

Sustainable Agriculture through ICT innovation

**A Methodology Study for the Application of *Precision Forestry*
Approach in Logging Operation Chains**

Gallo Raimondo, Mazzetto Fabrizio

Free University of Bozen-Bolzano, Faculty of Science and Technology, Piazza
Università, Bolzano, 39100, Italy.raimondo.gallo@natec.unibz.it, fabrizio.mazzetto@unibz.it**ABSTRACT**

A new methodology for monitoring the performance of forest chain was here proposed and described. The target of this methodology is to develop a system to analyse operational time monitoring. The aim of this study is to propose an innovative and standardized approach of *Precision Forestry* in the use of GNSS for performance and productivity relief. GNSS is used as an integrated tool for measuring the efficiency of the forest mechanisation chain. So far, these surveys have been carried out through the application of GNSS only for logging operations. The validation data has been done through the comparison with a clock time relief. The preliminary overview about the application of this approach on harvesting operations has permitted to assess a good feasibility of the use of GNSS in the relief of operative times in high mechanised forest chain. Results showed an easy and completely identification of the different operative cycles and elementary operations phases, with a maximum difference between the two methodologies of 11.49%.

Keywords: GNSS, forest mechanisation performance, operational-monitoring, tower yarder, South-Tyrol, Italy

1. INTRODUCTION

In the last decades the IT principles and strategies have been applied to management of agriculture sector and in the past ten years also for the forestry. The focus of the application of this methodology is to increase the performances and the efficiencies of these macro-sectors. Nowadays the precision agriculture is a discipline with high levels of application. While in the precision forestry sector some research topics have not yet been completely explored. The specific literature considers the precision forestry as that discipline that uses IT devices to make measurements and surveys in order obtain a decision support system (DSS) (Lubello *et al.*, 2006). The Global Navigation Satellite System (GNSS) device is one of the equipment employed in Precision Forestry for position detection. This operation is guaranteed through its communication with the satellite's constellation that, besides communicating data on coordinates, it also communicates information on times necessary for the synchronisation between them. Considering the characteristic above mentioned, the focus of the study is to develop a methodology for the operational time acquisition through GNSS application.

R. Gallo, F. Mazzetto. "A Methodology Study for the Application of *Precision Forestry* Approach in Logging Operation Chains".

EFITA-WCCA-CIGR Conference "Sustainable Agriculture through ICT Innovation", Turin, Italy, 24-27 June 2013. The authors are solely responsible for the content of this technical presentation. The technical presentation does not necessarily reflect the official position of the International Commission of Agricultural and Biosystems Engineering (CIGR) and of the EFITA association, and its printing and distribution does not constitute an endorsement of views which may be expressed. Technical presentations are not subject to the formal peer review process by CIGR editorial committees; therefore, they are not to be presented as refereed publications.

Sustainable Agriculture through ICT innovation

The operational time study is considered as “a set of procedures for determining the amount of time required, under certain standard conditions of measurement, for tasks involving some human, machine, or combined activities” (Mundel and Danner, 1994). At this regard, the operational time study became an important parameter for the assessment of the productivity of a “forest yard”. With the term “forest yard” the Authors points to all forestry activities of logging operations where a team of forest operators, through the use of several forest machineries, operates in order to harvest the selected aboveground biomass. Thanks to the time survey it is possible to evaluate which is the efficiency of the work systems, the equipment or the team of workers. The analysis of the operational times, in forestry sector, is usually done thanks to the use of manual chronometers – time board with three analogical chronometers – (Berti *et al.*, 1989), or digital chronometers (Manzone, 2012), both require the use of stopwatches and paper (Wang *et al.*, 2003). Otherwise a data collector, developed for industrial management, based on handheld computer with specific software (Spinelli and Kofman, 1995; Visser and Stampfer, 1998) was used. All these methodologies of operational time study in forest always require the presence of two surveyors: one placed in the felling point and the other one placed on the temporary storage area for the relief of possible operative down-time during the downloading operations as well as the relief of timber’s volumes exploited. Also an automatic operational time study based on the installation of GNSS on machineries that operate in forest was developed. This methodology is mainly applied for the tracking of the movements of the machineries for felling and skidding operations in forest (Taylor *et al.*, 2006; Cordero R., *et al.*, 2005; McDonald and Fulton 2005, McDonald *et al.*, 2001, Taylor, *et al.*, 2001; Veal, *et al.*, 2001; McDonald 1999), for tracking the trucks for timber haulage (Simwanda *et al.*, 2011; Devlin and McDonnell, 2009; Devlin *et al.*, 2008; Sikanen *et al.*, 2005). Only a document on the use of GPS for the analysis of tower yarder was found (Nitami *et al.*, 2011).

Aim of the research is to develop a methodology as well as algorithms for the GNSS acquisitions data, which elaborate and interpret autonomously the different work phases. So no initial data must be communicated. GNSS instrument is installed directly on forest machineries during the operational time relief. An interpretation of satellite’s signal in operational activities was possible thanks to the development of an inference-engine able to transform raw data into intelligible management information (Mazzetto *et al.*, 2012). The operational time data acquisition system was then validated through the comparison with an operational monitoring relief with stopwatch. This paper presents the first results that were obtained.

2. MATERIALS AND METHODS

2.1 Acquisition data

The study-case was set in a forest of Norway spruce (*Picea abies L.*), where cultural operations of thinning were planned. The operations were organized in the municipality of Rodenek, in the Autonomous Province of Bozen (N-E of Italy) in a forest managed

P0208

R. Gallo, F. Mazzetto. “A methodology study for the application of Precision Forestry approach in logging operation chains”. EFITA-WCCA-CIGR Conference “Sustainable Agriculture through ICT Innovation”, Turin, Italy, 24-27 June 2013.

Sustainable Agriculture through ICT innovation

by the State-Owned Forest Company. Besides the silvicultural management task, the provincial company must execute all silvicultural exploitations. For the logging operations chains saw and a mobile tower yarder with crane and processor-head were employed. The tower yarder was a Koller® K507 mounted on a truck, with a MSK3 carriage for uphill and downhill logging.

The reliefs were performed installing a GPS mobile device on a cable yarder's carriage. The GPS unit is an ASCTECH® MobileMapper 6, a 12-channel singular frequency device; which runs Windows Mobile 6, and the specific software MobileMapper Field on a 400 MHz cpu. In order to assure a better reception of the satellite's signals, an external antenna was connected. In order to protect the GPS from any accidental shocks, a plastic box with layers of foam was built. Finally the box, which carried the GPS, was fixed to the internal body of the carriage (Figure 1a) with plastic ties. Meanwhile the external antenna was placed on top of the frame by means of a magnet. The antenna connection cable was fixed to the frame of the carriage with scotch tape in order to avoid any entanglement with branches (Figure 1b).



Figure 1. Installation of GNSS device on carriage.

The GNSS device was set for an automatic acquisition data of the carriage's position every 2 seconds. At every long recovery period and also at lunch break the carriage was dropped in order to save the recorded data and restart a new acquisition session.

A chronometric board with three stopwatches was used for the manual relief of operative times necessary to the validation of the data. For these acquisitions a surveyor was present in felling points, while a second one was on the temporary storage area; they were in communication through walkie-talkie. The operational monitoring was based on the identification of elementary operations for operative times as following:

- Travel empty: when the carriage starts movement from the download area to when it stops along the line for starting the hooking phase;
- Hooking: from when the carriage stops to when the log movements start;
- Side-lining: from the start of the log movements to the unlock of the carriage;

P0208

R. Gallo, F. Mazzetto. "A methodology study for the application of Precision Forestry approach in logging operation chains". EFITA-WCCA-CIGR Conference "Sustainable Agriculture through ICT Innovation", Turin, Italy, 24-27 June 2013.

Sustainable Agriculture through ICT innovation

- Load travel: from the unlock of the carriage to the next lock in proximity of the tower yarder for the downloading operations.
- Unhooking: from the lock of the carriage and start of the download operation to the unlock for the start of the next cycle;

Meanwhile, the operative down-times were identified due to: mechanical reasons (in the case of machine break-down), operative reasons (delay because the operator is interested in more than one activity), operator's personal reasons (personal needs) or study reasons.

2.2 Elaboration data

Data acquisition that, as already mentioned, was set with a period of collection of 2 seconds of interval, were post-processed through the use of the software MobileMapper Office 4.0. The elaboration returned correct coordinates, altitude and recording time. Using these data it was possible to obtain values of instantaneous speeds, movements, advancement direction. Since the system must work without any reference data, and also reduce the influence of possible low accuracy of the data, a methodology to establish a reference point $P_r(x_r, y_r)$ – external to the points cloud in proximity of the starting point – was necessary. The determination of P_r is done in order to obtain a starting point as reference for all distances of the entire points of the data-set. The first point collected by GNSS device identifies the start of the relief, then, the recognition of the logging direction establishes the choice of the coordinates for P_r . The attribution is done considering the maximum or minimum coordinates of the points of the cloud in the proximity of the initial point. When the referencing point of the system is detected, the distances from P_r of the entire set of points were calculated in order to have a common variable to analyse the relationship between variables.

3. RESULTS AND DISCUSSION

During this study case a total of 2 days of monitoring were done, both with GNSS device and time board survey. The two days of reliefs are divided in 4 different raw data-sets. All data acquired were post-processed and elaborated (Figure 2). The following figures show results of data-set 4.

The relief consists in an effective survey of 10.6 hours of work with a total data-set of 5456 records. In fact the records recorded are lower than that respectively at 11.6 hours. This lack of information is due to empty spaces during the data acquisition, as showed in the as showed in the FIG. 3a. Anyhow the data have a good precision. The times gap as demonstrated in the following figures (FIG. 3a, 3b, 3c), are detected when the carriage is blocked for loaded or unloaded operations. This kind of phenomena do not happen during the advancement. These

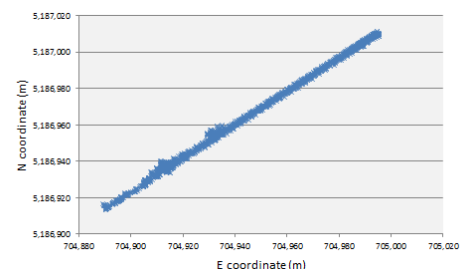


Figure 2. Coordinate distribution.

P0208

R. Gallo, F. Mazzetto. "A methodology study for the application of Precision Forestry approach in logging operation chains". EFITA-WCCA-CIGR Conference "Sustainable Agriculture through ICT Innovation", Turin, Italy, 24-27 June 2013.

Sustainable Agriculture through ICT innovation

errors could be due to the canopy coverage (McDonald *et al.*, 2005), to the loss or to the acquisition of new satellite's signal (Taylor *et al.*, 2006) – that determine a recalculation of the GNSS device position – or due to insufficient satellite coverage during the acquisition data or to the interference of huge steel equipment (truck). For making a first description of carriage's kinematic behaviour data about distances, advancement speeds, advancement directions and times are necessary for all data sets; the explicative figures on the left refer to the data-set 4 (Figures 3a, 3b, 3c). From the analysis of the figure 3b, it is possible to say that the carriage travels with an advancement speed higher than 1.5 m/s during its travel operations, from about 30m to 110m of distance from the reference point. It also possible note that the advancement speed is splittable in two different families of points with different average values of speed: 1.8 m/s for the lower and 2.4 m/s for the higher.

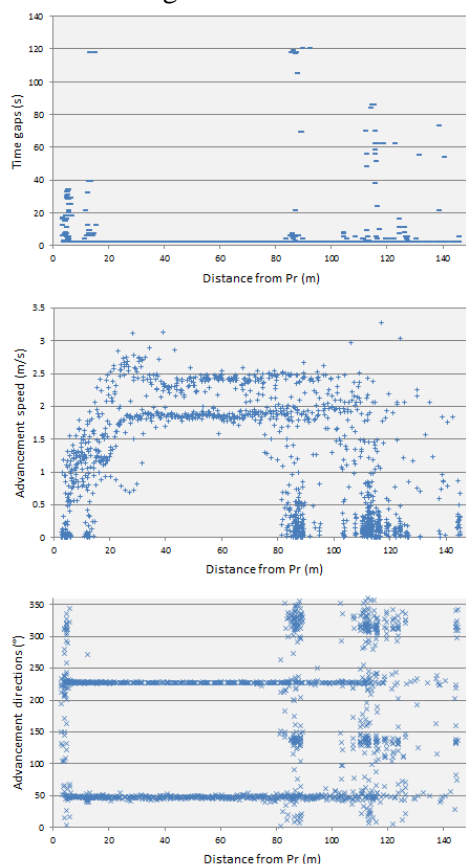


Figure 3. Time gap, velocity and distribution as a function of the distance from Pr.

the progressive time (considered as the time difference between two sequent points) and the respective distance from the point of reference was examined. In the following tables (Tables 1 and 2) all detections observed in the study are summarized.

This high difference between the two advancement speeds, present in all the data-sets, might be explained as the speed that the carriage reaches when travelling loaded or empty respectively. While during hooking and unhooking operations the speed decreases to zero. Also in the case of the advancement direction (Figure. 3c) the distribution of the points shows the presence of two different families of points. The average values, that describe them, refer to the carriage advancement direction value during empty and loaded travels. When the carriage stops the advancement and during the hooking and unhooking operations the values of direction do not have linear distributions. This is due to the oscillation caused by the weight of the logs during the load or unload operations, mainly detected in loaded phases. It is possible to suppose that it happens during the operative phases of side-lining.

Finally, for all data-sets, an analysis on the cycle time has been done to obtain the gross cycle time and the elementary operational times (Figure 4). These evaluations are done in order to proceed with the comparison between the two detections.

For each data-set the relationship between

P0208

R. Gallo, F. Mazzetto. "A methodology study for the application of Precision Forestry approach in logging operation chains". EFITA-WCCA-CIGR Conference "Sustainable Agriculture through ICT Innovation", Turin, Italy, 24-27 June 2013.

Sustainable Agriculture through ICT innovation

To facilitate the procedure of operational times recognition the down-time are not considered separately from these. During the study there was a total of 67 cycles. McDonald (2005) reported that the automatic time study with the use of GNSS device is able to correctly recognize at least 90%, of the cycles, in the present study the result is better because all cycles were recognized. As far as the gross operative time is concerned, a difference

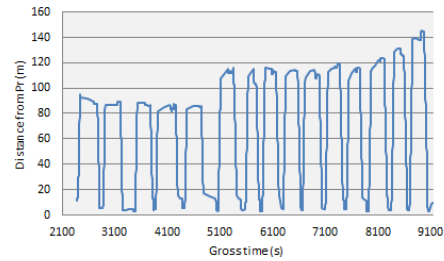


Figure 4. Working cycles over time.

Table 1. Summary of operative cycles and time

DATA- SET	Operative Cycle		Gross operative time		
	GNSS	clock	GNSS	clock	Δ
N.	N.	N.	min	min	%
1	22	22	185.63	184.86	-0.42
2	13	13	97.73	97.38	-0.36
3	17	17	129.93	128.06	-1.46
4	15	15	111.63	110.12	-1.37

Anyhow to proceed with the analysis, hooking and side-lining operations were considered together. Also in this case all operative phases were recognized. For the elementary phases, substantial time differences between the GNSS and clock detections were found. These are mainly present during travels. Explanation of that could be associated to the difficulties during the determination of the shift values between sequent phases.

below 2 minutes was observed between the two methodologies of relief. Probably these are due to discontinuities during time detections, or due to the presence of mistakes for the synchronisation of the work's starting and finishing times.

For the elementary time study, the side-lining operations were not identifiable, because the parameters detected were not sufficient for that.

Table 2. Summary of elementary operations monitoring

DATA- SET	Travel empty			Hooking & side-lining			Travel loaded			Unhooking		
	GNSS	clock	Δ	GNSS	clock	Δ	GNSS	clock	Δ	GNSS	clock	Δ
N.	min	min	%	min	min	%	min	min	%	min	min	%
1	20.85	22.81	8.59	79.88	81.85	2.41	39.12	35.38	-10.57	45.78	44.82	-2.14
2	8.83	9.47	6.76	56.32	56.33	0.02	15.53	13.93	-11.49	17.05	17.66	3.45
3	17.30	16.14	7.19	61.55	62.14	0.95	27.68	25.4	-8.99	23.40	24.38	4.02
4	13.8	14.3	3.50	57.87	57.75	-0.21	26.78	24.19	-10.71	13.18	13.88	5.04

4. CONCLUSIONS

Despite the short test period, experiences obtained very interesting and important results for further improvement of the assess methodology. This initial part of the research has

P0208

R. Gallo, F. Mazzetto. "A methodology study for the application of Precision Forestry approach in logging operation chains". EFITA-WCCA-CIGR Conference "Sustainable Agriculture through ICT Innovation", Turin, Italy, 24-27 June 2013.

Sustainable Agriculture through ICT innovation

shown that the use of GNSS devices presents a very interesting feasibility for performing operational time monitoring in forest logging operations. All operative cycles and all elementary operations have been exhaustively recognized. Considering the cycle's gross times the differences are lower than 1.5%, corresponding to 1.87 minutes. Meanwhile the differences between the elementary operations are higher. Indeed the two methodologies, considering all data-set, present a maximum difference of 11.49%, which means a maximum average error lower than 0.88% (0.12 minutes) for each cycle. This value could be considered acceptable.

From these first results several open points were found, next steps of the research will be the identifications of the reasons of the presence of discontinuities during the GNSS detection and also of the discrepancy between the times relieved mainly during travel operations. Besides this, new strategies for the detection of side-lining operations will be analysed. The possibility of including further sensors (such as load cells for measuring the weight of timbers hooked at the crane) will be considered as well in order to provide more information for a better performance of the inference-engine.

5. ACKNOWLEDGEMENTS

The Authors wish to thank the State-Owned Forest Company of the Autonomous Province of Bozen for their support and collaboration in this research.

6. REFERENCES

- Berti, S., Piegai, F., and Verani, S. 1989. Manuale di istruzione per il rilievo dei tempi di lavoro e delle produttività nei lavori forestali. Quaderno dell'Istituto di Assestamento e Tecnologia Forestale dell'Università degli Studi di Firenze, n° IV.
- Cordero, R., Mardones, O., and Marticorena, M. 2006. "Evaluation of forestry machinery performance in harvesting operations using GPS technology." *Precision Forestry in Plantations, Semi-Natural and Natural Forests, Proceedings of the International Precision Forestry Symposium, Stellenbosch University, South Africa.*
- Devlin, G. J., and McDonnell, K. 2009. Assessing Real Time GPS Asset Tracking for Timber Haulage. *Open Transportation Journal* 3: 78-86.
- Devlin, G. J., McDonnell, K., and Ward S. 2008. Timber haulage routing in Ireland: an analysis using GIS and GPS. *Journal of Transport Geography* 16(1): 63-72.
- Lubello, D., and Cavalli, R. 2006. Ambiti applicative della *Precision Forestry*. *Sherwood Foreste* 125: 11-16.
- Manzone, M. 2012. Esbosco del legname per via aerea, valutazione delle prestazioni di un carrello forestale motorizzato autotraslante. *Sherwood Foreste* 185: 25-29.
- Mazzetto, F., Sacco, P., and Calcante A. 2012. Algorithms for the interpretation of continuous measurement of the slurry level in storage tanks. *Journal of Agricultural Engineering* 43(1), e6.

P0208

R. Gallo, F. Mazzetto. "A methodology study for the application of Precision Forestry approach in logging operation chains". EFITA-WCCA-CIGR Conference "Sustainable Agriculture through ICT Innovation", Turin, Italy, 24-27 June 2013.

Sustainable Agriculture through ICT innovation

- McDonald, T. (1999). Time Study of Harvesting Equipment Using GPS-Derived Positional Data. *Notes*. <http://treesearch.fs.fed.us/pubs/1411>
- McDonald, T., and Fulton J. 2005. Automated time study of skidders using global positioning system data. *Computers and electronics in agriculture* 48(1): 19-37.
- McDonald, T., Rummer, B., and Taylor., S. 2001. "Automating time study of feller-bunchers." *Proceedings of the Canadian Woodlands Forum's 81st Annual Meeting and Council on Forest Engineering's 23rd Annual Meeting—Technologies for New Millennium Forestry, Kelowna, BC.*
- Mundel, M., and Danner D. 1994. Motion and time study – improving productivity. 7th ed. Prentice Hall, Upper Saddle River, NJ. 770pp.
- Nitami, T., Soil, S., Kataoka, A., and Mitsuyama, T. 2010. Tower Yarder operation in Japan and the performance analysis by GPS-based system. In *Pushing the boundaries with research and innovation in forest engineering. FORMEC 2011, Proceedings of the 44th International Symposium on Forestry Mechanisation, 9-13 October 2011*. Graz, Austria.
- Sikanen, L., Asikainen, A., and Lehtikoinen, M. 2005. Transport control of forest fuels by fleet manager, mobile terminals and GPS. *Biomass and Bioenergy* 28(2): 183-191.
- Simwanda, M., Wing, M. G., and Sessions, J. 2011. Evaluating Global Positioning System Accuracy for Forest Biomass Transportation Tracking within Varying Forest Canopy. *Western Journal of Applied Forestry* 26(4): 165-173.
- Spinelli, R., and Kofman, P. 1995. Cantieri agricoli e forestali, informatizzazione dei rilievi. *Macchine e motori agricoli* 11: 33-35.
- Taylor, S. E., McDonald, T., Veal, M. W., and Grift, T. E. 2001. Using GPS to evaluate productivity and performance of forest machine systems. In *Proceedings of the First International Precision Forestry Cooperative Symposium: University of Washington, College of Forest Resource*. Pp 151-155.
- Taylor, S., McDonald, T., Fulton, J., Shaw, J., Corley, F., and Brodbeck, C. 2006. Precision forestry in the southeast US. In *Proc., 1st Int. Precision Forestry Symp.* pp. 397-414.
- Veal, M., Taylor, S., McDonald, T., McLemore, D., and Dunn, M. 2001. Accuracy of tracking forest machines with GPS. *Transactions of the ASAE* 44(6): 1903-1911.
- Visser, R., and Stampfer, K. 1998. Cable extraction of harvester-felled thinning: an Austrian case study. *Journal of Forest Engineering* 1: 39-46.
- Wang, J., McNeel, J., and Baumgras, J. 2003. A computer-based time study system for timber harvesting operations. *Forest Products Journal* 53 (3): 47-53.

P0208

R. Gallo, F. Mazzetto. "A methodology study for the application of Precision Forestry approach in logging operation chains". EFITA-WCCA-CIGR Conference "Sustainable Agriculture through ICT Innovation", Turin, Italy, 24-27 June 2013.