QUANTITATIVE DETERMINATION OF THE MAIN ECOLOGICAL INDICATORS, USED IN DETERMNING QUALITY OF MOUNTAIN AND PRE-MOUNTAIN EUROPEAN BEECH FOREST SITES, SITUATED ON EUTRIC CAMBISOLS FROM BARAOLT AND BODOC MOUNTAINS

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Abstract: *Based on field observations and laboratory analyzes performed on 10 soil profiles of the type eutric cambisol were determined the main ecological indicators which determine forest site quality of mountain and pre-mountain European beech stand from Bodoc and Baraolt Mountains. Is found that the edaphic volume and soil trophicity are the main ecological indicators which condition forest site quality.*

Key words: *forest site, trophicity, site quality.*

INTRODUCTION

The production and productivity of the forest ecosystems is determined both by the composition and structure of the biocenosis, and by the favourableness degree of the forest site, as well as by the extent to which the forest site, by its ecological specificity, is capable of fulfilling the ecological and functional exigencies of the forest species. The tree and stand growth has, beside its biological character, also an ecological character, as it depends on the climatic, edaphic and physical-geographical factors (BĂCĂINȚAN AND KOVÁCS, 1976).

As a result of its ecological specificity, each forest site is characterized by its own capacity to sustain a certain phytocoenosis. The concentration degree of the ecological factors imprints on the forest sites, a certain productive potential or quality (SPÂRCHEZ *et al*., 2013). The reflection of the forest site quality, in the case of the non-degraded stands, is expressed by the stand class (ROȘU AND LĂCĂU, 1997).

Given the aforementioned, it follows that, in general, for each forest-site subclass, the site quality is mainly determined by the local climatic conditions and by the edaphic conditions, that is, by the soil type, subtype and variety, as well as by the edaphic volume, which condition the trophicity, the water supply capacity and the prevailing summer humidity.

With a view to increasing the site quality, two methods can be resorted to: the former is the deductive method (CHIRIȚĂ, 1977) which is based on determining the main ecological factors and fitting them into size classes, as well as on determining the favourableness of each factor for the considered species, and, eventually, on ascertaining the site quality; and the latter is the

inductive method which dwells on quantifying the ecological factors, in various subclasses of forest resorts, occupied by the non-degraded natural stands, and on alternately using the value of these ecological indicators, in order to ascertain the site quality, when the stand is either absent, or degraded, for various reasons. (Roşu, 1983).

In this paper, was resorted to the deductive method, that is, was identified some non-degraded stands, situated in various local climates, on eutric cambisols; likewise, a series of characteristic ecological indicators were quantitatively determined, for each quality category.

PURPOSE AND PLACE OF THE RESEARCHES

The purpose of the conducted researches is fitting the types of mountain and pre-mountain European beech forest sites, into quality categories, depending on the values of the ecological factors.

The place of the researches is represented by the mountain and pre-mountain European beech forest sites, situated in Baraolt and Bodoc Mountains, part of the Curvature Carpathians. The Mountains Baraolt and Bodoc are situated in the South-Western part of the Eastern Carpathians, within the great curvature of the Carpathians (xxx, 1987). The geological structure is mostly represented by marl-sandstone and conglomerate-sandstone flysch; and, in the Northern part, some volcanogenic-sedimentary formations also appear. In terms of altitude, they are low mountains; the altitude ranging between 800 and 1216 m (Henter Peak) in Bodoc Mountains, and between 700 and 1019 m (Havad Peak) in Baraolt; the dominant relief units being the slopes, the interfluve, as well as the relatively deep and short valleys (Băcăinţan, 1999). In terms of climate, the two mountain massifs fall into the climatic province Dfbx (D – boreal climate with wet and cold winters, with stable layer of snow, during wintertime; f – with sufficient rainfall, throughout the year; b – with the warmest month's temperature, below 22°C; yet, at least four months a year, over 10°C; x – the pluviometric maximum is recorded in early summer; while the pluviometric minimum, towards late winter) (xxx, 2007; xxx, 2008). The average annual temperatures range between 4°C on the peaks and 6-7°C upon contact with Braşov Depression. The average annual rainfall ranges from 850 mm in the uplands, to 650 mm upon contact with the depression.

The solification factors, represented by the parental material, to wit relief, climate and vegetation, favoured some characteristic pedogenesis processes. Thus, in the pre-mountain climate, the slight depletion of bases and argilization processes prevail, resulting in the formation of eutric cambisols and preluvosols, when an clay-eluviation process occurs. On hills, flat land or in depression, the eluviation process is more intense, favouring the formation of the luvisols. At higher altitudes, on acid sublayers and forest vegetation, mostly represented by coniferous species, dystric cambisols are formed. The soil statistics, based on the data in the forest management plans,

are as follows: 30% eutric cambisols, 26% luvisols, 24% dystric cambisols, 12% preluvosols, 3% rendzinas and 5% other soils.

MATERIAL AND METHODS

The research material consisted in the mountain and pre-mountain European beech forest sites, in Barolt and Bodoc Mountains, which cover a total surface of 8528 ha. To this end, 35 research areas were placed, each with an area of 1000 m^2 in compartments, which mostly consist in European beech, aged of over 80 years, naturally grown and regenerated from seed. In every research areas, all trees were inventoried, by measuring or determining the following biometric elements: the diameter at 1,3 m, the height, the age, the quality class, as well as Kraft class. On every area, a soil profile was placed, which was morphologically analyzed and wherefrom soil samples were collected, for analyses.

For this paper, 11 soil profiles belonging to the type eutric cambisol (4 underwoods of the 1st and 2nd production class, 3 underwoods of the 3rd production class, and 4 underwoods of the 4th and 5th production class) were analyzed. By laboratory analyses, the following physical and chemical indices of the soils were determined: the humus content, the nitrogen content, the adsorptive-complex indices (sum of exchangeable bases - Sb, total exchangeable hydrogen-Sh, total cationic exchange capacity - T, degree of base saturation - V), the reaction of the soil, the accessible phosphorus, the accessible potassium, the soil texture, the apparent density.

RESULTS AND DICUSSIONS

The main characteristics of the stands were determined after having processed the biometric data resulted from the total inventorying of the trees in the experimental areas; and they are shown in table 1.

Table 1

Main biometric characteristics of the stands in the research areas

FD,PU, c	Species	T (years)	Dgm (cm)	Hgm (m)	P.CL.	N/ha (units)	G (m^2)	V/ha (m^3)
Stands of superior productivity								
Tăliș, V Belin, 12 A	10FA	85	26,4	23,5	II	420	18,60	248,15
Tăliș, V Belin, 69 A	10FA	110	28,4	26,7	II	370	24,10	284,35
Șugaș, III Turia, 23A	10FA	90	30,8	26,2	II	390	24,25	286,84
Șugaș, VI Bodoc, 47A	10FA	105	36,4	28,6	I	270	30,95	360,25
Stands of medium productivity								
Tăliș, V Belin, 60 B	10FA	100	30,4	22,6	III	450	32,12	385,16
Șugaș, II	10FA	110	28,6	24,7	III	380	26,75	382,35

Dalnic, 235G								
Șugaș, IV Cetate, 38A	10FA	100	34,2	24,4	III	370	27,64	348,45
Stands of inferior productivity								
Șugaș, III Turia, 76C	10FA	95	26,2	18,0	V	490	18,25	185,40
Șugaș, IV Cetate, 33B	10FA	100	28,0	19,2	V	340	22,15	168,20
Șugaș, IV Cetate, 147C	10FA	80	32,0	22,6	IV	490	26,40	243,80

The higher-productivity stands are aged between 85 and 110 years; their average diameters vary between 28,4 cm and 36,4 cm; their average height between 23,5 m and 28,6 m; the volume per hectare ranges between 248,35 m^3 and 360,25 m^3.

The medium-productivity stands are aged between 100 and 110 years; their average diameter varies between 28,6 and 34,2 cm; their average height between 22,6 and 24,7 m; and the volume per hectare between 348 m^3 and 385,16 m^3.

The lower-productivity stands are aged between 80 and 100 years; the average diameter ranges between 26,2 cm and 32,0 cm; the average height between 18,0 m and 22,6 m; and the volume per hectare between 185 m^3 and 243,8 m^3.

Table 2

Physical and chemical properties of the analyzed eutric cambisols

Profile			pH	Humus (%)	Nt (%)	C (%)	P_2O_5	K_2O	Sh	Sb	V (%)
PU, c	Horizon	Depth (cm)					(mg/100 g soil)		(me/100 g soil)		
High quality forest site											
III Turia 23A	Ao	0-15	5,90	13,69	0,29	7,93	0,25	6,55	11,2	22,0	66,27
	A/B	15-35	7,61	-	-	-	-	-	2,8	95,2	97,14
	Bv	35-95	8,68	-	-	-	-	-	3,6	96,0	96,39
V Belin 12A	Ao	0-10	5,20	3,1	0,15	1,80	0,10	12,96	7,2	6,8	48,57
	A/B	10-25	5,80	-	-	-	-	-	4,8	9,2	65,71
	Bv	25-80	6,10	-	-	-	-	-	4,8	19,2	80,0
V Belin 69A	Ao	0-20	4,90	3,6	0,17	2,09	0,05	18,96	12,0	11,6	49,15
	A/B	20-45	5,51	-	-	-	-	-	8,0	15,2	65,52
	Bv	45-150	6,09	-	-	-	-	-	4,8	21,6	81,81
VI Bodoc 47A	Ao	0-20	5,65	7,5	0,18	4,35	0,15	4,5	8,2	8,45	50,75
	A/B	20-45	5,90	-	-	-	-	-	5,3	7,15	57,43
	Bv	45-110	6,55	-	-	-	-	-	4,15	7,85	65,42
Medium quality forest site											
I Dalnic 235G	Ao	0-15	6,2	12,4	0,45	6,45	0,18	8,4	15,4	18,5	54,57
	A/B	15-35	6,55	-	-	-	-	-	8,6	75,0	89,71
	Bv	35-75	6,95		-	-	-	-	10,5	84,0	88,89
IV Cetate 38A	Ao	0-15	5,36	6,72	0,16	3,89	0,19	5,43	6,8	9,6	58,54
	Bv	15-55	5,45	-	-	-	-	-	4,80	6,4	57,14
	C	55↓	6,3	-	-	-	-	-	3,6	7,6	67,86
V Belin 60B	Ao	0-15	6,23	5,40	0,23	3,13	0,92	17,4	6,4	21,2	76,81
	A/B	15-30	6,71	-	-	-	-	-	3,6	15,2	80,85
	Bv	30-65	7,08	-	-	-	-	-	3,6	12,8	78,04
Lower quality forest site											
I Vâlcel e 60A	Ao	0-28	5,34	2,52	0,13	1,46	0,07	10,56	8,0	7,6	48,72
	A/B	28-38	5,69	1,32	0,11	0,77	-	-	6,4	13,2	67,35
	Bv	38-60	6,01	-	-	-	-	-	6,0	19,6	76,56
III Turia 76C	Ao	0-25	5,30	4,9	0,22	2,95	0,68	13,55	14,3	13,40	48,38
	Bv1	25-40	5,75	-	-	-	-	-	8,60	9,50	52,49
	Bv2	40-65	5,90	-	-	-	-	-	7,20	7,80	52,0

IV Cetate 147C	Ao	0-20	5,4	6,04	0,25	5,2	0,22	8,7	8,35	25,65	73,28
	Bv	20-65	5,75	-	-	-	-	-	5,25	8,25	61,11
	C	65↓	6,15	-	-	-	-	-	6,30	9,65	60,5

As shown by the analytical data (table 2), the eutric cambisols are soils with a reaction from moderately acid to weakly acid, from mesobasic to eubasic; they are well supplied with nitrogen and with humus of the forest mull type. The site quality is conditioned by the edaphic volume and by the humus content. The average edaphic volume of the eutric cambisols is 0,96 m^3/m^2 in higher quality sites; 0,76 m^3/m^2 in medium quality sites and 0,62 m^3/m^2 in lower quality sites. The humus content that conditions the nitrogenous and mineral trophicity of the soils is 8,17% in higher quality sites; 6,47% in medium quality sites; and 4,28% in lower quality sites.

In figures 1 and 2 are presented two regressions, namely: regression between pH and degree of base saturation for both horizons (Ao, Bv) and regression between diameter and height of trees.

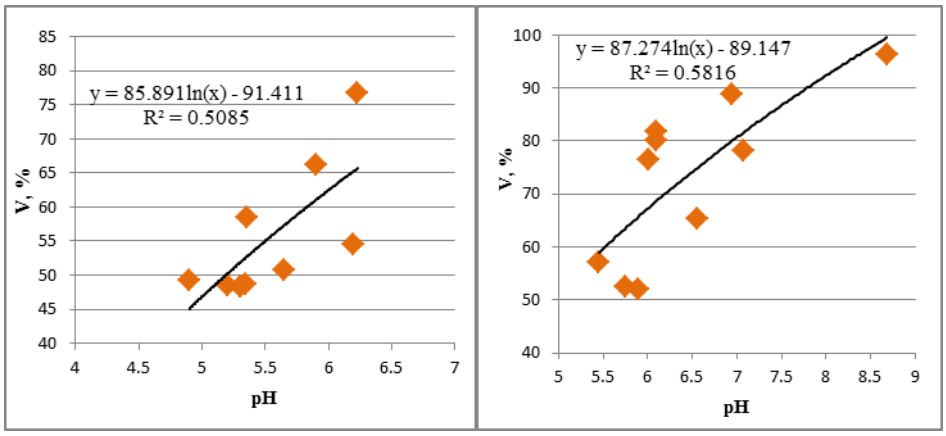

Fig. 1 Regression between pH and degree of base saturation (V) for the eutric cambisols studied in the horizon Ao (left) and the horizon Bv (right)

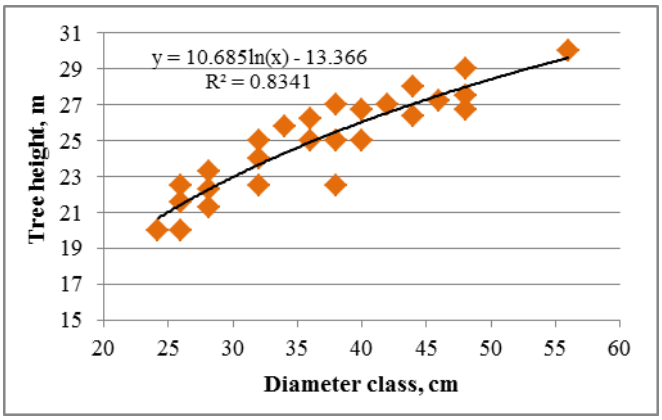

Fig. 2 Regression between diameter and height of trees

The box-plot charts shown in figure 3 and 4 highlight that the analyzed eutric cambisols present reaction and degree of base saturation, for these soils. The value of the median for pH is of 5,40 in the horizon Ao and 6,30 in the horizon Bv; and for the degree of base saturation, the median is 78,04% in the horizon Bv and 50,75% in the horizon Ao.

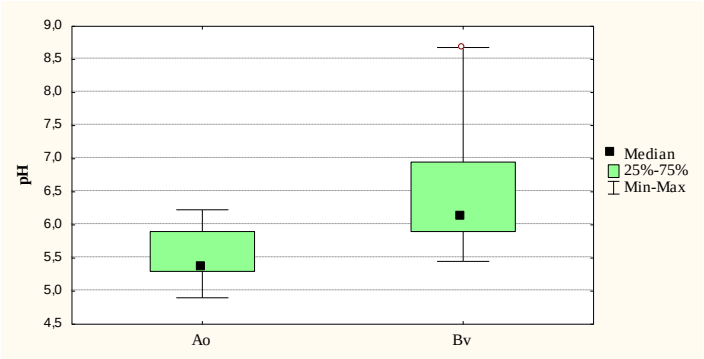

Fig. 3 Boxplot chart for the values of the pH in the horizons Ao and Bv

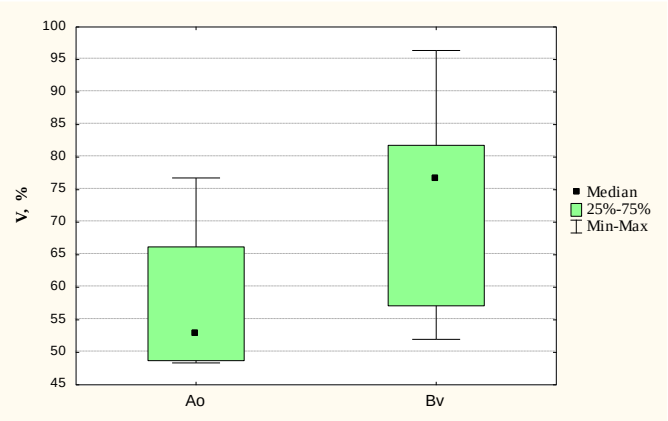

Fig. 4 Boxplot chart for the values of the degree of base saturation in the horizons Ao and Bv

Based on the climatic and edaphic ecological indicators, determined in the compartments under consideration, the types of forest sites submitted as follows have been identified.

1.Mountain-pre-mountain of European beech forest Bs, eutric cambisol, high edaphic, with *Asperula-Dentaria*: FM1 + FD4 BsT_{IV-V} H_{IV-V} Ue_{3-2} (c. 12A, 69A, 23A, 47A)

This type of forest site is encountered both in Baraolt Mountains and in Bodoc Mountains, on parental materials consisting in marl-sandstone as well as sandstone-clay-marl flysch, at altitudes ranging between 700 and 950 m; on lower and medium mountainsides, with Northern or North-Eastern exposure, on areas with moderate slopes (20 - 25%).

The soils where it develops are eutric cambisols, with weakly acid mull; they are deep, to very deep, with big and very big edaphic volume; the pH ranges between 4,90 and 5,90 in the horizon Ao, between 6,10 and 7,29, in the horizon Bv; the average being 5,41 in Ao and 6,35 in Bv; the degree of base saturation has the average value 55,85% in Ao and 85,76% in Bv (table 2).

The climatic conditions, characterized by average annual temperatures of 6,5 - 7°C and annual average rainfall of 700 – 750 mm are favourable to the development of the European beech stands.

The edaphic conditions are favourable to the development of the European beech stands, at higher production classes; the soils are eutrophic, euhydric to mega-hydric, with a reaction from weakly to moderately acid, from eubasic to mesobasic; as well as well supplied with nitrogen and exchangeable bases (Table 2).

The herbaceous layer consists in mull species: *Asperula odorata*, *Cardamine glanduligera*, *Cardamine bulbifera*, *Anemone nemorosa* etc.

They are higher-quality forest sites, for either pure European beech stands, or with disseminated mountain maple, mountain elm and hornbeam.

Following is presented the favorability polygon of ecological indicators for superior quality forest site (figure 5).

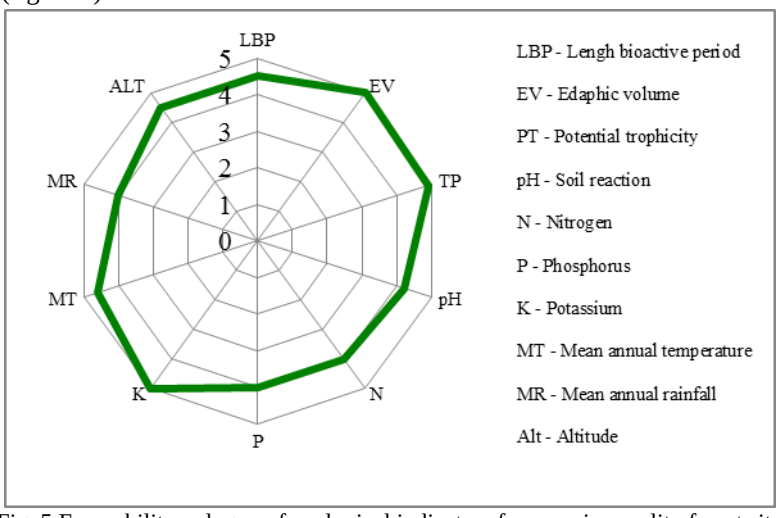

Fig. 5 Favorability polygon of ecological indicators for superior quality forest site

2.Mountain-premountain of European beech forest, Bm, eutric cambisol, medium edaphic, with *Asperula-Dentaria*: FM1 + FD4 Bm T_{III}-v$H_{III}Ue_2$ (c. 60B, 235G, 38A)

This type of forest site is encountered on predominantly medium-sized mountainsides, with moderate and steep slopes (25-30%) at altitudes ranging between 720-900 m. The upper layers, where the soils are formed come from sedimentary, eruptive or metamorphic, basic rarely intermediary rocks.

They are encountered on average-fertility eutric cambisols, with smaller quantities of humus, of the mull acid type, with middle and sub-middle edaphic volume. The soils present loam-sandy and loamy texture; they are moderately humiferous; the reaction is from moderately acid in the horizon Ao (pH = 5,36) to weakly acid in Bv (pH = 6,24); from mesobasic at the level of the horizon Ao (V = 63,29%) to eubasic at the level of the horizon Bv (V = 85%).

The climatic conditions are similar as in the higher-quality forest sites.

The less favourable ecological factors are: an edaphic volume from middle to sub-middle, which determines medium trophicity levels of water supply and accessible nutrients.

They are average-quality forest sites, for the pure beech stands, wherein the mountain maple, mountain elm, ash and hornbeam are the disseminated species.

Following is presented the favorability polygon of ecological indicators for medium quality forest site (figure 6).

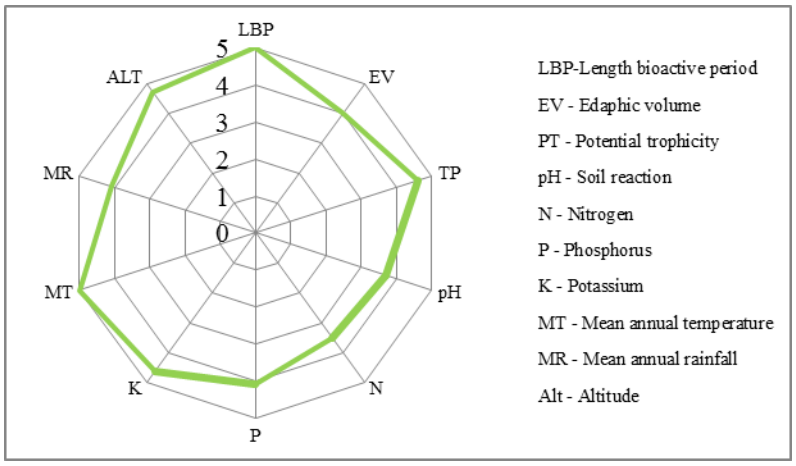

Fig. 6 Favorability polygon of ecological indicators for medium quality forest site

3.Mountain-premountain of European beech forest Bi, eutric cambisol, small edaphic with *Festuca sylvatica*: FM1+ FD4 Bi $T_{II}H_{II}Ue_2$ (c. 60A, 76C, 147C)

This type of forest site is mostly encountered in Bodoc Mountains, at lower altitudes (650 – 850 m) on summits, on higher ridges and mountainsides, steep and very steep, with slopes ranging between 20-30%, with Northern or South-Western exposure.

The characteristic soils are the eutric cambisols, with mull or mull-moder, which are superficial and averagely deep, with an edaphic volume from small to sub-middle. These are half-coarse fragments soils, with good internal and external drainage.

The climatic conditions characterized by annual average temperatures of 8-9°C and annual average rainfall of 640 mm, make the soils display a minus of humidity and a plus of warmth.

The chemical properties are slightly lower than in the case of the higher-quality forest sites; the reaction is moderately acid both in the horizon Ao (pH = 5,35) and A/Bv (pH = 5,73). The soils are mesobasic, across all profile.

The limiting factors are represented by the small edaphic volume and by the relief conditions (slope, exposition) which make the soil trophicity and water supply to the oligomezotrophic (T_{II}) and oligomezohydric (H_{II}) level.

They are lower-quality forest species, for either pure European beech stands or with disseminated elm, hornbeam, linden etc.

CONCLUSIONS

The fertility of the analyzed soils varies according to the soil depth, to the content in coarse fragments and in nutrients.

Even if the edaphic indicators have close values, in the case of the eutric cambisols in higher and lower-quality forest sites, the overall quantity per hectare is diminished, in the case of the lower-quality forest sites, because of the small or at most sub-middle edaphic volume.

It was highlighted that that the edaphic volume directly influences the height of the similarly-aged stands and, therefore, the forest site quality.

Correlations were made between diameters and heights.

Correlations were determined between the soil pH and the degree of base saturation on horizons.

Box-plot charts were drawn for the saturation degree in bases and pH on horizons, by means of which we determined the minimal, medium and maximal values, as well as the medians and the quartiles.

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