Fourth International Conference on Biohydrology, 2016

BOOKS OF ABSTRACTS

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FOURTH INTERNATIONAL CONFERENCE ON BIOHYDROLOGY

Walking on drylands

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Walking on drylands

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CONTENTS

From Editors

BioHydrology 2016 is the fourth international conference on biohydrology, after those of Prague (2006), Bratislava (2009) and Landau (2013). As the previous conferences, the aim is providing a forum to discuss any question related to the interactions between biotic systems and hydrology. Such interactions can be simple, bidirectional or including feedback, and occurring at any spatial or time scale. The conference is addressed to experts from ecology, hydrology, geography, soil science, environmental sciences, biology, geomorphology, forestry and similar; but any expert focusing in this issue is welcome and interdisciplinary contributions are encouraged.

The conference includes five topics covering a wide thematic range. This time the congress moves from central Europe to Almeria, at the extreme south-east Spain, probably the most arid region in Europe, and the peculiarities of the interactions between living organisms, biocenosis or organic matter and hydrological processes in drylands is the first topic. The areas were water is a limiting factor during at least a part of the year account for more than the 40% of the emerged land at planetary scale. The increasing human population as well as its socio-economic development increases the water demand and the availability of water is already a concern in most countries. On the other hand, this concern tends to increase due to climatic change. The deep understanding of these natural biohydrological processes, even those studied at very detailed scales, can have important consequences, e.g., in food production, water harvesting, nature conservation, flood prevention, ecosystem function understanding, land management or guidelines for sustainable land uses.

The conference includes some plenary lectures from top international scientists, and a session for every topic, with keynote lectures from relevant scientists in every session as well as oral and poster communications from the participants.

PLENARY LECTURES

Soil Science Societies and their role for improving soil governance at a global level

Rainer Horn

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Abstract

The International Union of Soil Sciences with ist more than 60,000 soil scientists around the world plays an important role in not only improve our understanding of the non-renewable skin of the earth – our soils- . We must also define the boundaries for a sustainable landuse as well as for adequate soil and management systems depending on the geological, parent material and climatic conditions worldwide.

It is wellknown that soils as 4-dimensional bodies at the land surface with liquid, gaseous and solid components containing inorganic and organic materials, including living organisms in a great number and variety must be used carefully according to their resilience and elasticity for the long-term maintenance of key properties and processes. Thus, non-site adjusted land-use and soil management will result in a mostly irreversible degradation, and because soil amelioration is seldom or only on the very long run perhaps partly effective, we may lose the basis for our future life.

The declaration of the International Year of Soils 2015 by the United Nations in Dec. 2013 has provided IUSS the best opportunity to discuss from now on more recognized the critical topics of "soils and their very specific properties" and "their sensitivity concerning the irreversible vulnerability due to mismanagement". Thus, we have the great chance to show the beauty of the soil types and the variability in the landscape, but to also increase the awareness of their limited (or defined) resilience for a sustainable land use worldwide. The limited resource "soil" with its various functions – from plant production to soil heritage - needs to be protected and only used according to the site specific properties and functions. It is obvious that we need more food in the near future for a growing population on a declining area (because of an irreversible soil degradation worldwide with a loss of more than 300km² /d), but this can be only achieved if the functionality of soils is at least maintained. These topics have to be discussed at various levels ranging from the Kindergarten to the public, to politicians, and scientists all over the world and should result in an improved handling of soils in the future. The public awareness must be increased with the slogan "healthy soil for healthy food" or "better soil functionality results in higher resilience". Thus, if we define urgently needed soil properties and ways how to gain the certainty for the future to stop hunger, to optimize soil use efficiency and to guarantee long-term soil conservation, these properties and functions need to be linked to an increased level of:

1) internal soil strength which is improved by a higher microbiological activity, more even distributed root growth and corresponding strengthening of the total rhizosphere due to swell shrink properties, exudation and coinciding glueing of single particles,

2) actual accessibility of surfaces of grains, aggregates, organic compounds, or pores in order to improve the nutrient storage and availability and more effective filtering and buffering

3) the quick and effective exchange of gas, or water by an enhanced and more effective biological activity in our soils which optimizes these uncounted functions of the hidden half under our feet as the basis for our long-term wellbeing.

Within the lecture several of these topics will be discussed in more detail.

Key Words
Sustainability, soil threats, soil degradation, micro- and macroscale, rigidity.

Hyperplains: The unique ecohydrological imprint of extreme flatness

Esteban G. Jobbágy

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Abstract

The limitation of horizontal water fluxes imposed by the extremely low regional hydraulic gradients of hyperplains (large sedimentary regions with regional slope <0.1%) drives distinctive ecohydrological features that are starting to become acknowledged over the last decade as many of these areas host rapid land use changes. Globally, extreme flatness, much more than climate, determines the widespread presence of shallow water tables (<3 m deep), favouring an intense coupling between groundwater and ecosystems that goes beyond riparian or lowland environments, engaging the majority of the landscape. Four key distinctive features that emerge from this condition are illustrated for the plains of Southern South America: (i) Long-term flooding cycles, (ii) salt accumulation/redistribution processes, (iii) groundwater-vegetation feedbacks, (iv) need for hydro-informed adaptation strategies for farmers and land managers. Floods originated by saturation excess runoff and water table level raises shift from seasonal regimes in humid plains (e.g. Northern Campos) to sporadic multiyear episodes in subhumid plains (e.g. Pampas) to novel episodes with no precedents over the last century in semiarid plains (e.g. Chaco). Remote sensing and field observations show that although periods of high rainfall trigger these flooding episodes, the massive expansion of annual crops displacing perennial pastures and native vegetation have increased their frequency, extension and intensity. The almost complete predominance of evapotranspirative water outputs over liquid outputs in semiarid and subhumid hyperplains limits solute flashing creating large salt accumulations in the deep vadose zone across the whole landscape (Chaco forests) or closer to the surface in lowlands or areas of high groundwater discharge (Pampas, Chaco croplands). Models suggest that groundwater-vegetation feedbacks are a central organizer of these systems shaping both flood regimes and plant production. Canopy water use capacity (leaf area + roughness), rooting depth, and salinity/watertlogging tolerance are the main vegetation attributes influencing groundwater levels and transport. Observations show that the replacement of the deep rooted vegetation (native woodlands in the Chaco, alfalfa pastures in the Pampas) by shallow rooted annual crops is favouring recharge pulses during wet years and limiting steady groundwater discharge during dry years, what ends favouring flooding and triggering salt redistribution processes. Waterlogging and salt tolerance, found across many native species of the Pampas and Chaco let native ecosystems increase groundwater use under raising water table conditions. This regulatory feedback gets inpaired under annual croplands where waterlogging/salinity drastically reduces plant transpiration an even inhibits farmers from planting. In hyperplains groundwater introduces reciprocal connectivity across contiguous vegetation patches or crop paddocks creating both challenges and opportunities to regulate water table levels through land use management and landscape design. This possibilities are just starting to get understood and implemented by farmers. Applying the simpler, one-way perspective of vegetation-groundwater interactions coined in sloped regions of the world into hyperplains is a perfect road for failure and frustration. As agriculture expands and intensifies across the South American hyperplains, adaptative farming and nature conservation schemes

based on groundwater monitoring and explicit flooding/salinization risks consideration are urgently required.

Key Words
Groundwater-ecosystem coupling, flooding, salinization, farming, deforestation.

Biotic controls of ecosystem functioning in global drylands under global change

Fernando T. Maestre

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Abstract

Substantial research efforts are being devoted to predict how biotic attributes such as species richness, composition and diversity will respond to global environmental change (GEC) drivers like climate change, land use change and increases in [CO_2] and nutrient availability. However, their impact on the relationships between biotic attributes and ecosystem processes is virtually unknown. Therefore, much remains unknown on the potential effects of GEC on the processes and ecosystem services that depend on biotic communities. This is particularly true for water-limited ecosystems such as drylands (arid, semi-arid and dry-subhumid areas), were biotic attributes such as the cover, type and spatial pattern of vegetation and biological soil crust patches largely affect key hydrological processes that largely determine ecosystem functioning, such as infiltration, runoff and evapotranspiration.

In this plenary lecture I will summarize the results of recent and ongoing studies evaluating how biotic attributes (species richness, evenness and composition, cover and spatial pattern) modulate the functioning of drylands and their response to GEC drivers such as climate and land cover changes. These studies use multiple experimental approaches (manipulative and natural experiments), biotic communities (vascular plants, microbial communities and biocrusts dominated by mosses, lichens and cyanobacteria), spatial scales (from local to global) and ecosystem processes linked to hydrology, plant productivity and nutrient cycling.

We found that the relative importance of biotic attributes such as cover or species richness as modulators of ecosystem responses to GEC drivers varies with the spatial scale considered, being more important at local and regional (~400 km) scales. The composition of both vascular plants and biocrusts played a key role as drivers of infiltration and desiccation dynamics at the local scale. At the regional and global scale, abiotic variables such as annual temperature or aridity largely determined the variation in processes related to nutrient cycling and on plant productivity, but attributes such as species richness, spatial pattern and composition explained significant fractions of this variation. Overall, our results indicate that biotic attributes are key drivers of processes linked to hydrology, plant productivity and nutrient cycling in drylands worldwide, and may partially buffer the negative effects of GEC on ecosystem functioning in these water-limited ecosystems.

Key Words

Drylands, biological soil crusts, spatial pattern, species richness, ecosystem functioning, global environmental change.

Forest survival and hydrologic feedbacks in a seasonally dry deep regolithic environment: options for management

K.R.J. Smettem[1,2], R.J. Harper[1], J.K. Ruprecht[1], B. Dell[1]

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Abstract

Jarrah *(Eucalyptus marginata)* forests cover 30,000 km^2 in south-western Australia, in deeply weathered landscapes formed from igneous rocks. Profiles are invariably infertile and 30-50 m deep. In the last 30-40 years there have been several profound changes in this forest including a major reduction in surface runoff, periodic periods of forest mortality and declining groundwater levels leading to increased disconnection of groundwater from streams. . There has clearly been a change in the water balance of the forest and indications that the regolith is drying. This has been ascribed to a 15-20% reduction in mean annual rainfall over a 40 year period, specific years of well below average rainfall, and increased tree water use due to past forest disturbance such as timber harvesting. Deforestation, forest thinning and reforestation studies suggest decadal-scale responses in regolith hydrologic response. Questions arise about the implications of this regolith drying in an environment with future projections of reduced rainfall. For example, will this result in further tree mortality? Will the forest adjust to a new eco-hydrologic equilibrium? And what are the management options in a forest where the major economic drivers, from timber and water production, have largely been removed? In this paper we describe the interactions and feedbacks between forest cover, forest ecology, hydrogeology, and water supply in this changing environment and draw conclusions applicable to other regions around the world that are experiencing rapid environmental change.

Key Words

Regolith, groundwater, climate change, seasonality, forest water use.

Community gully conservation with biological and structural controls in the humid ethiopian highlands

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Abstract

Sediment concentrations have been increasing in the humid Ethiopian highland during the last 30 years, despite large-scale efforts by donors and the Ethiopian government to install soil and water conservation practices. One of the culprits responsible for increased sediment concentrations are gullies that have formed in the periodically saturated vertisols in the valley. These gullies can be 10 m deep and 30 m wide with banks collapsing due to the high water table. We have studied the soil loss from several gullies, and in one small watershed of less than 50 ha an equivalent erosion rate of 5 cm per year was observed. These gullies negate any reduction in sediment concentration from structural and biological soil and water conservation practices installed upstream.

The cause of the gullies was a change in land use during the communist regime in the nineteen eighties, or shortly thereafter, when forests in the uplands and in the valley bottoms were cut to feed the increasing population. Shifting cultivation disappeared and has been replaced by continuous cropping. This resulted in a loss of organic matter, and cations to leach. Consequently, aggregates broke down and increased sediment concentrations in the runoff (the other culprit!) and in the water infiltrating in the soil forming a restrictive layer that blocked the original deep flow paths. This in turn caused more lateral and surface flow at the expense of baseflow. Gullies are the most energy efficient way to carry excess water downhill.

The graduate students of Bahir Dar University (BDU) in cooperation with USDA_ARS sediment lab in Oxford MS and Cornell University performing the research have been successful in rehabilitating cooperatively with the community the shallow gullies by regrading the banks and using vegetation for stabilization. Although it was extremely difficult to convince the farmers in the community that the gullies were not an act of god, once rehabilitated, farmer groups on their own initiative started to rehabilitate gullies.

In this talk we will discuss biological and structural management practices at the watershed scale for effective land restoration of the watershed bottom lands. This includes establishing the original deep flow paths (and reduce direct runoff) in the unsaturated uplands of the watershed. Both infiltration furrows and deep rooted crops and trees planted on the most degraded soils are effective. In addition, shallow gullies should be regraded and vegetated to stop the gully head advance. Finally, the deep gullies should be stabilized, but more research is needed to do this effectively using local materials.

Key Words

Watershed, erosion, land rehabilitation, east Africa, sediment.

SESSION 1

WATER-LIMITED CONDITIONS AND BIOHYDROLOGY

Conveners:

Yolanda Cantón Castilla, University of Almería, Almería, Spain

Esteban Jobbagy, National University of San Luis, Argentina

Giora J. Kidron, Hebrew University of Jerusalem, Jerusalem, Israel

Francisco Domingo, Arid Zones Experimental Station, CSIC, Almería, Spain

Keynote lectures

Water release through plant roots in drylands: consequences at the plant and community level

Cristina Armas

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Abstract

Water relations are key to understand the ecology of terrestrial plant communities, and one of the components that determines water balance is the process of hydraulic redistribution. Hydraulic redistribution (HR) is the passive movement of water between different soil parts via the root system driven by water potential gradients in the soil–plant–atmosphere continuum that takes place under some environmental conditions. HR enhances plant transpiration and other water-related processes. Recent experimental evidence suggests that HR has an effect on organic matter decomposition, nutrient uptake, and root foraging behaviour. At the community level there is evidence that HR affects net primary productivity and has an impact in plant-plant interactions, ultimately altering water, biogeochemical and vegetation dynamics. Plant-plant interactions mediated by HR range from negative to positive and the outcome is dependent on species functional groups, plant life stage, whether water is released to the soil or directly transferred to other plant through shared mycorrhizal networks and, ultimately, the composition of the water redistributed through the root-soil system. Evidence obtained in a semi-arid sand dune system suggests that some salt-tolerant species can release salty water in upper soil layers through HR. Deep-rooted, salt-tolerant *Pistacia lentiscus* shrubs exert a negative effect on the performance of salt-intolerant *Juniperus phoenicia* shrubs caused by the release of salty groundwater into shallow soil layers by *Pistacia*. Plant physiology, mortality patterns as well as community spatial structure reflect this interference of *Pistacia* on *Juniperus,* negating the potential positive effects of an additional water source via hydraulic redistribution. Overall, should water-soluble compounds like ions and some nutrients be redistributed with water, HR could have important consequences for the biogeochemical cycles of some elements in these water-limited systems.

Key Words

Hydraulic lift, hydraulic redistribution, nutrient cycling, plant-plant and plant-soil interactions, salinity, semi-arid.

Disentangling the multi-scale eco-hydrological feedbacks that underlie dryland functioning and dynamics

Susana Bautista

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Abstract

The biotic and spatial structures of dryland vegetation are tightly coupled to dryland functioning, dynamics, and stability. These structure-function relationships are critically influenced by eco-hydrological interactions and feedbacks that operate over as well as across different spatial and temporal scales. Both positive and negative feedbacks between plant spatial pattern, resource redistribution, and productivity, combined with the effect on and response of plant functional traits and diversity, create a complex network of interactions that underlies dryland function and resilience, nonlinear dynamics, and sudden shifts. A growing family of community-scale manipulative experiments is contributing to efforts to disentangle the multiple feedbacks and interactions involved and incorporate them into a new generation of dryland models. Using dryland mesocosms, with plant communities of particular species composition and spatial patterns created ad hoc, these experiments show that both plant cover and plant pattern exert a critical role in controlling water and soil conservation in drylands, with the connectivity of bare-soil emerging as the most critical pattern attribute for explaining both global resource losses from dryland slopes, and local resource gains at the patch scale. The response of dryland vegetation to these losses and gains depends on the functional types in the plant community, which modulate the strength and sign of the eco-hydrological feedbacks involved. Overall, the resilience and restoration potential of dryland ecosystems appear to be largely controlled by the combined effect of their spatial and biotic structures, which in turn result from the interplay between pattern-dependent resource redistribution and trait-dependent plant responses.

Key Words

Drylands, ecohydrological feedbacks, plant spatial pattern, mesocosm experiments, nonlinear dynamics, sudden shifts.

Dryland shrub as ecosystem engineer to modulate hydropedological processes and water use source in water-limited environment

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Abstract

Dryland shrubs locally modify soil structure and infiltrability, and therefore affect hydropedological processes. The spatial and temporal dynamics of water flow above- and belowground are altered by woody plants. Aboveground, woody plant canopies interact with characteristics of rainfall (e.g., rainfall intensity) and/or human disturbance (e.g., grazing), to influence patterns of soil water content through rainfall interception and shading the soil surface. Belowground, roots of woody plants and soil texture influence flow path and temporal soil water utilization. Shrubs tend to have deep roots, high ratio of leaf to sapwood areas, low vertical shading, and strong morphological plasticity to adapt to variations in climate and soils.

Shrub traits and soil architectures coordinate each other to evolve a self-organized strategy and holistic soil-vegetation adaptation system to accumulate water, storage, and efficient use at different scales. At the stomata scale, shrub stomata usually can tolerate much more severe soil water stress as compared to the grass stomata. Kocacinar and Sage found the mean hydraulic conductivities are $3.24*10^{-4}$ and $0.46*10^{-4}$ kg $m^{-1}s^{-1}$ MPa^{-1} for C3 and C4 species, respectively. At the individual plant scale, shrub captures water through stem–root preferential flow systems to divert water to deeper soil layers to reduce evaporation. Our study showed that stemflow could lead to 1.5–3.2 times increase in infiltration depth, and as much as 10–140% increase in soil water content for shrubs of *Sminthopsis psammophila* and *Helianthemum scoparium* as compared to that without stemflow in north China. Meanwhile shrub can transport water from deep, moist soil layers to shallow, dry soil layers by a process known as "hydraulic lift" (HL). In desert zones, hydraulic lift can supply between 15% and 20% of daily water requirements of shrubs during the dry season. At the patch or plant community scale, shrub patches and bare/grass ground couple in a landscape mosaic of sources and sinks of water, sediments, and nutrients, which is an efficient rainwater harvesting system with the bare ground serving as a runoff producing zone and vegetation as a water- and nutrient-concentrating zone; shrub also tends to use water from shallow soil in wet season but from deep soil layers in dry condition. At the regional scale, shrub divergently responses to rainfall pulses along a precipitation gradient, and the shapes and sizes of the shrub patches also varied with annual rainfall to optimize water use. We found that shrub in the Gobi desert and typical steppe responded much faster with 3.6 ± 2.0 day and 6.4 ± 4.6 day, respectively, contrast with a durable response in Desert steppe (10.2 ± 6.5 day). At the temporal scale, we take examples of shrub encroachment, conversion of cropland into grassland and co-evolution of vegetation and soil development during sand-dune stabilization to highlight that vertical soil water switches between shallow and deep soil layers are closely associated with shrub-grass transitions.

Key Words

Shrub, soil architecture, soil moisture, arid and semiarid region

Emergent changes in social behaviour and ecohydrological dynamics driven by landscape change in the Southern Great Plains, USA

Bradford P. Wilcox

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Abstract

Land cover in the Southern Great Plains of the United States has changed dramatically over the last 150 years, in the wake of historic overgrazing and the consequent shifting patterns of cultivation. The former grasslands and open savannas have been largely replaced by more dense savannas or woodlands, and in some regions even forests. For much of the State of Texas, this transformation has already occurred: what were once open rangelands are now largely woodlands or closed-canopy savannas. Interestingly, in the northern portions of the Southern Great Plains (states of Oklahoma and Kansas), trees are continuing to expand. The most likely reason for this transformation is the overall reduction in the frequency and intensity of fires. In addition, as some have suggested, rising levels of CO_2 may also be a factor. In any case, the net result is that this region is more wooded and perhaps more vegetated that at any time in the last 150 years or more, leading to cascading and nonlinear feedbacks with respect to both society and the water cycle. But the particular responses are region specific. In Oklahoma and Kansas, there is good evidence that as woodlands have expanded, streamflows and groundwater recharge have declined. In contrast, towards the south—and largely within Texas—the greater number of trees has actually increased infiltration, which has led to a reduction in overland flow (a primary mechanism for streamflow) as well as an increase in groundwater recharge. For much of the State of Texas, higher storage of groundwater has actually contributed to increasing springflows, particularly in those regions where the underlying geology is karst. People have adapted to the changing landscape with a combination of resourcefulness and resilience. In some areas, more woodland cover has resulted in greater biodiversity and higher numbers of large game species, both of which are viewed as assets, for economic as well as recreational reasons.

Key words

Savanna, semiarid, woody plant encroachment.

Session 1: Contributions presented in oral form

The key role of biocrusts in drylands water cycle

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Abstract

Dryland landscapes are structured as a mosaic composed of two phases: discrete vegetation patches and neighboring patches between the plants. The soil heterogeneity created by both patch types results in a spatial mosaic where patches are not isolated but dynamically connected and functionally linked by source-sink processes. During the episodic rainfall events, runoff is generated in the non-vegetated areas and redistributed to adjacent vegetation, which acts as surface obstruction for water, sediments and nutrients. Hence, functioning of vegetation is strongly conditioned by the hydrological response of interplant areas. In most drylands, these interspace patches are covered by a community of organisms comprised of cyanobacteria, lichens, algae and bryophytes, known as biocrusts. Despite being only a few millimeters thick, they play a major role in hydrological processes. Biocrusts influence numerous properties that affect water movement and retention through soils such as roughness, porosity, hydrophobicity, cracking, and albedo, and thus play a key role in different elements of the water cycle. However, their role in water processes is not completely clear, and published studies show very controversial results. The influence of biocrusts may greatly depend on their developmental stage. In addition, most existing studies have examined the influence of biocrusts on isolated components of the soil water balance, but few of them have tackled this topic from an integrated point of view, addressing the key components of the water balance together. In this study, we examine the influence of different developmental stages of biocrusts and their removal on infiltration, evaporation and soil moisture, in two semiarid ecosystems of SE Spain with contrasting soil texture, topography and distribution of biocrusts. The ultimate objective is to elucidate the role that these communities play in the soil water balance in semiarid ecosystems.

Our results show that site characteristics including topography and soil texture and biocrust characteristics such as cover and composition greatly condition the influence of biocrusts on hydrological processes. In addition, biocrust hydrological response is strongly conditioned by rainfall characteristics, mainly rainfall intensity, and the spatial scale at which infiltration-runoff processes are surveyed. Overall, we found that biocrusts have a positive effect on the water balance by increasing infiltration and soil moisture and reducing soil evaporation compared to biocrust-devoid soils. As a result, the available water to plants in the upper most layer of the soil is increased by the presence of biocrusts. Therefore, through their effect on water availability and redistribution in drylands, biocrusts may exert a strong effect on the structure and function of vegetation as well as soil biota communities, thus eventually controlling general ecosystem functioning in drylands.

Key words

Biological soil crust, hydrological processes, water availability, developmental stage.

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Remote sensing and geophysics to infer ecosystem dependence on groundwater: *Ziziphus lotus* matorrals in SE Spain

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Abstract

Phreatophytic vegetation is characterized by deep roots that are used to obtain groundwater directly from the aquifer. Identification of its spatial distribution and pattern across the landscape and their relationship with the access to fresh water is a key aspect to understand their functioning and this has been extensively analyzed in the riparian ecosystems from humid regions. However, in arid regions, non-riparian phreatophytes are very frequent and they play a key role from ecosystem to regional and local scales. For example, the phreatophytic shrub *Ziziphus lotus*, which has leaves and high photosynthetic rates during the Mediterranean summer drought, and it has deep roots up to 60 m in depth. The object of this work is to identify whether the spatial distribution of *Ziziphus lotus* is linked to fracture zones that provide access to groundwater in a semi-arid ecosystem from the southeast of the Iberian Peninsula drylands. Firstly, Object-based Image Analysis has been used to map the population of *Ziziphus lotus* and a map of fracture zones was derived from geomorphologic LiDAR DEM analysis. Secondly, Electrical Resistivity Tomography, a geophysic method, was used to validate the existence of fractures. And finally, the observed distance between fractures and *Ziziphus lotus* shrubs have been showed congruence between both from Average Minimum Distance analysis. The importance of the study lies in the combination of different technologies to disentangle spatial vegetation patterns in the context of drylands without a non-apparent water supply. *Ziziphus lotus* cartography showed high accuracy (0.90) and we have identified about 1832 individual shrubs of *Ziziphus lotus*, with a different shape, texture, and roughness. Shrubs showed a clear positive trend with dependence on groundwater, differencing two cohorts in *Ziziphus* population in relationship to the size of shrubs and the minimum distance of more than 20 km of fractures in directions N140ºE to N160ºE and N40ºE to N45ºE. This provides information about the size of shrubs and its relationship on groundwater dependence in fracture zones as corridors of groundwater. Therefore, smaller shrubs could be vulnerable to decreases the water table level. In addition, although these shrubs are considered a priority for conservation under the Habitats Directive (habitat 5220), establishing its links to groundwater allow support also their conservation in the context of Water Framework Directive (WFD, 2000/60/EC). This is particularly important since the inventory of Groundwater Dependent Ecosystems (GDEs) and its conservation represents a new mandate for environmental management in Europe. In fact, the overexploitation of groundwater resources can be the main threats to *Ziziphus lotus*, even when their populations include inside protected areas.

Key words

Average minimum distance, electrical resistivity tomography, fracture zones, groundwater dependent ecosystems, LiDAR, object-based image analysis, semi-arid, *Ziziphus lotus*.

Soil water dynamics and water utilization of six typical ecosystems in Heihe Watershed, China

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Abstract

Heihe River Watershed (HRW) is located in the middle part of the Hexi corridor in arid region of Northwestern China. Soil water content in 0cm-160cm depth of six ecosystems, i.e. alpine meadow, montane coniferous forest, montane steppe, desert shrub, cropland, and riparian forest, were automatically monitored every 30 min. from Jan., 2013 to Dec., 2014 in HRW. Alpine meadow, montane coniferous forest, and montane steppe are the typical ecosystems located in the upper-part of HRW with humid /semi-humid weather. There are croplands and riparian forests in mid- and lower-stream oasis, and extensive desert shrubs distribute in mid- and lower-stream with arid weather. To better understand the characteristics of vegetation-soil-atmosphere water exchange, soil water storage in growing season, temporal variability of soil water, and rainfall redistribution were analyzed based on the high temporal resolution soil water content data.

The soil water storage in cropland was the largest, followed by riparian forest, alpine meadow, montane coniferous forest, montane steppe, and desert shrub in HRW. The annual supply to soil water which was calculated with hourly soil water contents was greater obviously than annual rainfall in montane coniferous forest, and it also happened in desert shrub. The annual soil water recharge from irrigation was about 540mm in cropland and riparian forest. Soil water storage remained stable in cropland, but it declined continuously in riparian forest because it was usually irrigated only once in March each year. Seasonal soil frozen was observed in the six ecosystems, but soil water dynamic was only greatly impacted by freezing and thawing processes in alpine meadow. Alpine ecosystems constitute the main water source in HRW. Not only cropland and riparian forest but also montane coniferous forest and some desert shrubs need soil water recharge to maintain the ecosystem stability. The water exchange among different ecosystems is more intense in arid regions watersheds.

Key words

Soil water dynamics, soil water storage, water recharge, alpine, montane, oasis, desert.

The dual and contradictory effect of biocrusts on perennial plants

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Abstract

The effect of biocrusts on plants is not always clear. In the Nizzana research site in the western Negev Desert (Israel), frequent droughts in the last two decades resulted in high shrub mortality. This was especially the case for shrubs inhabiting the biocrusted interdune (such as as *Cornulaca monocantha*, *Noea mucronata*, *Artemisia monosperma*), explained by the negative effect of the dark low-albedo crusts on soil water evaporation. Alternatively, although inhabiting the biocrusted surfaces of the interdune, previous findings indicated that some shallow-rooted perennial plants such as *Panicum turgidum* and *Cyperus spp.* exhibit relatively little mortality. These hemicryptophytes can withstand long months of desiccation without losing their ability to regenerate new tissues once moisture is available again. Hypothesizing that these low-rooted perennials grow at or adjacent to small 2-4 m^2 and sparsely distributed depressions (ID-PONs), which serve as sink for short-distance runoff that takes place at the undulating microtopography of the crusted interdune, twenty five 5 x 5 m plots were demarcated in the uncrusted dune crest and the interdune, and the number and cover of live perennials in the dune crest and the interdune (in relation to ID-PONs) was monitored. In addition, moisture measurements at 0-40 cm were undertaken during 2011-2014 at a pair of ID-PONs and adjacent loci at the interdune, and at the uncrusted dune crest. The data show a substantially high survival rate at the uncrusted dune crest, and a clear link between *P. turgidum* and *Cyperus spp* and ID-PONs. Substantially higher moisture content was recorded at the dune crest (explained by reduced evaporation) and ID-PON (explained by addition of runoff) in comparison to the remaining interdune. The findings highlight the dual and contradictory role played by the biocrust: while being responsible for the mortality of shallow- and medium-rooted plants in most of the interdune following increased evaporation by the crust, biocrusts assist the growth and survival of some relatively shallow-rooted perennial at ID-PON following their role in runoff generation.

Key words

Soil water dynamics, soil water storage, water recharge, alpine, montane, oasis, desert.

Modelling the irrigation management options during water shortage period to improve the crop yield and water productivity using AquaCrop model

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Abstract

Modelling the soil, water and crop growth interactions are attaining major importance, considering the future climate change and water availability for agriculture to meet the growing food demand. Progress in understanding the crop growth response during water stress period through crop modelling approach provides an opportunity for improving and sustaining the future agriculture water use efficiency. An attempt has been made to evaluate the potential use of crop modelling approach for assessing the minimal supplementary irrigation requirement for crop growth during water limited condition and its practical significance in sustainable improvement of crop yield and water productivity. Among the numerous crop models, water driven-AquaCrop model has been chosen for the present study considering the modelling approach and water stress impact on yield simulation. The study has been evaluated in rainfed maize grown area of semi-arid Shanmuganadi watershed (a tributary of the Cauvery river system) located in southern India during the rabi cropping season (October-February). In addition to actual rainfed maize growth simulation, irrigated maize scenarios were simulated for assessing the supplementary irrigation requirement during water shortage condition for the period 2012-2015. The simulation results for rainfed maize have shown that the average maize yield of 0.5-2 t ha^{-1} was observed during deficit monsoon season (<350 mm) whereas 5.3 t ha^{-1} was noticed during sufficient monsoonal period (>350 mm). Scenario results for irrigated maize simulation during deficit monsoonal period has revealed that 150-200 mm of supplementary irrigation has ensured the 5.8 t ha^{-1} of irrigated maize yield. Thus, study results clearly portrayed that minimal application of supplementary irrigation during the critical growth period along with the deficit rainfall has increased the crop water productivity from 1.07 to 2.59 kg m^{-3} for major soil types. Overall, AquaCrop is found to be very effective for the sustainable irrigation assessment considering the model simplicity and minimal inputs requirement.

Key words

AquaCrop, crop modelling, rainfed maize, water stress, irrigation requirement.

Mechanisms of stabilization of organic carbon in sediments flowing along dryland rivers

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Abstract

Terrestrial sediments can have an important role in regional carbon budgets, however not much it is known on the mechanisms of organic carbon stabilization in sediments. The fate of organic carbon mobilized by lateral fluxes will ultimately depend on the mechanisms of its physical and chemical protection against decomposition during the transport and deposition phases. In addition its turnover rates will depend on the local conditions under which OC is stored in sedimentary settings.

The OC stabilization mechanisms are related to the aggregation characteristics of the sediment deposits and those are not well defined in intermittent and ephemeral streams of drylands. The main objective of this work was to characterize the stabilization and mineralization of OC in sediments in transport (suspended load), at a range of depositional settings (channel alluvial bars, reservoir sediments) and soils from the source areas in a sub-catchment (111 km^2) at the headwaters of the Segura catchment in South East Spain.

To characterize the predominant stabilization mechanisms corresponding at different erosional phases, fractionation of organic carbon in soils of the catchment area and fluvial sediments at different sedimentary settings was carried out. Four aggregate size classes were distinguished by sieving (large and small macroaggregates, free microaggregates, and free silt plus clay fraction), and the microaggregates occluded within macroaggregates (SMm) were isolated. As a further step, oxidation of the OC occluded in silt plus clay fraction and that of the free silt plus clay fraction was performed to estimate the oxidant resistant OC pool. Measured OC in these fractions can be related to three functional pools: active (free particulate organic matter), slow (carbon associated to clay and silt or stabilized in aggregates) and passive (oxidation-resistant OC). In addition, the potential mineralized C (incubation method)of each deposit and soil was determined.

The preliminary results indicate incorporation of OC in macroaggregates (250-2000µm) and free microaggregates in the original soils. This incorporation promotes the occlusion of microaggregates within the macroaggregates facilitating physico-chemical mechanisms of OC protection. Those mechanisms appear also in the channel and transport sediments where, besides the lower OC concentration than in soils, still microaggregates within macroaggregates are being formed and/or preserved. A good physico-chemical protection of OC in original soils determines a better physical protection of OC in sediments mobilized by fluvial transport and deposited downstream.

The OC distribution and concentration in aggregates at the surface layer (0-0.20 m) of reservoir sediments was very similar to the original catchment soils. When sediments are not flooded the establishment of fresh vegetation promotes the formation of microaggregates within macroaggregates. New processes of soil formation in exposed

layers of surface reservoir sediments strengthen the potential large role of those as carbon sinks.

This study also emphasizes the relevance of the fractionation method proposed in order to better understand SOC dynamics as affected by erosional processes and fluvial dynamics.

Key words
Organic carbon pools, fractionation, organic carbon redistribution, mineralization, sediments, intermittent streams.

Rainfall-exclusion experiments: to roof or not to roof controls?

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Abstract

Rainfall amount and distribution is expected to be altered by ongoing climate change, which may have dramatic impacts on ecosystem processes, functions and services. Consequently, the last decade has seen an increasing trend in the number of studies based on experimental rainfall manipulations, which continues growing at present. In most cases, rainfall is manipulated using permanent transparent roofs. These roofs may have impacts in other ambient variables (e.g, air temperature, radiation, etc.) that may influence the response variables and thus confound the experimental results. This side effect can be controlled by using roofed controls, which are however lacking in most experiments. In this work, we assess the effects of roofs on the response of plant and soil variables to a rainfall-exclusion treatment replicated in 6 field sites along an aridity gradient in southern Europe. The experiment included rainfall-exclusion roofs, roofed controls and unroofed control treatments. Roof effects showed a large variability across the study sites, from negligible to strong. In the sites with a significant roof effect, rainfall-exclusion had negative impacts in the response variables when compared to the unroofed controls, while differences with roofed controls were insignificant. These results suggest that positive effects (e.g., shading) from roofs compensated for negative effects of rainfall exclusion. In agreement with this, the intensity of roof effects increased with the aridity of the study site, being insignificant in the more mesic sites. Overall, our results herald the need for roofed controls in rainfall-exclusion experiment, particularly in semiarid ecosystems.

Key words

Experimental drought, roof artefacts, dryland ecosystems, climate change, Mediterranean, aridity.

Aridity induces nonlinear effects of human disturbance on precipitation-use efficiency of Iberian *Quercus ilex* woodlands

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Abstract

The effects of land degradation are pervasive worldwide, particularly under the present context of global changes in climate and land uses, which are affecting biodiversity and landscape functioning at an unprecedented rate. How ecosystems undergo environmental change is recognized as one of the main frontiers in ecology and environmental sciences. Land degradation may take place in either a smooth gradual way or a more abrupt manner. Theoretical studies and empirical evidences increasingly suggest that drylands are particularly prone to develop abrupt changes in their structure and functions in response to climate variations and human disturbance. Precipitation-use efficiency (PUE) represents the ratio of vegetation production to annual precipitation, and provides an excellent evaluation tool for the assessment of human and climate impacts on landscape functionality. Holm oak (*Quercus ilex*) forests are one of the most conspicuous dry woodlands in the Iberian Peninsula and the Mediterranean basin, and show a variety of conservation status, due to their very long history of human use. We study the response of holm oak woodlands to human disturbance along an aridity gradient (i.e. semiarid, dry-transition and sub-humid landscapes; annual precipitation to potential evapotranspiration aridity ratio 0.40-0.50, 0.50-0.65, and >0.65, respectively) across a 20,000 km^2 region in eastern Spain, using remote-sensing estimations of PUE from enhanced vegetation index (EVI) observations of the Moderate Resolution Imaging Spectroradiometer (MODIS). PUE decreases from semiarid to sub-humid climate conditions in the studied holm oak landscapes, suggesting that as aridity and water stress decrease, other factors (e.g. nutrient and light availability) may control vegetation production. Overall, our results indicate that aridity largely impacts the response of PUE to human disturbance, assessed as a function of the integrity of vegetation conditions. PUE decreases linearly with the degradation of tree cover in sub-humid holm oak woodlands. Differently, semiarid and dry-transition landscapes show little change in PUE by increasing disturbance intensity until a threshold is passed in vegetation conditions (30%-50% cover), where PUE decreases abruptly. The impact of disturbance on PUE is larger for dry years than for wet years, and increases with climate aridity from sub-humid to dry-transition and semiarid woodlands. Therefore, aridity may also interact with land degradation in Mediterranean holm oak woodlands by intensifying the loss of the ecosystem ability to buffer large changes in vegetation production caused by climate variability.

Key words

Aridity, degradation thresholds, disturbance, drylands, ecosystem functionality, holm oak woodlands, MODIS EVI, precipitation-use efficiency.

Water redistribution, a key driver for vegetation functioning in drylands

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Abstract

Drylands are characterized by high potential evapotranspiration rates and low precipitation that make water one of the main limiting factors. Water scarcity limits vegetation coverage that usually appears in the form of sparsely distributed patches within a heterogeneous non-vegetated matrix. Whereas non-vegetated areas, usually occupied by physical and biological soil crusts, show high runoff rates, vegetated areas act as runoff sinks, re-infiltrating most of the run-on from upstream non-vegetated areas. Thus, we may consider drylands as complex eco-hydrologically coupled ecosystems in which water and sediments redistribution from non-vegetated areas controls ecosystem functioning and vegetation productivity. Alteration of the non-vegetated areas by human disturbances or changes in the soil interplant communities by climate change may exert a strong impact on soil erosion, promoting rill formation and increasing flow connectivity between source areas and reducing run-on inputs to vegetation, with strong effects on ecosystem functioning. However the role of runoff source areas on vegetation productivity has been not studied in deep.

In the present study, we analysed the response of *Stipa tenacissima* to run-on exclusion during 2 years at El Cautivo experimental area, Almeria (Spain). To do this, we selected three pair of plants of *S. tenacissima*. In each pair, one plant was bounded by a circular steel ring to exclude run-on contribution from upstream areas, whereas the other was maintained as a control open plot having 2m^2 of contributing area mainly covered by lichens biocrusts. At the beginning of the experiment, we scanned the different plants with a terrestrial laser scanner and measured their spectral response with a spectroradiometer. Based on these data, and using a model especially developed for this area, we estimated total above ground biomass per plant and total photosynthetically active biomass. Moreover, we conducted several campaigns to monitor vegetation phenology and productivity. During these campaigns we measured net C uptake on leaves of the different plants and the spectral response at leave and plant level as a proxy of photosynthetically active biomass. The results showed that plants receiving run-on showed more photosynthetically active biomass and net C uptake rates than plants under run-on exclusion. Differences between treatments became more important over time and were especially remarkable after rainfall, when the differences in water availability were higher. Based on these results we may conclude that any alteration on non-vegetated areas, (e.g. trampling, vehicle traffic, fire) may have important effects on vegetation productivity, similar to those produced by changes in precipitation pattern, which eventually leads to a reduction of vegetation biomass and their capacity to respond to water pulses. This at the end will result in a new eco-hydrological equilibrium of the whole ecosystem that becomes less efficient and productive than in the previous stage.

Key words
Runoff, arid and semiarid ecosystem, biocrusts.

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Modelling ecogeomorphology feedbacks in Australian banded vegetation hillslopes

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Abstract

Dryland areas function as tightly coupled eco-geo-hydrological systems with strong feedbacks and interactions occurring over a range of fine to coarse scales. It is not uncommon for the vegetation of these regions to display a mosaic of patches with high biomass cover interspersed within bare soil. In many areas, a key process behind the development of these patterns is the emergence of a spatially variable infiltration field with low infiltration rates in the bare soil areas and high infiltration rates in the vegetated areas. Enhanced infiltration rates under vegetated patches are due to improved soil aggregation and macroporosity (and are therefore both the cause and consequence of the pattern). This spatially variable infiltration is responsible for the development of a runoff–runon system which, together with the effect of vegetation on soil erodibility, modulates the resulting sediment erosion and depositional areas, and can therefore affect soil depth.

Here we present results from a modelling framework that couples evolving vegetation, erosion, and soil depth to explore hillslope-scale ecohydrologic interactions between vegetation patterns and sediment movement in arid and semi-arid regions. The model reproduces the observed dynamics of banded vegetation patterns in mild slopes, as well as stippled or spotted patterns for steeper areas (details about the model can be found in Saco et al., 2007; Saco and Moreno de las Heras, 2013). The effects of climate variability on the hydrology and erosion are analysed and compared to the observations available from banded vegetation sites in Australia.

Model results highlight the importance of incorporating feedbacks between vegetation, soils and topography in order to correctly capture the redistribution of resources in these regions and assess possible responses to disturbances induced by changes in land use and/or climate. While the timescales of response of the vegetation are of the order of a few years, the coupled soil organization responds more slowly (decades or longer). This suggests the possibility of an out of phase response between hillslope runoff generation and vegetation response, which is qualitatively different in natural undisturbed and disturbed systems. Recent simulations on the effects of different plant functional types on the ecohydrologic responses of these systems will be also presented. The relevance and implications of these results for the successful reclamation of water-limited environments, in which vegetation stability largely depends on the redistribution of the scarce water resources, will be discussed. These implications will be illustrated using data and observations from agricultural sites across a (semi-arid) gradient in Australia. Finally, the need for additional work considering other alternative relevant mechanisms will also be examined which will hopefully trigger debate and future directions.

Key words

Ecogeomorphology, banded vegetation patterns, runon, erosion, feedbacks.

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The forgotten dimensions of carbon flux in drylands: potential effects of land degradation

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Abstract

There has been a significant emphasis recently on the role of vegetation change and land degradation in drylands on carbon sequestration and the provision of related ecosystem services. Studies have typically focussed on the storage of carbon in biomass over short timescales. Over longer timescales, an important component of carbon-related ecohydrological processes is the way in which carbon is transferred from biomass to soil organic matter, and also the sequestration and storage of carbon in soil carbonates. These transfers are significantly affected by land degradation via erosion processes which may result in redistribution and net loss of carbon from the local system. Many drylands are underlain by significant stores of inorganic carbon, some of which is deposited from aeolian material, but vertical transfer from the surface stores is also an important process. Numerous studies suggest that these stores are in place from thousands to millions of years and contain carbon that has long been taken out of the global cycle, and thus is considered to be 'inert'. As progressive land degradation occurs, these stores are increasingly being exposed at the surface, and thus reactivated as part of the global cycle. In the context of climate change where increasingly stormy conditions are likely to accelerate the mobilization of sediment and associated carbon, and where increasingly acidic rainfall exacerbates dissolution of inorganic carbon, there is the potential for a significant addition to atmospheric carbon at regional and global scales. We will evaluate the relative importance of this mechanism compared to sequestration in vegetation and discuss the implications for maximizing ecosystem-service provision in drylands.

Key words

Carbon, land degradation, hydrology, erosion, ecohydrology.

Session 1: Contributions presented as posters

Patterns of surface runoff at hillslope scale: insights into source-sink biohydrologic relationships

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Abstract

In semiarid ecosystems, eco/bio-hydrological relationships are crucial and complex because of the variable and limited amount of water and the existence of thresholds in several key processes. Soil water redistribution during rainfall events constitutes the first modulating effect on the water availability for plant use, where overland flow plays a fundamental role. Therefore, increasing knowledge on runoff response thresholds and hydrological connectivity become essential to deal with ecosystems functioning. This requires a methodology that considers the high spatial (pattern) and temporal (process) heterogeneity that characterizes these environments with a bottom-up approach across scales. Our hypothesis is that *soil surface components* (i.e. vegetation, biocrusts, rock fragments and others) have a variable runoff response and are the main source of spatial heterogeneity at the patch scale, arriving to determine the hydrological response up to hillslope scale. With the aim of investigating the hydrologic functioning of the ecosystem, our objective is to ascertain the spatial dynamics of surface runoff at hillslope scale during a high intensity rainfall. In the experimental site of Balsa Blanca (Almería, SE-Spain) characterized by a Mediterranean-semiarid-climate, the following specific goals have included: (i) to obtain the cartography of soil surface components (SSC) of a hillslope transect from a photo-mosaic with a centimetre resolution; (ii) to characterize the runoff response of each SSC type by means of rainfall simulation experiments under dry soil conditions and fitted to a hortonian model to obtain the corresponding *hydrograph type* for each SSC; (iii) to approximate a *effective saturation* threshold for each SSC type from the analysis the soil moisture dataset. The applied methodology consisted in the integration of the spatial and temporal dimension of the process by means of the development of an empirical-based model powered by the *hydrograph type* of each SSC (*patch scale*) and distributed according the SSC cartography (*hillslope scale*). Furthermore, it incorporates a threshold criterion of *effective saturation* of the soil, allowing the scaling-up from path to hillslope. The results show the evolution of the spatial patterns of runoff and infiltration during a simulated rainstorm of high intensity (55 mm h^{-1}). In this way we have been able to explore de potential source-sink relationships between vegetation and bare soil that determines the general connectivity of the whole hillslope transect.

Key words

Spatio-temporal patterns, surface runoff, infiltration, hillslope scale, soil surface components, threshold, connectivity, source-sink relationships.

Soil infiltration rates under different soil tillage managements in vineyards in Eastern Spain

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Abstract

Vineyard is one of the main crops in the Mediterranean region and it forms, along with wheat and olive, what it is known as the 'Mediterranean triad'. The degraded soil conditions, especially due to bad soil management practices, favour surface runoff at the expense of infiltration. Infiltration, apart from being a key hydrological process when determining surface runoff, can be used as an indicator of the soil quality as it is highly dependent on the soil organic matter and soil structure. The infiltration rates of the soils are highly determined by the land management and the soil properties. In fact, two practices are likely to affect infiltration: tillage, with superficial tillage of the interrow and chemical weeding of the row, and no tillage, with chemical weeding of the whole field. The objective of this research was to determine the impact of conventional tillage (CT) and no-tillage (NT) soil management systems in the infiltration rates in a vineyard farm, using the ring infiltrometer and the mini disk infiltrometer (MDI).

Regarding the ring infiltrometer method, no statistical differences were found for the different soil tillage systems applied On average, NT presented infiltration rates of 325.88 mm h^{-1} whilst CT had average infiltration rates equal to 263.71 mm h^{-1}. As for the saturated hydraulic conductivity (K_s), no statistically significant differences were found between both managements. The maximum K_s values were measured under NT soil tillage (151.43 mm h^{-1}), and the minimum values were reported for the CT soil management (37.00 mm h^{-1}).

For the MDI, statistical differences were neither found for the different managements nor between lanes. In terms of average values, NT presented infiltration rates of 248.61 mm h^{-1} whilst CT had 246.16 mm h^{-1} average infiltration rates. As far as unsaturated hydraulic conductivity (K_h) is concerned, no statistically significant differences were found between soil managements. The maximum and minimum K_h values were measured for the NT soil management (159.22 and 14.51 mm h^{-1} respectively). Statistical differences were found between the methodology used (ring PI and MDI), however, no statistical differences were observed between soil managements (CT and NT) and K_{sf} values. Average K_{sf} values were higher under ponding conditions than under tension conditions. The differences found between ring and mini disk might be influenced by other soil hydraulic properties related to ρb and θ_0.

Key words

Vineyards, soil tillage, infiltration, ring infiltrometer, mini-disk.

Soil water repellency in urban parks

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Abstract

Urban areas and thus, the process of urbanization is a worldwide issue. The expansion of those areas is usually done towards the surrounding areas. The involved areas are forest lands, range lands and agricultural lands as reported by the Natural Resources Conservation Service, NRCS (2014).

According to the Demographia of World Urban Areas (2015), 10.2% of Europe population live in urban areas. One of the main characteristics of these areas is the sealing processes in the soil by urban grey infrastructures. In fact, Prokop et al., (2011) reported that 2.3% of the European territory is sealed. As the world population prospects in 2015 is of continuing increasing up to about 10 billion in 2050 (United Nations, 2015), a better understanding of the environmental processes involved in urban soils is of need. We present the characterization of the soil water repellency conditions in the Turia River Park (Valencia, Spain). A spatial analysis from the tree trunk (0 cm) up to 100 cm distance of the Water Drop Penetration Time test (WDPT) and the molarity of ethanol droplet (MED) test were conducted for a total of 8 tree species (*Schinus moll*e, *Platanus orientalis*, *Nerium oleander*, *Casuarina*, *Pinus halepensis*, *Laurus nobilis*, *Grevillea robusta*, *Araucaria heterophylia*). For the MED test, a total of 10 drops at ethanol/% 1, 3, 5, 8.50, 13, 18, 24 and 36 were measured for each specie at a 10 cm interval. Our results show that soil water repellency values were higher (>100 s) for the *Pinus halepensis*, *Laurus nobilis* and *Grevillea robusta* species. In fact, soil water repellency values followed a decreasing trend: values were higher near the tree trunk (first 30 cm), decreased to 0 s and then rise at the 60 cm. This trend might be associated to a higher concentration in organic matter due to the leave decomposition, as observed in other tree species such as olive.

Key words

Urban parks, water repellency, infiltration, ring infiltrometer, mini-disk.

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Soil infiltration rates and water repellency on organic and chemically managed citrus plantation in in Eastern Spain

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Abstract

Organic farming is widespread in many regions of Europe, and in Spain is being applied in different crops and regions. Citrus were chemically managed during decades, but the growth of the organic agriculture is making that the soil management will move to the organic farming strategy: apply manure, avoid any pesticide or herbicide, use catch crops and chop the pruned branches. To determine the impact of organic farming management on soil hydrology three paired plots on citrus plantations were selected in Easter Spain. Measurements with ring infiltrometer (10 in each plot x 3 sites x 2 paired = 60 measurements), and Water Drop Penetration Time (WDPT) measurements 1000 drops x 3 sites x 2 paired = 6000 measurements) allow us to determine that organic farming increases the infiltration rates of soils but also increased the water repellency. This means that organic farming promote the water repellency due to the increase in organic matter, but also favours an increase in the infiltration rates due to the macropore flow.

Key words

Citrus, organic farming, infiltration, ring infiltrometer, WDPT.

The influence of weeds on net ecosystem CO_2 assimilation and water use efficiency in an irrigated olive orchard of SE Spain

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Abstract

Climate in the Mediterranean area is typically characterized by high potential evaporation and low rainfall during the growing season. These dry conditions during the period of higher vegetation activity limit growth and yield in croplands. Olive tree is considered one of the best adapted species to the semiarid environment, however under water stress, its photosynthetic activity is often reduced. As water supplied by rainfall is not enough to satisfy water needs by olive trees, water deficit is usually compensated by irrigation and thus, many traditional olive orchards have been converted to irrigation. On the other hand, conservation practices consisting on the maintenance of spontaneous resident vegetation cover (hereinafter, "weeds") from autumn to spring are increasingly adopted in these crops in order to combat soil erosion and degradation problems caused by conventional practices. The influence of weeds on the increase of soil organic carbon content in olive crops is well recognized, however little is known about their effect on CO_2 sequestration at ecosystem scale. Moreover, knowledge about the effect of weeds on evapotranspiration fluxes at ecosystem scale is scarce and this information is crucial to optimize irrigation conditions and ultimately, to improve crop management.

In this study, we measure Net Ecosystem CO_2 Exchange (NEE) and Evapotranspiration (E) in an irrigated olive orchard of SE Spain under two management treatments, conservation of weeds and weed removal with a glyphosate-based herbicide, using two eddy towers. Water Use Efficiency (WUE), defined as the ratio NEE/E, and the Bowen ratio (the ratio of sensible (H) to latent heat (LE) fluxes) were examined for both treatments. Our results show that during the main growth period (March-April), net C uptake was higher in the treatment with weeds compared to the weed-free treatment. Similarly, E was also higher in the treatment with weeds. Despite greater E in the former, ecosystem WUE was higher in this treatment due to the increase in the ratio of fixed C to water loss. Thus, under similar water loss, the treatment with weeds was able to increase C uptake by up to 4 times compared to the treatment without weeds. The presence of weeds also decreased the Bowen ratio. During weed growth, the Bowen ratio was lower in the weed-cover treatment than in the weed-free treatment. In spring, after weeds were cut and the hay left on the soil, the Bowen ratio markedly increased in this treatment and exhibited similar values to those of the weed-free treatment. Therefore, conservation of weeds represents a sustainable strategy to optimize C fixation relative to water loss in olive orchards as well as other Mediterranean crops where water scarcity restricts crop productivity.

Key words

Carbon uptake, evapotranspiration, Bowen ratio, conservation agriculture.

Phreatophytic vegetation and grasslands showed contrasting responses to soil water availability in drylands

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Abstract

Rainfall is the main limiting factor of the primary production in most of the drylands regions around the world. However, in areas dominated by phreatophytic vegetation precipitation is not the only limited factor but also groundwater level. This vegetation had deep roots and is able to use groundwater, showing higher productivity than expected, particularly during the driest season of the year. Monitoring the differences of the relationships between productivity and rainfall, in phreatophytic and zonal vegetation, can help us to disentangle factors affecting patterns of primary production in drylands.

In this study, we used the Normalized Difference Vegetation Index (NDVI) and soil water balance (SWB), as a proxy of vegetation productivity and rainfall water availability, respectively. Then we analyzed the relationship between both, NDVI time series obtained from Landsat 8 (36 images from 2013 to 2016) and SWB to analyze vegetation dependence on rainfall at two different areas from the South East of Spain. Both areas were located in the Cabo de Gata-Níjar Natural Park (southeast Spain) and were characterized by semi-arid climate. However, whereas one of them was dominated by *Stipa tenacissima*, the other area is mostly covered by the phreatophyte *Ziziphus lotus*. As we expected, there was a direct relationship between NDVI and SWC, at the two areas. Nevertheless, this effect was less important on areas dominated by phreatophytic vegetation than on *Stipa tenacissima* dominated areas, indicating an ability of *Ziziphus* to access additional water from aquifer.

This information could be helpful to identify phreatophytic vegetation and to analyze their fitness, phenology or coverage that could indirectly reflect changes in groundwater levels and water quality.

Key words

Phreatophytic vegetation, semi-arid ecosystems, vegetation index, remote sensing.

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Estimating runoff length from runoff plots under natural conditions: a proposal

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Abstract

Runoff coefficient (runcoef) strongly varies according the rainfall features and the surface characteristics (topography, vegetation, soil), particularly in drylands, where surface features are typically variable because vegetation is discontinuous. Surface hydrology is important because it affects the distribution of soil moisture and vegetation, and the hydrological functioning of slopes and catchments. The runoff at plot scale can be directly measured by rainfall simulation. However, for given rainfall and surface conditions, the runoff coefficient decreases while the considered area increases. Runoff at plot scale does not allow understanding runoff at wider scales, which measurement often requires long-time monitoring, especially in drylands. This decay of runoff coefficient is due to the limited slope length travelled by runoff (runoff length, RL). To know the RL is crucial. It (i) informs of the degree of runoff connectivity and allows modelling runoff; (ii) is a way to define/characterize discontinuous runoff fluxes which are a typical feature of drylands; (iii) will allow upscaling from plot to slope or catchment; (iv) affects soil erosion and mobilisation of soluble soil substances; (v) determines the spatial extent of bio-hydrological processes feedback; for example, by redistributing water, solutes and sediments, it feedbacks on the species composition and the spatial pattern of the community.

In this work we analyse twelve-year data series from six open runoff plots on silty soils covered by biocrusts at the Tabernas Desert (Almeria, semiarid SE Spain). These plots collect runoff by covered channels equipped with typing-buckets and data loggers. Each of three kinds of biocrusts has two plots and one rain gauge. To convert the collected runoff volume to mm to calculate runcoef, we need to know the catchment area. Assuming runoff comes from 1, 2, 3, 4… m upstream of the collecting channel (all the channels have the same width) it results that the runcoef potentially decreases while the supposed catchment area increases. The curves relating runcoef to the supposed plot length have resulted very different according both the rainfall characteristics and the soil and vegetation features, but they always have only one parameter and the form: runcoef = a*x-1, where 'x' is the supposed plot length. Therefore, once the runcoef is known for one given plot length, the runcoef for any other length for those given rainfall and surface conditions can be exactly determined. The curves from the runoff plots were consistent with the experiments carried out by rainfall simulation in those same surfaces, which allowed estimating RL under several types of rainfall, antecedent soil moisture and surface. So, we propose an easy and repeatable procedure to define and calculate RL: the minimum RL is equal to the plot length corresponding to the runcoef = 1. Since runcoef = a* x-1 = a/x, for runcoef = 1, a = x; ie, the RL so defined is given by the parameter 'a'. It doesn't matter whether the plots are open or bounded. The relationship between RL and runoff connectivity is discussed.

Key words

Carbon uptake, evapotranspiration, Bowen ratio, conservation agriculture.

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The effect of rain pulses in the net CO_2 exchange of a semiarid grassland in southern Spain

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Abstract

Drylands occupy one third of the terrestrial surface and determine the inter-annual variability of global carbon (C) balance. However, the processes composing the C cycle of arid and semiarid ecosystems are not fully understood. In this context, water inputs are crucial to biological organisms survival and frequently correspond to rain events that are commonly infrequent and stochastic, and strongly control arid land ecosystem structure and function. In the present study, we assessed rain pulses effect on the C balance at ecosystem, canopy and soil spatial scales by using eddy covariance technique, canopy and soil respiration chambers, and soil CO_2 probes in the experimental site of Balsa Blanca, a semiarid grassland located in the Cabo de Gata-Níjar Natural Park (Almería, Spain). On one hand, results showed, based on ecosystem-scale data acquired during the dry seasons over 2009-2013, that large increases in the net ecosystem CO_2 exchange (i.e. net CO_2 emission) occurred after water inputs, which gradually decrease over a few days following the rain event. In addition, only rain pulses equal or more than 20mm lead to net CO_2 uptake (i.e. negative NEE values), however, most of the rain events registered during the drought periods were lower than 10mm. On the other hand, the manipulation experiment (i.e. rainfall simulation) performed during five days in August 2014 demonstrated that only soil respiration was significantly enhanced by the rain pulse whereas net plant assimilation, together with aboveground respiration, did not show any significant response, although it represented up to 40% of the NEE during the third day after water input. Overall, this study suggests that rain pulses occurred during dry periods not only inhibit the re-activation of ecosystem C sequestration capacity, but even, provoke net CO_2 emissions to the atmosphere.

Key words

Drylands, precipitation pulse, drought, canopy net assimilation, soil respiration, net CO_2 flux, eddy covariance, flux chambers.

Soil moisture and environmental factors interactions control the CO_2 exchange in biocrusts from drylands

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Abstract

CO_2 exchange between the soil and the atmosphere, and its controlling mechanisms, have been less studied in drylands than in humid regions. In drylands complex community known as biocrusts (BC) have an important role in carbon cycle. BCs CO_2 fluxes are strongly influenced by several environmental factors as temperature, photosynthetically active radiation (PAR) and specially water availability. Depending on the combination of all these environmental factors, the BCs could be sources or sinks of carbon. In this work, we analyse *in situ* CO_2 fluxes from BCs on different environmental conditions throughout the year and we relate these fluxes to key environmental factors controlling the CO_2 exchange rates. To do this CO_2 fluxes in BCs was monitored at the El Cautivo from Tabernas desert (SE Spain) by infrared gas analyzers (IRGA): net CO_2 flux with a custom transparent chamber attached to a Licor Li-6400; and respiration with a PPsystems EGM-4. Photosynthetically active radiation (PAR) was measured by the Licor external quantum sensor 9901-013. The CO_2 fluxes were measured for one full day (from early morning to dusk) every 2 or 3 hours in four field campaigns carried out on days with different environment conditions (dry conditions and after different rainfall events). Air temperature and air relative humidity were monitored during the gas exchange measurements using the sensors DS1923 Hygrochron Temperature/Humidity Logger *iButton,* Embedded Data Systems, USA. Our results showed a large variability in BCs CO_2 fluxes in all field campaigns and also throughout the day for each campaign indicating that in natural conditions the BCs interact differently with several environmental factors (temperature, air moisture, rainfall events, PAR) greatly increasing the complexity of predicting CO_2 fluxes patterns in crusted soils. CO_2 fluxes were next to zero in summer (rainfall 0 mm) because BCs and soil microorganisms are inactive during periods of drought. The CO_2 exchange is clearly marked by low rainfall at El Cautivo (annual rainfall=212.85 mm). In the field campaign after the first rainfall event after a long summer period, all BCs issued CO_2 into the atmosphere. Nevertheless, after some rainfall events biocrusts showed photosynthesis peaks higher than respiration processes from both the biocrust and underlying soil behaving as CO_2 sinks at specific times throughout the day. The significant differences in the biocrusts CO_2 fluxes between the different measurements throughout the day were due to the interplay of environmental factors such as temperature, air humidity and PAR. Thus, the highest photosynthesis peaks were in the measurements in which increased the air humidity and PAR. In the measurements with higher air humidity and lower PAR, the photosynthesis of BCs were very low, and vice versa in the measurements with higher PAR but lower air humidity occurring

simultaneously with the higher temperature, increased the respiration but decreasing in turn the photosynthesis.

Key words
Biocrusts, CO_2 fluxes, carbon sink or source, environmental conditions, soil moisture.

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Virtual experiments on root sampling methods to infer the specific root traits by inverse modelling

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Abstract

Plant phenotyping methods based on architectural root traits to develop new genotypes are becoming increasingly important. These traits play a key role for crop performances under non-optimal environmental and climatic conditions. However, the main challenge in root phenotyping programs is the limited accessibility to the root system because it is hidden in the soil. Although lab based methods are widely used to retrieve root system architecture characteristics, these experiments are not capable of replicating the plant growth in the field, and often the studies are not carried out for the entire lifespan of a plant. On the other hand, classical field root sampling methods provide only the root distribution with depth or arrival times at each depth in the soil profile, which do not provide direct information about the root system architecture of the plant.

In order to overcome these challenges, we instigate the possibility of obtaining information about the root system architecture (RSA) using field based root sampling schemes. The root growth model "RootBox" was used to generate virtual 3-D root systems of 200 individual wheat plants. Ground truth of the virtual experiment was established for coring, trench profile and rhizotron methods. From these data, root length density (RLD), root intersection density (RID) profiles and arrival curves for rhizotubes were computed and considered as observation data. Morris OAT sensitivity analyses method was performed to quantify the sensitivity of each parameter of the root growth model to the observation data. The sensitive parameters will be optimized using "DREAM" inversion algorithm based on the observation data. The optimized parameters and the input parameters will then be evaluated with the sampling methods to determine the suitability of the sampling schemes to identify specific traits or parameters of the root growth model. Finally, the virtual experimental method will be applied in real field samples to obtain information about the specific traits of different genotypes for plant breeding programs. By combining sensitivity analyses with inverse modelling, parameters of a root system architecture model that can be inferred indirectly from traditional field observation methods were identified. This is an important step in the characterization of root traits from field observations. In a next step, these root architectures can be used in models that simulate water and nutrient uptake so as to evaluate the performance of root systems with certain traits.

Key words

Optimization, RootBox, root system architecture, sensitivity analysis.

Influence of precipitation on subterranean CO_2 molar fraction from a deep soil profile in a semiarid ecosystem experiments

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Abstract

Despite being the largest biome on the planet, semiarid ecosystems have been poorly investigated regarding their role in the global carbon balance. Most researchers have studied ecosystem-level CO_2 exchanges using eddy covariance towers and soil CO_2 fluxes at the top soil layer through respiration chambers, neglecting CO_2 exchanges at depth. However, recent studies focused on deeper soil layers have found large variations in the CO_2 molar fraction (X_c) associated with variations in atmospheric pressure or wind. Numerous studies have explored the role of rainfall variability and extreme events in the soil X_c, but always focused on the first soil centimeters. The effect of rain pulses on the carbon balance in semiarid ecosystems depends on the intensity of rainfall and the level of drought stress. Here, we studied the precipitation effect together with other determinants of the subterranean X_c. In order to characterize the main factors influencing subterranean CO_2 variability, we analysed edaphic and atmospheric data over two years (2014-2015) in a semiarid grassland situated in Cabo de Gata-Níjar Natural Park (Amoladeras; 36°50'0.96''N, 2°15'8.279''W). A vertical soil profile was installed to measure X_c, temperature, and humidity at four depths (0.05, 0.15, 0.5 and 1.5 m) in June 2013.

Results show that rain events influenced X_c variations exclusively at 0.05m, whereas in deeper layers, atmospheric pressure change was the principal driving factor. In the top layer, soil water content increases and the decomposition of soil labile organic matter accumulated by microorganisms provoked X_c rising in soil pores. Significant differences ($P<0.05$) were found in diel patterns of soil CO_2 molar fraction induced by small and large rainfall events. Small rainfall events increased shallow X_c (0.05m), whereas larger rainfall events were required to produce increases in deep X_c (0.15, 0.5 and 1.5 m). However, the most common rainfall magnitudes were insufficient to affect deeper soil layers, and neither rewetted nor activated microbial activity in the deeper soil layers. We conclude that, in our experimental site, X_c variations produced by rain events solely occur in shallow layers while their effect is negligible in deeper layers (≥0.15m), where atmospheric pressure acts as the most important factor.

Key words

Carbon balance, rain pulses, drylands, subterranean CO_2 processes, pressure pumping, soil respiration.

Soil water repellency as a vegetation-driven strategy in arid ecosystems: a case study in Banksia woodlands (Western Australia)

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Abstract

Soil water repellency (SWR) is caused by hydrophobic organic substances released by plant residues, roots or soil microorganisms that inhibit or delay rainwater infiltration. Banksia woodlands (BW) are iconic ecosystems of semi-arid environments of Western Australia (WA) comprised by an overstorey dominated by Proteaceae, e.g. *Banksia menziesii* and *Banksia attenuata*, in combination with other species, such as *Eucalyptus spp.* Although located in poor dune soils, BW provide numerous ecosystem services and sustain a high biodiversity. A characteristic feature of BW is their dimorphic root architecture, formed by a proteoid (cluster) system that radiate from the parent root and spreads to form thick mats below the soil surface. These clusters secrete large amounts of organic acids and phenolics to increase the uptake of P and other minerals that can be related to SWR. In contrast, the parent root penetrates soil deeply, reaching the water table. This study, conducted in natural BW of WA, aimed to assess SWR and its impact on water economy in relation with soil functioning and plant strategies for water uptake in pristine BW. Soil samples were collected at different depths (0-1, 1-10, 20-30 and 40-50 cm) based on the different SWR severities found in each layer under field conditions. SWR was assessed under laboratory conditions in oven-dry samples (48 h, 105 ºC) and the chemical organic assemblage of bulked soil subsamples from each layer was analysed by direct analytical pyrolysis (Py-GC/MS). SWR distributed discontinuously through the soil profile. The first thin layer (0-1 cm) composed of coarse sand and litter, located immediately above Banksia root clusters, showed wettable conditions. In contrast, the well aggregated soil layer where the cluster root system is located (1-10 cm) was severely water-repellent. The 20-30 and 40-50 cm deep layers rendered wettable or subcritically water-repellent. After Py-GC/MS analysis, major compounds were identified and grouped according to their probable biogenic origin. Among other soil organic compounds, well resolved bimodal alkane/akene (C8-C31, maxima at C13 and C26) and fatty acids series (short-chained, C5-C9, and long-chained even-numbered C12-C18) were associated to the root cluster soil layer (1-10 cm). Also, a relatively high contribution of fire-derived polycyclic aromatic hydrocarbons (PAHs) was observed (7%). These results point to possible indirect links between organic substances released by roots and soil wettability involving soil microorganisms. Further discussion should shed light on possible ecological plant strategies and specific adaptations for water uptake in such arid ecosystems of WA.

Key words

Soil moisture, soil hydrophobicity, analytical pyrolisis, ecological strategies, soil organic matter.

Spatio-temporal diversity of surface waters in semiarid rivers depends on groundwater. Case study of the Andarax catchment (Almería)

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Abstract

The interactions between surface- and groundwaters in semiarid regions are complex and varied and favour a diversity of surface water. We present examples from along the three largest watercourses of the Andarax catchment (Andarax river, Nacimiento river and Tabernas rambla) of the influence of groundwater on- surface waters.

The Andarax river is continuous in its headwaters, temporary in its middle reach and ephemeral in the lower reach. Its spatio-temporal variability has been studied based on a series of differential gauges and monitoring of surface water salinity. In the middle reach of the catchment, two zones are identified with permanent flow and salinity. One of them has more homogeneous and, less saline water (550 - 600 µS/cm), which reflects the influence of the carbonate aquifer Sierra de Gádor on the surface water flow. The other zone was characterized by a saltier water (1000 - 1800 µS/cm). The surface water flow shows a marked spatio-temporal variability and showed the highest salts content, as a consequence of the influence of the groundwater feed from the detritic aquifer. The Nacimiento river is an intermittent and ephemeral watercourse, although its middle reach contains a small permanent flow of saltier water (1440 – 2010 µS/cm), which is linked to a diffuse flow from the detritic aquifer. In the Tabernas Rambla, there is a series of small permanent saline surface water, discontinuous in space, which are continuous over time but have a very high and variable salinity (7730 – 13000 µS/cm). These permanent streams are associated with diffuse discharges of groundwater whose saline content is slightly lower (6800 - 9100 µS/cm).

In the Andarax catchment, riparian vegetation is affected by surface water with contrasted characteristics. The availability of surface water and its relationship to groundwater determines the spatial distribution of permanent and intermittent reaches and its highly variable salinity. It is necessary to emphasize the importance of knowing all the processes linked to the groundwater-surface water interactions in semiarid areas, since the presence of different water types and their spatial-temporal variability markedly favours biodiversity.

Key words

Groundwater-surface water interaction, hydrochemistry, Andarax.

Acknowledgements: This research has been supported by the project P11-RNM-8115 financed by the Consejería de Economía, Innovación y Ciencia of the Regional Government of Andalucia (Junta de Andalucía).

Tracking differences in the physiological response of vegetation and biocrusts to rain events based on multitemporal NDVI sequences from Landsat images

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Abstract

Dryland vegetation developed morphological and physiological strategies to cope with drought. However, as aridity increases, vascular plant vegetation and coverage gets sparse. Under these conditions biocrusts become a key player in ecosystem productivity. They are complex communities of poikilohydric life forms (cyanobacteria, algae, microfungi, lichens and bryophytes), that cover the uppermost millimeters of the soil surface and dry out and remain dormant when water availability decreases. Biocrusts modify soil properties and control water availability and erodibility. Moreover, they show a faster phenological response to water pulses than vascular vegetation, turning green (in a similar way as vegetation does) almost immediately after small rains, fixing atmospheric carbon and nitrogen. However, biocrusts have been traditionally not considered, probably also due to their largely inconspicuous growth. Thus, spatially and temporally continuous information about their response to water pulses is still necessary, and will help to advance the knowledge about their role in ecosystem productivity. Remote sensing data provide spatially continuous information that can be used to analyze biocrust dynamics by means of long-term series of vegetation indices, like the normalized difference vegetation index (NDVI).

In the present study, we used thirty six different LANDSAT images acquired during the year 2008 at to different study areas within the South African Succulent Karoo (15 from Soebatsfontain and 21 from the Knersvladkte quartz fields) to analyse biocrust response to water pulses, and we compared these with the vegetation response. The results showed that biocrust and vegetation greenness are controlled by water availability, showing minimum values during dry periods that increased after the rainy season and decreased again at the onset of drought. However, biocrusts and vascular plant vegetation responded physiologically differently to water pulses, which resulted in some differences in their NDVI dynamics. Biocrusts turned green almost immediately after small rains, producing a small NDVI peak only few days after rainfall, whereas longer time was necessary for vegetation to grow new green tissue. However, once the photosynthetic tissue of vegetation was restored, it caused the highest increase of NDVI values after the rain. Thus, multitemporal NDVI data are extremely helpful to not only analyze the vegetation density and response upon water pulses. It can also be used to distinguish between vascular vegetation and biocrusts and to analyze the relevance of biocrusts and its development during processes of global change.

Key words

Biological soil crust, remote sensing, vegetation indices, arid and semiarid ecosystems.

Biocrust recovery after disturbance improves soil fertility and reduce runoff and sediment yield

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Abstract

Biological soil crusts or biocrusts are widespread components in drylands where they are known to play key roles in numerous ecosystem processes. By forming microbiotic assemblages on the soil surface, biocrusts strongly protect soils from raindrop impact and the erosive action of overland flow, constituting one of the main protective agents from soil water erosion in drylands. In addition, biocrusts modify numerous soil properties including surface roughness, porosity, water retention capacity and hydrophobicity, thus having a key influence on hydrological processes. However, biocrusts are easily disturbed by human activities and climate changes, facts that may have strong implications on water redistribution and the loss of vital resources in drylands. Knowing how biocruts evolve after disturbance and contribute to restore soil functions is crucial to develop dryland rehabilitation techniques.

In this work, we explored the influence of biocrust recovery after disturbance by removal on the evolution of soil properties as well as their influence on runoff and sediment yield in a semiarid badlands catchment. Runoff and sediment yield rates were measured during an intense rainfall in 2012 on small plots covered by intact biocrusts (mainly cyanobacteria-dominated) and soils where the biocrust was removed in 2007 and 2012 and have remained unaltered since then. Hydraulic conductivity was also measured in these plots with a mini disk tension infiltrometer. Crust samples were collected annually in adjacent plots where the crust was removed in 2007 and have been unaltered since then in order to analyze the evolution of soil properties with biocrust recovery. We found that runoff and, especially, sediment yield, were higher in the plots where the biocrust was recently removed but similar in the undisturbed and 5-year recovery biocrust plots. Hydraulic conductivity and soil organic carbon and nitrogen contents increased with greater biocrust development, as soil was newly colonized by cyanobacteria after biocrust removal. Our results highlight the need to protect interplant soils in drylands, where biocrust disturbance has great impacts on the loss of soil fertility and runoff and erosion processes. In addition, the relatively fast growth of a cyanobacterial-dominated crust after disturbing arise the possibility of exploring their use in restoration projects in semiarid lands.

Key words

Biocrusts, disturbance, runoff, erosion, soil fertility, semiarid.

Acknowledgements: This work was funded by the Spanish National Plan for Research, Development and Innovation and including European Union of Regional Development Funds, under the RESUCI (CGL2014-59946-R) research project and the FPU predoctoral fellowship from the Educational, Culture and Sports Ministry of Spain and the foundation Tatiana Pérez de Guzmán el Bueno, under its predoctoral fellowship programme. We also thank the Viciana brothers, the landowners, and Alfredo Durán for his assistance with the field work.

Effect of different levels of pumice on sorption and retention of water in soil and Russian olive seedling growth

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Abstract

Using superabsorbent materials for holding moisture in soil, prevention from its evaporation and to increase irrigation efficiency is one of the practical methods in soil and water science. Pumice is one of these superabsorbent materials that it is a non-crystalline mineral made from aluminium silicate. This mineral has high ability for moisture absorption and retention. This research was performed in the Khajeh research station from 2012 to 2014 on the basis of randomized complete block design with four treatments and three replications to evaluate the effects of different amounts of pumice on water holding capacity in the soil and growth characteristics of Russian olive (*Elaeagnus angustifolia* L.) seedling in rainfed conditions. Experimental treatments were four rates of pumice (0, 10, 20 and 30% pumice). To apply treatments, a hole with depth and diameter of 70 cm was drilled and an olive seedling was planted at each hole. Also, a pair of TDR sensors with length of 70 cm was placed at each hole to measure soil moisture content. The dug-out soil from each hole was mixed with pumice at levels of 0, 10, 20, and 30% by volume and again returned to the holes. During the experiment, the average soil moisture content was measured by TDR every 10 days. Also, some vegetative characteristics of olive seedling such as height, stem diameter and leaf area were measured. Results showed that for control treatment (0% pumice), mean volumetric water content through growth period was the lowest. Volumetric soil water content considerably increased with the addition of pumice to soil. For control treatment, seedling height, stem diameter and leaf area were 56 cm, 6.2 mm and 62 cm^2, respectively. While at 30% pumice, these values increased considerably reaching values of 116 cm, 16.4 mm and 304 cm^2, respectively. Adding pumice to soil improves soil physical conditions (total porosity, water holding capacity of soil and prevent the formation of crust on the soil surface) leading to higher plants growth and yield. Therefore, pumice, due to its low bulk density, high porosity and high capacity for water absorption, leads to an increase in soil porosity, decreases bulk density and reduces soil surface crusting and it providing suitable physical conditions for roots growth. Also, pumice capacity to absorb and retain rain water, prevents water deficit stress of plants during growth season. Furthermore, pumice is cheaper than similar materials such as perlite and vermiculite, making economically possible its application on wide areas under rainfed conditions to increase production.

Key words

Russian olive, soil moisture, soil porosity, superabsorbent.

Pumice mulch effect on corn growth and yield

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Abstract

Mulching is one of the important agronomic practices in conserving the soil moisture and modifying the soil physical environment. The most serious problem facing humanity in the twenty-first century is the water crisis. The increase in world population and humans' exceeding demand for water in order to provide food supply on one hand and the phenomena of climate change as well as reduced precipitation and prevalence of droughts on the other hand has aggravated the situation. The application of mineral mulches such as pumice to soils has led to the increase of water retention, decline in water evaporation and consumption, and thus would have a significant impact on plant performance and growth. The present research was conducted in a complete randomized block design with three replications in a farm plots planted with corn (hybrid modified Maxima). The treatments consisted of four levels 0, 30, 60 and 90 tons per hectare of pumice. Irrigation was performed on a weekly basis. The pumice mulch produced a significant effect on corn morphological traits and yield. The highest and lowest levels of plant height, number of leaves, stem diameter, leaf area index, fresh and dry weight of leaves, fresh and dry weight of stems were obtained from 90 tons per hectare of pumice treatment and control treatment, respectively. Between 90 and 60 tons per hectare of pumice treatments, there was no significant difference in terms of the measured parameters.

Key words

Corn, morphological traits, mulch, pumice, yield.

SESSION 2

BIOHYDROLOGY IN LAND DEGRADATION AND RESTORATION

Conveners:

Albert Solé-Benet, EEZA-CSIC, Almería, Spain

Mariano Moreno de las Heras, IDAEA-CSIC, Barcelona, Spain

Keynote lectures

The effect of soil macrofauna on soil physical properties in post mining soils

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Abstract

Soil physical properties at post-mining sites can substantially affect plant growth. Many biological processes also influence changes in soil physical conditions of post-mining soils. Roots of plants and soil macrofauna are widely recognized as substantially altering soil physical properties. In this contribution, we explore the effect of soil macrofauna on physical properties of post-mining soils and elucidate the interaction of soil fauna activity with the technical operations used in mine site restoration. The most obvious effect of soil macrofauna bioturbation is the creation of various biopores that might increase soil porosity. These macropores can differ substantially in size and shape and in how they are formed. Worms burrow by pushing soil to the side, forming a layer of more compacted soil along the wall, which is covered by earthworm mucus. They also swallow soil during burrowing, which can be later deposited in the form of casts inside or outside soils. Ants and most other arthropods commonly dig in the soil with legs or mandibles, and excavated soil can be transported out from the hole, used to fill unused cavities, or partly spread on the walls to form a ceiling. Biopores are often reported to increase water infiltration in soil. Soil invertebrates also might support formation of soil aggregates, among which the water-stable aggregates of earthworms are particularly important. Soil fauna can enhance water-holding capacity by transformation of organic matter. Other members of soil fauna, namely earthworms, can support formation of organo-mineral aggregates, which can also contribute significantly to the greater ability of soil to hold water. Here, however, it is necessary to note that an increased water-holding capacity and water field capacity in both cases mentioned above is accompanied by a higher wilting point. Nevertheless, the increase in water field capacity was in both cases higher than the increase in wilting point, so soil fauna enhanced the ability of soil to hold water, which was then potentially available for plants. Fauna activity may affect formation of whole soil profile which then effect whole ecosystem development. Effect of tree species on soil development is substantially mediated by soil fauna activity and especially by earthworm bioturbation Sites with higher earthworm abundance and earthworm bioturbation have higher A layer thickness and carbon accumulation in the mineral topsoil. Sites with higher C accumulation in mineral soil had higher microbial biomass and lower microbial respiration, which may have contributed to the higher C storage. The gradient of bioturbation was correlated with changes in the composition of the bacterial community and other soil biota, but partial correlation showed that the effects of litter quality and bioturbation were largely independent. Overall, the results indicate that the colonization of post mining sites by soil fauna may substantially affect development of soil properties in these sites.

Key words

Soil fauna, bioturbation, infiltration, aggregate, water field capacity, soil formation.

Managing abiotic stress in turfgrass via rootzone modification– challenging existing paradigms

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Abstract

In the 1950's, turfgrass managers realized that dry spots commonly developed in highly managed turfgrass and that soils in these regions were difficult to rewet, compromising turfgrass quality, health, and performance. The primary management strategy to improve turfgrass recovery in such soils was the application of surfactants to reduce soil water repellency (SWR) leading to turfgrass recovery.

Over a decade of ago, non-ionic, alkyl-terminated block copolymers (ATBC) were introduced as a new category of highly efficient agents to manage SWR. ATBC treated soils are characterized by increased homogeneity of soil water across the soil profile though at lower volumetric water contents than observed in soils treated with other surfactants, resulting in turfgrass with higher visual quality and a denser, more uniform stand that better tolerated abiotic stress commonly occurring during periods of elevated temperatures and high evapotranspiration demand. Effects were reproducible under different climatic conditions and soils, whether irrigated or rainfed, or when applied in spray solutions, irrigation water, or via surfactant coated seed.

Why do plants perform so well in soils treated with ABTC? Plant responses suggested that effects beyond reduction of interfacial tensions and enhancement of wetting of water repellent soils might be occurring. Over an eight-year period, studies were conducted to better understand treatment effects on selected plant physiological responses, abiotic and biotic stresses, and on nitrogen efficiency in water repellent and wettable soils.

This presentation will outline the research strategy that was developed, its implementation, the effects validated under field conditions, and the implications to water use, management of abiotic stress, and sustainable turfgrass management.

Key words

Turfgrass management, soil water repellency, surfactants.

Water in terrestrial ecosystems: a thermodynamic perspective

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Abstract

In contrast to Venus and Mars, the Earth distance and relative size to the Sun allow conditions of temperature, pressure and gravitation that permit water to exist in its three phases, solid, liquid and gaseous. The transition between phases enables water working as a thermal pump and its liquid phase is the best medium for quick chemical exchanges. These characteristics facilitate water working at three scales.

The planetary scale concerns the interaction among oceans, emerged lands and troposphere, often far from adiabatic and isothermal conditions. At the molecular scale water works as a quasi-universal solvent that facilitates by orders of magnitude the interaction among reactants in key bio-geochemical processes and often participates or results from them. At the ecosystem scale, particularly in terrestrial ecosystems water acts mainly as a facilitator of growth processes (e.g. transport of nutrients and allelochemicals) and control of the sun energy dissipation power. Both roles involve extra-somatic work, which is performed by the water energy pump capacity.

After reminding basic thermodynamic concepts that apply to biological systems, such as energy, exergy, entropy, complexity and dissipation, ecosystems characterize as dissipative self-regenerating systems. That is, ecosystems consume exergy to grow biomass and information (complexity) at the cost of increasing entropy (dissipation and information loss/disorder).

Ecosystems evolution maximizes persistence and biomass accumulation; therefore it increases parsimony and complexity. Accordingly the input exergy efficiency, in terms of dry matter conversion of the intercepted radiation, is around 2.5%, a rather conservative value, and dissipation involves intricate hierarchical recycling loops. The outcome is that dissipation occurs through respiration after a lot of work has been done. One of the most crucial dissipative-growth loops involves soil, where the ecosystem garbage is transformed to derive nutrients for biomass increase and highly polymerized stable soil organic matter to improve this capacity during time.

The well-known Budyko curves offer a convenient synoptic view to discuss the eco-hydrological relations summarized before. A cluster of sites from a target area are plotted in a bi-dimensional orthogonal space: Evaporative Coefficient (AET/ P) against Dryness Index (PET / P) where AET, PET and P stand for actual evapotranspiration, potential evapotranspiration and precipitation respectively. Two asymptotes can be defined in the plot: The water limit, AET=P, AET>P is impossible unless there is an input of water beyond precipitation; and the energy limit, AET=PET, AET>PET is impossible unless precipitation is being lost (e.g. to ground water).

Interesting features can be learnt from such plots. PET is the exergy for evapotranspiration expressed in terms of evaporated water by using the latent heat of evaporation coefficient. At very dry conditions, PET exceeds several times precipitation and 'burns' to extreme dissipation soil and its organic matter. This can be shown by the associated high surface temperatures and Bowen ratio (H/LE) values, which sensible heat fluxes (H) dominate the latent heat of evaporation fluxes (LE).

Most of the ecosystem accumulated entropy is converted to heat in the sun furnace without opportunity of being recycled.

Where dryness becomes milder PET and AET converge to actual precipitation values. In this situation the plot's trend shows an inflection. Water limitation ceases its control in favour of energy to enable precipitation to be evaporated. In that case another kind of degradation occurs: entropy becomes accumulated in peats and bogs difficult to be processed by lack of oxygen (note that this was the origin of oil fossil reserves).

Finally some considerations are made about the hydro-biological impacts of humans on the ecosystems. Since the beginning of domestication humans proceeds to eliminate ecosystem's support structure either using fire or deforestation for agriculture. The result has been losing efficiency in the entropy management in terms of recycling capacity. This is most noticeable in the soil system, which organic matter content and water holding capacity declines and impairs the soil roles of nutrient and water supply.

The refinement of agriculture attained in the first half of the 20th century restored somewhat the situation but was unable to deal with the over-exploitation driven by the population increase in rural areas. The industrialization of agriculture thereafter introduced new and more acute problems: the external energy and agro-chemicals to increase productivity keeping minimal ecological structure creates enormous problems of entropy increase in soils and waters, which costs of management and replacement are hardly considered.

Key words
Biomass, entropy, evaporation fluxes, water overexploitation.

Restoration of soils that rendered water repellent by prolonged irrigation with treated waste water

Rony Wallach

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Abstract

Replacing fresh water with recycled water (treated wastewater and greywater) for crop irrigation changes the chemical, physical, and biological properties of soils. Most notably, soils become water repellent to a certain degree and in consequence their wetting behavior is changed. The synergistic effect of the uneven wetting patterns, known to occur in treated wastewater (TWW) irrigated soils, and TWW water quality on the spatial distribution of salinity and nutrients in the citrus tree's root zone will be first presented. In an attempt to examine the option of water repellent soil restoration, irrigation water in five out of the ten study plots was altered in 2012 with fresh water (FW) while TWW irrigation has continued in the other five plots.

The spatial and temporal water content distributions in the profile of TWW- and FW-irrigated soil was measured by subsequent electrical resistivity tomography (ERT) surveys. The contrast between the enhanced and lessened flow and transport through the preferential flow paths and the dry soil among these paths, respectively, a different soil sampling scheme was implemented. Soil samples for further chemical analysis were taken at "wet" and "dry" spots along transects that were a priori determined by ERT surveys made on the preceding day prior sampling. The salinity and nutrient distribution in the TWW soil profile was substantially affected by the uneven spatial water content distribution. In spite of the fact that water repellency of the FW soil gradually decreases, it remained water repellent after four years of FW irrigation. However, the lower salinity and nutrient concentration in the FW gradually lowered their concentration in the soil profile, in spite of the fact that they were affected by the still existing preferential flow paths.

The results of water quality alteration as a mean for water repellent soil restoration on the spatial and temporal distribution of soil water content, salinity, and nutrients in the soil profile will be presented and discussed.

Key words

Treated waste water, freshwater, water repellent soils, preferential flow, electrical resistivity tomography (ERT).

Session 2: Contributions presented in oral form

Effect of organic amendments on the afforestation performance of plant species on degraded semiarid conditions

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Abstract

Vegetation plays a fundamental role in soil conservation, so it is common to consider an increase in vegetation cover as one of the techniques to mitigate the effects of desertification in Mediterranean forest environments. There are two factors limiting the establishment and growth of seedlings in dry environments: (i) an excessive radiation and, (ii) the limited availability of water during the summer drought. During an afforestation plan, soil preparation is always necessary to reduce sapling mortality. The goal of this study was to analyze the effect of various organic amendments on soil according to chemical and hydrological properties, and to assess the effects of these parameters on an afforestal proposal under Mediterranean climate conditions.

Five amendments were applied in an experimental set of plots: straw mulching (SM); mulch with chipped branches of Aleppo Pine (PM); TerraCotten hydroabsobent polymers (HP); sewage sludge (RU); sheep manure (SH) and control (C). Plots were afforested following the same spatial pattern, and amendments were mixed with the soil at the rate 10 Mg ha^{-1}.

Under bare soil conditions (C), most of mortalities occurred during the summer period of the first year. A substantial positive effect of SM, PM and HP on the survival rates have been clearly observed. Conversely, when the soil was amended with SH, the survival rate quickly decreased or remained more or less constant regarding to C.

In this study, the lack of differences on chemical properties indicates that there may exist other reasons to justify the differences that were found in the pattern of vegetation. However, regarding to the hydrological properties some differences have been found.

In C, soils were registered below the wilting point during 4 months a year, and therefore, in the area of water unusable by plants. These months were coinciding with the summer Mediterranean drought and can justify the high mortality found on plants. Conversely, in SM, PM and HP, soil moisture remained below the wilting point less period than C and, the plant available water was also higher. In these treatments, the survival sapling rates measured were the highest. SH showed water holding capacity slightly more limited than C. For this treatment, the survival sapling rates measured were the lowest.

In conclusion, from a land management standpoint, the PM, SM and HP have been proved as a significant method to reduce sapling mortality rates during the Mediterranean summer drought.

Key words

Afforestation, organic amendments, soil properties, restoration, degraded areas.

The effect of restoration strategies on soil physical properties, hydrological behaviour and the plant growth in calcareous quarries under arid-semiarid climate

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Abstract

The addition of organic amendments and mulches are common soil restoration strategies in calcareous quarries, with proven benefits under sub-humid and semiarid environments. In this presentation both techniques were used in a quarry from SE Spain, in the climatic boundary arid-semiarid, and the results, four to six years after the experiment implementation, discussed. Sewage sludge from urban water treatment plant and compost from domestic organic wastes were the organic amendments. Siliceous fine gravel (GM) and woodchips (WM) were used as mulches. Nine experimental plots, 5 m x 15 m, were set in a two-way crossed design to test the two organic amendments, the two mulches, and the corresponding controls. Undisturbed natural soils around the quarry were used as soil quality reference. Soil aggregate stability was determined by two methods, wet sieving and drop test, and the soil hydrological behaviour (infiltration rate, wetting front, sediment production) by means of rainfall simulations (50 mm h^{-1} during 1h) over the experimental plots. Survival and growth of three autochthonous planted species (*Anthyllis cytisoides, A. terniflora and Macrochloa tenacissima*) were monitored at months 6, 18, 36 and 48 after plantation.

The combination of organic amendments and mulches enhanced the soil aggregate stability compared to the non-amended substrates, but still far from the values of the natural, reference soil. Both types of organic amendments increased infiltration and decreased water erosion, but mulches contributed to either enhance runoff (GM) or increase infiltration (WM) though water did not reach the soil below the mulch. Plant growth was favoured by both organic amendments and especially by compost, which improved the physical soil properties. Conversely, mulches did not show effective, conclusive results. Therefore, the use of organic amendments should be encouraged in quarry soil restoration for its proven environmental benefits.

Key words

Aggregate stability, organic amendments, mulch, rainfall simulation.

Evaluation of surfactant seed coating to improve cover of turfgrass under deficit irrigation in amended wettable sands

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Abstract

Lack of moisture retention on predominantly sand soils in golf course greens may reduce seed establishment. Water conservation in drought prone areas has also induced turfgrass managers to amend soils to enhance water retention to improve seed germination and cover. Our objective was to evaluate sand amendments and a new surfactant application technique to determine the best method for enhancing seed germination and growth under reduced water input. Two greenhouse studies were conducted at the Fort Lauderdale Research and Education Center in Florida, USA. A 100% sand (SAND), 90:10 sand:peat v/v (SP) and a 90:10 sand:calcined clay v/v (CC) were seeded with either uncoated perennial ryegrass (*Lolium perenne var. unknown*) or coated with a 10% alkyl-terminated block copolymer surfactant (SC) and placed under an irrigation regime of 2.5 mm of water every other day. To account for differences in seed weight, 2x the number of seed were sown in the uncoated treatment. Days to emergence (DTE) and percent cover (PC) were measured. Once established, dry downs were initiated and volumetric water (VWC) collected. SC did not significantly enhance DTE. PC was similar or significantly greater in SAND and SP treated with SC despite being sown with fewer seeds. VWC was greater in SAND and SP when sown with SC. Both PC and VWC results in CC were variable. Overall, SC enhanced percent cover and increased VWC and SP or CC yielded higher PC than SAND. Coating seeds with SC and sowing in peat or calcined clay amended sand may provide better establishment results in drought stricken areas.

Key words

Surfactant seed coating, peat, calcined clay, deficit irrigation.

An integrated approach to overcome soil limitations in restoration of arid ecosystems

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Abstract

Intensive land use and management, large scale disturbances such as extractive operations (e.g. mining), and global climate change have extensively contributed to degradation of arid ecosystems worldwide. Restoring these lands is particularly challenging due to limited rainfall, high temperatures, and soils with low nutrients level and decreased water holding capacity. Land degradation and altered environmental conditions such as changes in soil water availability, may significantly shift seedling recruitment or the composition and distribution of plant species from the pre-disturbed conditions. These limitations can be compounded by unfavourable edaphic conditions. Accordingly, understanding and improving soil physical, chemical and microbiological properties can be decisive for successful revegetation. Here we report on an integrated approach combining ecophysiological and hydrological measurements with analytical techniques and experimental and modelling methods to understand plant-soil-water relations and optimise vegetation establishment in restored arid environments. Specifically, we have assessed morphological and physiological plant responses and changes in soil physical, chemical and microbiological properties in reconstructed soils. These restored soils include blends of original topsoil and alternative materials in combination with different doses of organic and inorganic amendments. Here, we present our latest results obtained from laboratory and glasshouse experimental studies and field trials in the arid zone of Western Australia, and propose a set of soil quality indicators to assess functionality of restored soils. The methods used in our research can be effectively applied in a broad range of restoration projects in arid and semiarid environments.

Key words

Restoration seedbank initiative, mine rehabilitation, Pilbara, growth media, soil quality indicators, soil water retention.

Defining slope length and steepness factor for estimating soil loss in urbanizing mountainous landscapes

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Abstract

As mountainous regions become more urbanized, estimating soil loss is important for urban planning and natural conservation efforts, especially since more intense rainfall events have been occurring in recent years. The Revised Universal Soil Loss Equation is the most common way to predict soil erosion. However the model was developed for relatively flat agricultural fields. Limitations of the slope length and steepness factor (LS factor) does not allow for reliable estimates in more complex topography where water erosion is the main type of soil loss, and where with various landscape uses. While various model modifications to address this issue have been made, many fall short in either validation through ground-truthing slope length and steepness, have lower variability in length slopes and steepness, and or are too resource intensive (time and computer power to run models) to be utilized. To address this, PYTHON script was used to identify water flow pathways and R code was used to estimate the LS factors for two GIS parcel data sets (sub-catchment (large scale) and land cover (small scale)) in three watersheds of the Piedmont region of South Carolina, USA. Slope lengths and angles were ground-truthed to identify if model modifications were correct. The majority of slope length estimates based on land cover were within RUSLE restrictions (≤122m), whereas they were not when determined on the sub-catchment scale. Regardless of parcel data set used, the estimated slope angles were < 25%, which is the restriction for calculating RUSLE. Since land cover estimated lower LS factors, lower soil erosion rates were predicted when using this scale. This project identified that using land cover data is in most cases an appropriate size for determining the LS factor and estimating soil loss in urbanizing mountainous regions. Finally integrating PYTHON script to determine flow direction and R code to determine LS factors from polygons can reduce computing time and power in estimating soil loss.

Key words

RUSLE, soil loss, slope length, steepness factor.

Plant restoration after prescribed fires: testing the effect of seed provenance and seed predation in Mediterranean forest

Javier Sagra, Pedro Antonio Alvarez-Plaza, Raquel Alfaro Sánchez, Manuel Esteban Lucas-Borja, Daniel Moya, Pablo Ferrandis, Jorge de las Heras Ibáñez

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Abstract

Wildfires have an important influence in many different elements of the forest ecosystems. In order to reduce fire risk and occurrence, prescribed fires with low fire intensity have been widely used as a fuel reduction tool and silvicultural treatment in Mediterranean forest ecosystems. However, other than the fact that fire may alter microsite conditions, little is known about the impact of prescribed burning on natural regeneration or plant species renewal at the same time. Also, and after prescribed fires, some plant provenances may be more appropriated that other when ecosystem restoration is aimed. In this study, we compared the effects of prescribed burning on initial seedling recruitment of different seed provenances (*P. pinaster and P. halepensis* from Spanish dry and wet locations) after a low intensity prescribed fire was applied using a sowing experiment in 60 plots (30 burned and 30 control) set up in the Lezuza forest (Albacete, central-eastern Spain). Also, seed predation was evaluated since this is one of the most important factors limiting seedling recruitment. Different forest stand characteristics (slope, tree density, basal area and shrub/herbal cover) affecting each plot were measured. Our results showed that prescribed fires do alter initial seedling recruitment dynamics. Seed coming from dryer and warmer sites perform better in burned plots whereas seed from wetter and colder sites regenerates better in control areas. Seed predation was a really important factor in both burned and control plots. Understanding and balancing seed emergence and seedling survival in Mediterranean *Pinus* forests should help to improve prescribed burning plans with no debilitation of pine tree vitality or plant community persistence and aiming properly plant restoration.

Key words

Seed emergence, seeding survival, Mediterranean forest, prescribed fires, ecological restoration.

Long-term effect of afforestation and land abandonment on soil hydrological characteristics in semi-arid Spain

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Abstract

Land abandonment is common in Mediterranean landscapes and vegetation succession is hampered, as climatological conditions are not favourable. This makes their soils vulnerable for degradation and forestation projects have been conducted over the past 70 years with the aim to protect the landscape from degradation, although the effectiveness of these measures is not well known, especially on longer time scales.

So far the focus has been on the effect of land abandonment, natural succession, or land use change on soil hydrology, but not by afforestation. More soil hydrological data is needed to model catchment response, as until now most assumptions that are made rely only on changes in agricultural land use (e.g. Bormann et al., 2007).

The aim of this study was to link changes of soil chemical and physical parameters to observed changes in soil hydrological characteristics.

Fieldwork has been carried out in Murcia, south-eastern Spain, to study the effects of land abandonment and afforestation on a wide range of soil quality indicators along a chronosequence, including two afforested areas (from the early '70s and 1993). The *Pinus halepensis* trees were planted in rows, for which the underlying calcrete was broken. Soil hydrological properties between the afforestation projects, abandoned agricultural plots of similar age, semi-natural vegetation and cereal crop fields were determined using a portable rainfall simulator. Furthermore, undisturbed soil samples were taken for further testing in the laboratory. As the natural vegetation is characterized by a spotted pattern of bare areas and trees, forming so-called "islands of fertility", both bare and vegetation covered sub-sites were sampled.

First results indicated important changes in soil physical and chemical properties. The afforested areas showed a strong enhancing effect on soil quality compared with secondary succession on abandoned fields. Despite similar levels of SOM in the older afforested sites, aggregate stability lacked behind in undisturbed plots. These changes in soil physical and chemical parameters closely linked to observed changes in soil hydraulic and hydrological properties.

Key words

Afforestation, land abandonment, soil hydrology, soil quality.

References:

Bormann, H., Breuer, L., Gräff, T., & Huisman, J. A. (2007). Analysing the effects of soil properties changes associated with land use changes on the simulated water balance: A comparison of three hydrological catchment models for scenario analysis. *Ecological Modelling*, *209*(1), 29-40.

Session 2: Contributions presented as posters

Assessment of Libyan soil resources and degradation

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Abstract

Soil degradation is considered one of the most important factors limiting agricultural development in Libya, however no serious efforts have been taken to identify the distribution of soil degradation occurrence and type for the country. Limited existing soil texture, landscape features and degradation data from Libya's five primary agricultural regions were assembled into one map allowing for summarization and model development of soil occurrence and type. Thirty-three percent of the total soil area of the primary agriculture regions is degraded. A logistic regression model that included slope and soil texture was determined to best predict soil degradation occurrence ($P = 0.0003$, $\chi 2 = 8.432$, and Akaike Information Criterion = 34.02). Using the Leave-One-Field-Out validation approach, 62-82% of the model's degradation occurrence predictions were correct. Using the model, 53.5 % of all of Libya was predicted to have degraded soils. Using existing data for the primary agricultural regions, the proportions of degradation type (salinization, water, and wind erosion) were determined to change across soil textures found in the primary agricultural regions ($p < 0.001$). Salinization was found in all textures except sand, which only was degraded by wind erosion. Knowing this relationship, a multinomial logistic regression model using the same variables from the logistic model was developed to determine soil degradation type for the remainder of the country. This model predicted that salinization was the primary type of soil degradation (46.4 %) in Libya, with water erosion and wind erosion only causing 6.4 % and 0.66 % of soil degradation, respectively. The empirical models can assist stakeholders in identifying where agriculture is most likely to be sustainable, and determine measures to counter further degradation of existing agricultural regions. The models can also be used for neighboring countries with similar climate and soils in North Africa.

Key words

Libya, soil resources, soil degradation, multinomial logistic regression analysis.

Hydrological soil behavior in Beni Chougrane Mountains (Algeria)

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Abstract

In northern Algeria, the physical degradation of land by water erosion is one of the most important forms of degradation. As is well known, vegetation plays an important role against water erosion. In the mentioned area the potential natural vegetation called maquis is currently characterized by a certain level of degradation often ranging between sparse cover and bare soil. In the Oued Fergoug watershed belonging to the Beni Chougrane Mountains (NW of Algeria), a trial was carried out with a mini rainfall simulator designed by ORSTOM to evaluate the runoff rate and the sediment load at experimental plot scale and in a situation of bare soil. A total of 18 rainfall simulations were carried out on regular square plots each measuring 1 m^2. An experimental area located on the same parent material was selected on two different surface slope: 12.5% (7.12°) and 25% (14.04°) slopes. Nine plots were established in each area, distributed in a 3 by 3 matrix of plots, with 3 different rainfall intensities (30, 50 and 80 mm h-1), and 3 levels of initial soil moisture (dry, moist and very moist). In dry conditions the soils had not received rainfall for more than 25 days (soil moisture < 3% w/w). In moist and very moist states, rains of 10 mm h-1 intensity were applied to plots before the simulation. In moist conditions (near field capacity) the experiment was carried out 24 hours after rain application (soil water ranges around 29% w/w). In the very moist state (near saturation) the water content in the soil ranged from 32% to 35% w/w. In this case rainfall simulation was carried out 15 minutes after previous rain. The highest runoff values observed exceeded 0.50 mm min-1 and the maximum sediment load yield was 94.2 g L-1 per square meter. Summarizing, the intensity of rain is the main factor for runoff generation, independently of slope value and initial soil moisture. The only practice that is effective for protecting the soil against erosion is to provide protective plant ground cover. Vegetation ground cover is a crucial component in maintaining stable slopes and thus limiting soil losses. The different factors involved in this land degradation and the present success of some bioengineering techniques to obtain ground cover vegetation should be taken into account in this context. Moreover, rainfall simulations would be an adequate technique to evaluate the abovementioned restoration work.

Key words

ORSTOM rainfall simulator, Algeria, slope, rainfall intensity, initial soil moisture, contour strip-cropping.

The effect of *Robinia pseudoacacia* afforestation on soil, water and vegetation on Chinese hilly-gullied Loess Plateau

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Abstract

Revegetation is one of the primary management approaches for solving the problems caused by severe soil erosion worldwide. *Robinia pseudoacacia* was considered a promising tree for afforestation in the highly eroded region of the Loess Plateau due to its fast growth and ability to fix atmospheric nitrogen.

In this study we aimed to analyze the effects of *R. pseudoacacia* plantation on plant community composition and dynamics through its effects on light, soil fertility and soil water availability.

We used a chronosequence of plantations from 10 to 40 years and compared the environmental characteristics and vegetation composition of those areas along the chronosequence and with those of similar-year-old natural areas that were used as control.

The results showed that *R. pseudoacacia* plantations reached maturity around 30 years and then declined in density and canopy cover. We also found that soil nutrients and moisture at the superficial soil layer improved with age until maturity of plantations, but that photosynthetically active radiation at the ground level and soil moisture at deeper soil layers decreased with maturity in relation to control conditions. Plots with *R. pseudoacacia* of all ages had higher cover values, lower number of species but higher b-diversity (β-diversity) values than control plots and they also differed in species composition.

We concluded that revegetation with *R. pseudoacacia* dramatically changed the environment where plantations were established, thus favoring plant communities that played not a general higher protective role against soil erosion than natural vegetation but a negative effect on soil water storage of deep soil layers.

Key words

Afforestation, plant communities, soil nutrients, soil moisture, soil erosion.

The drying process in technosols: Effects of irrigation and compost on substrates used in limestone quarries

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Abstract

Technosols employed in limestone quarry restoration are characterized by irregular geometric properties of their pore spaces which result from materials of various sizes and poor structure of their components. Irregularity of soil porosity is expressed as total porosity, equivalent pore diameter and pore continuity. The water contained in pores must be able to flow to contiguous areas where plant roots grow, so that plant cover can develop and contribute to the success of restoration. In the absence of salinity, the matric potential is the main component of soil water potential. Decreasing soil water content modifies the soil water potential and, consequently, the water flow in the soil. The results of an experiment carried out in 18 plots established on substrates used to restore eight limestone quarries in NE Iberian Peninsula, under Mediterranean climate, are presented in this communication.

Two types of substrates were used – with and without compost – and two additional treatments were applied – irrigation and no-irrigation (control). Soil water content was measured weekly with vertically inserted TDR probes (20 cm long). The 1502C Techtronic device and the empirical relationship proposed by Topp et al., 1980 were used to calculate water content values from electric impedance.

Results show a continuous reduction of soil water flow in the technosol with drying. Vegetation access to soil water during periods of drought is hindered by both the reduction of the amount of water available in the soil and the reduction of soil water flow. These results validate the hypothesis that, when a continuous water supply is not possible during summer, maintaining a moderate plant cover during spring might ensure the survival of the vegetation through the following dry season.

Key words

Technosols, limestone quarry restoration, soil water.

Topographic modifications for soil erosion control in arid-semiarid restored quarry hillslopes

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Abstract

Erosion pins were used to monitor soil/substrate erosion in modified hillslopes in an experimental, arid-semiarid, calcareous quarry restoration area in SE Spain during one year (2014-2015). The survival of planted species was also monitored at the same sites as erosion pins were measured. The three hillslope modifications done with a mechanical backhoe consisted in *micro-catchments*, *micro-terraces* and *contour rills* which pretended to harvest runoff water for planted species (*Macrochloa tenacissima*, *Ephedra fragilis*, and *Lavanda angustifolia*) and controlling soil erosion. Rainfall during the monitoring period has only been 135 mm, about 50% of annual average, with a maximum I_5 = 28.8 mm h^{-1} and I_{30} = 11.6 mm h^{-1}.

At the end of the first year of monitoring all treatments show average balances almost neutral or with a very limited sedimentation (from 0.02 mm erosion to 0.73 mm sedimentation). *Micro-terraces* and *micro-catchments* showed average sedimentation of 1.40 and 0.47 mm respectively without organic amendments and 0.47 and 0.54 mm respectively with organic amendments. Erosion values were respectively 0.20 and 0.23 without organic amendments and 1.20 and 0.27 with them. *Contour rills* showed an average 0.53 mm and 0.38 mm of sedimentation with and without organic amendments respectively and an average 0.78 mm and 0.18 mm of erosion with and without organic amendments.

Simultaneous plant survival results indicated a maximum (100%) in non-amended *micro-terraces* followed by amended *micro-catchments* (65%), while the lowest plant survival values were obtained in *contour rills* (20% and 0% on non-amended and amended respectively). These preliminary results indicate that *contour rills*, though with an almost neutral behavior with regards erosion control, do not harvest enough runoff water for a significant plant survival and that *micro-terraces* and *micro-catchments* are the topographical modifications better suited for both erosion control and water harvesting.

Key words:
Erosion pins, plant survival, micro-catchments, micro-terraces, contour rills.

Rock fragment cover impacts on runoff and soil loss in Mediterranean vineyards (Les Alcusses valley, Spain)

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Abstract

Vineyards are characterized by particular regional practices (land management, soil tillage, crop management…) and identifiable bio-physical environmental conditions (soil, climate, landscape and topography) with direct influences on grape composition. In Germany, the occurrence of extreme rainfall events, non-conservative land management practices and in some cases steep slopes contribute to soil erosion processes and land degradation processes. There is a need to find soil conservation strategies to reach the sustainability on vineyards, and for this it is necessary to investigate the processes, the factors and the rates of soil erosion. The main goal of this research is to detect which factors are able to reduce the soil losses in conventional Mediterranean vineyards. The analysis was carried out in Les Alcusses valley (Valencia, Spain) using 96 rainfall simulation experiments at pedon scale (0.24 m^2) to measure the soil detachment and runoff under low frequency–high magnitude rainfall events of one hour at 55 mm h^{-1}. Runoff showed a total average of 40.6±17.9% of the rainfall, with maximum of 76.3% and minimum of 9.2% and soil erosion rates of 71.5±46.8 g m^{-2}. Regarding to these obtained results, the highest correlation was observed between rock fragment covers and soil erosion or runoff. There was a clear decrease of the soil erodibility with the increase of the rock fragment cover on the soil surface, but an increase in the runoff. A 60% rock fragment cover already offers a very efficient reduction in the soil erosion rates, but higher covers will increase the runoff rates. The results of our study showed that the rock fragments can act as mulch in Mediterranean vineyards, but a pavement of rock fragments will trigger high runoff rates.

Key words

Rock fragment cover, vineyards, runoff, soil erosion.

Spatial and temporal evolution of topsoil level on German steep vineyards. Approach from stock unearthing method

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Abstract

Vineyards are characterized by particular regional practices (land management, soil tillage, crop management…) and identifiable bio-physical environmental conditions (soil, climate, landscape and topography) with direct influences on grape composition. In Germany, the occurrence of extreme rainfall events, non-conservative land management practices and in some cases steep slopes contribute to soil erosion processes and land degradation processes. The aim of this research is to investigate the applicability of the stock unearthing method (SUM), using botanic benchmarks in two vineyards with different ages (3 and 35 years) to research the impact of land management on soil erosion rates. We analyzed: i) soil profiles and soil properties at different slope points; ii) soil redistribution using topsoil level maps applying botanic benchmarks; and, ii) soil erosion rates from 2013 to 2015 using the vine stocks botanic benchmarks. The stock unearthing method (SUM) showed that the old vineyard's erosion rates were between 3.3 and 3.8 Mg ha^{-1} yr^{-1}, which depended on the yearly rainfall amount and tillage practices. Data from the SUM in the young vineyard showed very high peak soil erosion rates (62.5 Mg ha^{-1} yr^{-1}), which showed that this method should not be applied to measurements in young vineyards.

Key words

Vineyard, Ruwer-Mosel valley, soil erosion, stock unearthing method.

Inoculation of soil native cyanobacteria to restore arid degraded soils affected by water erosion

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Abstract

Restoration of degraded soils from arid and semiarid regions has been traditionally focused on increasing soil retention by the establishment of a plant cover. However, the higher temperatures and the limited water resources in these regions result in low survival rates. Under these conditions, vegetation restoration is slow and a previous stage that improves the environmental conditions, such as soil fertility and stability, would turn out to a successful plant restoration.

Cyanobacteria are common inhabitants in arid soils, where they live in community with lichens, mosses, bacteria, algae and fungi, known as biocrust. Soil cyanobacteria have been demonstrated to enhance water availability, soil fertility (fixing atmospheric C and N), and soil stability (thanks to their filamentous morphology and the exopolysaccharides they excrete), and significantly reduce water and wind erosion. Besides, they are able to tolerate high temperatures and UV radiation. All these features convert cyanobacteria in pioneers organisms capable of colonizing successfully degraded soils and may be crucial in facilitating the succession of more developed organisms, as vascular plants.

The objective of this study is to test the effect of inoculated cyanobacteria on degraded soils from two different semiarid areas from the southeast of Spain: Tabernas badlands and a limestone quarry located in Gádor, both in the province of Almeria. Soil native cyanobacteria from three representative nitrogen-fixing genera (Nostoc, Scytonema and Tolypothrix) were isolated from both areas and grown under nitrogen-fixing conditions. Each strain belonging to these genera were inoculated (2g/L), separately and mixed, on 80 g of each soil in Petri dishes and biocrust development was monitored in these soils under laboratory conditions, at a constant temperature of 25ºC. During the experiment, irrigation was applied simulating a wet rainfall year (average recorded in the study sites). After 3 months, net CO2 flux of inoculated and control soils was measured with a transparent chamber attached to an infrared gas analyzer (IRGA, LI-6400) and their spectral response was measured with a spectroradiometer as a surrogated of photosynthetic activity. Samples of the surface crust were collected in order to determine total soil organic carbon (SOC) content.

The inoculated soils showed positive values of net CO2 flux, thus indicating a net CO2 uptake, whereas control soils showed CO2 fluxes closed to zero. This higher CO2 fixation in the inoculated soils was reflected in the higher SOC content found in these soils with respect to the non-inoculated soils. From the different treatments, soil inoculation with the mixture of the three strains promoted the highest SOC contents and absorbance at 680 nm (indicative of higher chlorophyll a content) on both soil types. The inoculated soils also showed lower albedo in the VIS region than the control.

Therefore, using a consortium of cyanobacteria to inoculate degraded soils seems to be a more promising strategy to restore soils than inoculating with individual species. Our results underline the benefits of cyanobacteria inoculation on biocrust development and the increase in SOC sequestration which could facilitate further plant cover establishment.

Key words
Restoration, cyanobacteria, biological soil crust, carbon fixation, semiarid.

Acknowledgements: This work was supported by the Spanish National Plan for Research, Development and Innovation and including European Union of Regional Development Funds, under the RESUCI (CGL2014-59946-R) and CGL2013-44870-R research projects, the FPU predoctoral fellowship from the Educational, Culture and Sports Ministry of Spain and the foundation Tatiana Pérez de Guzmán el Bueno, under its predoctoral fellowship programme.

Understanding gully erosion to reduce reservoir sedimentation in North-West Ethiopia. The case of Koga catchment

Amara Selamawit Damtew[1,2], Saskia Keesstra[1], Martine van der Ploeg[1], Tammo Steenhuis[2,3], Seifu Tilahun[2]

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Abstract

Gully erosion control is an important challenge the world is facing. Despite the immense on-site and off-site damages caused by gullies, studies on the process of gully and its management strategies in Ethiopian highlands are limited. This is especially true for low land gullies which form under different conditions and are caused by different processes than hillslope gullies. Therefore, this study will look into these processes at Koga watershed (mainly at the valley floor where gully expansion rate is found to be quite severe) located in the Blue Nile basin. The watershed drains to the Koga dam, Lake Tana, where the new Ethiopian great renaissance dam is now under construction. To make sure the water resource development activities are sustainable, insights are needed in the onsite effects of gullies and the influx of sediment these erosion features cause. The objective is to gain a better understanding on the process of gully formation and thereafter to find the best reclamation measures. Thus, in more detail the objectives of this research are: (1) A Review on the causes, controlling factors and existing management practices of gullies, (2) Quantifying long term gully changes using satellite imagery, aerial photograph and google earth, (3) Investigating the dominant mechanism of gully formation, (4) Measuring the impact of soil types and soil characteristics on the development and formation of gullies, and (5) Testing the effectiveness of integrated physical and biological gully reclamation measures. For this purpose a group of data on hydrological and metrological, soil hydrology and hydraulics, soil properties and types, aerial photograph and satellite imagery, drainage area characteristics of the gullies will be collected. Data analysis will be done by GIS and different statistical software. In this way a better understanding of the processes involved in the formation of low land gullies in the Koga catchment will gained. Finally, the aim is to set up a series of different gully reclamation measures to test the most effective gully prevention strategies, which will be used to give recommendations to catchment managers.

Key words

Gully, process, factor, reclamation, Koga.

SESSION 3

HYDROLOGICAL EFFECTS OF PLANT-SOIL COMPLEX FROM PATCH TO LANDSCAPE

Conveners:

Lubomir Lichner, Institute of Hydrology SAS, Bratislava, Slovakia

Erik L.H. Cammeraat, Univ. of Amsterdam, The Netherlands

Andrea Carminati, Georg-August-University of Göttingen, Germany

Artemi Cerdà, University of Valencia, Spain

Keynote lectures

Combining mechanistic model with water stable isotopes for identifying root water fluxes

Mathieu Javaux[1,2], Félicien Meunier[1], Jan Vanderborght[2], Valentin Couvreur[1], Harry Vereecken[2], Youri Rothfuss[2]

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Abstract

Plant root water uptake and release are very important component of the terrestrial water cycle but hardly measurable. Water stable isotopic analyses have been used for decades to quantify water uptake sources. By confronting the hydrogen and oxygen isotopic compositions (δ^2H and δ^{18}O) of plant xylem water with the isotopic compositions of other potential water pools, authors could determine the relative contributions of these water pools to plant water uptake. The objectives of this presentation are twofold: first, review and compare the different methods to quantify water uptake distribution from stable isotope analyses and second, to demonstrate with the analysis of a controlled experiment how mechanistic models can help improve our knowledge on the root water uptake and release processes. In the model comparison study, we use classical methods to analyse virtual experiments and compare their results with an inverse modelling method using a mechanistic root water uptake model. This benchmarking illustrates how one can benefit from using process-based models to retrieve entire RWU profiles but also to gain crucial information on the dynamics of root and plant resistances to water flow. This comparison also allowed us to quantify the uncertainty associated with the different statistical methods. However, this method requires other variables to be measured (profiles of root length density, soil water content or soil water potential, and time series of transpiration flux) in addition to water isotopic composition, which might be difficult to obtain under field natural conditions. In a second stage we used this inverse modelling method to retrieve the water uptake and release profile of Ryegrass (*Lolium multiflorum* Lam.) grown under controlled experimental conditions in a rhizotron and subject to a non-uniform profile of soil water stable isotopes. We could demonstrate the release of water in shallow layer (hydraulic lift). The combined use of mechanistic models and stable water isotopes as tracers, and specific controlled experimental conditions not only bring information on the water uptake and release profile but also allow one to obtain information on the hydraulic parameters of the soil-plant systems.

Key words

Water stable isotopes, root water uptake, soil-plant atmosphere continuum.

The effects of land management on soil characteristics and hydrological connectivity: combining insights from the COST Action ES1306

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Abstract

Agricultural management has distinct impacts on the properties and functions of the soil. Management strategies such as pesticides, ploughing, cover crops or mulching have distinct impacts on soil properties, ecosystem services and the related hydrological functioning of these areas. In addition, large areas in the Mediterranean are not managed at all anymore, since they were abandoned by farmers and encroached by natural vegetation. Agricultural management, or the lack of it, changes not only the hydrological functioning of the fields that are revegetated, but also the hydrology of the catchment these fields are part of. This is related to the connectivity of water transfer paths within catchments. Connectivity is a relatively new concept can be useful to understand the catchment system dynamics in terms of water and sediment budgets. However, quantifying connectivity is a challenge which is still largely ahead of us. Relating water and sediment transport processes from plot scale, to hillslope and catchment scale and Parameterizing models with these data is part of the work of the COST Action CONNECTEUR (ES1306). Within this scientific network we work on understanding how connectivity is useful as a concept, how we can measure and model it, and how this information can be used to develop management strategies to come to a more sustainable use of the landscape.

Key words

COST Action ES1306, connectivity, soil properties, water and sediment transfer.

Impact of plants on soil composition and transport processes in soils

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Abstract

It has been demonstrated by many studies that land use considerably modifies soil properties including soil structure and associated transport processes. Decomposition of organic material, i.e. different vegetation litter (grass, leaves or needles from trees etc.), leads to different soil-pore composition and consequently to different soil hydraulic properties (i.e. soil water retention and hydraulic conductivity curves). Micro-morphological images of thin soil sections for instance showed that decomposition of grass parts resulted in larger and more compact round clusters, which had larger retention ability in comparison to those under the spruce forest. Micro-morphological images and laboratory and field measurements of hydraulic properties also documented that plant parts decay and roots under the permanent grass cover considerably improved soil aggregation and hydraulic properties of the Haplic Luvisol and Haplic Cambisol in comparison to those at the arable land. However, plant roots strongly influence also soil structure and associated properties of arable soils causing their temporal variability, which was for shown instance for the Greyic Phaeozem, Haplic Luvisol and Haplic Cambisol. Roots may cause uneven water and solutes infiltration at the surface and even non-equilibrium water flow and tracer transport within the soil profile, which was documented for these three soil types at the macro- and micro-scale. Important plant function influencing soil hydrology is root water and solute uptake. Soil structure modification and root-uptake depends on root structure (i.e. depth, density, hierarchy etc.). For instance definition of vertical and horizontal root distribution for wheat and barley obtained using different techniques resulted in different simulated root water uptakes. Solute uptake is in addition affected by its characteristics and behavior in soil-water system (i.e. size of the molecule, sorption affinity on soil constitutes etc.) and ability of different plant to extract particular solute from soils (described in study employing three pharmaceuticals, three soils and five plants).

Key words

Soil structure, micromorphological images, soil hydraulic properties, non-equilibrium water flow, roots, solute transport.

Relating the effects of soil hydrophobicity at atomic, molecular, core and national scales

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Abstract

The detrimental impacts of soil hydrophobicity include increased runoff, erosion and flooding, reduced biomass production, inefficient use of irrigation water and preferential leaching of pollutants. Its impacts may exacerbate flood risk associated with more extreme drought and precipitation events predicted with UK climate change scenarios. The UK's Natural Environment Research Council (NERC) has therefore funded a major research programme to investigate soil hydrophobicity over length scales ranging from atomic through molecular, core and landscape scale. This presentation gives an overview of the findings to date. The programme is predicated on the hypothesis that changes in soil protein abundance and localization, induced by variations in soil moisture and temperature, are crucial driving forces for transitions between hydrophobic and hydrophilic conditions at soil particle surfaces. Three soils were chosen based on the severity of hydrophobicity that can be achieved in the field: severe to extreme (Cefn Bryn, Gower, Wales), intermediate to severe (National Botanical Garden, Wales), and subcritical (Park Grass, Rothamsted Research near London). The latter is already highly characterised so was also used as a control. Hydrophobic/ hydrophilic transitions were measured from water droplet penetration times.

Scientific advances in the following five areas will be described:

(i) the identification of these soil proteins by proteomic methods, using novel separation methods which reduces interference by humic acids, and allows identification by ESI and MALDI TOF mass spectrometry and database searches,

(ii) the examination of such proteins, which form ordered hydrophobic ridges, and measurement of their elasticity, stickiness and hydrophobicity at nano- to microscale using atomic force microscopy adapted for the rough surfaces of soil particles,

(iii) the novel use of a picoliter goniometer to show hydrophobic effects at a 1 micron diameter droplet level, which avoids the averaging over soil cores and particles evident in microliter goniometry, with which the results are compared,

(iv) measurements at core scale using water retention and wicking experiments, and

(v) the interpretation, integration and upscaling of the results using a development of the PoreXpert void network model, a significant advance on the Van Genuchten approach.
An explanation will also be given as to how the results will be incorporated into the JULES hydrological model of the UK Meteorological Office, used to predict flooding for different soil types and usage.

Key words
Soil water repellency, switching, across scales: molecular-nano-core-landscape.

Contributions presented in oral form

Sub-session 3-1. Biophysical interactions between soil and roots. Soil water repellence

Converners:

Andrea Carminati, Georg-August-University of Göttingen, Germany

Erik L.H. Cammeraat, Univ. of Amsterdam, The Netherlands

Root type matters: different water uptake rates of seminal, crown and lateral roots of maize

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Abstract

Roots play a key role in water acquisition and are a significant component of plant adaptation to different environmental conditions. Although maize (*Zea mays* L.) is one of the most important crops worldwide, there is limited information on the function of different root segments and types in extracting water from soils. Aim of this study was to investigate the location of water uptake in a mature maize roots.

We used neutron radiography to image the spatial distribution of maize roots in soil and trace the transport of injected deuterated water (D_2O) in soil and roots. Maize plants were grown in aluminum containers filled with a sandy soil that was kept homogeneously wet throughout the experiment. When the plants were five weeks-old, we injected D_2O into selected soil regions. The transport of D_2O was simulated using a diffusion-convection numerical model. By fitting the observed D_2O transport we quantified the diffusion coefficient and the water uptake of the different root segments. The method was developed and tested with two weeks-old maize (Ahmed et. al 2016), for which we found that water was manly taken up by lateral roots and water uptake of seminal roots was negligible. Here, we applied this method to measure root water uptake by a mature maize root system.

The root architecture of five weeks-old maize consisted of seminal roots with long laterals and crown (nodal) roots that emerged from the above ground part of the plant two weeks after planting. Crown roots were thicker than seminal roots and had fewer and shorter laterals. Surprisingly, we found that water was mainly taken up by crown roots and their laterals, while laterals of seminal roots, which were the main location of water uptake in younger plants, stopped to take up water. Interestingly, we found that in contrast to seminal roots, the crown roots were able to take up water also from their distal segments.

We conclude that for five weeks-old maize, there were large differences in water uptake by crown and seminal roots. Although seminal roots have been heavily investigated, they do not present the main location of water uptake of a mature maize root system. Furthermore, the fact that crown roots are able to take up water from their most distal parts shows that some of the conclusions that have been drawn using seminal root do not hold for all maize root types.

Key words

Diffusion-convection model, neutron radiography, root water uptake, deuterated water (D_2O).

Reference: Ahmed MA, Zarebanadkouki M, Kaestner A, Carminati A (2016) Measurements of water uptake of maize roots: the key function of lateral roots. *Plant Soil* 398:59-77.

Water repellency development along a coastal dune chronosequence in relation to vegetation succession

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Abstract

Water repellency is an important factor in infiltration of water into soils and as such extensively studied in many environments. However not very much is known on the development of water repellency over time. In this study the development of water repellency and infiltration is presented along a chronosequence of dunes and subsequent vegetation succession for several locations from the Dutch coastal dunes. Vegetation succession and soil ageing go together with topsoil acidification and nutrient accumulation on the calcareous and nutrient poor dune sands. This development has negative consequences for the biodiversity of the dune vegetation.

On three locations along the coast of Holland, a sequence of 4-5 areas was studied ranging from active blowing dune sands to (almost) fully vegetation covered areas on dunes that have been formed 200-300 year ago. In situ rainfall simulations were used, applying different rainfall intensities, to measure infiltration, runoff and sediment yield, as well as measurements on monoliths in the laboratory. Water repellency was determined using the contact angle and WDPT methods, from the surface to 30cm depth, together with soil development and organic matter.

Water repellency increased more or less gradually from not water repellent in active dune sands to very water repellent after 'long' vegetation succession. With increasing depth of the soil development also water repellency increased at the surface, with a decline going deeper, and getting the deepest water repellency effects in the oldest soils. Organic matter contents showed a good correlation with water repellency. Infiltration of water showed a clear water repellency effect with very low infiltration rates during the first 10 minutes, once vegetation had established. The sediment yield was quite variable, and contained large amounts of organic matter at the onset of overland flow and shortly thereafter.

Water repellency strongly affects water infiltration in the dunes, and especially after dry periods, rainfall will not infiltrate. Consequently, runoff will be produced, redirecting water from plants to lower areas in the dunes having ecological consequences for plant growth and stabilization of dunes. This enhances local water erosion, and water erosion can therefore be important in older dune surfaces, bringing the underlying sand to the surface which is important to counteract acidification and nutrient accumulation in the topsoil of the dunes. Consequently, eutrophication and acidification will be more important in the sediment accumulating zones.

Key words

Water repellency, dunes, chronosequence, infiltration, vegetation succession.

The hydraulic properties of the root-soil interface: A hairy story

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Abstract

The flow of water into the roots and the (putative) presence of a large resistance at the root-soil interface have attracted the attention of plant and soil scientists for decades. Such resistance has been attributed to a partial contact between roots and soil, large gradients in soil matric potential around the roots, or accumulation of solutes at the root surface creating a negative osmotic potential.

Our hypothesis is that roots are capable of altering the biophysical properties of the soil around the roots, the *rhizosphere*, facilitating root water uptake in dry soils. In particular, we expect that root hairs and mucilage optimally connect the roots to the soil maintaining the hydraulic continuity across the rhizosphere.

Using a pressure chamber apparatus we measured the relation between transpiration rate and the water potential difference between soil and leaf xylem during drying cycles in barley mutants with and without root hairs. The samples were grown in a well structured soil rich in organic material. At low soil moistures and high transpiration rates, large drops in water potential developed around the roots. These drops in water potential recovered very slowly, even after transpiration was severely decreased. The drops in water potential were much bigger in barley mutants without root hairs. These mutants failed to sustain high transpiration rates in dry conditions.

To explain the nature of such drops in water potential across the rhizosphere we performed high resolution neutron tomography of the rhizosphere of the barleys with and without root hairs growing in the same soil described above. The tomograms suggested that the hydraulic contact between the soil structures was the highest resistance for the water flow in dry conditions. The tomograms also indicate that root hairs and mucilage improved the hydraulic contact between roots and soil structures. At high transpiration rates and low water contents, roots extracted water from the rhizosphere, while the bulk soil, due its low unsaturated conductivity, failed to compensate root water uptake.

We conclude that root hairs are functional to increase the contact area between the roots and the soil structures and mucilage maintains wet the soil region between root hairs. These observations demonstrate the importance of the biophysical processes in the rhizosphere in modulating root water uptake.

Key words

Root hairs, rhizosphere, root water uptake, root pressure chamber, hydraulic conductance, barley.

Soil structure formation and its consequences on coupled processes in the root zone and pore walls

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Abstract

Transport and transformation processes of solid, liquid and gaseous soil compounds in soils are intimately connected and strongly dependent on the state of soil structure and pore space geometries. Soil structure in turn is inherently dynamic due to changes in pore water pressure resulting in shrinking and swelling and/or soil compaction and shear deformation by applying external loads and last but not least also continuously modified by biological factors (root growth and soil faunal activities). Appreciating the dynamic properties of soils and functions requires observing the evolution of soil structure with changing boundary conditions without disturbing the processes of structure formation.

Root growth as well as earthworm activities affect the macro- as well microscale functionality of soils and alter not only the internal wall strength but also the gas diffusivity and hydraulic properties which also alters the physico - chemical processes in the vicinity of root surfaces.

Processes which should be included when dealing with flux processes in dynamically altered structured soils will be documented within the lecture.

Key words

Intra-aggregate pore system, redoxpotential, microhabitat, aeration, coupled processes.

Extent and persistence of water repellency in soils from different climate zones

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Abstract

Soil water repellency (SWR) is a near surface phenomenon, which tends to be both spatially and temporally highly variable. The objective of this study was to compare three methods for assessing the extent of SWR by the repellency index and two methods for assessing the persistence of SWR in various soils from different climate zones. The cumulative infiltration vs. square root of time I = f(SQRT t) relationship measured by mini-disk infiltrometer was used to estimate soil sorptivity. In the first method of estimating the repellency index, the ethanol (Se) and water (Sw) sorptivities were estimated in pairwise arrangements and only one value of the repellency index, RI, was calculated from one pair of Se and Sw measurements. In the second method of estimating the repellency index, the combination of all the ethanol and water sorptivities was used to calculate an aggregated repellency index, RIa, that accounts for the influence of spatial variability. In the third method of estimating the repellency index, the water sorptivity Sww for nearly wettable state of soil and the water sorptivity Swh for water-repellent state of soil were estimated, respectively, from the steeper and less steep part of hockey-stick-like relationship of I = f(SQRT t) and their ratio used to define a single-test repellency index, RI*. In the first method of estimating the persistence of SWR, the water repellency cessation time (WRCT) was determined as the t-coordinate of the point of intersection of two straight lines, representing the I = f(SQRT t) relationships for water-repellent and nearly wettable states of the soil. Water drop penetration time (WDPT) test was used as the second method of estimating the persistence of SWR. The above-mentioned methods were used for assessing the extent and persistence of SWR in various soils in Germany, Hungary, Israel, Italy, Slovakia and Spain.

Key words

Soil water repellency, repellency index, water drop penetration time, water repellency cessation time.

New radial flow setup to derive soil hydraulic conductivity – Case study with calcium-polygalacturonic acid as a model for plant root mucilage

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Abstract

Roots are hypothesized to alter rhizosphere hydraulic properties by release of mucilage. This mechanism is expected to have strong implications for root water uptake under drought conditions. Direct measurement of rhizosphere hydraulic properties is hindered by the dynamic nature of the components involved; root hydraulics change with ontology; mucilage production, composition and diffusion are not constant; soil water content changes.

An experimental approach was developed which enables to simultaneously measure hydraulic conductivity and water retention curve around artificial roots covered with mucilage or modified model substances mimicking individual properties of mucilage. The methods consist in extracting water at constant suction using a suction cup covered with mucilage or analogues and recording the soil matric potential and the outflow. The system accounts for the radial geometry of root water uptake. To determine soil hydraulic conductivity we inversely fitted the outflow curves and soil matric potential by solving the Richards' equation in radial coordinates. Verification was done by measuring hydraulic properties of a sandy soil saturated with distilled water and comparison of results with classical evaporation method. Furthermore sandy soil was amended with increasing amounts of calcium-polygalacturonic acid gel (Ca-PGA) to mimic viscose nature of mucilage.

Experiments show a decrease in soil hydraulic conductivity in orders of magnitudes by increasing Ca-PGA concentration in the wet range; the reverse is observed in the dry range, when Ca-PGA increases the unsaturated conductivity. Contrary to many mucilage observations, Ca-PGA seems not to change water retention curve, which suggests that the gel stays in the mobile phase. Hence Ca-PGA is a suitable model to mimic influence of mucilage viscosity, but disregards other mucilage properties. In the future the setup will be used to study the local distribution of natural root mucilage around the artificial root.

Key words

Mucilage, rhizosphere, hydraulic properties, root water uptake.

Non-invasive analysis of root-soil interaction using complementary imaging approaches

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Abstract

Plant roots are known to modify physical, chemical and biological properties of the rhizosphere, thereby, altering conditions for water and nutrient uptake. We aim to capture the dynamic processes occurring at the soil-root interface *in situ.*

A combination of neutron (NI), magnetic resonance (MRI) and micro-focus X-ray tomography (CT) is applied to monitor the rhizosphere of young plants grown in sandy soil in cylindrical containers (Ø 3 cm). A novel transportable low field MRI system is operated directly at the neutron facility allowing for combined measurements of the very same sample capturing the same hydro-physiological state.

The combination of NI, MRI and CT provides three-dimensional access to the root system in respect to structure and hydraulics of the rhizosphere. The high spatial resolution of neutron imaging and its sensitivity for water is exploited to analyze the 3D architecture of the root system and the three-dimensional water content in the immediate root vicinity and bulk soil. MRI can yield complementary information about the mobility of water, which can be bound in small pores or in the polymeric network of root exudates (mucilage layer). Additional CT measurements provide information on the pore structure of soil, which is affected by the mechanical interaction of roots and soil, e.g. soil compaction or formation of cracks and macropores.

We co-register the NT, MRI and CT data to integrate the complementary information into an aligned 3D data set. This allows, e.g., for co-localization of compacted soil regions or cracks with the specific local soil hydraulics, which is needed to distinguish the contribution of root exudation from mechanical impacts when interpreting altered hydraulic properties of the rhizosphere. Differences between rhizosphere and bulk soil can be detected and interpreted in terms of root growth, root exudation, and root water uptake. Thus, we demonstrate that such a multi-imaging approach can be used as powerful tool contributing to a more comprehensive picture of the rhizosphere.

Key words

Dynamics of soil-root interface, neutron, magnetic resonance, micro-focus X-ray tomography, soil water content and mobility, soil pore structure

Soil CO_2 fluxes affected by seasonal changes in soil water repellency

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Abstract

Soil water repellency (SWR) is a seasonally variable phenomenon controlled by moisture and simultaneously regulating the infiltration, distribution and conductivity of water in the soil. Water availability is vital for biological processes in soil including the decomposition of soil organic matter by microorganisms. The microbial respiration is the main contributor to the CO_2 fluxes from soil therefore it has been hypothesised that under water repellent conditions the microbial activity decreases due to water stress resulting in lower CO_2 fluxes from soil. The hypothesis has been tested under field conditions by monitoring CO_2 fluxes, soil water repellency, moisture and temperature for 3 consecutive years at 2 sites (grassland and pine forest) in East Anglia, UK.

High seasonal variability in soil water repellency have been observed at both investigated sites with extreme (WDPT >3600s) to moderate (WDPT 60-3600s) SWR persisting for most of summer and early autumn periods. On most sampling occasions the severity of water repellency was variable; only on few instances soil had uniform WDPT values for all subsamples. The high spatial variability in WDPT values linked closely with higher deviations in soil water contents.

The response of CO_2 fluxes to seasonal changes in soil temperature, moisture content and SWR was evident with temperature affecting the CO_2 emissions to great extent. Unexpected results have been observed for the CO_2 fluxes under SWR conditions. SWR indeed reduced CO_2 fluxes but only under uniform extremely water repellent state, while under variable severity of SWR the overall CO_2 fluxes have significantly increased.

The main conclusion of the study is that the spatial variability of SWR could enhance the microbial activity in the 'hot-spots' leading to overall higher CO_2 fluxes from soils.

Key words

Soil water repellency, CO_2 flux, hydrophobicity, preferential flow, gas exchange.

Sub-session 3-2. Hydrology of vegetation-soil complex

Conveners:

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Application of minidisk infiltrometer to estimate soil water repellency

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Abstract

Soil water repellency (SWR) reduces affinity of soils to water resulting in detrimental implication for plants growth as well as for hydrological processes. During the last decades, it has become clear that SWR is much more widespread than formerly thought, having been reported for a wide variety of soils, land uses and climatic conditions.

The repellency index (RI), based on soil-water to soil-ethanol sorptivity ratio, was proposed to characterize subcritical SWR that is the situation where a low degree of repellency impedes infiltration but does not prevent it. The minidisk infiltrometer allows adequate field assessment of RI inherently scaled to account for soil physical properties other than hydrophobicity (e.g., the volume, connectivity and the geometry of pores) that directly influence the hydrological processes. There are however some issues that still need consideration. For example, use of a fixed time for both water and ethanol sorptivity estimation may lead to inaccurate RI values given that water infiltration could be negligible whereas ethanol sorptivity could be overestimated due to influence of gravity and lateral diffusion that rapidly come into play when the infiltration process is very fast. Moreover, water and ethanol sorptivity values need to be determined at different infiltration sites thus implying that a large number of replicated runs should be carried out to obtain a reliable estimate of RI for a given area.

Minidisk infiltrometer tests, conducted under different initial soil moisture and management conditions in the experimental sites of Ciavolo, Trapani (Italy) and Javea, Alicante (East Spain), were used to investigate the best applicative procedure to estimate RI. In particular, different techniques to estimate the water, S_w, and ethanol, S_e, sorptivities were compared including i) a fixed 1-min time interval, ii) the slope of early-time 1D infiltration equation and iii) the two-term transient 3D infiltration equation that explicitly accounts for the effects of gravity and lateral expansion. According to Pekárová et al. (2015), the combination of all the ethanol and water sorptivities was used to calculate an aggregated repellency index, RI_a, that accounts for the influence of spatial variability. Alternatively, the plot of the water cumulative infiltration vs. square root of time, exhibiting a clear "hockey-stick-like" shape, was used to estimate a single-test repellency index, RI^*, that overcomes the limitations of the traditional approach given that information on both the hydrophobic and the wettable states of soil are gathered from a unique infiltration test.

The mean RI values were affected by the technique used to estimate S_w and S_e. In particular, the choice of a fixed time interval lead to overestimation of RI up to a factor of 3.2 as compared with the other techniques. The RI_a yielded unbiased estimations of the mean RI values and also allowed to quantify the variability of SWR within a given area. A statistically significant relationship was found between RI^* and RI but also between RI^* and the water retention cessation time, that is the time hydrophobic turns into wettable soil, thus indicating that RI^* is potentially able detect both the degree and the persistence of SWR.

Key words
Infiltration, soil water repellency, minidisk infiltrometer, repellency index.

References:
Pekárová P., Pekár J., Lichner Ľ. 2015. A new method for estimating soil water repellency index. Biologia, 70 (11):1450-1455.

New insights of sediment connectivity and vegetation in contrasting Mediterranean catchments: an essential ecogeomorphological framework

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Abstract

Soil-plant interactions are one of the most interesting challenges to let us understand the complex relationship between the biotic and abiotic components of the ecosystems. Connectivity, defined as the transfer of matter between two different landscape compartments, can be used as a synthetic approach linking ecology, hydrology and geomorphology. Little research explicitly recognizes the different scales over which hydrological connections take place and its relationship with plant communities' behaviour. New technologies and methodologies with improved spatial and temporal resolution represent a good opportunity to monitor the vegetation evolution as well as the erosion and transport processes across different spatial and temporal scales. The remote sensing approaches on geosciences research has seen during the last two decades a revolution in topographic data measurement, with both a considerable increase in the rate at which it is possible to acquire precise, three-dimensional terrain data and the simplicity with which related methods can be applied. In conjunction with remote sensing technologies, there is a possibility to develop hybrid approaches using developments in a range of technologies together to achieve a better approximation of processes. Therefore, geomorphological models that explicitly include biotic effects are necessary to explore how intrinsically small-scale biotic processes can influence the form of entire landscapes, and to determine whether these processes create a distinctive topography. A previous survey developed by the research team showed a local significant relationship between the sediment connectivity index and the plant vigour through the Blue Normalized Vegetation Index (BNDVI) using high-resolution imagery obtained from an Unmanned Aerial Vehicle (UAV) in a micro-catchment. We pretend to up-scale this relationship using satellite imagery from a range of contrasting Mediterranean catchments as typical examples of drylands ecosystems. The utility of this methodology to study the local relationship between sediment connectivity and vegetation patterns will be further discussed for the assessment of ecosystem dynamics and management.

Key words

Ecogeomorphology, soil-plant interactions, plant community, dryland ecosystems.

Concepts, applications, and opportunities of biohydrology in turfgrass ecosystems

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Abstract

Biohydrology encompasses cross-disciplinary scientific inquiry in the areas of ecology and the environment, hydrology, biology, plant and soil sciences, and more. Turfgrass science is an excellent example of the complex role of plants and soils in biohydrological interactions. Turfgrass is a principal component in lawns and landscapes, parks and recreation, conservation land and roadsides, athletic pitches and golf courses, sod farms, and more. In turfgrass ecosystems, the complex interactions of soil biological, chemical, and physical properties occur at the spatial and temporal scale. Biohydrology research in turfgrass science includes investigations of water management and water conservation, water quality, irrigation and the use of soil surfactants to improve water use efficiency, soil water repellency and the use of soil surfactants to ameliorate soil hydrophobicity, soil moisture and environmental monitoring, pest management, plant ecology, plant pathology, plant physiology, the role of plant nutrition and biostimulants on phytobiomes, and sustainability. Managed turfgrass ecosystems are not evaluated in terms of yield like agricultural crops, rather qualitative and quantitative measurements are used to determine aesthetic value, function, and performance. Results of biohydrology research of turfgrass ecosystems have contributed greatly to fundamental scientific knowledge of turfgrass science, which therefore has translated to sustainable turfgrass management solutions for the practitioner.

Key words

Sustainable, turf, turfgrass.

Drought enhances net CO_2 release via vadose zone ventilation in a semiarid grassland of southern Spain

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Abstract

Recent research has highlighted the important role of arid and semiarid ecosystems in the global carbon (C) cycle. However, investigation of the biophysical processes involved is still necessary in order to fully understand how drylands behave and to determine the main factors affecting their C balance. In the present study, we explore the potential biological and abiotic processes that may compose the net CO_2 exchange in a semiarid grassland in SE Spain by means of eddy covariance measurements registered over six hydrological years (2009-2015). Results point out the great importance of subterranean ventilation, an advective transport process responsible for net CO_2 release from the vadose zone to the atmosphere, especially during drought periods and under high-turbulence conditions. Accordingly, extreme annual CO_2 release was measured over the whole study period, on average 230 g C m^{-2} $year^{-1}$, which was very unlikely to correspond to variations of *in situ* organic C pools given the low concurrent biological activity. Additionally, contrary as expected, CO_2 molar fraction within the vadose zone reached its maximum during the dry season at 1.5 m depth below the surface, and showed sustained high values at 0.15 m depth. Therefore, we hypothesize, based on published literature, that potential origins of the released CO_2 can be (i) geological CO_2 degassing or (ii) subterranean translocation of CO_2 in both gaseous and aqueous phases. However, future research is needed in order to understand how CO_2 transport and production processes interact and modulate the C balance of semiarid and arid regions through the interaction between atmosphere, biosphere, pedosphere, vadose and saturation zones. Overall, the present study exposes how subterranean ventilation and hydrogeochemistry can improve the interpretation of the terrestrial C cycle and how it will be perturbed by climate change.

Key words

Net CO_2 flux, drylands, advective transport, eddy covariance, non-local CO_2 source, vadose zone, pressure pumping.

Application of soil wetting agents with urea fertilizer increases plant uptake of nitrogen and reduces nitrogen leaching

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Abstract

Increasing nitrogen (N) plant uptake efficiency may result in less nitrogen susceptible to leaching and potential contamination in to surrounding environments as well as reduced N inputs needed. Soil wetting agents have been previously documented to increase water infiltration and enhance water uniformity throughout the soil profile. Applying a wetting agent along with a fertilizer may assist in more fertilizer available to the plant rootzone. To investigate this theory, common bermudagrass pelts were trimmed and placed on leaching columns filled with one of three soils (sand, sandy loam and a sandy clay loam). Once pelts were established, ^{15}N labeled urea was applied with one of three wetting agent treatments (NONE = no wetting agent, just water, SWA1 = D-Glucopyranose, oligomeric, decyl octyl glycoside, and SWA2 = 10% an oleic acid esters of coblock polymers). An unfertilized control irrigated with water for determining background ^{15}N was also replicated in each soil. Each treatment combination was replicated five times and the greenhouse experiment was repeated. Grass quality and density, leachate volume, and volumetric water content were determined over a 28d period following application. At experiment termination ^{15}N in soil (%RFN), plant (% UFN) and leachate were determined and used to develop a ^{15}N mass balance. The split plot repeated measure design was tested using a two-way ANOVA with main effects and interactions tested at $P = 0.05$. Experiment was not found as a significant main effect and thus data was pooled over the two experiments. Soil was found to be a significant main effect and thus results are discussed for each soil separately. On six of the 12 measurement events the sandy loam soil treated with the SWA2 had greater volumetric water content than SWA1, which was greater than NONE. This trend was also found in the sandy clay loam for five of the 12 measurement events. Treatment differences were less apparent in the sand soil. Bermudagrass grown on the sandy loam and sandy clay loam soils had greater %UFN when either SWA was applied compared to bermudagrass receiving the labeled urea alone. SWA did not influence %UFN in the sand soil. Regardless of soil texture, similar %RFN in the soil was determined for all SWA treatments. Applying a surfactant with urea can increase bermudagrass N uptake efficiency and reduce potential N leaching.

Key words

Soil wetting agent, nitrogen isotope, nitrogen uptake efficiency, ^{15}N, bermudagrass.

Electrical capacitance measurement for monitoring root growth and activity in soil

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Abstract

Measurement of electrical capacitance (EC) is a potential method to assess root system size *in situ*. The EC detected in plant–soil systems is proportional to the actual uptake activity of the root system, indicating plant responses to the environment. The influence of various environmental factors on root growth was investigated in pot experiments. We showed *in situ* the growth-impeding effect of total herbicide treatment, drought stress and weed competition in maize. We found the method suitable for detecting the enhanced rhizosphere activity of maize colonized by arbuscular mycorrhizal fungi. In this case, the increased host's root EC was due to the higher water and nutrient uptake activity of root associated with external hyphae. The technique was successfully applied for monitoring the cultivar-specific differences and the phenological changes in root water uptake using several crops. In our research we examine possibilities for developing the method, focusing mainly on selection of the efficient measuring current frequency and significance of the detectable capacitive loss to improve the authenticity of measurement data. A comprehensive investigation is in progress currently to quantify the relationship between the water content of growth medium and EC detected. This awareness offers us an opportunity to apply the method for continuous monitoring of root activity under real field conditions (in soil with changing moisture content). The method may be of interest for future applications; it can partially substitute the intrusive and time-consuming techniques, or may be combined with other physiological investigation methods. It can play a role in applied agricultural research including breeding programs aiming to produce crop cultivars with improved performance under stressed conditions (*e.g.* drought or nutrient limitation), or in detection of plant responses to changing environment. Indicating the plant status, EC detects soil hydrology or soil environment in a wider scale. Mitigation of the influence of some external factors affecting capacitance measurements is an important objective of our future research.

Key words

Environmental stress, *in situ* root investigation, plant response, rhizosphere activity, root electrical capacitance.

Effects of vegetation at different succession stages on soil properties and water flow in sandy soil

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Abstract

Vegetation succession is the evolution of plant communities at a site over time from pioneer species to climax vegetation. At each stage of the succession the vegetation alters the soil and microclimate, allowing the establishment of another group of species. The objective of this study was to quantify the effects of vegetation at different succession stages on soil properties and water flow in sandy soil. The effects of vegetation at different succession stages on soil properties and water flow were assessed in sandy soil at 3 experimental sites near Sekule village (southwest Slovakia). Site S1 was a pioneer site dominated by mosses, site S2 was an early successional stage with a thin stand of grasses, and site S3 was an early successional stage (more advanced compared to the previous), richer in species, with a denser stand of grasses.

The persistence of water repellency was measured using the water drop penetration time (WDPT) test. Field measurements of infiltration were performed using a minidisk infiltrometer under a negative tension $h_0 = -2$ cm, and the the repellency index RI was estimated from ethanol (S_e) and water (S_w) sorptivity: $RI = 1.95 \times S_e / S_w$. Infiltration experiments were undertaken at three 100 cm × 100 cm plots (one plot per site). In each of these plots, the volumetric water content was measured in four steel access tubes using the neutron moisture meter with Am-Be probe before and after application of water.

It was found that vegetation at different succession stages affected soil properties and water flow in sandy soil, but the order of some changes was different from the order of succession stages. WDPT increased with the organic carbon content accumulated during vegetation succession (i.e., S1 < S2 < S3). Water sorptivity and hydraulic conductivity decreased in the order: S3 > S1 > S2, but repellency index decreased in the order of S2 > S1 > S3. Water penetration depth increased in the order: S2 < S1 = S3.

Key words

Sandy soil, vegetation succession, soil properties, water flow, water repellency.

Session 3: Contributions presented as posters

Influence of meteorological characteristics on the interception process in living and dead Norway spruce stand

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Abstract

The paper analyzed the interception losses during individual rainfall events in living and dead spruce stand. Experimental dates were recorded at the research plot Červenec in the Western Tatras in altitude of 1420 m a.s.l. during the growing seasons 2013 and 2014. The precipitations were observed simultaneously under the living and standing dead spruces stand (net precipitation) and in open area (with diameter of 1-2 tree heights, gross precipitation). Branches of dead trees with subsided needles were partly covered with lichen *Pseudevernia furfuracea*. For recording of net precipitation were used automatic rain gauges MetOne 370 with a modified receiving area of 4000 cm^2. Rainfall events for further analysis were divided in two units; those which were affected by occult/fog precipitation and without their presence. Mean interception loss during rainfall events without the expected occurrence of occult precipitation (mean gross precipitation was 5.7 mm) in living stand reached 2.82 millimeters (52.2%) and in dead stand 2.18 millimeters (40.4%). In the case of interaction of occult precipitation (mean gross precipitation was 8.7 mm) mean interception loss in the living stand reached 0.64 mm (7.2%) and in dead stand 2.71 millimeters (31.2%). Therefore the dead spruce stand reflected the lower interception loss as well as the lower income of occult precipitation. Similarly, we investigated the correlation between interception losses and meteorological characteristics during rainfall events. The most important factor influencing interception losses was variability of gross precipitation. It explains 74.5% and 67.1% of interception loss variability in living and dead stand during rainfall events without interaction of occult precipitation. The observations confirmed the increase of net precipitation in case of rainfall events without presumed occult precipitation and their decrease during rainfall events with interaction of occult precipitation due to declining process. Statistically significant correlation between interception losses and maximal and average intensity of rainfall events was recorded in the stands during rainfall events without interaction of occult precipitation. From other meteorological characteristics we observed the significant correlation with rainfall duration (with and without interaction of occult precipitation) and air temperature in the beginning of rainfall (only events with interaction of occult precipitation). With the increase of temperature decrease the interception loss in stands. The contribution is focused on complexity of prediction of interception process changes due to declining the climax spruce stands in mountain areas.

Key words

Interception loss, net and gross precipitation, forest declining.

Plant species determine the runoff rates in the Massis del Caroig shrubland

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Abstract

The Scrublands of the Mediterranean are characterised by high plant diversity. Scrubs can be successfully used for restoration of fire-affected land, mine spoils, abandoned agriculture fields, or quarries. The decision to which species must be use for afforestation does not take into account basic hydrological information, which is definitive for the success of the restoration. The objective of this research is to characterise the runoff generated under different plant species in small plots of 1 m^2 under natural rainfall. Twenty-four plots (6 species x 4 plots were installed in the El Teularet Soil Erosion Experimental Station from 2011 till 2015. Runoff was collected in 25 l deposits. The species selected were: *Pistacea lentiscus, Quercus Coccifera, Ulex parviflorus, Rosmarinus officinalis, Pinus halepensis and Quercus coccifera*. The results show that the runoff coefficient was higher for the *Pinus halepensis* plots (8.23) meanwhile was almost null for *Quercus ilex* and *Quercus coccifera* (1.21 and 1.32 %, respectively) and intermediate for *Pistacea lentiscus* (2.76 %) and slightly higher for *Rosmarinus officinalis* (5.76 %) and *Ulex parviflorus* (4.87 %).

Key words

Plants, soil, runoff, scrubland, plots.

Acknowledgements: The research leading to these results has received funding from the European Union Seventh Framework Programme (*FP7/2007-2013*) under *grant agreement* n° 603498 (RECARE project) and the CGL2013- 47862-C2-1-R national research project.

Soil water repellency under different plant species in the Serra de Enguera, Eastern Spain

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Abstract

Water repellency is highly determined by the type and amount of organic matter. The source of organic matter is the plants, and they show different compositions and as a consequence the soil water repellency can be different. Within the Mediterranean scrublands there is a contrasted response due to the plant species. The objective of this paper is to research the soil water repelency under different plant species. *Pistacea lentiscus, Quercus Coccifera, Ulex parviflorus, Rosmarinus officinalis, Pinus halepensis, Cistus albidus, Thymus vulgaris, Juniperus oxicedrus and* Quercus coccifera *were selected*. Measurements by means of the Water Drop Penetration Time demonstrated that the water repellency is higher in *Quercus ilex* and *Pinus halepensis*, meanwhile *Cistus albidus* and *Thymus vulgaris* show lower water repellency. The water repellency was mainly found in summer, when the soil moisture was very low.

Key words

Plants, soil, repellency, Mediterranean, WDPT.

Acknowledgements: The research leading to these results has received funding from the European Union Seventh Framework Programme (*FP7/2007-2013*) under *grant agreement* n° 603498 (RECARE project) and the CGL2013- 47862-C2-1-R national research project.

The use of chipped pruned branches to control soil and water losses in citrus plantations in the Canyoles river watershed

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Abstract

Citrus plantations under chemical management show high erosion rates due to the lack of vegetation cover and compacted soils. The pruned branches can act as a soil erosion and runoff control mulch. In order to determine the amount of cover that is necessary to reduce the non-sustainable soil erosion rates and shorten runoff discharge a laboratory experiments was carried out in 0.5 m^2 plots under 46.2 mm h^{-1} rainfall intensities for one hour. Eight chipped branch covers were selected: 0, 5, 10, 15, 25, 50, 75 and 100 %; and six experiments were carried out with each cover. The results showed that erosion rates were 10.23 Mg ha^{-1} h^{-1} on bare soils, that a 5% cover of chipped branches reduced the soil losses to 7.55 Mg ha^{-1} h^{-1}, a 10% cover resulted in 5.49 Mg ha^{-1} h^{-1} and the 15% cover 4.22 Mg ha^{-1} h^{-1}. The 25 % cover reduced soil losses to 2.43 Mg ha^{-1} h^{-1} and 50 % cover to 2.09 Mg ha^{-1} h^{-1}. The 75 and 100 % cover of chipped branches reduced soil losses to 1.09 Mg ha^{-1} h^{-1} and 0.99 Mg ha^{-1} h^{-1}, respectively in average values. The average runoff coefficients were reduced from 67.4 % on the bare plots to 57.3, 51.98, 47.5, 45.8, 44.6, 42.4, and 40.3 % for the 5, 10, 15, 25, 50, 75 and 100 % covers, respectively. There was a one order of magnitude reduction in the sediment yield due to the mulch effect of the chipped branches.

Key words

Mulch, erosion, citrus, Spain, runoff, chipped branches.

Acknowledgements: The research leading to these results received funding from the European Union Seventh Framework Programme (*FP7/2007-2013*) under *grant agreement* n° 603498 (RECARE project).

The use of straw mulches to reduce the soil losses in citrus plantations

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Abstract

Chemically managed sloping citrus plantations result in high erosion rates. The use of catch crops or weeds is efficient but is usually rejected as a management option by farmers due to the tradition to avoid other plants than the crop in the orchards. The use of straw mulch is more welcomed by farmers, but little is known about the impact of straw and the cover (doses) that should be applied. A laboratory research was conducted under different straw mulch covers to reduce soil and water losses in 0.5 m^2 plots under 43 mm h^{-1} rainfall intensities during one hour. Seven straw covers were selected: 0, 5, 15, 25, 50, 75 and 100 % and five experiments were carried out at each cover. The results show that the erosion rates were 9.43 Mg ha^{-1} y^{-1} on bare soils, and that a cover of 5 % reduced the soil losses to 5.34 Mg ha^{-1} y^{-1}, and the cover of 15 % to 3.23 Mg ha^{-1} y^{-1}. The 25 % cover contributed to 1.54 Mg ha^{-1} y^{-1} and 50 % cover to 1.05 Mg ha^{-1} y^{-1}. The cover of 75 and 100 % cover reduced the soil losses to 0.89 Mg ha^{-1} y^{-1} and 0.76 Mg ha^{-1} y^{-1}, respectively. The results show that a cover of 25 % reduces the soil losses by one order of magnitude at the scale of 1 m length. Increasing the straw cover increase the expenses but does not result in a relevant reduction in soil losses.

Key words

Citrus, erosion, straw, mulches, management.

Acknowledgements: The research leading to these results has received funding from the European Union Seventh Framework Programme (*FP7/2007-2013*) under *grant agreement* n° 603498 (RECARE project).

Microorganisms and physical-chemical properties of summer snow patches in Slovak mountains

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Abstract

Snow cover plays an important role in the climate, hydrological and ecological systems not only in the polar area but also in other regions. Despite the fact that it is one of extremely cold environment it provides space for development microbial community. The High Tatras Mts., the highest mountains of the Carpathians, were the most studied mountain area in the Europe in terms of cryoflora. Currently in Slovakia absent actual knowledge about microorganisms linked to the snow and their living conditions. The aim of the study is investigation of the occurrence and environment of snow microbiota in high mountains of Slovakia (High Tatras, Low Tatras, Veľká Fatra Mts., Malá Fatra Mts.). In samples of taken snow dominated cf. *Chloromonas nivalis* which is considered as cosmopolitan species. We recorded only occasionally the colourful surface of snow patches caused by the snow algae. Similarly, in snow samples we also identified individuals of cyanobacteria, microscopic fungi, ciliates, rotifer and tardigrade.

Recorded daily running of air temperature above the snow patches with the appearance of sub-zero temperatures in late summer and high intensity of PAR can cause stress on the development of microbiota in the snow. The pH values were slightly acidified, in some cases neutral. The conductivity of water from melted snow had high coefficient of variation. We recorded values characteristic for distilled water until values 160 $\mu S.cm^{-1}$. Chemical analysis determined a significant content of $N\text{-}NO_3$, $N\text{-}NH_4$ a $P\text{-}PO_4$. We explained it by the possible leach out of organic matter stored on the snow surface mixed with water from melted snow. This paper yield information about occurrence of cryoseston in the mountains of Slovakia, but also there is another researcher challenges related to examine the microbial community living in one of the most extreme conditions on the Earth.

Key words

Cryoseston, snow algae, snow patches.

Quantification of soil macropores under alpine vegetation using computed tomography in the Qinghai Lake watershed, NE Qinghai-Tibet Plateau

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Abstract

The importance of soil macropores as preferential pathways for water, air, and chemical movement in soils has long been recognized. However, studies concerning macropores of soils under alpine vegetation remain scarce. The objective of this study was to quantify the architecture of soils beneath Alpine *Kobresia* meadow, *Achnatherum splendens* steppe, and *Potentilla fruticosa* shrubs using computed tomography in the Qinghai Lake Watershed of northeastern Qinghai-Tibet Plateau. Nine soil cores (0–50 cm deep) were taken at three sites with three replicates. At each site, the three cores taken were scanned with a GE HISPEED FX/I Medical Scanner. The number of macropores, macroporosity, and macropore equivalent diameter within the 50-cm soil profile were interpreted from X-ray computed tomography, to analyze soil architecture. The results indicated that soils under *Achnatherum splendens* steppe and *P. fruticosa* shrubs had greater macroporosity, and developed deeper and longer macropores than those in the other vegetation types. For the Alpine *Kobresia* meadow, macropores were distributed mainly in the 0–100-mm soil layer, while they were distributed in the 0–200-mm soil layer for *A. splendens* steppe and in the 0–200-mm soil layer for *P. fruticosa* shrub. The large number of macropores found in the soil surface layer under Alpine *Kobresia* meadows can be attributed to "mattic epipedon". The large number of macropores found in soil under *A. splendens* steppe and *P. fruticosa* shrubs can be attributed to greater root development. Soil hydraulic conductivity was significantly greater for *A. splendens* steppe and *P. fruticosa* shrub (great macroporosity) than for Alpine *Kobresia* meadow (small macroporosity).

Key words

Alpine *Kobresia meadow, achnatherum splendens* steppe*, potentilla fruticosa* shrub*,* vegetation, soil architecture, macropore, root, mattic epipedon.

Water dynamics in the rhizosphere - a new model of coupled water uptake and mucilage exudation

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Abstract

The flow of water from soil to plant roots is affected by the narrow region of soil close to the roots, the so-called rhizosphere. The rhizosphere is influenced by mucilage, a polymeric gel exuded by roots that alters the hydraulic properties of the rhizosphere.

Here we present a model that accounts for: (a) an increase in equilibrium water retention curve caused by the water holding capacity of mucilage, (b) a reduction of hydraulic conductivity at a given water content due to the higher viscosity of mucilage and (c) the swelling and shrinking dynamics by decoupling water content and water potential and introducing a non-equilibrium water retention curve.

The model has been tested for mixtures of soil and mucilage and we applied it to simulate observations of previous experiments with real plants growing in soil that show evidences of altered hydraulic dynamics in the rhizosphere. Furthermore we present results about how the parameters of the model depend on soil texture and root age.

Finally we couple our hydraulic model to a diffusion model of mucilage into the soil. Opposed to classical solute transport models here the water flow in the rhizosphere is affected by the concentration distribution of mucilage.

Key words

Mucilage, root water uptake, hydraulic properties.

Evaluation of drought response of four coniferous species based on the analysis of their radial stem growth

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Abstract

The contribution deals with the dynamics of stem circumference changes and stem water deficit of four coniferous species: Scotch pine (*Pinus sylvestris* L.), Norway spruce (*Picea abies* Karst), European larch (*Larix decidua* Mill.) and Silver fir (*Abies alba* Mill.) during the growing season of the year 2015 and the drought period that occurred during the growing season. The individual tree species are located at four different parts of the Borová hora Arboretum (Zvolen valley, Slovakia) which has a character of uplands with altitudes from 290 m a.s.l. to 377 m a.s.l. The species originate from different regions of Slovakia (larch, fir), Ukraine (pine) and Russia (spruce, pine) characterised by different environmental conditions (climate, soil, bedrock). Stem circumference was continuously measured and recorded at 20 minute intervals with digital dendrometers DRL26 which were installed on five trees per species at the beginning of the growing season 2015. The air temperature average in the growing season of the year 2015 was extremely above-average compared to the long-term average (1961–1990). Although the precipitation total of the growing season was normal, we recorded significant intra-seasonal fluctuations of precipitation. We determined one drought period (39 days; from 10 June to 19 July 2015) when soil water potential fell below -1.0 MPa and which was bounded by days with heavier precipitation events.

The analysis of variance of the annual radial increments showed a significant effect of tree species on the annual stem circumference change. The regression analysis of the daily mean radial fluctuations in the drought period revealed that *P. sylvestris* and *L. decidua* reacted to the drought period by continuous stem contraction, whereas the stem circumferences of *N. spruce* and *A. alba* were slightly increasing during the drought.

Daily stem water deficit (ΔW) was extracted from the daily mean stem circumference changes. Pearson correlation statistics (r) was calculated between daily time series of environmental variables (global radiation, precipitation, relative air humidity, vapour pressure deficit, air and soil temperature, soil water potential) and ΔW for the period April–October and the drought period. During the drought period, ΔW of all species reached higher values and was more closely related to the environmental variables ($P<0.05$) than for the whole studied period. For all species, the highest correlation was found between soil water potential and stem water deficit. The results suggested that the origin of the individuals has a significant effect on their response to environmental conditions.

Key words

Conifers, stem water deficit, dendrometer, environmental variables.

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Transpiration and stem circumference changes affected by drought in mature beech stand (*Fagus sylvatica L.*) - irrigation experiment

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Abstract

Recurrent droughts, the severity and frequency of which is likely to be amplified by climate change, may adversely affect large tracts of temperate forests. The presented study addresses the ecophysiology of mature beech forest in Central Europe (Slovakia, 450 m a.s.l.) exposed to drought during the growing seasons of 2012–2014. Sap flow, stem circumference changes and increment of European beech (*Fagus sylvatica* L.) were measured in two contrasting treatments (drought vs. irrigation). We assessed the impact of atmospheric and soil drought on the growth and physiological performance of adult beech trees. Reduced water availability induced stem contraction and significantly limited the transpiration extrapolated using sap flow measurements. Trees stressed by drought conditions in years 2012 and 2013 showed remarkably lower values of morning tree water status (ΔW, morning net stem shrinkage) in comparison with irrigated group. This suggests: i) lower water potential of the stems' conducting hydraulic tissues, and ii) increased use of internally stored water to maintain daily transpiration. Morning ΔW showed close relationship with soil water potential in the non-irrigated trees (in 2012 and 2013). Statistical analysis showed that potential evapotranspiration, vapor pressure deficit and global radiation were the main drivers of sap flow variability in the irrigated group of trees. In the non-irrigated group, these explained less of the variability in sap flow than in the irrigated group of trees.

Key words

Drought, irrigation, European beech, stem circumference changes, sap flow.

The amount of dew condensed on small trees of European beech (*Fagus sylvatica L.*) and Norway spruce (*Picea abies (L.) Karst.*) in depend on micro-meteorological conditions

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Abstract

In conditions of the temperate climate of Central Europe is dew only a minor component of the water balance. Dew has a positive impact on the reduction of evapotranspiration of plants, especially in dry periods. However the dew has also negative influence for pathogens and pollutants because of creating a moist environment for them. The observation was recorded in mountain area Kremnické vrchy (840 m a.s.l.), we analyzed the measurements of dew quantities formed on five beech tree seedlings (FS) and spruce seedlings (PA) collaterally with control measurements on rosografe M35. Similarly, we measured the micro-meteorological parameters: air temperature, soil temperature, air humidity, evaporation, wind speed vertical profile 2 - 120 cm. Beech tree seedling leaf area was 0.0814 - 0.1998 m^2 and leaf area of spruce seedlings was 0.3058 - 0.6023 m^2. The amount of water from dew, attributable to the area of assimilation organs, represented 3-196 (FS) and 13-87 $g.m^2$ (PA) during night. The amount of dew 13-130 $g.m^2$ per night was measured by dew recorder. The amount of dew and its curve course significantly depended on real Miko-meteorological conditions (e.g temperature and humidity gradient, wind speed and cloud).

Key words

Dew, beech, spruce, microclimate, mountain forest, hydro-meteorological elements.

Drought impact on autumn phenological phases of selected tree species in the central part of Slovakia

Jana Škvareninová, Jaroslav Škvarenina, Miriam Váľková, Martin Bartík, Jaroslav Vido

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Abstract

The contribution presents the knowledge of the drought impact on the onset of leaf yellowing and leaf fall of selected tree species (*Quercus robur* L., *Fagus sylvatica* L., *Crataegus laevigata* (Poir.) DC.) at elevations between 290 and 320 m a.s.l. In the years from 2009 to 2015, we recorded 10% occurrence of the phenological phase on 10 trees of each tree species. From meteorological parameters we examined precipitation, number of tropical days, and their periods from June to August. We revealed distinct differences in temperature and precipitation between the years, which affected the onset of autumn phenophases. Based on the values of Thornthwaite moisture index and climatic water balance, the year 2014 was the wettest with the shortest periods of tropical days, which shifted leaf yellowing of all tree species to a later period. The year 2015 was the driest and warmest, and the yellowing of leaves of beech and hawthorn started by 6 to 12 days earlier than their 25-year-long average of this phenophase. Oak was the least sensitive to weather extremes, and had the lowest variation of this phenophase in the monitored period as well as of the long-term average. The largest variation of leaf fall was recorded for beech, and the lowest for hawthorn. This phenological phase reflects temperature and precipitation conditions in summer months, as well as the weather pattern in autumn after leaf yellowing. Wind and heavy rain can accelerate its onset. The onset of the phenophases of all tree species was observed later than their long-term averages, which can be a signal of climate changes at the studied site.

Key words

Drought, phenology, forest-tree species, Slovakia.

Metaproteomics of wettable and repellent grassland soils

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Abstract

Soil water repellency is a common phenomenon affecting the hydrological responses of many soil and land use types in different climates. This now recognised 'extreme' environment leads to decreased water infiltration, reduced vegetation cover, fertiliser run off and soil erosion. The fundamental (biological) causes of (bulk) soil repellency and its dynamic behaviour remain poorly understood.

We have applied soil metaproteomics, the systemic extraction and identification of proteins from a soil, to understand the biological (adaptive) processes and potential for bio-modification of mineral surfaces, which occur at the molecular level in soils switching between wettable and repellent states.

Extreme, moderate and sub-critical water-repellent UK silt-loam soils under permanent grass vegetation, including Park Grass at Rothamsted Research, were sampled below the root zone depth under wettable and repellent conditions. Soils were subjected to our new extraction methods for determining the specific ultrahydrophobic and total metaproteomes.

Comparative profiling of the total metaproteomes of wettable and repellent soils revealed similarities and dissimilarities in proteomes and microbial diversity, which have created a deeper understanding of soil biomolecular processes common and adaptive to soil moisture and to the severity of repellence.

Using our ultrahydrophobic extraction protocol, we have identified novel ultra-hydrophobic microbial proteins, which could be extracted from hydrophobic grassland soils with medium to low soil moisture levels, but were absent in the comparable wettable soils. These proteins have the potential to act as soil biomarkers for precision land management, especially in irrigation.

Key words

Soil water repellency, proteins, metaproteomics, bulk soil, microbial adaptation.

How to monitor drought in forest ecosystem using simple drought index

Jaroslav Vido[1], Katarína Střelcová[1], Paulína Nalevanková[1], Adriana Leštianska[1], Radoslav Kandrík[1], Alena Pástorová[1], Jaroslav Škvarenina[1], Tsegaye Tadesse[2]

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Abstract

The contribution presents relationship between the Standardised Precipitation Index (SPI) and physiological responses of individual trees in a beech stand using an example of an experimental plot in Bienska valley (Zvolen, Slovakia). SPI is a widely used tool for monitoring both short-term and long-term droughts, and for the assessments of drought impacts on agriculture. Due to the complex ecosystem bonds, monitoring of drought in forests often requires a sophisticated technological approach. The aim of the contribution was to correlate the SPI on the physiological responses of trees that were recorded during the performed physiological research (sap flow, and stem circumference increment) at the site in the growing seasons (May to September) of the years 2012–2014. The results revealed a relationship between the index and the physiological responses, although the problem with the impact of other environmental factors has also come up. The secondary correlation, in which soil water potential that significantly affects physiological responses of forest tree species was used as a dependent variable, showed a tighter relationship with the SPI. We found the highest correlation between the soil water potential and the values of SPI aggregated for five weeks. This indicates that the beech forest has a five week resistance to drought stress. The results also enable simple monitoring of the initiation of the drought stress by applying SPI for five weeks.

Key words

Drought, physiological responses, beech, standardised precipitation index, soil water potential.

SESSION 4

THE IMPACT OF FOREST FIRES ON HYDROLOGY

Conveners:

Jorge Mataix-Solera, Miguel Hernández University, Elche, Alicante, Spain

Matthias Boer, Western Sydney Univ., Richmond, Australia

Saskia Keesstra, Wageningen University, The Netherlands

Keynote lectures

Hydrologic response to fire of eucalypt forests in south-eastern Australia: effect of soils, climate and vegetation

Patrick Lane, Gary Sheridan, Petter Nyman, Phillip Noske, Christoph Langhans, Richard Benyon, Rene Van Der Sant

School of Ecosystem and Forest Sciences, The University of Melbourne, Australia

Abstract

Australian eucalypt forests have evolved with fire as an intrinsic part of their ecology. They are subject to fire regimes that produce frequent large scale intensive fire events, with several "meg-fires" in the past 15 years. In south-eastern Australia, the combination of this pyro-ecology and climate and soils have produced upland forests with highly contrasting eco-hydrologic responses to fire. The most striking example is the evapotranspiration/streamflow response from *Eucalyptus regnans* forests. These wet forest stands die when subject to moderate-severe fire, then regenerate at high density as single aged stands. A combination of high leaf area index and sapwood areas in the younger stands results in a significantly higher ET than mature or old-growth state. These younger stands may yield 25-50% less streamflow than the stands they replaced. Re re-establishment of hydrologic equilibrium takes several decades, depending on the age of the burnt stands. Conversely, drier mixed-species eucalypt stands are resistant to fire, with low mortality rates, and far more rapid return to hydrologic equilibrium (< 10 years). The changes to ET are far less in absolute terms, although recent research suggests there can be ET increases from moderate burns that leave a mix of canopy and epicormic leaves and a flush of understorey, resulting in transient, but higher, system LAI and water use. There is a trend toward a gradient of ET/streamflow response with rainfall gradient and topographic position.

In terms of surface runoff and erosion, recent experimental data suggests the opposite gradient occurs. Drier forest types have soil properties that act to produce runoff and erosion following fire at far greater rates than wetter forests, despite the lower rainfall. A combination of decreasing macroporosity and more strongly developed and persistent water repellency with increasing aridity appears to exert a significant influence on post-fire erosion, and even in erosion processes. Soils in wetter forests (eg. *E. regnans*) are deep, well-structured with high macroporosity and high infiltration rates, even when water repellency is present. Erosion rates can be elevated but channelized processes are rare, dampening erosion. In contrast, the drier forests soils are far more erodible and prone to rilling. These soils on steep slopes can produce debris flows, with >300 mapped after the 2009 Black Saturday fires.

Overlaying a 20 m grid of the Aridity Index suggests there are distinct associations between hydrologic response and the longterm balance of radiation and rainfall, as expressed in soil properties and the vegetation type and density.

Key words

Fire, eucalypts, erosion, eco-hydrology, aridity.

Erosion as affected by natural and managed vegetation recovery after wildfires in the western United States

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Abstract

The effects of climate change have increased the number, size, severity, and cost of wildfires globally, especially in the western U.S., Australia, and Eurasia regions where effects of climate oscillation and extreme climate events are intensifying drought conditions. Drought has escalated the number and severity of wildfires across rangeland, temperate, and boreal forest environments. Given the increasing numbers of people living in and adjacent to wildland areas, the risk to public safety, homes, roads, infrastructure, water quality, and valued natural resources from fire and secondary fire effects has also increased. Major advancements in our knowledge of post-fire assessment, risk analysis and rehabilitation treatment effectiveness have improved our ability to understand, predict and prepare for the consequences of post-fire effects. An assessment of fire effects on soils, together with local climate and watershed characteristics are used to identify the burned areas that are most prone to increased flooding and erosion. These assessments are often used to justify the installation of post-fire hillslope and road treatments, and timber salvage management. Vegetation recovery occurs naturally after wildfires which reduces erosion risk over time; however, various management decisions can alter the inherent recovery trend. Potential post-fire treatments include the application of various mulches to increase immediate ground cover to reduce erosion, seeding to increase vegetation, and timber harvest to gain economic benefit of the burnt timber—all of which can affect natural vegetation recovery. For example, burnt areas with mulch treatments had varying cover ratios of grasses, forbs, shrubs, and seedlings depending on the mulch treatment applied. Species richness and diversity were also affected. Although plant communities differed more in the first few post-fire years, the differences will likely persist for decades. Post-fire timber harvest is a secondary disturbance which increases erosion risk and delays vegetation recovery by one year or more. Drawing upon various studies of post-fire treatments for erosion, vegetation recovery and effects on erosion will be discussed as well as implications for post-fire management.

Key words

Wildfire, erosion, recovery, vegetation management.

Session 4: Contributions presented in oral form

Prescribed fires effects on physical-chemical properties and quantity of runoff and soil erosion in a Mediterranean forest

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Escuela Técnica Superior de Ingenieros Agrónomos y de Montes de Albacete, Universidad de Castilla La Mancha.

Abstract

Wildfires have an important influence in forest ecosystems. Contrary to high severity fire, which may have negative impacts on the ecosystems, low-severity fires induce small changes on soil properties. Thus and in order to reduce fire risk, low-severity prescribed fires have been widely used as a fuel reduction tool and silvicultural treatment in Mediterranean forest ecosystems. However, fire may alter microsite conditions and little is known about the impact of prescribed burning on the physical-chemical properties of runoff. In this study, we compared the effects of prescribed burning on physical-chemical properties and quantity of runoff and soil erosion during six months after a low severity prescribed fire applied in twelve 16 m^2 plot (6 burned plots and 6 control plots used for comparison) set up in the Lezuza forest (Albacete, central-eastern Spain). Physical-chemical properties and quantity of runoff and soil losses were monitored after each rainfall event (five rainfall events in total). Also, different forest stand characteristics (slope, tree density, basal area and shrub/herbal cover) affecting each plot were measured. Results showed that forest stand characteristics were very similar in all used plots. Also, physical-chemical runoff properties were highly modified after the prescribed fire, increasing water pH, carbonates, bicarbonates, total dissolved solids and organic matter content dissolved in water. Electrical conductivity, calcium, sodium, chloride and magnesium were not affected by prescribed fire. Soil losses were highly related to precipitation intensity and tree interception. Tree intercepted the rainfall and significantly reduced soil losses and also runoff quantity. In conclusion and after the first six-month experiment, the influence of prescribed fires on physical-chemical runoff properties should be taken into account for developing proper prescribed burnings guidelines.

Key words

Soil erosion, water quality, low intensity fires, runoff.

Effect of prescribed fires on different soil properties in a Mediterranean pine forest

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Abstract

The use of prescribed fire as a tool for reducing fuel accumulation in forest areas has become more important in the recent years. This is mainly due to their effectiveness, and low cost in comparison to other techniques, such as thinning or scrubbing. In this context, the objective of this work is to evaluate the effect of three prescribed fire in several soil properties (water repellency, infiltration, respiration, changes in texture, structure or nutrient content). For this purpose, we conducted prescribed fires in three areas: a mixed mass of *Pinus halepensis* and *P. Pinaster* located in Lezuza, province of Albacete, Spain, a mixed mass of *P. pinaster* with *P. nigra* located in El Pozuelo, and a pure mass of *P. nigra* in Beteta, the two last zones in province of Cuenca, Spain. In spite of low intensity of fire, we found differences in changes of texture, infiltration, water repellency and efflux, which were higher in the pure *P. nigra* forest. In general, tendencies pointed to an increase in water repellency and reduction of infiltration values mainly due to loss of organic matter and soil texture. Moreover, soil respiration decreased, indicating a loss of biological activity.

Key words

Low-intensity fires, infiltration, water repellency, soil respiration.

Session 4: Contributions presented as posters

The impact of ant mounts as a source of sediments and sink of runoff in recently fire affected scrublands in Eastern Spain

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Abstract

After forest fires soil erosion and runoff generation mechanism are accelerated. This is a consequence of the lack of vegetation cover, the combustion of the litter, and changes in the soil properties. After the fires there is still life. Flora and fauna recover. Ants easily survive to the forest fires in the nests, and after few hours they built new mounts and collect seeds. The effect of the ant mounts on soil erosion and runoff production is researched here in the Massís del Caroig (Eastern Spain) by means of rainfall simulation experiments in the field on 0.25 m^2 plots under 55.4 mm h^{-1} rainfall intensities during one hour to determine the changes in the detachment as a consequence of the fire and the ant burrowing and nest construction. We selected plots with ant mounts (10) and control plots without (10), in fire affected (10) and in the nearby non-fire affected land (10). The results show an average erosion rate of 1.23 Mg ha^{-1} y^{-1} on the fire-affected area, and 0.12 Mg ha^{-1} y^{-1} in the non-fire affected. The plots with ant mounts yield 3.55 Mg ha^{-1} y^{-1} on fire-affected soils and 1.87 Mg ha^{-1} y^{-1} in the vegetated ones. The runoff coefficient was 23.2 % in the fire-affected area, and 7.8 % in the non-fire affected sites. The plots with ant mounts yield 33.23 % and 55.34 % of the rainfall as runoff on fire-affected soils and in the vegetated ones, respectively. The results shows that the ant mounts activate the sediment delivery and increase the soil erodibility and they act also as a source of runoff due to the morphology of the nest.

Key words

Fire, ants, erosion, runoff, scrubland.

Acknowledgements: The research leading to these results has received funding from the European Union Seventh Framework Programme (*FP7/2007-2013*) under *grant agreement* n° 603498 (RECARE project) and the CGL2013- 47862-C2-1-R national research project.

Long-term runoff and soil yield after forest fires in the Massis del Caroig

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Abstract

Forest fires are recurrent in Mediterranean-Type Ecosystems and they accelerate the runoff and the soil erosion rates. Most of the research focussed on the changes after two years, or they are based in the comparison of the burn and non-burn sites. However, little is known about how this will evolve at long-term. In order to determine the long-term changes in soil and water losses in Mediterranean type ecosystems ten study sites were selected in the Canyoles River watershed on limestones with 0, 1, 2, 5, 10, 14, 25, 37, 51, >100 years after fire. Ten plots per study site (10 plots x 10 sites, 100 experiments) under simulated rainfall in the field on 0.6 m^2 plots under 46.6 mm h^{-1} rainfall intensities in summer 2014 show that the soil erosion is active in the first 2 years, and specially high during the year after the fire. The soil erosion rates measured were 0.54, 5.87, 3.23 Mg ha^{-1} h^{-1} for the 0, 1 and 2 years after the fire. The low erosion rates measured during the first year is due to the ash cover as mulch. The lack of vegetation cover (3 and 13 % in the first and second year after the fire) is the reason of the high erosion rates found. After five years the vegetation reached 40 % and the erosion rates dropped to 1.23 Mg ha^{-1} h^{-1}. The soil erosion rates were 0.88, 0.65, 0.43, 0.21, 0.12, 0.03 after 10, 14, 25, 37, 51 and 100 years after the forest fire in average values for 10 plots, respectively. The runoff rates follow the sequence of 12.2 %, 54.3 %, 32.0 %, 21.4 %, 15.3 %, 12.6 %, 8.3 %, 5.2 %, 4.3 %, 2.9 % respectively for 0, 1, 2, 5, 10, 14, 25, 37, 51, >100 years after fire. The vegetation cover was the main factor of the soil erosion control as it moved from 35 % in the area burnt 5 years before to 51 %, 60 %, 68%, 72 %, 83 % and 91 % respectively for the 10, 14, 25, 37, 51, >100 years after fire study sites. There is a clear reduction in the soil and water losses with the time since the fire, which is very efficient in the period between 5 and 10 years after the fire.

Key words

Erosion, runoff, plants, forest fires, mediterranean.

Acknowledgements: The research leading to these results has received funding from the European Union Seventh Framework Programme (*FP7/2007-2013*) under *grant agreement* n° 603498 (RECARE project) and the CGL2013- 47862-C2-1-R national research project.

Hydrological connectivity in a Mediterranean forest before and after a wildfire in South of Spain: modelling scenarios

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Abstract

Overland flow connectivity depends on the spatiotemporal interactions of hydrological and geomorphic processes as well as on the human footprint on the landscape. This study deals with the modelling of hydrological connectivity in a burned area with different levels of fire severity. Namely, the objectives are to i) characterize and ii) modelling the pre and post-fire scenarios, as well as iii) evaluate the effect of the vegetation changes due to the fire and the initial post-fire management practices (construction of new skid trails) on the magnitude and spatial pattern of connectivity. The study area corresponds to eight disconnected headwater sub-catchments that were totally or partially burned in 2014, 27 June. This area is located in the province of Malaga, South of Spain, and covers a total surface of 275 ha. The landscape is mainly mountainous, with very steep slopes and marble rocks, Mediterranean climate, and a land use of shrubs and pine forests (pre-fire scenario). Settlements appear at the bottom of the slopes. After the wildfire, land management was carried out in order to remove completely the burned trees and thus new skid trails were built. The different scenarios of linear landscape elements, vegetation cover, and modifications on the topography related to the construction of new trails were included in the simulations. The Connectivity Index was chosen to perform this metric at a spatial resolution of 5 x 5 meters. The analysis of the different spatial patterns and temporal changes was done considering the different levels of fire severity and changes in hydrological connectivity were also analysed at the outlet of each sub-catchment.

Key words

Hydrological connectivity, wildfire, connectivity index, modelling, scenarios.

Soil water retention curves and related properties two years after salvage logging treatments in a Mediterranean burnt forest

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Abstract

In Mediterranean areas, water availability for plants is the main limiting factor for ecosystem restoration after fire. Post-fire management can have a negative impact on the soils that in some cases is even more severe than the fire itself. Salvage logging (SL) is a common management technique in fire-affected areas, but carrying it out, by using heavy machinery, leads to a consequent increase in the vulnerability to erosion and soil degradation. We monitored some soil properties in an area affected by a big forest fire (>500 has) in July 2012. The study area is located in the "Sierra de Mariola Natural Park", Alicante (E Spain). The forest was composed mainly of *Pinus halepensis* trees with an understory of typical Mediterranean shrub species. The soil was classified as a Typic Xerorthent developed from Miocene marls. In February 2013, the SL treatment, comprising a complete extraction of the burnt wood using heavy machinery, was applied in a part of the affected forest. Plots for monitoring were installed and in a similar nearby area there was no treatment (control, C) for comparison. Soil samplings were done immediately after treatment and every 6 months. We found that all soil properties were negatively affected by SL treatment compared with C plots: a progressive decrease with time of soil organic matter content, microbial biomass, soil respiration, aggregate stability, water holding capacity and an increase in bulk density were observed. In May 2014, undisturbed soil cores (100 cm^3) from both treatments (C and SL) were taken in order to study water retention curves. Results showed differences between treatments, most likely due to differences in the pore size distribution of soils and the strong influence of parent material. The underlying marl rocks contain only very fine pores and thus they are "impermeable" once saturated with water. The water does not infiltrate into these rocks but flows down the surface and increases the erosion. The soil samples from SL treatments have higher content of coarse pores and thus they retain more water under wet conditions compared C samples where the humus horizon is preserved. But they have a lowered ability to retain water at high water tension in dry conditions. The soil samples from C plots showed the best properties. The soils have relatively stable structure and higher content of finer pores and thus the soil retains more water in dry conditions compared to the eroded soil at SL plots.

Key words

Forest fire, salvage logging, water retention curves, aggregate stability, soil quality.

Acknowledgements: We thank to the "Ministerio de Economía and Competitividad" of Spanish Government for finance the POSTFIRE project (CGL2013- 47862-C2-1-R) and Alcoi council.

Rainfall and wet and dry cycles effect on ash hydrophobicity: A laboratory experiment

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Abstract

Ash is the main soil protection in the immediate period after the fire. Fire severity has implications on the ash properties and consequently in their resistance to erosion, type and amount of nutrients release and water repellency since ash hydrological properties are strongly dependent on the type of vegetation and degree of combustion. It is assumed that ash produced at low fire severity are hydrophobic, occurring the opposite when the ash is produced at high severity. The objective of this work is to study the effects of rainfall and wet-dry cycles in ash hydrophobicity.

Litter from Oak (*Quercus robur*) and Spruce (*Picea abis*) were collected, cleaned with deionized water to remove the impurities and exposed during 2 hours to produce ash at 200 and 400 ^{0}C. An ash layer of 15 mm was spread on a water repellent soil (placed carefully in 24x32 cm diameter boxes). Boxes were placed at a 17% of inclination. After this task, a rainfall intensity of 55 mm/h for 40 minutes was applied. After the rainfall simulation, the plots were stored in an Oven at the temperature of 25 ^{0}C during four days, in order to identify the effects of wet and dry cycles. Ash hydrophobicity was measured previous to the first rainfall (PFR), after the first rainfall (AFR), before the second rainfall (BSR) and after the second rainfall (ASR).

The results showed that PFR, the ash produced by Oak at 200 ^{0}C was significantly more hydrophobic that the ash produced by Spruce at the same temperature. The opposite was observed at 400 ^{0}C. At 200 ^{0}C, the hydrophobicity of Oak ash AFR, BSR, and ASR was significantly higher than the ash produced by Spruce. This pattern was also identified at 400 ^{0}C. At 200 ^{0}C in Oak and Spruce ash, hydrophobicity decreased significantly AFR, increasing also significantly BSR. ASR ash hydrophobicity decreases significantly in relation to BSR in both species. At 400 ^{0}C, no significant differences were identified among the treatments in Oak ash. In relation to Spruce ash, the water repellency was significantly higher PFR in comparison to the other treatments. Finally, the hydrophobicity of ash produced at 200 ^{0}C was significantly higher than at 400 ^{0}C for Oak in all the experiments. In relation to Spruce ash, we identified the same pattern with the exception of ASR, were no significant differences were observed between temperatures.

Key words

Wet and dry cycles, ash, hydrophobicity, *Quercus robur, Picea abis*.

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The analysis of long term forest fire weather indices in National Park Slovak Paradise in relation to the risk of climate change

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Abstract

The territory of the National Park of Slovak Paradise is highly vulnerable to occurrence of forest fires. From our point of view, there are several reasons why this territory is susceptible to burn and so strongly vulnerable from the forest fire occurrence: e.g., limestone and karst relief, shallow soils, mostly coniferous forest stands, rain shadow of the High Tatras, etc. This contribution is focused on the detection of a climate change within the territory of Slovak Paradise National Park during the period of years 1970 – 2014. The objective of a study is to investigate the significance of a climate change progression trend measured by the values of particular fire weather indices (FWI) recorded in this experimental territory for the whole observed period. For the purposes of the analysis the following 3 FWIs describing the development of a fire occurrence danger here have been selected: the Angström index, the Nesterov ignition index and the Baumgartner index. The significance of assumed linear trends of a climate change progression described by each particular FWI was tested by means of the Student`s (t) test by using the significance levels of (α) = 0.05 and 0.01. To master the more thorough statistical analysis, the original scaling concerning all 3 FWI was changed. The values of 0, 1, 2, 3 and 4 instead of former values 1, 2, 3, 4 and 5 have been used. The null hypotheses concerning the observed differences between particular couples of $F_n(t)$ were investigated by using the Kolmogorov-Smirnov two-sample test. The results of the above described analysis have revealed a very significant (R_{xy} = 0.470744 and α = 0.01) trend of a climate change progression in the experimental territory, measured by the annual totals of days when the Angström FWI values approached degrees 4 and 5. As the best measure of the change concerning fire occurrence risk in the experimental area, here, again the $F_n(t)$ of the Angström FWI can be regarded. The significant increase of fire danger was detected, what obviously points out the significant change of a climate as well.

Key words

Forest fire, hydro-meteorological elements, forest fire weather indices.

SESSION 5

ROLE OF BIOGEOCHEMICAL INTERFACES IN BIOHYDROLOGY

Conveners:

Gabriele Schaumann, University of Koblenz-Landau, Landau, Germany

Jörg Bachmann, University of Hannover, Hannover, Germany

Keynote lectures

Characterization of intact biopore walls and aggregate coatings for describing inter-domain mass transfer during preferential flow in structured soils

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Abstract

Soil consists of a dynamic and hierarchical system of organic and inorganic constituents and organisms. Physical as well as biological activities result in soil aggregation or in the formation of biopores that are affecting the 3D pore structure of the soil. Preferential flow in structured soils has frequently been described as the process of rapid and preferential water and solute movement along soil macropores such as earthworm burrows, decayed root channels, and the network of inter-aggregate cracks. When bypassing the lower permeable soil matrix, the soil's filtering function is strongly reduced and preferentially transported chemicals can negatively impact ground and surface water quality.

Based on model analyses and observations, one key component for understanding preferential flow processes was the transfer of water and solutes between aggregates and inter-aggregate pores that controlled local non-equilibrium conditions during storms. This inter-domain mass transfer depends on the properties of biopore walls and crack coatings, which characterize the macropore-matrix interface. Properties at such interfaces can strongly differ from bulk soil properties with respect to texture, organic matter (OM), pore geometry, density, and porosity; and for each type of soil and structure, interface properties depend on soil parent material and soil management.

We studied intact surfaces of soil aggregates, biopores (i.e., decayed root channels, worm burrows), and coated cracks. With X-ray CT, a spatially-distributed bulk density increase around worm burrows was found. With infrared spectroscopy (in the diffuse reflectance mode), we found that the composition of organic matter (OM) of coatings differed from that of the matrix. Differences could be observed for the Bt horizons of Luvisols developed on loess and glacial till as parent materials, for crops and land use. Small-scale maps of the OM composition of coated aggregate surfaces and burrow walls revealed that the potential wettability and the sorption properties of the OM of coatings are spatially distributed even at the mm-scale. For major structural features such as burrow walls and coatings, droplet infiltration tests qualitatively confirmed wettability patterns predicted from OM composition. The local distribution of physical and chemical properties is important not only for predicting the movement of reactive solutes during preferential flow events. How to include these results in mass transfer coefficients of two-domain models remains a challenge.

Key Words

Preferential flow, mass transfer, local non-equilibrium, macropore-matrix interface, dual-porosity, dual-permeability.

Microbial 'hot spots' of pollutant degradation: Common themes of burrow walls and hyporrheic zones

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Abstract

Aromatic agrochemicals in terrestrial as well as micropollutants in aquatic environments are potentially hazardous for human health, impacting ecosystem services such as food safety and drinking water quality. Thus, a mechanistic understanding of pollutant removal from the environment is of concern. The degradation of aromatic pollutants often requires molecular oxygen and occurs primarily under oxic conditions by microbial catalysis when light is absent. Earthworms create large oxic surfaces in soils due to their burrowing activity. Oxic water flowing through stream sediments (in the hyporheic zone) likewise generates oxic surfaces in aquatic environments. Thus, the degradation potential of burrow wall and sediment material for aromatic model pollutants was assessed in microcosms. Microbial key players were identified by a combination of RNA and DNA stable isotope probing, quantitative PCR of functional gene markers, cultivation as well as isolation, and next generation sequencing. Diverse microbes were associated with pollutant degradation and novel functional genes encoding for enzymes putatively catalyzing pollutant transformations were identified. Interestingly, Sphingomonadaceae (Alphaproteobacteria) were key degraders of various model pollutants in burrow wall and sediment material, highlighting their role as widely distributed, metabolically versatile organisms suitable for bioremediation purposes.

Key Words

2,4-dichlorophenol, 4-chloro-2-methylphenoxyacetic acid, ibuprofen, tfdA, r/sdpa, cadA, earthworms, drilosphere, hyporheic zone.

Long-term effects of crop management on the structure of a silt loam soil in a cold temperate climate

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Abstract

The structure of soil pore space is intimately connected with soil organic carbon, which in turn is strongly affected by crop and soil management practices (e.g. tillage and crop rotations). Land use also affects soil pore structure through impacts on macro-faunal species that function as 'ecosystem engineers'. The objective of our study was to investigate the long-term effects of grass-clover leys on soil organic carbon, earthworm populations and the structure of a silt loam soil in a cold climate. The measurements were made in a long-term field trial established in 1956 at Offer in northern Sweden. This experiment includes four treatments with varying proportions of ley (1, 2, 3 or 5 years) in a 6-year forage-based rotation. We used X-ray tomography to quantify topsoil structural pore networks in the first year of arable cropping following the ley break, a few weeks after sowing in spring. Near-saturated infiltration was also measured as a proxy for soil structure in both topsoil and subsoil. Earthworm populations were quantified by both hand-digging and infiltration of mustard solution.

The treatments with a greater proportion of ley in the rotation had larger organic carbon contents, near-saturated hydraulic conductivity and earthworm biomass as well as smaller bulk densities and larger total porosities. In contrast, no treatment effects were found for the volume, size distribution, connectivity and heterogeneity of the X-ray imaged pore space. Topsoil structure is seasonally dynamic and it seems possible that significant effects of long-term cropping treatments on soil structure may have been found later in the season, as a result of the re-establishment of earthworm biopores after tillage. No effects of crop treatment on organic carbon content were found in the subsoil. Likewise, there were no treatment effects on subsoil infiltration capacity, which was also generally very small (averaging 5 mm h-1). No individuals of deep-burrowing earthworm species were found, while previous work also showed shallow rooting at this site, with almost all visible roots of spring barley confined to the uppermost 30 cm. We therefore conclude that the poorly developed subsoil structure at the site results from a lack of biological and physical structure-forming processes due to the combination of the silty soil texture and a harsh winter climate.

Key Words

Soil, structure, X-ray, land use, earthworms, crop rotation, cold climate.

Session 5: Contributions presented in oral form

A new method to enhance rhizosheath formation

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Abstract

The rhizosheath is defined as the soil that adheres to the roots by help of root hairs and mucilage. Rhizosheath maintain the contact between roots and soil improving water and nutrient uptake. Here we introduce: (1) a technique to quantify the formation of rhizosheath around the roots, and (2) a method to enhance the formation of rhizosheath around the roots. Additionally, we measured the relation between rhizosheath thickness and the carbon content and enzyme activities in the rhizosphere.

We grew 8 lupine plants in aluminum containers (28×30×1 cm) filled with a sandy soil. When plants were two weeks-old and the soil had a water content of 30%, we stopped the irrigation and let the plants dry soil to a water content of 4-5%. Thereafter, half of the plants were irrigated with water and the other half with water treated with rhizoligand, which is defined as an additive that has the ability to rewet the rhizosphere and to bind mucilage. The plants were let dry and were rewetted six times. At the end of the sixth cycle, when plants were 40 days old and soil had a water content of 4-5%, the containers were opened and the roots with their rhizosheath were gently collected. We imaged the excavated roots and associated rhizosheath using Winrhizo. By image analysis we quantified the thickness of the rhizosheath. We also determined the carbon content and enzyme activity in the rhizosheath.

The rhizosheaths of plants irrigated with the rhizoligand were 63% thicker than those of plants irrigated with water and they had a higher carbon content and enzyme activity. We hypothesized that the interaction between hydrophobic groups of mucilage and rhizoligands increased the degree of gelation in the network of mucilage. These interactions resulted in an increased mucilage viscosity that maintains mucilage close to the root. The high viscosity and consequent high concentration of mucilage close to the root increased the capacity of mucilage to binding the soil particle together and to the root surface. Also, we postulate that the higher viscosity of mucilage maintains root exudates close to the root, increasing the concentration of soil organic matter close to the root and microbial activity.

In summary, we introduced and tested the concept of rhizoligand, which is defined as an additive that binds the mucilage network and maintains it wet. The method increases rhizosheath formation as well soil organic matter and enzyme activity in the rhizosphere, and it has the potential to improve physical, chemical and biological rhizosphere properties.

Key words

Rhizosheath, enzyme activity, mucilage, soil organic matter.

The effect of pH modification on wetting kinetics of a naturally water repellent coniferous soil

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Abstract

Hydrophobic properties of organic matter can significantly affect soil water dynamics in the field. The causative agents and the underlying mechanisms responsible for the development of soil water repellency (SWR) are still under discussion. Various environmental factors control the appearance and degree of SWR. Besides water content and temperature, wetting of soil depends greatly on the physicochemical characteristics of soil surface which in turn depends on the pH. In this contribution, we proposed a mechanism for the change in SWR which followed the artificial change in soil pH. Wetting kinetics were studied by the time dependent sessile drop measurements (TISED) of the contact angle, the work of spreading and the drop base diameter at longer time and at control relative humidity. Artificial modification of pH strongly changed the wetting kinetics, suggesting maximum wetting resistance at control pH (3.60) and decreasing wetting resistance at lower and at higher pH. The enhancement of the wetting kinetics by artificial modification of soil pH can be attributed to the chemical modification in organic materials coating soil particles based on the magnitude of activation energy, associated with the spreading process, and the hydrophobic/hydrophilic functional groups ratio of treated soil samples measured by (MIR spectroscopy). The combined appearance of pH and temperature dependence on the wetting kinetics, as well as the involved compensation effect, are evidences that suggest acid and base catalyzed hydrolysis-condensation reactions as dominant processes responsible for the chemical nature of SWR.

Key words

Soil water repellency, time dependent sessile drop measurements, wetting kinetics, activation energy, catalyzed hydrolysis-condensation reactions.

Pore-scale mechanisms of water repellency in the rhizosphere

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Abstract

Roots are known to exude a large amount of organic compounds into the soil. One of these exudates called mucilage is released at the tip of roots during growth and is known to turn water repellent upon drying. We investigated the natural distribution of various concentrations of mucilage in soil and its effect on the magnitude of water repellency employing the sessile drop method.

Our results showed a distinct threshold-like behaviour for dry soils of different grain-size. As the mucilage concentrations reached a critical value, the soil abruptly turned hydrophobic. The critical mucilage concentration at which soils turned hydrophobic decreased with increasing particle size. The threshold-like behaviour was more moderate after the samples were repacked.

Our findings can be explained by a preferential distribution of mucilage in the contact between soil particles. During drying water menisci recede and draw mucilage towards the inter-particle space where it is deposited. At low mucilage concentrations, the region occupied by mucilage is bypassed by water and the apparent contact angle is small. As the amount of mucilage increases, the area where it is deposited becomes larger until it occupies the perimeter of the pore-bottle neck, blocking the flow and resulting in a high contact angle. On the contrary, in the re-packed samples, the apparent contact angle reflects the more-uniform distribution of mucilage through the pore-space. This hypothesis was confirmed by light microscopy images.

This study shows the impact of non-uniform pore-scale distribution of organic matter (in this case mucilage) on soil water repellency and explains the criticality of this process.

Key words

Rhizosphere, contact angle, mucilage, percolation.

The "gel effect": effect of mucilage on water properties in the rhizosphere

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Abstract

Mucilage is mainly produced at the root tips and has a high water holding capacity derived from highly hydrophilic gel-forming substances. The objective of the MUCILAGE project is to understand the mechanistic role of mucilage for the regulation of water supply for plants. Our subproject investigates the chemical and physical properties of mucilage as pure gel and mixed with soil.

1H-NMR Relaxometry represents a non-intrusive powerful method for soil scientific research by allowing quantification of the water distribution as well as monitoring of the water mobility in soil pores and gel phases. Relaxation of gel water differs from the one of pure water due to additional interactions with the gel matrix. The two types of relaxation rates 1/T1 and 1/T2 measured with 1H-NMR relaxometry refer to different relaxation mechanisms of water. The objective of our study is to distinguish water in gel from pore water in a simplified soil system, and to determine how the "gel effect" affects both relaxation rates in a porous system. From this knowledge, we demonstrate how mucilage drying and rewetting alter the properties of water in the respective gel phases and pore systems in the rhizosphere.

To distinguish gel-inherent processes from classical processes, we investigated the variations of the water mobility in pure chia mucilage under different conditions by using 1H-NMR relaxometry. Using model soils, the signals coming from pore water and gel water were differentiated. Mucilage-containing model soils were consecutively dried and rewetted in order to characterize the swelling and shrinking of the mucilage gel in the soil matrix and the potential effects on the soil water mobility. The water properties for mucilage-rich soils were shown to evolve in function of the mucilage history. Further, by affecting the mobility of water entrapped in the mucilage network, we show that mucilage can modulate the rhizosphere hydraulic properties. Several factors influence the effect of mucilage such as its drying-wetting history, the soil particle diameter and the soil solution composition.

Based on these findings, we discussed the potential and limitations of 1H-NMR relaxometry for following natural swelling and shrinking processes of a natural biopolymer in soil.

Key words

Mucilage, water properties, 1H-NMR relaxometry.

Hydrogel swelling in soil and its contribution to soil microstructural stability

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Abstract

Soil organic matter (SOM), mucilage and synthetic polymers are swellable polymeric substances (called synonymously 'hydrogels') that can alter water holding capacity of soils, soil wettability, but they also alter soil microstructural stability by forming a three-dimensional hydrogel network in soil. Mucilage can significantly contribute to soil microstructure in the rhizosphere and protect it against external forces, e.g. by gluing soil particles together. It is currently under discussion how the swelling of hydrogels between soil particles contributes to soil microstructural stability. Although continuous efforts have been made to identify the mechanisms behind hydrogel-induced soil microstructural stability, the relationships between hydrogel swelling degree and soil microstructural stability remain unclear.

In this study, we aimed to identify the hydrogel-induced mechanisms which are stabilizing soil microstructure and to quantify the contribution of swollen hydrogel structures between soil particles on soil microstructural stability. For this, we prepared artificial soils and treated them with highly swellable polyacrylic acid (PAA) as model hydrogel. The effect of hydrogel-swelling on the water entrapment in the artificial soils was characterized by 1H proton nuclear magnetic resonance relaxometry (1H NMR relaxometry). From the rheological characteristics of each artificial soil sample, we were able to link the degree of water entrapment with the measured soil microstructural stability. The results indicated that the microstructural stability of the hydrogel treated artificial soil was significantly higher than for the untreated artificial soils. This is most probably due to a higher viscosity of the hydrogel than of pure water between the soil particles. In addition, we found that the soil microstructure was more stable, when the clay content and PAA concentration were higher. Additionally, clay-polymer interactions such as polyvalent cation bridging were suggested to further increase soil microstructural stability, independently of the degree of water entrapment.

These results are of special relevance for the rhizosphere since mucilage can swell and dehydrate between soil particles and thus stabilize soil microstructures in various ways.

Key words

Relaxometry, hydrogel, swelling, rheology, microstructure, stability.

Effect of flow interruption on transport and retention of iron oxide colloids

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Abstract

The mobility of iron oxide colloids in soils is of relevance due to their role in soil-forming processes as well as their capacity to act as "shuttles" for the transport of adsorbed contaminants. As a consequence of the complexity of flow conditions as well as solid matrix and colloid surface properties in soils, knowledge about the mobility of iron oxide colloids remains scarce. The aim of this study was to determine the effect of flow conditions on the mobility of iron oxide colloids. For that, breakthrough behavior of negatively charged, organic matter-coated goethite (OMCG) colloids was investigated under continuous and stagnant flow conditions in saturated quartz sand columns. Classic DLVO and extended DLVO (XDLVO) interaction energies including Lewis acid/base parameters between colloids and solid matrix were estimated from sessile drop contact angle and zeta potential measurements. Results elucidate that OMCG colloids are highly mobile under continuous flow conditions, which can be predicted by unfavorable attachment conditions predicted with both DLVO and XDLVO approaches. These findings are in agreement with previous studies. In contrast, phases of flow interruption lead to the retention of a significant amount of OMCG colloids. The colloids cannot be remobilized from the solid matrix by re-establishment of flow. Colloid retention increases with the duration of flow interruption; OMCG colloids are almost completely retained in the solid matrix after 112 hours. Sedimentation experiments show fast gravitational settlement of OMCG colloids onto the solid matrix at stagnant flow conditions. We conclude that OMCG colloids are highly mobile under continuous flow conditions, which can be predicted by both DLVO and XDLVO approaches. However, phases of flow interruption relevant in natural soils lead to significant colloid retention. It is likely that sedimentation facilitates colloid capture at favorable retention sites on the solid matrix surfaces. Under continuous flow conditions, this retention mechanism is hindered by hydrodynamic drag forces.

Key words

Iron oxide colloids, organic matter, flow interruption, DLVO.

Integration of nanoscale imaging and quantitation of (bio) nanomechanical properties of wettable and repellent soils using Atomic Force Microscopy

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Abstract

Atomic Force Microscopy (AFM) is a high-resolution surface-sensitive technique, which provides three-dimensional topographical information and material properties of both stiff and soft samples in their natural environments. Traditionally AFM has been applied to samples with low roughness: hence its use for soil analysis has been very limited so far.

Here we report the optimization settings required for a standardization of high-resolution and artefact-free analysis of natural soils with AFM: soil immobilization, AFM probe selection, artefact recognition and minimization. Beyond topography, AFM can be used in a spectroscopic mode to determine nanomechanical properties, such as soil viscosity, stiffness, and deformation. We have used Peak Force-Quantitative NanoMechanical (QNM) AFM to quickly and easily determine physical properties from AFM force curves in real-time to obtain soil nanomechanical properties. Here we show for the first time the ability of AFM to describe the topography of natural wettable and repellent soils at nanometre resolution, with observation of micro-components, such as clays, and of nano-structures of likely biotic origin, the visualization of which would prove difficult with other instrumentations. Nanomechanical profiling has been applied to soils at different wettability states and the respective physical patterns are discussed. We have also compared these properties of natural soils to similar nanoscale observations of proteins able to modulate the wettability of materials in vitro.

Key words

Soil water repellency, atomic force microscopy, nanotechnology, high-resolution imaging, nanomechanical properties.

How to link soil wetting properties and surface elemental composition? An XPS pilot study

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Abstract

Under natural conditions soil minerals will always be coated by mainly organic components sorbed or attached to the surface. Soil wetting properties (quantified in terms of contact angle CA) as a crucial parameter for soil functioning hence will be determined by the soil particle coating components and here by the chemical composition of the outmost 1 nm ("CA analysis depth"). To relate CA and chemical composition therefore requires an analytical technique with an at least similar analysis depth. This indicates X-ray photoelectron spectroscopy (XPS) to be an appropriate tool. Irradiation of the surface with X-rays results in the emission of photoelectrons (PE) with element-specific binding energy (BE). Due to the mean free path of PE, the XPS analysis depth is restricted to a maximum of about 10 nm. For a basic study we used a suite of eight samples from a soil chronosequence (Damma glacier, Switzerland) where CA increased from 0° (0 yrs soil age) to 98° (120 yrs soil age) to test the relationship between CA and particle surface elemental composition. With soil age the concentration of all detected elements (Na, Fe, O, N, K, Ca, C, Si, Mg, Al) changed distinctly. While C and N concentration increased, concentration of the mineral-derived cations (Na, Fe, K, Ca, Si, Mg, Al) and O decreased due to increasing coating that progressively diminished the amount of the underlying mineral phase within XPS analysis depth. The concentration of all elements could be related to CA as a direct consequence of the increasing coating thickness. In line with earlier observations, the surface O/C ratio was found to be closely related to CA and here for the first time could be demonstrated for the whole range of CA (i.e., 0° - >90°). Addition of further soil sample sets (n = 48) of different texture and even functionalized glass surfaces could prove this relation to be universally valid, independent of the material regarded. The decreasing wettability with soil age indicated increasing amounts of non-polar C species within newly acquired C compounds. Applying a fitting scheme to the C 1s peak that discriminates between polar (Cp, higher BE) and non-polar (Cnp, lower BE) C species as function of soil age indeed indicated nearly constant Cp and increasing Cnp concentrations. Both, Cnp concentration and the Cp/Cnp ratio were closely related to CA.

Key words

Contact angle, XPS.

Rhizosphere water repellency: Implications for irrigation efficiency

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Abstract

The ability of plants to extract water from the soil is controlled by the hydraulic conductivity of roots and their rhizosphere. Recent experiments showed that mucilage secreted by roots turns hydrophobic after drying and it causes water repellency in the rhizosphere. The objective of this study was to investigate whether rhizosphere water repellency limits root water uptake.

We grew lupines in aluminum containers (30 × 30 × 1 cm) filled with a sandy soil which was partitioned into five vertical compartments (same size). When plants were thirty-four days old, we let them dry till a soil water content of 0.02-0.04 cm3 cm-3 and then we irrigated one side of the compartment with water and the symmetric compartment with a rhizoligand, which is defined as an additive that has the ability to rewet the rhizosphere hydrated and to bind mucilage. The soil water content during the irrigation experiment was imaged with neutron radiography. Water flux into the root was determined based on root swelling, also visible using neutron radiography.

The results showed that after irrigation, the rhizosphere of root segments immersed in water stayed temporarily hydrophobic, while it was uniformly rewetted by the tested rhizoligand. The rehydration rate of roots irrigated with the rhizoligand was ca. 7 times faster than that of the roots irrigated with water. We also observed that the final swelling of roots plus their rhizosphere was lower in the rhizoligand treatment.

The experiments proved our hypothesis that rhizosphere hydrophobicity limits root water uptake in sandy soils after drying and subsequent rewetting. Indeed, application of the rhizoligand that rewetted the rhizosphere also increased the rehydration rate of the roots. This effect lasted for at least 2-3 hours. Less obvious was the observation that the applied rhizoligand limited the maximum rehydration of roots and their rhizosphere. We hypothesize that the lower rehydration after the rhizoligand treatment was caused by a reduced mucilage swelling, probably due to cross-links between the hydrophobic groups of the rhizoligand and the mucilage networks. This hypothesis was confirmed in parallel experiments in which we measured the swelling of dried mucilage immersed in water and rhizloigand. The reduced mucilage swelling, with the consequent increase in viscosity, are likely to have an impact on flow and transport properties of the rhizosphere, offering new possibilities to engineer the rhizosphere to optimize the interactions between plant roots and soil.

Key words

Rhizosphere engineering, root water uptake, rhizoligand, mucilage, drying, wetting.

Session 5: Contributions presented as posters

Prediction of unsaturated hydraulic conductivity and capillary-sorption potential of water in cultivated and uncultivated soils

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Abstract

The vertical and lateral movement of soil water by gravitational forces in the plant-root zone occurs principally through the macro-pores, while the redistribution and upward flow occur in the capillary soil matrix pores. The purpose of this study is to apply derived equations to predict the hydraulic conductivity K(θ) into capillary-matrix and non-capillary macro pores of soils as well as to predict the capillary-sorption potential (ψ) at moisture adsorption capacity (Wa) and water content (Wi) in cultivated and uncultivated calcareous soils. The proposed equations are based on field basic infiltration rate (Ib), water sorptivity (S), and saturated hydraulic conductivity (Ks). Five alluvial (saline and non-saline clay) and calcareous soil profiles were investigated for applying the assumed equations. Water sorptivity was determined at steady infiltration and un-saturation conditions where a decrease in S value was observed with an increase in soil water content. At steady infiltration, S decreased by 35-40% in calcareous soils and by 45-60% in alluvial clay soils. The K(θ) has been discriminated into saturated macro-pore K(θ)RDP saturated matrix K(θ)sh, matrix unsaturated K(θ)h and lateral K(θ)L. The value of K(θ)RDP for macro pores remained higher than those for soil matrix pores in the studied soils. The highest value of K(θ)L and K(θ)h was in calcareous soil profiles, while the lowest value was existed in saline clay soil. The contribution of K(θ)L to K(θ)sh was evident in alluvial clay soils with markedly values in non-saline clay soil profiles. The predicted values of capillary-sorption potentials in calcareous cultivated soil with Zea mays were higher than those of uncultivated soil at the same water content.

Key words

Infiltration; sorptivity; hydraulic conductivity; soil matrix and macro pores; water capillary-sorption potential.

Impact of interfacial properties on aggregate stability of volcanic ash soils

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Abstract

Almost all processes in soils are located at the solid particle surfaces, emphasizing the relevance of interfacial properties for physical, chemical and biological processes due to the typically large solid-surface to mass ratios. In soils, these high-energy mineral surfaces become easily covered by amphiphilic organic compounds adsorbed from the soil solution or exudated by roots, fungi and bacteria, which lowers the surface energy of mineral surfaces and may render originally wettable soil particles water repellent. Soils are commonly enriched with soil organic matter which contains potentially a variable density of electrical surface charges affecting the strength of electrostatic interaction between charged particle surfaces as well as soil wettability. The underlying hypothesis of our work is that basic physicochemical properties such as specific surface charge or soil particle wettability are useful to describe modifications of complex micro-hydraulic and mechanical soil properties such as aggregate stability under changing environmental conditions. In contrast to many existing studies that relate aggregate stability and erodibility to static mass-based factors like organic matter content, clay content and type of clay minerals or Fe and Al (hydr)oxides, our approach considers variable particle surface properties. Results obtained for a wide range of volcanic ash soils from Chile rich in natural organic matter showed a relation between (sessile drop) contact angle and aggregate stability (sieved fraction 8-12 mm) with a steep increase in the low contact angle domain up to 30° and a stable plateau of high aggregate stability for contact angles > 30°. Significant variation of soil pH (initial pH = 6, modified to pH 2 to 9) resulted in a change of specific surface charge from neutral to negative at high pH and to positive charge at low pH, but only led to minor changes in wettability. We conclude that aggregate stabilization processes either by water repellency or increasing surface charge act in part contradictory, i.e. increasing surface charge causes higher water infiltration rates due to smaller contact angles but this effect is counterbalanced by higher cohesion between particles due to higher (especially negative) surface charge stabilization through cation bridges. We conclude finally that in particular the contact angle is an easily accessible and significant proxy parameter that consistently reflects dynamic changes in aggregate stability from weak to strong.

Key words

Soil wettability, surface charge, aggregate stability, volcanic ash soil.

Impact of bacterial biomass on soil particle wettability

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Abstract

Wettability is an important property of soil particle surfaces as it affects a wide range of soil processes where water is involved. For instance, low wettability (i.e. water repellency) reduces the water infiltration capacity which can promote erosional processes and strongly limit the water availability for microorganisms and plants. Moreover, water repellency affects the distribution and continuity of the liquid phase in the soil matrix which is crucial for diffusion of dissolved organic substrates, nutrients and exo-enzymes, and hence, the overall conditions for microbial life. In general, pure soil minerals are well wettable, however, under environmental conditions they become easily covered by organic compounds which can modify particle surface properties considerably. Organic compounds identified to cause water repellency comprise waxes, alkanes, fatty acids, free lipids and amphiphilic molecules in general. Our contribution will focus on bacterial biomass residues as one important component of soil organic matter which has been neglected in the past regarding its role in water repellency development. Recent research indicates that increasing mineral surface coverage by bacterial cell envelope fragments is accompanied by increasing microbial lipid contents and water repellency. In addition, it has been shown that the chemical composition of the cell envelope and the surface properties of bacteria vary with respect to water availability. However, it is unclear so far to which extent bacterial cells and their fragments contribute to the occurrence and persistence of soil water repellency and whether bacterial adaptation to water stress plays a role in the frequently observed variation of water repellency in response to wetting and drying. Our project aims at answering these questions by (i) studying the factors and conditions that contribute to the occurrence of bacterial surface hydrophobicity, (ii) investigating how bacterial surface properties are reflected by soil wettability, and (iii) testing the potential feedback of soil particle wettability on bacteria and their surface properties.

Key words

Bacteria, cell fragments, contact angle, interfacial properties, water repellency, wettability.

Links between nanoscale and macroscale surface properties of natural root mucilage studied by atomic force microscopy (AFM) and contact angle

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Abstract

Dried films of natural root-mucilage from Sorghum (Sorghum sp. MOENCH) on glass substrates were studied in order to assess experimental and evaluation methods that allow to link between macroscopic soil water reppellency (SWR) and nano-/microscopic surface properties. SWR was assessed by optical contact angle measurements. The nanostructure of topography and adhesion forces of the mucilage surfaces was revealed by atomic force microscopy (AFM) measurements in ambient air, using PeakForce Quantitative Nanomechanical Mapping (PFQNM). Contact angles showed that water repellency of surfaces was reduced, when concentration of mucilage was decreased by dilution. AFM height and adhesion images displayed hole-like structures in those diluted samples that frequently exhibit increased adhesion forces. Spatial analysis of AFM data via semivariograms was shown to be able to numerically represent such adhesion holes as well as information on surface roughness. Thus, the use of geostatistical approaches in AFM studies of soil compound surfaces was considered meaningful in view of the need of comprehensive analysis of large AFM image data sets that exceed the capability of comparative visual inspection. Furthermore, force curves measured with the AFM could show increased break-free distances and pull-off forces inside the observed ‘adhesion holes’, indicating enhanced capillary forces due to capillary water. This finding offers the possibility of mapping capillary water films on soil surfaces. The collected information on wetting properties roughness and adhesion structure of investigated surfaces are discussed in view of the applicability of the wetting models from Wenzel and Cassie-Baxter. Because additional investigations of contact angle droplet locations with environmental scanning electron microscopy and energy dispersive X-ray spectroscopy (ESEM-EDX) suggested an influence of microscopic hydrophobic particles on surface wettability, for future studies it is supposed to examine physico-chemical surfaces properties on a broad range of spatial scales in attempt to more fully explain macroscopic wetting properties of soils.

Flow cell sampling technique: A new approach to analyze physical soil and small-scale surface properties of undisturbed soil samples

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Abstract

During unsaturated water conditions in soils, water flow occurs mainly by water film flow, depending on water content, pore topology (pore size, tortuosity, and connectivity), and pore surface properties. Coatings enclosing soil particles, may affect wetting properties as well as hydraulic soil functions. Particle coatings are most likely responsible for adsorption processes and are expected to favor local heterogeneous microstructure with enhanced biological activity. These effects cannot be characterized on the basis of conventional soil column experiments. The general objective of this study was to develop a new field sampling method to characterize heterogeneous flow processes and additionally concerning the spatial distribution of soil properties at small scales of intact soil under controlled lab conditions. This will be done by using modified flow cells (transparent acrylic glass). The direct modification from the sampling frame to the flow cell provides the advantage to combine several analyses by cutting up to 5 thin undisturbed soil slices (quasi-replicates) down to 10 and/or 5 mm. Beside the use as a flow cell for measurements of breakthrough curves, the developed technique has several advantages in contrast to common columns or existing flow chamber/cell designs. The large observation area of up to 150 cm2 allows characterizing the spatial distribution of soil properties in a mm-scale resolution at quasi-intact bulk soil samples. The applicability of the new flow cell technique was shown with i) tracer experiments in a quasi-2d flow field, ii) small-scale contact angle measurements, iii) mapping of extracellular enzyme activities by zymography and iv) 2d-mapping of the spatial distribution of functional groups of soil organic matter via Diffusive Reflectance Infrared Fourier Transform (DRIFT) spectroscopy. The flow cell technique provides a promising tool for mapping the two dimensional distribution of physicochemical and biological soil properties which may promote the formation of heterogeneous moisture and flow patterns in sandy soils.

Key words

Sampling technique, undisturbed soil, flow cell, DRIFT, zymography.

The integrated effect of organic matter and moisture content on phytoremediation characteristics of a Cu-spiked soil by *Brassica juncea* L.

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Abstract

The potential of Brassicacea family plants to clean up soils contaminated with heavy metals has been proved by numerous studies. The purpose of this research was to assess the accumulation of copper (0, 50, 100, 200 and 300 mg kg-1 soil as copper sulfate) by indian mustard (*Brassica juncea* L. Czen & Coss) as affected by organic matter (0 and 3% as aged cow manure) and soil moisture (0.4-0.6 FC and 0.8-FC) in a greenhouse experiment for 60 days. At the end of growing period, some growth indicators and concentrations of Cu, K, Mg, Fe, Mn and Zn in shoot and root parts were determined. Based on results, sharp decline in shoot and root growth was started at 200 mg Cu kg^{-1}. An increase in Cu addition from 0 to 300 mg kg^{-1} implied nearly a 4.1 fold increase in shoot concentration of Cu and nearly a 2.6 fold decrease in shoot dry weight. Concentrations of Fe in shoot as well as root parts and also chlorophyll index decreased sharply by Cu treatment. Addition of organic matter had no effect on shoot Cu concentration, but through the increasing shoot and root dry weights, the Cu uptake increased. Likewise, the incorporation of organic matter increased the stem diameter but had no effect on root length and plant height. As supply of both Cu and organic matter increased, shoot concentrations of K and Mg increased, but no significant differences were observed for Mn and Zn. Water deficiency reduced the shoot dry weight and through this way, the shoot Cu concentration increased. Significant decreasing effects of water deficit on shoot and root dry weights were seen only at 50 and 100 mg Cu kg^{-1}. Therefore, soil moisture condition had no effect on mustard biomass at toxic levels of Cu. Moreover, under water deficiency conditions, shoot concentrations of Cu, Zn and K increased, while shoot concentration of Fe decreased. This factor had no significant effect on shoot concentrations of Mn and Mg. Nutrient concentrations in the roots were not significantly affected by soil moisture content.

Key words

Copper, mustard, organic matter, phytoremediation, soil moisture.

Increased ambient air temperature alters the severity of soil water repellency

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Abstract

Soil repellency, the inability of soils to wet readily, has detrimental environmental impacts such as increased runoff, erosion and flooding, reduced biomass production, inefficient use of irrigation water and preferential leaching of pollutants. Its impacts may exacerbate (summer) flood risks associated with more extreme drought and precipitation events. In this study we have tested the hypothesis that transitions between hydrophobic and hydrophilic soil particle surface characteristics, in conjunction with soil structural properties, strongly influence the hydrological behaviour of UK soils under current and predicted UK climatic conditions. We have addressed the hypothesis by applying different ambient air temperatures under controlled conditions to simulate the effect of predicted UK climatic conditions on the wettability of soils prone to develop repellency at different severities.

Three UK silt-loam soils under permanent vegetation were selected for controlled soil perturbation studies. The soils were chosen based on the severity of hydrophobicity that can be achieved in the field: severe to extreme (Cefn Bryn, Gower, Wales), intermediate to severe (National Botanical Garden, Wales), and subcritical (Park Grass, Rothamsted Research near London). The latter is already highly characterised so was also used as a control. Soils were fully saturated with water and then allowed to dry out gradually upon exposure to controlled laboratory conditions. Soils were allowed to adapt for a few hours to a new temperature prior to initiation of the controlled experiments. Soil wettability was determined at highly regular intervals by measuring water droplet penetration times. Samples were collected at four time points: fully wettable, just prior to and after the critical soil moisture concentrations (CSC), and upon reaching air dryness (to constant weight), for further (ultra)metaproteomic and nanomechanical studies to allow integration of bulk soil characterisations with functional expression and nanoscale studies to generate deep mechanistic understanding of the roles of microbes in soil ecosystems.

Our controlled soil pertubation studies have shown that an increase in ambient temperature has consistently affected the severity of soil water repellency. Surprisingly, a higher ambient air temperature impacts soils that in the field develop subcritical and extreme repellency, differently under controlled laboratory conditions. We will discuss the impact of these results in relation to predicted UK climatic conditions. Soil metaproteomics will provide mechanistic insight at the molecular level whether differential microbial adaptation is correlated with the apparent different response to a higher ambient air temperature.

Key words

Soil water repellency, temperature, climate change, proteins, microbial adaptation.

Temperature dependent surface tension of biosolids derived dissolved organic matter

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Abstract

Soil amendment of agricultural soil with biosolids (composted sewage sludge) is a common practice worldwide. The benefits from land application of biosolids are well established and are related to recycling nutrients, improving the hydraulic properties of the soil and its fertility. Several studies demonstrated that biosolid derived dissolved organic matter (DOM) may exhibit surface activity at the liquid-air interface. Under unsaturated conditions, the reduction of the DOM surface-tension (ST) relative to water may affect some chemo-physical properties of the soil solution. For example, the capillary pressure saturation relations of water may vary and consequently the hydraulic properties. The lower surface tension may also improve the wettability of the rhizosphere and the surface of the plant roots. Consequently, the efficiency of water and nutrients adsorption may improve. From a critical DOM concentration, the apparent solubility of some hydrophobic pollutant (e.g. pesticides) may significantly increase and subsequently their mobility through the vadose zone to groundwater. The main factor that affects the ST of DOM solution is their concentration. However, for a given concentration, the environmental conditions such as, ionic strength, the valance of cations, pH and temperature may also change the surface activity of the DOM. The temperature of the soil solution at the root zone may significantly vary between day and night and between seasons. For example, in the Negev Desert of Israel, the temperature at the top soil layers (where the biosolid is applied) may range from 10 to 50 ºC during the summer months. The main objective of this study was to evaluate the extent of ST decay as a function of the DOM concentration and temperature. The DOM was extracted from a composted biosolid (Compost OR, Israel) using aqueous solutions of 0.05N KCl or CaCl2. The equilibrium surface tension was measured by the Wilhelmy plate method using a Tensiomat (DCAT-11, DataPhysics) with a temperature control unit. For a given DOM concentration the ST was measured for 5, 10, 20, 30, 40 and 50 ºC. One of the main findings of our research is the inversed linear relations obtained between the ST and temperature. The quantitative analysis of these results will be presented and discussed.

Key words

Biosolids, dissolved organic matter, surface tension, temperature.