

## RELIABILITY CONTROL OF DIGITAL IMAGES THAT ARE USED IN FOREST INVENTORY AND MANAGEMENT IN GREECE

V. C. Drosos

School of Forestry and Management of the Environment and Natural Resources,  
Democritus University of Thrace,  
N. Orestiada, Greece  
e-mail: vdrosos@fmenr.duth.gr

**Keywords:** reliability, control, forest inventory, forest management, digital image

**Abstract:** *Aim of this paper is the reliability control of digital images that are come of photogrammetry and are used in forest inventory and forest management in Greece. The method is based, on the determination of control points' number for the cover of image. The control points are distributed accidentally so that is achieved unbiased evaluation for the total of the image. With the help of accuracy criteria of the measurements is estimated the error in various positions of the image. The improvement of control process of the orthophotomaps is resulted and more generally images that are useful as bases. Digital orthophotographs are used first either for visual reproduction or as base. However, orthophotographs offer many independent potentialities, possibilities especially for the cadastre, digital maps' update, cartography, create of databases, road network design and construction, harvesting, environmental impact assessment etc.*

### 1. Introduction

According to the decision of Ministry of Agriculture No 99580/506 from July 1, 1999 under Law 2664/1998 "National Land Registry and other terms" specified in section 6.8.3, a digital terrain model (DTM) that will be submitted along with forest maps in the "National Digital Cadastre", also by decision of the Organization of Cadastre and Cartography of Greece (O.C.CH.G.) Board of 168/3a/17-7-2003 Official Gazette Fascicle (OGF former, ex-B/1042/28-7-2003) on the content and structure of the Cadastre sheet, and management of digital cadastral data, maintaining, keeping and storing data files based on Law 3127/2003 "Amending and supplementing the laws 2308/95 and 2664/98 and other terms" (OGF former, ex-A/67/19-3-2003) in Article 3 determine that the digital database of spatial information of the "National Digital Cadastre" will be maintained and updated by the "Cadastre LC" (Limited company) using GIS technology.

Forest Cadastre and application of modern technologies such as digital photogrammetry and geographic information systems can contribute to reliable and efficient in mapping and assessment of trends in changing forest land use in a planned zoning - Development Planning (Stergiadou et al., 2006).

The current technology of photogrammetry, remote sensing and hybrid information systems results in the digital image. The contribution of photogrammetry in the working out of Cadastre is very important and key role played by digital orthophotos. The digital orthophoto has practically the same characteristics as a linear map, and can be used as a basic background in Geographical Information System (GIS), significantly reducing both the cost and duration of a work. The data for the creation of digital images are from observations at E, N and H (elevations) and whenever possible additional information on spatial phenomena that significantly influence the shape of the earth's physical surface or non-spatial phenomena.

Digital video recording allows us to record not only the visible but the invisible spectrum (infrared, ultraviolet, thermal part etc.) (Hord, 1986; Torlegård, 1992). The surface recording of information is no longer the film, but a series of vectors of pixels, which has a direct influence on the resolution, but also on the flatness of the surface and on the way the image processing among many others. The digital collection of data has a direct impact on the way we appreciate the data any more, which may have a life cycle much shorter than before, known as “consumables” data (Leberl, 1991). Both the nature and rate of data collection have changed radically detrimental fatal and the same the nature of photogrammetry (Ehlers, 1991; Bähr and Wiesel, 1991), which was no longer deals only with the mapping of space, but rather to monitor events that develops in it (Patias, 1993).

The digital cartographic bases in format image are geometrically corrected digital images related to a geodetic reference system and have basic cartographic processing (Offermann, 1993). Often come from several images, may even be a composite of images of different types. These images can be derived from satellite, aerial and surface platforms. The characteristics and magnitude of errors associated with each type of image are different (Richards, 1986). A basis consisting of two or more types of images can present significant changes of geometric precision in various positions (Thapa and Bossier, 1992). Each pixel (image pixel) in a digital orthophoto is a unique feature of the real world on the ground (Baltsavias, 1996). The production of digital orthoimagery is the first fully automated procedure of digital photogrammetry (Baltsavias, 1996).

The digital image (orthophoto) provides major advantages compared to the corresponding analog, especially the flexibility of production and the expected product along with other data. The other advantages are more and others less obvious. The largest percentage of information that including in digital image, the Digital Terrain Model (DTM) as an intermediate product, the minimum on time and economical cost review of information, almost no dependence on old data, are some of them. Nowadays, the production of digital orthophotos has become more functional due to the development of greater computing power with sufficient resources, easier retrieval of data entry, increased production of digital data, development of several commercial systems producing orthophotos and new application fields, especially in combination with GIS and digital cartography. Today, digital orthophotos are mainly used either for visualization or as a background. However, orthophotos provide many independent features, especially for cadastre, updating digital maps, automated Cartography, production databases, extraction of three- dimensional information and classification of features.

The purpose of this work is to assess the reliability of digital images derived from photogrammetry that are used in forest inventory and management in Greece.

## **2. Materials and Methods**

### **2.1 Materials**

To achieve the aim of research have used a pair of dispositive with No. 223 404 and No. 223 405 scale 1:30.000 around Arnaia taking year in 1994, following a digitized (scanned) by a special photogrammetrical scanner, processed with software package Leica Photogrammetry Suite (LPS 9) of Leica Geosystems Corporation. Like this created a digital orthophoto that is necessary for the comparison with the territorial coordinates.

### **2.3 Methodology**

The relative orientation as well as the automated production of digital terrain model (DTM) was carried out with the application of automatic correlation of homologous pixels using the standard frames of the radiometric values of the pixels (area based matching). This method is commonly used among other methods in the digital photogrammetry (Wolf and Dewitt, 2000). Also LPS 9 software offers the production and use of the digital images' pyramids in order to improve the final results as they are a helpful tool for finding the appropriate initial values which are used to determine the best solution to the problem of digital correlation (Kraus, 1996).

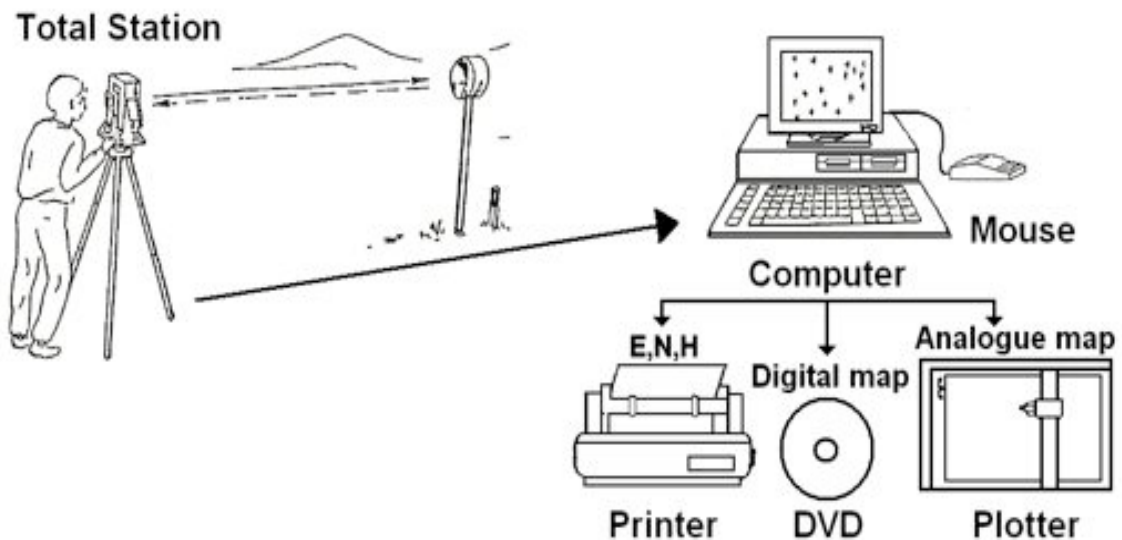
The final product of the photogrammetric processing of diapositives (D/P) is a digital orthophoto for the year 1994, resulting from the differential regression of D/P by eliminating the position errors that are entailed because of the terrain relief. Regarding the geometric accuracy of images used as backgrounds, checking all the pixels is practically impossible and in theory unworkable. So the checked points were selected by random sampling. As sampling method was applied the simple random sampling, because of its simplicity and that requires the least possible knowledge on population than any other method (Matis, 1989). Simple random sampling is a fundamental scientific method of choice. All other sampling procedures are modifications (variations) of simple random sampling, designed to achieve greater economy and accuracy (Matis, 1989).

The suitability of the selected pixels was confirmed by their renown on the ground. Any feature was not recognizable on the ground was canceled and another pixel was selected in its position. If there was an area covered by water or wet lands, and there was no recognizable feature in the field, then this area was excluded.

The difference between image coordinates and surveyed ground coordinates E and N can be estimated satisfactorily by the following precision criteria because the errors of scale in the axes of E and N are similar. This hypothesis applies to the H axis, although the morphology of the ground may result in different scale errors of altitude.

More the differences in the coordinates should to be statistically tested for gross errors before they are used. Gross errors may be presented in coordinates derived from the image as on the ground ones. One source of error may be that we were included information - data from independent measurements. Any gross errors detected should be eliminated by repeating the measurements. For best accuracy the size of repeats can vary from three (3) to ten (10) observations (measurements).

The data obtained were processed statistically in the light of equal weight observation. In order to check the error of measurements as “true values” were the ground coordinates derived from the topographic method (total station). The collection of topographic data was shown in Figure 1.



**Figure 1. Classical method for collecting data**

#### **2.4 Precision criteria of series measurement**

The error is a criterion for estimating the degree of precision of a series of measurements or estimating if a set of measurements is more accurate than another one. To this end, the following criteria are often used (see, e.g., Simbahan et al., 2003; Rodriguez-Pérez et al., 2006):

a. The criterion of mean absolute error ( $\sigma_a$ ).

The mean arithmetic error of a series of measurements is defined as the ratio of the sum of the absolute values of potential errors  $u_1, u_2, u_3, \dots, u_n$  divided by the number of measurements  $n$ .

a1) Mean (horizontal positional) absolute error along Northing and Easting directions  $\sigma_{aE}$  and  $\sigma_{aN}$  (or  $MAE_E$  and  $MAE_N$ ):

$$\sigma_{aE} = \pm \sum_{j=1}^n |E_{true} - E_d| / n \quad (1)$$

$$\sigma_{aN} = \pm \sum_{j=1}^n |N_{true} - N_d| / n \quad (2)$$

a2) Mean (horizontal positional) absolute error  $\sigma_a$  (or MAE):

$$\sigma_a = \pm \sqrt{\sigma_{aE}^2 + \sigma_{aN}^2} \quad (3)$$

a3) Mean (vertical positional) absolute error  $\sigma_v$  (or  $MAE_v$ ):

$$\sigma_v = \pm \sum_{j=1}^n |V_{true} - V_d| / n \quad (4)$$

where  $\sigma_a$  is the mean (horizontal) absolute error (MAE),  $E_{true}$ ,  $N_{true}$  and  $V_{true}$  are the true coordinates of the total station for the x, y and z-axis respectively,  $E_d$ ,  $N_d$  and  $V_d$  are the corresponding coordinates measured in the digital image and  $n$  denotes the total number of measurements.

b. The criterion of mean squared measurement error ( $\sigma_s$ ).

There are errors that characterize the quality of measurements. Such is the typical or mean square error which standardizes a specific set of measurements and is considered the best criterion for accurate results.

b1) Root Mean (horizontal positional) square error along Northing and Easting directions  $\sigma_{rE}$  and  $\sigma_{rN}$  (or  $RMS_E$  and  $RMS_N$ ):

$$\sigma_{rE} = \sqrt{\left( \sum_{j=1}^n (E_{true} - E_d)^2 / n \right)} \quad (5)$$

$$\sigma_{rN} = \sqrt{\left( \sum_{j=1}^n (N_{true} - N_d)^2 / n \right)} \quad (6)$$

b2) Root Mean (horizontal positional) square error  $\sigma_r$  (or RMSE):

$$\sigma_r = \pm \sqrt{\sigma_{rE}^2 + \sigma_{rN}^2} \quad (7)$$

b3) Root Mean (vertical positional) square error  $\sigma_{rV}$  or  $RMS_V$ :

$$\sigma_{rV} = \sqrt{\left( \sum_{j=1}^n (V_{true} - V_d)^2 / n \right)} \quad (8)$$

where  $\sigma_r$  is the root mean square error (RMSE),  $E_{true}$ ,  $N_{true}$  and  $V_{true}$  are the true coordinates of the total station,  $E_d$ ,  $N_d$  and  $V_d$  are the coordinates measured in the digital image and  $n$  is the total number of measurements.

The RMSE tends to place more emphasis on larger errors and, therefore, gives a more conservative measure than the MAE (Simbahan et al., 2003).

Briefly in order to estimate the accuracy of a digital image the following steps can be used:

- The calculation of sample size using random sampling.
- Identify the sample size from the image in the field and check the topography.
- Calculate the ground coordinates of the points of objects.
- Calculate the differences between ground and image coordinates of the selected items.
- Define point precision. Calculation of the horizontal errors  $RMS_E$ ,  $RMS_N$  and calculation of the vertical error  $RMS_V$  (ASPRS, 1990; Goodchild, 1991).

## 2.5 Calculation of sample size

To obtain the estimate of the proportion of the population (denoted by  $\hat{p}$ ), which is the unbiased estimator of the actual proportion of the population  $p$ , we use the following expression:

$$\hat{p} = \frac{\sum_{i=1}^n P_i}{n} \quad (9)$$

The estimated standard error of the proportion of the population  $s_{\hat{p}}$  - without the finite population correction because the sampling fraction is small - and the corresponding confidence interval of  $\hat{p}$  is given by the equations:

$$s_{\hat{p}} = \sqrt{\frac{\hat{p} \times (1 - \hat{p})}{n - 1}} \quad (10)$$

$$CI(p) = \hat{p} \pm s_{\hat{p}} \quad (11)$$

where  $t$  denotes the value of the student distribution for probability  $(1-\alpha) = 95\%$  and  $n-1$  degrees of freedom.

The sample size was determined based on simple random sampling methodology (see, e.g., Yates et al., 2003; Matis, 1989; Kalamatianou, 2000; Damianou, 1999). Simple random sampling was the sampling method selected, due to its simplicity and the fact that it requires a minimal knowledge of the population compared to any other method. Although simple random sampling without replacement was used, the finite population correction can be ignored because the sample size  $n$  is small relative to the population size  $N$  (see Pagano and Gauvreau, 1996).

Pre-sampling was conducted on a sample size of 50 points to estimate the variable with the greatest variance under the desired selected error, while the rest are estimated with a greater accuracy than was

initially defined (Matis, 2001). According to the pre-sampling the higher proportion value is  $p=0.49 \approx 0.50$ , therefore  $1-p=0.5$  and consequently due to that the variables refer to proportions, the determination of the total sample size is based in the following expression:

$$n = \frac{t^2 \times \hat{p} \times (1 - \hat{p})}{e^2} = \frac{1.96^2 \times 0.5 \times (1 - 0.5)}{0.05^2} = 384.16 \quad (12)$$

Where:

$t$  = the value of the Student distribution for probability  $(1-\alpha) = 95\%$  and  $n-1$  degrees of freedom. Because the sample size is large ( $n$  greater than 50) the  $t$  value corresponds to the value of normal probability distribution for the desired probability. In practice, for the 95% probability, the  $t$  value is 1.96 (Matis, 1988).

$\hat{p}$  = the estimated proportion from the sample.

$e$  = maximum acceptable difference (proportion of error we are prepared to accept) between the sampling proportion and the unknown proportion of the population (We accept for the current analysis that  $e = \pm 0.05$ , i.e.  $\pm 5\%$ ).

We therefore accepted a sample size of 385 points.

### 3. Results

Table 1 shows the topographic and digital coordinates of points and their differences.

Based on the theory of errors statistically analyzed the differences between the topographic and digital coordinates and arise, come to light the data in Table 2.

### 4. Discussion - Conclusion

From a close examination of results we investigate that:

- The accuracy of digital images in pure forest areas are small (Table 2) and dependent on how dense is the wood in the region.

- The accuracy of digital images is less than the topographic (Table 2). The height accuracy of 10.929 m (Table 2) is less than planimetric 8.989 m and meets for guidance - management purposes. If used in digital basis for the cadastre, a greater contribution of topographic methods to control and then the details such as buildings, roads, fields, etc. shopper greater reliability.

- Note based on the mean square error of measurements characterizes their precision that the error in E (X, east) is smaller than in N (Y, north). This is followed as can be seen from the data in Table 2 and the criterion of mean absolute error. The main reason for its existence is the magnetic variation and that the magnetic north is different from the north of the map and geographic north.

**Table 1. Topographic and digital coordinates and their differences**

Topographic			Digital			Topographic - Digital		
E	N	H	E	N	H	$E_T - E_D$	$N_T - N_D$	$H_T - H_D$
2693.347	16781.88	976.11	2693.347	16781.88	977	0	0	-0.89
2667.195	16788.59	975.07	2667.448	16789.51	976	-0.253	-0.92	-0.93
2659.448	16792.09	775.873	2659.829	16793.28	774	-0.381	-1.19	1.873

2657.205	16800.29	782.316	2657.876	16801.55	779	-0.671	-1.26	3.316
2650.5	16838.71	804.405	2652.528	16840.18	807	-2.028	-1.47	-2.595
2648.618	16858.62	803.224	2651.348	16860.15	806	-2.73	-1.53	-2.776
2655.334	16876.39	800.255	2658.686	16877.68	801	-3.352	-1.29	-0.745
2659.015	16885.69	799.8495	2662.692	16886.84	779	-3.677	-1.15	20.85
2660.584	16905.63	800.947	2664.962	16906.71	795	-4.378	-1.08	5.947
2656.439	16924.17	800.808	2661.473	16925.39	806	-5.034	-1.22	-5.192
2644.115	16943.59	862.051	2649.84	16945.23	874	-5.725	-1.64	-11.95
2621.118	16943.23	863.48	2626.844	16945.67	860	-5.726	-2.44	3.48
2595.275	16940.38	864.33	2600.917	16943.73	875	-5.642	-3.35	-10.67
2575.285	16939.75	864.56	2580.917	16943.66	872	-5.632	-3.91	-7.44
2555.484	16942.57	863.77	2561.228	16947.17	872	-5.744	-4.6	-8.23
2526.207	16949.11	867.13	2532.199	16954.74	859	-5.992	-5.63	8.13
2506.561	16952.86	861.62	2512.698	16959.18	862	-6.137	-6.32	-0.38
2486.563	16952.55	857.18	2492.701	16959.57	864	-6.138	-7.02	-6.82
2461.613	16954.11	863.46	2467.821	16962.02	856	-6.208	-7.91	7.46
2442.634	16955.01	863.9	2448.886	16963.58	856	-6.252	-8.57	7.9
2435.64	16972.68	866.27	2442.518	16981.48	858	-6.878	-8.8	8.27
2433.391	16984.46	866.24	2440.686	16993.34	835	-7.295	-8.88	31.24
2425.354	16997.13	866.256	2433.099	17006.28	835	-7.745	-9.15	31.256
2412.689	16989.09	866.043	2420.159	16998.69	858	-7.47	-9.6	8.043
2402.417	16981.12	653.46	2409.613	16991.09	660	-7.196	-9.97	-6.54
2389.687	16978.49	653.9	2396.798	16988.91	660	-7.111	-10.42	-6.1
2364.884	16975.35	656.27	2371.9	16986.65	663	-7.016	-11.3	-6.73
2345.921	16974.16	657.24	2352.907	16986.12	664	-6.986	-11.96	-6.76
2327.676	16979.46	656.256	2334.86	16992.06	665	-7.184	-12.6	-8.744
2309.287	16977.43	657.043	2316.411	16990.68	667	-7.124	-13.25	-9.957

**Table 2. Orthophotograph accuracy**

$\sigma_{uE}$ $\pm m$	$\sigma_{uN}$ $\pm m$	$\sigma_u$ $\pm m$	$\sigma_v$ $\pm m$	$\sigma_{rE}$ $\pm m$	$\sigma_{rN}$ $\pm m$	$\sigma_r$ $\pm m$	$\sigma_{rV}$ $\pm m$
5.124	5.614	7.601	8.040	5.632	7.006	8.989	10.929

- The position error in the orthophotos depends on their scale, the surveying errors, the errors of performance, the accuracy of the methods by which identified the locations, inexperience or cognitive deficiencies of the involver and problems with the geodetic reference model or problems with calibration of measuring instruments and performance.

The advantages of digital orthophotos are (Kersten and O' Sullivan 1996):

- High precision, stability and delivery of large volume of information.
- The production is more economical and efficient than the production of analogue orthophotos.

- Flexibility in the way of production and the derived products.
- High degree of automation.
- Simple radiometric image processing (image quality photo mosaic creating, editing of colors, etc.).
- Add vector data and additional information (context, place names, numbers, etc.) and orthophotomap creating.

All the above advantages are in the digital orthophoto of the study area. The orthophoto is an accurate representation of the study's area earth surface. It has the benefits of high detail, timely coverage combined with the benefits of a map including uniform scale and true geometry because we checked the geometry with the help of a number of precision criteria.

Based on the above conclusions we suggested:

Accuracy issues were of central concern in all scientific disciplines. The accuracy of digital orthophotos can be considerably enhanced if attention the factors affecting the position error and detailed mentioned above.

The scanning of the disapositives have to be done with care and diligence as it constitutes the primary source of spatial (altitude and horizontal) information during the process of creating a D.T.M., thus contributing to the composition of the final accuracy and quality of the D.T.M. together with other factors involved in the process. Also available from the original diapositive can produce orthophoto of smaller scale without losing clarity and precision, in say without loss of spatial and thematic information.

The proposed detection of accuracy is statistically sound and easily followed. They are not involved complex algorithms or difficult calculations.

The field tests are painful and expensive, but offer a unique precision used as a yardstick. The introduction of sophisticated measurement techniques GPS (three frequencies) in real time can provide an effective and economical technique for identification and exact location of discrete objects, hedges, shrubs and trees, elements that present in abundance in digital images. The procedure used in practice seems to be economical, it gives good results in terms of performance moves is good.

## References

- American Society for Photogrammetry and Remote Sensing, (ASPRS). (1990). ASPRS accuracy standards for large-scale maps. *Photogrammetric Engineering and Remote Sensing*, 56 (7), 1068-1070
- Bähr, H – J. and Wiesel, W. (1991). *Cost-Benefit analysis of Digital Orthophoto Technology*. In: Ebner/Fritsch/Heipke (Editors), *Digital Photogrammetric Systems*: Wichmann
- Baltsavias, Emmanuel P. (1996). Digital ortho-images - A powerful tool for the extraction of spatial - and geo-information. *Photogrammetry and Remote Sensing*, 51, 65-77
- Damianou, C. (1999). *Sampling Methodology: Techniques and Applications*. 3<sup>rd</sup> edition. Aithra Publications: Athens
- Ehlers, M. (1991). Digitization, digital editing and storage of photogrammetric images. *Proceedings of the 43<sup>rd</sup> Photogrammetric Week*, Stuttgart, 15, 187 – 193



- Goodchild, M. (1991). *Advances in Cartography*. In: J. Muller (Editor), Elsevier Applied Science: London
- Hord, R.M. (1986). *Remote Sensing: Methods and Applications*. J. Wiley Series: London
- Kalamatianou, A. (2000). *Social Statistics, One-dimensional Analysis Methods*. The Economic: Athens
- Kraus, K. (1996). *Photogrammetrie Band II. Verfeinerte Methoden und Anwendungen*. Duemmler Verlag: Köln
- Kersten, T. and O' Sullivan, W. (1996). Project Swissphoto-Digital Orthophotos for the entire area of Switzerland. *Proceedings of International Archives of Photogrammetry and Remote Sensing*, Vienna, Vol. XXXI, Part B2, 186-191
- Leberl, F. (1991). *The promise of Softcopy Photogrammetry*. In: Ebner/Fritsch/Heipke (Editors), Digital Photogrammetric Systems: Wichmann
- Matis, K. (1989). *Forest Biometry. I. Statistics*. Issue Press Office Aristotle University: Thessaloniki
- Matis, K. (2001). *Forest Sampling*. Issue Press Office of Democritus University of Thrace: Xanthi
- Offermann, W. (1993). Cartographic finishing and production of image map. *Conference Proceedings, EGIS '93*, Italy, 2, 1091-1095
- Pagano, M. and Gauvreau, K. (1996). *Principles of Biostatistics*. Ellin Publications: Athens
- Patias, P. (1993). Ortho, ortho and putting them in a Geographic Information System. *Proceedings of Scientific weekend*, Athens, 142-153
- Richards, J. A. (1986). *Remote Sensing Digital Image Analysis: An Introduction*. Second Edition. Springer-Verlag: New York
- Rodriguez-Pérez, J.R., Alvarez, M.F., Sanz E. and Gavela, A. (2006). Comparison of GPS Receiver Accuracy and Precision in Forest Environments. Practical Recommendations Regarding Methods and Receiver Selection. *GNSS Processing and Applications*.
- Simbahan, G.C., Dobermann, A. and Ping, J.L. (2003). Screening Yield Monitor Data Improves Grain Yield Maps. *Agronomy Journal*, 96, 1091-1102
- Stergiadiou, A., Karantzidis, N. and Drosos, V. (2006). Changing land use along the road Panorama - Hortiatis. *Proceedings of the 2nd Conference Environment Council of AUTH*, Thessaloniki, 542-549
- Thapa, K., and Bossier, J. (1992). Accuracy of Spatial Data Used in Geographic Information Systems. *Photogrammetric Engineering & Remote Sensing*, 58 (6), 835-841
- Torlegård, K. (1992). Sensors for photogrammetric mapping: Review and prospects. *ISPRS Journal for Photogrammetry and Remote Sensing*, 47, 241 – 262
- Wolf, P. and Dewitt, B. (2000). *Elements of Photogrammetry with applications in GIS*. 3th Edition, McGraw-Hill: New York
- Yates, Daniel, S., Moore, David, S., and Starnes, Darren, S. (2003). *The Practice of Statistics*, 2nd Edition, W.H. Freeman: New York