, 17, 22, 23 appear 3 times; some units of bio-climate appear 2 times and up to 8 units of bio-climate appear only once (Table 5).

From the above mentioned bioclimatic units, the unit of IIC0b occupies the largest area of 17, 260 km^2, equivalent to 31.5% of the whole region; the second largest area equivalents to unit of IIIC1b with 5,667.8 km^2 (accounting for 10.3%) and the unit has the smallest area is VB3a with 92.2 km^2 (accounting for only 0.2%).

Table 4. Legend system of bioclimatic map of Tay Nguyen, scale 1:250.000

Humid regime / Thermal regime	Total of annual rainfall	A: Excessive rain (Rn ≥2.500)		B: Abundant rain (2.000 ≤ Rn<2.500)		C: Moderate rain (1.500 ≤ Rn<2.000)		D: Little rain (1.200 ≤ Rn<1.500)		E: Very little rain (Rn<1.200)
Average annual temperature	Dry season / Cold season	a. Short dry season (n ≤ 2)	b. Average dry season (3 ≤n ≤4)	a. Short dry season (n ≤2)	b. Average dry season (3 ≤n ≤4)	b. Average dry season (3 ≤ n ≤4)	c. Long dry season (n ≥5)	b. Average dry season (3 ≤ n ≤ 4)	c. Long dry season (n ≥5)	b. Average dry season (3 ≤ n ≤4)
V. Cold climate (Tn ≤18 °C)	3. Average cold period ≤ (4 months)			VBAc(3)	VB3a(3)					
IV. Cool climate (18<Tn ≤20 °C)	2. Short cold period ngắn (2-3 months)			IVB2a(1)	IVB2a(2)	IVC2a(2)				
III. Warm climate (20<Tn ≤22 °C)	1. Very short cold period ngắn (2-3 months)			IIIB1a(4)	IIIB1b(3)	IIIB1c(11)		IIID1b(2)		
II. Hot climate (22<Tn ≤24 °C)	0. No period of cold			IIB0a(1)	IIB0a(2)	IIC0b(2)		IID0b(2)	IID0c(1)	
I. Very hot climate (Tn>24 °C)	0. No period of cold						IIC0c(1)	IID0c(1)	IID0c(1)	IID0c(1)

Note: (*) The number of occurances of bioclimatic units

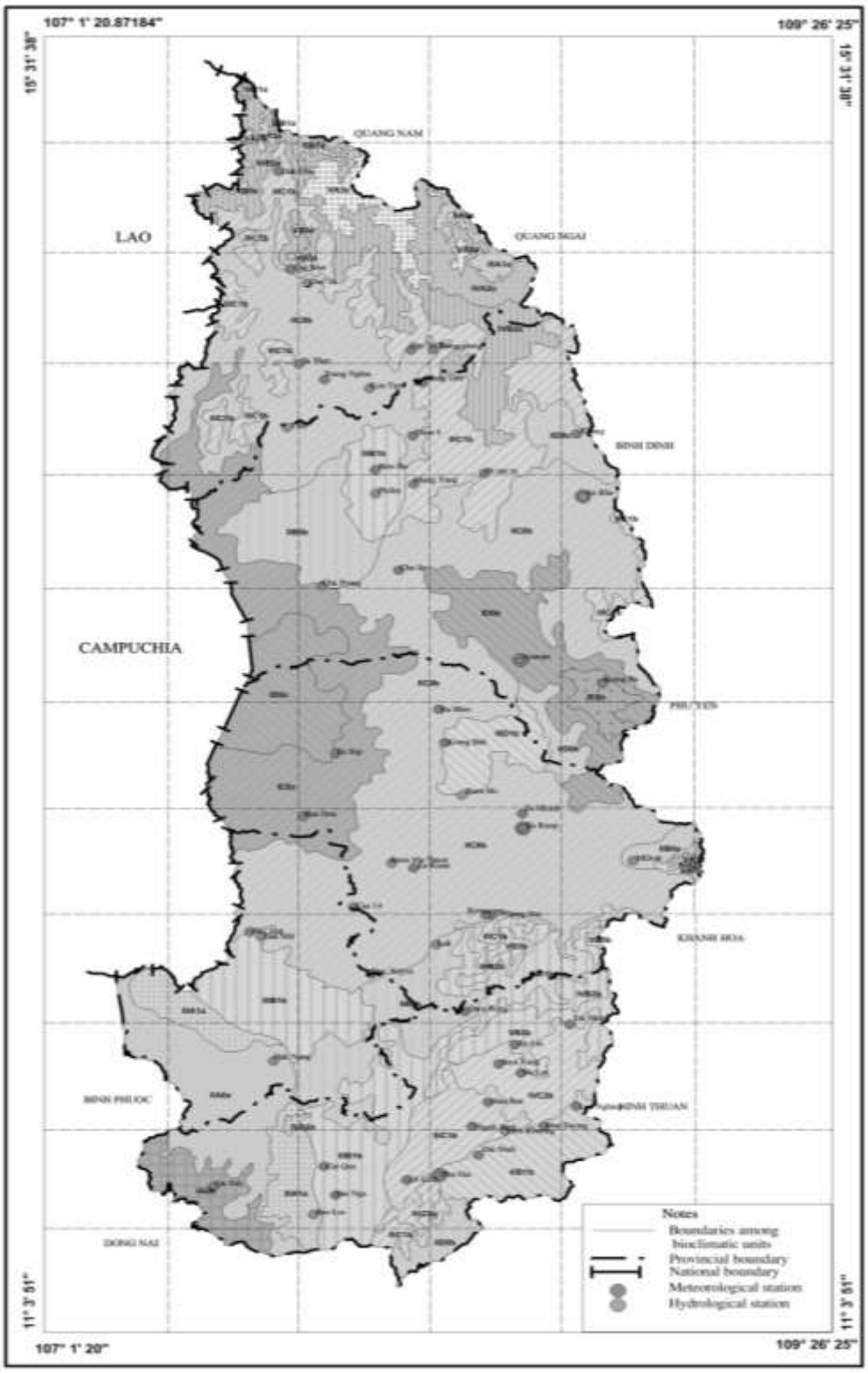

Figure 1. Bioclimatic map of Tay Nguyen, at scale 1:250,000

Description of the differentiation of bioclimatic units in Tay Nguyen territory was conducted from low lands to hills and mountains; from unit of the driest bio-climate to the wettest bio-climate, in the following order:

1. IE0b: Very hot bioclimate, no cold period, very little rain (below 1,200mm/year), average dry season, appearing in Krong Pa district of Gia Lai province with a small area (33.8km^2).

2. ID0c: Very hot bioclimate, no cold period, little rain, long dry season appearing only once in the area of Ea Sup district, DakLak province.

3. ID0b: Very hot bioclimate, no cold period, little rain and average dry season. This type occurs in the eastern province of Gia Lai and a small part in DakLak province.

4. IC0c: Very hot bioclimate, no cold period, moderate rain and long dry season. This type occurs only once in the west of Tay Nguyen with elevations below 300 m stretching from several districts of Kon Tum province through Gia Lai, DakLak and expanding to a small part of DakNong province.

5. IA0b: Very hot bioclimate, no cold period, excessive rain and average dry season. This type happens only once in Da Teh district of Lam Dong province.

6. IID0c: Hot bioclimate, no cold period, little rain, long dry season appearing only once with a relatively small area in Kbang district, Gia Lai province.

7. IID0b: Hot bioclimate, no period of cold, little rain and average dry season appearing twice with a small area of Krong Pa district, Gia Lai province and south of Di Linh district, Lam Dong province.

8. IIC0b: Hot bioclimate, no cold period, moderate rain, average dry season. This type only appears twice but occupies the largest area of 17, 260 m^2, accounting for 31.5% of Tay Nguyen area. It appears in the district of southwest Kon Tum province such as Sa Thay district, Kon Tum town, Dak Ha district, Dak To district,Ngoc Hoi district, some districts of Northern Gia Lai such as An Khe and Chu Se, occupying most of DakLak province and a part of DakNong province.

9. IIB0b: Hot bioclimate, no cold period, abundant rain and average dry season: Appeared twice in Duc Co and IaGrai district, Gia Lai province and in the bordering area of three provinces of DakLak, DakNong and Lam Dong.

10. IIB0a: Hot bioclimate, no cold period, abundant rain, short dry season. This type appeared once in M'Drak district, DakLak province.

11. IIA0a: Hot bioclimate, no cold period, excessive rain, short dry season. It is available twice in the height from 200/300 to 600/700 m, with a large area in DakR'Lap district, DakNong province and a part in the Bao Lam, Cat Tien districts, Lam Dong province; and a very small area in the eastern Kong Plong district, Kon Tum province.

12. IIID1b: Hot bioclimate, short cold period, little rain and average dry season. This type appears in KrongBuk district, DakLak province and Don Duong and Duc Trong districts, Lam Dong province.

13. IIIC1b: Warm bioclimate, short cold period, medium rain and average dry seasons. This type appears in the territory the most with 11 times, scattered in some districts of Kon Tum province such as Ngoc Hoi, DakGley, Dak Ha, Kon Ray, expanding down to Chu Pah, DakDoa, Mang Yang, Kbang, a part of Kong Chro, Ia Pa district, Gia Lai province and Di Linh district, Lam Dong province. The area of this type is the second largest, after type of IIC0b.

14. IIIB1a: Warm bioclimate, short cold period, abundant rain and short dry season. This type appears 4 times in which 3 times in the north of DakGley district, Kon Tum province and one time in the M'Drak district, DakLak province.

15. IIIB1b: Warm bioclimate, short cold period, abundant rain and average dry season: Appeared 3 times in the Bien Ho area, Gia Lai province, in Dak Song district, DakNong province and a part of Di Linh, Bao Lam district, Lam Dong province.

16. IIIA1a: Warm bioclimate, excessive rain, short cold period and short dry season. On the map, this type appears 3 times in Kong Plong

district, Kon Tum province; in DakR'lap district, DakNong province and in BaoLoc, Bao Lam district, Lam Dong province.

17. IVC2b: Cool bioclimate, average cold period, little rain and average dry season: Appeared twice in the southern Tay Nguyen, in the areas of Da Lat and Di Linh of Lam Dong province.

18. IVB2b: Cool bioclimate, average cold period, abundant rain and average dry season. This type appears twice in Lak, Krong Bong of DakLak province and in Lac Duong of Lam Dong province.

19. IVB2a: Cool bioclimate, average cold period, abundant rain and short dry season. This type appears only once at the altitude belt between 11000 and 1400 m surrounding Nam Truong Son range in the Kon Tum - Gia Lai region.

20. IVA2a: Cool bioclimate, average period of cold, excessive rain and short dry season. This type appears 3 times in Kong Plong, Kon Tum province, Bao Lam, Lam Dong province and in the M'Drak district, DakLak province.

21. VB3b: Cold bioclimate, long period of cold, abundant rain and average dry season. This type appears 3 times in Krong Bong and M'Drak, DakLak province and in the area of Da Lat of Lam Dong province.

22. VB3a: Cold bioclimate, long period of cold, abundant rain and short dry season. This type appears 3 times in the altitude of more than 1400m in some peaks of Kon Tum province. This bioclimatic type occupies the smallest area of Tay Nguyen.

23. VA3a: Cold bioclimate, long cold period, excessive rain and short dry season appearing 5 times, mainly in peaks with altitude of more than 1400 m in DakGley, Dak To and Kong Plong of Kon Tum province and M'Drak of DakLak province.

Based on the bioclimatic characteristics of the vegetation types in Tay Nguyen, it is possible to group bioclimatic units with close characteristics of thermal-humid conditions and seasonal constraints into bioclimatic types, corresponding to 9 vegetation types listed in section 2.2 of this report.

Table 5. Statistic area and times of appearance of bioclimatic units in Tay Nguyen

Source: Summaried from GIS

Order	Bioclimatic unit	Area		Times of appearance
		Km^2	%	
1	IE0b	363.8	0.7	1
2	ID0c	1,543.0	2.8	1
3	ID0b	2,121.0	3.9	1
4	IC0c	4,397.0	8.0	1
5	IA0b	823.2	1.5	1
6	IID0c	519.3	0.9	1
7	IID0b	731.0	1.3	2
8	IIC0b	17,260.0	31.5	2
9	IIB0b	3,164.0	5.8	2
10	IIB0a	224.5	0.4	1
11	IIA0a	2,390.4	4.4	2
12	IIID1b	2,014.1	3.7	2
13	IIIC1b	5,667.8	10.3	11
14	IIIB1b	4,820.6	8.8	3
15	IIIB1a	157.7	0.3	4
16	IIIA1a	1,484.4	2.7	3
17	IVC2b	1,230.9	2.2	2
18	IVB2b	763.8	1.4	2
19	IVB2a	2,613.0	4.8	1
20	IVA2a	854.5	1.6	3
21	VB3b	825.5	1.5	3
22	VB3a	92.2	0.2	3
23	VA3a	747.1	1.4	5
Sum	23 units	54,808.8	100,0	57 polygons

4. Conclusions

Overall, results of the study of Tay Nguyen bioclimatic classification show that the regional bioclimatic resources are very rich, corresponding to the diversity of vegetation types from tropical, subtropical to temperate plant species (by elevation) and from tropical evergreen seasonal closed forests to semi-deciduous forests and deciduous forests in dry season of Tay Nguyen.

In particular, in plateaus with the altitude of more than 1,500 meters such as Da Lat, Lam Vien plateau, or Di Linh plateau, some species of vegetables, flowers of temperate zone origin (cold climate) can grow well; these areas are also known for coniferous woodlands, similarly as they are in temperate latitudes. With this natural privilege, Tay Nguyen has a solid premise to develop many sustainable ecological economic models in an abundant and diverse agriculture and forestry, potentially bringing high economic benefits to Tay Nguyen.

This study is a part of project: "Research, valuation of synthetic source of nature, fluctuation in resource using and the establishment some sustainable economic models for major geographical areas of Tay Nguyen region" (code TN3/T03) funded by the 3rd Tay Nguyen program, to whom the authors extend their thanks and appreciation.

References

Lam Cong Dinh, 1992: Bioclimatic applications in forestry in Vietnam. Science and Technology Publishing House, Hanoi.

Houérou, H.N., Popov, G.F., See, L., 1993: Agrobioclimatic Classification of Africa (Working paper) - FAO Agrometeorogy Series, N° 6. 227 pp.

Vu Tu Lap, 2002: Vietnam natural geography.Education Publishing House, Hanoi.

Legris, P., Blasco, F., 1989: Classification and mapping of vegetation types in tropical Asia (Reviewed by K.D. Singh) - FAO of the United Nations, Rome. 135 pp.

Nguyen Duc Ngu, 1988: Climate of Tay Nguyen. Monographs of 2ndTay Nguyen Program. Vietnam Academy of Science and Technology.

Thai Van Trung, 1978: Eco-genesis and classification of forest vegetation of Vietnam (From ecosystem perspective), Second edition, with correction, Science and Techniques Publishing House, Ha Noi. 276 pp. (In Vietnamese, Resume in French, Summary in English, Russian and Spanish).

Nguyen Khanh Van, 1993: Bioclimatic Typology of Vietnam - Journal Izvestia, Geographical Series, Russian Academy of Sciences, Moscow (6) pp. 114-123 (in Russian: НгуенКханьВан 1993: ТипологиябиоклиматовВьетнама. Известия,СерияГеографическая, РоссийскаяАкадемияНаук, Москва).

Nguyen Khanh Van, 2006: Bioclimatic basis (Master curriculum), Hanoi Pedagogical University Publishing House of.

Nguyen Khanh Van, Nguyen Thi Hien, 1999: The available methods of bioclimatic classification in Vietnam. Vietnam Journal of Earth Sciences No. 2, Academy of Science and Technology of Vietnam, Hanoi.

Appendix 1

Technical specifications of meteorological, hydrological stations and rain gauges in Tay Nguyen

N	Name of stations	Longitude	Latitude	Elevation (m)	types of stations
I	KON TUM				
1	ĐakGlei	107˚44	15˚05		Rain gauge site
2	Đak Mot	107˚46	14˚45		Hydrological station
3	*Đak To*	*107˚49′*	*14˚42′*	*620*	*Meteorological station*
4	Pe Me Re	108^{0}08	14˚28		Hydrological station
5	Kong Plong	108˚12	14˚28		Hydrological station
6	Sa Thay	107˚47	14˚25		Rain gauge site
7	TrungNghia	107˚52	14˚22		Rain gauge site
8	Mang Den	108˚10	14˚21		Rain gauge site
9	*Kon Tum*	*107˚37*	*14˚20*	*538*	*Meteorological station*
II	GIA LAI				
10	*Yaly*	*107˚45*	*14˚12*	*547*	*Meteorological station*
11	Thon 4	108˚08	14˚10		Rain gauge site
12	Kbang	108˚38	14˚10		Rain gauge site
13	Bien Ho	108˚01	14˚03		Rain gauge site
14	Po Me Re	108˚21	14˚02		Hydrological station
15	Mang Yang	108˚08	14˚00		Rain gauge site
16	*Pleiku*	*108˚01*	*13˚58*	*779*	*Meteorological station*
17	*An Khe*	*108˚39*	*13˚57*	*422*	*Meteorological station*
18	Chu Se	108˚05	13˚42		Rain gauge site
19	Chu Prong	107˚51	13˚39		Rain gauge site
20	*Auyun Pa*	*108˚27*	*13˚23*	*160*	*Meteorological station*
21	Krong Pa	108˚42	13˚18		Rain gauge site
III	ĐAK LAK				
22	EaH'leo	108˚12	13˚13	614	Rain gauge site

N	Name of stations	Longitude	Latitude	Elevation (m)	types of stations
23	KrongBuk	108˚13	13˚06		Rain gauge site
24	Ea Sup	107˚53	13˚04		Rain gauge site
25	*Buon Ho*	*108˚16*	*12˚55*	*707*	*Meteorological station*
26	Ban Don	107˚47	12˚51		Hydrological station
27	EaH'Dinh	108˚27	12˚51		Rain gauge site
28	EaKNop	108˚27	12˚48		Rain gauge site
29	*Buon Ma Thuot*	*108˚03*	*12˚41*	*470*	*Meteorological station*
30	*M'Drak*	*108˚47*	*12˚41*	*419*	*Meteorological station*
32	*EaKmat*	*108˚07*	*12˚40*	*516*	Rain gauge site
31	KrongKmar	108˚20	12˚30		Rain gauge site
33	GiangSơn	108˚21	12˚30		Hydrological station
34	*Lak*	*108˚11*	*12˚24*	*423*	*Meteorological station*
IV	ĐAK NONG				
35	Cau 14	107˚56	12˚32		Hydrological station
36	Duc Lap	107˚37	12˚27		Rain gauge site
37	*Đak Mil*	*107˚39*	*12˚26*	*760*	*Meteorological station*
38	ĐucXuyen	107˚59	12˚18		Hydrological station
39	*ĐacNong*	*107˚41*	*12˚00*	*631*	*Meteorological station*
V	LAM ĐONG				
40	ĐamRong	108˚16	12˚10		Rain gauge site
41	ĐaNhim	108˚35	12˚07		Rain gauge sitent
42	XaLat	108˚25	12˚03		Rain gauge site
43	SuoiVang	108˚22	11˚59		Rain gauge site
44	*ĐaLat*	*108˚26*	*11˚57*	*1509*	*Meteorological station*
45	Nam Ban	108˚20	11˚51		Rain gauge site
46	Lac Nghiep	108˚36	11˚50		Rain gauge site
47	ThanhBinh	108˚17	11˚46		Hydrological station
48	Đon Duong	108˚30	11˚46		Rain gauge site
49	*Lien Khuong*	*108˚23*	*11˚45*	*957*	*Meteorological station*
50	ĐaiNinh	108˚18	11˚40		Hydrological station
51	Cat Que	107˚50	11˚38		Rain gauge site
52	PhuGia	108˚11	11˚36		Rain gauge site
53	Di Linh	108˚05	11˚35		Rain gauge site
54	DạTeh	107˚30	11˚34		Rain gauge site
55	ĐaiNga	107˚52	11˚32		Hydrological station
56	*BaoLoc*	*107˚48*	*11˚28*	*840*	*Meteorological station*

Appendix 2

Monthly, Yearly average temperatures and the number of cold months in Tay Nguyen

Stations	1	2	3	4	5	6	7	8	9	10	11	12	Year	Cold months
Dak To	19.1	21.0	23.1	24.4	24.5	24.0	23.5	23.2	22.9	22.0	21.0	19.4	22.3	0
Kom Tum	20.8	22.6	24.6	25.8	25.4	24.9	24.4	24.2	24.0	23.5	22.3	20.9	23.7	0
Pleiku	19.1	20.7	22.7	24.1	24.0	23.1	22.4	22.3	22.3	21.8	20.8	19.3	21.9	0
An Khe	19.8	21.2	23.7	25.3	25.7	26.4	25.8	25	24.6	23.1	21.2	20.6	23.6	0
Ayun Pa	23.1	22.7	25.3	28.3	27.8	28.3	27.5	27.1	26.3	26.0	24.3	22.7	25.8	0
Buon Ho	20.2	22.8	23.5	25.4	25.9	24.9	23.8	23.3	23.5	22.5	20.8	19.4	22.0	0
Buon Ma Thuot	20.4	22.2	22.5	24.9	25.9	24.8	24.5	24.7	23.9	23.8	23.2	20.8	23.8	0
M'Drak	20.3	21.6	23.7	25.6	26.2	26.2	25.9	25.7	24.9	23.6	22.1	20.6	23.9	0
DakNong	20.4	21.7	23.2	24.1	24.1	23.4	23.0	22.8	23.0	22.7	22.1	20.7	22.6	0
Da Lat	16.2	17.1	18.1	19.1	19.6	19.3	18.8	18.7	18.7	18.3	17.5	16.5	18.0	4
Lien Khuong	19.6	20.4	21.6	22.7	22.8	22.3	21.9	21.7	21.6	21.1	20.6	19.7	21.3	0
BaoLoc	19.4	22.3	22.8	23.4	23.2	23.3	22.4	23.3	21.9	22.5	22.1	21.4	22.0	0

Appendix 3

The totalannual rainfall and numbers of dry, arid and desert dry months[1] in Tay Nguyen

N	Stations	Total annual rainfall (mm)	Number of rainy months	Number of dry months	Number of arid months	Number of desert dry months
I	KON TUM					
1	ĐakGlei	1694.0	6	3	3	1
2	Đak Mot	1879.6	6	4	3	1
3	*ĐacTô*	*1875.5*	*6*	*4*	*3*	*1*
4	Pe Me Re	1291.8	6	4	3	2
5	Kong Plong	1385.0	6	4	3	2
6	Sa Thay	1802.6	6	5	3	3
7	TrungNghia	1746.4	7	5	3	1
8	Mang Den	1701.9	7	4	2	1
9	*Kon Tum*	*1806.5*	*6*	*4*	*3*	*1*
II	GIA LAI					
10	*Yaly*	*1793.7*	*6*	*5*	*3*	*1*
11	Thon 4	2001.4	7	4	3	2
12	Kbang	1388.8	6	3	3	1
13	Bien Ho	2032.3	6	4	3	1
14	Po Me Re	1567.7	6	4	4	3
15	Mang Yang	1835.4	7	4	3	2
16	*Pleiku*	*2247.8*	*6*	*4*	*3*	*1*
17	*An Khe*	*1552.2*	*8*	*3*	*3*	*0*
18	Chu Se	1740.4	6	4	4	2
19	Chu Prong	2325.7	6	4	4	2
20	*Auyun Pa*	*1298.0*	*7*	*4*	*4*	*2*
21	Krong Pa	1177.1	6	5	3	2
III	ĐAK LAK					
22	EaH'leo	1800.7	6	4	4	2
23	KrongBuk	1444.7	7	3	3	0
24	Ea Sup	1549.1	6	4	4	3
25	*Buon Ho*	*1550.3*	*7*	*4*	*3*	*1*
26	Ban Don	1627.5	6	4	3	2
27	EaH'Dinh	1859.2	7	4	4	1
28	Ea Knop	1597.5	8	3	3	1
29	*Buon Ma Thuot*	*1814.8*	*6*	*4*	*3*	*2*
30	*M'Drak*	*2258.2*	*8*	*2*	*0*	*0*
32	*EaKmat*	*1943.2*	*7*	*4*	*3*	*1*
31	KrongKmar	1873.1	8	4	3	2
33	GiangSơn	1895.2	8	3	2	0
34	*Lak*	*2029.1*	*7*	*4*	*3*	*2*
IV	ĐAK NONG					
35	Cau 14	1708.7	6	4	3	2
36	Duc Lap	1788.1	7	4	3	1
37	*Đak Mil*	*1796.8*	*7*	*4*	*3*	*0*
38	ĐucXuyen	1914.6	7	4	3	1
39	*ĐacNong*	*2563.6*	*8*	*3*	*2*	*0*
V	LAM ĐONG					
40	ĐamRong	2010.8	8	4	3	1
41	ĐaNhim	1584.9	8	2	2	0
42	XaLat	2013.7	8	3	1	0
43	SuoiVang	1865.3	8	3	2	0
44	*ĐaLat*	*1865.0*	*7*	*3*	*2*	*0*
45	Nam Ban	1689.4	7	3	3	0
46	Lac Nghiep	1344.9	7	4	3	2
47	ThanhBinh	1581.9	7	3	3	1
48	Đon Duong	1397.8	6	4	2	2
49	*Lien Khuong*	*1567.8*	*7*	*3*	*3*	*1*
50	ĐaiNinh	1331.2	6	4	3	0
51	Cat Que	2461.8	8	3	3	0
52	PhuGia	1322.2	6	4	3	2
53	Di Linh	1644.4	7	4	2	0
54	DạTeh	3126.8	8	3	2	0
55	ĐaiNga	2206.8	8	2	0	0
56	*BaoLoc*	*2815.3*	*9*	*0*	*0*	*0*

[1]Dry month - a month, in which totalmonthly rainfall r (mm)equal or twice lower than monthly average temperature t (°C): $r \leq 2t$; *Arid month*: $r \leq t$; *Desert dry month:* $r \approx 0$. According to Thai Van Trung, 1978 (6) in tropic region such as Vietnam, the dry month, arid month and desert dry month have total monthly rainfall approximately 50mm, 25mm and 5mm, respectively.