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Mobilizing greater crop and land potentials sustainably

Amir KASSAM[1], Gottlieb BASCH[2], Theodor FRIEDRICH[3], Emilio GONZALEZ[3],
Paula TRIVINO[3] and Saidi MKOMWA[4]

Abstract

The supply side of the food security engine is the way we farm. The current engine of conventional tillage farming is faltering and needs to be replaced. It is faltering because it causes unacceptable level of soil erosion and land degradation, and loss in yield potential, productivity, efficiency, resilience and ecosystem services. 'Business as usual' is no longer considered to be a suitable option for the future. This article addresses the supply side issues of agriculture to meet future agricultural demands for food and by industry with the alternate Conservation Agriculture (CA) paradigm (involving no-till seeding and weeding in soils with mulch cover and in diversified cropping) that is able to raise productivity sustainably and efficiently, reduce costly inputs, regenerate degraded land, minimize soil erosion, and harness the flow of ecosystem services. CA is an ecosystems approach to farming capable of enhancing not only the economic and environmental performance of crop production and land management, but also promotes a mindset change for producing 'more from less', the key attitude towards sustainable production intensification. CA is spreading globally in all continents at an annual rate of some 10 million hectares of cropland. In 2013–2014, CA covered more than 157 million hectares of rainfed and irrigated cropland and it is likely that its current spread is close to some 200 million hectares. In addition, perennial cropping systems such as orchards and plantations are being transformed into CA systems in all continents. In addition to being a best option for large-scale farmers, CA offers a real pro-poor agricultural development model to support sustainable agricultural intensification for low input smallholder farmers.

Keywords: conservation agriculture, supply side, demand side, tillage agriculture, no-till, sustainable intensification

Introduction

A scrutiny of agricultural production systems, their functioning and organization must consider how appropriate and sustainable the current agricultural paradigm is for the future for farmers, their communities and the society at large, and how environmentally sustainable it is? The agricultural supply side is generally analysed by mainstream scientists in terms of available resources and inputs for agriculture to meet future demand. Only more recently analyses have begun to address externalities of the production systems, such as environmental damages, associated input factor efficiencies and system resilience against major external challenges. However, relatively rarely do mainstream researchers question the conventional agricultural paradigm regarding its appropriateness for the sustainable development agenda and the environmental challenges the world is facing. Equally, the delivery of ecosystem services by conventional agricultural has not been an area of serious mainstream research concern (MEA 2005; Beddington, J. 2011; Lal, R. and Stewart, R.A. 2013).

This article elaborates on the nature of the supply side of food and agriculture systems and discusses: How much food is being pro-

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[1] University of Reading, UK. E-mail: amirkassam786@googlemail.com. Correspondent author.

[2] University of Evora, Portugal

[3] University of Cordoba, Spain.

[4] ACT Kenya

duced currently? How much more do we need to produce to meet our future needs? How appropriate is the current production paradigm of tillage agriculture for meeting future food and agriculture needs? The article illustrates and discusses the inherent destructive nature of the conventional tillage agriculture itself in causing soil, land and environmental degradation, and its consequent inability to function at maximum output with efficiency and resilience, or to deliver ecosystem services. The article shows how sustainable production intensification can be and is being mobilized with the alternate paradigm of no-till CA that has been spreading in all continents since the 1990s (Goddard, T.M. *et al.* 2007; Kassam, A. *et al*. 2009, 2013, 2015, 2016; Jat, R.A. *et al.* 2014; Farooq, M. and Siddique, K.H.M. 2015).

Nature of the supply side

Latest estimates from FAO suggest that the world needs to produce some 60 per cent more food to meet the demand of the expected global population of 9.2 billion at 2050 (FAO 2012). Recent FAO forecast indicates that this can be achieved if we can maintain an annual increase in food production globally at an average rate of 0.9 per cent, with a variation in regional rates from 0.3 per cent in Europe to 1.6 per cent in Africa (FAO 2014). In terms of the actual output of food, this corresponds to an increase in cereal production from 2.53 billion tons in 2014, from an area of 715 million hectares (3.54 t/ha), to 3.28 billion tons in 2050, from an area of some 736 million hectares. This output equates to an average yield of 4.3 t/ha to meet food, feed and biofuel demands as well as losses of some 40 per cent. If wastage was halved, the yield required would drop to 2.64 billion tons, corresponding to average yield of 3.44 t/ha, and not much more than what the world agriculture is producing currently.

Reducing wastage is not going to be a simple matter because the issues involved are to do with our food habits and life styles as we become more affluent, urbanized and globalized, and the way the modern food system operates to store, process, and package and deliver food to meet demands. However, we can presume that there will be increasing pressure in the future from the consumers and governments to minimize wastage of food as cost of production and consumer prices rise, particularly in view to comply with the SDG 12 on responsible consumption and production.

To characterise the nature of the supply side, we have used cereal output required, and the corresponding net land area and average yield, to set the quantities involved. This is because cereals meet two-thirds of our calorie needs. Also, the proportion of net land area under cereals to annual non-cereal crops is generally about 50:50 (Bonte-Friedheim, C. and Kassam, A. 1994), and as cereal production increases, so does the non-cereal production. Thus the total agricultural land area required to meet global agricultural needs from annual cropping at 2050 will be some 763 × 2 = 1.53 billion hectares. Assuming that there is additional need for land for permanent crops of various kinds of some 0.5 billion hectares would suggest a total net land area needed for annual and perennial crops of around 2 billion hectares.

Currently the total agricultural cropped area is 1.6 billion hectares. According to FAO (FAO/IIASA 2002; (FAO 2012), potential suitable agricultural land area globally (i.e. very suitable, suitable and moderately suitable land combined) is some 4.5 billion hectares. Thus, the net current cropped land area corresponds to some 36 per cent of the total global available suitable land area. In addition to the suitable agricultural land, there is some 2.7 billion hectares of marginal lands. We believe that this includes some 0.4 to 0.5 billion hectares of land area that was once suitable agricultural land but has been abandoned over the years (Dregne, H.E. and Chou, N.T. 1992; Pimentel, D. *et al*. 1995; Montgomery, D.R. 2007; Gibbs, H.K. and Salmon, J.M. 2015), particularly since the World War II, due to severe land degradation and erosion arising from the unsustainable way land is managed under the tillage-based agriculture in industrialized countries and in developing countries (Montgomery, D.R. 2007).

For the expected plateau population of 10 billion around 2100 and beyond, the total cereal required could be some 5 billion tones, if everyone were to demand some 500 kg per capita of cereals, which is the current level in Europe to meet food, feed and biofuel demands and the amount that is wasted. This equates to a yield of some 6.55 t/ha assuming no more area expansion in the net cropped area beyond 2050 (i.e. 763 million hectares) and no decrease in wastage, or 5.24 t/ha assuming 50 per cent decrease in wastage. Alternately, if we assumed an expansion of net land area for cereal cropping to 1 billion hectares, then the corresponding yields would be 5 t/ha, assuming current levels of food wastage, or 4 t/ha assuming a 50 per cent decrease in food wastage.

Whichever way the future unfolds, it would seem that the total net area required to meet global food and agricultural needs would be between 2 and 2.5 billion hectares. Based on the assessments of land and water resources available, FAO and their collaborators have maintained that it should be possible to meet 2050 global food, feed, biofuel demand (including wastage) within realistic rates for land and water use expansion and yield development (FAO 2014).

The 'hidden' reality and societal cost of conventional tillage agriculture

While the quantities of yield and total output supply involved to support the food demand at 2050 appear agronomically doable, and there appears to be enough available land and water resources to support the required output, the reality on the ground on farms tells a different story.

The FAO future projections are based on assessments that assume the continued use of the tillage-based agricultural production systems (FAO 1978–l981, 2012, 2014; FAO/IIASA 1984, 2002). However, the assessments do not explicitly take into account the resulting degradation and loss of crop and land productivity that has been occurring over the past years and which will continue in the future, leading to loss in productivity and marginalization and abandonment of agricultural lands. The marginal suitability category of land in the FAO assessments includes much of the degraded and abandoned agricultural land whose original agroecological suitability status is unknown.

Additionally, it is assumed that yield gaps can continue to be filled based on the current practice of intensive tillage and increased application of costly and excessive production inputs, assuming the same or even higher production increase rates than in the past. In other words, the paradigm assumed to meet future food demand in the future scenarios of FAO and their collaborators is the degrading 'business as usual' (FAO 1978–1981, 2012, 2014; FAO/IIASA 1984, 2002).

This 'more of the same' approach to intensification can no longer be considered to be sustainable economically, environmentally and socially anywhere including in the industrialized nations and in the emerging economies. In the low income countries, tillage agriculture based on the use of hoes and animal traction to pull simple ploughs leads to land degradation and loss of top soil to the point where land is eventually abandoned. Often, the lack of mineral fertilizers accelerates the loss in crop and land productivity.

Further, in many important high yield production areas the yields have reached a ceiling (Brisson, N. *et al.* 2010), with declining or even negative rates of yield increase. Conventional tillage-based production systems (sometime referred to as the Green Revolution (GR) agriculture paradigm) have generally become unsustainable for the future. This is because they have been causing land and ecosystem degradation, including loss of agricultural land, and loss of productivity and ecosystem and societal services (Montgomery, D.R. 2007; Goddard, T.M. *et al.* 2007; Kassam, A. *et al.* 2009, 2013;

Lindwall, C.W. and Sontag, B. 2010; Basch, G. *et al*. 2012; Jat, R.A. *et al*. 2014; Farooq, M. and Siddique, K.H.M. 2015).

This GR approach does not seem to be going anywhere now even in the nations where it is claimed to have made an impact in the 1960s and the 1970s. For example, it is often stated that countries in Asia were the first to benefit from the GR, but the question is why did it not continue to spread? In fact, the conventional 'modern' approach to crop production intensification based on expensive intensive tillage, seeds, agrochemicals and energy is often not affordable by resource poor smallholder farmers, nor does it lend itself to socio-culturally inclusive development, given that all the individual production enhancing interventions of increased inputs must fit into some form of a 'neoliberal business model' in which it is assumed that farmers must purchase additional inputs from retail dealers in the supply chain who are buying those inputs from the wholesale dealers who are supplied by the manufacturer.

The point we are making is that the so called GR approach has led, particularly since World War II, to a paradigm for production intensification that is based on intensive tillage and the notion that more output can only come from applying more purchased inputs, and that farmers and their service providers and governments do not need to worry about the negative externalities that may arise as a result of the production practices being applied (Pretty, J. 2002; Beddington, J. 2011). Nor is there any concern being expressed in the conventional GR agriculture approach about agricultural land area continuing to be severely degraded and abandoned due to the negative impact of the conventional tillage-based production paradigm (Kassam, A. *et al*. 2009, 2013). Many areas, which in human history were the cradle of culture and intensive agriculture, are deserts today (Montgomery, D.R. 2007).

Some 400 million hectaresof agricultural lands are reported to have been abandoned since the World War II due to severe soil and land degradation; and yields of staple cereals in industrialized regions appear to have stagnated under tillage agriculture (Montgomery, D.R. 2007; Brisson, N. *et al*. 2010, Gibbs, H.K. and Salmon, J.M. 2015). These are signs of unsustainability at the structural level in the society, and it is at the structural level, for both supply side and demand side, that we need transformed mind sets about production, consumption and distribution. Intensification under the GR paradigm globally has led to more intensive and aggressive mechanical soil tillage, input use and the application of economic models such as the specialization leading to extended monocropping. The result is more land degradation, erosion, pollution and vulnerability of agriculture related to extreme climatic events under a climate change scenario.

These practices in the tillage-based conventional production systems have all contributed, at all levels of development, to soil degradation and loss of agricultural land, decrease in attainable yields and input factor productivity, and excessive use of seeds, agrochemicals, water and energy, increase in cost of production, and poor resilience. They have also led to dysfunctional ecosystems, degraded ecosystem and societal services, including water quality and quantity, nutrient and carbon cycles, suboptimal water, nutrient and carbon provisioning and regulatory water services, and loss of soil and landscape biodiversity. They all constitute the unacceptable food, agricultural and environmental costs being passed on to the public and to the future generations.

This is why we say that if we are to: (i) mobilize greater crop and land potentials sustainably to meet future food, agriculture and environmental demands; (ii) maintain highest levels of productivity, efficiency and resilience ('more from less'); and (iii) rehabilitate degraded and abandoned agricultural land and ecosystem services, we need to replace the faltering production 'engine'– the conventional tillage-based production paradigm – and transform the food and agriculture systems that are built upon it. This transformation is now ongoing and needs to be accelerated (Goddard, T.M. *et al*. 2007; Kassam, A. *et al*. 2009, 2013, 2015, 2016; Lindwall, C.W. and Sontag, B. 2010; Jat, R.A. *et al*. 2014; Farooq, M. and Siddique, K.H.M. 2015).

Replacing the faltering conventional tillage-based production engine with no-till CA

Soil's productive capacity is derived from its many components (physical, biological, chemical, hydrological, climate) all of which interact dynamically in space and time within cropping systems and within agroecological and socio-economic environments. A productive soil is a living biological system and its health and productivity depends on managing it as a complex biological system, not as a geological entity. A regularly tilled soil, whether with a hand hoe or with a plough, eventually collapses and becomes compacted, cloddy and self-sealing. Instead of having 50 to 60 per cent air space in a healthy undisturbed soil, tilled soils have much lower volume of air space and no significant network of biopores. Of the 50 to 60 per cent pore space in a healthy soil, some 50 per cent can be filled with water, thus serving as a major buffer against climate variability. On the other hand, a regularly tilled soil would hold much less water due to its low pore volume and poor aggregate stability.

Scientific studies and empirical evidence worldwide have shown that the biology of the soil and all the biological processes along with the other chemical, hydrological and physical processes depend on soil organic matter content.

So the real secret of maintaining a healthy soil is to manage the carbon cycle properly, so that the soil organic matter content is always as high as possible above 2 per cent, that the soil is not disturbed mechanically to minimize the decomposition of organic matter, and that the soil surface is protected with a permanent layer of organic mulch cover which also serves as a substrate for soil microorganisms. In addition to maintain and support natural enemies of pests, a food web must be allowed to establish itself in the field, and this can only occur if there is a source of decomposing organic matter upon which to establish a food web above and below the ground surface, providing habitats for the natural enemies of pests.

As FAO's 'Save and Grow' approach shows (FAO 2011, 2016), to harness the conditions that are sufficient for achieving sustainable production intensification, agriculture must literally return to its roots and rediscover the importance of healthy soils, landscapes and ecosystems while conserving resources, enhancing natural capital and the flow of ecosystem and societal services at all levels – field, farm, community, landscape, territory and national (and beyond). The no-till production paradigm, known as CA (CA), is totally compatible with the above multi-dimensional goal as defined by its following three interlinked principles (www.fao.org/ag/ca):

1. *No or minimum mechanical soil disturbance.* Avoiding tillage and sowing seed or planting crops directly into untilled soil in order to: lessen the loss of soil organic matter and disruptive mechanical cutting and smearing of pressure faces, promote soil microbiological processes, protect soil structure and connected pores, avoid impairing movement of gasses and water through the soil, and promote overall soil health.

2. *Maintaining a permanent mulch cover on the soil surface with growing plants and crop residue***.** Use crop residues (including stubbles) and cover crops to: protect the soil surface, conserve water and nutrients, supply organic matter and carbon to the soil system and promote soil microbiological activity to enhance and maintain soil health including structure and aggregate stability (resulting from glomalin production by mycorrhyza), and contribute to integrated weed, pest and nutrient management.

3. *Diversification of species.* Use of diversified cropping systems with crops in associations, sequences or rotations that will contribute to: diversity in rooting morphology,

root compositions, enhanced microbiological activity, crop nutrition, crop protection, and soil organic matter build-up. Crops can include annuals, trees, shrubs, nitrogen-fixing legumes and pasture, as appropriate.

Implementing the above three principles using locally appropriate practices, along with other good practices of crop, soil, nutrient, water, pest, energy management, the above principles appear to offer entirely-appropriate solution, potentially able to slow or reverse productivity losses and environmental damages. They also offer a range of other benefits, which generally increase over time as new and healthier soil productivity equilibrium is established, including:

- Increase yields, farm production and profit, depending on the level of initial degradation and yield level (ECAF 2011; Soane, B.D. *et al*. 2012; Jat, R.A. *et al*. 2015; Farooq, M. and Siddique, H.K.M. 2015; Li, H. *et al*. 2016; Kassam, A. *et al*. 2013, 2016).
- Up to 50 per cent less fertilizer required if already applying high rates, and greater nutrient productivity with increased soil organic matter level (Sims, B. and Kassam, A. 2015; Lalani, B. *et al*. 2016; Kassam, A. *et al*. 2016).
- Some 20–50 per cent less pesticides and herbicides required if already applying high rates, and greater output per unit of pesticide or herbicide. In the case where pesticides and herbicides are not used or available, integrated weed and pest management can achieve adequate pest and weed control with less labour requirements (Lindwall, C.W. and Sonntag, B. 2010; Lalani, B. *et al*. 2016; Kassam, A. *et al*. 2016).
- Up to 70 per cent less machinery, energy and labour costs. In manual production systems there can be a 50 per cent reduction in labour requirement as there is much less or no labour required for seedbed preparation and for weeding (Sims, B. and Kassam, A. 2015; Freixial, R. and Carvalho, M. 2010).
- Decrease in soil erosion and water runoff (Derpsch, R. 2003), increase water infiltration, water retention and up to 40 per cent reduced water requirement and increased water productivity in rainfed and irrigated conditions (Landers, J. 2007; Basch, G. *et al*. 2012; Jat, R.A. *et al*. 2015).
- Greater adaptability to climate change in terms of more stable yields, and lower impact of climate variability from drought, floods, heat and cold (Thierfelder, C. *et al*. 2015; Kassam, A. *et al*. 2016).
- Increased contribution to climate change mitigation from increased soil carbon sequestration, reduced greenhouse gas emissions, and decrease in the use of fossil fuel. Additionally, lower carbon and environmental footprint due to reduced use of manufactured inputs such as agrochemicals and machinery (ECAF 2011; Corsi, S. *et al*. 2012; Gonzalez-Sanchez, E.J. *et al*. 2012; Kassam, A. *et al*. 2009, 2013).
- Lower environmental cost to the society due to reduced levels of water pollution, and damage to infrastructure such as roads, bridges and riverbanks as well as water bodies due to reduced erosion and floods (Mello, I. and van Raij, B. 2006; ECAF 2011; Laurent, F. *et al*. 2011; ANA 2011; ITAIPU 2011).
- Rehabilitation of degraded lands and ecoservices from all agricultural land under use as well as from abandoned agricultural land in which the eroded topsoil and the soil profile need to be rebuild (Kassam, A. *et al*. 2013).
- Greater opportunity for establishing large scale, community-based, cross-sectorial ecosystem service programmes such as the watershed services programme in the Parana Basin in Brazil, and the carbon offset trading scheme in Alberta, Canada (Mello, I. and van Raij, B. 2006; Haugen-Kozyra, K. and Goddard, T.M. 2009; Kassam, A. *et al*. 2011, 2013; Laurent, F. *et al*. 2011; ANA 2011; ITAIPU 2011; CCC 2011).

The above benefits have now been documented on large and small farms throughout the world (Goddard, T.M. *et al.* 2007; Jat, R.A. *et al.* 2015; Farooq, M. and Siddique, K.H.M. 2015; Kassam, A. *et al.* 2015, 2016).

Consequently, increasingly greater attention is being paid to support the adoption and upscaling of CA by governments, international research and development organizations, national research and development bodies, NGOs and donors. They all see it as a viable option for sustainable production intensification to support local and national food security, poverty alleviation, especially of smallholders, improving ecosystem services, and reducing cost of production and minimizing land degradation. In 2013–2014, the global spread of CA was 157 million hectares of annual cropland, and since 2008–2009, the global area under CA has expanded at an annual rate of expansion of 10 million hectares. Some 50 per cent of the area is located in the developing regions and 50 per cent in the industrialized world.

Increasingly, CA is also seen to be complementary to System of Rice Intensification (SRI) because SRI performs best when aerobic soil conditions are maintained. Integrating SRI into rice crop management under CA increases significantly the water saving and yield potential. In practice, the SRI crop management method of planting in wide square spacing appears to benefit not only rice but many other crops including wheat, millet, tef, pulses and oilseeds, and vegetables (Uphoff, N. 2015).

Concluding remarks

In light of the above, we draw the following conclusions:

- Meeting 2050 food demand is agronomically doable. However, business as usual, and continuing to rely on conventional tillage-based farming system for further intensification of agricultural production, is not an option to meet future needs sustainably.
- For the farming communities, CA addresses the root causes of agricultural land degradation, sub-optimal ecological crop and land potentials or yield ceilings, and poor crop phenotypic expressions and yield gaps.
- CA is potentially applicable in most land-based agro-ecosystems and all cropping systems in rainfed and irrigated conditions.
- CA is increasingly seen as a real alternative and constraints to adoption are being addressed. It is now increasing at the annual rate of 10 million hectares and covered some 157 million hectares in 2013–2014.
- Land, water and climate constraints affect regions differently. All regions, but especially resource-poor regions, and areas affected by climate change would benefit immediately from CA.
- For developed regions, CA can improve profit, sustainability and efficiency at high yields with less degradation and more resistance to climatic shocks. For the high output farmer, CA offers greater efficiency (productivity) and profit, resilience and stewardship.
- For developing regions, CA offers greater output and profit to small and large farmers with less resources and land degradation. CA not only provides the possibility of increased crop yields for the low input smallholder farmer, it also provides a pro-poor rural and agricultural development model to support agricultural intensification in an affordable manner and an affordable way to adapt to climate change.
- CA is capable of rehabilitating degraded lands and ecosystem services on land-based production systems world-wide.
- Policy and institutional (including education and research) support, farmer organizations and champions are needed to mainstream the adoption of CA globally.

As national economies expand and diversify, more people become integrated into the economy and are able to access food. However, for those whose livelihoods continue to depend on agriculture to feed themselves and the rest of the world population, the challenge is for agriculture to produce the needed food and raw material for industry with minimum harm to the environment and the society, and to produce it with maximum efficiency and resilience against abiotic and biotic stresses, including those arising from climate change.

There is growing empirical and scientific evidence worldwide that the future global supplies of food and agricultural raw materials can be assured sustainably at much lower environmental and economic cost by shifting away from conventional tillage-based food and agriculture systems to no-till CA-based food and agriculture systems. To achieve this goal will require effective national and global policy and institutional support (including research and education).

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Sustainability using cover crops in Mediterranean tree crops, olives and vines – Challenges and current knowledge

José A. GÓMEZ[1]

Abstract

Tree crops cover a large area of European landscape, 13.3 million hectares, with olive, grapes, nuts and almonds been the most extended and mostly concentrated in Mediterranean areas. The cultivation of tree crops in rain limited Mediterranean areas depend on an adequate management of water balance that, been historically mostly based on bare soil, has created severe erosion and offsite contamination problems. Temporary cover crops can be an alternative to control these problems with a larger effect on erosion control than on reducing runoff, and a moderate impact on soil properties. This impact depend strongly on the ability to implement temporary cover crops that achieve a significant development during the rainy season while simultaneously minimizing the competition for soil water with the major crop, which is not always easy in commercial farms. This balance between soil protection and yield has been achieved in some conditions but not in others, and a significant reduction in yield has been reported for some situations. This potential risk of yield decrease, combine with the difficulty to see a collapse in yield due to soil degradation by water erosion in the short/medium term can explain, partially, the reluctance of farmers for an extensive use of temporary cover crops. The development of improved strategies for using temporary cover crops which could include the use of water balance models, new varieties better adapted to the region, and strategies for restoring ground cover in severely degraded orchards seems to be necessary, coupled with regulations and incentive to their use by farmers. Future research should focus in the less understood elements of this system, among them root development, biomass production, phenology under different microclimate of the cover crops and the main tree crops, use of cover crops mixes, which are hampering the tuning of the system for specific conditions. It is also necessary a better definition and measurement of the impacts of cover crops on biodiversity that should be related to the landscape conditions.

Keywords: olive, vines, sustainability, water balance, erosion, Mediterranean

Mediterranean tree crops

Tree crops are a key element of the European agricultural landscape with more than 13 million hectares of permanent tree crops in the EU-28. The majority of them, approximately 80 per cent of the surface, are concentrated in areas with Mediterranean type of climate *(Table 1).* This is because the majority of these crops in the EU (such as olives, citrus or almonds) are best grown under a Mediterranean type of climate. The only exception among the dominant tree crops are vines. The 3.2 million hectares of vines in the EU-28 are distributed across the continent among 21 countries, from Sweden to Malta, albeit the majority of them are also concentrated in Mediterranean areas.

The major reason for that distribution is the favourable conditions in terms of temperature and radiation. Other reasons are the rusticity of some of these tree crops, particularly olives and almonds, which allows cultivation in areas not suitable for other crops or grazing and their double role as a food and cash crop. However, the Mediterranean type of climate is characterized by a limited, and highly variable, precipitation in relation

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[1] Institute for Sustainable Agriculture (IAS) CSIC. Avenida Menéndez Pidal S/N 14004. Cordoba, Spain.
E-mail: joseagomez@ias.csic.es

Table 1. Summary of tree crops extension in the European Union in 1,000 ha

EU member countries	Total	Olives	Grapes	Citrus	Almonds	Nuts	Apples	Pears	Peaches and nectarines	Cherries
EU 28 countries	13,333	*4,992*	*3,178*	*521*	*654*	*1,240*	*539*	*117*	*226*	*173*
Belgium	41	0	0	0	0	5.00	7.06	9.08	0	1.3
Bulgaria	96	0	38.7	0	0.57	6.76	4.81	0.34	3.71	9.3
Czech Republic	46	0	15.8	0	0	0	8.98	0.88	0.48	2.3
Denmark	7	0	0	0	0	0	1.38	0.36	0	1.1
Germany	195	0	100.10	0	0	1.00	31.65	1.92	0	7.2
Estonia	3	0	0	0	0	0	0.90	0	0	0
Ireland	13	0	0	0	0	12.00	0.62	0	0	0
Greece*	1,357	938.3	109.8	49.10	12.57	54.95	12.93	4.97	48.10	13.8
Spain*	5,491	2,526.5	941.1	302.46	548.60	697.90	30.79	23.64	86.51	26.5
France**	1,038	17.1	753.9	4.16	1.12	52.41	52.50	5.36	9.89	8.1
Croatia*	84	17.5	25.6	2.17	0.31	10.52	5.80	1.04	1.06	3.1
Italy*	2,775	1,130.4	683.8	140.16	57.43	198.39	53.01	30.15	67.51	29.4
Cyprus*	30	11.0	5.8	2.69	2.76	3.08	0.63	0.08	0.45	0.2
Latvia	7	0	0	0	0	0	2.80	0.20	0	0.1
Lithuania	34	0	0	0	0	0	11.70	0.90	0	0.8
Luxembourg	7	0	1.3	0	0	5.00	0.24	0.02	0	0
Hungary	131	..	73.1	0	0.20	0.60	33.36	2.89	..	16.1
Malta*	1	0	0.7	0	0	0	0	0	0	0
Netherlands	37	0	0.2	0	0	0	7.91	8.60	0	0.8
Austria	65	0	44.8	0	0	3.00	6.97	0.44	0.17	0.2
Poland	559	0	0.6	0	0	13.00	162.40	9.20	2.40	39.1
Portugal*	844	351.3	178.9	19.80	30.15	173.08	13.66	12.01	3.75	6.4
Romania	388	0	177.7	0	0	3	60.28	3.46	1.65	5.7
Slovenia	19	..	15.7	0	0	0	2.64	0.21	..	0.2
Slovakia	14	0	8.8	0	0	0	3.65	0.13	0.40	0.2
Finland	3	0	0	0	0	0	0.60	0	0	0
Sweden	3	0	0.1	0	0	0	1.30	0.10	0	0.1
United Kingdom	46	0	1.8	0	0	0	20.00	1.00	0	0.7

*Countries with predominant Mediterranean climate. **Some areas with Mediterranean climate. ..= Data non available. *Source*: Own elaboration from Eurostat (2016) available data.

to the potential evapotranspiration (ETo) and by a dry season during the period of maximum temperature and ETo (*Figure 1*).

Agronomical practices in orchards in Mediterranean areas have evolved in the direction of prioritizing the improvement of soil water balance for the tree, to insure productivity and survival of trees and crops under limiting water conditions.

Historically this has been achieved combining three major elements. One is a low tree plant density, which allows a large soil volume for the roots to explore for soil water, with the other two been a limitation of the canopy size by pruning and elimination of weeds to prevent competition for soil water with the tree. This, agronomically sounded, strategy has been successful for allowing tree cultivation over centuries in Mediterranean areas, but it has also created landscapes, like the one shown in *Photo 1* characterized by a simplified landscape with limited ground cover on sloping areas. This has resulted in some environmental problems, particularly severe in some areas of the Mediterranean. Several studies have noted these problems, particularly in olives growing areas (e.g. Beauffoy, G. 2001; Scheidel, A. and Krausmann, F. 2011). They can be summarized in: soil degradation by accelerated water erosion, decrease of water quality by offsite contamination, decrease of biodiversity and an increasing pressure on water resources in areas where irrigation, which is almost exclusively deficit irrigation, has expanded in recent decades.

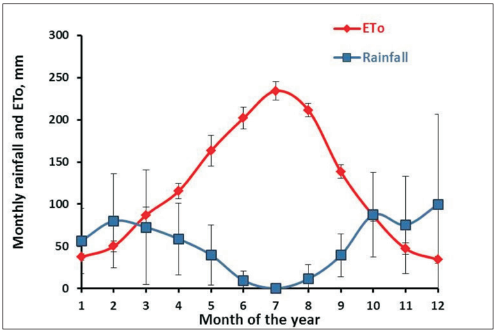

Fig. 1. Average monthly precipitation and potential evapotranspiration (ETo) for Cordoba, Southern Spain, from 2001 to 2015. Error bars indicates standard deviation.

In an effort to mitigate some of these problems it has been an continuous attempt for in introducing the use of cover crops in tree crops on Mediterranean areas, at least since 1969 (Ruíz de Castroviejo, J. 1969). It is worth clarifying that when talking about cover crops in the context of rainfed (or deficit irrigation) tree crops in Mediterranean conditions we always refer to temporary cover crops. *Photo 2* summarized the concept of temporary cover crops which is based on seeding, or allowing growing, of herbaceous vegetation in the lanes during the rainfall season (autumn/fall and winter) controlling chemically or mechanically the cover crop in early spring to prevent losses of soil water by transpiration, and maintaining its residues over the surface until next fall when, ideally, it will regrow from seeds produced during the previous year.

This communication revises some of the issues regarding sustainable cultivation of tree crops in Mediterranean conditions with the use of cover crops, focusing particularly in olives and vines.

Modification of soil properties, erosion and runoff losses at plot scale

Most of the available information to evaluate the impact of the use of temporary cover crop as an alternative to bare soil comes from experiments at plot scale. *Figure 2* summarizes results from experiments carried out under natural rainfall conditions in experiments lasting 2 or more years in plots at least 12 m long. This criterion was followed to limit the bias induced by short term experiments, simulated rainfall, or those performed at very small scale not including relevant processes. *Figure 2* (top side) shows how the use of cover crops has a clear and significant effect on reducing soil losses in olive orchards and vineyards at plot scale. In all the experiments this reduction was found, with an average reduction close to 60 per cent.

Photo 1. View of olive cultivation in a mountainous area in Southern Spain (Montefrío).

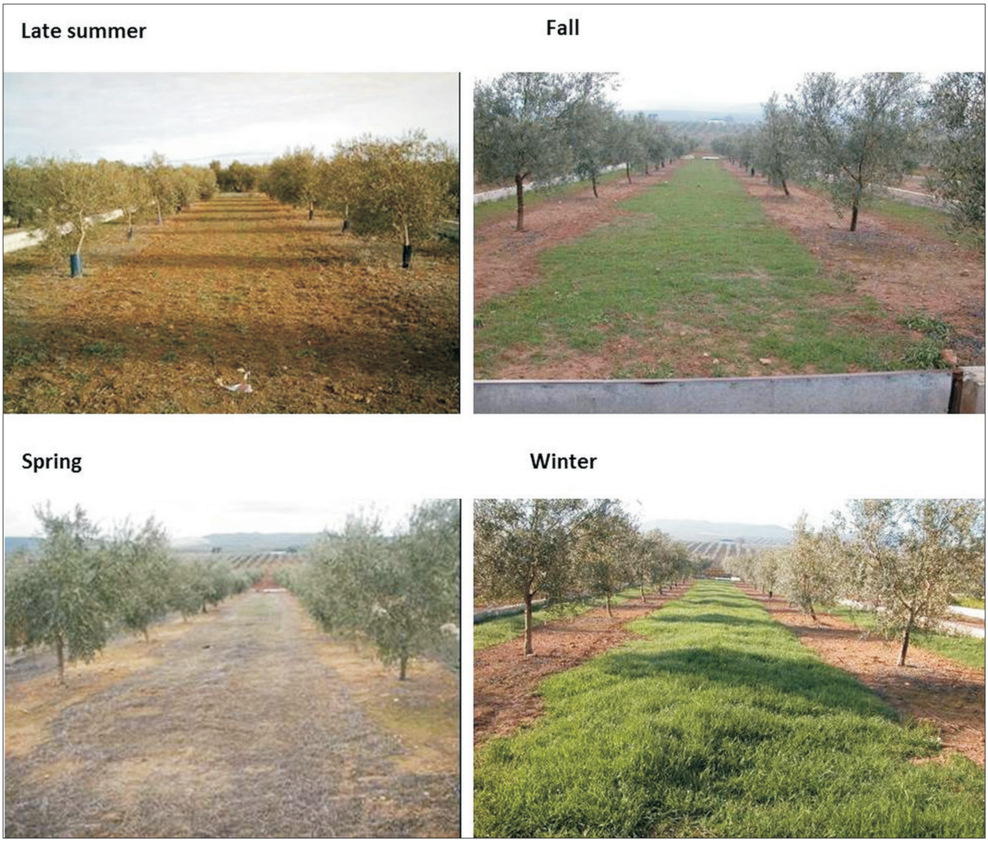

Photo 2. Evolution of a temporary cover crop in an olive orchard during the four seasons of the year.

The effect on average annual runoff is shown in *Figure 2* (down side). In this case the effect of the use of cover crops is not as clear and although there is an overall reduction in average annual runoff of approximately 25 per cent, this reduction is site specific with some orchards and vineyard presenting very small reductions in cover crops (CC) compared to bare soil by conventional tillage (CT) or no tillage with bare soil with herbicide (NT) or even slight increase in runoff, with others showing a large reductions. The reasons for that different answer in runoff and soil losses have been discussed in detail elsewhere (e.g. Gómez, J.A. *et al*. 2011).

They can be summarized in that while the reduction in soil losses is primarily the result of physical protection by the cover crop and its residues, the mechanism controlling infiltration is more complex and varied with sites. In situations where infiltration is limited by surface sealing or reduced porosity of the top soil the over crop has a clear effect, however in situations while the infiltration rate is controlled by saturation of the soil profile or by subsurface layers the effect of the cover crops is very small or negligible.

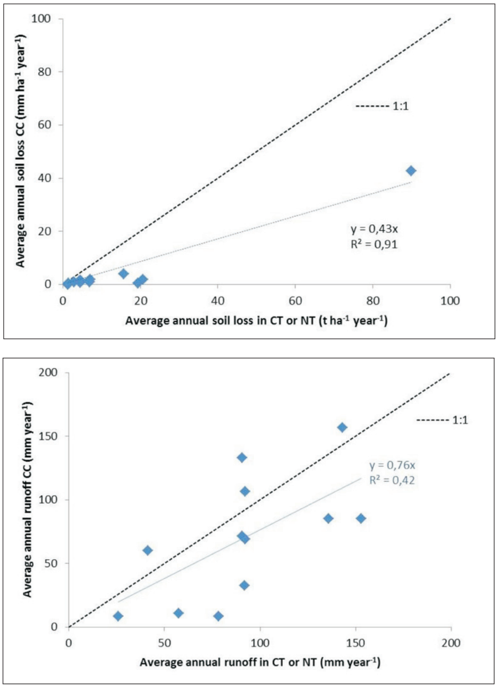

Fig. 2. Comparison of average annual runoff losses (top) and soil losses (down) between cover crops (CC) and bare soil management by tillage (CT) or herbicide (NT) in olives and vineyards. *Source*: Own elaboration from data in Biddoccu, M. *et al*. 2016, and Gómez, J.A. *et al*. 2009a, 2011.

In Mediterranean areas it is frequent to have orchards and vineyards on shallow soils and also periods of high precipitation in which the soil profile is close to saturation. It reasonable to expect that this different answer in runoff and soil losses when using cover crops can be a widespread phenomenon in Mediterranean tree crops. It is worth noting that Maetens, W. *et al*. (2012) in a metanalysis of plot experiments in Europe also detected a higher effect of conservation tillage in reducing soil losses compared runoff losses when compared to conventional systems. *Figure 3* shows for two long term experiments in vineyards and olives the annual variability of the reduction in runoff and soil losses. It is apparent the same overall trend commented before and also that this variability must be related to the interaction between rainfall, soil conditions and soil management within each year, since the overall correlation with annual rainfall is weak.

The spatial distribution of soil properties within an orchards or vineyard is different to those in a field crop, since it has a mosaic pattern in which the influence of the tree and the cover crop induces differences in some of them, like infiltration rate or bulk density. When interpreting and modelling hydrological processes, such as runoff generation, water balance or water erosion, this heterogeneity depicted in photos needs to be considered (*Photo 3a* and *3b*). For instance, Castro, G. *et al*. (2006) showed the relevance of run-on in the under canopy and cover crop area with some of the runoff generated in the area of the lane with bare soil These effects have been, sometimes, incorporated into the efforts for modelling runoff and water erosion in olives and vineyards at hillslope scale. For instance, Romero, P. *et al*. (2007) developed and validated values for the CN method for different soil

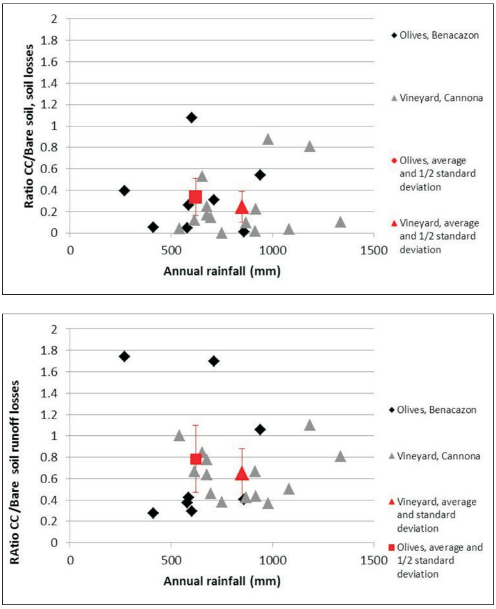

Fig. 3. Annual ratio of soil (top) and runoff losses (down) between cover crops (CC) and bare soil management by tillage (CT) or herbicide (NT) in olives and vineyards. *Source*: Own elaboration from data in Biddoccu, M. *et al*. (2016), and Gómez, J.A. *et al*. (2011) and unpublished data.

management in olive orchards, and these CN values have been used successfully in water balance models in olives (Abazi, U. *et al*. 2012).

The CN method has also been used for determining runoff losses in water balance modes in vines in Mediterranean conditions (e.g. Celette, F. *et al*. 2010) although in these case the CN values were apparently taken from the values developed for orchards in USA by the USDA. The effect of soil management in water erosion in olives and vines has been incorporated in RUSLE through calibration of C values for specific conditions. Gómez, J.A. *et al*. (2003) proposed several C values for different olive plant density and soil management in orchards considering the influence of the variation of soil moisture content during the year.

These C values seem to provide reliable predictions of soil losses when compared to long term erosion rates estimations (Vanwallegem, T. *et al*. 2011) or plot data (Marin, V.J. 2013). Auerswald, K. and Schwab, A. (1999) proposed C values for USLE for different soil management and vine plant density in Germany, although to our knowledge, these values have not been validated. When comparing C values for vines proposed by different authors in Europe (Gómez, J.A. *et al*. 2016) it is noticeable that they show large differences even for apparently similar managements. This is probably for a combination of differences in the conditions for which they have been determined and the lack of a standard approach for its calibration and validation. Overall, all the C values proposed for olives and vines capture the trend towards reduced erosion with the use of cover crops, albeit there is the need for extensive validation to evaluate the uncertainty existing on the predicted values of soil loss.

The modification of soil properties induced by the cover crop in an orchard and vine tend to be limited to the area where the cover crop is implanted, usually only a fraction of the orchard (see *Photo 3–4*), and tend to be concentrated in the top 0–20 cm of the soil (see Gómez, J.A. *et al*. 2009a). For this reason their overall impact on nutrient and carbon content in the orchards and vines, albeit significant, tend to be limited and related to the spatial extension of the cover crop strip. An element of major concern when extrapolating the benefits of the cover crops, in term of runoff and soil loss reduction, from experimental areas to commercial farms should be the large variability in the "quality" of the cover crop found in different farms *(Photo 5–6)*. This "quality" should be understood as the ability to provide enough ground cover and biomass during the rainy season in a significant area of the orchard. In transects within a relatively small areas Gómez, J.A. *et al*. (unpublished data) measured in spring (before killing the cover crop) values of aboveground biomass for the cover crop area from 0.1 t/ha (almost bare soil) to 1.8 t/ha (which provided a good ground cover).

There are several reasons for this large disparity in cover crops development, among them differences in soil quality, seed bank and soil management among different orchards.

Photo 3–4. View of orchards showing the area of influence of the olive canopy (top) and the cover crop (down).

Photo 5–6. Comparison of two olive orchards declaring use of cover crops, Note narrow over crop strips in the upper picture compared to the one below.

Similar differences in cover crop biomass production in the lanes of olive orchards have also been noted by other authors (e.g. Vicente-Vicente, J.L. 2017). These results highlight the need of more focused efforts in developing innovative strategies for achieving successful implementation of temporary cover crops in these situations which in many cases are associated to severely degraded soils. Gómez, J.A. *et al.* (2009b) noted this heterogeneity of cover crop conditions as one of the reasons for the large variability found in organic olive orchards with cover crop management. Gómez, J.A. *et al*. (2014a) discussed the implications of these large differences between experimental results and field situations when trying to estimate regional erosion rates for olive growing areas in Andalusia. He noted a variation of approximately 30 per cent in the predicted average erosion rate and severely degraded area estimation under current common agricultural policy (CAP) regulations regarding the compulsory use of cover crops when introducing a decrease in the efficiency of these cover crops based on calibrating the C factor of RUSLE based on observations of cover crops status from field visits to several orchard in the region.

Water balance and yield

Water is the major limiting factor for agricultural production in semiarid environment with soil management playing a major role in controlling that water balance (Henderson, D.W. 1979). A modification of soil management such as the use of temporary cover crops in Mediterranean tree crop cannot be successful without understanding the implications for yield due to the modification of the water actually available to the crop. *Figure 4* depicts the results of some experiments comparing the impact on olive fruit and wine yield of temporary cover crops in olives and wines. It is apparent that in some situations the system of temporary cover crops has been adjusted to provide soil protection while achieving yields that are similar to those under bare soil management (e.g. CC controlled in early spring in *Figure 4*), although in other situations, (e.g. those controlled in mid-late spring in *Figure* 4) there is a significant decrease in yield.

This decrease when comparing those approaches (CC vs. CT) has been noted by other researchers in long-term experiments (e.g. Ferreira, I.Q. *et al*. 2013). This potential risk of a yield decrease remains a major obstacle for expanding the use of temporary cover crops in Mediterranean tree crops particularly under rainfed conditions. Another tool to fine tune the management of cover crops under a broad range of conditions is the use of simulation models to study its impact on water balance.

The literature describes several models developed for vines or olives. For instance, Celette, F. *et al*. (2011) presented WALIS as a simple model to simulate water partitioning in a crop association and use it to study the case of an intercropped vineyard, while Abazi, U. *et al*. (2013) presented WABOL, other conceptual model for the case of intercropped olives. These studies concluded that the models provided realistic simulations, and they could be useful tools in providing a better understanding of cover crops in olives and vines. However, in both studies the authors mentioned the need for an extensive validation of the model results, which to date

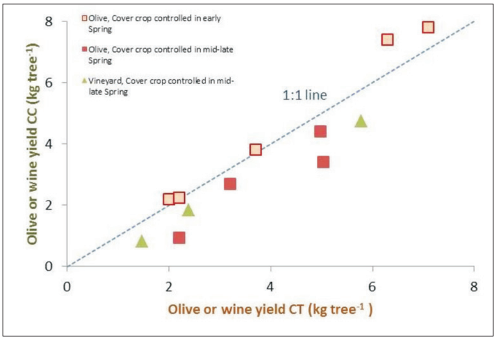

Fig. 4. Comparison of vine and olive yield in conventional tillage (CT) and temporary cover crop (CC). *Source*: Own elaboration from data in Gómez, J.A. 2005, and Ruíz-Colmenero, M. *et al*. 2011.

still lacking. Parameterization of these models is of paramount importance and some of their key parameters still remain relatively poorly understood. Among those less understood are the phenology and root development of the tree crops and cover crops species under different conditions, the effect of capillary rise of subsurface layers during the dry season, and improved determination of the transpiration of the tree and cover crops in complex situation such as only partial ground cover or vertic soils are among the processes on which future research could be focused.

Even with the caveats mentioned by the authors, these conceptual models have provided insight into the feasibility of cover crop use under different conditions. *Figure 5* summarizes the results of a study made by Abazi, U. *et al*. (2012) in which the variations in olive transpiration under different conditions in cover crop and conventional tillage conditions were evaluated for Andalusia (Southern Spain). The model results predicted for some situations no significant differences in olive transpiration while it also predicted in other locations that CT seems to have slightly higher transpiration compared to CC, which agree with the agronomical experiments previously commented.

These conceptual models incorporate the effect of soil depth into soil water storage capacity, and so they have the potential to be used in the evaluation on the decrease of vine or olives potential productivity due to the reduction of soil water availability accompanying the decrease of available soil depth by accelerated erosion. Gómez, J.A. *et al*. (2014a) evaluate the effect of decreasing soil depth on olive potential productivity under two contrasting situations both characteristic of large areas in the Mediterranean: soils with relatively good water holding capacity and stony soils with worse water holding capacity.

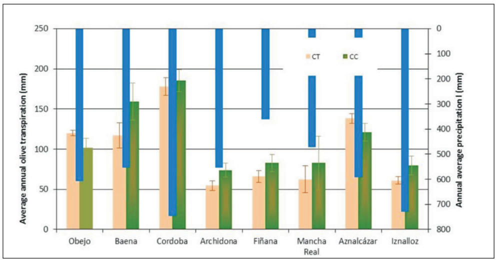

Fig. 5. Predicted olive transpiration for the average conditions rainfed olives in eight locations in Andalusia under conventional tillage (CT) and temporary cover crop (CC) for period 2006–2010. Error bars are standard deviation. *Source*: Adapted from Abazi, U. *et al*. 2012.

Figure 6 summarizes some of the major results of this study. One is that for soils with relatively deep rooting zones and good soil water holding capacity the decrease in potential yield appears clearly only at very shallow soil depths (see lines for Cordoba situation in *Figure 6*). The other is that the slope of the decrease in potential yield with decreasing soil depth is not very steep, so the year to year decrease in potential year can be masked by other factors such as climate variability, pest and effect of agronomical practices.

Both facts combined can help to understand, at least partially, the low priority given by farmers to the implementation of soil erosion control practices in olives. Basically, because the effects of soil degradation in the reduction of potential yield are difficult to be observed in the short or medium term, and its worst effects will be suffered in the future. Vanwalleghem, T. *et al*. (2011) noted this situation in an mountainous olive growing area in Southern Spain in which the loss of ap-

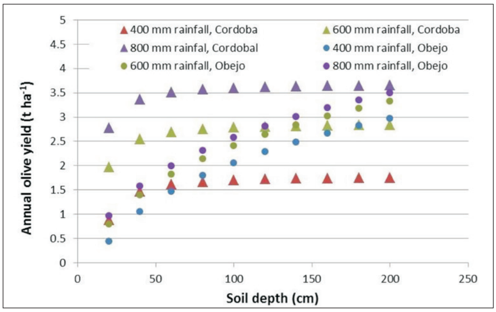

Fig. 6. Potential olive tree yield for different average annual rainfall and rooting depth for two contrasting situations: Obejo, sandy soils with coarse material and moderate water holding capacity; Cordoba, fine textured soils with high water holding capacity. *Source*: Adapted from data in Gómez, J.A. *et al*. 2014a.

proximately 40 cm of rooting depth (from 120 to 80 cm approximately) in olive orchards in the area in the time span of two centuries was accompanied by an increase in yield, attributed to improved agronomical practices.

This situation, soil degradation due to soil erosion which is not currently decreasing yields dramatically and it will not do it in the medium term, can be a recurrent pattern in some of the tree crops growing areas in Mediterranean regions. All these facts considered suggest the need for regulations and incentives for erosion control on tree crops growing areas in the Mediterranean regions, particularly when most of the cost of erosion from these areas has been played downstream. Costs of soil erosion from agricultural areas in Europe has been estimated by Montanarella, L. (2007) as an average of 48 EUR/ha per year (within the range from 4.8 to 93.0 EUR/ha per year) with off-site damages representing more than 90 per cent of this costs.

A review of possible strategies for implementation cover crops

Table 2 summarizes the major kind of cover crops alternatives and some of the main issues regarding the choice of the option best suited for a given objective, as well as some of the major features and decisions to be considered regarding their implantation and management. In the context of limited water availability the decision for temporary cover crops aimed mostly to soil management has oriented many of the experiences in olives and vines towards the use of grasses.

Several research projects has pursued the selection of grasses from local species which present a shorter growing cycle and could emerge with the first rains in fall and complete the seed development by late winter or early spring. This is the situation depicted in *Photo 7* in which a difference in phenology of several weeks can be appreciated among several grasses. A shorter, best adapted, cycle will results in a lower risk for water competition but also in a better persistence of the

Table 2. Summary of alternatives of cover crops based on objectives and major questions regarding management practices

Purpose	Kind of cover crops	Main features	Management	
			Alternatives	Decisions
Biodiversity	Mixes, including several species with flowers	Composition, persistence of the differences species, phenology	Composition of mix	Which us? Cost
Fertility	Legumes/Legumes and grasses	Annuals or perennials? Phenology? Resilience? Size? Precocity?	Control methods: herbicide, mowing, grazing, tillage?	Control method: When? Frequency?
Erosion	Grasses			
Grazing	Legumes/Legumes and grasses			
Trafficability	Grasses	Biomass production and ground cover?	Extension of cover crop	Layout in the slope, width of cover crop?

Photo 7. View of a cover crops experiment in Cordoba (Southern Spain) in early May. It is apparent the different in phenology between raygrass (front of picture still green) with *Bromus* (mid position in the picture, already eared and dried).

introduced cover crop in the plot, since it will have greater chances of producing seed before been controlled. In the search of better adapter species of grasses, precocity in emergence and a shorter size (an eventually lower biomass production) are also characters favoured. In vineyards, and lately although sporadically in olives, it is relatively frequent the use of mixes combining many species designed to increase biodiversity providing a large period with flowers in the orchard (e.g. Sweet, R.M, *et al*. 2010; Gómez, J.A. *et al*. 2014b).

There is a limited understanding of the dynamic of these mixes composed by a large number of different species. Gómez, J.A. *et al*. (2017) noted how a large number of them were not found in surveys in the seeded plots one and two years after their seeding, indicating how a lower number of species composed the majority of the flora in the plots. A better understanding the dynamic of mixes, in terms not only of composition and long term evolution but also in terms or air and root biomass production of the different components are necessary if we want to evaluate these promising new alternatives using water balance models. The use of less diverse mixes can be useful in this objectives, as well as in optimizing expenditure in seed of species that could actually been viable in a mix for a given condition. *Figure 7* shows preliminary results of a study comparing the evaluation of a simple mix with three species chosen from local flora for their potential.

Despite all these efforts, statistics indicates that in many situations farmers still choose not to seed but to develop a cover crop from the flora naturally present in the

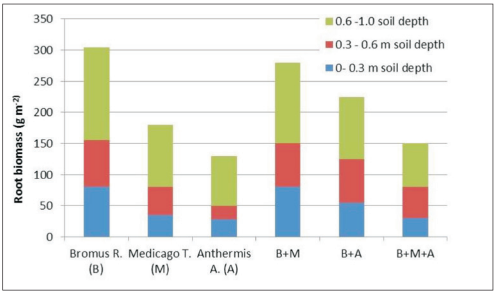

Fig 7. Distribution of root biomass with depth for different cover crops alternatives. *Source*: Adapted from Soriano, M.A. *et al*. (2016).

orchard or vineyard. In Spain, for instance of the 30 per cent of the olive orchards using some kind of cover crops, 97 per cent of them opted for natural weeds and only 3 per cent were seeded (MAGRAMA 2013). Cost is probably the major reason for this situation, although other reasons, such as the loose coupling between severe erosion and yield losses discussed above can also play a role. Within this context it might be appropriate to consider strategies for introducing cover crops that will require a very limited cost for farmers, for instance species that could be easily propagated by them. Also concentrating more studies in situations where the naturally present weeds cannot be an alternative, such as in extremely degraded soils with poor fertility and exhausted seed bank.

Effects on biodiversity

An improvement in biodiversity is one of the benefits frequently mentioned when recommending the use of cover crops in tree crops under Mediterranean conditions. However, for an issue which is extremely complex involving different orders of plants and animals and different scales the experimental data are relative limited and indicate less conclusive results than when compared to other of the questions commented in this article.

For instance, Beaufoy, G. (2008) evaluating the results of a project evaluating the future of olive production in sloping land in several EU countries noted how the evaluation of the impact on biodiversity was extremely superficial, indicating the need for a more focused research. In the last years more publications have been published on the subject indicating the need for establishing a clear link between the biodiversity indicator measured and the landscape conditions where the study was performed. Paredes, D. *et al*. (2015) presented the results of a metanalysis evaluating the effect of cover crops in olive orchards in reducing the effect of several pests in Andalusia (Southern Spain), expected due to the increase of natural predators for these pests when using cover crops. Their results show that the presence or not of cover crops explained a very small part of the pest response, with local, landscape and regional variability explaining a large proportion of the variability in pest response variables.

This study points to perennial vegetation close to the focal crop as a promising alternative strategy for conservation biological control that should receive more attention. Focusing in a different indicator of biodiversity, songbirds, Castro-Caro, J.C. *et al*. (2015) predicted that the presence of ground cover and landscape heterogeneity would have a positive effect on songbird communities, although the effect would be greatest in homogeneous environments.

The same team, however, in another study (Castro-Caro, J.C. *et al*. 2014) measured a different response in the abundance and richness of omnivorous vs insectivorous birds to the use of cover crops depending on the presence or not of hedgerows. In their study, they indicated how the richness of insectivorous birds increased with the presence of cover crops, or hedgerow, in the olive orchards, with a maximum increase in richness when both elements (cover crops and hedgerows were present simultaneously). However, in the case of omnivorous birds they did not found a significant increase with any the presence of a cover crop, hedgerows, or both elements in the olive orchards compared to an orchard managed with a bare soil and not hedgerows.

These examples illustrate the complexity of the relationship between use of cover crops and biodiversity. In this context it is not surprising that metanalysis evaluating the impact of cover crops on biodiversity in vineyards have found a moderate impact (Winter, S. *et al*. 2016). However, despite this complexity many of the studies on biodiversity indicate that for a proper understanding of the effect of cover crops in Mediterranean tree crops they need to be linked to the landscape structure and, particularly, to the role of other vegetation in that landscape. The need for this link has been noted also in erosion studies. For instance, Gómez, J.A. *et al*. (2014c) in study in a small catchment on a vertic soil note the relevance of gully erosion which could explain the high erosion rates in very rainy years which had high runoff coefficients.

It is clear that much benefit could be achieved if some of the future studies evaluating the impact of cover crops could incorporate this across-scale effects and interaction with other vegetation for hydrological and biodiversity studies. Also for innovative approaches in the design of environmental regulations that link the benefits of the use of vegetation on landscape, biodiversity and erosion control on solid technical knowledge.

Conclusion

Soil protection, enhancement of biodiversity and water quality are three major ecosystem services that should be delivered by agricultural areas in addition to crop production. Tree crops cover a large area of the European landscape, particularly in the Mediterranean areas. Although research have demonstrated the potential of temporary cover crops to deliver those services in Mediterranean tree crops this potential is not fully exploited. The need to balance two conflicting objectives: an appropriate ground cover vs. an adequate management of the cover crop to limit its water consumption by transpiration to prevent yield reductions, results in many farm situations in a reduced ground cover and biomass production, which it is not enough to deliver those ecosystem services.

The conservative approach of many farmers to cover crops reflects also the limited understanding of key elements that are hampering the fine tuning of the system for specific farm conditions, which is a critical element for success. Future research should focus in the less understood elements of the tree and cover crops system such as: cover crops and tree root distribution and development; biomass production; phenology under different microclimate of the cover crops and the main tree crops; or performance of cover crops mixes. It is also necessary a better definition and measurement of the impacts of cover crops on biodiversity that should be related to the landscape conditions.

This research should lead to the development of improved strategies for using temporary cover crops which could include the use of water balance models, new varieties better adapted to the region, and strategies for restoring ground cover in severely degraded orchards. All they are necessary to expand the use of effective cover crops in Mediterranean tree crops by farmers, coupled with regulations and incentives to promote their use.

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Influence of tillage systems on short-term soil CO_2 emissions

Darija BILANDŽIJA, Željka ZGORELEC and Ivica KISIĆ[1]

Abstract

Agricultural ecosystems can play a significant role in greenhouse gas emissions, specifically, carbon dioxide. Tillage management can increase atmospheric CO_2 concentrations and contribute to global warming but it is uncertain to which extent tillage enhances the transfer of soil CO_2 to the atmosphere. Our objectives were (1) to determine short-term, tillage-induced soil CO_2 emissions; (2) to determine the effect of different tillage systems and time after tillage operation on soil CO_2 emissions and soil microclimate and (3) to examine the relations between short-term soil CO_2 emissions and microclimate (soil temperature, soil water content; air temperature and relative air humidity). Soil CO_2 concentrations were measured on Stagnic Luvisols, in a temperate continental climate of the central lowland Croatia in October 2013 before, zero and three hours after tillage operations with *in situ* closed static chamber method. The four tillage systems were no-tillage (NT), ploughing to 25 cm (P_{25}), very deep ploughing to 50 cm (P_{50}) and subsoiling to 50 cm (PS_{50}). The study showed that tillage has impact on soil CO_2 emissions and soil microclimate. Tillage has accelerated the transfer of soil CO_2 to the atmosphere but soil CO_2 emissions declined sharply within three hours after tillage operations. Soil temperature has decreased after tillage operation and afterwards continued to rise while soil water content has been decreasing during whole study period. Correlations between soil CO_2 emissions and microclimatic factors were mostly weak or modest while best type of studied correlations between soil CO_2 emissions and microclimate showed to be the second order polynomial correlation.

Keywords: short-term soil CO_2 emissions, tillage, soil water content, soil and air temperature, relative air humidity

Introduction

Agricultural sector has contributed by 9.4 per cent to total Croatian greenhouse gas emissions in 2014 (NIR 2016). Agricultural soils can act both as a source or a sink of greenhouse gases. Tillage often accelerates and increases soil CO_2 emissions by speeding organic carbon decomposition i.e. decreasing soil organic matter, changing soil microclimate (temperature and water content), disrupting soil aggregates, increasing aeration and increasing contact between soil and crop residues (Gebhart, D.L. *et al.* 1994; Reicosky, D.C. *et al.* 1995, 1997; Gregorich, E.G. *et al.* 2005; Bilen, S. *et al.* 2010; Bilandžija, D. *et al.* 2016). Tillage may have long-term influence on soil CO_2 emissions but also it often increases short-term soil CO_2 emissions due to a rapid physical release of CO_2 trapped in the soil air pores (Bilandžija, D. *et al.* 2013). Tillage management can increase atmospheric CO_2 concentrations but it is uncertain to which extent tillage enhances the transfer of soil CO_2 to the atmosphere.

The objectives of our research were (1) to determine the effects of ploughing (30 cm depth), very deep ploughing (50 cm depth) and ploughing (30 cm depth) with subsoiling (50 cm depth) on short-term soil CO_2 emissions relative to no-tillage (NT); (2) to determine the effect of four different tillage systems and time after tillage operation on soil CO_2 emissions and soil microclimate; (3) to determine best function of correlation between soil CO_2 emissions and microclimatic conditions.

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[1] Department of General Agronomy, Faculty of Agriculture, University of Zagreb. Svetošimunska cesta 25, 10 000 Zagreb, Croatia. E-mails: dbilandzija@agr.hr; zzgorelec@agr.hr; ikisic@agr.hr.

Materials and methods

Experimental site and tillage systems

Field experiment with four different tillage systems usually implemented in Croatia was set up in Blagorodovac near Daruvar (elevation: 133 m a.s.l.; N 45°33′54′′, E 17°02′56′′) in central lowland of Croatia. Field experiment was established in 1994 with the aim of research on determination of soil degradation by water erosion and later, in 2011, expanded to the research on soil CO_2 concentration measurements. Soil type at the experimental site is determined as Stagnic Luvisols (IUSS 2014). Size of each tillage plot is 22.1 m × 1.87 m. Tillage systems differed in tools that were used, depth and direction of tillage and planting.

Tillage was conducted in October 2013 and tillage systems were:

a) no-tillage (NT) – planting directly into the mulch along the slope;

b) ploughing to 30 cm (P_{30}) – tillage and planting across the slope;

c) very deep ploughing to 50 cm (P_{50}) – tillage and planting across the slope;

d) ploughing to 30 cm + subsoiling to 50 cm (PS_{50}) – tillage and planting across the slope.

Measurement of CO_2 concentrations and calculation of soil CO_2 emissions

Soil CO_2 concentrations were measured before, zero and three hours after tillage implementation in three repetitions at each plot. For the measurement of soil carbon dioxide concentrations, *in situ* closed static chamber method was used. The chambers were made of lightproof metal material and they consist of two parts: frames (25 cm in diameter) and caps (25 cm in diameter and 9 cm high) fitted with a gas sampling port. The circular frames were inserted about 10 cm into the soil at the beginning of measurements. Before the chambers closure, near the soil surface, the initial CO_2 concentrations inside the frames were measured. Afterwards, the chambers were closed with caps and the incubation period was 30 minutes after which accumulated CO_2 in the chamber was measured *(Photos 1–4)*. Measurements of CO_2 concentrations (ppm) were conducted with portable infrared carbon dioxide detector (GasAlertMicro5 IR, 2011). Measurements were conducted on bare soil and when necessary (at no-tillage system), vegetation was removed before the beginning of measurement.

The soil CO_2 emissions (efflux) were afterwards calculated according to Widen, B. and Lindroth , A. (2003), and Tóth, T. *et al.* (2005) as:

$$FCO_2 = \frac{M \times P \times V\,(c_2 - c_1)}{R \times T \times A\,(t_2 - t_1)},$$

where FCO_2 = soil CO_2 efflux (kg/ha per day); M = molar mass of the CO_2 (kg/mol); P = air pressure (Pa); V = chamber volume (m^3); $c_2 – c_1$ = CO_2 concentration increase rate in the chamber during incubation period (μmol/mol); R = gas constant (J/mol/K); T = air temperature (K); A = chamber surface (m^2); $t_2 – t_1$ = incubation period (day).

Photos 1–4. Measurement of short-term soil CO_2 emissions (from left to right): tillage implementation (1); inserted circular frames into the soil (2); incubation period (3); measurement of accumulated CO_2 in the chamber (4).

Determination of microclimate

Soil temperature, soil water content, air temperature and *relative air humidity* were measured in order to determine their influence on tillage-induced CO$_2$ emissions. Soil temperature (°C) and soil water content (%) were determined with IMKO HD2 - probe Trime, Pico64 (2011) at 10 cm depth in the vicinity of each chamber along with measurement of soil CO$_2$ concentrations. The air temperature (°C) and relative air humidity (%) were determined with Testo 610 (2011) and air pressure was determined with Testo 511 (2011) at the height about 1 m above the soil surface.

Data analysis

Soil CO$_2$ emissions were analyzed using statistical Software SAS (SAS 2002–2004). Variability between tillage systems were evaluated with analysis of variance (ANOVA) and tested, if it were necessary, with adequate *post-hoc* (Bonferroni) t-tests. In all statistical tests significance level was $p \leq 0.05$.

A linear, exponential, logarithmic and second order polynomial regression procedure was used to determine the dependence of each climatological factor on soil surface CO$_2$ emissions. The value of the correlation coefficient was ranked by Roemerk-Orphal scale (0.0–0.10: no correlation; 0.10–0.25: very weak; 0.25–0.40: weak; 0.40–0.50: modest; 0.50–0.75: strong; 0.75–0.90: very strong; 0.90–1.00: full correlation) (Vasilj, Đ. 2000).

Results

Microclimate and short-term tillage-induced soil CO$_2$ emissions

During the studied period on October 28, 2013 (between 8.00 and 17.00 hours) it was mostly sunny and warm, air temperature ranged from 23.2 to 28.2 °C and relative air humidity varied from 50.9 to 60.4 per cent *(Table 1).* Soil temperature before the tillage operations varied from 26.9 to 33.0 °C, immediately after the tillage operations it declined sharply up to 10.9 °C and afterwards it mostly continued to

Table 1. Soil CO$_2$ emissions and climatologic factors (means ± SD) before, zero and three hours after tillage operation (n = 3)

Parameter	Tillage system	Before tillage operation	Zero hours	Three hours
			after tillage operation	
Air temperature, °C	NT	23.2 ± 0.7	25.7 ± 0.5	28.1 ± 0.7
	P$_{30}$	23.2 ± 0.9	25.7 ± 0.3	28.1 ± 0.4
	P$_{50}$	23.4 ± 1.2	25.8 ± 0.3	28.2 ± 1.1
	PS$_{50}$	23.4 ± 0.8	25.8 ± 0.2	28.2± 0.9
Relative air humidity, %	NT	60.4 ± 2.2	55.6 ± 0.8	50.7 ± 1.1
	P$_{30}$	60.4 ± 1.9	55.6 ± 0.7	50.7 ± 0.9
	P$_{50}$	56.7 ± 2.2	53.7 ± 0.9	50.9 ± 1.3
	PS$_{50}$	56.7 ± 2.1	53.7 ± 0.9	50.9 ± 1.1
Soil temperature, °C	NT	33.0 ± 1.7	33.4 ± 2.2	33.0 ± 2.0
	P$_{30}$	31.5 ± 1.3	10.9 ± 0.7	11.5 ± 2.7
	P$_{50}$	26.9 ± 1.3	12.8 ± 2.1	16.2 ± 2.5
	PS$_{50}$	31.0 ± 3.2	11.6 ± 1.5	10.7 ± 1.5
Soil water content, %	NT	23.4 ± 0.1	22.7 ± 0.1	16.2 ± 0.0
	P$_{30}$	23.9 ± 0.3	23.0 ± 0.0	16.2 ± 0.1
	P$_{50}$	25.7 ± 0.1	23.8 ± 0.1	18.7 ± 0.0
	PS$_{50}$	25.7 ± 0.1	23.7 ± 0.1	18.6 ± 0.1
Soil CO$_2$ emissions, kg CO$_2$/ha per day^{-1}	NT	114.1 ± 13.3	100.5 ± 20.1	122.8 ± 16.3
	P$_{30}$	85.9 ± 4.7	126.0 ± 10.2	45.6 ± 6.3
	P$_{50}$	76.5 ± 4.5	116.6 ± 18.8	49.6 ± 6.4
	PS$_{50}$	85.9± 6.3	123.3± 15.3	34.9± 7.6

rise while on no-till system, soil temperature was mostly steady. Soil water content ranged from 23.4 to 25.7 per cent before the tillage operations, and after the tillage operations it was continuously declining during the study period up to 16.2 per cent *(Table 1)*.

The soil CO_2 emissions measured on tilled systems before tillage ranged from 76.5 to 85.9 kg CO_2/ha per day$^-$. Immediately after tillage soil CO_2 emissions ranged from 116.6 to 126.0 kg CO_2/ha per day and were on average 47.4 per cent greater than the average emission before tillage operations, while three hours after tillage it was on average 48.6 per cent lower compared to average emission before tillage operation. The exception was no till system where soil CO_2 emissions were high and ranged from 100.5 to 122.8 kg CO_2/ha per day during the whole study period *(Table 1)*.

Influence of tillage systems and time on soil CO_2 emissions and soil microclimate

Different tillage systems didn't have any significant impact on average soil CO_2 emissions and soil water content while average soil temperature determined at no-till was significantly higher compared to other tilled systems *(Table 2)*.

Average soil CO_2 emission of the experimental plot measured before tillage operation was not significantly different from soil CO_2 emissions after tillage but emissions measured immediately after and three hours after tillage operation were significantly different. Soil temperature measured before tillage was significantly higher compared to those measured after tillage. Soil water content was significantly declining within hours after tillage operation

Correlation between short-term soil CO_2 emissions and microclimate

Between soil CO_2 emissions and soil temperature, very weak positive logarithmic (r = +0.23), modest positive second order polynomial (r = +0.41), weak positive linear (r = +0.25) and exponential (r = +0.35) correlation was determined. The values of correlation coefficients indicate the presence of positive modest linear (r = +0.40), exponential (r = +0.48) and logarithmic (r = +0.40) correlation between soil CO_2 emissions and soil water content. An exception is the correlation in the second order polynomial type which is negatively modest and amounts r = -0.41. Between soil CO_2 emissions and air temperature, negative weak linear (r = -0.36), negative modest exponential (r = -0.47), negative weak logarithmic (r = -0.35) and negative strong second order polynomial (r = -0.70) correlation was determined. Positive weak linear (r = +0.37) and logarithmic (r = +0.38), positive modest exponential (r = +0.46) and negative strong second order polynomial (r = -0.52) correlation was determined between soil CO_2 emissions and relative air humidity.

Table 2. Influence of different tillage systems and time on soil CO_2 emissions and soil microclimate

Tillage	Soil CO_2 emission, kg CO_2/ha per day	Soil temperature, °C	Soil water content, % vol.
NT	112.5 a	33.2 a	20.8 a
P_{30}	85.9 a	18.0 b	21.0 a
P_{50}	80.9 a	18.6 b	22.7 a
PS_{50}	81.4 a	17.8 b	22.7 a
Time	**Soil CO_2 emission, kg CO_2/ha per day**	**Soil temperature, °C**	**Soil water content, % vol.**
Before tillage	90.6 ab	30.6 a	24.7 a
Zero hours after tillage	116.6 a	17.2 b	23.3 b
Three hours after tillage	63.2 b	17.9 b	17.4 c

Averages followed by same letter are not significantly different.

Discussion

Air temperature was rising and relative air humidity was declining during the measurement period. Soil temperature was high and steady at no till during the whole study period while on tilled systems soil temperature declined sharply after tillage operation due to the disruption of soil aggregates and increasing aeration by which the soil climate was changed; after which soil temperature continued to rise. Soil water content was continuously declining, partly due to the tillage operation but also due to the increase of air temperature and an increase in soil water evaporation. Decreased soil water content in tilled treatments just after tillage and the greatest soil water content in NT was observed by Alvaro-Fuentes, J. *et al.* (2007). Lampurlanes, J. *et al.* (2001) also observed greater water contents in NT and suggested that better infiltration rates in NT promoted greater soil water content as compared to tilled treatments.

At no till system, soil CO_2 emission was not significantly higher compared to tilled systems and was high and steady during the whole study period. Soil CO_2 emissions increased rapidly immediately after tillage operation due to physical release of CO_2 from soil pores and solutions at all tilled treatments. A significant increase of CO_2 emission immediately after tillage operations in tillage treatments, except NT, was also observed by Alvaro-Fuentes, J. *et al.* (2007). Already three hours after tillage operation, soil CO_2 emissions declined sharply and were lower compared to emissions measured before tillage operation. Reicosky, D.C. (1997), observed a decrease within 2 hours after a pass with plough.

Many authors (Reicosky, D.C. and Lindstrom, M.J. 1993; Reicosky, D.C. *et al.* 1997; Ellert, B.H. and Janzen, H.H. 1999; Al-Kaisi, M.M. and Yin, X. 2005) also obtained in their research that the effect of tillage on soil CO_2 emission was short-lived. Reicosky, D.C. and Lindstrom, M.J. (1993), and Prior, S.A. *et al.* (2000) suggested that initial CO_2 emission after tillage was also related to the depth and degree of soil disturbance. In our experiment, similar results were not determined. Within tilled treatments, P_{30} was the tillage operation with greatest CO_2 flux after tillage compared to other tilled treatments although the differences were not significant.

In our study, no significant relationships between CO_2 emissions and microclimate conditions were found. Microclimatic conditions had mostly weak or modest impact on soil CO_2 emission. Similar results were reported by Kessavalou, A. *et al.* (1998); Al-Kaisi, M.M. and Yin, X. (2005); Omonode, R.A. *et al.* (2007); Jabro, J.D. *et al.* (2008); Li, C. *et al.* (2010); Bilandžija, D. *et al.* (2014) and Bilandžija, D. (2015). Of all tested functions, best type of correlation between soil CO_2 emissions and microclimatic factors, showed to be the second order polynomial correlation, except for soil water content.

According to its determination coefficient, 17 per cent of soil CO_2 emissions depended on soil temperature, 17 per cent of soil CO_2 emissions depended on soil water content, 27 per cent of soil CO_2 emissions depended on relative air humidity and 49 per cent of soil CO_2 emissions depended on air temperature. A possible explanation for this lack of relationship with CO_2 flux may be related to the fact that soil microclimate conditions were only measured to 10 cm depth and soil tillage was implemented to 30 and 50 cm soil depth. Therefore, a large proportion of the CO_2 emission could come from deeper than 10 cm soil layer.

Conclusions

At no till system soil CO_2 emissions were steady and high during whole study period. Tillage did not have significant, on 3 hours average, short term impact on soil CO_2 emissions. However, tillage accelerated the transfer of soil CO_2 to the atmosphere and caused an immediate sharp increase in soil CO_2 emissions which were on average 40–50 per cent higher compared to those before tillage. This was a relatively short lived process, lasting less than 3 hours from tillage operation after which the soil CO_2 emissions were on average 40–50 per cent lower compared to those measured before tillage.

At tilled systems, soil temperature rapidly declined after tillage operation and afterwards continued to rise while at no-till system it was steady during whole study period. Soil water content was declining with time of measurement during whole study period. The tillage-induced soil CO_2 emissions appeared to be independent of changes in microclimate as correlations between soil CO_2 emissions and microclimatic factors were mostly weak or modest. The obtained data suggested that correlations were independent from the function type used. Further long term research is needed to better assess also the impact of other agroecological factors such as soil physical and chemical parameters, especially changes of soil organic matter content in the topsoil on CO_2 emissions.

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The ecosystem services supplied by soil in relation to land use

Jarmila MAKOVNÍKOVÁ[1], Radoslava KANIANSKA[2] and Miriam KIZEKOVÁ[3]

Abstract

The concept of ecosystem services has become an important tool for modelling interactions between ecosystems and their external environment in terms of global bio-climatic changes. The provision of ecosystem services depends on biophysical conditions and changes over space and time due to human induced land cover and land use. Ecosystem services linked to natural capital can be divided into three services categories (provisioning, regulating and cultural), and ecosystem functions (structures and processes relevant for ecosystem self-organisation, biodiversity, soil macro-organisms, micro-organisms) must be added. Traditionally, agroecosystems have been considered primarily as sources of provisioning services, but more recently their contributions to other types of ecosystem services have been recognized. Agroecosystems can provide a range of other regulating and cultural services to human communities, in addition to provisioning services and services in support of provisioning. Six agricultural study areas, each of them with two different land use categories (arable land and permanent grasslands) located in various natural conditions of Slovakia, were evaluated. For the analysis of the agroecosystem services seven study sites were selected on the basis of the following criteria: 1) polluted area (inorganic contamination); 2) non polluted area (without the inorganic contamination); 3) area threatened by erosion; 4) abandoned land; 5) low productive land; 6) productive land. For each locality two study sites were selected: arable land with annual plant and permanent grassland. The greatest differences can be seen in the relation to land use and diversity of soil types. The agroecosystem services potential value of arable land and grassland sites located in different soil-ecological regions of Slovakia differ in all categories of services. The most significant differences are in provisioning and regulating services. Our results confirm significant negative correlation only between provisioning and cultural agroecosystem services

Keywords: agroecosystem services, filtration potential, sorption potential of soil, soil organic carbon, grassland, arable land

Introduction

The concept of ecosystem services has become an important tool for modelling interactions between ecosystems and their external environment in terms of global bioclimatic changes. The provision of ecosystem services depends on biophysical conditions and changes over space and time due to human induced land cover and land use. Ecosystem services linked to natural capital can be divided into three services categories (provisioning, regulating and cultural) adding ecosystem functions (structures and processes relevant for ecosystem self-organisation, biodiversity, soil macro-organisms, micro-organisms) (Dominati, E. *et al.* 2010; Burghard, B. *et al*. 2014). Nevertheless, few studies on ecosystem services are conducted in agroecosystems (Feld, C.K. *et al.* 2009; Vihervaara, P. *et al.* 2010). Agroecosystems are managed to fulfil basic human needs, such as food and raw materials (Zhang, W. *et al.* 2007).

According to several authors (Daily, G.C. 1997; Power, A.G. 2010) agroecosystems can provide a range of other regulating and cultural services to human communities, in addition to provisioning services and services in support of provisioning. Traditionally, agroecosystems have been considered pri-

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[1] National Agricultural and Food Centre/ Soil Science and Conservation Research Institute Bratislava, Regional Station Banská Bystrica, Slovakia. E-mail: j.makovnikova@vupop.sk. Correspondent author.

[2] Matej Bel University Banská Bystrica, Faculty of Natural Sciences, Department of Environment.

[3] National Agricultural and Food Centre, Grassland and Mountain Agriculture Research Institute, Banská Bystrica.

marily as sources of provisioning services, but more recently their contributions to other types of ecosystem services have been recognized (MEA 2005).

A number of recent studies have mapped the supply of services at global (Naidoo, R. *et al*. 2008), continental (Schulp, C.E.J. *et al*. 2012), national (Bateman, I.J. *et al*. 2011) or regional scales. The most common indicators for modelling ecosystem services are land use cover, soils, vegetation and nutrient related indicators. However, provisioning services are mapped more frequently than regulating and cultural service (Crossman, N.D. *et al*. 2013).

The work presented in this paper aims at the ecosystem service potential supplied by agroecosystem in relation to land use.

Material and methods

Seven agricultural study areas, each of them with two different land use categories (arable land and grasslands) located in various natural conditions of Slovakia, were evaluated. The study sites suitable for the agroecosystem service analysis were selected on the basis of the following criteria: 1) non polluted area, 2) polluted area (with inorganic contamination), 3) low productive area, 4) land threatened by erosion, 5) medium productive land, 6) abandoned land, 7) productive land *(Table 1).*

The basis for analysing the potential for the provisioning agroecosystem services was a point value (BH) of productive potential based on typological and production classification of agricultural soil of Slovakia:

$$BH = (HPJ + SE + KH + Z) \times T,$$

where HPJ = point value of the main soil unit, SE = inclination score and exposure score, KH = score of skeleton and soil depth, Z = texture score, T = coefficient for climatic regions. The BH value is a basis for the rationalization and environmental exploitation of natural resources of a particular territorial unit and its value in Slovakia ranges from 0 to 100.

Regulating services, soil filtration potential (FP) – or immobilisation potential – (5 categories) was calculated as accumulative function:

$$FP = SP + K,$$

where SP = sorption potential of soil, K = potential of total content of inorganic contaminants evaluated according to the Slovak Law 220/2004 Z. z. (Makovníková, J. *et al*. 2007).

Point evaluation of sorption potential of soil (SP) was calculated as a sum of two different factors:

$$SP = F(pH) + F(Q46) + F(Cox) \times F(H),$$

where $F(pH)$ and $F(Q46)$ are quantitative factors, $F(Cox)$ and $F(H)$ are qualitative ones according to function. H = depth of humus horizon.

Soil organic carbon (SOC) is a part of soil organic matter (SOM). Soil organic carbon was determined on C,N analyser EA. Soil carbon stock ($SOCS$ – in t/ha) (5 categories) was calculated like function:

$$SOCS = 10 \times SOC1 \times BD1,$$

Table 1. Study sites characteristics

Study sites*	Geographical location	Altitude, m a.s.l.	Climate	Inclination	Distance to the roads, m	Soil type
ST	Eastern Slovak Hills	121	02	0°	100–200	Fluvisol
ME	Krupina Plain	151	04	0°	100–200	Fluvisol
ZA	Borská Lowland	170	00	2°	100–200	Regosol
CO	Slovak Karst	354	06	7°	200–500	Cambisol
TA	Kremnica Mountain	647	07	2°	100–200	Cambisol
VI	Low Tatras	945	08	5°	>500	Rendzina
ZE	Danube Slovak Hills	136	01	2°	>500	Chernozem

*ST = Stráňany, ME = Medovarce, ZA = Závod, CO = Čoltovo, ZE = Zeleneč, TA = Tajov, VI = Vikartovce.

where *SOC*1 = soil organic carbon content in per cent in the depth 0–10 cm, *BD*1 = soil bulk density in the depth 0–10 cm in g/cm^3 (Barančíková, Makovníková, VP VUPOP 2013). The categories are as follows: 1 = very low potential (lower than 20 t *SOC* /ha), 2 = low potential (20–40 t *SOC* /ha), 3 = medium potential (40–60 t *SOC* /ha), 4 = high potential (60–80 t *SOC* /ha), 5 = very high potential (more than 80 t *SOC* /ha). The loss of soil by erosion was evaluated with the RUSLE model.

The potential for outdoor recreation (*RP*) (cultural ecosystem services) was evaluated. We presume that each agroecosystem has the potential (capacity) for carrying out the outdoor recreation. All agroecosystems are considered to be potential providers of these services. Recreation potential was evaluated through agroecosystems landscape components that have a specific link with summer, winter and year-round recreation. The recreational potential for all these activities was calculated as sum of individual recreational activities potential without added points (Natura 2000) which were added only to the final sum in order to prevent multiple evaluations of additional factors (Makovníková, J. *et al*. 2016).

In the analysis of the suitability of the area in terms of recreational usage, the altitude, inclination, drainage, precipitation, temperature (climate) and their distance to the roads were taken as basis. Five categories of agroecosystem to provide outdoor recreational activity were determined: 1 = very low, 2 = low, 3 = medium, 4 = high and 5 = very high relevant capacity.

Results and discussion

Provisioning services in relation to cultural services

Despite the fact, that all agroecosystems are considered to be potential providers of all ecosystem services, primary services of arable land are provisioning services (*Figure 1*).

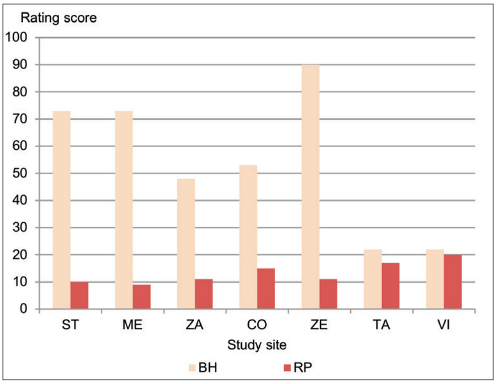

Fig. 1. Provisioning services (BH) in relation to cultural services (RP) for *arable land*. Study sites: ST = Stráňany; ME = Medovarce; ZA = Závod; CO = Čoltovo; ZE = Zeleneč; TA = Tajov; VI = Vikartovce.

At arable land, provisioning services are in opposite to cultural services. Our results showed that study sites Stráňany, Medovarce and Zeleneč have higher provisioning potential compared to outdoor recreation potential. Their provisioning services have the first order priority with the exception of the site Medovarce. This study site is polluted area (by inorganic contamination). The soil is not able to fulfil its hygienic function. Therefore, crops grown on the soil cannot be used for human consumption. The locality is more suitable as grassland or for production of energy crops.

Agricultural utilisation can contribute to ecosystem services, but can also be a source of disservices as we observed in the CO study site. CO study site is threatened by erosion. The ecosystems affect the water balance through two processes, interception and infiltration. The interception depends on the structure of the ecosystem, on the land cover. It would be appropriate to change the land use of this locality and use this area as grassland. Study sites Tajov and Vikartovce have low provisioning potential and their use as arable land has only local significance.

Grasslands are considered to be not only actual providers of provisioning services but also actual providers of cultural services. The capacity of grasslands to provide provisioning services in relation to outdoor recreational activity is shown on *Figure 2.*

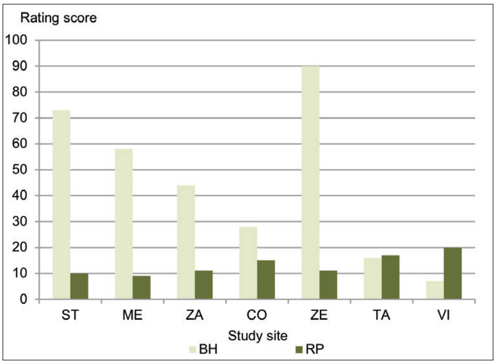

Fig. 2. Provisioning services (BH) in relation to cultural services (RP) for *grassland*. For ST, ME, ZA, CO, ZE, TA and VI = see *Fig 1*.

The altitude negatively affects the potential to provide provisioning services, on the other hand, positively affects the potential of cultural services.

The capacities of grasslands to supply cultural agroecosystem services can significantly contribute to the economic stability and prosperity of a particular region. The utilisation of soils with low production potential (Tajov and Vikartovce) primary for the recreational purposes can help to prevent degradation and loss of agricultural soil.

Regulating services

The categories of regulating services (soil filtration potential and soil carbon stock) are shown on *Figure 3* (arable land) and *Figure 4* (grassland).

It is well known that the variation in soil properties such as pH, organic matter content and quality, texture, the quantity and quality of adsorbing sites, can significantly influence the distribution as well as availability of inorganic risk elements to plants and water (Makovníková, J. *et al*. 2007; Bujnovsky, R. *et al*. 2009). Potential of soil to immobilisation and thus transport of risk elements is dependent on total amount of these elements in soil and the potential of soil sorbents responsive to risk elements behaviour and availability.

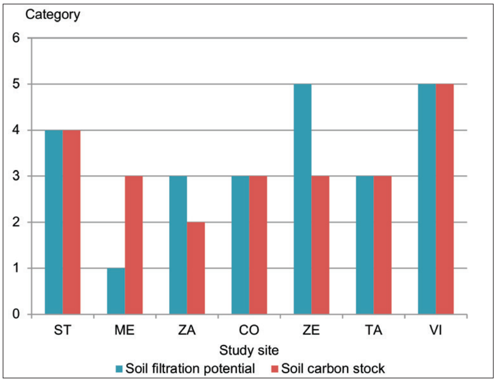

Fig. 3. Categories of soil regulating services for *arable land*. 1 = very low; 2 = low; 3 = medium; 4 = high; 5 = very high potential. For ST, ME, ZA, CO, ZE, TA and VI = see *Fig 1*.

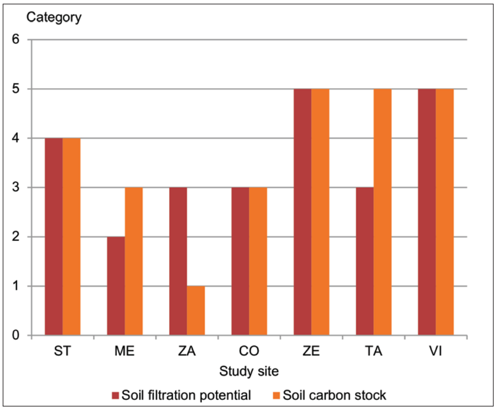

Fig. 4. Categories of soil regulating services for *grassland*. 1 = very low; 2 = low; 3 = medium; 4 = high; 5 = very high potential. For ST, ME, ZA, CO, ZE, TA and VI = see *Fig 1*.

Results of soil filtration potential showed that very high soil filtration potential has been evaluated for Vikartovce site (arable land as well as grassland). At Vikartovce site, the value of soil reaction is in neutral or slightly alkaline range. There is high content of organic matter in the surface horizon of the soil, which decreases with depth. The study site belongs to the areas with soil with high potential of soil sorbents and very low potential of risk elements evaluated in accordance with the Slovak Law 220/2004. Overall, regulating services are the lowest at the degraded study site Medovarce (site loaded with inorganic pollutants). At this study site, the high contamination is connected with a higher amount of potential risk elements in sediment deposited on the flood plains as well as with local anthropogenic sources (mining activities).

Very high potential to immobilisation of risk elements was recorded in 19.74 per cent of Slovak agricultural soils, high potential in 26.06 per cent, medium in 27.38 per cent, low in 21.64 per cent and very low potential to immobilisation of risk elements only in 5.18 per cent. Categories with very high and high immobilisation potential, thus, with low risk of inverse process, transport of risk elements, comprise 45.80 per cent of all agricultural soils of Slovakia (Makovníková, J. *et al*. 2007).

At arable land, the stocks of soil organic matter decreases in the order Vikartovce > Stráňany > Tajov = Medovarce = Zeleneč = Čoltovo > Závod.

Our results showed some different results for grassland. Higher *SOC* values on grassland in comparison to arable land are typical for all soil types of Slovakia (Barančíková, G. 2014) and it is conform with many literature data (Sanford, G.R. 2014; Gelaw, M.A. *et al*. 2014). The highest soil organic carbon stock has been determined at grassland localities Vikartovce, Zelenec and Tajov. The lowest stocks of soil organic matter were calculated for locality Zavod, due to the strong mineralization of organic matter that is determined by good aeration and drainage.

Soil carbon stocks are determined primary by the soil forming processes and the secondary by land use and management. Management regime governs the carbon storage. Conversion of grassland to cropland can release 0.90 Mg C /ha per year in average during a 20-year period. Conversion of arable land to permanent grassland generally results in 0.49 Mg C /ha per year carbon storage over 20 years (Hönigova, I. *et al.* 2012). According to Conant, R.T. *et al*. (2001) extensive grasslands constitute an important reservoir for atmospheric carbon. Our results confirm significant negative correlation only between provisioning and cultural agroecosystem services *(Table 2).*

Conclusion

The agroecosystem services potential value of arable land and grassland sites located in different soil-ecological regions of Slovakia differ in all categories of services. The most significant differences are in provisioning and regulating services. Agricultural management practices are the key for realizing the benefits of ecosystem services, especially if trying to induce synergism effect. In other words, a synergism occurs when ecosystem services interact with one another in a multiplicative or exponential fashion (Felipe-Lucia, M.R. 2014).

These can be positive, i.e. multiple services improving in provision. Explicit modelling

Table 2. The correlation analysis of agroecosystem services

Correlation coefficient/ agroecosystem services		Correlation coefficient			
		Provisioning services	Regulating services		Cultural services
			Soil filtration potential	Soil carbon stock	
Arable land					
Provisioning services		1.00	0.03	-0.41	*-0.84*
Regulating services	Soil filtration potential	0.03	1.00	0.62	0.35
	Soil carbon stock	-0.41	0.62	1.00	0.56
Cultural services		*-0.84*	0.35	0.56	1.00
Grassland					
Provisioning services		1.00	-0.35	-0.61	*-0.85*
Regulating services	-0.35	1.00	-0.39	0.05	0.35
	-0.61	-0.39	1.00	0.57	0.56
Cultural services		*-0.85*	0.05	0.57	1.00

of agroecosystem services is considered to be one of the main requirements for the implementation of the concept of these services in institutional decision-making. The assessment of the potential of the country to provide agroecosystem services allows us to evaluate the impacts of land use change on the capacity to adapt AESS and management for local conditions.

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Rural change in the context of globalization: examining theoretical issues

Felipe DA SILVA MACHADO[1]

Abstract

Early discussions and theoretical positions concerning rural change were developed by researchers from countries with post-production economies in order to explain the rural transformations. When discussing economic change in rural space over the last decades, Marsden, T. *et al.* (1993) presented a new perspective for understanding rural restructuring that includes new subjects, such as capital mobility, flexible production regimes, complexity in the relationship between technology and environment, economic deregulation and new political processes. According to these authors, in order to understand such processes, it is necessary to research the effects of globalization at local scale of action. A recurrent theme in rural studies has been the significance of diverse globalization processes as drivers of rural change (Marsden, T. 2003; Robinson, G.M. 2004; Woods, M. 2005, 2007; Ploeg, J.D. van der 2008). Multidimensional and multidirectional perspectives have indicated that rural space has become more embedded within a globalized rural world. Therefore, in recent years, researchers have displayed an interest in understanding the dynamics of the rural spaces in developing countries which are also being affected by global processes in different pathways (Wilson, G.A. and Rigg, J. 2003; Rigg, J. 2006; Bryant, C.R. *et al*. 2008; Ploeg, J.D. van der *et al*. 2010). In summary, this article forms a critique of the simplistic assumptions formulated in the literature regarding spatial change, which assumes the rural is essentially subject to external actions. I argue that the rural space should also be seen to possess its own dynamics which contribute to complex pathways and so adapts to new scenarios of spatial change in the contemporary world.

Keywords: contemporary rural space, rural change, rural geography, globalization, developing countries

Introduction

This article provides a framework for understanding rural change, based on an extensive literature review, and discusses the diverse characteristics of this process, primarily in developed countries. It also includes a discussion of rural change and globalization, with a focus on the contemporary conceptual debate concerning rural studies in the global world. As much of the critical literature on rural change and globalization (Marsden, T. *et al*. 1993; Pierce, J.T. 1998; Marsden, T. 2003; Woods, M. 2005, 2007; Bryant, C. *et al*. 2008) has emphasized, rural studies need greater focus on the diversity of contexts in which rural restructuring takes place. Agricultural and non-agricultural production systems are involved in this process and are interconnected to different degrees, including rural and urban interaction and the articulation of rural dynamics with urban and global dynamics. Last years have probably seen most dramatic changes in rural areas and pace of change appears to accelerate in an increasingly globalised and interlinked world (Robinson, G.M. 2004).

National and regional interests also play an important part, particularly in rural spaces with higher levels of rural and urban interaction, such as occurs with large industrial projects and transport infrastructure that converges on urban agglomerations and connects different regions (Bicalho, A.M.S.M. *et al.* 1998). Sánchez, G.P.Z. (2000) pointed out that rural spatial transformations caused

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[1] School of Geography, Earth and Environmental Sciences, Plymouth University, UK. CAPES Foundation, Ministry of Education of Brazil, Brasília – DF Brazil. E-mail: felipe.dasilvamachado@plymouth.ac.uk

by large-scale development projects, such as dams, airports, electric transmission lines, oil exploitation or tourist resorts, imply spatial modifications that, in turn, cause changes and new dynamics in every aspect of local life, generating profound transformations for the rural population.

Sánchez, H.A. (2012) emphasized the need to create practices that introduce the most inherent aspects of territorial dynamics and that acknowledge the development of endogenous processes, whose actions are crucial for strengthening and consolidating territorial management with the participation of actors in their different economic, political and cultural expressions, notably, in spaces of rural and urban interaction. There is an increased need for understanding governance in spaces where conflict can exist between different agents and institutions involved in concrete territorial processes. Some examples are: "disputes for land and natural resources, real estate speculation for new non-agricultural activities, gentrification, outsourcing of rural space, spatial mobility of rural population or even strengthening the rural land market with new farm activities" (Sánchez, H.A. 2012, 49). Therefore, the focus on the territorial dimension is crucial for managing and enforcing public policies in multifunctional rural space.

This theoretical debate is based on the critical discussions that have moved away from the rigid notion of simply 'exporting' indicators developed in advanced economies to the developing world situation towards an analytical framework that emphasizes complex rural space. This would mean, I have explored the diverse meanings that have been attached to the recurrent significance of globalization as a driver of rural change, arguing that it needs to be adapted and developed to address conditions found in the developing world. Furthermore, this analysis questions the implied linearity of the traditional concept of rural space and explores different perspectives in human geography. The theoretical discussion is based on debates concerning contemporary rural space with an emphasis on spatial processes and globalization in a rural context (Wilson, G.A. and Rigg, J. 2003; Marsden, T. 2003; Wilson, G.A. 2007, 2012; Woods, M. 2007, 2011).

Understanding rural change

When discussing economic change in rural space over the last decades, Marsden, T. *et al*. (1993) emphasized a new perspective for understanding rural restructuring that includes new issues, such as capital mobility, flexible production regimes, complexity in the relationship between technology and environment, economic deregulation and new political processes. According to these authors, in order to understand such processes, it is necessary to research the effects of globalization at local scale of action. Thus, the modes of development that are internal to particular rural areas must be linked to external influences upon such areas.

In geographical theories of rural restructuring since the 1990s the role of local actors has been highlighted, mainly that involving local people transforms rural spaces (Bryant, C. 1997; Pierce, J.T. 1998; Woods, M. 2005). Structures, other than purely economic ones, are taken into consideration by Pretty, J.N. (1995), van Huylenbroek, G. *et al*. (2007) and Wilson, G.A. (2010), allowing for local decision-making, control and management, i.e. focussing on the peculiarities of different kinds of social agents and modalities for organizing rural space. Collective strategic thinking, involving regional institutions and organizations oriented towards territorial development, including the political perspectives of local social actors, is considered to be fundamental for the success of governance *(Photo 1)*.

Local development may be deemed the coherent initiatives and actions, based on the mobilization of local social actors who agree to contribute expertise and assistance for improving specific territories. "Actors or a group of actors may contribute in all four functions necessary and required for developing a ter-

Photo 1. Patterns of community are significant for measures to respond to rural change, as any attempt to engage local actors in the delivery of rural development. Community telecenter in Piquiatuba, Pará state, Amazon Region, Brazil. *Source*: Field research, 2013.

ritory: information, integration, planning and action" (Clément, C. and Bryant, C. 2004, 191). Participation, cooperation, joint work and construction of partnerships are undertaken giving rise to networks of local actors who devise strategies of resistance, resilience or adaptation of rural communities to new global contexts (Wilson, G.A. 2012). A similar concern is present in assessments of environmental impacts and in socioeconomic policy in developing countries that highlight the need for integrating local knowledge into planning and evaluation of development projects (Bryant, C. *et al.* 2004).

At the local level, different rural patterns are also driven by diverse elements, and are shaped by various social, economic, and political forces according to different social and geographical contexts (Marsden, T. 2003).The focus for rural studies has been placed on the local community level, as it is at this level that spatiality of resilience are implemented 'on the ground' (McCarthy, J. 2005; Parnwell, M.J. 2007; Wilson, G.A. 2010). The justification for this is both analytical and pragmatic. As commentators such as Agrawal, A. and Gibson, C.C. (1999) or Wilson, G.A. (2012) emphasized, over the past two decades, there has been resurgence in attention to community as a critical arena for addressing a range of issues, including societal pathways of change. To address this issue, this article questions how rural communities from developing world address resilience in the context of rural change and globalization.

Rural change in the context of globalization

Accumulation crises in capitalist societies provoke periodic and, sometimes, radical restructuring of productive processes in order to establish new investment opportunities, a consequence of which is the reassessment of resources and spaces previously deemed unproductive or marginal. For several reasons, some rural areas, previously deemed places of declining economic activities, start to be seen as investment frontiers (Marsden, T. *et al.* 1993) and rural elements, which until then had little social or economic value and are reset and re-functionalized. Good examples are the 'commoditization' of nature, landscapes for tourism and environmental preservation, production of healthy foods and creation of rural leisure activities, all of which are part and partial of globalization.

A recurrent theme in rural studies has been the significance of diverse globalization processes as drivers of rural change. The variety of contexts in which globalization has been encountered – economic production, services and tourism, migration, and environmental protects – points to the multiple character of globalization. As a result, new directions in rural studies have called for researches that examine the impact of globalization on everyday life (Woods, M. 2012). Methods in rural geography in the era of globalization have provided wider theoretical frameworks and insights into the rural domain through in-depth studies and bottom-up model and multidimensional approaches (e.g. political economy, cultural studies and political ecology) *(Table 1).*

Table 1. Contemporary rural studies have provided wider theoretical frameworks and multidimensional approaches

	Approach	Global critical issues	Rural change in globalization
Political economy	A critical account of the impacts of planning and policy-making, and by interpreting decision-making for rural areas in a political economy context (Newby, H. 1985; Cloke, P. 1987, 1989; Marsden, T. *et al.* 1993).	During the 1980s, rural geography was a field for political-economy analyses of agriculture, planning, rural development and rural class re-composition	The privatization of many services, conflicts of land use and the growing of the external interferences in local politics and planning.
Political ecology	It has indicated the environmental problems result from inequality associated with the spread of capitalism and emphasize the need for changes in political and economic process at local, regional, and global levels to solve environmental problems (Watts, M. 1983; Hecht, S.B. 1985; Neumann, R.P. 1998; Peet, R. *et al.* 2011).	Political ecology looks beyond regional and national boundaries to the structural contexts and transnational interests, networks, and discourses that shape many local cases (Moore, D. 1995; Escobar, A. 2001; Robbins, P. 2004). Political ecology presumes relations and conflicts at more 'local' scales.	Questions concerning social and environmental impact, conflict of land use, and toxicity pose recurring problems to the agro-industrial dynamic.
Cultural turn	In the 1990s, it introduced post-structuralist theory and prompted interest in the multiple experiences of rural life by different social groups (Murdoch, J. and Pratt, A. 1993; Cloke, P. 1997; Halfacree, K. 1993, 2006).	The dilemmas of local actors who resist and adapt to contemporary rural contexts.	The rural may lead to a dilution of previously coherence space by to other groups who are already changing the face of rural areas.

Globalization has changed the relationship between urban and rural areas. The city and the countryside modify their dynamics through the intermediation of global exogenous factors, strengthening local-global direct connections. In this way, the rural is not reduced to a mere geographical location, it becomes a place where occurs the mediation of macro social and economic operations directly articulated to global processes. The answers to these processes, however, are different in the political and social content interacting with the exploration of local resources that depends on the characteristics and the relationships of the countryside in the regional context (Cloke, P. 1990; Marsden, T. *et al*. 1993).

The process of globalization has a pervasive influence in transforming rural economies and societies, with implications for the major societal challenges of environmental change and resource security. However, in comparison to studies of the global city, relatively little research has focused on the 'global countryside' (Woods, M. 2007), and existing research lacks integration. Thus, contemporary rural studies have developed an integrated perspective by drawing on relational analysis to focus on the actual mechanics by which rural localities are 're-made' through engagement with globalization processes, examining the mediating effect of national and regional context and the opportunity for local interventions.

Woods, M. (2007) posited the notion of the 'global countryside' as a geographical and conceptual counterpoint to the 'global city'. The global countryside is presented as a space that has become increasingly integrated and interconnected through globalization process. This emergent global countryside is not a uniform, homogenous space, but rather is differentially articulated, and contested, through particular rural places. According to Woods, M. (2007), the concept of place is a space of interconnections reconstituted by globalization into hybrid dimensions of transformations and interactions between local, national and global actors.

Wilson's work on community resilience and transitions particularly pointed towards the fact that the notion of exogenous macro-scalar 'transitional corridors' shaped by national and global decision-making processes, and analysed how such corridors influence community resilience (Wilson, G.A. 2012). He argued that the critical literature often portrays macro-scalar corridors as 'negative' for innovation. Then analysed the importance of macro-scalar lock-in effects external (i.e. globalization) to communities and discussed how these can shape community pathways and resilience in both positive and negative ways *(Table 2).*

With regard to experiments in local development in different parts of the world, the Sustainability of Rural Systems Commission

Table 2. Contemporary rural change, concepts and global critical issues

Concept	Debate	Global critical issues
	The global countryside	
Woods, M. 2007, 2011. Cheshire, L. and Woods, M. 2013. McDonagh, J. *et al*. 2015.	Rural space that has become increasingly integrated and interconnected through globalization process	Globalization alters employment opportunities, raise or depress income levels, and change patterns of local service provision. The impact of globalization on everyday life in a rural context.
	Rural resilience	
Wilson, G.A. 2010, 2012. McManus, P. *et al*. 2012. Scott, M. 2013. Welsh, M. 2014.	The potential of social innovation and collective agency at the community scale in exploring new development	An exploration of farming and its role for rural resilience. The various aspects of community resilience within rural localities

of the International Geographical Union has produced a number of studies which treat rural restructuring in different countries (e.g. Bicalho, A.M.S.M. and Hoefle, S.W. 2004; Frutos, L.M. *et al*. 2010; Kim, D. *et al*. 2013; Bicalho, A.M.S.M. and Laurens, L. 2014). These studies focus on the influence of globalization, internationalization of agriculture, urbanization of rural areas, the rise of multifunctionality, strategies for promoting sustainable rural development and territorial governance, all linked to the new functions of rural space and the dilemmas of local actors who resist and adapt to new rural contexts.

(Re)positioning debates surrounding rural change and globalization

In recent years, researchers have displayed an interest in understanding the dynamics of rural spaces in developing regions of the world which are also affected by global processes in different ways and the sum result is great global spatial diversity (Marsden, T. 2003; Wilson, G.A. and Rigg, J. 2003; Rigg, J. 2006; Wilson, G.A. 2007; Woods, M. 2007; Bryant, C. *et al*. 2008; Ploeg, J.D. van der *et al*. 2010). Recognition of the global inter-connection and inter-dependency of rural places points to a dismantling of the separation between rural research on the global north and rural research on the global south, and the promotion of more transnational research. As Woods, M. (2005, 2011), in particular, emphasized, although rural geographers often consider the global north and south separately, in our ever shrinking world society these two paradigms are often coming together.

Multidimensional and multidirectional perspectives have indicated that, over time, rural areas in developing countries increase embeddedness into a globalized rural world (Wilson, G.A. and Rigg, J. 2003; Rigg, J. 2006; Parnwell, M.J. 2007; Wilson, G.A. 2008). This article suggests that the repercussion of the challenges for rural areas in the developing world in the early twenty-first century, such as the political economies of new strategies for economic development and the resilience of rural communities, should receive more attention. Traditionally, a lot of research in rural studies has been empirical in nature, but over the past years a more critical rural social science has developed which has employed a range of conceptual theories in its analysis, including political-economic concepts and post-structuralism (e.g. 'Handbook of Rural Studies' edited by Cloke, P. *et al*. 2006).

The complexity of spatial restructuring present in the developing world in the era of globalization contributes to better understanding the contemporary rural, going beyond the view of inert spaces only subject to external interferences. Cutter, S.L. *et al*. (2008) and Wilson, G.A. (2010, 2012) indicated that there is a need for further research in these arenas, arguing that despite metaphorical and theoretical models which have progressed to the operational stages, processes of resilience should be measured and monitored at local level.

Rural transformation in the global world is a hybrid and contested process, that involves actors and forces operating at multiple scales, and which echoes elements of rural restructuring in both the developed world of Europe and North America and the developing world, yet has distinctively different characteristics. Accelerating globalization processes exacerbate the already precarious situation in many rural districts in both the global North and South, as virtually all areas are affected by global propelling forces often outside the control of regional and national regulatory structures.

In addition, agriculture no longer necessarily forms the essential backbone for rural development, and instead rural spaces in both the global North and South are characterised by complex, multidimensional and hybrid development path ways in which questions about the right and wrong development trajectories are increasingly difficult to answer.

Woods, M. (2011) has highlighted how the global tipping point has come with rapid urbanization in Brazil, China and India, and other fast-growing countries of the global south. (*Photo 2*). Yet, the population shift

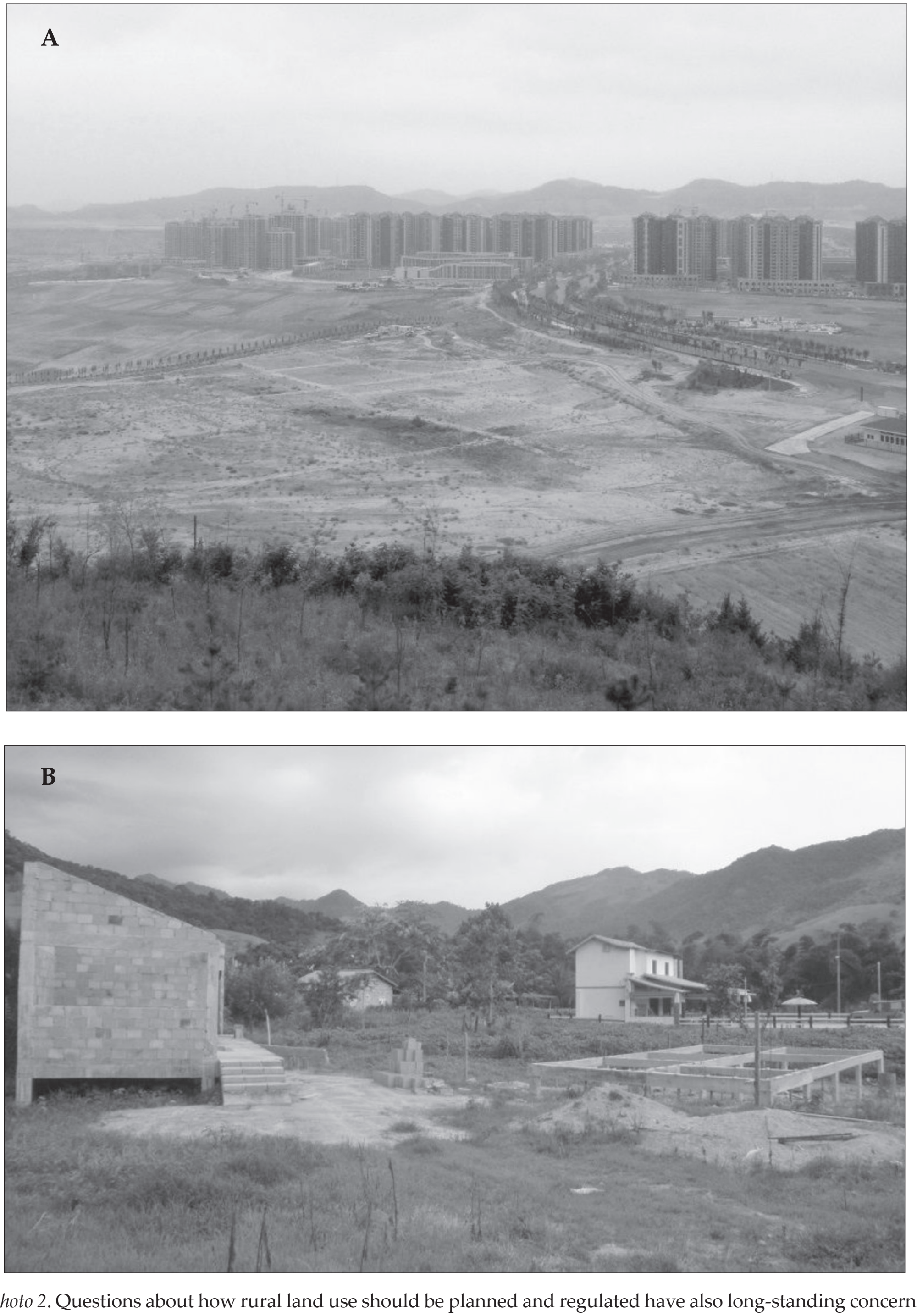

Photo 2. Questions about how rural land use should be planned and regulated have also long-standing concerns geographers: Yan'an New District, Shaanxi Province, China, 2016 (A). Cachoeiras de Macacu, Rio de Janeiro state, Brazil, 2013 (B). *Sources*: Field research in 2016 (A) and in 2013 (B).

does not in itself necessarily mean that the rural has been eclipsed, or become irrelevant. On the contrary, as rural studies has demonstrated, the rural continues to be central to many of the key issues confronting the world today, and the study of rural geographies is arguably as important as ever.

Hu, Z. and Rahman, S. (2015), based on an in-depth case study of a rural community, pointed to the fact that the contemporary state of Chinese smallholder agriculture and changes that it has been experiencing in the context of socio-economic transition through the lens of three main economic drivers: livelihood diversification, market conditions and government interventions. Results reveal that the change in China smallholder agriculture has been complex and multidimensional. All three factors exert profound influence and shape the current state of Chinese agriculture. Massive rural-urban migration has resulted in labour shortages, which in turn have led to a reduction in agricultural diversity and land use intensity.

Understanding the economic drivers of smallholder agriculture is important in the present day, because both the media and academia have recently raised grave concerns regarding a crisis of smallholder agriculture driven by massive nonfarm employment and expressed doubts about an argument used in both policy and academic spheres for reform towards large-scale capitalist agriculture.

Studies have illustrated that agricultural change may involve multidimensional and often parallel processes, which are not only labour-driven intensification, but also technology driven intensification (Ploeg, J.D. van der 2008; Ploeg, J.D. van der *et al*. 2013). As Brookfield, H. (2001) rightfully contended, driven by livelihood diversification, agricultural change has taken multiple pathways so that intensification alone can never fully capture the complexity of the processes involved. He has highlighted the capability of smallholders and further argues that the key for survival and successful change of smallholder agriculture has been adaptation and innovation. In the context of Asian deagrarianization, Rigg, J. (2001) indicated that both intensification and disintensification have occurred in Asian rural change. The theory of rural change in developing countries so far has underscored at least two points. First, change is complex, diverse and multidimensional. Second, change is context dependent and can be affected in diverse pathways.

Conclusions

The repercussion of the challenges for rural areas in the early twenty-first century, such as the political economies of new strategies for economic development based on the use and management of resources and the resilience of rural communities to macro-scalar effects, have been paid little academic attention (Wilson, G.A. 2012; Woods, M. 2012). This article questions the changes of contemporary rural space under the context of its socio-economic integration into global capitalism.

Most of the studies have explained and interpreted the causality between globalization and factors of rural change in a linear way and therefore produced homogenous conclusions. Consequently, to more comprehensively interpret the effects of different socio-economic and political change drivers on rural dynamics, the main aim in contemporary rural studies is to explore the processes through which differential factors have affected the rural with a focus in how different degrees of rural-urban interaction and global influences give rise to multifunctional diversity and spatial complexity.

However, the literature of rural geography in developing countries still is constituted mainly by agricultural economies and analysis of agricultural policies, such as institutional change, agricultural technological development, rural-urban migration, which emphasize the empirical evidence of how structural factors affect agricultural production (Delgado, G.D. 2012; Ioris, A.A.R. 2012). At present, great enthusiasm is expressed by the media and governments concerning economic growth directly related to the spread of agribusiness-scale production in the countryside in developing countries such as Brazil.

In contrast, academics have explored agro-industrial food networks through a critical perspective, placing agribusiness-scale production within a mass production model which includes volume and standardization (Bernardes, J.A. and Freire Filho, O.L. 2005; Bernardes, J.A. 2015; Hosono, A. *et al*. 2016). Questions about social and environmental impact, conflict of land use, and toxicity pose recurring problems to this agro-industrial dynamic. In these cases, the study of globalization in a rural context has commonly focused on commodity chains and its contradictions.

This article argues that the complexity of rural areas and its spatial diversity contribute to better understanding of the multi-directional and multidimensional paths in globalization, going beyond the view of economic space as only subject to external interferences that demand resources. In the case of developing countries, little attention has been paid to investigating the rural space by combining macro-political economy with the analysis of local strategies. In conclusion, I have drawn insights for advancing social resilience in the global countryside through an analysis of rural restructuring related to the current global changes 'on the ground'. It attempts to develop a connection between rural change, rural community resilience in developing countries and broader rural studies in the context of globalization.

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Review of soil tillage history and new challenges in Hungary

Márta BIRKÁS, Igor DEKEMATI, Zoltán KENDE and Barnabás PÓSA[1]

Abstract

This study provides an overview of the development of soil tillage in Hungary. The primary goal is to present factors that have been promoting and hindering progress in tillage from the first authoritative records – from the eleventh century – up to now when soil tillage became a tool in the climate damage mitigation methods. Progress was restricted during the first eight hundred years of the history of tillage by lack of expertise and the use of primitive tools. In retrospect, much of the traditions are regarded as obstacles to progress while the adoption of certain foreign trends fostered development in most cases. The history of the development of tillage in Hungary is divided into seven eras, with equal positive and negative impacts on the quality of the soils. The quality of soils was threatened before 1900 primarily by the multi-ploughing systems, while reasonable tillage offered a chance for improvement. The geographical location of Hungary in Europe and the Hungarian language entailed a certain degree of isolation as well. It may have been the reason why Hungarian reasonable tillage could not become a forerunner of minimum tillage. New soil tillage methods developed abroad had influenced primarily education and experiments carried out in Hungary. After the regime change, however, such methods came to be driving progress in practice as well, thanks to a widened horizon. In 1998 soil conservation tillage were used on about 25 per cent of the total sown land, however, a decade and a half later the area cultivated by conservation methods had doubled. A survey conducted five years ago found that significant progress had been made in soil conservation tillage in dry seasons but the achievements are often eroded by return to the conventional modes during wet seasons.

Keywords: conventional tillage, tillage development, soil conservation, climate focused tillage

Introduction

No critical discussion of the development of soil tillage in Hungary has ever been published in English so far, apart from details (Birkás, M. *et al.* 1989, 2004), from which is hardly to draw comprehensive conclusions for the reasons why local tillage practices are lagging behind or how progress has been made. The development of tillage techniques in Hungary, respect for tillage in general, its position in the system of cropping, the efforts made at conservation the soil along with the acceptance of new approaches, have always been substantially affected by traditions (Szabó, J. 1909; Sedlmayr, K. 1954). This influence has – in view of contemporary articles and periodicals in various phases of the soil tillage history – more frequently hindered than encouraged the adoption of new techniques (Páter, K. 1953).

Birkás, M. (2008) gave an overview on the history of soil tillage and pointed the facts that obstructed the progress over centuries, such as the traditions stuck to the multi-ploughing practice; refused adoption the reversible plough for centuries (however, the first horse-drawn reversible ploughs were introduced in the 1500s); delayed in implementing the improvement of orthodox plough; rejected tillage tools other than the plough without even giving them a try e.g. the Hungarian Plough Planter (Pethe, F. 1818), the rotavator (1907), disk tiller for alkaline soils (in the 1920s); aversion to use technique of loosening (from 1860 till the

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[1] Institute of Crop Production, Szent István University, H-2100 Gödöllő, Páter K. u. 1.
E-mails: birkas.marta@mkk.szie.hu, dekemati.igor@mkk.szie.hu, kende.zoltan@mkk.szie.hu, posa.barnabas@mkk.szie.hu

1960s) and blaming the weather instead of recognising soil structure defects; insistence on applying the same old routines instead of learning and adopting new techniques; taking a poor view of soil conserving tillage techniques e.g. cultivators or mulch tillage.

Moreover, Birkás, M. (2008b) listed progressive examples too, such as the 'Hungarian reasonable tillage' strategy, promoted at the end of the 1800s and that was aimed at reducing tillage without increasing the risk of crop production (Cserháti, S. 1900, 1902a,b). Working the soil to the depths exceeding 20 cm from the year 1860 made a chance to loosen the pans ensued from shallow ploughing (Cserháti, S. 1891). The first experiments were carried out with reasonable ploughless tillage and the first results were thus achieved in Hungary by Baross, L. (1909) and Manninger, G.A. (1938). At the beginning of the 1920s Gyárfás, J. (1925) gave chance for adoption of the dry farming methods. Kemenesy, E. (1924) was the first scientist to draw attention to the possibilities lying in biological tillage, that is, in keeping the soil in a mellowed state.

The trend of minimum tillage took off in the 1960s, soil conservation was quite negligible as an objective in comparison to efforts made to reduce tillage interventions and minimise tillage costs. The new concept that is soil conservation tillage (Schertz, D.L. 1988) was viewed positively all over the world, including in Hungary.

Mention should also be made of the influence of new foreign tillage tools. Before and during the 1800s interest focused primarily on the use of ploughs (e.g. Brabant and Hohenheim types and later Sack) constructed abroad. It was in such circumstances that the Kühne factory manufactured of a variety of promising tools, including Campbell's disk and roll. A lot of Russian machines were imported to Hungary after 1945 but there was an upswing in the domestic manufacture of agricultural machinery as well. Farm machinery demonstrations drew attention to high quality products, particularly those that could be reliably operated even under difficult conditions. Progress in soil tillage however, was triggered not so much by the availability of up-to-date machines but the growing demand by farmers, concerning soil condition (Birkás, M. 2008a).

Materials and methods

Lessons drawn from the history of soil tillage

This study evokes the most important ideas and conclusions that appeared in articles published earlier on the development of soil tillage and the trends observed in Hungary. Among the information sources, an agricultural journal – namely "Köztelek" – had significant importance considering the well-informative articles, published between 1891 and 1944. "Köztelek" was the main bulletin of the National Hungarian Economic Association (OMGE) and through these publications of the famous classic authors (e. g. Bittera, Cserháti, Gyárfás, Hensch, Kerpely, Sporzon, Surányi) had wide professional appreciation. In addition, Milhoffer, S. (1897) published useful information – looking back till the Conquest – about contemporary soil management practice and the strange climate extremities.

A critical review of efforts ranging from the earliest ones up to those aiming at reducing the damage caused by climate change is a key part of this paper, along with the tasks to be tackled in the future. Among the cited literature are – in accordance with the objective of this study – dominated the publications by Hungarian authors, primarily those that came out before 1960.

Investigation of the tillage practice

Monitoring the tillage practice and the soil condition has started in the end of 1970s (it's going nowadays, too), and covers all soil types located in the different micro regions in Hungary. Main aspects of soil tillage practice monitoring are as follows: advantages and considerations of the ploughing; depth and efficiency of the soil loosening; adaptability of the tine tillage by cultivator and considerations of the disk tillage. Surveying the tillage practice – that are conventional, conservation and reduced constraints – delighted in higher attention in the years 1998 and 2011. Monitoring the soil conditions covers: occurrence of the pan compaction; consequences of the outdated tillage traditions on soils; types and seriousness of the tillage and climate (both drought and rain stress) induced soil defects; results of the different soil remediation. Methods of the assessment were presented by Bottlik, L. *et al*. 2014. These data and information are widely discussed in the relevant publications, e. g. Birkás, M. *et al.* 2015a. Machinery dealers and sellers have provided also important – but non-published – information.

Soil and climatic characteristics within Hungary

The total area of Hungary is 9,303,000 ha, of which 5,346,000 ha (57.5%) is agricultural land, and 4,332,000 ha (46.5%) is arable land. According to Stefanovits, P. (1981) the topsoil textures of Hungarian soils can be characterised as follows: sand 15 per cent, sandy loam 12 per cent, loam 47 per cent, clay and loamy clay 26 per cent. Várallyay, Gy. (1989) stressed that approximately 34.8 per cent of the soils are sensitive to degradation and compaction (e. g. Solonetz, Gleysol and Vertisol), 13.9 per cent are non-sensitive (e. g. Calcisol) 23.0 per cent are slightly sensitive (e. g. Arenosol, Cambisol, Histosol) and 28.3 per cent have moderate sensitivity (e. g. Luvisol, Chernozem, Phaeozem).

The climate is continental, although extreme phenomena have occurred more frequently in recent decades. The average annual precipitation decreases from 800 mm in the west to 500 mm in the east. During the past decade one year was average, two years were dry, two years were rainy and five years – due to the alternation of the dry and rainy periods – were extreme.

Eras of soil tillage development in Hungary

The history of soil tillage in Hungary was rich and full of unexpected challenges in the past. The chronological order of the seven main eras in the development of soil tillage as well as their main characteristics, are summed up in *Table 1.*

Seven eras and the main features of the eras were recorded first by Birkás, M. (1995) and since then only minor changes were

Table 1. Soil tillage development in Hungary (by Birkás, M. 2008)

Eras of soil tillage development	Main characterization of the era*
1. Early (–1700)	Lack of tools and expertise (–)
2. Introduction of low intensity farming techniques (1700–1800)	Challenges in crop production (±)
3. Multi-ploughing systems (1750–1900)	Soil structure deterioration (–)
4. Reasonable tillage (1860–1920)	Adoption to soil state (+)
5. Conventional tillage (1900–1988) *5.1. Classic, based on draught animal (1900–1960)* *5.2. Temporary, partially mechanized (1920–1970)* *5.3. Technology focused, fully mechanized (1960–1980)*	High dependence on weather conditions (–) Adaptability to soil state (+) Crop focusing efforts, deterioration in soil quality (–)
6. Energy saving and soil conservation tillage (1975–1988	Soil quality focusing tillage (+)
7. Modern adaptable tillage (1988–) *7.1. Declining period (1988–2000)* *7.2. Period of transition (2000–2015)* *7.3. Soil and environment conservation period (?2020–*	Deterioration in soil condition (–) Climate threats (–); New challenges in soil conservation (+) Recognition of sustainability principles, soil quality improvement (+)

*+ progressive, – regressive, ± both features.

marked in given table (cf. 2008). In the *early era* of its development the quality of tillage was determined by the sites gained by clearing forests or grazing lands, by farming that were not suitable for overcoming unfavourable circumstances.

In the *era of low intensity farming* progress was limited by lack of machines and by a shortage of knowledge. The *era of multi-ploughing tillage* was ushered in by the introduction of improved ploughs that were suitable for working the soil to greater depths. This practice has become the bounds of the development considering the deterioration of the soil quality. The principles of *reasonable tillage* were developed by Cserháti, S. (1900) to reduce detrimental impacts of ploughing up to 3–4 times a year and of excessive manipulation of the soil.

Certain new approaches to tillage, which had been devised abroad and which were radically different from the national practices, arose a wide range of interests. A method named after a French farmer called Jean, was based on a gradual crumbling of dry soils, using cultivators (Gyárfás, J. 1925). The American Campbell's method was discussed – both positively and negatively – in agricultural periodicals at the time. Campbell, H.W. offered a solution for the tillage of dry soils, which may have been the reason for the intensive attention paid to the technique in Hungary, primarily during the years between 1909 and 1913.

Nearly a hundred articles published during those years and experiments were set up to test the special new method (Fechtig, I. 1909; Grabner, E. 1909; Káldy Szűcs, J. 1909; Kerpely, K. 1910a). The results, however, did not bear out the expectations. Reading Campbell's book (1907) carefully, one finds that winter wheat was sown after up to 12–14 tillage passes while it took up to 20 passes to work the soil before seeding in the spring. So many tillage passes were bound to lead to soil degradation; posterity refers to the period as the "Campbell-boom" (Birkás, M. 2003).

The anti-plough movement by Bippart (1920–1930) did have some favourable impacts and effects to the benefits of applying ploughless tillage from time to time it also draw attention to reasonable tillage (Beke, L. 1922; Blascsok, F. 1923). The Mechwart steam plough (1893–1897) and the power tiller by Kőszegi (1907–1913) have really offered a better system to cut time and energy requirements. The era of conventional tillage systems is a step back from reasonable tillage, while multiple tillage passes were still being carried out, i. e. from stubble to sowing.

The Second World War and the allocation of land to masses of landless people hampered the development of soil tillage for quite some time. In the 1950s farmers had an obligation applying deeper (more than 20 cm) ploughing, which was considered to be the guarantee for higher yields. Any effort to reintroduce Manninger's reasonable ploughless tillage system however, was met with severe criticism (Páter, K. 1953). Besides the difficulties, however, some progressive measures were also taken and landscape research and crop production research institutions were established or reactivated. Soil tillage experiments covering shorter or longer periods of time were started by research institutions and universities (Győrffy, B. 1964). At that time research and experiments were aimed at increasing yields or consolidating the stability of yields. A number of experiments were aimed at studying the optimum depth of tillage (Sipos, S. 1978).

Experimental studies of the impacts of deep tillage had probably been stimulated by the need and urge in the 1960s to increase low yields on soils that had probably been poorly tilled for quite some years by that time, along with the introduction of tools suitable for deeper tillage in the whole of the Central and Eastern European region (Drezgic, P. and Jevtic, S. 1963). At the same time, one could not disregard publications concerning, and results achieved by, the reduction of tillage interventions (e. g. Cannell, R.Q. 1985; Allen, R.R. and Fenster, C.R. 1986). A technique referred to as "minimum tillage" including direct drilling, was found to be of interest practically only by scientists; experiments with this system have been under way since the early 1960s (Győrffy, B. 1964; Zsembeli, J. *et al*. 2015).

Era of the energy saving tillage developed from fully mechanized systems with the aim of preventing additional damage and of enabling reasonable cuts in tillage costs. The steady increase of fuel prices and the advent of a dryer period had also stimulated the spreading of soil preserving techniques. Mulch tillage by disk was first adopted for use between the harvest of sunflower and the sowing of wheat, in the early 1980s, and mulch tillage by tine has adopted from the early of the 2000s (Birkás, M. 2008a). A decline in the standards of soil tillage caused by the system change lasted over a period of about 10 years.

During the *period of transition* new opportunities for improvements in tillage are offered by encouraging the high quality production, by a new appreciation of expertise and recognition of the need for soil preservation as well as by a great variety of tillage equipment available in the market. The progress in soil tillage picked up again when new tillage systems (direct drilling, mulch-till, ridge-till, strip till, precision farming) were studied in the newly launched tillage experiments (Győrffy, B. 2001; Birkás, M. *et al.* 2009, 2015b).

Conventional versus conservation tillage

Soil tillage trends throughout the past 18 years in Hungary were evaluated with regard to the methods being used, its impact on soil condition, and the desirability for continuing to use the systems for the next two decades *(Table 2).*

A close correlation was found between the level of the machinery and knowledge and the tillage impacts on soil condition in both (1998 and 2011–2012) surveys. The tillage practices were grouped into three tendencies, conventional, conservation and those designed to reduce specific constraints. Conventional tillage was characterised by tilling the whole surface and using the plough as the primary tool. Achieving a soil condition suitable for crop production often requires more time than is reasonable and much higher energy costs. Furthermore, conventional tillage often has a negative effect on soil condition and the need for ineffective secondary tillage is typical.

Conventional-developing systems that consisted of those farms using up-to-date reversible plough combined with surface levelling element, and improving soil conditions by subsoiling periodically. Soils managed this way are considered free from degradation processes, disregarding a light degree of dustiness in the upper layer; the conventional-stagnating-declining systems are those where most of tillage tools and applied techniques are out-of-date and ratio of degradation (i.e. compaction and dustiness in the topsoil) reaches 50 per cent of the total area. Practices were classified as conservation tillage if the soil was not deteriorated by implements while fulfilling the carbon, water and structure preservation or if it improved the physical and biological state of the soil resource (Birkás, M. 2011). Economically, the main feature of conservation tillage is that the soil condition for crop production can be achieved on a well-protected soil with less energy input.

The soil conservation-fully implemented category includes those tillage systems that are designed to eliminate harmful clodding, dusting, smearing or puddling. Soil conservation-partially adopted systems apply reduced or soil conservation tillage practices, but have a medium or high level of machinery. The level of soil conservation is equal to the damage imposed on the soils through the tillage operations. Systems classified as "to reduce soil constraints" are those being forced to save energy and to reduce tillage traffic because inadequate capital and appropriate equipment. An even greater problem associated with the latter systems is the imperfect level of knowledge. As a result, soil physical conditions are often deteriorated (e.g. disk-pan compaction and/or topsoil dustiness) and the biological state is typically poor (Birkás, M. *et al.* 2004).

*Table 2. Estimated area cultivated by three types of tillage nationally and the desirable progress**

Tillage types	Percent of adoption in		Desirable adoption trend in the next two decades
	1998	2011–2012	
Conventional	50	33	25
Developing	10	20	20
Stagnating, declining	40	13	5
Conservation	25	51	68
Fully	5	44	53
Partially	20	7	15
To reduce soil constraints	*25*	*16*	*7*

*Data from field and soil monitoring and discussed with machinery dealers and sellers.

Soil conservation tillage increased fairly in the last decade. The main factors that encouraged the adoption of conservation tillage practices – both fully and partially – were the extreme dry seasons and the economic pressures. In 1998, conservation tillage was used on 25 per cent of all tilled area and 14 years later the area cultivated by conservation way had doubled. Most of the farms were from mid-sized to large-sized and most of the owners had up-to-date knowledge in soil management. The goals for the next two decades are to substantially decrease the 'declining' and 'stagnating' pattern associated with the conventional way, and to decrease the 'reduced tillage of necessity' from 16 to 7 per cent. This trend may continue for quite a while since there will probably always be new land owners with little knowledge of the ins and outs of farming. However, the soil conservation practices will hopefully increase to approximately 68 per cent of the arable fields *(Table 2).*

Soil quality improvement and climate threat mitigation

The process from the beginning of the history of tillage in Hungary to the announcement of tillage aimed at reducing climate change damage was neither short, nor easy. References to extreme climate phenomena appeared in agricultural periodicals right from their earliest editions, back in the late 1800s. Weather extremes occurred in Hungary even 100–150 years ago (Milhoffer, S. 1897). The extent of damage must have been greater than today and it came without mitigation. Gyárfás, J. (1925) suggested that appropriate tillage and cropping methods have to be applied to prevent damage by frequent drought.

Reviewing the articles published by periodical "Köztelek" an important fact was concluded, that is tillage problem caused by droughts were more often discussed than damage caused by too much rain. When exploring the causes of low wheat yields a classical author on soil tillage, Cserháti, S. (1902) found that low yields were caused by poor tillage because the more defects there were in the soil the more harm was caused by unfavourable weather patterns. He argued that the weather should not be used as an excuse covering up errors made in cropping. The impacts of defective soil conditions resulting in increased damage caused by droughts can be proven today too (Birkás, M. *et al.* 2009), although they are less frequently encountered in arable fields.

A number of authors (Rázsó, I. 1901; Szabó, J. 1909; Jattka, F. 1910; Küzdényi, Sz. 1921; Dworák, K. 1923; Tokaji, I. 1932) emphasised that damage caused by climate conditions could be diminished, however site adopted solutions are to be applied. Cserháti (1900) and Kerpely (1910a,b) drew attention to two important requirements, facilitating the soil's water intake, and impeding evaporation from the soil, by way of tillage techniques. Gyárfás, as a follower of Cserháti, also worked on promoting reasonable tillage *(Table 3),* which is why there is an understandable similarity between their recommendations.

Table 3. Proposals from the classic authors for soil tillage development

Criteria of the adaptable soil tillage		Criteria of the biological soil tillage from Kemenesy (1964)
From Cserháti (1900)	From Gyárfás (1922)	
1. Creating crumbly structure. 2. Improving level of the nutrients uptake. 3. Changing soil layers from time to time. 4. Good mixing. 5. Inverting (manure, stubble residues). 6. Weed and pest control. 7. Consolidation of the upper layer after tillage. 8. Promoting soil mellowing. 9. Forming of the soil surface.	1. Stubble soil breaking just after harvest 2. Autumnal primary tillage. 3. Avoiding the spring ploughing on soils were ploughed in autumn. 4. Creating good seedbed. 5. Fallowing 6. In dry conditions: – Maintaining crumbly structure on the soil surface; – Reducing the number of ploughing.	1. Creating the conditions that are beneficial for microorganisms by site adopted soil preserving tillage and organic material recycling. 2. Promoting and maintaining a mellowed soil state. 3. Improving soil water infiltration and storage capacity and reducing water loss (increasing humus and water source).

Gyárfás listed the first five items among the fundamental tillage tasks in combating drought impacts. Item 6 can be found in his book, without his stressing, while the application of surface cover as a tillage technique was simply out of the question. Though the first – accidental – experience of surface cover was observed by Káldy Szücs (1909), that report failed to attract much attention. It was not until much later that the positive impacts of the crop residue after harvest (a soil and straw mixture as a mulch) came to be proven, by Manninger (1957) and Kemenesy (1964).

Data and projections relating to climate change pose new challenges to soil tillage as well. As Szalai, S. and Lakatos, M. (2013) outlined, four main climate induced risk factors can be formulated from the optimistic and the pessimistic scenarios in the region that are milder winters with more precipitation, warmer and dry summers, extreme fluctuations in the annual distribution of the total precipitation and increased numbers of windy and stormy incidences.

Soil tillage researchers has frequently stated that the existing land use and soil tillage systems were most often based on the classic – and outdated – beliefs. Soils will really be exposed to the climate stresses. Vulnerability of soils has already become an acute problem for agricultural and environmental sustainability, and it will be even more complex problem in future decades.

Birkás, Kisic, Mesic, Jug and Kende (2015a) made a detailed proposal concerning the tasks following in the new climate situation. The main proposals are as follows. The predicted milder winters with more precipitation give chance for more water storage if the soil moisture intake capacity is maintained and improved by adaptable tillage. Any tillage intervention should be aimed at helping rainwater infiltration and at minimising the loss of water in and out of the growing season.

A relatively new challenge is the water loss from soils during colder periods, which call attention to form water preserving surface before soil wintering. Considering the possibility of dry and hot summers, the conventional soil preparation requires an evaluation from a new aspect. Rationalising soil disturbance and extending the period during which the soil is covered will be indispensable. A water managing tillage is to be combined with the organic matter conservation including OM recycling and carbon preserving solutions. When monitoring tillage practices, it was found that dry periods definitely promote the application of soil conservation methods and thus reducing climate risks *(Table 4).*

According to Birkás (2011) climate risk means the defects in the soil quality condition along with likely consequences of soil disturbance. A regrettable fact, that during wet periods – particularly in the autumn –, landowners tend to return to the convention-

*Table 4. Conservation tillage adoption in Hungary (2009–2015)**

Plant and tillage task	Area, 1,000 ha	Conservation tillage, %	
		in dry seasons	in wet seasons
Stubble tillage after summer harvest**	1,590–1,670	52–56	37–45
Primary tillage for oilseed rape	190–250	65–77	52–60
Primary tillage for winter wheat	1,720–1,780	52–55	33–40
Primary tillage for maize, sunflower	1,620–1,770	42–49	27–34
Primary tillage for sugar beet, soybean	40–70	60–70	49–51
Ploughing adaptable to wintering	150–180	32–35	17–24
Total (without stubble tillage)	*3,570–3,870*	*50–57*	*36–42*

*Sown area in Hungary: 4,332,000 ha (KSH, 2015), data from field and soil monitoring and discussed with machinery dealers and sellers. **Pea, rape, barley, oat, wheat, durum, triticale and rye.

al tillage methods. Accordingly, about 15 per cent of those applying soil conservation tillage methods are facing uncertainties in regard to the methods that are suitable for reducing climate-induced damage. There is difficult task to convince landowners who apply conventional methods that endanger the quality of soils. Preserving tillage of wet soils has become an acute issue during the recent decades. Dry periods have become increasingly frequent – in connection with climate forecasts – wet periods also occur primarily during the late summer and autumn tillage seasons. In spite the fact that the tillage season has expanded to the first winter month, some 36–42 per cent of the total arable land is tilled before the soil becomes actually suitable for tillage. Applying ploughs and conventional disks and causing damage to wet soils lead to increased tillage costs during subsequent seasons.

As Birkás and Dekemati (2015b) noted that there is a demand for the elaboration of methods suitable for conservation tillage of wet soils. A brief summary of such methods is as follows: any damage already done must be remedied, while avoiding any new damage. Farmers must check their soils frequently enough to be always aware of their condition. No intervention obstructing the soil's recovery (disking or ploughing resulting in smearing and kneading the soil) should be carried out. Traffic on the soil and the number of tillage interventions must be minimised. Any compact layer blocking the water infiltration to the soil must be loosened (this method is not the same as the technique of loosening the soil with effects lasting at least one year). The soil surface must be protected to alleviate the impact of rain stress resulting in silting. Organic matter recycling and conservation is required.

Crop focused tillage versus climate focused tillage

Classical authors emphasised the importance of creating good seedbed for plants (Birkás, M. 2008). In the physical approach tillage was believed to play an important role in controlling soil processes. Consequently the period of several centuries dominated by this approach is referred to as the era of crop oriented tillage (Birkás, M. *et al.* 2015b). References to plants' alleged tillage needs have been found in literature since the 1800s to date. Particular emphasis has been and is still often being laid on the need for creating a fine crumbly seedbed. The need for preserving the soil used to be absent from the lists of objectives of tillage in textbooks, but today it has gained primary importance (Birkás, M. 2008).

The over-estimation of the importance of crop requirements resulted in damaging the soils (e.g. structure pulverisation, siltation, crust formation on the topsoil, etc.), which inevitably led to the recognition, in the mid-1960s, of the need for protecting soils quality hence that was the beginning of the era of soil focused tillage (Bartalos, T. *et al.* 1995). Any crop requirements can be met by a soil kept in a good physical and biological condition by soil preserving tillage, with the added benefits of causing less damage and cutting costs. Since the first years of the climate change, as the new trends have raised concern, tillage must be turned into a climate focused effort with the aim of reducing climate-induced stresses through improving soil quality (Birkás, M. 2011).

Conclusions

Progress and development in soil tillage has been fraught with contradictions since the beginning of the history of tillage in Hungary. Conclusions drawn from the overview of the process:

- At the beginning progress was hindered by lack of knowledge of soil and plants, inadequate draught power and imperfect farming implements as well as natural disasters. Technical advancement could be indicated first in terms of improvements in ploughing tools and the increase in ploughing depths.
- The higher yields resulting from deeper loosened layer had associated with inverting the soil. In the absence of knowledge of the soil the damage caused by the increasingly frequent use of the plough could not be recognised.
- Up to the 20th century the factors identified as threats to soils included – apart from wars – insufficient tillage, excessive tillage, soil depletion and drought.
- The tasks of soil protection have become highly complex in the 21st century because, on the one hand, the process of soil degradation that has been going on for centuries needs to be brought to a halt while on the other hand, threats relating to the climate change have to be managed, with the help of adequate knowledge.
- The Hungarian soil tillage literature has made a significant impact on the progress of tillage since the 1800s, but owing to the language barrier they never came to be tested at an international level. Scientists focusing on tillage today can widely distribute their methods developed for use under difficult conditions.

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Supporting transition toward conservation agriculture: a framework to analyze the learning processes of farmers

Hélène CRISTOFARI[1,2], Nathalie GIRARD[1] and Danièle MAGDA[1]

Abstract

Conservation agriculture (CA) is based on 3 principles, namely reduced soil disturbance, permanent soil cover, and more complex and legume-rich rotations; and multiple studies have shown its positive impacts. Because CA relies on a variety of ecological processes, it is more deeply rooted in a specific ecological context than conventional agriculture. The complexity of these processes makes it difficult to elaborate general recipes to be applied by farmers, who therefore need to learn to make their own choices adapted to their own agroecosystem. Consequently, helping farmers to move toward CA requires supporting them in learning to develop their own practices. Farmers' learning remains poorly investigated at the individual level, with in particular very little work focusing on learning in CA. We hypothesize that the processes involved in learning to practice CA may differ from those involved in conventional agriculture: for instance, the current lack of detailed reference documents may induce farmers to experiment more. Against this background, we here aimed at describing how farmers experienced in CA learn, by qualifying their learning mechanisms and processes. To do so, we conducted five comprehensive interviews with farmers experienced in CA, and then inductively analyzed the data to explore the diversity of learning mechanisms involved, i.e. the elementary actions or cognitive activities which, organized together, constitute a learning process. We, thus, propose a descriptive framework of non-ordered and non-obligatory learning mechanisms that appear to be mobilized by farmers experienced in conservation agriculture, as a first step toward a deeper analysis of their learning processes. We further emphasize the often unintentional aspect of learning, as well as the importance, for farmers who wish to implement CA practices, of developing new standards of comparison. A better understanding of these learning processes would help improving extension services and training for farmers.

Keywords: agroecology, conservation agriculture, farmers' learning, learning mechanism, learning process, qualitative analysis, inductive approach

Introduction

Conservation agriculture as a promising agroecological approach

Conservation agriculture is classically defined today as a set of practices respecting three main principles, namely reduction of soil disturbance, permanent soil cover, and diversification of the crop rotation (FAO 2012); a fourth principle, related to the integrated management of weeds, has also been suggested (Farooq, M. and Siddique, K.H.M. 2015). These principles, taken together, primarily aim at reducing soil erosion: this was in fact the main goal pursued when such practices became popular in North America in the 1930s, following the ecological and social catastrophe of the Dust Bowl in the American Mid-West.

However, a number of additional benefits have also been largely suggested or demonstrated, including an increase in soil water retention, a reduced need for mineral fertilization, the enhancement of biodiversity and so on (Hobbs, P.R. *et al.* 2008; Dordas, C. 2015; Nawaz, A. and Ahmad, J.N. 2015). It is important to note that such advantages may be at-

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[1] AGIR, Université de Toulouse, INRA (French National Institute for Agricultural Research), INPT, INP-EI PURPAN, Castanet-Tolosan, France. E-mail: helene.cristofari@toulouse.inra.fr. Corresponding author.

[2] Université Toulouse III Paul Sabatier, Toulouse, France.

tained – at different degrees – through a diversity of practices: following the three main principles may, thus, encompass different levels of soil disturbance, from "zero disturbance" to strip-till or a very shallow tillage, different choices of cover crops and cover crop management, more or less diversified rotations.

These practices tend to share a common characteristic: they are mostly based on the management of ecological processes to replace technological inputs. For instance, the introduction of sorghum in the crop rotation results in a partial compensation of the absence of tillage by the fissuring effect of the sorghum deep taproots. Consequently, conservation agriculture practices can be considered as agroecological practices, in the sense of practices based on the management of ecological processes.

An adoption still limited in Europe

Despite the manifold advantages brought to farmers and society as a whole by conservation agriculture practices, their adoption remains somehow limited in Europe, with wide differences between countries. Diverse possible explanations have been put forward, at the political, economic and cognitive levels. Basch, G. *et al.* (2015) underline the important role of the Common Agricultural Policy (CAP) in this matter: they argue that because of a historical orientation of the CAP toward high yields, farmers tend to think more in terms of maximizing their yields and the subsequent subsidies, rather than reducing their production costs or investing in long-term soil amelioration.

It has also been suggested that conservation agriculture is difficult to adopt because of its "knowledge-intensive" character (Friedrich, T. *et al.* 2009; Ingram, J. 2010): it relies on ecological processes that are only very partially known, and very specific to a particular place (Lahmar, R. 2010; De Tourdonnet, S. *et al.* 2013). Farmers, thus, need to change the way they make their daily decisions, and the objects they observe to found such decisions (De Tourdonnet, S. *et al.* 2013). Consequently, a better understanding of the way farmers learn may help mitigate such a cognitive issue.

Farmers' learning: overview and missing aspect

A number of authors have studied how farmers learn, but usually focusing on specific situations where learning occurs. For instance, some studies explored the learning situations involving an "expert", such as a more experienced farmer or a technician (Labarthe, P. 2009), while other works concentrate on the transmission of knowledge between newcomers and more experienced farmers (McGreevy, S.R. 2012; Chrétien, F. 2013). Some authors examined learning situations involving knowledge exchange groups: building on two case-studies of Australian breeders, Millar, J. and Curtis, A. (1997), thus, suggested that farmers may undervalue their own knowledge, and that exchange among peers may help them get aware of their own knowledge, as well as facilitate the construction of common understandings between farmers and scientists.

Others focused on the origin of the information used: Kilpatrick, S. and Johns, S. (2003), thus, proposed a typology of farmers according to the learning sources they mobilize (extension agents, peers, single individuals or a diversity of persons). Finally, a growing body of studies explores the modalities and consequences of farmers' experiments (e.g. Kummer, S. *et al.* 2012; Vogl, C.R. *et al.* 2015).

However, fewer works deal with farmers' learning in a more comprehensive way, as a process encompassing a diversity of such specific learning situations. Some efforts were made in this direction by authors such as Lyon, F. (1996), who described diverse aspect of the learning processes of British farmers, without a specific focus on a certain learning situation. More recently, Chantre, E. *et al.* (2014) proposed 10 learning styles defined by the learning source used and/or typical action (e.g. "Autonomous testing of an idea coming from an extension agent") undertaken by farmers reducing their chemical inputs doses.

Such studies shed light on the way farmers learn, but they are not concerned with complex agroecological practices such as conservation agriculture: thus, the question remains of how farmers learn to develop these practices based on the management of ecological processes, in the absence of exhaustive technical references. Moreover, it is noticeable that quite a few authors (*Table 1*) interested in farmers' learning processes usually base their analysis on rather convergent views of learning: they tend to consider it as an intentional process based on problem resolution and occurring through roughly similar steps, namely defining a problem, conceiving a solution, testing the solution, monitor the outcome and decide if the solution is adequate or not.

We thought that such a view of learning may be relevant mostly for farmers who are intentionally trying implement a specific change of practices (such as reducing synthetic fertilizers doses, for instance). However, in the case of farmers who are learning to practice conservation agriculture, there is not one single clear-cut change of practice: quite the contrary, switching to this type of agriculture requires an evolution of the whole system, as well as a deep change in the way the system is perceived (Ingram, J. 2010; De Tourdonnet, S. *et al.* 2013). Furthermore, learning does not necessarily result from the intentional resolution of problems, it may also happen as a consequence of a surprise, an unexpected outcome (Lyon, F. 1996; Darnhofer, I. *et al.* 2010). As a result, it is possible that such a representation of learning, organized in ordered steps starting from a problem to be solved, may not be the most accurate one for farmers experienced in conservation agriculture.

Our research goal

In this study, we therefore adopt an inductive approach to see how farmers' learning may be described. To do so, we here explore the diversity of *learning mechanisms* involved – i.e. the elementary actions or cognitive activities which, organized together, constitute a *learning process* – with an aim at proposing a descriptive framework of the learning mechanisms that appear to be mobilized by farmers experienced in conservation agriculture, as a first step toward a deeper analysis of their learning processes.

Method

Study area: South-Western France

We focused on a region located in South-Western France (roughly between the cities of Toulouse and Carcassonne), because it presents several issues which make the implementation of conservation agriculture

*Table 1. Example of sequences of learning steps for farmers**

Steps of learning	Authors
– Expectation – Planning – Scale – Observation – Repetition – Documentation	Leitgeb, F. *et al.* 2014
– Warning sign stage – Experimenting stage – Evaluation stage	Chantre, E. *et al.* 2015
– Choice of a technique, decision to apply it and preparation for the implementation. – Several tests and errors, adaptation of specific monitoring and operational methods, amplification. – Evaluation of consequences of new practices on the cropping system.	Toffolini, Q. 2016

*According to recent studies.

especially interesting. Soil erosion is particularly high in this area, causing regular problems to both farmers and other citizens (e.g. loss of fertile soil, mudslides); moreover, the warm summers occasion frequent drought periods. Finally, it has been suggested that the past crops, such as the widespread culture of vine, has led in different places to an important reduction in soil organic content. Accordingly, the potential benefits of conservation agriculture in terms of reduction of soil erosion, enhancement of water retention and increase in soil organic matter would be especially promising in that region.

Sample of learning mechanism

Our study is based on 5 in-depth qualitative case studies of farmers experienced in conservation agriculture practices. We chose farmers based on two sets of criteria.

– First, they had to be *sufficiently experienced*: we considered that this was the case when they had been implementing the three principles of conservation agriculture for at least 10 years: it has been shown (Pittelkow, C.M. *et al.* 2015) that switching to conservation agriculture leads to a yield decline during the first few years after starting their transition, and that the yields increase again, back to the initial level or sometimes higher, over the later years. As a result, choosing farmers with at least 10 years of experience enabled us to select people who had some hindsight on the whole transition, and who learned to overcome the more difficult moments. Moreover, the 5 farmers selected were recognized by their peers as particularly advanced in conservation agriculture practices.

– Second, since our aim was the construction of a framework to describe the diversity of learning mechanisms, we had to select *a sample of learning mechanisms as diverse as possible.* It has been suggested that the way we learn depends on different factors, such as individual personality (Kolb, D.A. 1984), the object of learning – "what we learn about"– or the learning situation (Chantre, E. and Cardona, A. 2014). Consequently, we selected our sample according to the theoretical sampling strategy (Eisenhardt, K.M. 1989), trying to include diversity for all these factors. Practically speaking, this means that the selected farmers were characterized by a diversity of professional paths (more or less academic education, different family ties to agriculture), a diversity of relationships with other farmers and with extension agents, a diversity of productions (arable crops alone, with vines, with livestock), and a diversity of current conservation agriculture practices (from direct seeding to shallow tillage, different ways to manage cover crops, varied uses of chemical inputs…).

Qualitative data collection through comprehensive interviews

Our qualitative data was gathered through *comprehensive interviews*, i.e. a type of interview which leaves the informants ample room to develop their ideas and follow their own line of thought from one topic to another, while the interviewer only gives some prompting to re-launch the discourse and go deeper in details, or refocus the speech around the main topics of the interview, here exposed in *Table 2.* Our interviews lasted for a total duration of 11 hours and 30 minutes.

Inductive data structuring

The interviews were then integrally transcribed and we structured the resulting scripts using the Nvivo qualitative analysis software. Taking one interview after the other, in random order, we coded the learning mechanisms in the inductive way characteristic of *conventional coding* (Hsieh, H.E. and Shannon, S.E. 2005). Consequently, there was no previously defined list of nodes to be used. Each time the interviewee talked about how he learned something, we coded this excerpt of the text with a short expression describing "how the farmer learned".

Table 2. Comprehensive interview grid to analyze the learning processes of farmers experienced in conservation agriculture

I	General information	
	Surface? Soil type(s)? Irrigation? How long have you been working on this farm? Is it a family heritage? Other family links to agriculture? Initial training? Have you had any other profession? How long have you been a farmer? Since you started farming, which productions have you had?	
II	Technical themes	Types of questions
	Crop choices/rotation Soil management (including soil erosion) Cover crops Weeds Pests Choices of varieties/seed production	What are your current practices? How long has it been so? What did you do before? Why were such changes implemented? How were such changes implemented? Where did you get the idea from? How did you judge if the practice was satisfactory? Are you considering any other change now?
III	If not alluded to before	
	Relationships with peers (either in conservation agriculture or not, neighbours or farther away, casually or through networks, associations…). Relationships with extension agents. Relationships with researchers.	

We used words that were as close as possible to the farmer's, while also trying to choose an expression not too specific to one particular excerpt, so that it could be re-used to code other parts of interviews dealing with the same mechanism. In the end, twelve different nodes were created (such as "Monitor the system", "Analyze the information acquired during monitoring"…), and 169 excerpts, ranging from a few words to several paragraphs, were coded with these nodes: *these 169 excerpts constitute our total sample of learning mechanisms*. We observed that saturation (or the absence of apparition of any new learning mechanism) was reached around the end of the fourth interview, thus, confirming the adequacy of our sample.

Data analysis

The data, thus, structured into smaller units through coding was then analyzed following a strategy close to the *grounded theory* construction (Glaser, B.G. and Strauss, A.L. 2009). As a first step, we went through all excerpts coded with each node, and organized them in hierarchical categories. We then identified possible links between the twelve hierarchical systems of categories obtained, and merged part of them, thus, building the grid of learning mechanisms presented hereafter. Because the categories of learning mechanisms had to be sufficiently general to include elements of discourse from different farmers, we could not strictly keep the words used by interviewee: consequently, the labels of the categories mechanisms of learning exposed in our results are often our own scientific terms, chosen because they were large enough to encompass the diverse specific expressions used by different farmers.

Results

A grid to describe the diversity of learning mechanisms

We organized the learning mechanisms emerging from our interviews into five categories corresponding to different steps in the learning process *(Table 3)* these possible steps are not always present for each farmer, nor do they represent a logical sequence which is necessarily followed. They are merely larger cat-

*Table 3. Learning mechanisms of farmers experienced in conservation agriculture**

Learning steps	Learning sources		
	Personal experience	Peers' inputs	Scientific inputs
Get an idea of a new practice.	Conceive a new possible practice.	Find an idea of a new practice together with peers. Imagine a new practice, by getting inspiration from peers' practices.	Find an idea of a new practice from a scientific source. Imagine a new practice, based on a similar phenomenon scientifically understood.
Implement a new practice.	Choose a time scale. Choose a spatial scale. Choose a degree of intensity of change.		
	Experiment in a planned way. Experiment in an opportunistic way.		
	Experiment in a fortuitous way.		Rely on scientific methods to conceive an experimental design.
	Implement a new practice individually.	Implement a new practice collectively.	
Monitoring the state of the system.	Monitor the system in a quantitative or qualitative way. Monitor a specific experiment, or monitor the system in a more general way. Choose a frequency and spatial scale for monitoring activities. Find indicators for the information desired.		
	Analyze the information obtained through monitoring in a more or less formal, quantitative way. Choose a time and spatial scale for analyzing the information obtained through monitoring. Take into account independent variables.		
Develop standards of comparison.	Reject peers' standards.	Compare one's system with peers' systems. Construct and share common ideals.	Judge the state of the system with respect to scientific standards.
Construct a principle of action.	Confirm or disprove information coming from a scientific source.	Confirm or disprove information coming from a personal observation.	Confirm or disprove information coming from a personal observation.
	Confirm or disprove information coming from peers.	Confirm or disprove information coming from a scientific source.	Confirm or disprove information coming from peers.
	Put together different personal experiences.	Put together different opinions from peers.	Put together different scientific sources.
		Find among peers a direct explanation for an observed phenomenon.	Find in a scientific source a direct explanation for an observed phenomenon.
		Elaborate an explanation of a phenomenon based on an analogy with an explanation of a similar phenomenon heard from peers.	Elaborate an explanation of a phenomenon based on an analogy with a scientific explanation of a similar phenomenon.
		Take a piece of information coming from a peer as true without further inquiry, based on credit given to this peer.	Take a piece of information coming from a scientific source as true without further inquiry, based on credit given to this source.

* The left-side column indicates the main possible steps of the learning process, and the upper line presents the different sources that a farmer may mobilize when going through these different steps.

egories which we defined, based on our data, to cluster more specific learning mechanisms.

Get an idea of a new practice. This may happen on one's own, or it may result from exchanges with peers, either directly (i.e. getting the idea from another farmer) or indirectly (i.e. on the basis of exchanges with peers, geting inspiration to personally conceive a new practice). For instance, this farmer directly used the idea of simplified sowing coming from a peer, but he adapted the idea of the observed crop rotation:

> "For two years, we watched him do that…he'd sow, and it would work! And so yeah, we talked with him. From the start, he did a four-year rotation. So he had: wheat, sunflower, pea, rape. A wheat every four years, and he turned like that. And for us, we tried to do wheat-sunflower, wheat-soy, wheat-stuff…"

It may also come from scientific sources, this time again, directly or indirectly.

Implement a new practice. Farmers talked about implementing new practices at a variety of spatial scales (for instance, trying a cover crop on a smaller area first, or on a whole field at once) and time scales (e.g. trying direct seeding of corn just one year, or try it over several years to see whether the specific climatic conditions of the first year made a difference or not). New practices may also be implemented more or less progressively: some farmers try stopping tillage altogether, whereas others go through gradual change, from a 50 cm ploughing to 30 cm, 15 cm and so on, assessing the results as they proceed.

A farmer may implement a new practice in a more or less planned way, and we here suggest to distinguish three types of experiments: *planned experiments*, that are willingly foreseen and conducted by a farmer, *opportunistic experiments*, that happen when some mishap puts a farmer in an unexpected situation, prompting him to try something new which he would not otherwise have tried, and *fortuitous experiments*, that are not decided by a farmer but happen anyway. For instance, when a mistake or unforeseen climatic event leads to interesting results (because this last category is wholly unplanned, it can happen simultaneously to a group of peers, but it cannot include any scientific input, hence the exclusion of the "scientific inputs" column in *Table 3*). A case of opportunistic experiment was narrated by this farmer, who tried simplified sowing for the first time because of a machine breakdown:

> "And so, it took the plough to break down, in 1992. It was broken. So, we needed two days to repair it, to get the parts. And the weather was not propitious. I finished sowing with a cultivator, and actually, when I saw the results, the wheat, it made no difference."

A farmer may implement a new practice on his own, but exchanges with peers may also affect how he decides to go about experimenting. Scientific documents or extension agents may also provide methodological inputs to plan an experimental design. It was for example the case for this farmer, who set up a complete scientific design:

> "This year, I tried localized fertilization on soy (…). So, trials with liquid fertilizers, solid fertilizers formulas and mycorrhiza. There were six treatments, I believe … six treatments, four control plots, and that's it!"

Monitor the state of the system. It includes two aspects: the acquisition of information about the system, and the subsequent analysis of such information. Farmers may acquire information about their system or parts of it in a qualitative or quantitative way, at different frequencies and spatial scales, with a variety of indicators (coming from scientific sources, co-developed with peers, and/or personally developed). The analysis of such information may also be more or less formal (from a very rough guess to a computer-aided statistical analysis including a diversity of independent variables). A mere observation of a change in colour can provide evidence for the farmer that his practices are being successful, as was the case for this farmer who saw his soil darken because of the increase of organic matter due to conservation agriculture practices:

> "It isn't the compost that blackens the soil. But I see, each time the neighbouring ploughs, and it gets dry after, in my place the soil is much more coloured."

This monitoring activity can apply either to a specific change of practice, or more broadly to the evolution of the system. It may be conducted in relation to several changes of practices (for instance, the effect of a simultaneous reduction of tillage and implementation on cover crops on soil erosion), or in relation to no conscious, planned change in practice, but a simple overall acquisition of information about the evolution of the system.

*Construct standards of comparison***.** Farmers form an idea of what their system – or parts of it – should be like and what its performances should be. This can be based on exchanges with peers leading to the construction of a common ideal, on comparisons with other farmers' systems, or it can be inspired by scientific standards. Developing new standards seems to be particularly important for practicing conservation agriculture, as illustrated by a farmer who satirically talked about the idea of a "beautiful" soil for those who do not take into account the importance of soil life and organic matter:

> "So you took out all weeds, your soil is moon-like it is like flour…It's wonderful! It's beautiful! There isn't one single plant! (…) So every year in winter you add 500 to 1,000 kg of organic matter granules that you buy at the cooperative because your soil actually lacks organic matter…"

*Construct a principle of action***.** Farmers may construct a general principle of action based on different factors: for instance, they expressed to different degrees their needs to understand the cause of an observed phenomenon in order to consider it as generally true. Such an explanation may come directly from peers or scientific sources, or be more indirectly inspired from such sources. A farmer, thus, described how his crop rotation was based on his understanding of the ecological mechanisms at work:

> "Sorghum has a very efficient root system, (…) it explores the soil, it pumps everything that's available. Which is another advantage for growing peas after that, in my opinion. Because the peas don't find any nitrogen leftover, they have to install the symbiosis to be able to develop. (…) I found elements that go in this direction in the literature. But it's not validated."

The different learning sources

We chose to organize the diversity of learning mechanisms identified in our data according to two dimensions that appeared important, the sources mobilized by farmers to learn, and the main learning steps. Obviously, the three sources of learning (personal experience, peers' input and scientific inputs) are to be seen as widely overlapping, rather than distinct categories: for instance, knowledge exchanges among farmers often include scientific information. However, distinguishing those three main poles may help identify different ways in which they participate in farmers' learning.

As an example, our data suggest that farmers may turn toward peers or scientific inputs in different situations: peers' inputs seem to be mobilized when a solution to a specific, localized problem is needed, whereas scientific inputs seem to be more used as a mean to explain the biological processes underlying an observed phenomenon, thus, enabling the farmer to make generalizations, or to adapt a practice observed in another farmer's system to his own system, since he is able to understand why this practice leads to interesting outcomes.

An analytical framework based on non-ordered and non-obligatory learning steps

The 5 steps we proposed to describe the learning process *(Table 3)* are not to be understood as a fixed sequence: they are rather meant as non-ordered and non-obligatory categories of learning mechanisms. Learning can occur without the completion of each one, and our case studies showed examples of farmers going through these steps in different orders, as exemplified in *Figure 1.*

Explanation of patterns *A* and *B*:

A: By performing soil analysis, a farmer realizes that he has a problem of low organic matter content (*Mss*). Then he hears from a peer that this could be improved through the implementation of cover crops (*Gi np*).

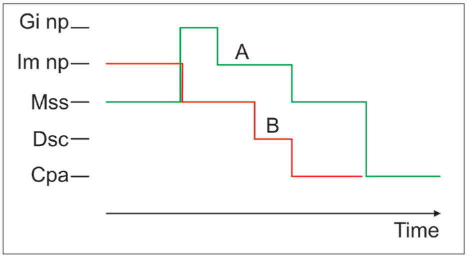

Fig. 1. Two different possible patterns (A, B) of learning mechanism for farmers experienced in conservation agriculture, drawn from our case studies. Explanation for A and B is in the text. Gi np = Get an idea of a new practice; Im np = Implement a new practice; Mss = Monitoring the state of the system; Dsc = Develop standards of comparison; Cpa = Construct a principle of action.

Consequently, he decides to try this for a couple of years (*Im np*) and the following soil analysis indicates slightly higher organic matter content (*Mss*). He decides to integrate cover crops in his whole system because he considers this is a solution for him (*Cpa*).

B: Because of a machine breakdown a farmer is unable to till as usual on a given year (*Im np*). However, he sees that the yields are satisfactory (*Mss*) and that even though the soil does not look as good as he usually likes to see it, he has less problems of soil erosion this year (*Mss*). In consequence, he starts rethinking about what makes a soil "good" or not (*Dsc*), and decides that reduced tillage may be a better opinion for him (*Cpa*).

Discussion

A new framework for describing the learning processes

The analytical framework that emerges from our study cases significantly differs from the "classical" view of learning from experience, on a number of aspects: the initiation of the learning process through problem identification, the underlying hypothesis regarding the conscious and deliberate quality of the learning process, the importance given to the construction of standards of comparison, and finally, the leeway left for diversity in the learning processes of farmers.

Initiation of the learning process. Drawing on our results, we would like to emphasize the fact that learning does not necessarily start with the definition of a specific problem or a "warning sign" (Chantre, E. *et al*. 2015): it can also occur either when the farmer wants to try something new in his system, which may be not a response to a problem identified as such, but simply a new practice that seems interesting. We, thus, suggest talking about "Implementing a new practice" rather than "Defining a problem" and "Testing a potential solution". Moreover, as some authors already noted (Lyon, F. 1996; Darnhofer, I. *et al*. 2010) learning can occur through chance events as well. Such chance events were often alluded to in our case studies, leading us to distinguish between the planned, opportunistic and fortuitous experiments detailed in the results.

Varied degrees of internationality and consciousness. The fact that a learning process can start with a chance event underlines the idea that not all learning is decided by the learner. The initiation of the process may occur without planning, and other learning steps as well; they may even happen without the awareness of the learner. For instance, our interviews illustrated the fact that "Monitoring the state of the system" may happen on an everyday basis, anytime the farmer goes around the fields, without having necessarily a specific monitoring purpose.

Likewise, constructing a principle of action may be done implicitly by the farmer. Such unconscious learning can be related to the notions of embodied, encultured or embedded knowledge (Blackler, F. 1995), but it seems to be quite absent from the classically described learning processes of farmers. We would therefore like to highlight the importance of taking into account unplanned and unconscious cognitive mechanisms as part of the diversity of farmers' learning processes.

A crucial role for the development of standards of comparison. The idea of developing standards of comparison seemed to be of crucial importance for farmers who had switched to conservation agriculture. It is often considered that monitoring the outcome of an experiment is enough to lead to a decision about the adequacy of the experimented practice, and in fact the development of standards of comparison is not explicitly present in the previous models of farmers' learning.

However, it is important to realize that in order to judge whether or not the practice is adequate, the experimenter needs to know what the outcomes of this practice are, but he also requires some standard or ideal against which the observed outcome is to be judged.

A farmer may acquire information about the outcome of a reduced tillage practice by examining the soil characteristics, but he also need some sort of mental grid of criteria or standards, some idea of what makes a soil "good" or not, to decide if this is a satisfactory outcome. In the case of conservation agriculture, this may be particularly important: the soil starts to be seen as a rich and complex ecosystem rather than an inert substrate; the crops are evaluated not only according to their yield and corresponding profit, but also in relation with their influence on soil structure and composition. We therefore argue that changing the standards of comparison is a major step in learning to practice conservation agriculture.

The framework we presented, thus, differs from the classical models of farmers' learning essentially in the fact that it enables us to account for a large diversity of learning processes, including multifarious starting steps, diverse possible orders of learning mechanisms, and varied degrees of planning and consciousness.

Practical implications

The implications of this work are mainly related to the improvement of extension services, farmers' workshops and other types of training.

*Clarification and discussion of the standards of comparison used***.** Given the apparent importance, for farmers who switched to conservation agriculture practices, of developing new standards of comparison, it seems that an explicit clarification of what these standards are would help in improving the impact of training.

Indeed, a farmers' workshop or extension service may lack efficiency if the arguments that are put forward ignore the existing standards. For instance, when the notion of a "beautiful field" implies a soil without any crop residue or small weed, discussing this standard with the farmers may be necessary so that practices such as reduced tillage are not argued against solely because they do not comply with the requirement for "beauty", in some farmers' acceptance of this term.

Roles for science in the learning processes of farmers. Our results show that scientific sources are mobilized by farmers in a diversity of ways: for instance, they can be used to provide ideas of new practices, indicators used by farmers to monitor the state of the system, explanation for a phenomenon observed by farmers, or scientific methodology which may be applied to a certain degree when farmers experiment.

Distinguishing the different roles that scientific information play in farmers' learning processes will help in identifying when to include such information in training, extension services and so on. For instance, as presented in our results, scientific explanation of an observed phenomenon may be especially sought after by farmers who are trying decide whether or not to apply and adapt a successful practice observed somewhere else.

Such hypotheses obviously need to be strengthened through the analysis of a broader sample of farmers, but nonetheless, they highlight the importance of a better understanding of how farmers actually use scientific information, in order so the accuracy of extension services and agricultural training design.

Conclusion

Through an in-depth analysis of discourses of farmers experienced in conservation agriculture, we proposed a framework to describe and analyze the learning mechanisms and their articulation over time. The study of a broader sample of farmers across different regions, (which we are currently doing) and complementary qualitative as well as quantitative work should then enable us to identify the more common learning mechanisms processes for farmers experienced in conservation agriculture. This would also enable us to assess potential relationships between the learning mechanisms and the objects of learning, or in other words, potential links between "how farmers learn" and "what farmers learn about". Such an understanding would help highlighting ways in which such learning processes may be fostered, in the case of conservation agriculture, but also potentially for other types of agricultural practices based on the management of ecological processes.

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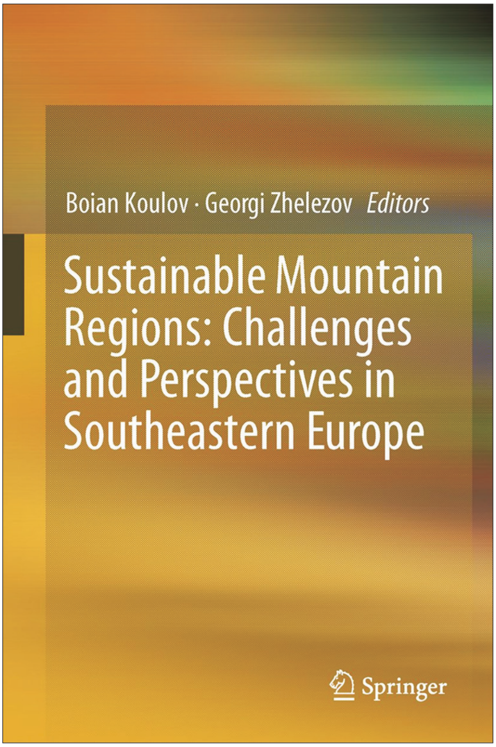
BOOK REVIEW

Koulov, B. and Zhelezov, G. (eds): Sustainable Mountain Regions: Challenges and Perspectives in Southeastern Europe. Switzerland, Springer, 2016. 268 p

The outcome document of the Rio +20 Conference on Sustainable Development states that the benefits derived from mountain regions are essential for sustainable development and encourages states to incorporate mountain-specific policies into sustainable development strategies (The Future We Want 2012). The mountain areas of Europe have social, economic and environmental capital of significance for the entire continent (EEA 2010). However, until recently, EU policy paid little specific attention to mountains. They appeared in the cohesion policy as regions with "severe and permanent natural or demographic handicaps", while with regard to agriculture and rural development they were identified as "less favoured areas" (Price, M. 2016a, p. 376).

The accession of new member states with large mountainous areas after the millennium has increased the area and proportion of such areas in the EU. The mountainous regions of the new member states, especially in Southeastern Europe, are often inner peripheries, their prospects further worsened by their border status (Koulov, B. 2016). Partly as a consequence, attention has started to turn to mountain regions in recent years. As Gløersen, E. *et al.* (2015) state, although mountain areas in the EU are too diverse to elaborate an integrated European strategy, a framework for development strategies in mountain areas can be developed. In 2016 the European Parliament asked for a regular assessment of the condition of the EU's mountain areas and of the implementation of cohesion policy programmes (Price, M. 2016a). Yet, necessary information is not equally available from the European mountain regions. In 2010 the project 'mountain.TRIP' found that EU funded research was unevenly distributed among different European mountain regions with the emphasis on the Alps and later the Carpathians. According to their findings, possible causes for this could be later EU accession, the lack of know-how and experience in carrying out EU research projects, or simply low visibility due to language barriers (mountain.TRIP). Price, M. (2016b) argues that the development and implementation of the Carpathian Convention, signed in 2003, were critical factors in the comprehensive and comparable mapping of the characteristics of the Carpathians, whereas a similar convention in Southeastern European mountains is still lacking.



SEEmore, an international network of scientists working in the mountains of the Southeastern European region, was launched in 2009, fostered by the Mountain Research Initiative (MRI). This book, 'Sustainable Mountain Regions: Challenges and Perspectives in Southeastern Europe' apparently comprises research presented at the 5th SEEmore meeting held in Borovets (Bulgaria) in 2015. A proclaimed aim of this meeting was to promote the establishment of a Balkan Convention on Sustainable Mountain Regions, similar to the already existing Alpine and Carpathian Conventions.

The volume contains 19 studies (chapters) from 11 Central and Southeastern European states, although the majority of them (9 chapters) are related to Bulgaria. The chapters are grouped into five major parts, entitled 'Sustainable Policies in Mountain Regions', 'Natural Resources and Ecosystem Services: Adaptation to Climate Change', 'Mountain Economies', 'Mountain Ecology, Risks and Protected Areas', and 'Population and Heritage Challenges'. Due to the very wide variety of topics, including both physical geographical and socio-economic aspects, it must have been a very difficult task to create the structure of the volume which, as a result, seems somewhat haphazard. Therefore the chapters are reviewed with a slightly different logic.

In Chapter 1, which is related to *regional development policy*, the authors analyse the relevant regulatory framework and related geographic problems of regional development policies from a Bulgarian perspective. After giving a thorough overview of changes in mountain-related policy in Bulgaria in the near past, they argue that policy instability and inadequate territorial policy integration are the main challenges at the state scale. A more precise definition of mountainous regions and their delineation are important tasks and prerequisite of the selection of regions that are eligible for assistance. As for the EU scale, they consider the lack of territorial policy integration and inept priority setting in regional development as the greatest challenge. By the latter, the authors understand that instead of targeting the Southeastern European mountain regions as a priority of EU regional development policy, the EU supports the Carpathian and Alpine conventions, in which three southern EU countries (Greece, Croatia and Bulgaria) with considerable mountain regions are not included.

The chapter leaves it at that, but possible solutions are mentioned in the preface of the book where either the extension of the Carpathian convention or the launch of a new Balkan convention are brought up. There is also promising recent progress in directing the attention of the EU to mountain regions (see Price, M. 2016a). In Chapter 15, a slightly different but still policy-related study, the author examines spatial discrepancies and potential linkages of ecological networks in the border region of Serbia and Bulgaria. He makes suggestions for the designation of some more future Natura 2000 areas in Serbia, so that there would be direct linkages to already existing protection areas in the neighbouring countries.

The most pronounced topic in the book is, not surprisingly, *sustainable tourism*. In most mountainous regions, traditional occupations are usually related to agriculture, mainly forestry and grazing, but in modern times tourism partly replaces, partly complements these. As Gløersen, E. *et al.* (2015) state, sustainable tourism is widely advocated as a means for economic restructuring and local development. There are six related chapters throughout the volume. The first of these (Chapter 2) is an insightful study from Italy (South Tyrol), which examines the cooperation models of small structured farms in the Alps. According to the study, the limited production capacity of local farms in the face of increasing demand and problems like seasonality inspire horizontal (between farmers) or vertical (e.g. farmers-accommodations) cooperation. Based on a case study analysis, the authors scrutinise some possible solutions (for instance certification of food products, regional food quality standards and logistics cooperation) and the related experience of the local stakeholders and finally identify four models. They conclude that such cooperation needs a strong basis of trust and the creation and maintenance of such regional systems do not necessarily result in increased profit but rather in social, cultural and innovation benefits.

Chapter 8 presents patterns of local tourism development in Bulgaria, describing and comparing the recent development processes of three destinations. The study intends to fill in a gap because, as the authors state, such information at the local level is very hard to access in Bulgaria. They find that although the three areas are different in their patterns of tourism development, a few general conclusions can be drawn. In their view, available attractions are 'necessary' requirements for success, whereas the will to promote tourism through developing accommodation and infrastructure is a 'sufficient' condition. Finally, partnerships and networks seem to be essential in achieving sustainability.

Chapter 9 is a study from Greece, where the authors examine the possibilities and potential of an e-tourism application, developed specifically for an area where a city and its sights are close to a mountain region. Most of the information and techniques proposed are already existing and available as well, but not in an integrated form. The authors state that besides its potential role in marketing, the value of such an app would also be to enhance and promote the identity of a region. Furthermore, it could help address navigational and risk issues (e.g. bad weather and dangerous spots).

Chapter 10 compares the perceived and actual roles of destination management organisations (DMOs) in sustainable mountain tourism, based on data gathered from highly successful tourist destinations in the Alps (in Switzerland, Austria, Italy and Germany). According to the findings of this study, in these areas sustainability used to be added value, but it is increasingly becoming a requirement, insofar it helps clear brand positioning. A successful improvement of cooperation, however, would need a strategic approach and a specialised organisation which is in charge of putting this approach into practice. The results show that DMOs have basic tasks such as marketing, but sustainability is also widely seen as their role. Yet, they consider themselves as lacking the resources to become leaders in sustainability, which they think to be more the task of the government. Another important finding is that many of the destinations keep regarding the economic aspect of sustainability the most important, namely they work towards sustainability because it provides a competitive advantage. The authors suggest that modern DMOs should take up the leading role in sustainable tourism and suggest concrete steps to achieve this.

Chapter 18 is a case study from Turkey, which examines how the increasing number of domestic tourists affects the summer pastures of the mountains of the Eastern Black Sea Region. According to the author's results transhumance activities have declined from the 1950s due to many young inhabitants moving into cities, but recreation, partly promoted by the authorities, started to get into the foreground. Still, these changes affect the region in socio-economic, cultural and ecological sense as well, especially since there is a lot of unplanned development. Finally, the last of the tourism-related chapters, Chapter 19, examines the role of cultural heritage in the development of mountain tourism on the example of Rudnik Mountain, Serbia.

The above studies on tourism may seem to be very different in geographical scope as well as methodology, but they point to some general conclusions. While real sustainability can only be achieved with strategic thinking, which requires some leading institution and/or consistent policy, the everyday paradoxes and practical issues are most effectively solved at the small scale, through mutual trust and cooperation of the local stakeholders.

Another major group of studies (five chapters) deals with *ecosystem services and risk mapping*, most of them in relation to water regulation and flood. The studies in this group apply similar methodologies, mainly GIS-based analysis. Chapter 3 presents the application of GIS-based hydrological models, developed in the US, for the assessment of three water-related ecosystem services in the Ogosta watershed, Bulgaria. These ecosystem services include two regulation services (water flow regulation and water purification), and one provision service (freshwater). The authors apply the models successfully, despite some inadequacies of the available data.

The authors of Chapter 4 aim to map carbon storage in the Central Balkans based on land use and land cover data. They create detailed maps based on the CORINE database and World View2 imagery and apply the InVEST model to calculate carbon stock. They compare the modelled results with reference data from field sampling. According to the results, total carbon stocks modelled with InVEST are higher than the reference values, thus the authors conclude the model would need further validation.

In Chapter 7 the author focuses on mapping the water retention ability of the landscape and estimating the effect of current landscape structure on this capacity in the Poprad River Basin, Slovakia. The sub-basins were classified into four hydric significance classes, from limited to excellent. According to the results all four categories are present in the basin, but most of the area falls into the good or average classes. Landscape structure is found to have a significant effect on water retention ability.

Chapter 13 examines the flood regulation capacity of a small catchment in Bulgaria. The study focuses on landscape units, and is based on the water retention ability of different individual landscape structure elements, which are represented with different weights. According to the results the area is threatened by a loss of water retention capacity. In Chapter 14 the authors also apply GIS methods and remote sensing (RS) data for modelling potential natural hazard areas in the mountainous border area between Bulgaria and Macedonia. Besides defining the 'potentially floodable area', soil erosion as well as sediment yield is modelled, and landslide susceptibility and forest fire risk are also mapped. According to the authors' findings, excessive erosion is the worst hazard in the area and landslides are connected to that.

Geographical Information Systems (GIS) are powerful tools which enable researchers and planners to integrate information and carry out detailed analyses of even large areas, which are crucial for regional planning. The (un)availability of data, either input or reference, can be a serious limitation though, as all studies mention it.

Although it is a crucial issue in most mountain regions, only two chapters deal with the *impact of climate change*. In Chapter 6 the authors present a study where the potential effects of future climate change (based on the predictions of the regional climate model RegCM 4.4) are examined on the technical and natural snow reliability of four major ski resorts in Bulgaria for the period 2016–2030. According to the results, total snowmaking capacities would only decrease slightly. Chapter 17 is related to climate change in a different way, since it deals with already existing impacts, namely the changes of three small glaciers in the Julian Alps. The authors apply an interactive orientation method on archive photos, the earliest from the late 19th century, where they use detailed DTMs to define the area of glaciers. They find an almost continuous decrease, except for a few years around 2010. They also consider the use of this methodology for other glaciers in Southeastern Europe, also for other sorts of research like studying floods or landscape changes.

The remaining four chapters deal with *geo-ecological aspects of the mountain regions*, both in terms of natural vegetation (in this case, forests) and in terms of invasive species. The spread of invasive species is a significant threat to native wildlife worldwide, while forest management is one of the main income-generating activities for the population of mountainous areas. Therefore, such research is of high importance from the sustainability point of view. Climate change-induced disturbances are becoming more frequent, so even economic interest dictates that resilience must be increased.

In Chapter 5 the authors examine how the non-intervention management of protected subalpine spruce forests in Bulgaria is compatible with the climate change-induced increase of disturbances. According to their findings, disturbances are part of the natural cycle, and resilience depends on the presence of natural structure elements most often missing in managed forests. Therefore, they suggest the adoption of long-term regeneration sylvicultural systems, which allow continuous forest cover and a higher diversity of structural elements. In Chapter 11 the authors present a new concept of forest protection in Slovakia, based on real and potential geo-ecosystems. They first describe the system and draw some general conclusions on the occurrence and protection status of the different types. Then they make suggestions on how this system could be used as a basis for planning in the future both for designating protected areas and designing ecological corridors.

In Chapter 12 the authors present a GIS-based potential distribution model for the invasive species *Ailanthus altissima* in Romania. The model successfully identifies areas with different distribution potentials. The modelled and the actual occurrence show an overlap of 70 per cent for the high and very high potential areas. And finally, Chapter 16 is a case study from Mala Planina, Bulgaria, in which the authors identify the invasive species which have already spread in the area and others, which have the ability to become invasive.

As described above in detail, the book mainly contains case studies, which are all the more interesting because information from many of the described regions is often hard to access or completely lacking. It provides valuable insight into recent research conducted in the Southeastern European mountain regions. And thus it can be of interest to a diverse audience, including students, researchers and practitioners of different fields, e.g. in the fields of geography, ecology, environmental studies and tourism. However as a book it fails to provide a synthesis, which could have been a step towards realising the wish formulated in the preface that the mountainous border regions of Southeastern Europe become a special target of an EU-scale regional development policy. Still, it reaches its goal of providing multiple pieces of evidence that sustainability principles should be used at every scale of geo-ecologic planning in mountain regions.

Eszter Tanács[1]

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[1] Department of Climatology and Landscape Ecology, University of Szeged, Szeged, Hungary. E-mail: nadragulya@geo.u-szeged.hu

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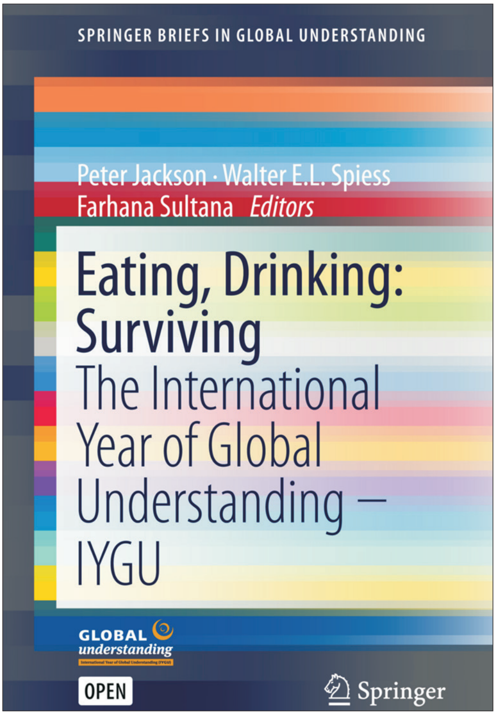
Jackson, P., Spiess, W.E.L. and Sultana, F. (eds.): Eating, Drinking: Surviving. The International Year of Global Understanding – IYGU. Cham, Springer, 2016. 105 p.

The problem of resource depletion in a world with growing population has been intensively deliberated over the centuries in both scientific and economic discourses. Malthus, who in 1798 published ‘An Essay on the Principle of Population’, argued that agricultural outputs would not be sufficient to meet the needs of an increasing global population. Although his predictions have not come true, the approach advocating either intensification or the extension of production and referred to as ‘productionist’ prevails in debates on food and water-related challenges. The current volume, however, contests these assumptions and presents some new trends in scientific, socio-economic and political discourses. It also shows that the problem of hunger and water scarcity emerges from unequal access to resources rather than insufficient supply. Not only does the book present current challenges that result from accelerating population growth rates and simultaneously exacerbate economic and social disparities, but also proposes possible solutions that have become increasingly widespread over the recent decades.

Eating, Drinking: Surviving’ is one of the Springer briefs published under the aegis of the 2016 International Year of Global Understanding and the Post-2015 Development Agenda. Its main goal is to address some crucial issues of food and water security and the influence of global food systems on the livelihoods of people from all over the world. According to Benno Werlen’s (Executive Director of the IYGU) series preface, the book aims to connect the local and the global, the social and the natural as well as the everyday and the scientific, in order to achieve better understanding of the current processes occurring in an ever-globalising world. The volume consists of eleven essays by various authors. The first chapter introduces the subject area. Chapter 2 covers the problem of malnutrition from a geographical perspective, whereas Chapters 3 to 6 and 7 to 11 address problems related to water and food security.



In the introduction, Peter Jackson, Walter E.L. Spiess and Farhana Sultana present a broad overview of contemporary issues that are discussed in the book, after a careful presentation of the historical context that provides the reader with the necessary conceptual background. Implications related to the Millennium Development Goals as well as the Sustainable Development Goals of the United Nations show what has been done to halve hunger and adequately supply the population of the world with improved drinking water as well as what other actions must be taken in order to ameliorate current conditions. Furthermore, in addition to introducing key definitions that are essential for comprehending the proceeding essays, the editors present short summaries of each chapter to familiarise the reader with the major issues of the book.

Elizabeth Young, the author of Chapter 2, focuses on geographical inequalities in access to food and water that are directly associated with current food systems and global networks of production and consumption. She spotlights the ‘cruel paradox’ that is evidenced by malnutrition in some regions and over-nutrition in others. Moreover, there are several countries nowadays where many suffer from hunger, while others suffer from obesity. A definite strength of the essay is its critical approach. The author contests (with concrete examples) commonly used aggregated statistics that provide us with false pictures of malnutrition for concealing disparities between various regions or countries. Additionally, the chapter provides an evaluation of two divergent political perspectives on food production systems. The first is the previously mentioned ‘productionist’ approach that promotes sustainable intensification and advocates an “increase [of] food production from existing farmland in ways that place far less pressure on the environment” (Garnett, T. *et al*. 2013, p. 33), and which the author criticises. The second perspective argues that the current mechanisms of food provision need profound changes in order to establish a more socially and environmentally stable system. The chapter, just as the entire book, also emphasises the role of economic and political power in shaping contemporary food.

Chapter 3 by Trevor Birkenholtz contests the technocratic paradigm with its concept of 'modern water', which is perceived only in a physical and calculable context, deprived of any socio-cultural substance. The author also rejects understanding water scarcity as an exclusively technical problem and strongly promotes the view that water should be regarded as part of a 'hydrosocial system'. In the recent years several publications have taken a similar approach (Swyngedouw, E. 2009; Boelens, R. 2014; Budds, J. *et al*. 2014; Budds, J. and Linton, J. 2014; Linton, J. 2014; Mollinga, P.P. 2014). The chapter is based on abundant statistics that reveal both regional and rural-urban disparities in access to improved water. The author emphasises that not only does the problem of water scarcity disproportionately affect certain regions, but also certain social groups like women and children.

Chapter 4 by Jeroen Vos and Rutgerd Boelens discusses the concept of 'virtual water', which refers to water used or contaminated to produce goods and services. The authors show repercussions of virtual water trade that was initially expected to cure inequalities in access to water on basis of comparative advantages. In fact, however, it has extended the distance between the place of production and the place of consumption instead. Although the authors claim that data on the volume of virtual water do not illustrate the social, environmental or economic value of water, they propose the application of the concept as an indicator of social, political and environmental risks associated with the current global food system. Furthermore, the chapter provides an interesting analysis of environmental, political and social threats that arise from the increasing production of high-water-consuming crops, and also employs remarkable examples. Finally, it critically evaluates the creation of multiple stewardship standards.

In Chapter 5 Olivier Graefe investigates the Integrated Water Resource Management, which is the new approach leading international institutions such as the Global Water Partnership (a strong supporter of choosing river basins as the primary unit of water management), UN and UNESCO are proposing to improve water access. Although the author notes that the basin approach is probably more relevant than focusing on administrative boundaries, he argues that the exclusive use of natural or ecological borders neglects the issues of water transfer between different rivers as well as the high complexity of water management itself. Similar to the authors of previous chapters Greafe underlines that the main reason for unequal access to water is barely regional water scarcity but rather political economy and poor management, what is proved by a number of accurately documented instances and requires substantial improvement.

Kathleen O'Reilly, the author of Chapter 6, raises the problem of limited access to hygienic sanitation that affects approximately 2.4 billion people in the world (p. 51). She underlines the risks posed by open defecation, most likely to occur among rural dwellers, and urges to provide the global population with access to clean water and sanitation. However, the provision of WASH (water, sanitation and hygiene) programmes should embrace long-term initiatives and be adjusted to the needs of local communities. O'Reilly emphasises that women and children are particularly at risk of, and suffer the most from, the lack of adequate water and sanitation. The chapter focuses on social aspects of sanitation and indicates that open defecation causes high stress levels above all among women and young girls.

In Chapter 7 Walter E.L. Spiess scrutinises some challenges to food security in light of the manifold threats the global community is facing or is predicted to face in the near future. Due to fast population growth the demand for food is estimated to increase. Hence, the volume of water required in food production will also grow. Spiess describes the main characteristics of the virtual meal referred to as the Standard Diet and points out changes in dietary habits of the global population that are very likely to occur. He highlights the risks posed by the extensive production of biofuels that causes concern among the international community and previous researchers (Clancy, J.S. 2008; Janssen, R. and Rutz, D. 2011). The chapter employs precise and complex statistical data.

In Chapter 8 Marisa Wilson introduces the term of moral economy, which indicates a relationship between social or moral dispositions and norms on the one hand, and economic activities on the other. The author compares two different food provision systems, the socialist (or post-socialist) and the liberal (or neoliberal), and their impact on food sovereignty. The essay is particularly valuable from a Central and Eastern European perspective as most countries in the region have transformed or are still transforming from the former to the latter. The choice of a Cuban case study is certainly enlightening. Indeed, due to its peculiar geographic location and historical past Cuba exemplifies the country exceptionally affected by a socialist political system on the one hand and by the global capitalist network on the other.

In Chapter 9 Matthew Kelly discusses substantial changes in the diet of Asian population. The process of 'Nutrition Transition' consists predominantly of the dramatic increase of oil, fat, sugar and meat consumption. Moreover, traditional ingredients of Asian cuisines are being replaced by temperate zone products like fruit, vegetable or dairy products. Demand for rice is progressively decreasing in favour of wheat, mainly in middle-income countries like China. The main engine of this shift is economic growth, as well as rising incomes and purchasing power of the consumers. Furthermore, the rapid pace of urbanisation results in increasing demand for convenience processed food. Kelly presents both positive and negative consequences of the Nutrition Transition and predicts that the process will soon occur in low-income countries, too. Although it might appear obvious that the term 'Nutrition Transition' was motivated by the concepts of 'Demographic Transition', 'Epidemiological Transition' and the sort, a reference to all these theories would have enriched the conceptual background of the essay in my view.

Chapter 10 by Ann E. Bartos investigates the main challenges faced by the inhabitants of Aotearoa, New Zealand, in light of two of the main concepts discussed in the volume, food security and food sovereignty. The author critically evaluates the former. In his opinion the food security approach has contributed to the growing production of export-oriented crops and the increasing reliance on food aid in many regions, which has resulted in worsening economic and social conditions. The food sovereignty approach that perceives food as a basic human right and highlights the fundamental role of culturally appropriate food was developed to redress some of the problems resulting from the neoliberal food security approach. The Aotearoa example reveals local social and economic disparities that have become obstacles for achieving food security and sovereignty. New Zealand is an apt choice with its ninth position in global rankings of the UN Human Development Report (UNDP 2015) for showing that profound discrepancies in access to food and water also exist in countries with very high human development. The chapter questions the 'purity' discourses that present New Zealand as a country of unspoiled nature and free of environmental contamination as well as food-related problems. The author claims that these discourses impede a thorough analysis of the intrinsic challenges the country is facing.

The last chapter by Jonathan Cloke calls for reconsideration of the term 'food security' and accentuates the narrowness of the approach. The author focuses his attention on food waste and disapproves of neglecting the problem in official discourses of food supply. Moreover, Cloke introduces the concept of a waste or 'vastogenic' system as important part of the global food system that has not been deliberated by previous researchers. On basis of relevant statistical data the author provides a complex analysis of food waste systems and the challenges created by their inadequate management. I consider the chapter most insightful and innovative as it offers a new perspective to the problems taken up in the volume.

The volume 'Eating, Drinking: Surviving' addresses many issues linked to global food systems and their effects on the lives of people in different parts of the world. It presents the challenges resulting from unequal access to natural resources and investigates them from various research perspectives, including environmental, economic, social and political ones. According to Werlen, B. *et al.* (2016), one of the aims of the International Year of Global Understanding was to highlight that local actions affect global situation. The reviewed book, however, makes the far more important claim that global circumstances strongly affect local conditions and improving access to food and water requires changes at both scales. Each chapter is based on relevant data and discusses theoretical as well as practical questions.

Although the book does not present the results of primary scientific research and provides rather an overview of current challenges of the global food system and its value chains, it introduces many innovative ideas. Nevertheless, the volume neglects the problem of unequal access to land and its consequences, what I regard as its main deficiency. Ongoing competition for land resources is one of the most important issues directly linked to the global food system. Previous studies underlined the role of land, its tenure system, management and distribution in the concept of food security and food sovereignty, as well as their utmost relevance for MDGs and SDGs (Garnett, T. *et al.* 2013; UNECA 2005). Moreover, the authors of the book do not properly address the problem of land grabbing (although the term is mentioned), that is the focal point of many debates among scholars (Tscharntke, T. *et al.* 2012; Cotula, L. 2013; Endelman, M. *et al.* 2013; Franco, J. *et al.* 2013; Golay, C. and Biglino, I. 2013). Land grabbing has remarkable negative impacts on food security as well as the food sovereignty of local communities, mainly those in the Global South. Hence, it would be necessary to take it into consideration while scrutinising the global food system. In addition, although the volume is supported by several interesting, innovative and illustrative maps (published with permission of the Worldmapper Project), as a geographer I reckon that such a remarkable publication might have been illustrated with more advanced cartographic elaborations.

One of the major strengths of the book is its interdisciplinary character and practical approach that makes it useful for both scientists and policymakers. Moreover, due to its comprehensive language on the one hand and the cross-section of many different topics it provides on the other, the volume is easily understandable and might be interesting for the general public. In my opinion it will serve as a useful instrument in university education as well as primary and secondary-level instruction. The fact that the book combines different spatial scales ranging from the global to the local enhances its value from a geographical point of view.

Despite the fact that the volume does not employ many examples from the region, it is also valuable from a Central and Eastern European perspective. First of all it examines global challenges that to some extent affect Central and Eastern European countries and their inhabitants as well. In light of increasing social and economic disparities it is important for the region to elaborate development strategies that will help overcome the current and predicted challenges presented in the book. In conclusion, I find the volume highly enlightening for building on previous research on food and water security and helping us to understand the mechanisms that control the global system of food provisioning.

Ada Górna[1]

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[1] Faculty of Geography and Regional Studies, University of Warsaw, Warsaw. E-mail: gorna.ada@gmail.com

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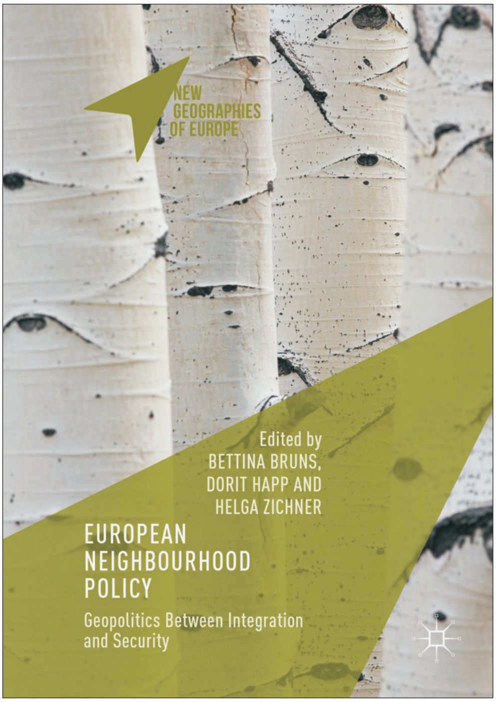
Bruns, B., Happ, D. and Zichner, H. (eds.): European Neighbourhood Policy. Geopolitics Between Integration and Security. London, Palgrave Macmillan, 2016, 242 p.

In the 1990s and 2000s the territory of the European Union showed a remarkable expansion, with its border significantly moving eastwards throughout these decades. It seems as though however, that with the accession of Croatia in 2013 the European Community finished its territorial project. Instead, "the EU acts more and more extraterritorially, claiming to promote prosperity, stability and security not only within the EU but within its direct neighbourhood as well" (Zichner, H. and Bruns, B. 2011, p. 78.). Yet, it is largely unclear what role and importance is attributed by the EU to these non-member neighbour states and how societies in these states are concerned.

In their new volume 'European Neighbourhood Policy: Geopolitics Between Integration and Security' Bettina Bruns, Dorit Happ and Helga Zichner, all from the Leibniz Institute for Regional Geography (IfL) in Leipzig, aim as editors to provide profound and comprehensive answers for these questions through the involvement of a series of authors from Central and Eastern Europe. As contribution to the 'New Geographies of Europe' series of Palgrave Macmillan, the book is an outcome of the 'Within a Ring of Secure Third Countries' project, implemented at IfL between 2011 and 2018.



The main objective of the book is to assess the instruments and measures that relevant actors, mostly EU policy and decision makers, gear towards determining the Community's relations with its neighbours in the Western Balkans and Central and Eastern Europe. As an important difference between policies towards the two country groups the willingness to a future enlargement is explicitly expressed in the case of the former group (consisting of Albania, Bosnia and Herzegovina, Kosovo, Macedonia, Montenegro and Serbia), whereas the integration of Central and Eastern European neighbouring countries (Belarus, Moldova and Ukraine) is expected to be carried out without offering them an EU membership. Considering these territorial foci, the title of the book is somewhat misleading as the EU's European Neighbourhood Policy (ENP) includes a total of 16 countries, most of which are not subject for the analysis. In contrast, countries in the Western Balkan are not involved in the ENP. In spite of this minor issue, scrutinising these countries is an entirely logical choice in light of the above research aims.

The distinctive nature of the book, already emphasised in the introductory chapter (Chapter 1) by the editors, is attributed to "[t]he shared focus of the contributions … on the strategies through which the EU tries to influence internal politics in third states, but seen from the perspective of those third states themselves … complemented by a critical assessment of EU interests lying behind its extra-territorial strategies" (p. 12). A key notion here is the EU's extra-territorial engagement which the authors understand "as a spatial-strategic means to control socio-spatial relations on multiple scales in sovereign states outside the EU" (p. 7) Through such strategies the European Community targets to set up a 'circle of friends', a virtual buffer zone which may provide, first of all, security for the EU against potential unwanted effects from the outside world, such as migration. It has remained largely unknown, however, how these strategies played out from the perspective of countries in this 'circle of friends'.

The label 'European' has been of crucial importance in the classification of EU neighbour countries in the course of the establishment process of this 'circle of friends', as is suggested by Frank Meyer (Chapter 2). The label, regularly used in high-level EU policy discourses, enabled "the demarcation of what belongs to Europe and what does not" (pp. 27–28), that is, who is friend and who is not. In his contribution, Meyer scrutinises the concept of the 'Area of Freedom, Security and Justice', derived from Title V of the Treaty on the Functioning of the European

Union, through a discourse analysis of political speeches held by the respective Commissioners of the Department for Justice and Home Affairs between 1995 and 2014, who addressed the question how the relation of the EU to itself and its neighbours was represented in the political discourse throughout this period. Through reconstructing the AFSJ concept, the author reveals the specific semantic strategies aimed at legitimising the strict border regime, i.e. the upscaling of formerly national responsibilities.

Migration to the EU as one of the most pressing current issues also comes into focus in the study of Lena Laube and Andreas Müller (Chapter 3). The authors apply the principal-agent approach to investigate how migration control tasks are delegated by EU Member States to third countries just outside the Community Area. In this sense, neighbouring countries, for example transit states, are required to introduce measures in order to stop illegal migration towards the EU. In return, these countries receive political profits for their cooperation, as in the case of Ukraine (among others), to which the EU granted visa facilitation after the readmission agreement was signed. From the EU perspective, the Community "has achieved its aim of delegation if 'unwanted' migrants have already been rejected extra-territorially" (p. 65). The success of delegation is, however, largely dependent on the internal political situation of the respective neighbour.

Chapter 4 by Micha Fiedlschuster also contributes to the analysis of the EU's extra-territorial engagement. Focusing on the European Commission's relationship with CSOs (civil society organisations), the text suggests that these contacts are strained by imbalances in many senses. Though there has been a shift toward putting more emphasis on the 'bottom-up' dimension, the 'top-down' approach is still more significant. At the same time, the EU's support to organisations in different spheres is uneven as "some sectors of civil society are more willing and/or capable to adapt to Brussels' political environment than others, who are, in turn, likely to become marginalized" (p. 77). Ultimately, the Commission was also compelled to rethink its support policy in the wake of the geopolitical crisis between the EU and Russia over Ukraine in 2014, in order to avoid "openly supporting anti-government protestors and pressuring governments through CSOs" (pp. 88–89).

The duality and ambiguity of EU member states' policies towards Ukraine as a co-host of the 2012 UEFA European Championship is scrutinised by Andrey Makarychev and Alexandra Yatsyk in Chapter 5. The authors discuss the dispute between EU Member States themselves, most notably between Germany and Poland, on the eventual boycott of Ukraine during Euro 2012. While the German side aimed to politically ostracise the Yanukovych regime for its authoritarian nature and the imprisonment of the former opposition side Prime Minister Yulia Tymoshenko through boycotting the events in Ukraine. In contrast, Poland was more willing to maintain the dialogue with Kyiv. This conflict not only shed light on the different notions and interests of the Member States with regard to Eastern relations but also on the "significance of other forms of institutional, economic, societal and cultural inclusion in Europe not necessarily based on the prospects of EU membership" (p. 110).

Particular attention is given to Ukraine in the volume. The country is often portrayed in public media as a natural ally of the EU. Nevertheless, the public attitude of Ukrainians towards the European integration may not be that unambiguous. This is the subject of the study of Tetiana Kostiuchenko and Liubov Akulenko (Chapter 6), who investigate the relation between public attitude towards the European integration and government efforts within the Eastern Partnership (EaP) framework in Ukraine and Georgia. Both countries experienced non-violent 'coloured revolutions' in the 2000s (Georgian Rose Revolution in 2003, Ukrainian Orange Revolution in 2004), which have widely been considered as pro-European social and political turns. Still, the population's attitude remained more nuanced than expected. According to the outcomes of various surveys public opinion has been more favourable towards the European integration in Georgia than in Ukraine in the recent years, what is largely in line with the internal political evolution of the two countries since 2004. Ukraine is further characterised by significant regional imbalances as "[t]he picture is more optimistic for the border regions where the visa regime is less strict and residents cross the border on an almost daily basis" (p. 125) than in more distant areas where personal experience of visiting EU states is largely absent.

The questions of migration and the extra-territorialisation of EU migration policy are discussed in the paper of Bettina Bruns and Dorit Happ (Chapter 7). Adopted from Bernard Ryan (2010), the term 'extra-territorialisation' is used for "immigration control within a legal area situated beyond a certain national and legal territory" (p. 141). The EU implements extra-territorialisation under the aegis of 'security', nevertheless, the authors point at the importance of not to confuse the term 'security' with 'safety'. With reference to Delcour, they argue that the two notions are not equivalent, but the former has a subjective nature and is socially constructed. When talking about security "there is no danger per se, but a perception of danger which differs across time and space and among policy actors" (Delcour, L. 2010, p. 536). Ultimately, the authors summarise that the European Neighbourhood Policy lacks an equal partnership between the EU and its eastern neighbours.

Neighbour countries are not only influenced by migration as transit states but also as source countries.

Helga Zichner and Vladislav Saran discuss outgoing migration in Chapter 8 as a challenge on the example of Moldova. The introduction of the exchange scheme Erasmus Mundus in 2004 was supposed to help academics from Moldova to conduct research and benefit from networking in the European Union, and also to make the EU more attractive for the country's society, substantially divided between pro-European and pro-Russian subgroups. Education thus represents a resource for creating 'soft power', through which one "can shape the preferences of others" (Nye, J. 2004, p. 5). On the basis of mainly qualitative research, however, the authors suggest that many of the students and researchers participating in the exchange did not return to Moldova but settled down in one of the Member States instead. This ultimately resulted in an unfortunate brain-drain from the EU side, whilst Moldova lost significant numbers of its (mostly pro-European) intellectuals. The authors consider this as an eventual lose-lose situation by suggesting that "the EU risks the loss of potential multipliers of its own values and ideas – exactly those who might also contribute to diminishing those very dividing lines" (p. 178).

Security issues are in the focus again in the paper of Stefanie Dreiack (Chapter 9), who analyses the EU's involvement in the regional cooperation of Western Balkan states. Dreiack takes the view that the EU proved to be inefficient in crisis management at the time of the Yugoslav wars which menaced with the Community's "marginalization as an international actor" (p. 190). It was in this spirit, that the EU developed its own Common Security and Defence Policy (CSDP) and was also interested in initiating cooperation between the Western Balkan states themselves in order to complement the European integration. It seems as though, however, that regional cooperation has been too much pushed from the outside and lacks the real interest of the states concerned, while it is largely reliant on EU support and the own interests of the participating states.

Last but not least, Chapter 10 deals with cultural policies. Iryna Matsevich-Dukhan raises the question whether the Belarusian cultural space, and thus Belarusian cultural actors, may appear as integrative part of the EU's notion of a 'creative Europe', or not. On the political level, Belarus shows little attention for EU relations and seeks for tighter partnership with Russia instead. Culture could, nevertheless, be an important linkage toward the EU. Yet, as the author suggests, Belarus seems to be neglected in sense of creativity as the language constructed by EU political programmes on creative industries is not compatible with how the term is interpreted in the Belarusian context.

All in the book and the whole project behind can hardly be more actual, than in these days. Besides the ongoing armed conflicts in Eastern Ukraine and the non-violent but vexing intra-state political tensions in Bosnia and Herzegovina, Kosovo or Moldova, for instance, that are important indicators of the internal difficulties these countries face, far less has been known about the challenges these countries need to tackle due to their peripheral location in the European geographical and political space.

The EU's external neighbours usually appear in the media as scenes of conflict situations, but far less public attention is given to their difficulties resulting from the fact that they are located at the edge of the Community but outside of it. In this sense, they are affected by many problems that are generated by the EU (e.g. illegal migration, black economy, brain drain, etc.), while they have very little chance to benefit from the positive side effects, first and foremost the membership status. In this respect, the book is an invaluable contribution. From the point of view of integration and security, both so much emphasised in this volume, European Neighbourhood Policy has seemingly brought along few tangible positive outcomes for the neighbours, but rather created new forms and spaces of exclusion. In light of this and the ongoing resistance against illegal migration on the one hand, and the Russian power struggle on the other hand, EU needs to rethink its strategy and may develop a more inclusive neighbourhood policy.

Márton Pete[1]

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[1] Institute of Geography and Earth Sciences, Eötvös Loránd University (ELTE), Budapest, Hungary. E-mail: petemarton@caesar.elte.hu

CHRONICLE

György Lovász (1931–2016)

A prominent representative of Hungarian physical geography, one of the last of his generation, passed away on 3 October 2016. Professor György Lovász was born on 23 May 1931 in Budapest. He studied geography and history at the Budapest University, where he gathered rich experience in fieldwork under the guidance of Professor Sándor Láng. While he worked as a teacher in a vocational school of Nagykanizsa and in a primary school of Gyál, Professor Béla Bulla encouraged him to start with scientific research.

In 1956 his first academic paper appeared in print on the origin of the ʼmeridional valleysʼ of the Zala Hills, an issue which is still a subject of heated debates among Hungarian geomorphologists. He himself also returned to this topic and summarised his opinion in a paper published in 1970.

The thesis written for obtaining the university doctorate in 1959 was concerned with the evolution of the Lenti Basin. He also studied the evolution of the Drava floodplain and concluded that the basin, originally thought to be uniform was dissected into subbasins during the Holocene. The focus of his research remained hydrogeography and its physicogeographical implications. In 1967 he successfully defended his dissertation on ″Water regime and runoff in the Drava-Mura water system″, which was also published by the Hungarian Academy of Sciences in the book series Geographical Monographs. For his study on the drainage system of the Danube he was awarded the "Doctor of Sciences in Geography" title in 1977. His hydrogeographical works are closely related to water management issues, including flood control and risk assessment. He contributed to a series of monographs with geomorphological and hydrogeographical chapters (e.g. Geology and surface evolution of Southeastern Transdanubia, 1974; The Physical Geography of Baranya County, 1977; Southern Transdanubia in the series Landscape Geography of Hungary 1981).

His hydrogeographical research focused on the quantification of the physical, topographic, climatic and pedological factors affecting runoff and the water balance of the individual subcatchments (Földrajzi Értesítő, 1972). Some of his publications discuss the temporal changes of the water temperature and ice cover conditions of the rivers Danube and Tisza. György Lovász also analyzed the changes of the longitudinal profile of the Danube, Tisza and Drava rivers, and his findings confirmed the role of channel erosional processes, triggered by river regulation works. He also pointed out the impact of recent tectonics on riverbed incision and subsidence of the aforementioned three rivers (published in the Journal of Hydrology and Hydromechanics in 2007).

Working in the Transdanubian Institute of the Hungarian Academy of Sciences in Pécs, his favourite topics encompassed the geomorphological issues of the Mecsek Mountains, such as the planated surfaces, the evolution of the Pécs Basin and the karst and loess landscapes of Baranya. His research systematically explored the major planation surfaces of the Mecsek Mountains, primarily developed by tectonic activities ("Surfaces of planation in the Mecsek-mountains" – in: Studies in Geography in Hungary Vol. 8., 1971). He also conducted hydrologic monitoring in the Abaliget Cave System (Földrajzi Értesítő, 1971). He explained the fluctuating water discharge rates in the system, primarily generated by clogging of flow channels by sediment deposition. With geomorphological analyses, he also verified the intermittent and multiple-step subsidence of the Pécs Basin over the Pleistocene.

On leaving Pécs, he became scientific advisor of the Geographical Research Institute of the Hungarian Academy of Sciences. He participated in various projects: engineering geomorphological mapping of Hungary, inventory of mass movements. He elaborated the development methodology of several thematic maps, including relative relief, slope categories and exposure, loss of sunshine duration, hydrogeographical maps (published in the Földrajzi Értesítő, 1965, 1985 and 1989). Professzor Lovász initiated the survey of recent geomorphological processes and guided the research group which compiled the legend of such maps. Some of his research topics are closely associated with human geography: the methodology of settlement density mapping is also linked to his name, similarly to the analysis of the mutual interconnection between landscape types and settlement density (published in the journal of Geodézia és Kartográfia in 1977 and the Földrajzi Közlemények in 1979).

Altogether, he wrote and compiled more than 100 Hungarian and international scientific publications, articles, books and book chapters, as well as several university textbooks.

In 1989 he became involved in university level geography teaching at Janus Pannonius University of Pécs, the legal predecessor of the current University of Pécs. Together with Professor József Tóth he organised the education of geography teachers and then of geography researchers at B.Sc., M.Sc. and doctoral levels. For eight years he was the head of Department of Physical Geography and also worked as deputy rector of the University. He taught various classes in his fields of research, including Physical Geography of Hungary, Hydrogeography and Geomorphology. He supported teaching by publishing university textbooks under the title General Physical Geography volumes I to III, General Hydrogeography and Physical Geography of Hungary.

He was awarded a plethora of international fellowships and internships in several countries of Central Europe and visited research centres and institutions across Central and Eastern Europe (e.g.: Federal Republic of Germany, Germany Democratic Republic, Czechoslovakia, Austria, Romania, Bulgaria, Soviet Union and Yugoslavia).

György Lovász was member of multiple Hungarian and international committees, for instance participated in the activities of the International Geographical Union, Advisory Board of the Geomorphologic Subcommittee and various committees of the Hungarian Academy of Sciences. He was also member of the Hungarian Meteorological, Geological and Hydrological Societies. He was active in the life of the Hungarian Geographical Society as member of Board and secretary of the South-Transdanubian Regional Division. He also owned several state and regional level awards and several honours were given to him from various scientific societies.

Although in the past two decades as a Professor Emeritus he only lectured and participated at special university events occasionally, nevertheless, he regularly published his new scientific results and enjoyed his hobbies that included gardening, bird watching, hiking and travelling. We miss his kind personality, sense of humour, eternal optimism and unlimited helpfulness and keep him in good memory.

Dénes Lóczy, Szabolcs Czigány and
Péter Gyenizse

GUIDELINES FOR AUTHORS

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