DOCUMENTATION AND EVALUATION OF VEHICLE MOVEMENTS IN THE FOREST – AN ELEMENT FOR QUALITY MANAGEMENT OF MACHINE OPERATIONS

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Abstract: *In the last 10 years the mechanized wood harvesting increased rapidly. More and more heavy machines, with high axle load are moving on forest soils.*
The impact of their weight and wheels leads to compressions or plastic deformation of the soils. With consequently driving on skidding lines the damages can be concentrated on these lines but they can not be stopped. However these lines are often not visible in the forest. Controlling in any way is necessary to keep the machine out of the productive area of the stands and to maintain the soil on skidding lines in a condition driveable for machines.
The past beginnings and methods of a quality assurance require more or less large expenditure. The information which is collected is imprecise and depends on individuals. So the controlling is insufficient.
Therefore a software was developed which can record the movings of harvesting vehicles. The recorded moving lines are smoothed automatically. They are a default for subsequently driving. This data collection is easy and economically. The developed program supports this data acquisition with GPS.
Furthermore the accuracy of the GPS-positioning was investigated in dense high spruce stands a difficult area for GPS.
On the basis of the results of the analysis of the systems in use and the GPS-Navigation, a concept for documenting vehicle movements was developed. This concept includes ecological navigation when the forest machine is in operation and also it allows an evaluation to be made (eco-controlling) once harvesting has finished.
A comprehensive approach will be presented, which records and presents the ecological and geometric aspects of driving quality. Sustainable data management with permanent data formats and a conclusive data storage concept is the prerequisite for this sustainable quality assurance in technical forestry production.

1. Introduction

Today international forestry in particular the German is in a phase of new orientation. No more monofunctional production of raw material is in the foreground, as it was still in the seventies. More and more multi-functional goals move into the focus. The reason is the variety of requirements of the society. Therefore the social pressure increases to use the resource forest soil carefully. In the last years the number of the machines was increasing constantly and also their individual size. The impact on soils on skidding lines during a rotation period is so intensive that a control and management system seems to be necessary for precautional soilprotection. Solutions are already present but they do not use the possibilities which are given by today information technology. Today GPS navigation and data storing for documentation of the movements is possible but not used. A documentation is necessary, in order to record quantity and quality of machine movements and for evaluation of movements with ecological criteria. This informs the forest owner about damages in his soil (destruction of values) and it gives him the possibility to control and intervene in the operation.

2. How is working such a program?

In a comparison of nominal and actual movements the real driving of vehicles can be compared to geometrical defaults. The driver can see this comparison on a display which helps him to correct his movements for the purpose of later supervision the movement data are stored in a file. In a second step the ecological quality of driving on forest soils can be recorded and compared to a target. The way is shown in the program PROFOR developed by Matthies and Ziesak.

Targets must be definded for the driver, for navigating machines in the area in a geometrical and ecological correct way. Also for a evaluation of the operation defaults must be defined.

While driving on skidding line the actual position of the machine is lacated with GPS and diplayed on a screen. This actual position is compared to the geometrical target which is the digital system of skidding lines in GIS.

Displayed is the actual position of the machine moving in the system of the skidding lines and also the deviation of the machine from the target line. The deviation from the target line will be recorded. So the geometrical quality of the operation is characterised.

The actual ground pressure of the used machine depends on the dead weight, the loading and the tyres. In addition the characteristics of the soil and its current moisture are important. With sensors axle loads and tyre inflation pressure can be queried. The actual moisture of soil can be measured manually with a TDR tube.
These are all data necessary to compare the actual ground pressure with a default. This default is a limit value for a specific soil site which is empically investigated and integrated into a schedule of datas. The exceeding or the adherence of the limit value shows the ecological quality of the operation. Also this information should be indicated to machine driver and stored in a file.

Because of the displaying of geometrical and ecological quality of actual vehicle movement the driver has the possibility of correcting the movings (geometrical) and to adapt the tire pressure (ecological) or of breaking the work off for the machine leader.

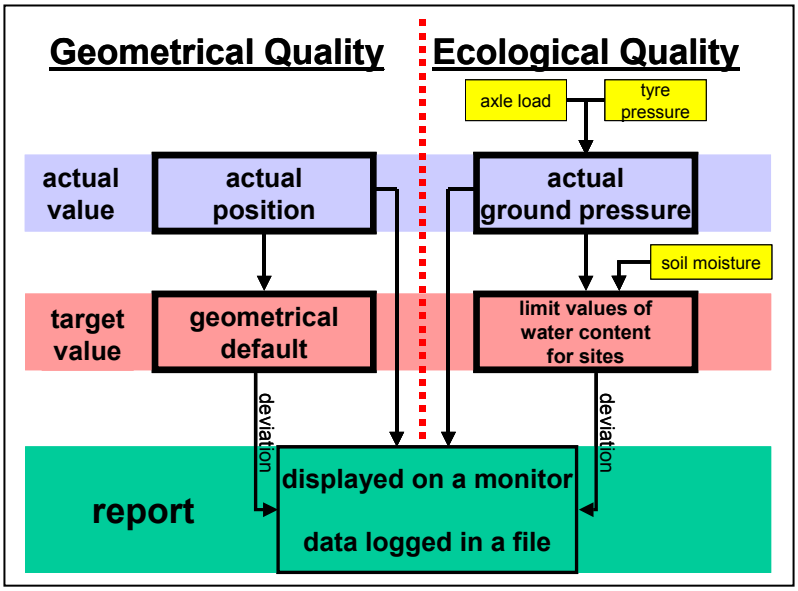

Figure 1: Camparison of actual value / target value of geometrical and ecological quality of vehicle movement.

The procedure for assessing the geometrical quality is connected with small technical effort (GPS) and with small preparatory work. But in collecting automatically data of ecological quality we are still at the beginning. The necessary sensor technique is available but it has still to be tested for this purpose. Tables with limit values are available so far only for few forest sites.

Nevertheless there are programs, which are already represent parts (WaldNav, ProFor). In foreseeable time integrated programs will measure the ecological and the geometrical quality of vehicle movements. This information can be printed out as a map to assist the local forest manager for purposeful controlling of the skidding lines.

So after a felling operation he has an overview about the quality of the machine operations. He can identify immediately critical places on the map and is able to visit them in the area and investigate them. With such a system the contractor can demonstrate the quality of his work, which can pay offs for him in money (bonus system) or in the reputation of his company.

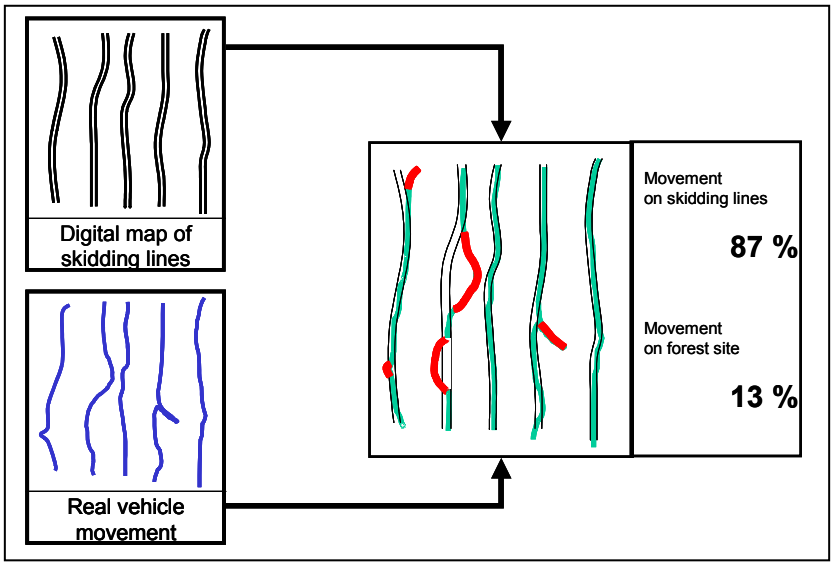

Figure 2: Example for real vehicle movement. It is compared to a reference. Deviations are displayed in a map and shown as values.

2. Investigation of accuracy of GPS

In order to test the serviceability of GPS receivers skidding lines in forest stands were measured. In the forest of the university Munich in Landshut/Bavaria and in the forest of the monastery of Schlaegl/Austria we measured conventionally with tachymeter and with differential GPS (Leica GS50). We compared the accuracy of the measured values. The values surveyed with Tachymeter served as reference size for the GPS measurement. Both investigations were implemented in spruce stands, which had high timber volumes and difficult conditions for signal reception (Table 1).

Table 1: Parameters of the investigated stands

	Monastery of Schlaegl	Landshut University forest
stand	Spruce with beech	spruce
age	50	74
heigt	26 m spruce, 22 m beech	29 m
basal area	60 m²/ha	57,6 m²/ha
Distance beetween extraction lines	50 – 70 m	30 m

The GPS receiver was mounted onto a skidder and drove on the skidding lines. We measured in kinematic mode, i.e. data logging whilst the machine was moving.

Nearly three quarters of all measurements fell into a stripe (corridor) with 4 m width around the middle of the extraction line (Table 2). The average deviation lies within in the width of a common strip road. It was 1,41 m (Schlaegl) resp. 1,51 m (Landshut). Nearly all values are in a stripe of 10 m.

Table 2: Results of kinematic GPS Measurements

Kinematic GPS Measurements		Monastery of Schlaegl	Landshut University forest
Distance of GPS measurement from the middle of extraction line	Average value	1,41 m	1,51 m
	Minimum	0,00 m	0,00 m
	Maximum	4,98 m	8,18 m
Number of positions in a stripe of ….	4 m	74 %	72 %
	10 m	100 %	98 %
Measured length of extraction line with Tachymeter		100 %	100 %
Measured length of extraction line with GPS		102 %	105 %

In Figure 3 it is shown for Landshut and Schlaegl the data recording of single GPS positions in the stands (left) and how these points merged to lines which are visualising the system of extraction lines.

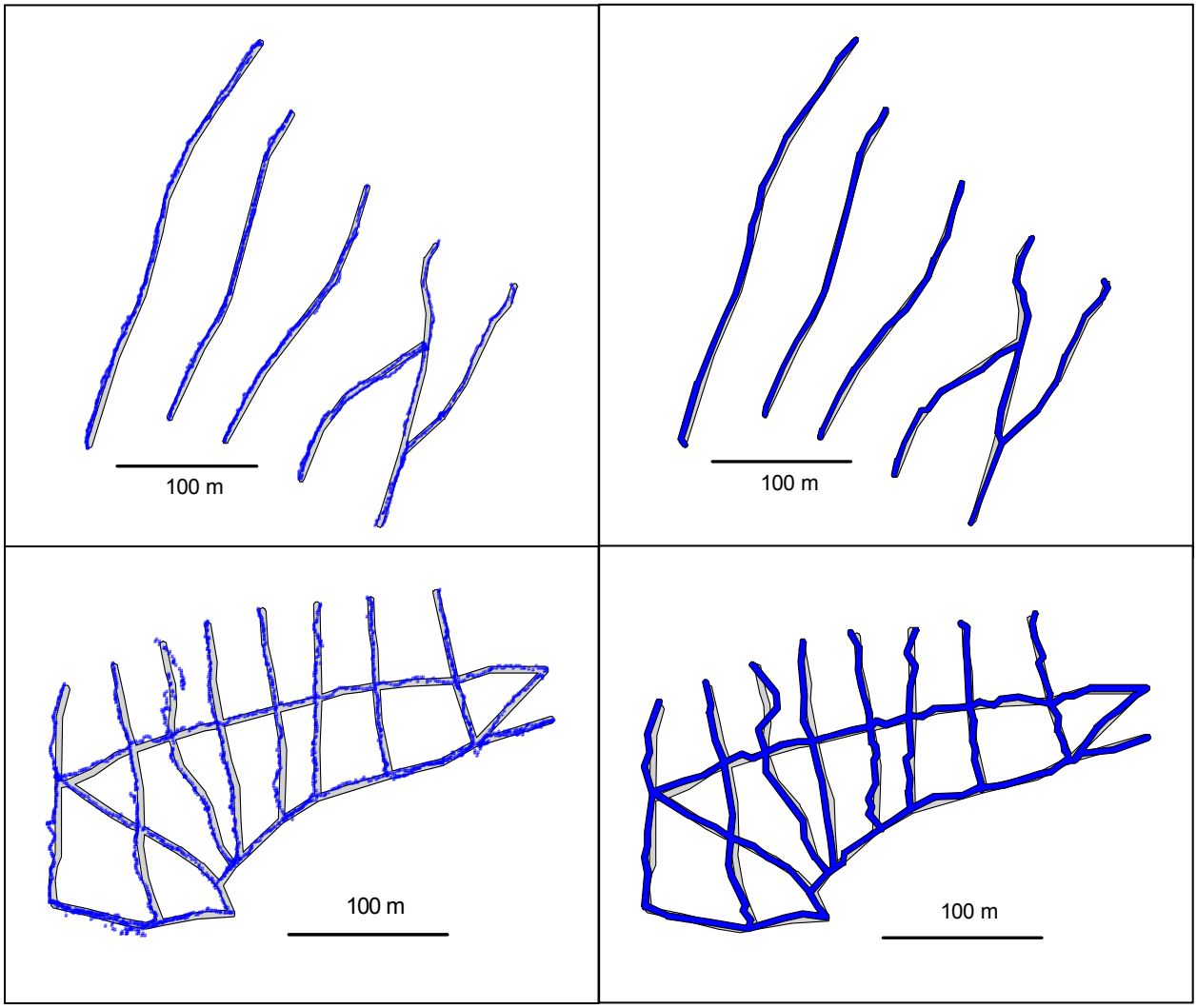

Figure 3: Top: system of skidding lines in Schlaegl. Bottom: in Landshut. Left: kinematic GPS measurement with moving skidder, right: system of skidding lines based on GPS.Grey: reference measurement, blue: differential GPS measurement.

The lines calculated by the GPS positions are smoothed and correspond largely with the reference. 98 % (Landshut) rsp. 100 % (Schlaegl) of the measurements are in the tolerance corridorof 10 m. At a glance it can be determined immediately whether the vehicles stayed on strip road or not. A field inspection is not necessary . Fig. 4 shows a situation where the strip road is left purposly for investigation. As position data are collected with GPS continously these irregular movments can be pointed out.

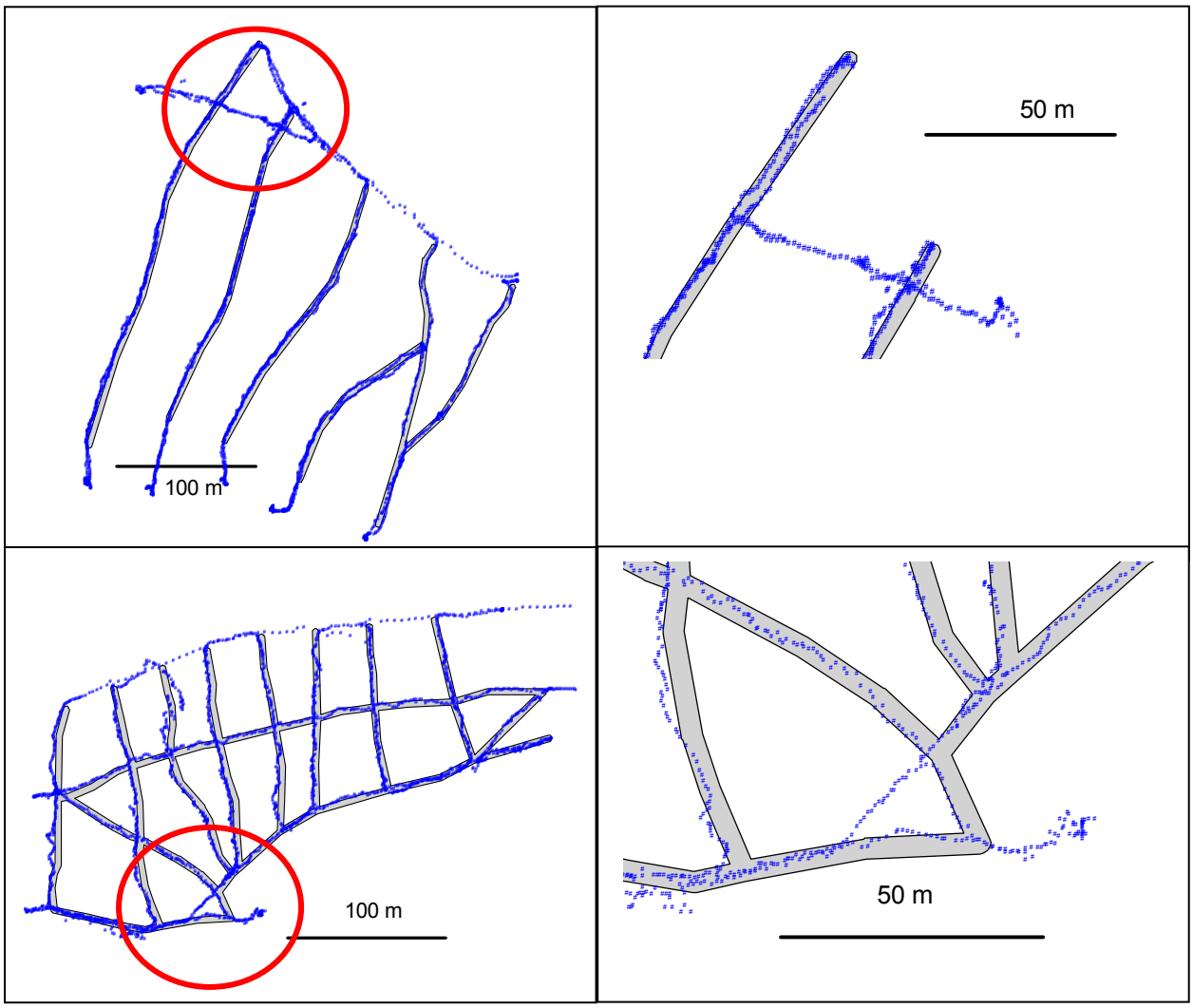

Figure 4: Intentionally driving into stands for documentation of vehicle movements with differential GPS. Top: system of skidding lines in Schlaegl, below in Landshut. Left: overview, right: detail. Grey: reference measurement, blue: differential GPS measurement.

3. Conclusions

The traffic of heavy loaded machines in forests increased rapidly in the last years which also effects skidding lines. It is necessary to guide the traffic streams temporally and locally. This will keep the sustainable fertility of the forest stands.

With navigation and documentation systems the movement of forest machines can be kept on target lines. Data of movements can be recorded automatically. Also the parameters interfering with the soil can be collected automatically in foreseeable time. Thus it can be recognised, at which time and in which intensity machine contacted the production object soil.

Important quantitative and qualitative data are available for evaluation and planning. The advantage of combining sensor information with position information during the automated collection is that numbers and not personal expert opinions can show the quality of vehicle movement. Thus the procedure is more objective and possibly controversy is prevented.

The described system can serve on operational level and as management system on control level.

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