# Analysis of the influence of distance on data acquisition intensity targets forestry Terrestrial Laser Scanner

**Fabiane BORDIN, Elba Calesso TEIXEIRA, Sílvia Beatriz Alves ROLIM, Francisco Manoel Wohnrath TOGNOLI, Luiz Gonzaga da SILVEIRA JUNIOR, Maurício Roberto VERONEZ and Camila Fernandes Natus de SOUZA, Brazil**

**Key words**: remote sensing, terrestrial laser scanner, time of flight, k-means, remote sensing

## SUMMARY

The forest sciences as well as other areas of knowledge benefit from technological advances to develop increasingly their working methods and increase their knowledge of their specific field of study. Are continually developed new equipment and methods to support these applications and, among the equipment and systems developed in recent years, systems for laser scanning and profiling have been consolidated as one of the most effective technologies for geospatial data acquisition. The automated data collection expanded rapidly in recent years, in line with the technological advances made in the areas of surveying and mapping. The scanning systems and laser profiling, also known as Terrestrial Laser Scanner (LST) have some characteristics that apply so important in forest analysis. The LST has the great advantage of being a method of data acquisition and fast non-destructive. In most cases, the equipment Terrestrial Laser Scanner generate its own format file of the data collected. However, these files have similarities with respect to the information. The files are based on a structure in which are stored the coordinates of the points in space (X, Y, Z), the value of the intensity of return laser pulse (I), and if there availability, the values f rom the digital camera (RGB) both internally and externally, creating a sequence of information (XYZ, I, RGB). Spatial information is commonly used for volume calculations and identification of geometric features. RGB data aid in the visual identification of features and provide a better understanding of the objects raised with the laser, but when it comes to return intensity values of the pulse laser, there is a lack of specific applications for the use of such information, which can provide Variations in physical-chemical characteristics of the targets. Thus, the main objective of this study was to evaluate the influence of the distance to the target in the data acquisition intensity targets forest in order to support future studies of correlation between this variable and the physicochemical characteristics of the targets. In this study we used the Terrestrial Laser Scanner 3D Ilris with Optech operating principle based on flight time and wavelength of 1535nm spectral range from infrared magnetic medium. The data acquisition targets intensity was assessed at distances (1m, 2m, 3m, and 5m) by using a target reference of 99% reflectance. The results were analyzed and showed that the distance interferes with the return of intensity. From the results of this research suggests that the intensity data are calibrated in relation to distance before using them as a source for study of the physical-chemical characteristics of the targets.

**RESUMO**

As ciências florestais assim como outras áreas do conhecimento usufruem de avanços tecnológicos para desenvolver cada vez mais os seus métodos de trabalho e ampliar os conhecimentos específicos da sua área de estudo. Continuamente são desenvolvidos novos equipamentos e métodos para subsidiar essas aplicações e, dentre os equipamentos e sistemas desenvolvidos nos últimos anos, os sistemas de varredura e perfilamento a laser vêm se consolidando como uma das mais eficazes tecnologias de aquisição de dados geoespaciais. A coleta automatizada de dados expandiu-se rapidamente nos últimos anos, alinhada com os avanços tecnológicos realizados nas áreas de levantamentos e mapeamentos. Os sistemas de varredura e perfilamento a laser, também conhecidos como Laser Scanner Terrestre (LST), possuem algumas características que se aplicam de forma importante em análises florestais. O LST tem a grande vantagem de ser um método de aquisição de dados rápido e não-destrutivo. Em sua maioria, os equipamentos de Laser Scanner Terrestre geram um formato próprio de arquivo dos dados coletados. Porém, esses arquivos possuem similaridades em relação às informações contidas. Os arquivos baseiam-se em uma estrutura onde são armazenadas as coordenadas dos pontos no espaço (X, Y, Z), o valor de intensidade de retorno do pulso laser (I) e, caso haja disponibilidade, os valores provenientes da câmera fotográfica digital (RGB) tanto interna como externa, gerando uma sequência de informações (XYZ, I, RGB). As informações espaciais são comumente utilizadas para cálculos de volume e identificação de feições geométricas. Os dados RGB auxiliam na identificação visual de feições e propiciam uma melhor compreensão dos objetos levantados com o laser, porém quando se trata dos valores de intensidade de retorno do pulso laser, existe uma falta de aplicações específicas para a utilização dessa informação, que pode fornecer variações das características físico-químicas dos alvos. Sendo assim, o principal objetivo desse trabalho foi avaliar a influência da distância ao alvo na aquisição dos dados de intensidade de alvos florestais com o propósito de subsidiar estudos futuros de correlação entre tal variável e as características físico-químicas dos alvos. Nesta pesquisa foi utilizado o Laser Scanner Terrestre Ilris 3D Optech com princípio de funcionamento baseado no tempo de vôo e comprimento de onda de 1535nm na faixa do espectro magnético do infravermelho médio. A aquisição dos dados de intensidade dos alvos foi avaliada nas distâncias de (1m, 2m, 3m, e 5m) com a utilização de um alvo de referência de 99% de reflectância. Os resultados foram avaliados e mostram que a distância interfere no retorno da intensidade. A partir dos resultados dessa pesquisa, sugere-se que os dados da intensidade sejam calibrados em relação à distância antes de utiliza-los como fonte para estudos das características físico-químicas dos alvos.

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## 1. INTRODUCTION

The forest sciences as well as other areas of knowledge benefit from technological advances to develop increasingly their working methods and increase their knowledge of their specific field of study. Are continually developed new equipment and methods to support these applications and, among the equipment and systems developed in recent years, systems for laser scanning and profiling have been consolidated as one of the most effective technologies for geospatial data acquisition. The automated data collection expanded rapidly in recent years, in line with the technological advances made in the areas of surveying and mapping. The scanning systems and laser profiling, also known as Terrestrial Laser Scanner (LST) have some characteristics that apply so important in forest analysis. The LST has the great advantage of being a method of data acquisition and fast non-destructive. In most cases, the equipment Terrestrial Laser Scanner generate its own format file of the data collected. However, these files have similarities with respect to the information. The files are based on a structure in which are stored the coordinates of the points in space (X, Y, Z), the value of the intensity of return laser pulse (I), and if there availability, the values f rom the digital camera (RGB) both internally and externally, creating a sequence of information (XYZ, I, RGB). Spatial information is commonly used for volume calculations and identification of geometric features. RGB data aid in the visual identification of features and provide a better understanding of the objects raised with the laser, but when it comes to return intensity values of the pulse laser, there is a lack of specific applications for the use of such information, which can provide Variations in physical-chemical characteristics of the targets. Thus, the main objective of this study was to evaluate the influence of the distance to the target in the data acquisition intensity targets forest in order to support future studies of correlation between this variable and the physicochemical characteristics of the targets. In this study we used the Terrestrial Laser Scanner 3D Ilris with Optech operating principle based on flight time and wavelength of 1535nm spectral range from infrared magnetic medium. The data acquisition of intensity in forest targets were evaluated from different distances (1m, 2m, 3m e 5m) and radiometric resolutions (8 e 16 bits). After processing, data were analyzed with in-house software based on the k-means algorithm in order to identify branches and leaves from their intensity values. Although the edge effect occurred in all experiments, the results show that this method is efficient for the identification de leaves and branches from distances up to 5 meters and resolution of 8 bits.

## 2. MATERIALS AND METHODS

The study materials for the execution of experiments data acquisition intensity LST return targets were two forest trees (called tree 1 and tree 2) located inside the campus of the University of Vale do Rio dos Sinos in Sao Leopoldo , RS. As the focus of the study was to develop procedures for data acquisition, did not bother to set a particular plant species in the study. The LST used was ILRIS 3D Optech, whose technical specifications are described in Table 1.

The method was planned in two stages. The first consisted of scanning the entire tree 1 for image classification and segmentation of branches and leaves. The second survey was carried out from two different targets on the tree 2. One was a sample on the tree trunk and the other was tested the pattern of Spectralon ® 99% reflectance at different distances and radiometric resolutions of 8 and 16 bits.

| |
|---|
| Maximum range between 400 meters for objects with reflectance of 10% and 1200 meters for objects with 80% reflectance |
| Linear accuracy of 7 mm and an angular precision of 8 mm, both at a distance of 100 meters from the equipment; |
| The divergence of the laser, of 0.00974 °, causes, in a distance of 100m from the equipment, the diameter of the laser beam emitted is of 2.2 inches. |
| The laser has class 1 so, it's safe to the human eye. The laser operates at a frequency of 1535 nm, thus, in the medium infrared range; |
| The Ilris 3D operates in windowed mode, so, at each position of the equipment it has a field of view of 20 º in all directions, giving a window of 40 º x40 º. |
| It has integrated a digital camera of 3.1 Mpixel, located off-axis of the machine, which causes a distortion in the parallax objects located less than 35 to 40 meters of the equipment. |

Table 1. Technical Specifications LST ILRIS - 3D, Optech (2009)

### 2.1 First Experiment

In the first experiment was performed scanning the tree 1 for approximately 40m of distance to be avoided parallax distortion. After scanning, the file from the cloud of points with 8-bit radiometric resolution was imported into software PolyWorks containing information (X, Y, Z, I). The data went through a process of manual cleaning, eliminating noise and / or objects that were not part of the study material. The point cloud was classified into two classes (trunk and leaves) using the k-average. This algorithm is a cluster classifier which performs a process of partitioning a population of "n" in "k" classes. These partitions represent satisfactorily the internal variation occurred within each class. In addition to the above, the k-mean classifier is easily programmable and computationally economical, being able to process large volumes of data in applications such as grouping by similarity, predicting nonlinear approximation of multivariate distributions and nonparametric tests, among others

(MacQueen , 1967). Two images were drawn from the classification performed with two and three classes. The third class was created to see if it would be possible to separate the effect of edges already described by Boehler et al. (2001). This effect relates to the first and second pulses to return to LST in that part of the beam energy reaches the other side of the tree and hits the target that is behind, the return, the sensor records a pixel that merges data tree and target ago.

**2.2 Second Experiment:**

The method of acquiring the intensity data of this stage is shown step by step in Figure 1. The stem of the tree originally possessed lichens, which were removed so that the target area was cleaned (Fig. 1a). After cleaning, an area has been selected in the trunk-shaped circle and marked with black marker (Figure 1b). In consequence, were marked distances from the outlet of acquiring the intensity data. For this, we used measuring tape, beacons measurement and pickets (Figure 1c and 1d). For fixing the Spectralon ® 99% on the tree stem has required a plastic bag so the Spectralon ® 99% does not have contact with the surface of the tree and would be fixed as well as removed (Figure 1e). The plastic was cut so that the center of Spectralon ® 99% was the same without the coating, leaving only a 5mm circular ledge to secure the card. It is worth mentioning that this fixation procedure was performed with plastic protection for the preservation of Spectralon ® 99%, because it cannot come into contact with dust or grease. For the viewing geometry was kept the same for both targets, sometimes scanned the Spectralon ® was 99% with the plastic down and was now raised to the scanning of the trunk (Figure 1e and 1f). For the same geometry, were also kept the heights of park equipment (Figure 1g). Scanning was accomplished with a spacing of 0.5 mm between points at four distances, 1m, 2m, 3m and 5m both the trunk and for the Spectralon ® 99%. These distances were analyzed to determine what minimum spacing between the target and the LST data acquisition intensity.

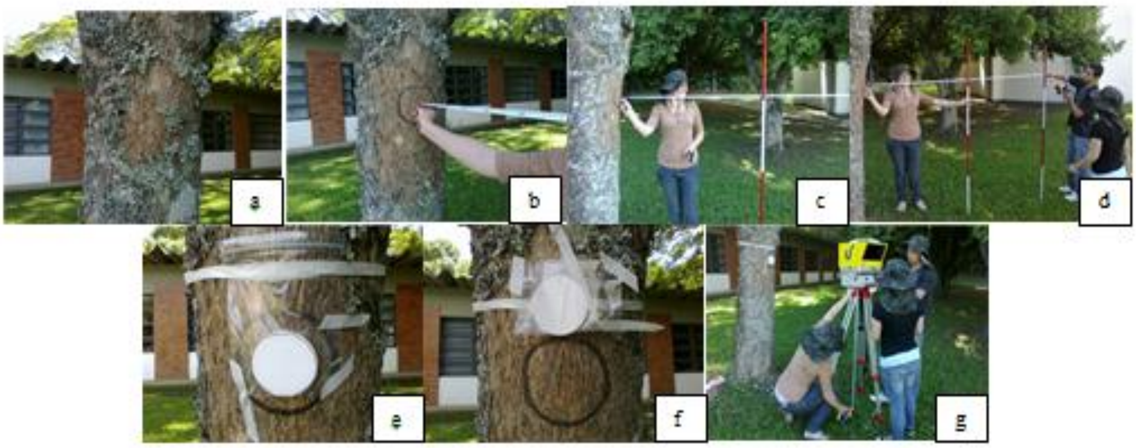


Figure 1. Mosaic of pictures showing the procedures for acquiring the intensity data as a function of distance and type of targets. a) tree before cleaning. b) after cleaning tree and the

target demarcated. 1c and 1d) Marking of distances. 1e and 1f) representation of the target in the trunk and 99% Spectralon ®. g) Measure the height of park equipment for maintaining the viewing geometry.

After the scans performed according to the method above data (X, Y, Z, I) were processed and spatially being possible to clearly identify the targets of interest (Figure 2). The detail in red illustrates the selection of the target point cloud in the stem of the tree without the Spectralon ® 99%.

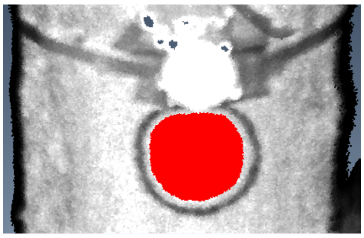

Figure 2. Selection of points of interest in the point cloud in red.

For the different distances of data collection (1m, 2m, 3m and 5m) could be generated for each target (stem and Spectralon ® 99%), a point cloud quantifying the number of points and the average intensity return laser. Such information could establish some criteria for imaging target forest when the objective is the correlation of physicochemical properties with laser intensity.

## 3. RESULTS AND DISCUSSION

### 3.1 First experiment

With respect to the first scanning tree, Figure 3 shows the results. Figure 3 (a) shows the picture of the camera coupled to the LST. It is from this image that makes the association attributes (R, G, B) at each point cloud. We noticed that the solar day lighting interfered in image quality. This did not affect the results since the variables were (X, Y, Z, I). Figure 3 (b) illustrates the scanning window, in this case with the tree of interest. In Figure 3 (c) you can view the image of the object of study, elaborated with information coordinates X, Y, Z and intensity (I).

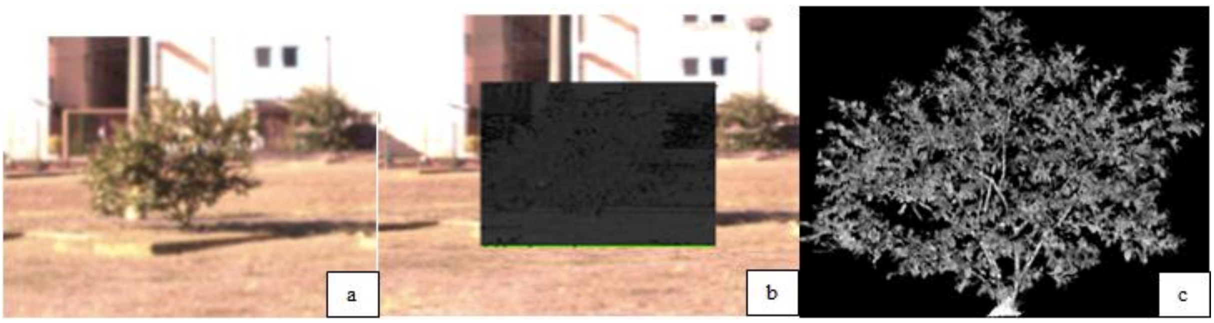

Figure 3. (a) Photograph of the digital camera coupled to LST before scanning. (b) Image of the LST screen during scanning, with the green line showing the pixels already scanned. (c) 3D model based on the coordinates X, Y, Z and intensity data from one tree after scanning.

The results of the classification of the object can be seen in figure 4, where the intensity of the point cloud with radiometric resolution of 8 bits was ranked 2 and 3 classes. Figure 4 (a) shows the tree classified into two classes and it was found that the algorithm could differentiate the branches of the sheets. In the process of 3D scene visualization was detected the occurrence of edge effect on the object. To try to distinguish the edge effect in the 3D scene the object was classified into 3 classes with the intention of segmental branches, leaves and edge effect as shown in Figure 4 (b). The edge effect can be observed around the two sheets of classifications in Figure 4 (a) white in color and in Figure 4 (b) more prominent in black. The branches were more visibly targeted in Figure 4 (a).

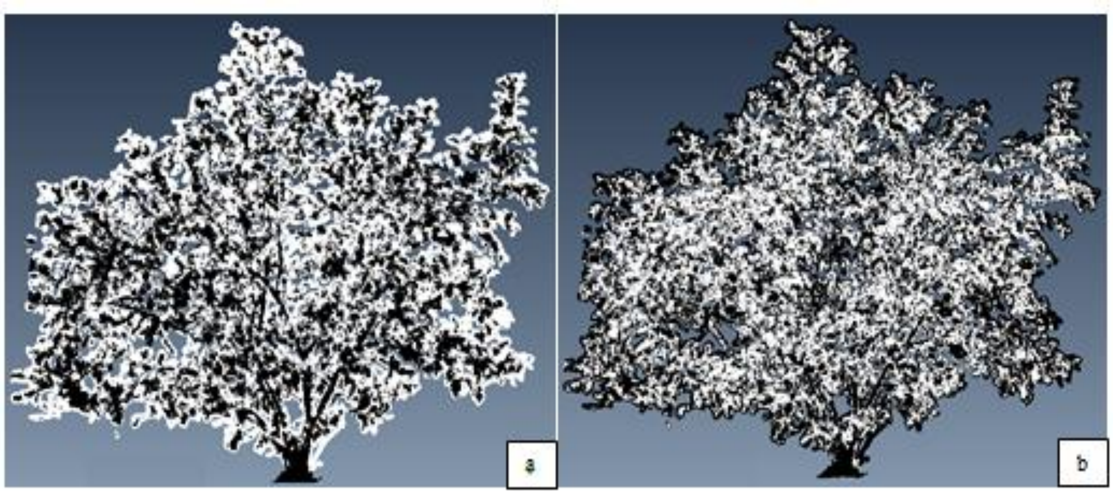


Figure 4. Cloud points for 8-bit intensity classified in k-average classes 2 and 3 respectively.

**3.2 Second Experiment:**

At this stage it was possible to verify the behavior of the return intensity of laser interacting with the targets set in the object of study. Data from intensities at distances of 1, 2, 3 and 5 meters were collected. For these distances the object was processed with radiometric resolutions of 8 and 16 bits.

In the scanning step was not possible to select only the target, since the camera causes a parallax distortion between the point cloud and photography. This distortion is caused by the fact that the camera be located off-axis equipment. Thus, the scans were performed with higher points than needed as an alternative to compensate for this distortion. Scanning at a distance of 1m was unable to register any return of intensity. Figure 5 illustrates the targets reconstructed from the point cloud generated by LST positioned a collection of 2 m from the target. It was found that this distance in some parts of the stem record does not occur, causing voids to both processing with radiometric resolution of about 8 bits to 16 bits (Figure 5a). Similar results were found by scanning the Spectralon ® 99% (Figure 5b). At that same distance was possible to verify the edge effect in both Figure 5a and Figure 5b, which appears in black. This effect appeared in all images.


| | | | | | |
|---|---|---|---|---|---|
| Picture from LST Camera | Tree with distance of 2m with 0.5 mm and 8-bit resolution | Tree with distance of 2m with 0.5 mm and 16-bit resolution | Picture from LST Camera | Tree with Spectralon® 99% with distance of 2m, 0.5mm of spacing and 8-bit resolution | Tree with Spectralon® 99% with distance of 2m, 0.5mm of spacing and 16-bit resolution |

Figure 5. Images produced by the intensity of the LST in 2m target with 0.5mm spacing between points and radiometric resolution of 8 and 16 bits. Edge effect highlighted in red rectangle.

There were no return points in different parts of the target area of interest including the distance of 3m (Figure 6). The mean intensity of return of 99% Spectralon ® was maximal (ND = 255) over a distance of 5m (Figure 7). Although ILRIS - 3D operate with the principle of time of flight, the same result was observed by Kaasalainen et al. (2009), who used equipment with early stage.


| | | | | | |
|---|---|---|---|---|---|
| Picture from LST Camera | Tree with distance of 3m with 0.5 mm and 8-bit resolution | Tree with distance of 2m with 0.5 mm and 16-bit resolution | Picture from LST Camera | Tree with Spectralon® 99% with distance of 3m, 0.5mm of spacing and 8-bit resolution | Tree with Spectralon® 99% with distance of 3m, 0.5mm of spacing and 16-bit resolution |

Figure 6. Images produced by the intensity of the LST 3m target with 0.5mm spacing between points and radiometric resolution of 8 and 16 bits.

The image with radiometric resolution of 16 bits contrast presented very close to 8 bits at a distance of 2m. In the distance of 5m there was no sufficient contrast for selecting points in the 16-bit image (Figure 7). At a distance of 5m and radiometric resolution of 8 bits, the return of the average intensity of the trunk was ND = 239.08, indeed expected since the trunk does not reflect 100% of the incident energy (Figure 7a). Table 2 shows the summarized results of the second stage of the research.


| | | | | | |
|---|---|---|---|---|---|
| Picture from LST Camera | Tree with distance of 5m with 0.5 mm and 8-bit resolution | Tree with distance of 5m with 0.5 mm and 16-bit resolution | Picture from LST Camera | Tree with Spectralon® 99% with distance of 5m, 0.5mm of spacing and 8-bit resolution | Tree with Spectralon® 99% with distance of 5m, 0.5mm of spacing and 16-bit resolution |

Figure 7. Images produced by the intensity of the LST 5m target with 0.5mm spacing between points and radiometric resolution of 8 and 16 bits.

Table 2. Summary of the results of the second stage.

| | Tree | | Spectralon® 99% | |
|---|---|---|---|---|
| Distance | 8 bits<br>n° of points* / average intensity | 16 bits<br>n° of points* / average intensity | 8 bits<br>n° of points* / average intensity | 16 bits<br>n° of points* / average intensity |
| 1m | no LST return | no LST return | no LST return | no LST return |
| 2m | 4985 / 86,87 | 4985 / 255 | 15614 / 110,43 | 19357 / 255 |
| 3m | wasn't possible to select points | wasn't possible to select points | wasn't possible to select points | wasn't possible to select points |
| 5m | 45733 / 239,08 | wasn't possible to select points | 19593 / 255 | wasn't possible to select points |

* selected area of interest

## 4. CONCLUSION

The main objective of this paper is to present a method for data acquisition intensity targets forest in order to support future studies of correlation between this variable and the physicochemical characteristics of the targets.

The laser scanner was used Ilris 3D Optech whose operating principle is based on flight time and its electromagnetic spectrum is the range of the mid-infrared.

The study showed that the segmentation technique based on the intensity of return laser could efficiently separate leaves and branches in a target forest. As the object is formed by a cloud of points in space is possible to determine the total volume of each variable separately, thus facilitating the process of determining the biomass.

Any object modeled from an LST is subject to the edge effect. In this study it was observed this phenomenon and the k-mean classifier is efficient for your viewing when the object was segmented into 3 classes: twigs, leaves and edge effect. In the specific case of a target forest, once targeted that effect is possible to implement algorithms to try to reduce it in a cloud of points.

Due to the results obtained with laser scanner Ilris 3D suggests that the minimal distance for scanning target forestry, in order to study correlation between the intensity of the return laser and the physicochemical properties of the target, either 5 meters modeling point cloud with radiometric resolution of 8 bits.

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