Demmel, Markus; Brandhuber, Robert; Kirchmeier, Hans; Müller, Martin and Marx, Marc

Controlled traffic farming – technical and organizational realization

Controlled traffic farming (CTF) systems have been installed and investigated on three arable farms in Bavaria. Particularly the technical realization, the advantages of different systems and the effect on soil water should be examined. The farm equipment used meet German traffic regulations. Hence, the portion of non-trafficked land is limited to 58–67 %. RTK DGPS based automatic steering systems were used for all field work. Already in the second year of the experiment a tendency to increased water availability was observed in the non-trafficked areas. Crop yields did not show unidirectional reactions in the seasons of 2010 and 2011. Because long dry periods in the main seasons did not occur the expected advantages of controlled traffic farming could not be confirmed.

Keywords

Controlled traffic, farming, compaction, guidance, soil

Abstract

Landtechnik 67 (2012), no. 6, pp. 435–440, 2 figures, 1 table, 19 references

Technologies for the reliable positioning and guidance of agricultural vehicles and machines make new applications in arable farming possible. With highly accurate satellite based positioning systems the tracks of agricultural machines can be documented and localized and relocated again at any time. Thereby Controlled Traffic Farming (CTF) systems can be realized, which have been discussed intensively in the 70th of the last century.

Controlled traffic farming corresponds to beet systems in vegetable farming. During all field work the areas where the machines drive are separated from the areas where the plants grow. Track widths and implement working width have to be harmonized. Field work must be done using automatic guidance. In a stringent CTF system adapted equipment with identical track width and small tires width are used, the tracks are free of plants and the portion of tracks is lower than 15 % of the field. If equipment with common track width and tire dimensions is used the portion of wheeled land increases above 30 % while the tracks are normally cultivated.

To realize CTF a reliable relocation of the tracks at any time is essential. CTF promises benefits in crop yields, soil conservation and climate protection. Also savings in energy consumption can be expected and the emission of nitrous gas might decline.

During the last years CTF has become a widely adopted farming system in Australia. Under semi-arid conditions the un-wheeled areas in the fields show a high capability to infiltrate, store and deliver precipitation water.

The climate conditions in Middle Europe are different to Australia. But the vulnerability of the system soil-plant, relating to soil erosion, soil compaction and dryness is also very high on many locations. The acreage of crops with a high risk of erosion is increasing. Climate change might cause more extreme weather conditions. In a research project funded by the Bavarian Ministry of Food, Agriculture and Forstry the Bavarian State Research Center for Agriculture investigates if CTF can be realized under local conditions, which technical, organisational and agronomic problems will arise by introducing CTF, how they can be solved, and if the expected effects in soil water efficiency and resource conservation can be realized. The project started mid of 2009 and will be continued until end of 2014.

State of the art

First investigations with consequent controlled traffic farming where carried out in the 70th and 80th of the last century in Dutch vegetable field production using gantries [1, 2]. Also in Germany "traffic oriented farming systems" have been discussed to reduce soil stress and soil compaction, especially in sugar beet production [3]. The expected improvements of soil structure and reduction in energy consumption could be realized, due to a number of technical problems the system could not be established in practical farming.

Today agricultural research and practice work again on that topic [4-6]. Together with affordable high accuracy GPS based automatic steering systems, powerful tractors, wide tillage, and planting equipment with 6, 9 or 12 m working width, and harvesting equipment with identical cutting width make it possible to successfully realise controlled traffic farming.

In Australian crop production on erosion sensitive soils CTF is established as a standard grain production technology on several million hectares [7, 8]. Scientific investigations show an increased water infiltration, improved soil structure, reduced erosion, higher germination rates, more intensive rooting and more stable and higher yields [7, 9–11]. Bowman [12] reported economic advantages of CTF under Australian conditions.

Positive effects regarding water efficiency, erosion control, and yield have been also documented for the dry loess soil areas in Northern China [13].

Today different research groups in Great Britain, Switzerland, Slovakia, the Czech Republic, the Netherlands, Denmark and Germany are investigating how controlled traffic farming system can be established under Western and Middle European conditions and if similar effects can be realised like in dryer regions. For single aspects publications are available [14–19], all-embracing scientific research results based on finished field experiments in Europe have not been published until now.

Material and methods

Farms and locations

With three farms in southern Bavaria cooperation was arranged to establish CTF field trials. The farms are situated in the county of Eichstaett (1), in the county of Neuburg Schrobenhausen (2) and in the county of Pfarrkirchen (3). Farms 1 and 2 are arable farms with winter wheat, winter rye, oilseed rape and sugar beet. Farm 3 has bull fattening and poultry and is growing winter wheat, oilseed rape and corn.

All three farms are practicing mulch tillage and are using automatic guidance systems since several years. They also showed interest in improving their arable farming systems and have thought about the adoption of controlled traffic farming before. Based on the technology already available on the farms all needed tractors have been upgraded or equipped with highly accurate guidance systems (RTK-DGPS). Some of the used automatic guidance systems work with electro magnetic steering valves, others with electric drive actuators at the steering wheel. Only the self propelled sugar beet harvester on farm 1 does not use a DGPS based steering system because his sensor based automatic steering system is following the sugar beet rows which are planted using RTK DGPS guidance.

In the years 2009 and 2010 the total precipitation on farms 1 and 2 were 804 res. 768 mm, the average temperatures 8.7 °C res. 7.5 °C (weather station Haeringhof). The location of farm 3 was characterized by higher precipitation (2009: 890 mm, 2010: 804 mm) and higher temperature (8.9 °C res. 8.1 °C, weather station Reith).

The soils of the experimental fields are deep and influenced by silty loam. Soil type on farm 1 is silty to weak clayey loam, of Farm 2 medium silty clay to sandy-clayey loam, and on farm 3 medium sandy loam.

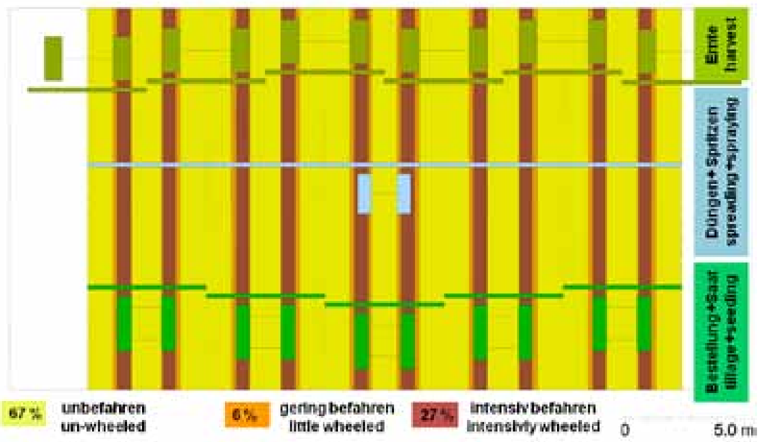
Field experiments

To realize a consequent controlled traffic farming system for every experimental site, traffic patterns based on the available equipment have been developed. This pattern took into account the working width of the key machines (tillage, seeding and harvesting), the track width of all equipment and the tire width. The result has been the different system widths of 5.4 m (farm 1), 6.0 m (farm 2), and 4.5 m (farm 3). All field work, e. g. tillage, drilling and harvesting is done with this working width. Fertilizer application and spraying is done with a multiple of these system (working) widths. Based on the different traffic pattern the following (theoretical) portions of un-wheeled soil could be realized: 67 % on farm 1, 58 % on farm 2 and 66 % on farm 3.

Figure 1 shows the traffic pattern of farm 1 with 67 % un-wheeled soil surface in a rotation with only combinable crops. On the fields with sugar beet the portion of un-wheeled soil is much smaller because of the fact that the working width of the sugar beet harvester is only 2.7 m (6 rows). Therefore sugar beet harvesting is causing additional tracks.

Figure 1 also shows that tractors and combine do not use/are not able to use the same track, but drive shifted by half a track (“Twin-Track-System”). The reason is that combines are

Fig. 1



Traffic pattern (rotation with combinable crops, farm 1) allowed to have a much wider track width than tractors (3.5 m vs. 2.5 m). Due to the shift by half a track the tires of the tractor run in the tracks of two neighbouring combine runs. This solution is limited to system width up to 6 m. With larger working width the distance between neighbouring combine tracks is too wide to match with typical tractor track widths. This illustrates, that in our CTF trials we had to modify the typical CTF approach with adapted equipment with wide and identical track width and narrow tires as reported and known from Australia to meet our traffic regulations. A ratio of wheeled soil around 15 % like in Australia cannot be reached under our conditions. Therefore the effects on yield and soil functions within the wheeled areas also have to be investigated intensively.

On all three locations extensive soil moisture measurement networks to determine soil water content were installed in the area of the tracks and in the un-wheeled areas and in three depths down to 0.6 m. Sampling and analysing soil probes gave information on soil physical properties and yields were separately determined within the tracks and in the un-wheeled areas.

Soil and crop

Soil water balance

A mayor topic of the project is to investigate if and how a CTF system changes the soil water balance. Changes would be caused by changes in the soil structure. Therefore at all three field trials during the whole vegetation season the soil moisture tension is measured. In addition penetration resistance (soil cone index) and bulk density was determined at different dates.

To measure soil moisture tension equi-tensiometers are used. All installed tensiometers are sluiced using quartz powder to realize a optimal soil sensor contact.

On farm 1 two measurement points in a distance of 90 m were set up. At each location the sensors have been installed in 0.15 m, 0.375 m and 0.60 m depth, in the wheeled and in the un-wheeled area and on both part fields with different crops, mirroring the whole installation. The horizontal distance between the sensors (in the different depths) at one location is 0.50 m. In the depths of 0.15 m at measuring point 1 three sensors each 0.50 m apart should give additional information about the small scale heterogeneity of the soil moisture tension.

The installation of the soil moisture tension measurement network on farm 3 was similar to farm 1 with the difference that 3 measuring points with distances of 25 m were set up.

On farm 2 three measurement point with distances of 60 m were installed. Due to the fact, that only one crop per year is grown on that field, the installation was not mirrored.

All data are continuously collected and stored by data loggers and can be accessed via modem. In addition precipitation was measured and compared with the nearest official weather station.

At the experimental sites also soil samples have been collected from all measuring points and depths to determine texture and pf-curve.

Yields and yield determining parameters

To evaluated the expected differences in the yield between wheeled and un-wheeled areas of the CTF system 10 harvest samples have been taken in the tracks (not in the tramlines) and in the area without any field traffic. Such a kind of local directed small plot harvesting was not possible with oilseed rape due to its intensive branching. To characterize its yield potential its root mass and main root length was determined at the beginning of flowering.

First Results

In the following the first results of the project are presented, without demanding a comprehensive consideration or evaluation of the different and numerous collected data.

Technology

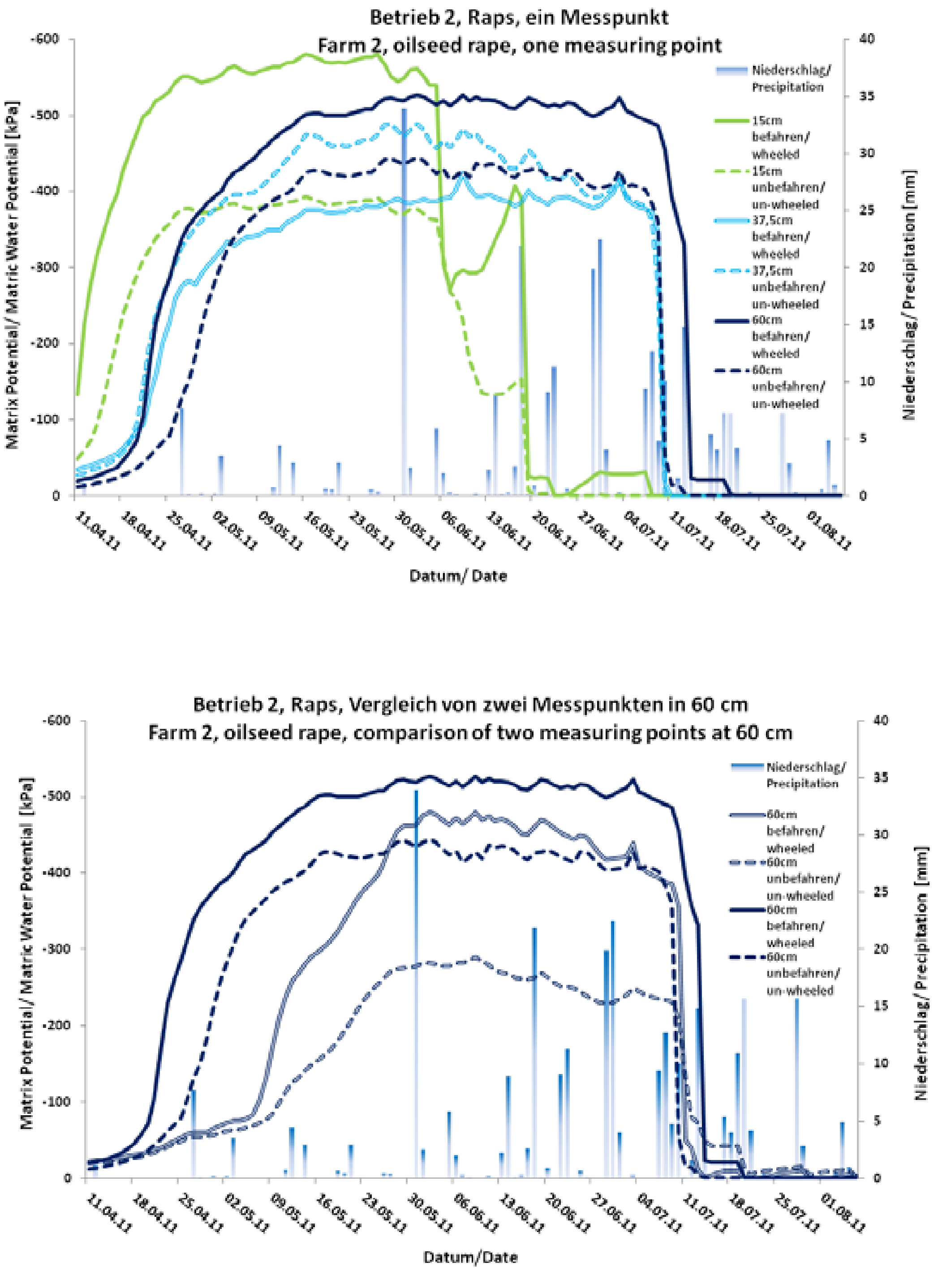
All RTK DGPS based automatic steering systems used in the investigations on the three farms worked reliable and accurate.

A CTF system can only develop its advantages if the traffic pattern is realized strictly and consistently. Thereby restrictions in the management and the operating procedure are connected with CTF. A change between implements with different working width is not possible. The replacement of equipment or the use of services from contractors must be well planned and organised. Precondition for a successful realization of CTF is the willingness of the farm manager to abandon some flexibility.

Soil

Figure 2 shows precipitation and water potential in the depths of 0.15 m, 0.375 m (1 measuring point) and 0.60 m (2 measuring points) under oilseed rape from May until August 2011 on farm 2. The soil moisture tension increases with the uptake of water by the plants continuously, starting in the top soil and reaching the lower depth later. Precipitation reduces the soil water tension only in the top soil. After the plants ripen and die off starting end of June repeated rain can fill up the soil water.
Soil moisture tension clearly differentiate in 0.15 m and 0.60 m depth between wheeled and un-wheeled areas, starting in April the wheeled soil is dryer than the un-wheeled. In the depth of 0.60 m the development is even-tempered, because evapotranspiration and root penetration are limited. In the depth of 0.375 no clear differentiation can be detected.
In general the development in 0.60 m depths shows the tendency at many other measuring points and locations. In many cases the soil moisture tensions in the wheeled soil in 0.60 m depth have been higher than in the un-wheeled areas. This complies with the expectations that in un-disturbed soils the infiltration of water is higher. But before generalized conclusions can be made long term measurements have to be conducted and analysed and combined with additional soil physical investigations.

Fig. 2



Soil moisture tension in 15 and 60 cm depth in wheeled and un-wheeled areas (Farm 2)

Crops

The yield results of the two years do not differentiate in a specific direction (**Table 1**).

While no differentiation between wheeled and un-wheeled areas could be detected on farms 1 and 3 in the year 2011, in the year 2010 the winter rye yield in the un-wheeled areas on farm 1 was significantly higher than in the wheeled areas.

On the experimental field of farm 2 the winter wheat yield in 2010 in the tracks was higher than in the un-wheeled areas. The reason for the small and not expected differentiation cannot be explained. For reliable results more experimental years are needed.

Table 1

Cereal of Controlled Traffic Farming experiments in 2010 and 2011

Situation ***Situation***	**Ertrag befahren** [1)] ***Yield wheeled area*** **[t/ha]**	**Ertrag unbefahren** [1)] ***Yield unwheeled area*** **[t/ha]**
Winterroggen – Betrieb 1, 2010 *Winter rye – farm 1, 2010*	4.9 (73 %)	7.2 (107 %)
Winterweizen – Betrieb 2, 2010 *Winter wheat – farm 2, 2010*	8.3 (108 %)	7.5 (98 %)
Winterweizen – Betrieb 1, 2011 *Wwinter wheat – farm 1, 2011*	8.3 (102 %)	8.1 (100 %)
Winterweizen – Betrieb 3, 2011 *Winter wheat – farm 3, 2011*	6.1 (97 %)	6.4 (101 %)
Relativer Durchschnittsertrag *Relative average*	95 %	102 %

[1)] Durchschnittsertrag Gesamtfläche/*average yield whole field* = 100 %.

Conclusions

The process and the preliminary results of the establishment of controlled traffic farming experiments on three farms in southern Bavaria show that the needed technology to realize CTF under our conditions is available.

In Germany and Western Europe CTF can only be realized with equipment available and meeting the existing traffic regulations. Differences in track width cause a higher portion of wheeled areas in the field. Minimizing the portion of unwheeled soil can be reached by increasing the working width and matching the track width of all used machines. How crop yields react on CTF under local conditions cannot be estimated after 3 years. The same applies for the reaction on severe dryness (draught).

The challenge of CTF for the farm manager is on one hand to match working width and track width of all used machines and on the other hand the consequent implementation of the track based field traffic. On farms with sugar beet or potatoes CTF system cannot be realized today because the used bunker harvesters with off-set/crab steer mode are wheeling the whole field nearly totally. Also the sugar beet harvesting technology used on farm 1 without off-set/crab steer mode cover a very large portion of the field with tracks.

The first detected effects of CTF on the soil water balance are promising. An improved water infiltration and storage capability under the un-wheeled areas seem to become apparent.

Less compacted soil means less energy consumption to loosen the compaction by tillage. Similar to the yields more data and a balance integrating un-wheeled and wheeled areas are necessary. Together with an improved soil structure there might be a chance to reduce nitrous oxide emissions. Emission measurement might be interesting as soon as the trend in soil water balance becomes stable.

CTF is not yet applicable for the German or Western Europe agriculture. Further investigations, adaptations and experiences are needed.

Literature

[1] Lamers, J.G.; Perdok, U.D.; Lumkes, L.M.; Klooster, J.J. (1986): Controlled traffic farming systems in the Netherlands. Soil & Tillage Research (8), pp. 65–76

[2] Tillett, N.D.; Holt, J.B.; Chestney, A.A.W.; Reed, J.N. (1988): Experimental Field Gantry for Leaf Vegetable Production: Specification, Design and Evaluation. J. agric. Engng. Res. 41, pp. 53–64

[3] Kromer, K.-H. (1989): Verkehrsorientierte Anbausysteme – Definition und verfahrenstechnische Lösungen. Landtechnik 44(6), S. 225–232

[4] Tullberg, J. (2008): CTF and Climate Change. 6th Australian Controlled Traffic Farming Conference, pp. 86-90; www.actfa.net/further_reading/documents/Tullberg.Jeff.pdf, Zugriff am 10.9.2012

[5] Tullberg, J. (2010): Tillage, traffic and sustainability – A challenge for ISTRO. Soil & Tillage Research (111), pp. 26–32

[6] Reeder, R.C. (2002): Maximizing Performance in Conservation Tillage Systems – an Overview. ASAE Paper No. 021134, 2002 ASAE Annual Meeting / CIGR XVth World Congress, ASABE St. Joseph, MI, USA

[7] Tullberg, J.N.; Yule, D.F.; McGarry, D. (2007): Controlled traffic farming - From research to adoption in Australia. Soil & Tillage Research (97), pp. 272–281

[8] Department of Agriculture, Gov. of Western Australia (2004): Tramline Farming Systems – Technical manual, Bulletin 4607, ISSN 1448-0352 www.agric.wa.gov.au/objtwr/imported_assets/content/lwe/land/cult/bulletin4607_complete.pdf

[9] Kingwell, R ; Fuchsbichler, A. (2011): The whole-farm benefits of controlled traffic farming: An Australian appraisal. Agricultural Systems (10), pp. 513–521

[10] Li, Y.X.; Tullberg, J.N.; Freebairn, D.M.; Ciesiolka, C.A. (2004a): Effects of controlled traffic and conservation tillage on runoff and crop yield. ASABE Paper No. 041071, 2004 ASAE Annual Meeting, ASABE St. Joseph, MI, USA

[11] Li, Y.X.; Tullberg, J.N.; Freebairn, D.M. (2004b): Infiltration and runoff associated with controlled traffic and soil compaction under simulated rain. ASAE Paper No. 041072, 2004 ASAE Annual Meeting, ASABE St. Joseph, MI, USA

[12] Bowman, K. (2008): Economic and Environmental Analysis of Converting to Controlled Traffic Farming. In: 6th Australian Controlled Traffic Farming Conference, 61-68, www.ctfsolutions.com.au/ebm3-doc/132275/Bowman%20Economics.pdf, Zugriff am 10.9.2012

[13] Qingjie, W.; Hao, Ch.; Hongwen, L.; Wenying, L.; Xiaoyan, W.; McHugh, A.D.; Jin, H. and Huanwen, G. (2009): Controlled traffic farming with no tillage for improved fallow water storage and crop yield on the Chinese Loess Plateau. Soil & Tillage Research (104), pp. 192–197

[14] Roberts, M. (2011): Ackern auf dem rechten Weg – Controlled Traffic Farming in Großbritannien. profi 7, S. 70–73
[15] Holpp, M.; Anken, T.; Saueter, M.; Rek, J.; Reiser, R.; Zihlmann, U.; Oberholzer, H.R.; Weisskopf, P.; Hensel, O. (2011): Swiss Controlled Traffic Farming Trial – Preliminary Results 2008-2010. In: Precision Agriculture 2011, Czech Centre for Science and Society (ed.), Prag, Czech Republic
[16] Bochtis, D.D.; Sørensen, C.G.; Busato, P.; Hameed, I.A.; Rodias, E.; Green, O.; Papadakis, G. (2010): Tramline establishment in controlled traffic farming based on operational machinery cost. Biosystems Engineering (107), pp. 221–231
[17] Kroulik, M.; Kviz, Z.; Kumhala, F.; Hula, J.; Loch, T. (2011): Procedures of soil farming allowing reduction of compaction. Precision Agriculture 12, pp. 317-333
[18] Bommes, Ch. (2009): Immer in der Spur bleiben. dlz 8, S. 35–39
[19] Holpp, M.; Anken, T. (2008): Ackerbau wie auf Schienen. Mulchsaatpraxis, DLG-Mitteilungen 7, S. 48–51

Authors

Markus Demmel, **Hans Kirchmeier** and **Martin Mueller** work at the Bavarian State Research Center for Agriculture at the Institute for Agricultural Engineering and Animal Husbandry, Voettinger Str. 36, 85354 Freising, e-mail: markus.demmel@lfl.bayern.de

Robert Brandhuber and **Marc Marx** work at the Bavarian State Research Center for Agriculture at the Institute for Agroecology, Organic Farming and Soil Conservation, Lange Point 12, 85354 Freising, e-mail: robert.brandhuber@lfl.bayern.de