Results of observations of damages to field and landscape

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Abstract. It is a fact that crop growth conditions vary greatly within the same field. Provisionally actual growth conditions are made up of many components, i.e. variation of natural conditions (climate & soil), results of effects of machinery on soil (soil compaction) and unfavourable conditions for plant growing. In Estonia rather widely used ATV's are causing remarkable damage to landscapes.

All collected data were geo-referenced by means of a GPS-receiver and post-processed for position correction. For All Terrain Vehicle (ATV) damage assessment the trajectory was recorded. Both the area and forms of damages were assessed for damaged sites, (e.g.) damage to potato by Colorado beetles. The collected data were compared to the digital soil map.

Economic loss on the average, due to unfavourable conditions for plant growth, in the case of winter rye "Portal" was 131 euros per ha, for medicago 18.5 euros per ha, for spring barley "Anni" 1000 euros per ha and for potato "Ando" 27.1 euros per ha.

Key words: GPS, soil, yield, ATV, penetrometer, rye, medicago, potato, barley

INTRODUCTION

Previous studies have proved the efficiency of GPS-based precision farming with regards to the quality of the final product, the protection of environment, and its applicability in intensive agricultural production. A number of positive examples can be given: Backes, M. and Plümer, L. (2003), Kim, Y. and Reid, J.F. (2003), Shibusawa, S. (2003). In Estonia, the search for possibilities to apply precision farming has been under way since 1999. By now, GPS-receiver accuracy for both position and area measurements has been studied. Six receivers have been compared. Results indicate that although position accuracy for GPS receivers is not remarkably good, area measurement errors are acceptably low, even on non-corrected GPS-receivers, compared to traditional measurement methods. Therefore, a GPS-receiver is suitable for area measurement through its robustness, ease of use and fast results.

We have relevant positioning experience as a result of the use of a satellite navigator, however, through the years, our main problem has been the diversity of soils. So a question arises: What size soilscape unit is necessary to plausibly determine such diversity and appreciate the factors influencing the final yield of crops? It appeared that even in the USA with its very large fields, the authors Q.E. Larson and P.C. Robert point out as an example from Minnesota (Larson & Robert, 1991) that when soil maps are overlaid by landscape maps, the soilscape becomes extremely large. Extremely negative factors may occur in the field incidentally and specifying these by means of a navigator is of considerable importance. We made an approach to connect it with bioproductivity modelling, based on the principle of maximum plant productivity by H. Tooming (1967), and developed further together with J. Kadaja (Kadaja & Tooming, 2004) . Briefly, these ideas have been reflected in a number of publications. Connections with the topic of this particular work are published by E. Nugis, J. Kadaja and T. Vösa (2003).

Estonia is halfway towards the level achieved in developed countries. Despite this, we have set wide-range objectives for our research work, primarily, to investigate the possibilities of increasing the efficiency of agricultural machines and their respective technologies in Estonian soil and climatic conditions.

MATERIALS AND METHODS

Soil units, study sites, co-authors/author of experiments are as follows:

1) *Fragi-Stagnic Albeluvisol* (sandy loam), *Haage* Agro Ltd., near Tartu, N58°22´ and E26°37´ (tramlines and winter rye (*Secale cereale* L.) cv, "Portal"), co-authors of field experiments are Andres Härm, Edvin Nugis, Jaan Kuht and Kersti Vennik;

2) *Enti-Umbric Podzol* (loamy sand), landscape, recreation centre Andu Ltd. near Otepää, N58°04´ and E26°26´, special route for All Terrain Vehicle (ATV), co-author of experiments are Kersti Vennik and Edvin Nugis;

3) *Endoeutri-Mollic Cambisol* (sandy loam), field with chosen random deep tracks after the application of liquid organic manures; Juuliku piggery, Saku Community, near Tallinn, N59°18´ and E24°36´ (after that, spring barley (Hordeum Vulgare) cv. "Julia") was sown, co-authors of field experiments are Edvin Nugis and Taavi Võsa;

4) *Calcari- Eutric- Cambisol* (sandy loam), experimental field of Agricultural Research Centre (PMK), N 58°58´ and E 24°43´, Kuusiku, near Rapla (*Medicago varia Mart.*) cv. „Karlu" co-author of field experiments are Heli Meripõld and Edvin Nugis;

5) *Fragi-Stagnic Albeluvisol* (loamy sand) *Weiss Ltd*., near Pärnu, N58°13´ and E24°32´ (tramlines and *Triticale*), co-authors of field experiments are Kalmer Metsaru, Edvin Nugis and Mait Müüripeal;

6) *Endoeutri-Mollic Cambisol* (sandy loam), experimental field of Private Farm "Miili" for potato (*Solanum tuberosum*) cv. „Ando" growing, near Klooga, Keila Community, N59°19´ and E24°15´, author of field experiments is Edvin Nugis.

Georeferencing of our investigations was carried out by using GPS receiver Trimble GeoExplorer 3 for specifying the co-ordinates of soil samples and the damaged areas in the field. For GIS data management and primary analysis, computer programme Pathfinder Office 2.80 (Trimble Inc.) was used. Further data analysis was carried out by means of Microsoft Excel 2003.

We have also used some experiments for measuring the soil physical properties in several soil layers: penetrometer MOBITECH for registration of cone resistance, Eijkelkamp´s ring kits (100 cm^3) for measuring soil bulk density and percometer for measuring soil volumetric moisture content through dielectric conductivity and permittivity, respectively. Crop yield was measured by ordinary weighing with a weighbridge in the case of rye and by means of test weights in the case of medicago.

RESULTS AND DISCUSSION

Crop damages

As can be seen in Fig. 1, there are significant damages on the winter rye canopy. These areas are not producing grain although they have the required amount of fertilizers, pesticides, seeds, soil tillage and seeding work. Thus, expenses have been incurred but no yield harvested. This is neither an economically nor ecologically desired result. Calculations show that this field loses from 94 to 163 euros due to winter damages. It is not clear yet whether all these damages are soil-originated because the winter of 2006 was very cold and snowless and, consequently, plants suffered a lot.

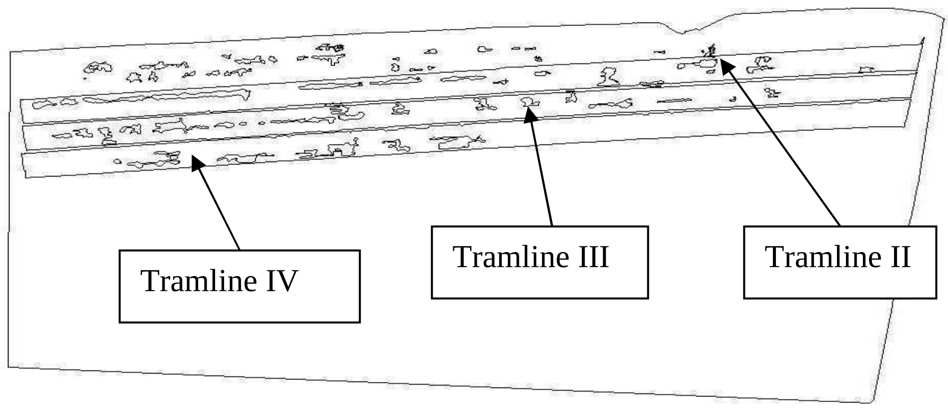

Figure 1. An excerpt from field map with crop damage areas and tramlines in the field of "Peedimäe", Haage Agro Ltd (areas per tramline (II, III and IV are 1.36, 1.32 and 1.37 ha, and yield (t ha^{-1}) 4.6, 4.6 and 4.7 respectively).

As can be seen from the above, thanks to the GPS receiver it became possible to determine on a large scale the damages caused due to unfavourable winter conditions, i.e. a barren crop area where only weeds grew. The crop yield was assessed in the range of each tramline separately, and varied greatly because of barren areas, which, in fact, is the result of differences in growing conditions of the winter rye "Portal". The latter exerts a substantial effect on the quality of crop yield.

A similar economical loss can be calculated in the case of medicago. The observed field had suffered noticeable damages, with no medicago plant areas within a total area of 285 m^{-2}. The measured yield from this field was 145 kg seeds per ha and the seed price on calculations was 4.5 euros. Consequently, damaged areas of fields reduced the income from the field by 18.5 euros per ha.

We have also recorded negative results concerning the potato (variety “Ando”): damages by a great number of Colorado beetles at Klooga, Keila Community on areas 656 m^{-2} and yield 11.3 t ha^{-1} reduced the income by about 27.1 euros per ha (Fig. 2).

Both cases serve as examples of heterogeniety of actual fields as compared to good farms. A much worse picture can be observed on the farms with inevitable risks in agriculture and some difficult input managementof the above mentioned negative factors.

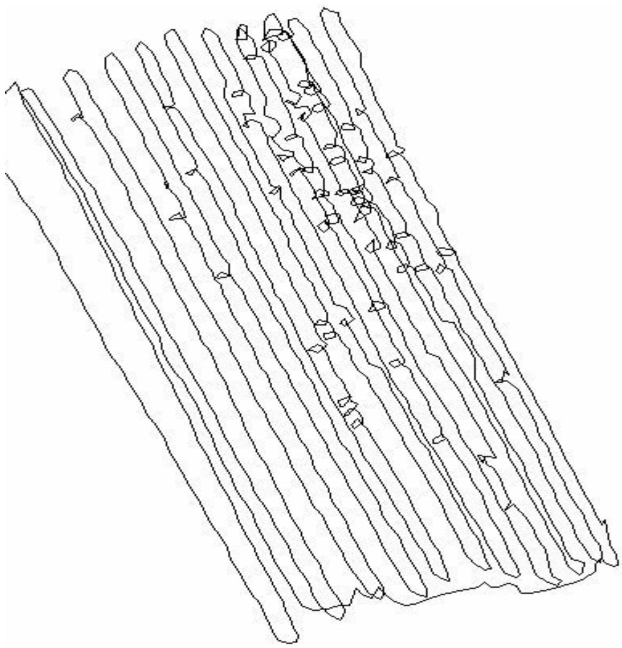

Figure 2. Example of outline of distribution places of the Colorado beetles at field in Klooga, N59°19´04.5´´ and E24°15´39.5´´.

Soil Erosion and Trafficability

We applied the same principles in a completely different domain, i.e. in assessing erosion-hazardous sites of soil. The ATV route under observation was passed together with a GeoExplorer in operation and the map below was obtained (Fig. 3). Two erosion-hazardous places can be observed and are marked by rings in Fig. 3. There were signs of erosion hazard in their initial stadium. This situation is hazardous because, with a long period of heavy rain, it could become an irreversible process. This illustrates the particularity of our approach at the present stage of experimentation.

Concerning the aftereffect of repeated compaction of soil in Juuliku experiments in 2002 with fresh track, old track and not compacted soil (penetration resistance – 322, 311 and 288 N cm^{-2}, and volumetric soil moisture – 18,9, 19,9 and 20,1 % accordingly) we have had negative results on areas covered with cultured plants (10, 50 and 90 %), and yield 0.4, 1.3 and 2.1 t ha^{-1} which also reduced the income by about 1164, 936 and 734 euros ha^{-1} respectively.

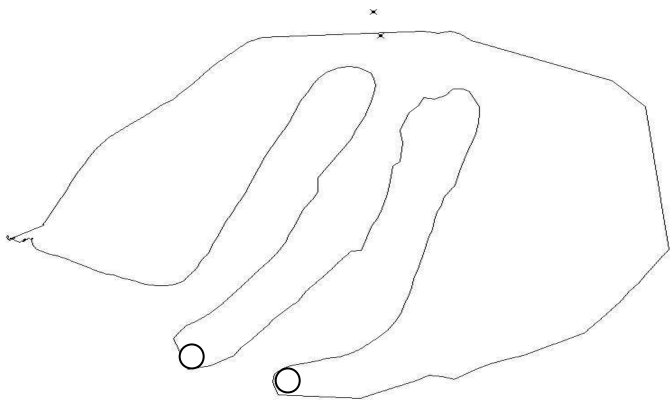

Figure 3. Example of outline of an ATV route, N58°04´ and E26°26. (**x** – denotes places for more detailed observation of soil physical properties; **o** – marks erosion-hazardous places).

For this purpose we had chosen a field in the sprouting phase of spring barley "Anni". The field had suffered from extreme trafficability and large amounts of winter swine sludge was poured onto it via the hose of a truck tank. In spring, the field was a sad sight: there were deep tracks with a maximum depth up to 33 cm. Still, untouched places could still be found (calculated area 12.5 m^2) and old tracks remaining from autumn were also taken under observation. In summary, we are facing a rather serious situation, in which both consequences to fields and protection of the environment are being ignored.

CONCLUSIONS

As a result of the complex investigations using GPS technology and the relevant information it yielded, growers were able to produce high quality cereals in different soil and climatic conditions of Estonia and, consequently, to obtain higher incomes. A data bank (accessible and stable in functioning) of quality indicators for most widespread cereal varieties and suitable digital maps will be produced. It should be possible to cover topics highly significant to Estonia: GIS, GPS, and precision farming. These innovative investigations are the basis for patentable inventions which, if implemented, should lead to improvement of the agricultural sector. In conclusion, it can also be pointed out that the substantial deviations which appeared as we developed our methodology for use in soil tillage, also occurred in the development of the techonology for use in the entertainment sector. These deviations can be specified by means of modern GPS-receivers and assessed. Lost income speaks for itself and provides a reason for both farmer and economist to re-estimate agricultural strategies and to exclude risks.

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