MINISTÉRIO DA CIÊNCIA E TECNOLOGIA
INSTITUTO DE PESQUISAS ESPACIAIS

AUTORIZAÇÃO PARA PUBLICAÇÃO
AUTHORIZATION FOR PUBLICATION

PALAVRAS CHAVES/KEY WORDS	PHYTOMASS CERRADO VEGETATION INDEX
AUTORIZADA POR/AUTHORIZED BY	Marco Antonio Raupp General Director
AUTOR RESPONSAVEL / RESPONSIBLE AUTHOR	João Roberto dos Santos
DISTRIBUIÇÃO/DISTRIBUTION	☐ INTERNA / INTERNAL ☐ EXTERNA / EXTERNAL ☐ RESTRITA / RESTRICTED
REVISADA POR / REVISED BY	Yosio Edemir Shimabukuro
CDU/UDC	551.588.42
DATA / DATE	June 1988
PUBLICAÇÃO Nº / PUBLICATION NO	INPE-4603-PRE/1326
ORIGEM / ORIGIN	DPA
PROJETO / PROJECT	IVEG
Nº DE PAG. / NO OF PAGES	10
ULTIMA PAG. / LAST PAGE	09
VERSÃO / VERSION	
Nº DE MAPAS / NO OF MAPS	

TÍTULO/TITLE

THE TRANSFORMED VEGETATION INDEX (TVI) FOR ESTIMATION OF BRAZILIAN CERRADO'S PHYTOMASS

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RESUMO-NOTAS/ABSTRACT-NOTES

The main objective of this study is to make an analysis of the relationship between the cerrado's foliar phytomass and the vegetation indices ($TVI_{4,3}$ and $TVI_{5,3}$), obtained by the Thematic Mapper/LANDSAT-5. The ground and remote sensing data were gathered in three selected areas: Roncador Ecological Reserve-IBGE, Experimental Station of Brasilia University-UnB and CPAC/EMBRAPA Station, located at the central region of Brazil. The linear ($y = a + bx$) and exponential models ($y = ae^{bx}$) were used to analyse the functional relationship between each of the vegetation indices (x) and cerrado's phytomass (y). From the results it can be inferred that the exponential regression model shows a better fit compared to the linear one although a significant difference was not obtained. Also, the results showed better performance of the $TVI_{4,3}$ to fit cerrado's phytomass (dry weight). It explained 62 percent of the variation in the dependent variable ($\hat{y}$). This study is part of the large project that is being carried out by INPE and CPAC/EMBRAPA, of the test the TM/LANDSAT data capability for phytomass estimation of the cerrado in order to support future monitoring of this ecosystem.

OBSERVAÇÕES/REMARKS

Accept for presentation in REMOTE SENSING WORKSHOP "Vegetation Indices and their Interpretation". The University of Nottingham, ENGLAND. 25 may 1988.

INPE-149

THE TRANSFORMED VEGETATION INDEX (TVI) FOR ESTIMATION OF BRAZILIAN CERRADO'S PHYTOMASS

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ABSTRACT

The main objective of this study is to make an analysis of the relationship between the cerrado's foliar phytomass and the vegetation indices ($TVI_{4,3}$ and $TVI_{5,3}$), obtained by the Thematic Mapper/LANDSAT-5. The ground and remote sensing data were gathered in three selected areas: Roncador Ecological Reserve-IBGE, Experimental Station of Brasilia University-UnB and CPAC/EMBRAPA Station, located at the central region of Brazil. The linear ($y=a+bx$) and exponential models ($y=ae^{bx}$) were used to analyse the functional relationship between each of the vegetation indices (x) and cerrado's phytomass (y). From the results it can be inferred that the exponential regression model shows a better fit compared to the linear one although a significant difference was not obtained. Also, the results showed better performance of the $TVI_{4,3}$ to fit cerrado's phytomass (dry weight). It explained 62 percent of the variation in the dependent variable ($\hat{y}$). This study is part of the large project that is being carried out by INPE and CPAC/EMBRAPA, of the test the TM/LANDSAT data capability for phytomass estimation of the cerrado in order to support future monitoring of this ecosystem.

1. INTRODUCTION

Savanna formations constitute a substantial part of the vegetation cover of tropical America. In some regions, such as the Brazilian cerrado, only narrow fringes of gallery forests bordering the streams interrupt the monotonous continuity of the savanna landscape (Sarmiento, 1983). In the last decade the cerrado region has shown a high productive pontential in the Brazilian agricultural process.

This growing land use increased the demand for research on the environmental variables which affect the productive system. As a consequence, a continuous data collection on vegetation is necessary to monitor the cerrado region.

In Brazil Central the cerrado vegetation occupies an area of 1.8 million km^2. It makes necessary to develop a system compatible with data collection so as to monitor such large areas. Thus, the main objective of this study is to make an analysis of the relationship between the foliar phytomass of the cerrado (stricto sensu) and the vegetation indices (TVI) obtained by the Thematic Mapper/LANDSAT-5.

This study is part of the larger project that is being carried out by INPE[1]/MCT and CPAC[2]/EMBRAPA, to test the TM/LANDSAT data capability for phytomass estimation of the cerrado in order to support future monitoring of this ecosystem.

2. STUDY AREA

The ground and remote sensing data were collected in three selected areas in Federal District (DF-Brazil):

- CPAC Farmer: 15°39' - 15°41'S and 47°43' - 47°44'W;
- Roncador Ecological Reserve (IBGE): 15°55' - 15°58'S and 47°51' - 47°54'W;
- Experimental Station of Brasília University (UnB): 15°55' - 16°00'S and 47°53' - 47°58'W.

In this region the climate is characterized by rainy summer and dry winter (Aw, according to Köeppen classification), with the average annual temperature above 20°C and mean annual precipitation about 1600mm. The dark-red latosol and red-yellow latosol (according to Brazilian Soil Classification), with approximate correlation in the U.S. Soil Taxonomy-ustox or orthox - are soil unities predominantly present in the cerrado area. Table 1 presents the main physiognomic types of cerrado vegetation with the corresponding English name.

TABLE 1

THE MAIN PHYSIOGNOMIC TYPES OF THE CERRADO (LATO SENSU)

Type	Total cover of woody layers (%)	Average trees density (trees/ha)	English name
Campo limpo	-	-	Savanna grassland
Campo sujo	<2	500	Tree and/or shrub savanna
Campo cerrado	2-15	1000	Wooded savanna
Cerrado (stricto sensu)	15-40	3000	Savanna woodland

Source: Adapted from Sarmiento (1983)

[1] Instituto de Pesquisas Espaciais
[2] Centro de Pesquisas Agropecuárias dos Cerrados

3. METHODS

The best approach to describe the methodological procedure of this work is to present the three phases:

a) ground truth data acquisition: foliar biomass measurements were taken in $100 m^2$ sample plots with spatial distribution as shown in Figure 1. The size of $100 m^2$ allows a characterization of the cerrado (stricto sensu) under the floristic and structural point of view. The plots were sampled in May/June - 1986 and August/September. Biomass samples were oven dried at $80^{\circ}C$ for 48 hours and expressed on a dry weight basis (g/m^2).

b) vegetation indices acquisition: digital counts for cerrado (stricto sensu) were obtained from TM3 (0,63-0,69μm), TM4 (0,76-0,90μm) and TM5 (1,55-1,75μm) of LANDSAT-5, for the dates of 17/06/86 and 4/08/86. This became possible through outlining of the ground data collection samples on the LANDSAT data. The algorithm (SUBTRA) avaiable in the IMAGE-100 System was used for the attenuation of the atmospheric scattering. The digital counts were obtained by the algorithm ONEPIX, which allows the visualization of the gray levels in sample of 6 pixels x 6 pixels.

With the average values of the digital counts of the 36 pixels, representative of each plot, a transformation into reflectance values as performed. The so transformed data allowed the elaboration of the following indices:

- transformed vegetation index: proposed by Rouse et al (1973) and modified by Deering et al (1975)
- $TVI_{4,3} = |(TM4-TM3)/(TM4+TM3)+0,5|^{1/2}$
- $TVI_{5,3} = |(TM5-TM3)/(TM5+TM3)+0,5|^{1/2}$

c) relation analysis between "foliar phytomass" and "vegetation indices".

Many researches concern a regression analysis for evaluating the relationship between phytomass and spectral data, from which several works were selected: Tucker (1979), Wispelaere and Fabregues (1986), Prince and Astle (1986). Two functions were used in the regression model:

(linear) $y = a + bx$,

(exponential) $y = ae^{bx}$,

where:

y = dependent variable corresponding to foliar phytomass (dry weight);
x = independent variable corresponding to vegetation indices $TVI_{4,3}$ and $TVI_{5,3}$);
a,b = regression coefficients.

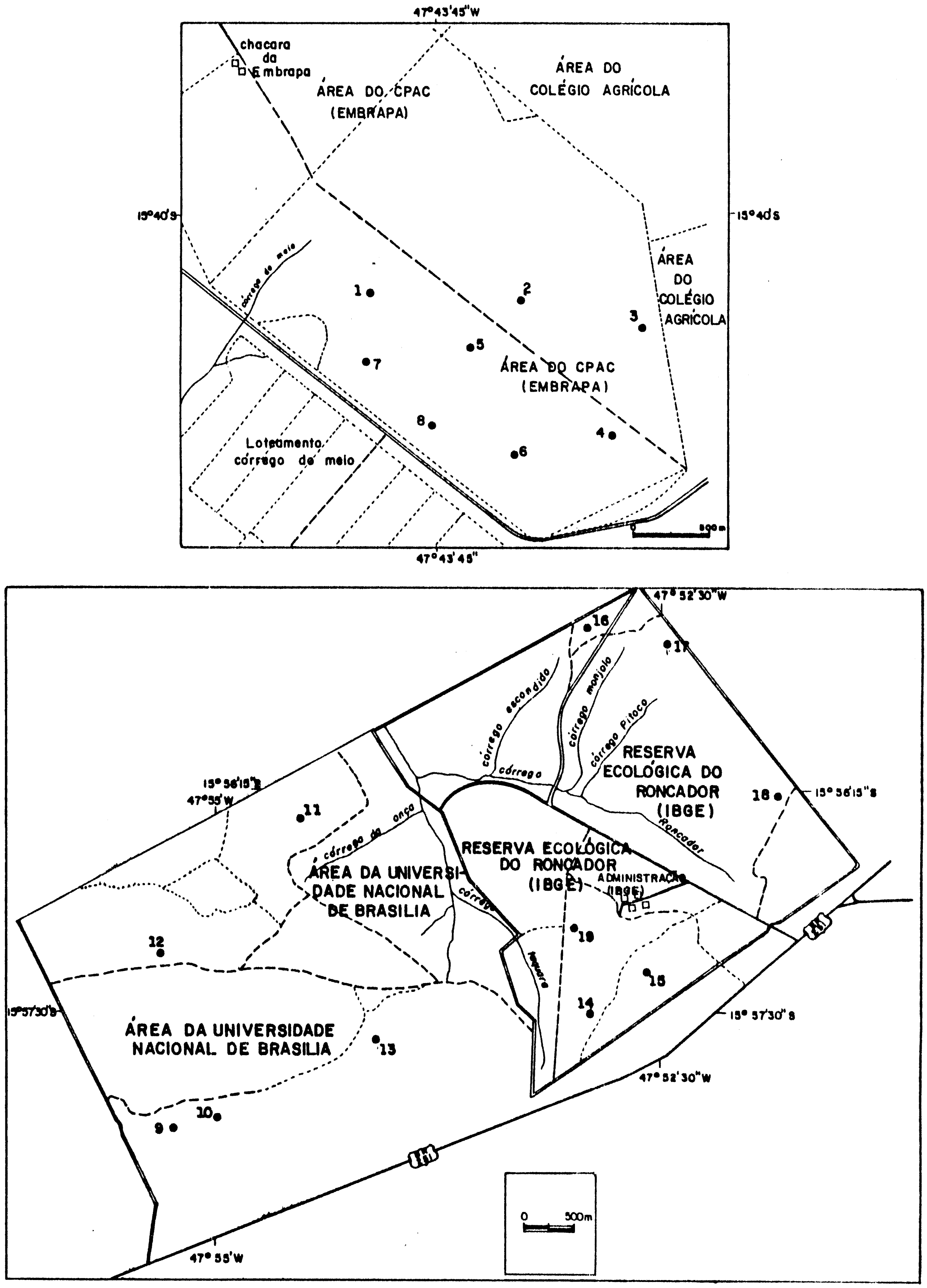

Figure 1 - Map showing the spatial distribution of the sample plots in the CPAC, UnB and IBGE areas.

From the analysis of the regression parameters (correlation coefficients, "t" and "F" values, ...) it is possible to verify that the vegetation index may explain better the total variation of $\hat{y}$ (dependent variable) in the determined model. The definition of the better function, linear or exponential, are also based on the analysis of the standard error of estimate (Sxy). The tested model is in the linear and exponential form; thus, it cannot be directly compared and it is necessary to have a transformation of the standard error of estimate according to formulation:

- arithmetic function

$$Sxy\% = \frac{Sxy}{\bar{y}} . 100,$$

where $\bar{y}$ = arithmetic average of the dependent variable;

- exponential function

$$Sxy\% = (e^{Sxy}-1).100 \qquad \text{(Meyer, 1938)}.$$

The effective method for detecting deficiencies in the regression model is the examination of residuals. (Draper and Smith, 1961). This procedure was elaborated for the detection of the data point which is not typical in the rest of the data.

4. RESULTS AND DISCUSSION

The cerrado (stricto sensu) is here structurally defined by the cover percent of its tree (16,62%), shrub (12,48%) and ground (70,90%) layers. (Figure 2).

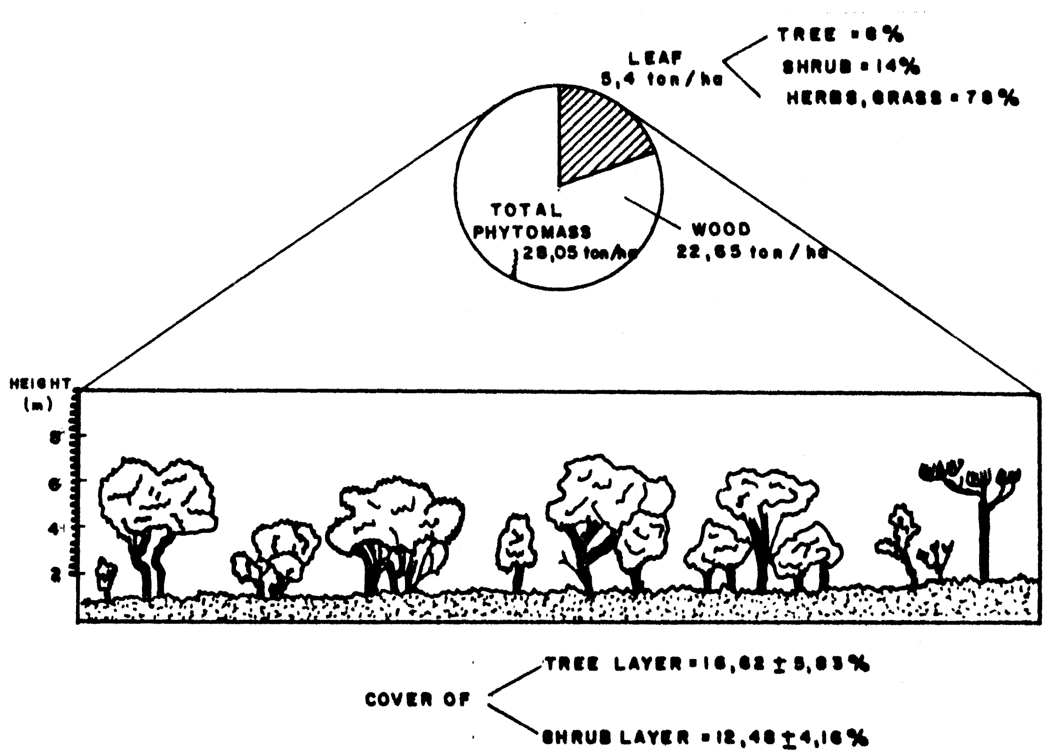

Figure 2 - Schematic profile of the cerrado (stricto sensu) showing the structure of the foliar phytomass.

Table 2 shows the vegetation index values obtained by TM3, TM4, and TM5 of LANDSAT-5, besides the phytomass values of the cerrado, which were collected in 38 sample plots.

TABLE 2

VEGETATION INDICES (TVI) AND FOLIAR PHYTOMASS VALUES (DRY WEIGHT) OF THE CERRADO (STRICTO SENSU)

Sample Plot	Local	Phytomass (dry weight) g/m^2	$TVI_{4,3}$	$TVI_{5,3}$
1	CPAC	517,106	1,0411	1,0604
2	CPAC	490,634	0,9935	1,0011
3	CPAC	541,404	1,0367	1,0454
4	CPAC	547,036	1,0111	1,0337
5	CPAC	589,777	1,0478	1,0482
6	CPAC	584,597	1,0184	1,0399
7	CPAC	530,422	1,0165	1,0320
8	CPAC	537,584	1,0359	1,0492
9	UnB	781,229	1,0394	1,0633
10	UnB	769,883	1,0447	1,0638
11	UnB	706,048	1,0343	1,0621
12	UnB	635,142	1,0484	1,0647
13	UnB	622,116	1,0382	1,0560
14	IBGE	666,565	1,0578	1,0738
15	IBGE	711,759	1,0733	1,0757
16	IBGE	876,672	1,0441	1,0720
17	IBGE	797,118	1,0510	1,0636
18	IBGE	723,207	1,0627	1,0615
19	IBGE	520,750	1,0423	1,0693
20	CPAC	352,186	1,0062	1,0517
21	CPAC	323,832	0,9765	1,0046
22	CPAC	407,019	1,0113	1,0432
23	CPAC	335,121	0,9985	1,0424
24	CPAC	412,675	1,0308	1,0520
25	CPAC	400,585	1,0047	1,0468
26	CPAC	368,166	0,9984	1,0429
27	CPAC	374,783	1,0161	1,0529
28	UnB	447,585	1,0153	1,0676
29	UnB	470,451	1,0254	1,0681
30	UnB	573,498	0,9934	1,0640
31	UnB	456,325	1,0239	1,0664
32	UnB	492,228	1,0135	1,0589
33	IBGE	573,567	1,0219	1,0669
34	IBGE	564,446	1,0488	1,0725
35	IBGE	425,228	1,0064	1,0644
36	IBGE	489,803	1,0210	1,0682
37	IBGE	493,476	1,0414	1,0679
38	IBGE	483,097	1,0081	1,0689

The data from number 1 to 19 correspond to the period May/June; the ones from number 20 on, to the period August/September.

Table 3 presents the parameters of the regression between the foliar phytomass and the vegetation index, using the linear and exponential models.

TABLE 3

REGRESSION PARAMETERS BETWEEN PHYTOMASS (DRY WEIGHT) OF CERRADO AND TRANSFORMED VEGETATION INDEX (TVI)

INDICES / PARAMETERS	$y = a+bx$		$\ln y = \ln a+bx$	
	$TVI_{4,3}$	$TVI_{5,3}$	$TVI_{4,3}$	$TVI_{5,3}$
a	-4164,20528	-3104,54575	-2,59120	-0,71003
b	4585,6008 (t=6,26**)	3554,9909 (t=2,83**)	8,6286 (t=6,64**)	6,6080 (t=2,99**)
r	0,72208	0,42664	0,74201	0,44562
F	39,22**	8,01**	44,10**	8,92**
Sxy	96,57027	126,24990	0,17136	0,22883

Those models where the independent variable is formed by $TVI_{4,3}$ permit a better fit to phytomass (dry weight). This is confirmed by the observation of "r", "t" and "F" values ,that are always higher than those of $TVI_{4,3}$ when the independent variable is $TVI_{5,3}$. Taking into account these regression parameters, it is observed that the exponential model is slightly superior to the linear model. Nevertheless, the difference between both is not significant. (Figure 3). Considering only the exponential model, 55% of the variations found at $\hat{y}$ are due to the index $TVI_{4,3}$.

At Figure 3 two data points (outliers) could be found at a series of 38 observations. Removing these points, the models show the better fit. The equations are then expressed as:

$y = 4283,5963 + 4690,1063 (x);$

$\ln y = -3,00531 + 9,0122 (x),$

where:

y = foliar phytomass (dry weight),

$x = TVI_{4,3}$ value,

with $r_{linear} = 0,77558$ and $r_{exponential} = 0,79160$.

In this case, considering the deletion of two data points, those variations at $\hat{y}$ are due to the independent variable $TVI_{4,3}$ at 62% (average value).

The standard errors of estimate, obtained by the regression analysis between phytomass and $TVI_{4,3}$, were 15,57% and 16,28% for the linear and exponential models, respectively.

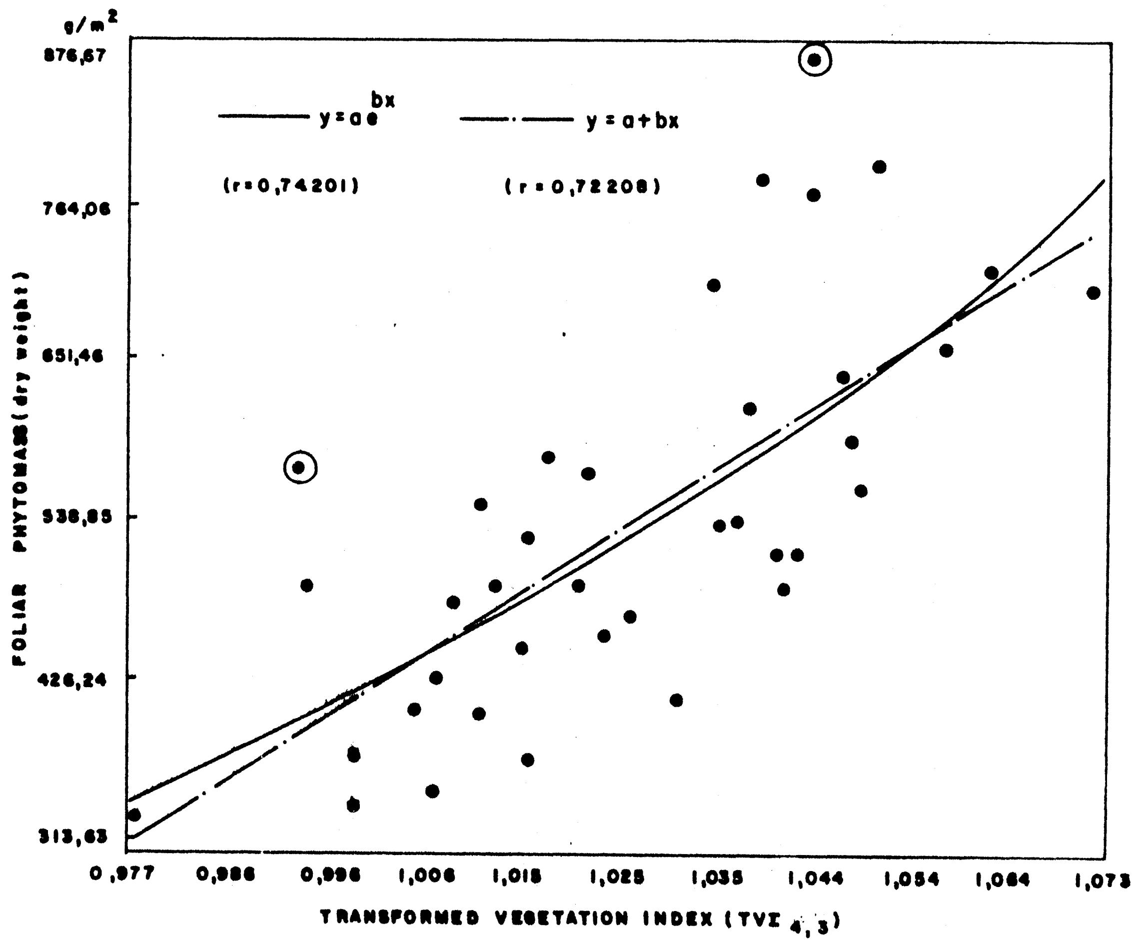

Figure 3 - Diagram showing the relationship between phytomass (dry weight) of the cerrado and $TVI_{4,3}$.

5. CONCLUSIONS

The results showed the best performance of $TVI_{4,3}$ to fit cerrado phytomass (dry weight), independently of the model utilized in the regression. It explains 62 per cent of the variation in the dependent variable ($\hat{y}$). The difference is not significant between linear and exponential models utilized, when fitting the data. The standard error estimate (Sxy), was 16% in the estimation of the cerrado phytomass by the remote sensing data, utilizing the $TVI_{4,3}$.

The reasonable results of these techniques in the evaluation of the cerrado phytomass encourage us continuously to improve the treatment of remote sensing data. This study can help in the monitoring process of this natural vegetation change as a result of the extensive human activities in the Central Brazil region.

AKNOWLEDGMEMTS

This research was supported by the "Centro de Pesquisa Agropecuária dos Cerrados (CPAC/EMBRAPA)" and Brazilian Space Agency (Instituto de Pesquisas Espaciais-INPE), Brazil.

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