Revista Brasileira de Agricultura Irrigada v.11, nº.5, p. 1685 - 1692, 2017
ISSN 1982-7679 (On-line)
Fortaleza, CE, INOVAGRI – http://www.inovagri.org.br
DOI: 10.7127/rbai.v11n500749
Protocolo 749.17 – 23/05/2017 Aprovado em 31/08/2017

COMPARISON BETWEEN ALTIMETRIC SURVEY METHODS FOR SYSTEMATIZATION OF LANDS FOR IRRIGATION AND DRAINAGE

Antônio Henrique Cardoso do Nascimento[1], Ana Karla Paiva Pereira[2], Alan Cézar Bezerra[1], Edilson Santos Silva[3], Aline Luz de Oliveira[2], Olga Rubênia da Silva Caminha de Menezes[4]

ABSTRACT

The systematization of the terrain is a set of operations necessary to regularize the irregular surface of a terrain in uniform slopes in one or two directions. It is one of the most costly and indispensable techniques in surface irrigation. In this sense, the objective was to compare the obtaining of quotas, with different methods of altimetric survey to systematize the terrain of four different areas located in the Sertão do Pajeú - PE. The standard method was hose leveling (HL) and was correlated with the geometric (GL), tachometric (TACL), trigonometric (TRL) and GNSS receiver (GNSSL) leveling. The comparison of the results was by means of the standard error of estimation (SES), maximum error (MAXE), Willmott concordance index (d), Pearson correlation coefficient (r) and coefficient of confidence (c). The results of the assessment of the estimates of the (TRL), (TAL) and (GL) indicate, in this order, a better adjustment and are well correlated to (HL), whereas the (NGNSL) did not present satisfactory adjustment, thus, it is not recommended to obtain quotas for systematization of the land.

Keywords: Altimetry, quotas, topography.

COMPARAÇÃO ENTRE MÉTODOS DE LEVANTAMENTOS ALTIMÉTRICOS PARA SISTEMATIZAÇÃO DE TERRENOS PARA IRRIGAÇÃO E DRENAGEM

RESUMO

A sistematização do terreno é um conjunto de operações necessárias para regularizar a superfície irregular de um terreno em pendentes uniformes em uma ou duas direções. É uma das técnicas mais onerosa e indispensável na irrigação superficial. Neste sentido, objetivou-se comparar a obtenção de cotas, com diferentes métodos de levantamento altimétrico para sistematização de terreno de quatro diferentes áreas localizadas no Sertão do Pajeú - PE. O

[1] Professor at Rural Federal University of Pernambuco, Academic Unit of Serra Talhada - UFRPE / UAST - Serra Talhada - PE. E-mail: antonio.cardoso@ufrpe.br
[2] Student at Rural Federal University of Pernambuco, Academic Unit of Serra Talhada - UFRPE / UAST - Serra Talhada - PE.
[3] Fishing Engineer, HG2 - Graduate Nucleus - Petrolina - PE.
[4] Professor at Paulista University - UNIP - Brasília - DF

método tomado como padrão foi o nivelamento com mangueira (NH), sendo correlacionado com os métodos de nivelamento geométrico (NG), taqueométrico (NTA), trigonométrico (NT) e nivelamento com receptor GNSS (NGNSS). A comparação dos resultados foi por meio do erro-padrão da estimativa (EPE), erro máximo (EMAX), índice de concordância de Willmott (d), coeficiente de correlação de Pearson (r) e do coeficiente de confiança (c). O resultado da avaliação das cotas estimadas pelo (NT), (NTA) e (NG) indica um melhor ajuste, nesta ordem, mostrando-se bem correlacionados ao (NM), ao passo que os (NGNSS) não apresentou ajuste satisfatório, não sendo, portanto, recomendado para obtenção de cotas para sistematização do terreno.

Palavras-chave: Altimetria, cotas, topografia.

INTRODUCTION

The soil systematization is an expensive and indispensable technique for surface irrigation, since it is necessary that the water flows in the soil and maintains a uniform lamina (LORENSI et al., 2010). This procedure is aimed at the regularization of uneven terrain, which consists of the soil handling technique, providing some advantages for irrigation, such as: better control and more efficient distribution of water, avoid soil erosion and loss of fertilization and greater efficiency of surface drainage.

Thus, it is fundamental to choose a Survey Method that is more appropriate to the local reality so that the results are accurate, but with the possibility of maintaining the technical feasibility. Melo et al. (2011) states that one must seek equipment with the minimum acceptable accuracy, rather than instruments with the maximum precision. Therefore, we seek instruments and processes that allow us to reach the desired goal with the minimum of work and expenses.

With regard to Agricultural Sciences, in which the vast majority of topographic works applied to agriculture are simple in nature, one can look for simple and alternative equipment for surveys. In the case of topographic leveling it is known that it is an operation that allows to determine the vertical distances between horizontal planes, or between level surfaces, in which the different types of leveling are based on different principles (COELHO, 2003).

The following types of leveling can be defined: Trigonometric with theodolite or total station; Geometric: with levels and hydrostatic: principle of communicating vessels. The hydrostatic leveling is the only one that allows us to determine several points belonging to the same surface (differences of null altitudes), in the case of considering a single homogeneous liquid. Admittedly the technological advances of the last decades have allowed the production of sophisticated measuring instruments, such as total stations and signal receivers transmitted by satellites, has made the acquisition, treatment and analysis of topographic data fast and, most of the time, more accurate (BUSNELLO & CONTE, 2015; MELO et al., 2011).

Even with these evolutions and upgrades of the equipment, several situations and characteristics of equipment operation influence the quality and final cost of a topographic survey and, consequently, the systematization of the terrain. With the inappropriate use of these instruments, it is possible to generate data and information that is not reliable and even out of the reality of the place, thus generating doubts about the quality and confidence of the activity (SOUZA SANTOS et al., 2016).

Thus, it is necessary to analyze the quality of the data collected and the best cost / benefit among the main methodologies and techniques used for the planialtimetric surveys to better perform the systematization of the terrain. The objective of this work was to compare the obtaining of quotas with different methods of altimetric survey to systematize the terrain of four different areas located in the Sertão do Pajeú - PE.

MATERIAL AND METHODS

Experimental areas characteristics

The work was carried out in four areas of 0.48 hectares (60 x 80 m), with different slopes, located at the Federal Rural University of Pernambuco, State University of Serra Talhada - UFRPE / UAST, in the municipality of Serra Talhada – PE (Figure 1).

To collect the topographic data, in each of the four areas, two basic lines perpendicular to each other were drawn, with the aid of a theodolite, staked in spaces equidistant from 20.00 m, the first stake was half a space of the basic lines (10 m), in order to begin delimiting the surface of the area to be systematized. For a safe identification of the vertices of the grid, the abscissa were represented by numbers (columns) and those ordered by letters (lines).

After marking the two basic lines perpendicular to each other and their stakes, the remainder of the area was marked using two mesuring tapes with lengths equal to the spacing and three beacons whose intersection gave the location of the next stake until the closure total of each area. Subsequently, a Topographic survey was carried out using five different methodologies: Hydrostatic Leveling (HL), Geometric Leveling (GL), Tachometric Leveling (TACL), Trigonometric Leveling (TRL) and GNSS Receiver Leveling (GNSSL).

The altitude data obtained and corrected by the navigation GNSS receiver of the First Topographic Point was used as reference value (RV) so that it could correlate the data with the same magnitude. So, for the calculation of orthometric altitude, was used the ellipsoidal or geometric altitude obtained by the receiver. Geoidal Ondulation were obtained using MAPGEO2010 and PROGRID software, both from IBGE, from which a geoid ripple of -8.72 m was observed for 4 areas; this way it was not necessary to use the correction, due to the size of the area.

Comparison of the quotas obtained by different leveling methods, with the quotas measured by the hydrostatic leveling.

For comparison of the quotas measured by the hose level (hydrostatic leveling) with the estimated heights with the different topographic leveling methods, the data of 12 quotas of the four different areas were used.

In order to evaluate the performance of the models, the linear regression was adjusted by forcing the zero intercept. For the dependent variable we considered the measured dimensions with the hydrostatic leveling (hose level), and the independent variable the quotas estimated by the different topographic leveling methodologies. Were used the Willmott concordance index (d), the correlation index (r), the confidence index (c), the standard error of the estimate (SES) and the maximum error

(MAXE), through equations 1, 2, 3, 4 and 5 respectively.

$$d = 1 - \left[\frac{\sum_{i=1}^{n} (Pi - Oi)^2}{\sum_{i=1}^{n} \left[\left| \left(Pi - \bar{O} \right) \right| + \left| \left(Oi - \bar{O} \right) \right| \right]^2} \right] \quad (1)$$

$$r = \frac{\sum_{i=1}^{N} \left[\left(Oi - \bar{O} \right) \times (Pi - \bar{P}) \right]}{\sqrt{\sum_{i=1}^{N} \left(Oi - \bar{O} \right)^2} \times \sqrt{\sum_{i=1}^{N} \left(Pi - \bar{P} \right)^2}} \quad (2)$$

$$c = r \text{ x } d \quad (3)$$

$$SES = \left\{ \frac{\sum_{i=1}^{n} (O_i - P_i)^2}{(n-1)} \right\}^{\frac{1}{2}} \quad (4)$$

$$\mathrm{MAXE} = \mathrm{MAX}\ (|\,\mathrm{Oi} - \mathrm{Pi}\,|)_{i=1}^{n} \quad (5)$$

In these equations, Pi is the predicted or estimated value, Oi is the observed value and $\bar{O}$ is the mean of the observed or measured values. The observed value is the one taken as reference for the others (hydrostatic leveling). The Willmott index (d) ranges from 0 to 1, where the value 1 means perfect accuracy between the estimated and adopted data as the standard, while the zero value means that there is no agreement between the values analyzed.

RESULTS AND DISCUSSION

Figures 2 to 5 present the graphs and models resulting from the linear correlation considering the comparison of the quotas measured by the hose level with different topographic levels in the four different areas.

In the studied areas, the comparison of the values of the quotas measured by the hydrostatic leveling and the values of quotas estimated by the trigonometric and tachometric leveling (Figures 2 A and B, 3 A and B, 4 A and B e 5 A and B) were better adjusted than the comparisons obtained by the hydrostatic leveling and the geometric leveling, the later considered as standard method (Figures 2 C, 3 C, 4 C and 5 C). Batista (2013), designing small earth dams from topographic surveys carried out by different methodologies, verified that trigonometric leveling was the most apt method to replace the geometric leveling in obtaining the dimensions.

While in Figures 2 D, 3 D, 4 D and 5 D and Table 1, it was found that the Navigation GNSS Receiver leveling method presented unsatisfactory correlations (r = 0.50) when compared to the hydrostatic leveling, presenting a performance classified as poor, according to Camargo and Sentelha (1997). For Batista (2013), the use of GNSS navigation receiver is not recommended for the design of dams because of the inefficiency of this device for this purpose. Due to the presented performance, it is not recommended the GNSS receiver navigation leveling method for altimetric surveying, corroborating with Coelho (2002) and Melo et al. (2011).

However, it is important to note that the qualities of the GNSS receiver are associated with the internal characteristics of the devices, such as clock and antenna quality, and external, such as atmospheric conditions, quantity and geometry of the satellite constellation. When their characteristics are respected and the interferences corrected, the result obtained by this equipment can perform better and adjust to the purposes of agricultural activities (SOUZA SANTOS et al., 2016)

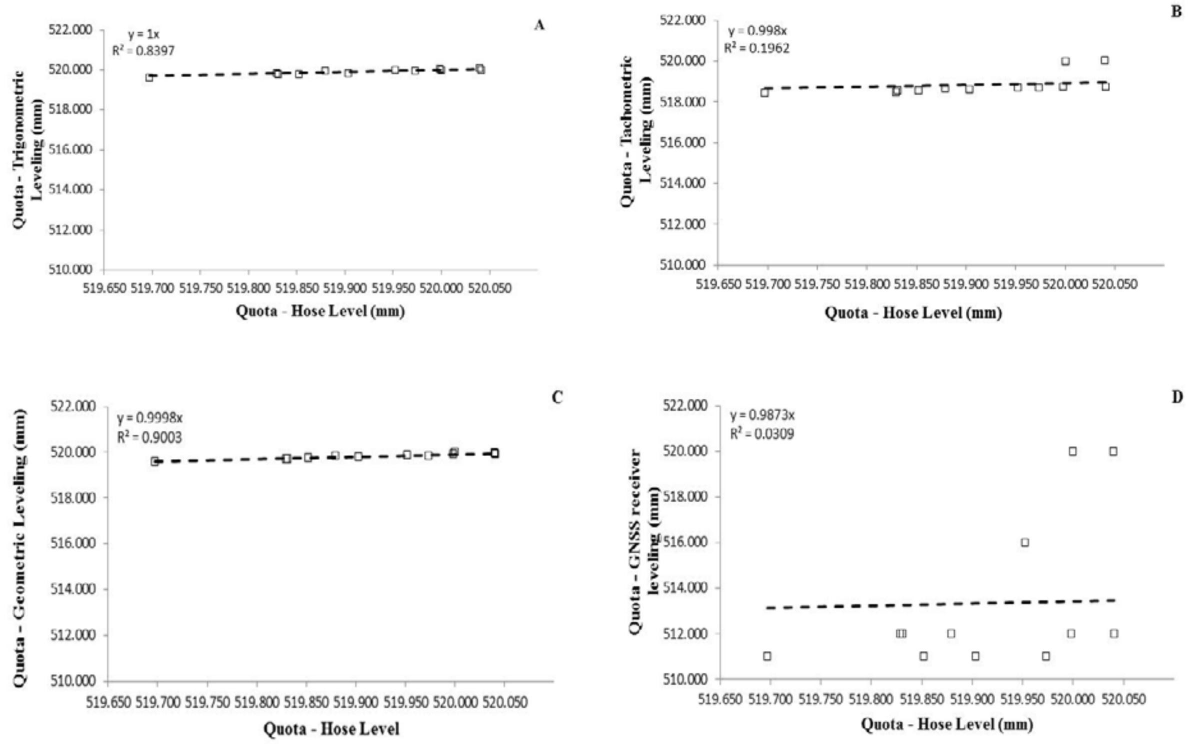

Figure 2. Correlation analysis of area 1 quotas between Hose Leveling x Trigonometric Leveling (A), Hose Leveling x Tachometric Leveling (B), Hose Leveling x Geometric Leveling (C), Hose Leveling x GNSS Receiver Leveling (D).

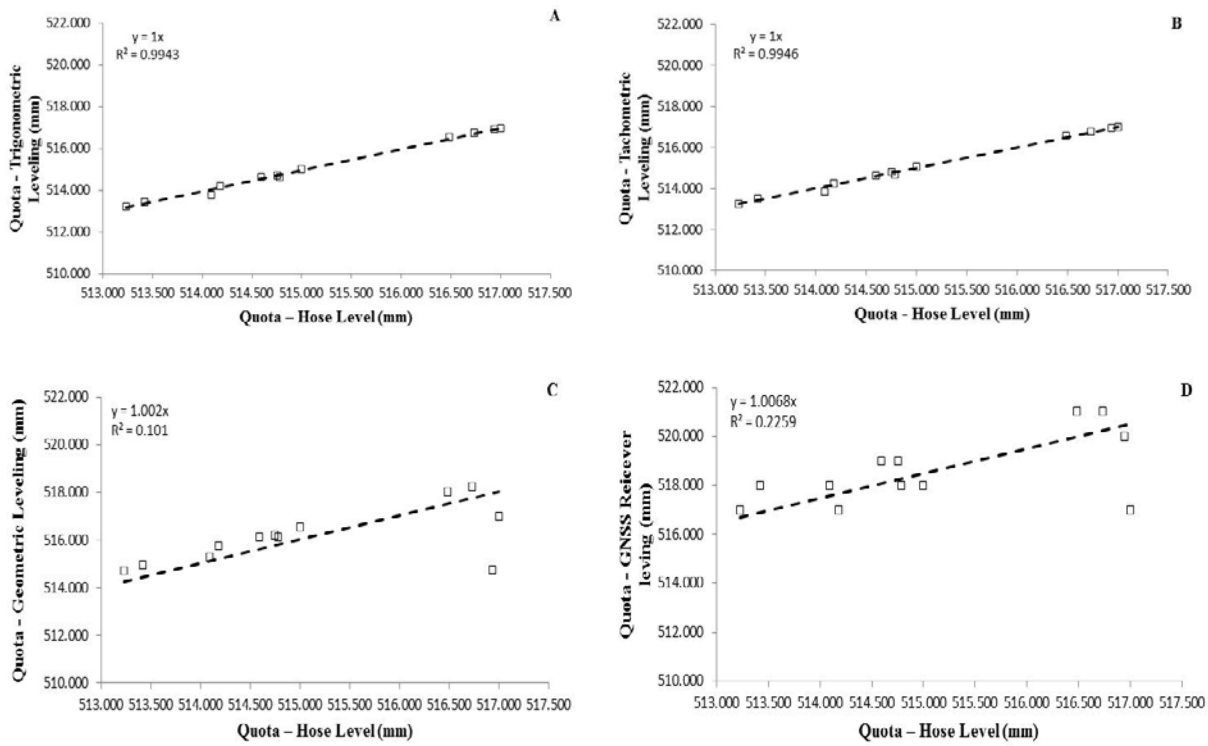

Figura 3. Correlation analysis of area 2 quotas between Hose Leveling x Trigonometric Leveling (A), Hose Leveling x Tachometric Leveling (B), Hose Leveling x Geometric Leveling (C), Hose Leveling x GNSS Receiver Leveling (D).

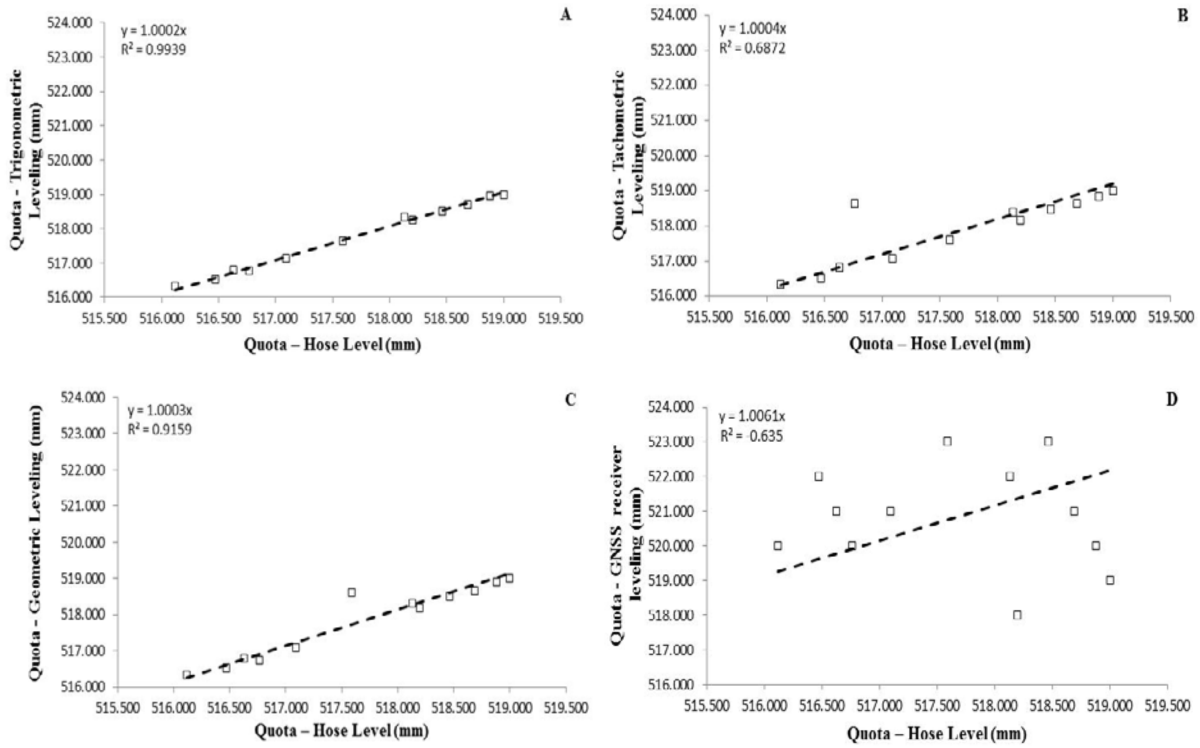

Figure 4. Correlation analysis of area 3 quotas between Hose Leveling x Trigonometric Leveling (A), Hose Leveling x Tachometric Leveling (B), Hose Leveling x Geometric Leveling (C), Hose Leveling x GNSS Receiver Leveling (D).

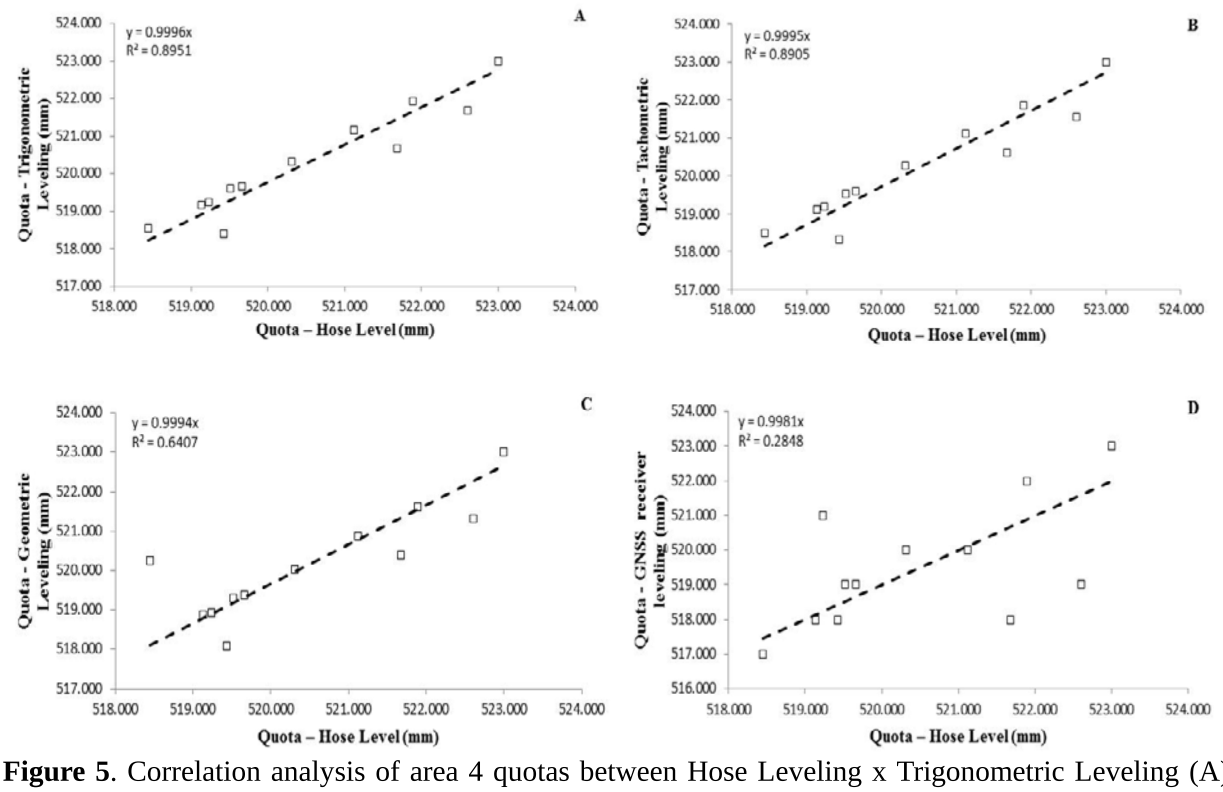

Figure 5. Correlation analysis of area 4 quotas between Hose Leveling x Trigonometric Leveling (A), Hose Leveling x Tachometric Leveling (B), Hose Leveling x Geometric Leveling (C), Hose Leveling x GNSS

Receiver Leveling (D).

Table 1 shows that the correlation coefficients (r) ranged from 0.39 to 0.97 for the GNSS receiver leveling and trigonometric leveling methods, a poor and good equipment accuracy, respectively. In addition to the results of (r), it can be seen from Table 1 that the concordance index (d) also presented satisfactory results for all methods, with d values higher than 0.90 for all comparisons. The results indicate that the measurements with the hydrostatic leveling allowed to estimate the values of quotas with good accuracy for the analyzed areas, since they presented values of (d) closer to 1 when compared to the measurement of the other leveling methods, that is, with a low deviation between the estimated and observed values, being justified and observed in Figures 2 to 5.

In relation to the estimation errors (MAXE and SES), Table 1 shows that the best results were obtained from the correlation of the Hydrostatic Leveling x Trigonometric Leveling, followed by the correlation with the Taqueometric, Geometric and GNSS receiver Leveling. The value of the standard error of the estimate ranged from 0.174 m to 1,834 m and for the absolute maximum error of 0.412 to 5.690 m for the trigonometric and GNSS receiver leveling methods respectively.

It is verified when analyzing the data of the quotas, that there was a greater dispersion when it correlated the standard quotas by the GNSS receiver (Figure 2 to 5 and Table 1), evidenced by the greater average absolute error and standard error of the estimate. This variation of the measurements for this type of equipment was already expected and corroborates with the results of Souza Santos et al. (2016) that when comparing different navigation GNSS with the GNSS geodesic found variations of the orthometric altitude of the different equipment in the order of 0.020; 1.419; 0.698 and 3.101. While Melo et al. (2011) obtained for the same GNSS navigation for the same area level differences in different tests of 132; 86; 96 and 95 m.

Table 1. Correlation coefficient (r), concordance index (d), performance index (c), standard error of estimation (SES) and maximum error (MAXE) for correlations between values with hose leveling with different methods of leveling.

Methods of Leveling	**r**	**d**	**C**	**SES**	**MAXE**	**Classification**
HL xTACL	0.85	0.97	0.83	0.390	1.154	Very good
HL x GL	0.84	0.98	0.83	0.523	1.289	Very good
HL x GNSSL	0.39	0.93	0.37	1.834	5.690	Terrible
HL x TRL	0.97	0.99	0.96	0.174	0.412	Great
Average	**0.76**	**0.97**	**0.75**	**0.730**	**2.136**	-

HL: Hose leveling; TACL: Tachometric Leveling; GL: Geometric levelling; GNSSL: GNSS receiver leveling TRL: Trigonometric levelling.

CONCLUSION

Although the use of trigonometric leveling is not the most suitable method for the systematization of the terrain, the study showed that it is the most apt to replace the geometric leveling in obtaining the quotas.

Leveling with GNSS navigation receiver is not recommended for systematization of the terrain due to the inefficiency of this apparatus for this purpose.

REFERENCES

BATISTA, P. I. F. **Dimensionamento de**

pequenas barragens de terra a partir de levantamentos topográficos realizados por diferentes metodologias. 2013. p.43. Monografia em Ciência e Tecnologia. Universidade Federal Rural do Semiárido – UFERSA, Mossoró.

BRASIL. INSTITUTO BRASILEIRO DE GEOGRAFIA E ESTATISTICA. Rio de Janeiro, 2017. Disponível em: www.ibge.gov.br/home/geociencias/geodesia/modelo_geoidal.shtm. Acesso em: 10 de maio de 2017.

BUSNELLO, F.J.; CONTE, P.R. Levantamento topográfico planialtimétrico com diferentes métodos de levantamento de dados a campo. **Revista Tecnológica**, v. 3, n. 2, p. 196-205, 2015.

CAMARGO, Â. P.; SENTELHAS, P. C. Avaliação do desempenho de diferentes métodos de estimativa da evapotranspiração potencial no Estado de São Paulo, Brasil. **Revista Brasileira de Agrometeorologia**, v.5, n.1 p.89-97, 1997.

COELHO. A. C. S. **Avaliação do desempenho de receptores GPS em levantamentos altimétricos, para fim sistematização de terras.** 2003.128f. Dissertacao (Mestrado Irrigação e Drenagem)- Escola Superior de Agricultura Luiz de Queiroz, Universidade de São Paulo, Piracicaba.

LORENSI, R. P.; ZARDO, K.; MATTAR, D. M. P.; NISHIJIMA, T. A utilização dos recursos hídricos no sistema de irrigação por superfície (inundação) na cultura do arroz mediante as normatizações. **Ambiência**, v. 6, n. 2, p. 355-364, 2010.

MELO, A.S.; AQUINO, I.S. O uso do gps de navegação em pequenas áreas agrícolas. **Revista Verde de Agroecologia e Desenvolvimento Sustentável**, v. 6, n. 4, p. 137-141, 2012.

SOUZA SANTOS, R.; BRAGA, J. O. F.; GUEDES, C. R. R.; LANÇAS, K. P. Utilização de receptor de sinal de GPS de navegação como ferramenta de apoio à atividade agropecuária. **Energia na agricultura**, v. 31, n. 1, p. 97-101, 2016.

WILLMOTT, C. J.; CKLESON, S. G.; DAVIS, R. E. Statistics for evaluation and comparation of models. **Journal of Geophysical Research**, v. 90, n. C5, p. 8995-9005. 1985.