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Министерство на образованието и науката

Land-use and management impacts on carbon sequestration in mountain ecosystems

BSRP

Start date: 01/01/2013

End date: 31/12/2015

Year of reporting: *1.5*

PI 1 – PD Dr. Jens Leifled, Agroscope Rechenhlz-Tänikon ART

PI 2 – Dr. Miglena Zhiyanski, Forest Research Institute, Bulgarian Academy of Sciences

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Scientific context and objectives (1/2)

- **Background / Problem statement:**

Mountain ecosystems - indicators of environmental change, because they are heavily impacted by changed climate and land use, resulting in land abandonment and reforestation of formerly treeless areas.

Land-use changes (LUCs) as well as forest management, including change in tree species composition through forest conversions, are widely accepted as measures for mitigating climate change through carbon sequestration.

Soil organic carbon stocks are influenced by the changes in vegetation and land-use (Desjardins et al., 2004; Meyer et al. 2012 a, b).

Land use impacts have been identified as a major knowledge gap in soil carbon modeling (Gärdenäs et al. 2011).

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Scientific context and objectives (2/2)

- **AIM:**

The project addresses the effects of LUCs' and management within forest-related land uses in mountain regions on soil and biomass carbon stocks.

Research directions:

More specifically, knowledge on changes in C stocks and their drivers following LUC and management change in order to support better national Green House Gases (GHG) inventory and reporting will be synthesized.

Focus is on forest-related land-use and management that are expected to be most conducive to C changes, e.g. afforestation of former grassland, abandonment, forest conversions and different forest management practices.

- This participants combine new as well as already existing knowledge under a coherent scientific framework following an interdisciplinary approach.
- The joint collaboration provides the scientific basis necessary for developing models and adjusting management strategies together with local and regional stakeholders as well as policy recommendations for national and European policy makers.

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Working plan and work packages (WPs) (1/2)

WP1 - Site evaluation / Objectives: Sampling design, field visits and sampling procedures;

WP2 – Soil carbon content in relation to forest-related land-use changes and management / Objectives: to provide more precise estimates of carbon sequestration in living biomass and in soil as a result of LUC, afforestation activities and to assess the impact of afforestation and forest management options on carbon storage in mineral soil and in forest floor;

WP3 – Modeling / Objectives: to evaluate the suitability of three different approaches for describing land-use related soil carbon dynamics and stock changes in mountain soils in Bulgaria and in the Alps. In addition, possible extensions of dynamic models will be implemented and tested to improve their correctness.

+ **Dissemination activities**, e-based exchange platforms, knowledge exchange, PhD and Post-Doc positions, publications, events, reports etc.

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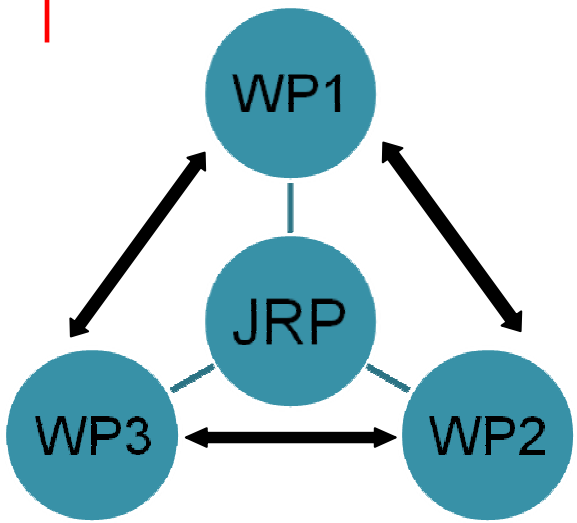
Working plan and work packages (WPs) (2/2)

	I year	II year	III year
WP1			
WP2			
WP3			
Dissemination activities			
Management activities			

	Research and Technical Development incl. field visits
	Demonstration activities - workshops, meetings, publications, reports and mobility of scientists incl. training visits
	Management activities



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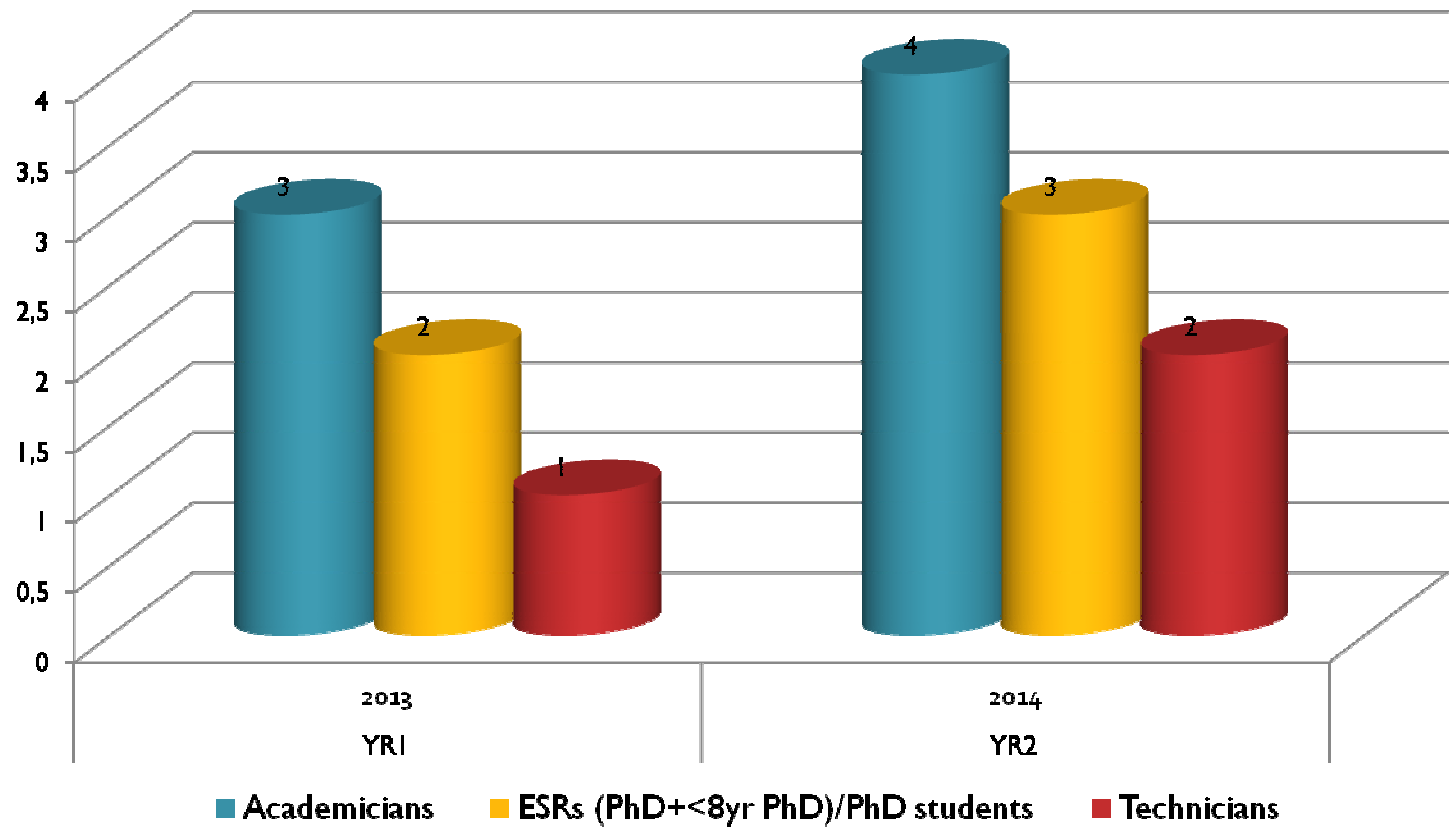
Project participants (BG part)



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Use of BSRP instruments

Activity (No.)	Year 1 (2013)	Year 2 (2014)
Meetings	3*	2
Post-Doc	-	1
PhD students	1	1 (+1 Oct.)
Participation in Workshops or Conferences	2	6 (4 forthcoming)
Joint Publications	1	4 (2 accepted 2 under preparation)

* PLUS One kick-off meeting in Sofia in January 2013

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Results vs. Objectives

Deliverable (Milestone)	Delivery month
D1 (M1)	5
D2	6
D3 (M2)	9
D4 (M3)	11
D5	18
D6	18

The **initial report** based on assembled data on LUC and forestry managements effect on soil carbon has been produced (**M1**)

Selected sites (**existent and new experiments**) were sampled and one report about their special characteristics was produced (**M2**)

Identifying the driving factors for changes in soil carbon sequestration is under **book preparation** (**M3**)

UP-COMMING D5 and D6 – Analyses to be completed and exchanged within the network established.

A web-based platform used in communication strategy was created http://www.mountain-soils.eu as well as a e-based platform http://mountain-soils.pbworks.com/w/page/63626692/FrontPage

- The participants from Bulgaria and Switzerland **integrated different kinds of knowledge** from mountainous regions of both countries (Alps, Balkans, Rila and Rhodopes Mnts) and **realized the Scientific Plan for the first 18 months.**
- This **networking under BSRP has already resulted in a number of publications, joint presentations, ESRs training and other initiatives**.
- BG and Swiss participants are aiming to combine ecological and modeling approach in environmental research studies.

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Significant Highlights in Science & Networking (1/2)

PhD student Lora Naydenova (Forest Research Institute, BG) Thesis: "Land use and management impact on soil carbon in Central Balkan Mountain"

ACTIVITY: Review on effects of land use change on soil system properties; Site evaluation and sampling; Laboratory analyses; Interpreting results.

OUTPUT:

D1 – **Report** "Bibliographical review on carbon sequestration in forest soils in the context of land use impacts", M. Zhiyanski and L. Naydenova, presented in the conference of FRI "Scientific research studies in Forest Research Institute for the period 2010-2012, 4-5 April 2013, Sofia. Paper submitted in "Forest science" Journal.

Poster entitled "Comparative study on carbon accumulation in soils under managed and unmanaged forests in Central Balkan Mountains", by L. Naydenova, M. Zhiyanski and J. Leifeld, was presented in EGU General Assembly 2014, Vienna, Austria, 28.04-02.05.2014. One paper is under preparation.

Paper accepted: "Carbon accumulation in soils in selected mountain regions in Bulgaria", L. Naydenova, M. Zhiyanski, M. Sokolovska, will be presented in the International Conference "Carbon-Land-Property", 1-4 July, Copenhagen, Denmark.

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Comparative study on carbon accumulation in soils under managed and unmanaged forests in Central Balkan Mountains

Lora Naydenova[1], Miglena Zhiyanski[1], Jens Leifeld [2]

[1]Forest Research Institute, BAS, Sofia, Bulgaria – l.naydenova@gmail.com, zhiyanski@abv.bg

[2]Agroscope, Zurich, Switzerland - jens.leifeld@art.admin.ch

1. Introduction

Mountain forest ecosystems are important for their distinct ecological features and also due to the ecosystem services they offer. Forests ecosystems capture carbon dioxide and store carbon (C), but when they are disturbed this influences the carbon balance. More than 1/3 of the carbon is stored in the vegetation, and nearly 2/3 in the soil of the temperate forests (Gorte, 2007). Thus the **soil carbon pool** is a major component of the global carbon cycle.

Forest soils are good indicator for impacts of two global change drivers: **land use change and climate change**. Experiments have found different effects of forest management activities on C sequestration (Post and Kwon, 2000; Johnson et al., 2002, Nave et al., 2010). Treatments such as thinning, harvesting, and fertilization modify soil C dynamic and the variations can be explained by specific site and soil conditions.

2. Aim

In this paper, we studied the effects of timber **thinning** with medium intensity (10%) on C storage in beach and spruce forests soil. We attempt to generalize about the differences in carbon accumulation in forest floor layers and mineral soil horizons under managed and unmanaged spruce and beech forest ecosystems, and to recommend activities that can lead to long-term C accumulation in forest soils.

Bird view at the area of Balkan Mountains with location of studied experimental sites

3. Materials and methods

3.1.Region and object of investigation:

The high mountainous forest's growing zone of Central Balkan Mountain was studied between 1200 m and 1400 m of altitudes. Four experimental sites in natural European beech forest (*Fagus sylvatica* L.) and Norway spruce (*Picea abies* Karst.) managed and unmanaged were chosen. The sites characterized by the same soil type – Cambisols (WRB, 2006) and the northern aspect of slope. This gave a possibility to perform comparative approach in analysis(Table 1). The region characterizes with mountain climate. Balkan Mountain is a significant climatic barrier, which determines the differences in temperature and precipitation between the northern and the southern slopes.

Table 1. Characterization of studied experimental sites

Site	Altitude, m	Type of forest	Tree species	Origin	Soil type according (WRB, 2006)	Management activities
F1	1490	Coniferous, pure	*Picea abies* Karst.	Plantation	*Mollic Cambisols*	Un-managed
F2	1100	Coniferous, pure	*Picea abies* Karst.	Plantation	*Dystric Cambisols*	Managed – 10% thinning
F3	1210	Broadleaf, pure	*Fagus sylvatica* L.	Natural	*Dystric Cambisols*	Un-managed
F4	1280	Broadleaf, pure	*Fagus sylvatica* L.	Natural	*Dystric Cambisols*	Managed – 10% thinning

3.2.Sampling:

- Four representative experimental sites (0.5 ha each) within the altitude range 1100 - 1500 m were chosen in the Beklemeto region, Central Balkan Mountains.
- Shale bedrock
- Soils are *Dystric Cambisols and Mollic Cambisols* (WRB, 2006)
- Experiments have been conducted in 2013.
- One representative soil profiles plus four additional core profile were opened per site giving a total **60 soil samples** from the soil layers respectively at **0-10, 10-30 and 30-50 cm** depth.
- The samples for bulk density determination have been taken with volumetric ring, from each soil layer in two repetitions, only in one soil profile per site.
- A total of 48 **samples from forest floor layers** (Aol, Aof, Aoh) were collected with 25:25 cm plastic frame.

4. Results and Discussion

4.1.Forest floor:

- On the base of made analyses we have concluded that the forest floor in F1 is type Mor, Moder in F2 and Mull in the other two sites. The pH is acid with variations between 4,78 and 5,75. The values are similar in the broadleaf and coniferous forests.
- The dry weight of forest floor was higher in F1 – which could be explained by the lack of silvicultural and management activities in this land-use(Table 2). There are different accumulation of litter, resp. forest floor layers between coniferous and broadleaved forests.
- Forest floor carbon stock is significantly different between hardwood beech forests and softwood spruce forest layers ($p<0,001$), with an overall mean values for F3 and F4 of 4,8 and 18,3 and for F1 and F2 24,6 and 35 t ha^{-1}, respectively. The carbon content in forest floor layers is similar between all studied land-uses varying between 39,10 and 46 %.

Nitrogen content in forest floor also differs between both forest types with values obtained of about 0,63-0,64% under beech and 0,76-0,92 under spruce, respectively.

Very high C:N ratio was established in forest floor under all studied land-uses.

Table 3. Mean parameters for forest floor in the studied plots

Site	C% (mean ± SD)	N % (mean ± SD)	C:N
F1	42,46 ± 4,09	0,92 ± 0,32	46
F2	45,45 ± 11,7	0,76 ± 0,28	59
F3	46,01 ± 7,14	0,63 ± 0,1	73
F4	39,10 ± 5,81	0,64 ± 0,17	61

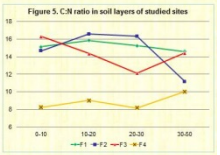
3.3.Analises:

- The following soil properties have been determined in accordance with the standardized methods in the Laboratory of Forest Soil Science at the Forest Research Institute – BAS (Donov et al., 1974):

morphological description, bulk density, coarse fractions, textural fractions, pH in H2O (ISO 10390:2005), nitrogen content (Kjeldahl method), and carbon content (modified Turin method).

- The IPCC Good Practice Guidance for Land Use, Land Use Change and Forestry was used to estimate the soil organic carbon stock in soil and litter (IPCC-GPGLULUCF, 2003)

Figure 5. C:N ratio in soil layers of studied sites



4.2.Mineral soil:

Concerning mineral soil *Dystric Cambisols* characterized with more acid reaction compared with *Mollic Cambisols* (F1). For all studied forest land-uses in 0-10 cm layer the pH was more acid compared with the deeper layers. This is due to the influence of tree species – both spruce and beech provoke acidification of superficial soil.

The determined bulk density varied within the limits reported in the bibliography for these soil types. We confirmed that *Mollic Cambisols* are characterized by lighter texture. For all studied profiles a compaction expressed with higher BD was determined for deeper soil.

Coarse fractions content was relatively higher in the superficial soil, which could be explained by the deluvial processed in the mountainous region. Sand content is increasing toward deep soil in *Dystric Cambisols* and for *Mollic Cambisols* is similar along the whole profile. According the results obtained for textural composition the studied soils could be referred as sandy-loam.

Based on the data obtained for physical properties of studied soils no differences between forest-related land-uses were established.

Table 2. Main soil and forest floor parameters in studied experimental sites

Site	Layer (cm)	pH (H_2O) mean ± SD	Bulk density	Sand, (%)	Clay, (%)	Coarse fractions, (%)	Dry weight of FF (g)
F1	AoL (1,4)	5,00	-	-	-	-	126,99
	AoF (1,2)	5,19	-	-	-	-	353,34
	AoH (3,7)	4,90	-	-	-	-	1071,90
	0-10	**5,01** ± 0,60	0,91	81,14	18,86	41,14	-
	10-20	5,08 ± 0,23	0,95	67,73	32,27	26,00	-
	20-30	5,15 ± 0,21	1,05	72,18	27,82	22,12	-
	30-50	4,96 ± 0,19	1,10	72,88	27,12	31,32	-
F2	AoL (1,3)	4,89	-	-	-	-	122,90
	AoF (1,0)	5,35	-	-	-	-	414,96
	AoH (1,2)	4,87	-	-	-	-	521,54
	0-10	**4,26** ± 0,08	0,80	58,43	41,57	40,12	-
	10-20	4,39 ± 0,1	1,03	61,6	38,4	26,40	-
	20-30	4,44 ± 0,13	1,03	65,73	34,27	35,99	-
	30-50	4,50 ± 0,08	1,03	72,18	27,82	36,05	-
F3	AoL (0,8)	5,72	-	-	-	-	90,01
	AoF (0,4)	5,03	-	-	-	-	270,04
	AoH (0,5)	4,78	-	-	-	-	371,59
	0-10	**4,15** ± 0,26	1,11	58,43	41,57	28,00	-
	10-20	4,63 ± 0,24	1,15	50,29	49,71	28,59	-
	20-30	4,89 ± 0,35	1,45	64,73	35,27	28,10	-
	30-50	5,15 ± 0,55	1,50	81,33	18,67	29,06	-
F4	AoL (0,3)	5,33	-	-	-	-	54,62
	AoF (0,5)	5,75	-	-	-	-	72,66
	AoH (0,5)	5,56	-	-	-	-	98,28
	0-10	**4,30** ± 0,05	0,64	57,66	42,34	42,98	-
	10-20	4,44 ± 0,11	0,90	57,81	42,19	28,59	-
	20-30	4,51 ± 0,14	1,10	58,23	41,77	28,10	-
	30-50	4,53 ± 0,18	1,41	75,78	24,22	29,06	-

4.3. Carbon content:

The mean carbon content in the soil is higher in the superficial layers and the tendency of reduction to deeper layers was observed (Figure 1). In the managed coniferous plantation F2 higher C, % in 10 – 30 soil layer is found compared to the unmanaged F1, which indicates better decomposition processes of the organic matter and its further incorporation in mineral soil. In the managed beech forest we confirmed this trend, which is even well expressed up to 50 cm of depth.

4.4. Nitrogen content:

This characteristic varies from 0,2 to 1,16 % for the entire soil (0 – 50 cm) and it is higher in the superficial layers, following the trend of organic matter content in most of the cases. Extremely high amount of N, % was established in 0 – 10 layer in F4, with high variation in the standard deviation – indication for high variability of the parameter probably related with the effect of the management activity over the microclimate at plot level.

Figure 1. Mean carbon content in soil layers of studied forest land uses

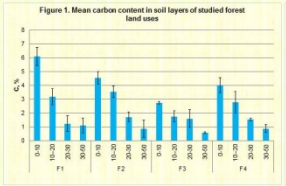
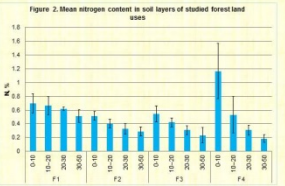


Figure 2. Mean nitrogen content in soil layers of studied forest land uses



4.6.C:N ratio:

The degree of decomposition of soil organic matter can be expressed by the ratio of carbon to nitrogen (C:N).

The organic matter transformation rate is higher when the carbon content is lower and the nitrogen is higher (Penkov 1991).

The results obtained in present study showed that the C:N ratio for the upper soil layer vary between 8,2 and 16,3. C:N ratio is only slightly differentiated in F1, F2 and F3 sites. This similarity is an indication of relatively good decomposition rate of SOM.

Figure 3. SOC stock in soil layers of studied forest land uses

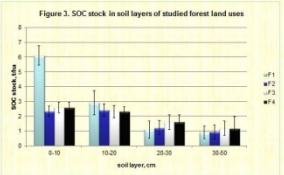
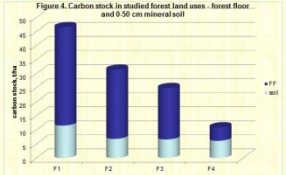


Figure 4. Carbon stock in studied forest land uses - forest floor and 0-50 cm mineral soil



4.5. Carbon stock:

Carbon stock in the soils under coniferous forests varies between 0,92 and 6,1 t C ha^{-1}. Significant storing of carbon in the soil is observed in the first (0 – 10 cm) studied layer under unmanaged spruce plantation – F1 (Figure 3).

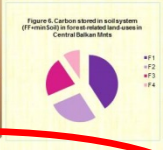
The carbon stock in mineral soil is strongly dependent on other parameters in the calculation equation – as coarse fractions content and bulk density.

The effect of management activities is clearly expressed when the entire soil and carbon content distribution along profiles are considered (Figure 4).

Opposite situation concerning carbon stock is seen when estimate stocks both in the forest floor and the soils (Figure 6). Generally greater amounts of carbon were stored in the unmanaged plots – F1 and F3, and the highest is in the Norway spruce plantation.

Forest floor stock is main indicator of the influences of management activities.

Figure 6. Carbon stored in soil system (FF+minSoil) in forest-related land-uses in Central Balkan Mts



5. Conclusions:

- No significant differences in main physical properties of studied soils between unmanaged and managed forest stands were established;
- Both European beech and Norway spruce stands had higher accumulation of organic matter in the forest floor and the Ah horizon under unmanaged conditions.
- When managed, carbon contents tended to be higher in deeper horizons of the mineral soil, probably due to differences in microclimate after thinning.
- The lack of management activities in spruce and beech forests increase the content of forest floor and carbon stocked in its layers.
- Management activities influence the forest floor in both beech and spruce stands, while no significant changes in carbon stock in same soil type were determined.
- The results obtained in present study showed that the C:N ratio is slightly differentiated in F1, F2 and F3 sites. This similarity is an indication of relatively good decomposition rate of SOM.
- The total nitrogen content followed similar relative distribution as for the soil organic matter with well expressed decrease toward depth.
- From an environmental point of view in the long term perspective the carbon incorporated in soil organic matter is more stable, so therefore we could recommend thinning with low intensity as a good management activity, which could be performed in beech and spruce forest stands.

Acknowledgements:

The work is a part of project "**Land-use and management impacts on carbon sequestration in mountain ecosystems**" financed under the framework of the Bulgarian-Swiss Research Programme ("BSRP"), 2011-2016, between the Government of Bulgaria and the Swiss Federal Council.

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Significant Highlights in Science and Networking (2/2)

OUTPUT:

D3 – **Scientific paper** prepared by Zhiyanski, M., A. Ferezliev, J. Leifeld, "Land use change effect on carbon stocks in mountain ecosystems from Rhodopes Mountain, Bulgaria" will be presented as poster in the World Congress of Soil Science, 8-13 June, Jeju, South Korea – poster will be presented by Prof. Bech (Spain). Article is under preparation for submission in impacted journal.

D4 – Scientific paper "Soil humus composition in mountain grasslands with different land-use intensity", by E. Filcheva, M. Zhiyanski, L. Naydenova, is accepted for publication in the Proceeding of Scientific Papers of the 17th International Humic Substances Society Meeting, 1-5 September, Ioannina, Greece.

One scientific and activity report of 32 p. (62 p. with Anexes) was prepared and presented to MEYS, R Bulgaria for the first financial year (2013).

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Field work, Photo: Private archive.

Challenges

- Enhancing different methodologies of ecological and modeling studies in mountain areas affected by LUCF;
- Ranking the most applicable indicators for assessment and monitoring the soil parameters in an ecological perspective;
- To clarify the role of belowground root biomass in soil humus formation;
- To include several environmental changes (climatic change, land use changes, forestry and management) to monitor the resilience capacity of a variety of mountainous ecosystems.

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Министерство на образованието и науката

Thank you!

Beklemeto, Central Balkan,
Photo: M. Zhiyanski

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