НОВЫЕ МЕТОДЫ И РЕЗУЛЬТАТЫ ИССЛЕДОВАНИЙ ЛАНДШАФТОВ В ЕВРОПЕ, ЦЕНТРАЛЬНОЙ АЗИИ И СИБИРИ

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This monograph shall inform you about up to date methodologies and recent results in landscape research. It is intended as a guide for researchers, teachers, students, decision makers, stakeholders interested in the topic of landscape science and related disciplines. It provides information basis for decision makers at various levels, from local up to international decision bodies, representing the top level of landscape science in a very short form.

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INTRODUCTION
Soil erosion is a global problem. For understanding and modeling erosion processes measured high resolution on-site data are most appropriate [3, 4, 5] because most influencing soil properties like soil surface shear strength and roughness are heterogeneous even on a small scale. Stochastic modeling of soil erosion is based on this type of data to calculate probability density functions of influencing soil parameters like soil surface shear strength and roughness [4, 5]. A couple of methods have been established for on-site measurement of soil roughness [6, 7, 8]. But only a few methods are used for measurement of soil surface shear strength on-site like fall-cone penetrometer and vane tester [9, 1, 10] or in laboratory like “resin plate method” [11] or “sandpaper method” [12, 13]. With all this methods average values are measured based on a certain soil area and/or volume. But it is not possible to perform a lack of experimental in-situ data with high spatial resolution at the point scale. To fill this gap a new field device was developed to measure soil surface shear strength and roughness simultaneously with high spatial resolution. The name “4S-device”

Chapter III/41: HIGH RESOLUTION, ON-SITE MEASUREMENT OF SOIL SURFACE SHEAR STRENGTH AND ROUGHNESS WITH NEW 4S-DEVICE
Глава III/41: Измерение прочности и шероховатости почвы с высоким разрешением в поле с новым 4S-устройством

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ABSTRACT. Soil surface shear strength and roughness are two important controlling factors for soil erosion processes [1, 2]. Soil aggregate destruction and erosion starts at the weakest point of the soil surface. This means that high resolution field data are needed for process understanding and modeling. Some methods are established for on-site measurement of soil roughness and only a few for on-site measurement of soil surface shear strength. Due to a lack of experimental in-situ data with high spatial resolution for soil surface shear strength a new field device was developed to measure soil surface shear strength and roughness simultaneously. The new multitool consists of three components: i) a cutting blade combined with force transducer for shear force measurement, ii) a laser for determination of soil surface roughness and cutting depth and iii) two cameras imaging the recorded data for analysis and discussion. Multiple tests in the laboratory and on-site under regular field conditions showed that the 4S-device reproducibly determines highly resolved data on spatial and temporal changes of physical and mechanical soil surface properties.

Резюме. Прочность и шероховатость поверхности почвы являются двумя важными определяющими факторами для процессов эрозии почв [1,2]. Уничтожение и эрозия почвенного агломерата начинается в самой слабой точке поверхности почвы. Это означает, что для понимания и моделирования процессов необходимы полевые данные высокого разрешения. Существует несколько методов для измерения шероховатости грунта в поле и совсем мало для измерения сопротивления поверхности почвы на сдвиг на месте. Из-за отсутствия экспериментальных данных in situ с высоким пространственным разрешением для сопротивления поверхности почвы на сдвиг было создано новое полевое устройство, которое разработано для одновременного измерения прочности и шероховатости поверхности почвы. Новый мультинструмент состоит из трех компонентов: i) режущего лезвия в сочетании с силовым преобразователем для измерения поперечной силы; ii) лазера для определения шероховатости поверхности грунта и глубины резания; iii) двух камер, отображающих записанные данные для анализа и обсуждения. 4S-устройство воспроизводимо определяет данные высокого разрешения о пространственных и временных изменениях физических и механических свойств поверхности почвы.

KEYWORDS: soil surface shear strength, soil surface roughness, high resolution data, on-site measurement, new field device, soil erosion

INTRODUCTION
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refers to its primary use to measure the Soil Surface Shear Strength. The goal of the following remarks is to give a brief technical device description and to point out its potential to provide appropriate high resolution data.

**AIM OF THE METHOD**
A new on-site device was developed and tested to deliver exact in situ point data along a measuring line of about 1 m with high spatial resolution. Data should describe the variability/heterogeneity of soil surface shear strength and roughness simultaneously, thus enabling an improved identification of the influencing parameters and processes. Furthermore, data should be useful e.g. as stochastic input parameters for erosion modeling.

**PRINCIPLE AND PROCEDURE**
**Principle:** The idea for developing a new device is based on the idea of Sidorchuk [14] to determine the shear strength of a soil surface in the laboratory by cutting a disturbed soil sample with a narrow blade. He stated that “based on the principle that the resistivity to movement of a solid body through plastic media is controlled mainly by dry friction” [14]. The first application of this concept was to modify a standard box shear apparatus in the laboratory. The aim was to measure the surface shear force of a soil sample with a combination of a fixed blade and a sensitive force transducer at a defined speed and cutting depth to calculate the shear strength (relation of shear force and related contact blade area). Tests for taking and investigating disturbed and undisturbed soil samples with the new technology were successful. Based on these results the new 4S-device for on-site measurement of undisturbed soils under field conditions was developed (Fig. 1). The new field device should be able to collect data for cutting force (shear strength) and surface roughness with high spatiotemporal resolution simultaneously while running along a guide rail over a distance of about 1 m. Multiple calibration tests have been carried out in laboratory and field to control influencing factors such as blade type, cutting depth, running velocity, running direction (uphill/downhill), soil water content, bulk density and structure (disturbed or undisturbed soil, aggregate size).

**Procedure:** *Technical information:* The 4S-device (see Fig. 1) measures 133.5 cm x 33 cm x 20 cm (LxWxH). A stainless steel frame carries two guide rails (1) on which the measurement system (2), driven by a battery-powered (3) spindle drive (4), can be moved back and forth. The measuring system consists of one cutting blade (10, industrial tool steel, 2.5 cm cutting length), two cameras (6 - top view, 7 – lateral view), one force transducer (8, measuring range 10 µN to 100 N) and a laser scanner (9). The measurement system can be adjusted upwards and downwards.

![Figure 1 - 4S-Device](image)

**Figure 1 - 4S-Device:** 1 guide rails, 2 measurement system, 3 power supply, 4 spindle drive, 5 start button, 6 camera for top view, 7 camera for lateral view, 8 force transducer, 9 laser scanner, 10 cutting blade
4S-device is controlled via new developed computer software, where advance rate (0.3 – 2.5 mm/s) and measurement interval for shear force transducer, laser and cameras (200, 500, 1000 ms) can be set. While the blade moves along the guide rails and cuts the soil’s surface the force transducer records the shear force [N]. The laser scanner determines the surface roughness and by that simultaneously the cutting depth of the blade [mm] can be calculated. The two cameras take pictures of the front area of the cutting blade.

Field preparation: As far as possible, the measurement should be performed on an undisturbed soil surface with preferably sparse vegetation cover. Loose plant residuals and larger stones should be removed carefully from the soil surface of test area, without disturbing the soil surface too much. Plants can be cut down; larger roots should be left in the soil to maintain the surface structure.

TEST RESULTS

Test measurements based on the high resolution data showed a great spatial variability/heterogeneity of the soil surface shear strength even on the millimeter scale for example within and between different tillage systems. Other investigations based on sprinkling experiments also pointed out a clear small scale spatial and temporal change of shear strength and roughness at the soil surface. During a measuring run different processes may proceed (Fig. 2): i) the soil surface or single soil aggregates are cutted, ii) aggregates, stones or other pieces are pushed, iii) thread-like structures like roots I the soil are pulled. The combination of force and laser measurement with the simultaneously taken pictures from front and side perspective enable to distinguish between this cutting, pushing and pulling forces. Examples: Figure 2.a1 (cutting process): A soil aggregate with stable position is cut. Force is increasing first up to a maximum value and then decreasing. Figure 2.a2 (cutting and/or pulling process): A flat, homogeneous soil surface is cut. Longer increase and decrease of force values is measured caused by a root or an aggregates below the surface. Figure 2.a3 (pushing process): An aggregate is detached and moved in front of the blade while interlocked several times by surrounding aggregates creating several force peaks of similar height. So the device enables to measure the maximum resisting forces of soil aggregates against displacement and vice versa thresholds for minimum pushing forces of water to move aggregates. Figure 2.a4 (cutting process): Although the cutting depth of the blade is large (about 2.5 cm) the force values are low because the soil is very loose in this area. In addition all on-site measurements revealed that the laser system is able to detect soil surface roughness on the mm-scale and to use this data for cutting depth recording as well as cutting depth correction related to the simultaneous determined shear force.

![Figure 2 - Soil surface shear force of a sandy-silty fluvisol and related images for data and process understanding. (White color: powdered soil surface with flour for optimized laser reflexion, only for first device version)](image-url)
APPLICATION
The applicability of the device in the field was tested in flat and sloped positions, on differently soils (Cambisol, Fluvisol, Stagnosol, stony vineyard soil), under different types of tillage (conventional & zero tillage), with and without irrigation. The results were reproducible and proved the suitability of the new 4S-device to measure soil surface shear resistance and surface roughness simultaneously under variable conditions in field and laboratory with high resolution.

CONCLUSIONS
1. The new 4S-Device enables to measure soil surface shear strength and soil roughness on-site under variable field conditions with high spatial and temporal resolution regarded to small scale (mm) soil variability/heterogeneity.
2. This may lead to a better understanding e.g. of initial and ongoing erosion processes and provide helpful input parameter for erosion modeling, especially based on stochastic processes.
3. The system can be used for all types of terrestrial and semi terrestrial soils. Problems may exist under frozen conditions (energy supply, frozen hard soil). It has not yet been tested with fibrously structured peat soils.

REFERENCES