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Measuring systems for the evaluation of fen grassland vehicle carrying capacity

Measuring systems for the evaluation of the vehicle carrying capacity of fenland must reflect the site-specific carrying capacity of the driving tracks with sufficient precision so as to indicate competently the mechanical stress permitted whilst driving over the surface. The systems must also require no more than justifiable effort in the field. The conical invasive resistance (cone index) does not give enough information on drivability. The plunger is fundamentally suitable, its application, however, too expensive. The shearwing permits an acceptable identification of carry capacity and permissible mechanical loading and is therefore suitable for assessing drivability.

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Fenland ground in Germany covers 1.1 m ha. From an load-bearing aspect, overgrown organic locations are classified under the vertically-stratified soils, whereby there is a firm surface layer grown-through with roots with peat, which is less able to bear loads, underneath [1]. Breaking through the grass layer is to be avoided , for mechanical reasons as well as ecological ones [1,9]. Factors that have an influence on the firmness of driving tracks on fen grassland are vegetation and ground type. The stability of the track can be determined through the tried and tested methods for assessing degree of ground compaction.

The cone indices determined by a number of authors with the penetrometer on organic soils lie in the region of from 17 to 1500 kPa [6, 7, 8, 9]. From the results of a large number of driving trials with track laying vehicles [8] a drivability index for moorland on the North American Tundra has been empirically calculated. [6] determined cone indices for two fen locations in north-eastern Germany and identified, through analogue calculations, areas of the ground that could be driven over with high loadings.

Using the plunger [1] calculated fundamental associations for ground with a firm covering layer on North American Tundra moorland. Comprehensive analyses of pressure-penetration-curves on two Tundra locations in Canada was undertaken by [9]. There exists many shear measurement procedures for field and laboratory investigations. On Canadian Tundra moorland [9] carried out investigations with Scherring sheer-tension-ground-transfer-curves. On east-German fenland, a shearwing used on the turf determined shear resistances of 5 to 25 kPa [5].

Aims and assignments

Required was the development of a simple, practical and transferable method for evaluating the drivability of fen grasslands. For this reason, measuring systems have to be evaluated and selected that reflect with sufficient accuracy the site-specific carrying-capacity of the driving track. They also have to show clearly enough the acceptable mechanical loading during driving and the tests have to be able to be carried out in the field with no more than justifiable effort.

Investigations of measuring systems to determine drivability of fen grassland

Penetrometer

For measuring the cone index, a manually operated shaft-friction-free penetrometer was used. The cone utilised had a base area of 3.23 cm^2 and a peak angle of 60°. From 1047 individual measurements on fen grassland it became clear that in most cases the

Table 1: Cone index of fen grasslands with different vegetation and soil moisture contents

Biotype / Soil moisture content	Vegetation-density	Flood grasses sparse	medium	high	Fresh grassland sparse	medium	high	Grossseggen grassland sparse	medium	high
≤60	CI [kPa]	**402**	**967**			**773**	**393**		**823**	**567**
Vol%	n	2	3	n.b.	n.b.	102	14	n.b.	2	7
	VK %	37	33			57	57		43	53
>60 bis 70	CI [kPa]		**367**		**473**	**590**	**497**		**470**	**340**
Vol%	n	n.b.	13	n.b.	44	204	19	n.b.	10	5
	VK %		64		39	48	47		54	44
>70 bis 80	CI [kPa]		**270**	**240**	**473**	**407**	**433**	**487**	**443**	**307**
Vol%	n	n.b.	31	11	45	70	23	3	16	18
	VK %		69	68	52	36	51	19	66	57
>80	CI [kPa]		**264**	**266**	**316**	**307**	**298**	**454**	**404**	**342**
Vol%	n	n.b.	55	10	24	247	58	8	25	5
	VK %		63	54	50	64	62	53	57	43

Vegetation density Soil-moisture vol%	Testing body area	average small plate $185\ cm^2$	 large plate $370\ cm^2$	high small plate $185\ cm^2$	 large plate $370\ cm^2$
≤60	p_{max} [kPa]	**439**	**344**		
	n	3	1	n.b.	n.b.
	VK %	5			
>60 bis 70	p_{max} [kPa]	**420**	**337**		
	n	3	4	n.b.	n.b.
	VK %	7	10		
>70 bis 80	p_{max} [kPa]	**392**	**325**	**422**	**351**
	n	28	12	10	6
	VK %	14	6	10	9
>80	p_{max} [kPa]	**380**	**299**	**408**	**323**
	n	8	9	11	8
	VK %	10	14	7	15

Table 2: Maximum pressures p_{max} from load-penetration-curves for a fen grassland with different soil moisture contents and density of vegetation

cone index increased in line with reductions in soil moisture content (*table 1*).The influence of the vegetation on the load bearing capacity was not able to be determined by the cone index. Neither type of biotope nor vegetation density offered a calculable connection. Regression factors for the calculation of the required cone index with differing load parameters indicate very low indices of coefficient of under 0.17.

Although the cone index can be determined with this with minimum effort it allows, however, only an unsatisfactory evaluation of the drivability. The reason for this is possibly that the cone sensor is too small to give a representative measurement of the considerable compaction differences in the root layer within very small areas.

Plunger

The plunger that was used was a soil sample collection implement manufactured by Fritzmeier GmbH and rebuilt by the Bavarian Federal Institute for Agricultural Engineering. For measuring, a hydraulically powered series of round plates with areas of 740 cm^2, 370 cm^2 and 185 cm^2 are pressed into the ground one after the other at a speed of 3 cm/s. The signals from the pressure and direction sensors are digitalised and recorded by computer.

The evaluation of 226 pressure-penetration-curves recorded on fresh grassland showed in 46% of the investigated cases a more or less well-developed maximum pressure. On average, the maximum pressure occurred at a penetration depth of 9.4 cm. The use of small plates always resulted in a higher pressure than with large ones. The extent of the maximum pressure was influenced by the driving track parameters soil moisture content and vegetation density (*table 2*).

The determined association of selected parameters of pressure-penetration-curves to soil moisture content and vegetation result in the measuring procedure for the evaluation of the carrying capacity of fen grassland seeming to be fundamentally suitable. The same applies to the identification of the possible mechanical loads where driving takes place. The maximum vertical loads determined in the plate-pressure trial are, however, not transferable onto vehicles. For the large number of measurements that is necessary, the application of the plunger is too expensive.

Shearwing

The shearwing GEONOR H-704 with a wing sensor diameter of 7.58 cm and a height of 13.96 cm [3] can be used for the manual measurement of shear resistance. From 3441 data inputs, it was clear that the shear resistance in the first place depends on the type of biotope and, with that, on the composition of the vegetation (*table 3*). Within the different biotope types the shear resistance rose – where soil moisture content was the same – with the vegetation density. Finally, the shear resistances became closer with increasing soil moisture. From the results of many driving experiments the necessary shear resistance required before fen grassland can be driven-on can be estimated from parameters of the technology-caused mechanical stress with the help of regression factors [4]. The function indicates a sufficient index of determination of from 0.87 upwards and shows a sufficient agreement between measures and calculated values.

The shearing thus satisfied the formulated demands on the measurement system and proved suitable for the evaluation of the drivability of fen grassland on the basis of empirical associations.

Conclusions

The investigated measuring systems met the demands that were formulated at the beginning in very different degrees. Between the different measuring systems evaluated the shear resistance approach proved most suitable for the evaluation of drivability of fen grassland. With this, the fundaments for revealing the load carrying and stress classifications are created with functionally suitable technology [4]. The results are useful for factually based advice on the choice of technology. Decision aids for the operational technological application require large-scale mapping and, with this, a further increase in the efficiency of the system.

Table 3: Shearing strength τ_{max} of fen grasslands with different vegetation and soil moisture contents

Biotope Soil-moisture content	Vegetation-density	Flood grassland sparse	 mediuml	 high	Poor wet grassland spare	 medium	 high	Dense wet grassland sparse	 medium	 high	Fresh grassland sparse	 medium	 high	Grossseggen grassland sparse	 medium	 high
≤60	τ_{max} [kPa]		**28**	**31**	**29**	**32**	**36**	**29**	**34**	**41**	**33**	**45**	**50**		**46**	**57**
Vol%	n	n.b.	8	5	41	49	39	45	194	117	10	39	65	n.b.	20	36
	VK %		21	21	10	10	13	14	16	12	15	18	16		13	14
60 bis 70	τ_{max} [kPa]	**23**	**24**	**27**	**27**	**27**	**29**	**21**	**33**	**39**	**33**	**39**	**44**		**45**	**48**
Vol%	n	5	61	27	22	40	65	2	38	22	31	191	135	n.b.	34	33
	VK %	10	28	25	9	20	19	31	18	8	15	20	17		15	18
70 bis 80	τ_{max} [kPa]	**17**	**20**	**27**	**22**	**25**	**29**	**21**	**28**	**37**	**28**	**36**	**44**	**31**	**40**	**46**
Vol%	n	24	125	44	60	91	97	64	63	6	12	146	157	6	31	44
	VK %	27	24	18	9	20	15	20	19	3	23	22	17	14	20	23
>80	τ_{max} [kPa]	**15**	**19**	**26**	**22**	**25**	**28**	**19**	**25**	**28**	**22**	**31**	**44**	**29**	**40**	**46**
Vol%	n	41	64	37	39	69	43	78	71	10	26	228	134	33	142	82

1)Overall area proportion in the growth density classes are based on the remaining stubble; sparse >40%; medium: 40 to 80%; high: >80%