EXPERIENCES IN THE FIELD ASSESSMENT IN THE S&T PROJECT

(HR-43/2008 (OMFB-01289/2009) bilateral S&T project)

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The teams of researchers established at respective partner institutions are complimentary because of different kind of research equipment they have as well as of different nature of existing field research programs under their management. Colleagues from Gödöllő have field research sites distributed to different parts of Hungary, primarily related to tillage, while Croatian partners have few research sites in Croatia with studies related to tillage but also to fertilization and liming as necessary practices.

Field assessment objectives of the project are

- Comparisons of soil parameters regarding different land use methods (arable land, pasture, plantation)
- Comparisons of soil parameters considering different agro-ecological conditions (*Pannonian basin, Mediterranean karst, Balaton Uplands* – stony soils, chernozem, meadow and alkalic soils in Trans Tisza region and at Tisza lake), and different soil developing processes (*Figure 1*).
- Meeting regional farmers, discussion about soil condition and attending soil tillage demonstration.
- Recommendations for agricultural land and soil use.

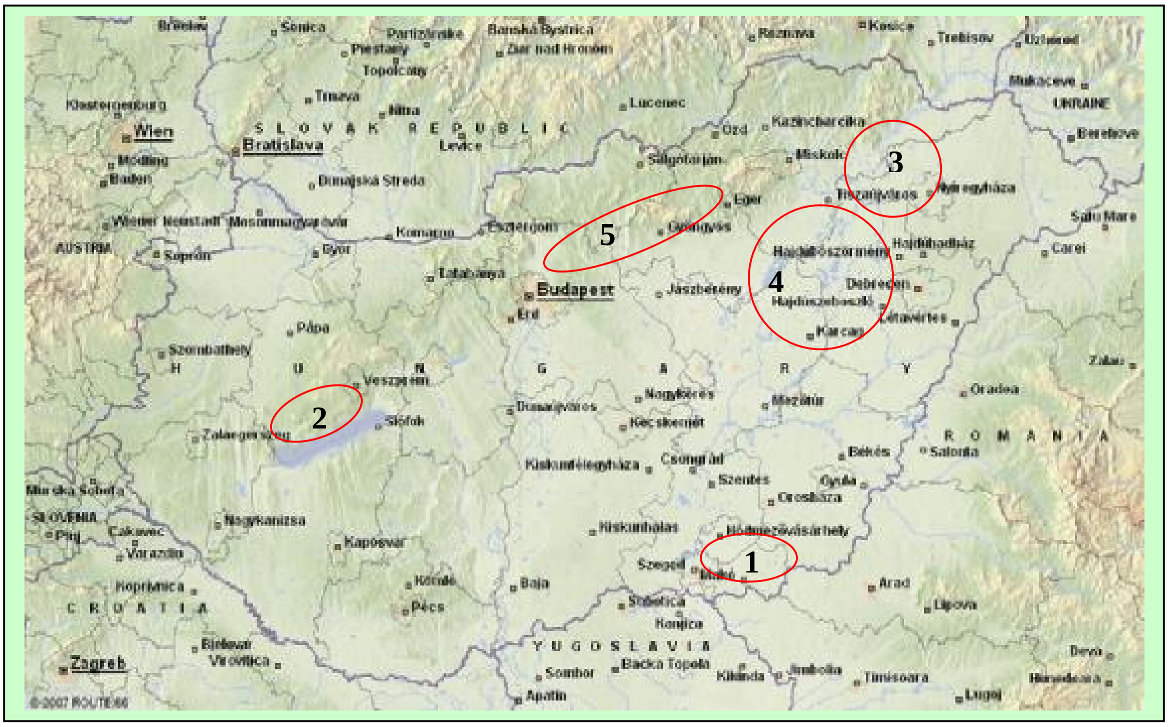

Figure 1 Visited and assessed places in Hungary in S&T project (2010-2011) **From**: **www.szallasmagyarorszag.hu/.../Terkep_hu.html**

Note: 1: Mezőhegyes, 2: Balaton Uplands, 3: Borsod basin and Tokaj hill; 4: Karcag, Tisza-lake, Hortobágy, 5: Hatvan.

County and regional data from Hungary

Total area is 93,030 km^2
Administratively, Hungary is divided into 19 counties (*see below*).

hu.wikipedia.org

The counties are further subdivided into 174 (1 January 2011) ***subregions***. The counties and City of Budapest have been grouped into 7 regions for statistical and development purposes. These seven regions are as follows (*see below*): Northern Hungary (counties Borsod-Abaúj-Zemplén, Heves and Nógrád), Northern Great Plain (counties Hajdú-Bihar, Jász-Nagykun-Szolnok and Szabolcs-Szatmár-Bereg), Southern Great Plain (counties Bács-Kiskun, Békés and Csongrád), Central Hungary (county of Pest and the capital Budapest), Central Transdanubia (counties Komárom-Esztergom, Fejér and Veszprém), Western Transdanubia (counties Győr-Moson-Sopron, Vas and Zala), Southern Transdanubia (counties Baranya, Somogy and Tolna) created in 1999 by the Law 1999/XCII amending Law 1996/XXI.

www.terport.hu/.../regiok

Land use assessment in Hungary

1. Mezőhegyes micro-region

Town **Mezőhegyes** is renowned for its horse breeding and the stud estate established in 1785. Most of its heritage buildings are also connected to horse breeding and peasant agriculture. The town was presumably named after the slightly raised land it was built on, the name signifying 'Sloping Field'. The unusual coat of arms of the town depicts a rearing horse and a triumphal arch. These symbols refer to the most significant turning point in the history of the town which had been deserted during the Turkish time. Recovery started when Emperor Joseph II established a military stud here to supply the army of the Habsburg Empire. This stud first focused on the Spanish bloodline and wild horses but, from 1816 onwards, it acquired international fame by popularising the Nonius, a breed of Norman origin excellently suited to both military and civilian purposes (www.mezohegyes.hu).

From the 1830's agricultural production started at the extensive army estate. Thus Mezőhegyes became the example of a consciously established and developed agro-industry unique in the Great Plain. In 1869 the stud and the estate became the property of the Hungarian Treasury. Many inhabitants of the settlement, granted city status in 1989 still live in the large farmsteads on the outskirts. Although most of the sights are within the atmospheric town, it is also worth spending time in the surroundings.

In 1984 the settlement was awarded the *Hild Medal of the Hungarian Urban Studies Association* for preservation of its architectural heritage. Beautiful and remarkable building located close to the estate: *Riding hall, Coach museum, Northern barrack* (now hotel Nonius), *Southern barracks, Stud-farm headquarters* (now management building of estate, *Photo 1*), *Triumphal arches, Oat towers* etc.

A famous great plane (*Photo 2*) decorates the park of the estate, it was planted in 1819, and its height is 33 m, stem diameter is 4,5 m, its leafage covers of 900 m^2).

Mezőhegyesi Ménesbirtok Zrt (estate), founded in 1785
Address: H-5820 Mezőhegyes, Kozma Ferenc u. 30 (N46°18′ E 20°49′, altitude 100m)
Telephone: +36-68 566 566; Telefax: +36-68 566 567, e-mail: info@menesbirtok.hu
Total area: 9862 ha (distance from the town 5-10 km), from this ploughed land: 8067 ha.
Yearly average temperature: 10.5^{o}C, including extreme winter minimum (-27^{o}C) and summer maximum (+41^{o}C). Number of the sunny hours: 2140. Yearly precipitation: 550 mm (in a bed distribution), and extreme climate phenomena are also occurred.
Location: Southern Great Plain region.
Soils: Calcic chernozem, meadow chernozem.
Humus content of soils: 3-4 % (*Figure 2, Table 1*)
Irrigation: from 1985; 80 % of arable lands are irrigable (150 mm/year)
Crop production: a) Intensive seed production (seed corn, peas, wheat, w. rape) in 3500-4000 ha; b) fodder cropping in 350-400 ha; c) cash crops (w. wheat, sunflower, rape, corn, soybeans) in 3500-3800 ha.
Yields: winter wheat: 6-7 t/ha, seed maize: 2.6-3.2 t/ha, seed peas: 2.7-3.3 t/ha, sunflower: 2.7-3 t/ha, rape: 2.9-3.9 t/ha, corn: 7-11 t/ha, silage corn: 30-36 t/ha, alfalfa: 6-8 t/ha,

Strategic goals in crop production:
- seed maize (2400-3000 ha) grown in the best field situation and with irrigation,
- seed peas production,
- industrial plant production utilising the irrigation system capacity,
- fodder plant growing for cattle,

- cereal production for food and seed,
- soil quality improvement (*Photo 3-5, 7-8*).

Soil tillage systems in the estate

- Stubble tillage (6-10 cm) following peas, wheat, and rape (summer plants) harvest.
- Peas, rape stems are chopping at harvest, and then mixed into the soil.
- Straw baling or chopping before stubble tillage.
- Ploughing (28-32 cm) for spring-sown plants, and for rape (75% of the rape area) combining surface preparation (*Photo 3*).
- Use subsoiling (~40 cm) in compacted soils and for rape (25 % of the field area).
- Tine tool is required which can be used both in dry and wet (trafficable) soil.
- Disk tillage for wheat – using only in case of necessity.

Climate phenomena during the project

A strong hailstorm damaged the area in 18th June, 2010, and about 6000 ha (seed corn, peas, wheat, rape, sunflower, soybeans, maize, silage corn, 2nd cut of alfalfa and planted grass) were totally destroyed (*Photo 6*). The hail storm was followed by an extremely heavy rain, some 70 mm falling in about an hour. Field state assessment and new sowing plan stated in 19-21 June. Soil were deteriorated less – due to long-term soil structure and OM conservation – only in the upper (0-30 mm), that is new sowing realised following one pass (crack breaking) seedbed preparation. The cost saving interventions was strongly required. Reseeding occurred on 1000 ha with maize, seed corn, silage corn, green bean and grass. Half part of the wheat straw was baled (for litter), and other part was chopped and mixed into the soil with 3 passes.

Table 1 Soil data (2009) in two selected fields

Field	pH	K_A*	H%	P_2O_5 ppm	K_2O ppm	NO_3NO_2N	Na ppm	Mg ppm	SO_4-S ppm
No 09	7.18	48	**3.52** (good)	220 (good)	247 (good)	26	114	249	21.7
No 15	7.15	50	**4.05** (very good)	225 (good)	259 (good)	30	57	259	17.2

* Arany-number, an empirical indicator of soil density, e.g. workability at 40-55 is medium, at 55-65 is heavy, at >65 it is very heavy textured.

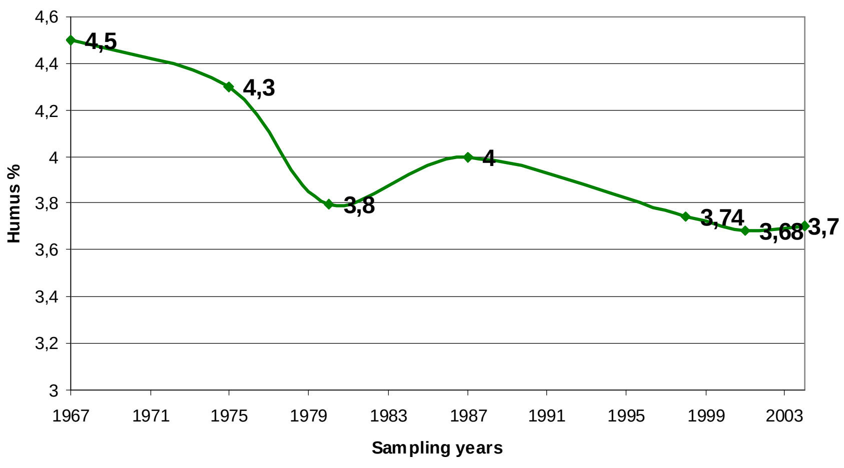

Figure 2 Average humus content in soils of Mezőhegyes estate (1967-2004, from *Páll*, 2010)

Field assessments in Mezőhegyes estate

April 21, 2010

Field No9: preceding crop was winter wheat, planned to be followed by seed maize. Soil tillage system: stubble stripping, stubble treatment, primary tillage by ploughing (30-32 cm) in the middle of November, and surface levelling (in March)
Seedbed preparation (by Väderstad NZA combinator without roll, regarding soil moisture content) has just followed. Surface of the soil (0-2 cm) is dry (< 10 m/m %), and below the surface is moist and wet, and soil looseness of the soil is fairly right (*Figure 3*).

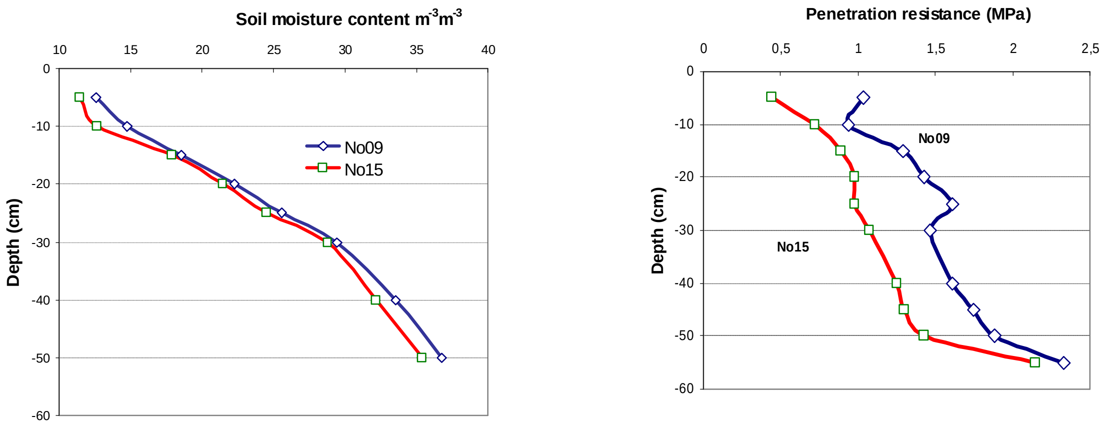

Figure 3 Soil moisture content (left) and looseness condition (right) in two fields prior to seed corn sowing

Field No15: preceding crop was winter wheat, planned sown is seed maize. Soil tillage system: stubble stripping, stubble treatment, primary tillage by ploughing (30-32 cm) in the end of October combined with surface levelling. Soil is prior to seedbed preparation. Moisture content and looseness of the soil is right (*Figure 3*).

24 August, 2010

Field picture is strongly differs from the normal situation. Out of the hailstorm soils were suffered from water-logging damages during spring and early summer (subsoil creeks of the river Maros rose to the surface and occupied the deep field-parts). More time was required to restore the damaged fields and tools – e.g. irrigation equipment.

1st field: devastation (chopping) of male rows of seed maize (machine type: Modern Flow). Maize is fairly lower – planted following hail damage – related to the normal years, cobs state is adequate. **2nd field**: sunflower, which damaged by strong rains in June – a medium yield level can be planned. **3rd field**: ploughed soil (2 days ago) with levelled surface. Soil structure is good below surface, and depth of the loosened layer is about 35 cm. **4th fi**eld: Ploughed and prepared soil, seedbed preparation for alfalfa planting is going. Soil is loosened deeply, and structure is very well. **5th field**: Ploughing (28-32 cm) and surface levelling (by packer) is in progress. Upper layer of the soil is dry, below 10 cm is moist, and below 20 cm is wet. Seagulls on the soils are in number (biodiversity seems good). **6th field**: tillage of the hail-destroyed wheat field for w. rape. Straw (5 t/ha) mixing into the soil was done three times (the 3rd pass in progress by VRT cultivator). Depth of the loosened layer is about 25 cm.

13, May, 2011

Background: water-logged area in January 1000 ha, in May 400 ha (soils are not cultivable in these parts of fields).

Field No66: oilseed rape sown for seed, preceding crop was hail-stormed winter wheat, *primary tillage*: ploughing. Depth of the loosened layer is 20-25 cm, and rooting of the rape is normal. Soil a bit humid (plants height is 140-160 cm, and they fairly utilised the water). There are straw remains in the soil, and are earthworms and burrows in number.

Field No42: seed corn planted following secondary sown seed corn. Stalk chopping of the corn was done in early spring. Primary tillage was disking only therefore the depth of loosened state is 7-14 cm. Soil surface between corn rows is a bit cloddy. Part of the field covered by irrigation system was ploughed, and soil is deeply loosened. Here soil surface is crumbly, and soil below 6 cm is humid and crumbly, and it is fairly wet below 20 cm.

Field No35: seed corn planted into ploughed soil. This field were damaged and settled by hail 10 days ago (plants were prior to shooting, so no damaged). Depth of soil looseness is 30-35 cm, and moisture content is favourable.

Field No 28: winter wheat sown into disk tilled soil. Preceding crop was seed corn. A part of the field has damaged by water-logging since last October, and in these soil spots wheat stock density is poor. Soil is fairly settled and depth of loosened layer is 12-14 cm (roots of wheat has reached the pan). Other part of the field was under water in 2010, so it was tilled by tine in this spring, and sown maize. Soil surface is slightly cloddy and crusty however it really humid and crumbly below 5-6 cm. Depth of the loosened layer is 35-40 cm.

Field No 08: disk and tine were used to cultivate one-year grass, and 1st fraction of seed corn was sown. Soil surface is a bit dry however soil is humid and crumbly in the deeper layers (no pan layer).

The Calcic Chernozem of Mezőhegyes is less – except in regularly irrigated soils – sensitive to settling. The depth recorded at the time of ploughing in the autumn – 32.0 - 32.5 cm – at the time (21 April) of seedbed preparation. By the 2nd day after the hail the depth of the loosened layer decreased by 9-11 %. Settling was most prominent in the top 5 cm layer. Under the amount of wheat straw or rape stalks beaten down by the hail however, 0-0.2 % settlement was measured. The agronomical structure of the soil also changed in a particular way (*Figure 4*).

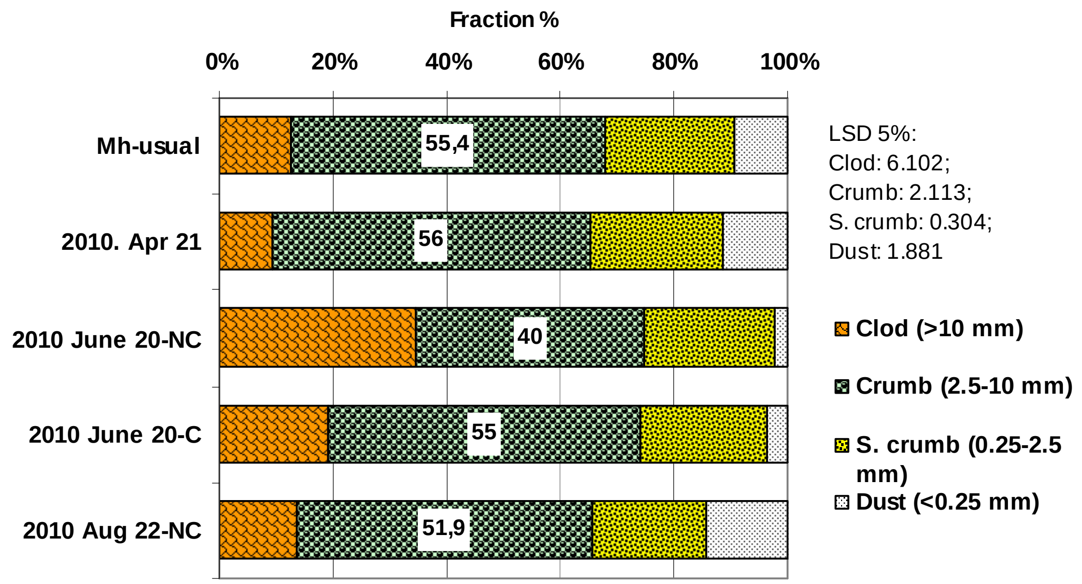

Figure 4 Trends in the agronomical soil structure in a Calcic chernozem soil at Mezőhegyes (2010). Note: NC-non covered, C: covered; n: 24-32

In the top 5 cm of the ploughed soil layer there is usually a 78 % crumb ratio (Mh - usual), while in April 2010 it was as high as 79.4 %. In bare areas beaten down by the hail it decreased by 30-31 % (June 20, NC), while in areas covered by destroyed vegetation it dropped by 0-3 % (June 20, C). It should be noted that in the damaged soils (August 22, NC) some 70 % crumb ratios were found after the passage of two months, despite the continued frequent rains. The generally favourable crumb ratio and the relatively modest damage was due to the continuous organic matter and structure preserving tillage (the biomass of the dead plants had been incorporated in the soil by 2-3 mixing treatments by the month of September, instead of removing it as had been done by other farms hit by the hail where the crumb ratio remained below 30 % until the autumn tillage season).

The tasks to be carried out after the damage had been done were chosen with a view to preserving the looseness of the soil and to improving the damaged structure. New sowing could be planned after the drying of the soil only in uncovered areas. The damaged top soil layer dried into a hard crust, thus sowing was possible after the crumbling of this hardened layer. The requirement of soil structure preservation was met by applying combinator assemblies without rolls, which made it possible to improve the soil's crumb structure during the two months after the hails (*Figure 4*).

Soil state assessment conclusions

1. Extreme climate impacts on soil condition are found in most of fields. 2010 year was rainy (904 mm, 60 % over the average, and hail in June) and spring in 2011 seemed dry. Area of the water-logged field has been decreased till July at the same time irrigation was needed on the field of high valuable crops.
2. As a consequence of the colloids leaching in 2010, the drying (to the trafficable state) of the ploughed soils surface have really passed for weeks in spring 2011. By this means soils were definitely deteriorated from sowing processes of at **peas**. There are two pan layers in peas' soils, one occurred below sowing depth, and other at the depth of regular ploughing. These soils require efficacious remediation.
3. Soil state in **oilseed rape** fields are differed regarding depth of primary tillage. Disk tillage no recommended on soils disk tilled in the last year. State of the ploughed soils is adequate, these soils needs preserving operations (e.g. tine tillage).
4. Soil state in **winter wheat** fields are also differed considering the depth of tillage were realised in the last season. Soils in disk tilled fields deteriorated by disk pan, for that very reason they require soil conditioning tillage for the next crop (may be rape).
5. Soil condition in **seed maize** fields may be affected by settling impact of irrigation and compacting effect of the harvest traffics. A less rate of deterioration may be expected.
6. Reducing the **weed** infestation is also expected, so chemical treatments on the stubbles can be realised (inverting weed seeds has great risk because of seed viability).
7. **Soils in water-logged spots** after desiccation: surface is a bit crusty, but soil structure below these cracks is adequately good. So, soils structure conservation tillage can be expected.
8. Soils in water-logged spots have sufficiently been infested by weeds in the last 12-14 month, so chemical control is recommended prior to tillage.
9. **Soil structure** deteriorated in 2010: it is very good under rape, wheat mulch, so the remedying process is in progress. Soil structure in bare soils: cracking can be ensued.
10. **Depth of the loosened layer**: it was protected from hail under rape, wheat etc. straw residues, but deteriorated by tillage operations done in wet soils (from September, 2010 till May, 2011). This fact may call attention to invest and apply tillage tools are adaptable to humid and wet (but trafficable) soils. These tools can successfully used in dray soils as well.

Some photos may make perceptible soil condition assessment executed in the fields of the Mezőhegyes estate in 2010 and in 2011 years.

Photo 1 **Young Croatian scientist and host in front of the management building**

Photo 2 **At the foot of the famous plane-tree (A. Jurisic, I. Sestak, D. Capka, Z. Zgorelec)**

Photo 3 **Ploughing and surface levelling – a good practice proven at the Mezőhegyes estate**

Photo 4 **Crumbly structure after wintering**

Photo 5 **Seed corn sowing in April, 2010**

Photo 6 **Field and tree destroyed by a hailstorm (June, 2010)**

Photo 7 **Corn stalk mulch on the surface**

Photo 8 **Healthy soil below oilseed rape in May, 2011**

2. Land use assessing in Balaton Uplands

One of the most natural valuable parts of the Balaton Uplands is the Káli basin (established in 1984 on an area of 9,111 hectares, *Figure 5*). Geological structure is the basin is peculiar, Permian red sandstone mountains located in the south, special basalt mountains in the north, sandstone conglomerates in the west, limestone and dolomite in the east and in the middle of the basin. Several basalt cones emerge from the level of the basin (e.g. Hegyestű GPS coordinates: 46.9024N 17.6397E). In the middle of the basin, dolomite and limestone ridges cross wetlands. The stony fields at Salföld, Kővágóörs and Szentbékkálla (*Photo 9*) have geological values throughout Europe. The most beautiful is the rocky field of Szentbékkálla **(**46. 53400N 17.33404E, alt. 190 m), which has remained almost intact until now (www.kali.hu). The bogs of the area are of outstanding botanical value (e.g. subalpine primrose, protected orchids, gentian and iris). The forests on the mountain tops also show a great variety of trees.

Figure 5 Map of Káli basin (www.kali.hu)

Úrkút, Ancient Karst has geological values. Here, a surface manganese mine opened in 1917 worked until 1930. The area was explored searching for mineral coal, and the manganese was exploited with manual tools, which makes the abandoned mine unparalleled and the manganese compound sediment remained intact. The karst phenomena from the Mesozoic became uniquely visible in the abandoned mine where are sink-holes, water-holes and other karst formations (*Photo 10*). A rich material of finds of intact lime frames of once lived creatures including different shells and snails, sea lilies can be found in the limestone.

Káli basin became a protected area, and there have maintained pastures, and mown fields. Reconstruction of the vineyards on the hills has begun since some years.

Hegyestű rises between Zánka and Monoszló reaching as high as 337 metres in Káli basin. The northern part of the hill has been quarried, but, the remaining nearly 50-metre high mine-wall reveals the inside of the basalt volcano which was active 5-6 million years ago. The stiff lava in the crater of the volcano during the stiffening process split up into several vertical polygonal columns (*Photo 11*).

Photo 9 **Peculiar rock formation in the stone field of Szentbékkálla**

Photo 10 **View from the Ancient Karst, Úrkút**

Photo 11 **Typical vertical polygonal column from Hegyestű**

Photo 12 **Landscape panorama from the top of Hegyestű**

There are many signs of a variety of agricultural work, vineyards, meadows and ploughlands, characterise landscape in the Káli basin (*Photo 12*). Forest – as a more important environmental element – is the dominant land use pattern in the Uplands, and the second is the grassland. Area of the ploughland has really reduced in the last decades, and vineyards have expanded slightly. Soils are affected by bedrocks, e.g. rendzina and forest soils formed on Permian red sandstone, dolomite, crystalline slate, marl and loess. Some of them are chalky and volcanic (lava, basalt, tuff) originated. The volcanic rocks ensure excellent potassium and microelement content in the soils. The slopes of the volcanic mountains are covered by clay, sand and sometimes loess that are mixed near the top of the mountain with basalt and basalt tuff debris. Slopes are prone to erosion require establishment of terraces, forests or grasslands and grassing of the bare soil between the vine rows.

Field assessment in the micro-region Szentgál-Úrkút-Bánd

Farm fields are located in a basin of the Bakony hills, and the NE from Kali basin.

Name of the farm: Agroszen Kft. Szentgál (47.11148N, 17.73492E)
Address: H-8444 Szentgál, Kossuth u. 2.

Site

- **altitude:** 230-380 m
- **fields**: mostly on slope
- **soils**: mostly brown forest (Luvisol), having different clay content and stone content and shallow fertile layer; are sensitive to settling

Average precipitation (mm): 752 (varied between 600-702 mm in last ten years)
Yearly average temperature: 8.7-9.3 ^{o}C

Figure 6 Map of Szentgál micro-region (www.szentgal.hu)

Area of the farm: 900-1000 ha, and they have 1000-1500 ha production by contract.
Crops and possible yield levels in the farm: w. oilseed rape (1.4-2.7), w. barley (2.6-4.6), w. wheat (2.4-6.1), spring barley (2.5-4.7), rye (2.5-3.0), oilseed radish, mustard (~1.7), sunflower (1.5-2.1), rye-vetch mix, and flower seeds (e.g. cornflower). Yearly climate induced loss (from frost, drought or hail): 5-50 %, connected with crop sensitivity and damage.

Table 2 Soil tillage systems used in the farm Agroszen

Work	w. wheat	w/s. barley	sunflower	rape
Stubble chopping	x	x	x	x
Stubble tillage (6-10 cm)	FP	FP	FP	FP
Stubble treatment (weed and volunteer control)	x	x	x	x
Primary tillage	Ploughing or disking	Ploughing or disking	Ploughing	Loosening 30-35 cm
Surface preparation	NR	NR	FP	FP
Seedbed preparation			NR	NR
Sowing	Rapid	Rapid	planter	Rapid

Notes: FP: flat plate disk + roll (Carrier); NR: seedbed preparation tool (NZ Aggressive) combined with Rollex roll; Rapid: a sowing machine type combined seedbed preparation and sowing in one pass.

Climate change consequences in the farm

- *Seasons:* Spring comes earlier, it is shorter; autumn and winter incalculable.
- *Sowing and harvest time:* soil moisture content as a modifying factor in sowing time; winter cereals can usually be harvested earlier; oilseed rape is usually suffered from

the frosts; optimal crop rotation is to be used as winter barley – rape – winter wheat – spring barley. No time consequences in the harvest of spring cereals.

- *Technology steps are to applied:*

 - Soil tillage based on a loosening technique, including water conservation, surface preparation and plant. Soil tillage systems are used in the farm is presented in *Table 2*.

 - Timing of the seed-bed preparation and plant of rape and winter cereals is crucial.

- *Fertilisation:* leaf/liquid fertilisation is used in dry seasons (e.g. in 2007, 2009) in 2-3 times doses while solid fertilisation has less efficiency.
- *Weed control*: is more difficult now, mainly in the spring sown crops and winter cereals, new methods are required, e.g. chemical weed following shooting.
- *Pest and disease control*: exact timing and dosing are highly recommended in dry years (in w. cereals and rape).

Soil state assessments (15 July, 2010)

Cornflower field *(Centaurea sp),* located in a gentle sloped area (soil is brown forest, but a bit stony). Plants having dark violet, blue and pale blow flowers' colour are produced for seeds. Cover percentage of the surface is right (80-90 %), and height of plants is between 50-70 cm. Flowering – considering changeable weather – is continued. Soil has poorer quality tan rape field, it is very settled as a consequence of the heavy rains. Depth of the loosened layer is 10-15 cm. Crumb formation below the soil surface is also poorer. This field covered up nice cornflower makes beatify surroundings (*Photo 13*).

Rape field situated in a plane area: soil – classified to brown forest – was tilled shallowly (as stubble stripping) following rape harvest. Stubble tillage was executed in way of water and soil conservation. Depth of the soil looseness is really changeable (16-25 cm) as a consequence of the settling processes. Rooting of the rape is a special, there are horizontally and vertically growing roots. Surface layer of soil is consolidated and dry, and subsurface layers are in humid and wet conditions. Dust formation in the surface is moderated and crumb formation in the layer close to the surface is good (55-65 %). Next crop – winter cereal – requires a deeper loosening, to the depth of 22-25 cm (*Photo 14*).

Grassland field (grass is used for hay) over sown with red clover. Field is located in a gentle sloped area (soil is brown forest and it can be qualified stony). Some hay bales are found in the field, and grass has reshot. There a few weeds in the field, however they are typical natural plants of this area (plantain; *Plantago sp*, achillea; *Achillea sp*., field scabious; *Knautia sp*.). Soil is settled, but crumb formation can be found below and above grass roots. This field is really harmonised with landscape conservation requirement.

Photo 13 **Cornflower field in a gentle sloped area**

Photo 14 **Site coordination of the assessed rape field**

3. Studying less favoured soils and forest soils in the Borsod basin

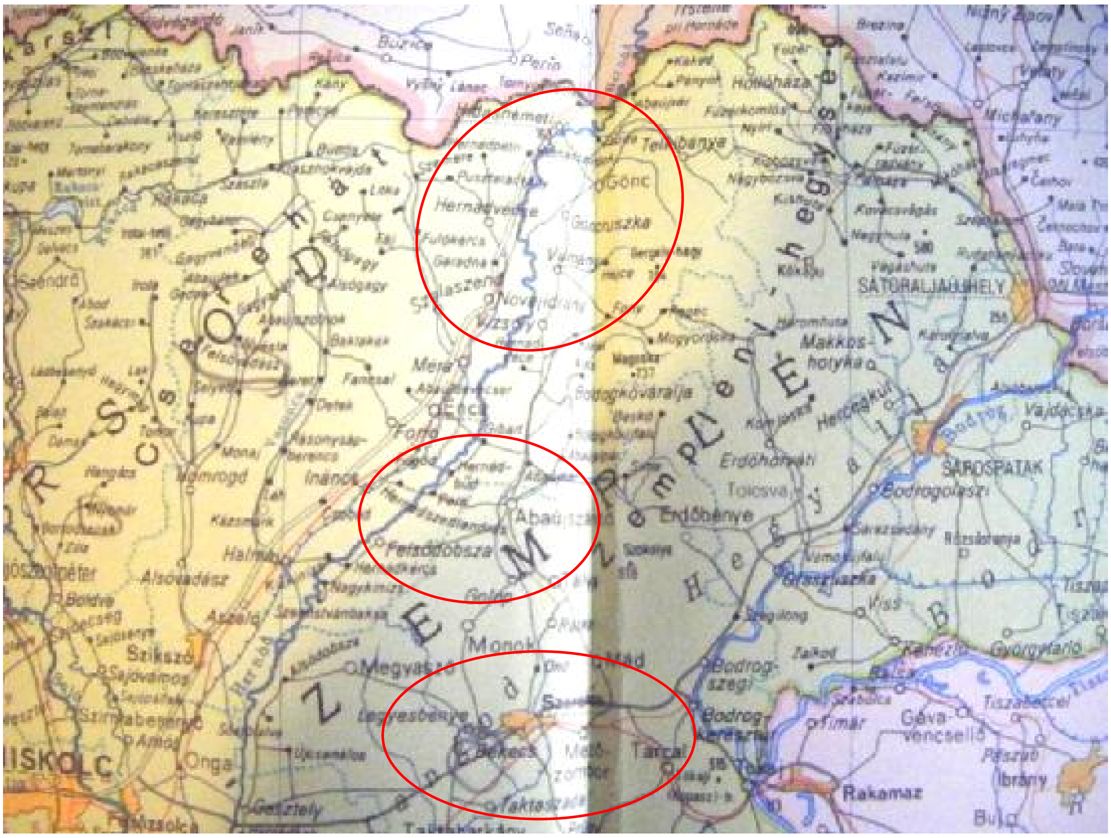

Figure 7 Studied areas in and out of the Borsod basin

Stone-quarry at Vizsoly (48.225665N, 21.125753E). The quarry became a geological exhibitory place and it had formed as the result of the volcanic activity miocen age of the Earth history. The sandstone (rhyolite tuff) was used for house building in the past. Area is under protected now (*Photo 15*).

Telkibánya (48.485722N, 21.362682E) Area is located in the NE part of Hungary, 20 km from the Slovakian border. The place was famous for its gold mines in the Middle Ages (started from 1341 and finished in the end of the 1800s). The area is a part of the Miocene volcanic arc stretching from Tokaj in the south. Most of the mountains are built by volcanic rocks such as andesite, dacite and rhyolite. Forests, arable lands and pastures (*Photo 16*) are dominant in the-micro-region. Left pastures are in number in the gentle sloped fields as a consequence of the animal husbandry and grazing repressing.

Photo 15 **Stone-quarry at Vizsoly, now protected area**

Photo 16 **Grassy habitat in Telkibánya**

Soil conserving land use can be found in the fields of progressive farms, however water erosion damages are found in the narrow, hill-sided parcels. State of this and similar areas require more attention in the future.

Vineyard soils

The area has unique conditions both geohistorical and geographical aspects. The rock-forming mineral stones originated from volcanic and post-volcanic activities have been resulted different kinds of soil types. These have had special effects to soil like productiveness, mineral extracts, and having different properties like heat absorbing, heat accumulating and heat emitting. The well-situated south-facing sunny slopes, the vicinity of the rivers (Bodrog and Tisza causing autumnal mists), and the long-lasting autumn (cooler nights and warmer day-times) result very beneficial climatic conditions. Soils consist of clay or loess formed on volcanic subsoil. The brown volcanic coverage of soil was mainly exfoliated from the tuffs of liparite, rhyolite and andesite. These minerals give beneficial background for grapes. Soils workability is hard considering those contain adherent and flinty clay. However, the advantage of this soil is the water preserving in the deeper layers which very important factor in hot summer periods for drought tolerance of the plants.

A smaller part of the region (Tokaj Hill) is covered by loess soil which can be cultivated easier, although it has the ability to store the heat as well. Zeolites are a group of minerals for industrial and other purposes (at Mád, Rátka and Bodrogkeresztúr). There are cultivated vineyards, renovated areas, and – unfortunately – abandoned yards as well. A new conception is the soil conservation of the inter-row areas in the sloped parcels, using plants demanded less water in the growing season (e.g. white-clover and grass mixture, crimson clover etc.). Moreover, composts, leaf-moulds, green manure, catch crops are used in bio-vineyards. Steppe meadows are also found in the region these areas were covered by vineyards before phylloxera (*Viteus vitifolii*) infection (1875-1897), and now give habits for many preserved plant species (*Photo 17-20*).

Photo 17 **Cultivated vineyard in Tokaj wine region**

Photo 18 **Landscape panorama from Boldogkő castle**

Name of visited farm: Czinagro Kft. Bekecs (48.153175N, 21.180621E, altitude: 200-320 m)
Address: H-3903 Bekecs, Tűzoltó u. 64; Tel.: +36-47-364136

- **Fields** (683 ha, consist of 52 fields): mostly plane and some of them gentle sloped. Villages where located fields: Bekecs, Szerencs-Ond, Abaújszántó, Fony, Vilmány, Hernádcéce, Hejce, Vizsoly, Gönc, Megyaszó, Prügy.
- **Soils**: acid meadow soils (along stream Takta, covers 30 ha), cheznozem-like meadow (round town Szerencs, covers 43 ha), acid brown forest soils (at Villages Hejce and

Fony, covers 150 ha), and calcareous sandy loam alluvial soils (in the valley of Hernád river, covers 460 ha). pH: 4.0-7.5; humus content: 1.98-4.0, P and K supply mostly good.

- **Average precipitation** (mm): 580 (varied between 450-670 mm in last ten years); Yearly average temperature: 9.0-9.6 ^{o}C. 2 years of the last five years were extreme dry, and one (2010) afflicted by river floods and water-logging

Crops and possible yield levels in the farm: w. oilseed rape (2.3-4.0), w. barley (4.-7.0), w. wheat (2.5-6.0), sunflower (2.0-3.0), seed corn (3.0-3.8), poppy (0.6-1.3), pumpkin (0.5-1.2). Yearly climate induced loss (from frost, drought or hail): 7-100 %, connected with crop sensitivity and climate damage. Crop production – in 683 ha – follows in an integrated system. *Planted forest* covers 67 ha (acacia, poplar, and robur), and *apple plantation* covers 18 ha (used integrated and intensive management combined cooling storage). They utilised flood damaged cereal and weed seeds for heating in winter 2010/2011.

Soil state assessment (20, May, 2011)

Poppy field (at town Szerencs) covers 20 ha. Preceding crop was cereal, soil tillage passes were stubble tillage, primary tillage by tine tool, and seedbed preparation and sowing in one pass. Stock density is good, plants are health. Soil surface is slightly crusty, but below this layer soil is crumby and humid (*Photo 21*). Depth of the loosened layer is 15-20 cm. They plan subsoiling for the next crop, following poppy harvest.

Rape field (at village Hernádcéce), where plants damaged by frost. Rape is flowering, and height is about 70-80 cm. Depth of the loosened layer is 15-20 cm. A compact pan layer occurred below loosened layer. Rooting forms are showed the pan compaction impacts (grow horizontally). They plan subsoiling for the next crop, following rape harvest.

Seed corn field (at village Hernádcéce). Second fraction sown is just followed. This field was damaged by river flood in 2010. Sand and weed seeds (mostly knotweeds) were transported by flood, so chemical treatment is adequate. Soil surface is dry, however, it humid below 5-10 cm. Depth of the loosened layer is 40-50 cm, will be favourable for corn rooting.

Winter barley fields (at village Hernádcéce), where preceding crop was pumpkin. Kind or barley is Vanessa, will be used beer basic material. Sown rate was 140 kg/ha, so stock density is not dense, however plants and ears are well-developed. Depth of the loosened layer is 14-15 cm, and a dense pan occurred below loosened layer. This is a bad consequence of the tillage on wet soil in the last September (*Photo 22*). Subsoiling for the next crop is adequate.

Soils of the sunflower and pumpkin fields are relative good physical condition. Crumb rate of the soils are between 55 and 60 cm, and loosen state is acceptable.

Vineyard (at town Abaújszántó), where grass and white clover mix are planted between vine-stock lines. Grass is mowed regularly, so water utilization of the grass may be managed. Mulching of the surface – by mowed grass – is a well-tested soil conserving method, and that is adaptable solution regarding slope field.

Soil tillage solutions of the Czinagro farm (realised since 2003)

1. Harvest and straw/stalk chopping in one pass and in good quality.
2. Mulch-tillage on stubble fields closely followed the harvest.
3. Stubble treatment (mechanical) prior to weed flowering.
4. Ploughless primary tillage by tine or subsoiler.
5. Periodical soil conditioning of the root zone.
6. Combining equipment if is possible (e.g. seedbed preparation and plant).
7. Soil structure and water (min 50 mm/ year) conservation in any tillage passes.
8. Preserving earthworm activity.

9. Organic material conservation: stubble residues mixing into the soil, and following OM preserving tillage.
10. Reducing area of the ploughing; if that is used only in humid soils.
11. Save energy and costs, and mitigating impacts of climate extremes.
12. Filling the requirement of the integrated crop production.

Photo 19 **Green manure plants for soil protection in a vineyard**

Photo 20 **Landscape from Borsod basin**

Photo 21 **Soil structure below poppy**

Photo 22 **M. Mesic at a winter barley field in Hernádcéce**

Photo 23 **River Hernád with high water level**

Photo 24 **Field close to river Hernád in May, 2011 (it was under water in 2010**

4. Studying heavy, hard-workable soils

Research Institute of Debrecen University in Karcag
Telephone: +36 59 311 255 (Jász-Nagykun-Szolnok county)
5301 Karcag, PO Box 11; 5300 Karcag, Kisújszállási út 166.
http://portal.agr.unideb.hu/research_institutes/rik/index.html

The Research Institute of Karcag, with its area of more than 1000 hectares, is a good representation of the characteristics of the soils found in the Great Plain. This, together with the three sites (Karcag, Kisújszállás, Kunhegyes), provides a good opportunity for the practical training of students and the establishment of model farms, demonstration areas, and bases for technical advising.

The Institute investigates the possibilities of agricultural development on soils of hard mechanical composition along the Mid-Tisza (*Figure 8*). The Research Institute, established in 1947, was annexed to the Agricultural University in 1976. From that point on it has been actively participating in agricultural research and education in Debrecen. Upon the establishment of the Institute, Szolnok county, the Bihar part of Hajdú-Bihar county, and the areas along the Tisza were designated as areas of its activity. The common agroecological features of the given areas are heavy mechanical composition (*Photo 25*), high ratio of soils endangered by physical and chemical deterioration (acidification, salinization).

During its operation, the Institute has produced numerous research results which are not only of scientific value, but are also important from the point of view of practical applicability: working out a system for periodic deep cultivation; adapting protective and cost-effective tillage systems; developing methods for the chemical and mechanical amelioration of alkaline and acidic soils; enhancing the nutriment utilization systems of ameliorated or chemically unfavorable soils; developing large-scale application technologies for multicompotent complex soil amelioration materials.

The Institution has four main areas of research activity:

- researches related to soil protection, cultivation, and nutrients management
- plant breeding, seed-production
- grassland management, sheep-farming
- land utilization, rural development.

Some up-to-date research projects are going on, e.g. studying of interaction between land use and CO_2 emission; development of water conservation tillage systems. The number of research and development activities of the Institute increased resulting in new researches of great perspectives in the area of bio-energy and the carbon cycle of the soils (*Photo 26*).

Photo 25 **Spade probe from field of Karcag-Magyarka (21, April, 2010)**

Photo 26 **CO_2 emission measuring in the sunflower field**

Karcag-Magyarka (meadow chernozem soil, Luvic Chernozem by WRB)

Location: φ= 47°16.932' λ= 20°53.678'

Topography: **Hills**
Landform: **Plain**
Land use: **Arable**

Photo: E. Michéli, Desc.: J. Szabó Data: E. Michéli

Elevation= 110 m
Temperature regime: **Mesic**
Soil moisture regime: **Ustic** Parent material: **Loess**
Depth of the ground water table: **500 cm**

Profile Description

Ap Dark grayish brown (10YR4/2), very dark gray (10YR3/1) moist. Weak, slightly firm, medium prismatic primary structure, medium blocky secondary structure. Compacted, slightly sticky, plastic. Common roots. Gradual smooth boundary.

A Very dark grayish brown (10YR3/2), very dark gray (10YR3/1) moist. Medium granular structure. Friable. Abundant wormholes, casts and crotovinas (more than 50%). Slightly hard when dry, slightly sticky, plastic. Humus coatings on surface of peds. A few calcium carbonate accumulation in forms of fine powdery coatings, and pseudomycelia. Gradual smooth boundary.

Bw Dark grayish brown (10YR4/2), very dark grayish brown (10YR3/2) moist. Fine sub angular blocky structure. Slightly compacted, slightly sticky, plastic. Humus coatings on surface of peds. Abundant wormholes, casts and crotovinas. Fine powdery secondary $CaCO_3$ accumulation filling the pores and root channels. Gradual smooth boundary

Bk Light brownish gray (10YR6/2), grayish brown (10YR5/2) moist. Soft, friable "loess structure". Secondary calcium carbonate accumulation in forms of fine powdery coatings and small concretions.

Figure 8 Description of a soil profile From Karcag-Magyarka

- Preceding crop in the field (2009): maize, recent crop: canary-grass
- Soil tillage system: Ploughing 25-28 cm, surface preparation (March): harrow + leveller.
- Sowing by JD 750-A drilling machine (5 April)

Photo 27 **Soil sampling from soil of Karcag-Magyarka (M. Mesic)**

Photo 28 **Soil condition discussion in the canary grass field (M. Mesic and J. Zsembeli)**

Soils and climate in the micro-region of Abádszalók, Tiszaderzs and Kunhegyes

Climate is very changeable in this micro-region, as temperature fluctuation is between + 39.8 ^{o}C, and -28,2 ^{o}C, yearly average is 10 ^{o}C). This area is one of the drier micro-region of the Great Plain (average amount of yearly precipitation is 550-600 mm), crowned with extreme precipitation distribution, hails and storms in the summer period. Year of 2009 proved to extreme, considering the drought in the first half-year, and wetness of the second one. Opposite if this, year 2010 is qualified rainy, and amount of the precipitation surpassed the average with 60 %. Level of the water table has harmfully been increased, and this nature-induced water-logging not only killed the crops but limited field traffics (harvest, transport, tillage etc.) as well. Moreover, water-loggings have been lasted in the fields till the next May. Solving of the water surplus problems is fairly difficult, because most of the arable fields located in deeper areas (*Photo 29-34*).

Types of soils are also varied there are chernozems, meadow chernozems (same of them are salt-affected), typical meadows, alcalic (solonetz, meadow solonetz) and alluvial soils. Workability of these soils – except medium-heavy chernozems – is difficult, while unfavourable physical characters are accompanied by insufficient water management. Alcalisation, both primary and secondary (irrigation by salty water) is also occurred in the solonetz soils.

During soil state assessment late sown sunflower, maize growing in good and bed condition, winter oilseed rape, winter cereals fields were evaluated (*Table 3*).

Table 3 Results of field assessment in micro-region of the Tisa-lake

Field	Soil tillage (2009-2010)	Preceding crop (2009/2010)	Plant sown	Soil structure (U, D)	Soil moisture $m^{-3}m^{-3}$ (0-20 cm)	Penetration resistance (MPa)	Pan layer occurred (cm)
1.	Loosening and non-tilled	W. wheat unsown	Green manure	U: dry, crumbly, D: humid, settled	18-25	1.3-3.0	30-35
2.	Loosening Disking	W. wheat unsown	Maize	U: dusty, D: wet, settled	12-22	1.2-3.1	15-25
3.	Looseng Disking	W. wheat unsown	Sunflower	U: dusty, D: humid, settled	16-23	0.9-2.8	-
4.	Disking Ploughing	Rape W. wheat	Sunflower	U: dusty, D: humid, settled	15-22	0.6-3.0	20-30
5.	Loosening Disking	W. barley Maize	Maize	U: dusty, D: humid, settled	17-24	1.0-2.9	8-10, below30
6.	Loosening Disking	W. barley	Sunflower	U: dry, crumbly, D: humid, crumbly	15-23	1.3-3.0	10-20 below40
7.	Loosening	W. wheat	Rape	Covered: Humid, crumbly, Bare: dry and settled	15-21	2.2-3.1	below30

Note: U: upper layer 0-10 cm, D: deeper layer 10-20 cm

Soil tillage systems are used in the micro-region of the Tisa-lake

The heavy workable soils are known as “minute soils” considering the short time for good soil tillage interventions. Both clod formation in dry soils and formation of “bacon-like” structure in wet soils are real dangers in this micro-region. Earlier the ploughing and shallow disking were typical tillage primary tillage methods. Using subsoiling to alleviate tillage-induced compaction has really been expanded for ten years. Moreover, tine tillage system had some years of practice.

- **Ploughing system** is dominated for spring sown crops, and surface levelling following plough has sufficiently less popularity (farmers believe in the frost effect). Fuel consumption of the ploughing in the heavy soils is high (30-40 l/ha), and higher (> 50) in frozen or wet soils. Plough pan compaction considering ploughing wet soils has really become a typical soil physical defect. Ploughing for winter cereals has a less practice resembling oilseed rape. However, ploughing in summer calls forth demand of 2-4 secondary operations including surface crumbling, pressing and levelling. As it believed, a great mass of maize stalk requires inverting operation. Reducing of the yearly ploughed area supposed some tillage equipment investment, e.g. stalk chopper adapters on harvesting machines, tine tools for residue mixing into the soil and sowing machines showing less sensitivity to the residues in soil surface.
- **Disk till system** is usually used for winter cereals which preceding crop (sunflower, rape or maize) was obtained a deeper primary tillage. However, conventional disk preferred to the secondary operations *following ploughing or subsoiling*. This tool is used also for stubble tillage, but regrettably without pressing roll. The disk pan compaction is a typical phenomenon in the winter cereal fields, and most of farmers do not ready to recognize this soil defect (and yield loss both in dry and wet seasons). A good fact that flat plate disks have really been used for stubble tillage in the last five years. These flat disks combined with rolls, and surface consolidation carrying out in one pass. Fuel consumption of the use conventional disking is adequate (8-12 l/ha), but consequences (pan compaction, dust formation, weed infestation) of this low consumption are really unfavourable.
- **Subsoiling** is the most important tillage intervention regarding settlement and compaction of the heavy-structured soils in the micro-region. It is favourable for crops are rooted deeply (maize, rape, sunflower), and on soils are deteriorated by any tillage pans. As known, compaction extending deeper than 30 cm (usual depth of ploughing). The expected depth of soil ripping is deeper than pan compacted layer was occurred. Fuel consumption of the subsoiling is lower (25-30 l/ha) compared to ploughing, and investment of the tool is similarly low. However, taking adequate tractive power into account.
- **Tine tillage** has less popularity in this micro-region regarding high cost of investment and higher tractive power demand for deeper (25-30 cm) tillage. However, farmers know the advantages of the tine tillage that is soil structure, water and carbon conservation, adaptability to dry, humid and wet (trafficable) soils. Fuel consumption of the tine tillage for stubble stripping is low (5-7 l/ha), and for primary tillage realising 28-30 cm is 10-14 l/ha on humid, and 16-19 l/ha on dry, and 22-24 l/ha on wet soil. Heavy rigid cultivators can generally be used to shatter compacted layers to the required depth. The design of tine tools is very adaptable to soil condition, and that has loosening, mixing, levelling and pressing elements.


Photo 29 **A part of the Tisza-lake seems fairly shallow (July, 2011).**


Photo 30 **Water-logged field in the spring, 2011**


Photo 31 **Aquatic vegetation in the field, as the last year water surplus consequence**


Photo 32 **First step of the soil reclamation after water-logging**


Photo 33 **A thick pan layer below 12 cm**


Photo 34**"The Sunflower Group": M. Poljak, I. Tursic, M. Mesic, I. Kisic**


Photo 35 **Wet (left) habitat and…**


Photo 36 **…dry (right) habitat at Hortobágy puszta**

5. Soil condition observation results in the Hatvan micro-region

Training Farm at Hatvan-Józsefmajor

Farm is operated under management of the GAK Kft. (address: Gödöllő, Páter K. u. 1), and supervision of the Faculty of Economics and Social Sciences. The farm gives possibilities for students learning farming practice and university teachers for conducting short or long term experiments. It has chance to initiate cooperative field assessment between farmers having arable plots near to Farm. This idea led to success, and a group of farmers may assess and discuss state of own soils and crops three times in a year (in spring, summer, and autumn). Moreover, they attend a growing season opening event, where the last year conclusions and new season plans are also discussed.

Agro-ecological data:
Yearly average **temperature**: 9,5 - 10 ^{o}C, in the vegetation period: 16,3-16,8 ^{o}C.
Daily **temperature** is >10 ^{o}C between 13 April and 13 November (183 days).
Number of the days free from the frost: 180.
Yearly average **precipitation**: 580 mm (in vegetation period 323 mm).
In terms of **precipitation** the years of the experience qualified as average (2002: 595 mm, 2006: 593 mm), dry (2003: 442 mm, 2004: 479 mm, 2007: 545 mm and 2009:), and rainy (2005: 705 mm, 2008: 732 mm, 2009: 641 mm, 2010: 962 mm).

Farming data:
Total area: 270 ha, from this ploughed land 255 ha (others: pasture and forest).
Crops are produced: maize for silage, alfalfa (for hay), winter wheat, maize and sunflower for grain market. Wheat straw is used for litter in the cow-house (except in the trials, where straw incorporating to the soil).

Area of the central part: 5 ha, where are cow houses (for 200 Holstein-Friesian cows and calves), stable (for 2-4 horses), hay-barns, store-houses, office, social welfare rooms, machine-shed, silage-storing, slurry-storing and house of the farm managing director.

Soil tillage machines: 2 reversible ploughs, one V&N-5/5 and one Kverneland LM-4/4 with Packomat roll; 1 TerraDig subsoiler (4.5 m); 1 Kverneland CLC cultivator (3 m), 1 conventional plough (IH-5, combinable with Vertikum SZE surface levelling elements; 1 Väderstad Rollex (6 m) designed cross-board levelling elements combined crumbling roll; 1 heavy conventional disk (IH, 6.2 m), 1 seedbed preparing and sowing combination (Väderstad Super XL-300), and 1 KUHN planter.

Soil quality and climate experiment
Objectives of the research are soil organic matter and soil condition maintenance and improvement by the combination of biological and mechanical methods.
Challenges of the trial:

- calling farmers' interests to use soil and water conservation tillage and planting systems,
- organizing tillage and experiment demonstrations and field assessment days for local and micro-regional farmers,
- research possibilities for PhD students to obtain their scientific degree and for students to elaborate their diploma works.

The **experiment** was started in 2002 in a soil of medium sensitive to compaction that responds to interventions well, whose top layer was of a slightly degraded structure – Chernic Calcic Chernozem by WRB, developed on loam, with clay loam texture – in the vicinity of the town of Hatvan (N47^{o}41', E19^{o}36'). The site of the experiment is a flat plain area exposed to N-W winds. The soil's OM content in the top 40 cm is 2.84 (2003) and 3.00 (2009), with a 46-49 % clay content and good nutrient supply.

This soil quality-climate experiment was carried out in four repetitions of random arrangement in patches. Six treatments were applied: direct drilling (DD), shallow disking (15 cm, D), shallow and medium deep tillage with cultivator (15 cm SC, 22 cm C), ploughing (32 cm, with surface forming, P) and loosening (40 cm, L).

The **crop sequence** was designed to increase the soil OM content and to protect the soil surface. The main crops provided different rates of soil coverage: densely sown winter wheat (2003, 2005, 2006 and 2009) and rye (2004), maize (2007, 2010), sunflower (2008) and oat (2011, *Photo 37, 38*). Mustard (2002, 2005 and 2009), peas (2004) and phacelia (2006) were sown as secondary crops to enhance soil surface protection

Photo 37 Condition of oats in two times (21 June…

Photo 38…and 7 July) in the soil quality and climate experiment

Soil state measurement: the looseness of the root zone, the depth of the loosened layer, the duration of looseness, the occurrence of compaction, the extension of the compact layer, soil structure, surface cover, the balance of water absorption and loss, the workable soil moisture range, the CO_2 flux, the OM balance, the earthworm number and activity and climate consequences on soil quality.

Crop state measurement: germination, early stage growth, drought or rain stress, green/dry biomass, yield, yield quality, rooting depth, root biomass and other phenological assessment.

The soil's degraded structure – aggravated by water wasting land use – was an important aspect taken into account in selecting the experiment site. The percentages of clods (>10mm), crumbs (2.5-10 mm), small crumbs (0.25-2.5 mm) and dust in the seedbed were 35 %, 31 %, 24 % and 10 %, respectively showing a very poor soil structure in the case of a Chernic Calcic Chernozem soil (*Figure 9*).

The proportion of the dust fraction increased to 20-25 %, at the expense of the crumb fraction, in the summer. Maize and wheat was grown in the field in two year terms in alternation, entailing the application of 26-28 cm ploughing alternating with 14-16 cm disking. We found, that the disk pan compaction was loosened by plough once every two years but the plough pan had grown to a thickness of 40-50 mm. Such was the soil in which the challenge of improving the soil quality was undertaken. The tillage treatments and the crop sequence (involving primarily densely sown crops) were selected with this goal in view. In the first step the field was sown with mustard to boost the soil biological activity, and the second to reduce soil disturbance and moisture loss and by adaptation to the workable soil moisture range. The negative impacts of the production of cereals were offset by growing crops that improve the soil biological activity (mustard, phacelia).

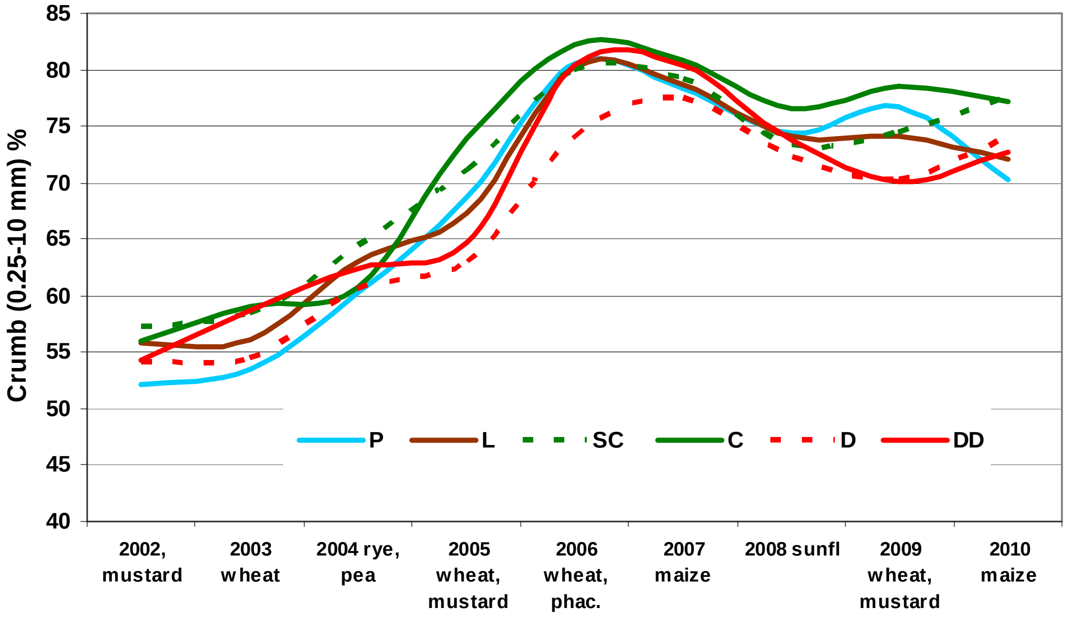

Figure 9 Trend of the changes in the crumb fraction during the 8 year period, in soils under different tillage techniques.
LSD05%: year: 1.904; tillage: 2.875

Dust forming in the summer was reduced partly by the continuous coverage in the first years of the experiment. Crumb forming also improved at the same time. In the fourth year mustard was sown again in the stubble after the harvest of the wheat, which was followed by winter wheat and then phacelia was grown in the field without stubble stripping. In the 5th year (2006) the crumb ratio was up to 80 % as an average of the different treatments (*Figure 9*) and annual fluctuations also diminished.

The only disadvantage of soil structure preserving tillage and crop sequence and of integrated weed control was also observed in the fifth year: the coverage of *Bromus* species increased to nearly 15 %. Instead of terminating soil preserving tillage the crop sequence was altered and wide-row crops (maize and sunflower) were grown in the next two years. The crumb fraction dropped (c.f. *Figure 9*), but the dust fraction did not increase, it remained below 8 % in the 3rd to 9th year, i.e. the improvement of the soil structure continued. The favourable position of the ploughed soil was highly welcome (3rd after C and SC), due to soil forming and the protection of the deeper layers of the soil (except in rainy season, 2010).

The fourth goal, that is to improve the humus balance, was met from the 5th year on (*Table 4*), as the humus content increased by 15 %, to 3.26 % as an average of the treatments.

Table 4 Total C input and output affecting different soil disturbance (Hatvan, 2002-2009)

Factors	P	L	SC	C	D	DD
Total C input (t ha^{-1}) from stubble residues	26.92	28.46	21.88	24.84	22.808	18.612
Tillage-induced C loss (t ha^{-1})	6.18	6.04	3.87	3.93	3.802	2.368
C content of yields (t ha^{-1})	16.46	16.58	12.41	14.16	13.754	11.544
Theoretical balance (t ha^{-1})	2.28	5.96	5.60	5.75	5.246	4.700
Humus % (0-40 cm, 2003)*	2.650	2.851	2.910	2.982	3.048	2.561
Humus % (0-40 cm, 2006)	3.247	3.263	3.186	3.306	3.274	3.342

*Humus (2003-2006) tillage variants: p>0.1%;

The depletion of organic matter was turned around by radically reducing the number of tillage interventions and by mixing (SC, C, D, L) or inverting (P) field residues – after exploiting their soil surface protection effects – into the soil. The humus content highest after DD, all the more so, as it used to be the lowest after the same type of treatment earlier on. After C, SC and D the humus content was as had been expected, however, P offered a new opportunity for tillage systems based on ploughing.

Stubble-Climate Experiment (2004 -)

This type of trial has repeated every summer in stubbles of the winter wheat tilled by disking in the previous autumn (*Photo 39, 40*).

Objectives of the research are investigations of the soil sate improvement or deterioration at different summer stubble tillage variants in a changeable climate (average, dry, rainy). The second goal is comparing and demonstrating the typical stubble tillage methods (e.g. CD) and the new (recommended) methods (e.g. SP, K) on w. wheat stubbles (*Table 5*).

Periods of the trials: 2004: July 27–Sept. 17 (51 days); 2005: Aug. 1–Sept. 24 (54 days); 2006: July 26–Sept. 25 (61 days); 2007: July 9–Oct. 11 (61 days); 2008: July 12–Sept 29 (78 days), 2009: (100 days); 2010: July 20–Sept. 30 (73 days); Precipitation in the periods was usually extreme (low or high) in extreme distribution.

Table 5 Variants of the stubble-climate experiments (2004-2010)

Tillage variants	Depth	2004, 2005	2006, 2007	2008	2009	2010
Untilled (control)	0	x	x	x	x	x
Tool of the stubble tillage						
Conventional disk (CD)	9-12	x	x	x	x	x
CD + ringed roll	9-12	x	x	x	x	
Flat plate disk (SP)	6-9	x	x	x	x	x
Mulch-cultivator (K)	6-9	x	x	x	x	x
Conventional plough + rotary element	20-22		x	x		
Plough + flat plate disk	20-22		x	x		
Reversible plough (RP)	32-35		x	x	x	x
RP + packer	32-35		x	x	x	x
Subsoiler (SS)	35-40		x	x		
SS + flat plate disk	35-40		x	x		

Photo 39 Summer stubble-tillage experiment in 2010…

Photo 40 …and in 2011

Soil state measurements: looseness, depth of loosening (increase, decrease), agronomical structure – clod (>10mm), crumb (2,5-10mm), small crumb (0,25-2,5mm), dust (<0,25mm) rata –, aggregation, soil moisture content and trend, number of earthworms, and earthworm burrows, surface cover and trend (from the beginning to the end), decrease in straw mass mixed/inverted to the soil, CO_2 flux, shooting of the weeds and volunteers.

Risk assessment (using quality assurance methods): 1) Probability of the water loss from soil. 2) Realisation of the water conservation. 3) Probability of the soil structure deterioration/improvement. 4). Heat and rain-stress during the period. 5) Decomposition of the straw (or limiting, postponing). 6) C loss (great, mid, low). 7) Probability of the improvement/deterioration of soil workability.

We found that both surface conservation and duration of the surface cover are important, and during the middle of the summer a higher while towards the end of the season a smaller rate of cover will do. It is confirmed that in the summer of 2010 the settling and crumb degrading impacts of the frequent heavy rains, often coming in the form of rain storms, could be alleviated only by increased surface cover.

Table 6 Coverage (%) of tilled fields after harvest in different seasons

Season	Optimal	Adequate	Poor	Positive impacts of optimum surface cover
Rainy	40 – 50	25 – 35	< 15	Less soil structure deterioration and settling, improved straw decomposition and earthworm activity
Average	30 – 45	15 – 25	< 10	Maintaining soil workability
Dry	45 – 55	25 – 35	< 25	Good moisture retention, crumbling, earthworm activity and straw decomposition

The indicators of the impacts of soil cover included soil loosening or settlement, crumb forming or silting and the earthworm counts. Within the plot the straw mulch : soil ratios varied between 70:30, 75:25, 80:20, 85:15, 90:10, 95:5 and 100:0 % (*Table 6*). At the end of the rainy season in question a 70-80:30-20 % straw mulch : soil ratio was found to be most favourable, at least 15-25 % of which was made up of plant residues (secondary protective materials).

Disturbed soil is particularly in need of protection therefore the minimum cover ratio was set at 40 %. In dry seasons higher cover layers (45-55 %) were found to provide improved protection. After the tillage treatments the straw mulch : soil ratios were 40:60 (FD, C), and 20:80 (CD), while in the FD and C plots even ratios as high as 45:55, 50:50, 55:45 were found, while under the CD treatment it was 80:20. In average season the optimal cover rata is varied between 30:70 and 45:55, however a less surface cover gives poor conservation. The rainy summer of 2010 was highly favourable for weed and volunteer crop emergence but no strong growth of weeds or volunteer crops is considered to be desirable in any season. In this case rate of the secondary protection is also poorer.

Soil tillage practice at the Training farm: 1) Stubble tillage following harvest and/or removing bales. Tool: conventional disk combined Rollex roll. 2) Stubble treatment (mechanical or chemical). 3) Primary tillage for wheat is tine tillage or ploughing, for wide row crops is subsoiling completed with surface preparation, or ploughing and levelling. 4) Sowing of cereals executes by Rapid which prepare soil and sows in one pass; prior to sowing of wide row crops seedbed preparation is applied.

Tine tillage for winter wheat was used first time in 2010 in wet soils, earlier conventional disking was the regular experience. This type of tillage was used also in the spring 2011 for maize, while chance of ploughing was lost in wet soil condition. Subsoiling, regarding plough pan occurrence, has begun in the summer 2011 (by investment new equipment).

Photo 41 **Control of the winter wheat rooting**

Photo 42 **In the wheat field of the training farm**

Photo 43 **New subsoiler of the Training Farm (2011, July)**

Photo 44 **This maize condition is right in the tine tilled soil, in spite of the dry spring and summer (I. Dekemati – an ERASMUS' student from Zagreb, spending his practice period in Hungary – I. Tursic, M. Poljak, and M. Mesic)**

Land use assessment in Croatia

County and regional data

Area: total: 87.609 km² consisting of 56.542 km^2 (64,5%) of continental land area and 31.067 km^2 (35,5%) of territorial sea area. The whole territory may be divided into the following geomorphologic units: Panonian Plain 31,000 km2 (54.8%), mountain area 7,540 km^2, (13.3%) and Adriatic zone 18,000 km^2 (31.9%). Croatia is currently made up of twenty-one županija or counties (*see below).*

1. Istria County
2. Rijeka County
3. Karlovac County
4. Zagreb County
5. Krapina and Zagorje County
6. Varazdin County
7. Medjimurje County
8. Koprivnica and Krizevci County
9. Bjelovar and Bilogora County
10. Pozega and Slavonia County
11. Virovitica and Podravina County
12. Osijek and Baranja County
13. Sisak and Moslavina County
14. Slavonski Brod and Posavina County
15. Vukovar and Srijem County
16. Lika and Senj County
17. Zadar County
18. Sibenik and Knin County
19. Split and Dalmatia County
20. Dubrovnik and Neretva County
21. The City of Zagreb

www.mapsofworld.com/indexmaps/croatia

In 2011 they created five EU-style regions. Moreover they have main 3 agricultural regions basing on the natural diversity of the country (*Basic et al.*, 2007.)

The total area of the mainland part of Croatia is 5,654,200 ha, and total agricultural area is estimated to about 1,500,000 ha, out of which arable land is 863,000 ha. Pastures cover 1,153,000 ha, and forests 1,963,800 ha, marshes and reeds cover 33,000 ha. **Arable land covers about 86,000 ha** (while orchards 37,000 and vineyards 34,000 ha) (From Statistical Yearbooks and Annual Reports, 2007-2010). Many rural areas were severely damaged by the war in the mid 1990s (117,400 ha and from this 20,120 ha arable area, date from Croatian Mine Action Centre). This area has regrettably slightly decreased, in 2007 was 99,700 ha, in 2010 was 82,500 ha.

Climate is Mediterranean and continental; continental climate predominant with hot summers and cold winters, and along coasts mild winters, dry summers.

Soils. *From total agricultural area* (2,955,728 ha) Automorphous soils cover 1,502,100 ha, Hydromorphic soils 1,087,900 ha, Halomorphic soils 0,400 ha, Subaqual soils 0,300 ha, and rocky soils cover 365,000 ha (Kajba, Domac, Segon, 2010). According to Bogunovic, Vidacek, Racz, Husnjak and Sraka *presence of soil types in the Republic of Croatia* are as follows: Automorphic soils cover 3,153,432 ha (56.63%), of which Lithosols cover 32,703 ha, Chernozem 51,808 ha, Rendzina 420,184 ha, Eutric brown soil 172,495 ha, Red soil (Terra rossa) 245.289 ha, Luvisol 703,215 ha, Podzol 1,382 ha. Hydromorphic soils cover 163,000 ha, of which Pseudogley 64,555 ha, Pseudogley-gley 84,713 ha, Alluvial 136,343 ha. Halomorphic soils cover 532 ha, of which Solonchak and Solonetz cover 121 and 411 ha. Rocky soils cover 796,459 ha.

Figure 10 Visited and assessed places in Croatia in S&T project (2010-2011)

During the S&T project some characters of the most typical soil and land use were studied located in different micro-regions (*Figure 10*): Vukovar and Srijem county (Otok, Vukovar), Osijek and Baranja county (Nasice, Osijek, Knezevo, Branjin Vrh), Varazdin county

(Varazdin, Lepoglava), Virovitica and Podravina county (Orahovica), Sisak and Moslavina county (Popovaca), Bjelovar and Bilogora county (Daruvar), Lika and Senj county (Krbavsko polje), islands: Cres, Losinj, Rab, Dugi Otok.

Studying soils in experimental and field conditions

According existing soil classification in Croatia, thirty-six soil types occur in Croatia (Husnjak et al., 2011). The largest area is covered by luvisol (12.1%). This is followed by pseudogley (9.87%), gley amphigley (9.62%), calcocambisol (8.36%), rendzina (7.50%), and dystric cambisol (5.48%). Other soil types cover areas much smaller than 5% each.
Occurrence of almost all soil types has been recorded on agricultural land. The largest part of total agricultural land area is covered by gley amphigley (13.8% of total agricultural land area). It is followed by luvisol (13.3%), pseudogley (11.9%), calcocambisol (7.79%), rendzina (7.36%), terra rossa (5.48%), and hydroameliorated hydromorphic soil (5.21%). Other soil types cover areas smaller than 5% each; some soil types occur only sporadically.

During visits we had chance to study chernozem, forest (Cambisol, Luvisol), meadow (gleyic, Stagnosols, Gleysols), and rocky (Leptosol, Regosol) soils. Findings are summarised and discussed as follows.

Soils developed by the predominant influence of continental climate

Slavonia and Croatian Baranja

Shaped by the force of the rivers (Drava, Danube, Sava, Ilova), Slavonia is characterised by the wide, endless expanse of the Pannonia plains. Rivers that gave birth to the flood areas, provide an ideal habitat for the now centuries-old forests of common oak (*Quercus robur*) as well as some 2000 biological species. The soil of Slavonia has been tilled by human hand for over 8000 years. Ever since this part of the continent rose from the Pannonian Sea some 370 million years ago the fertile Slavonian plains have been a promised land. Slavonia is notable for its light forests, wide plains and significant agricultural industry. The land is the most productive in Croatia, yielding wheat, corn, soybean (*Photo 45, 46*), sugar beets, sunflowers, alfalfa and clover as well as oil and gas. In contrast to the rugged Croatian coastline, their terrain is veritably flat (however some low hills – vrh – with vineyards are crowned the landscape.

Photo 45 **Meadow Chernozem soil in the Baranja region**

Photo 46 **Secondary crop soybean sowing in July, 2011**

According to *Jug et al.* (2010) development and adoption of reduced or conservation tillage systems are relatively slow. In the region of Slavonia and Baranja are still ploughing as a primary soil tillage treatment, applied to about 94% of the area (*Kosutic et al.,* 2005).

However, the estimate is that at last few years some form of reduced tillage is applied to more than 10%. So, the past few years the acceptance of other tillage systems which exclude ploughing is experiencing significant changes. This acceptance is the result of significant joint involvement of scientists and farmers, but it is probably the most important reason is that the detected positive financial effect of reduced tillage systems compared to conventional tillage system. Unfortunately, the other positive effects arising from the application of conservation tillage systems are still in the background, such as: reduction of soil erosion, less traffic and soil compaction alleviation, nutritional status a quality traits of crops, weed infestation.

Photo 47 **Subsoiling along the road 2nd in July, 2011**

Photo 48 **Conservation tillage demonstration – managed by PMT – at town Otok (21 July, 2011)**

The most common and most applied reduced tillage system is disk tilling as basic tillage treatment for winter wheat, and the period of application of reduced tillage on a field is usually one growing season, and then re-applies system with conventional ploughing. However, some farmers applied continuous reduced tillage systems with variable success. Soil loosening applied instead ploughing (*Photo 47*) is usually performed as a measure of repair of compacted soil mainly breaking tillage pan, which followed by – later than loosening – disk tillage for surface preparation.

Photo 49 **The second (shallower) ploughing destroyed soil state and turned that unfavourable for sugar beet**

Photo 50 **Soils in Slavonia suffered from water-loggings in the year 2010**

Photo 51 **Water- and carbon losing stubble tillage in summer, 2010 (along road 2nd).**

Photo 52 **Water and carbon conserving stubble tillage in summer, 2011 (in a field, Otok)**

Other applied tillage systems which exclude ploughing are more in the domain of rational tillage systems (few tillage operation in one pass), and less in the domain of reduced and/or conservation tillage.

With regard to reduced / conservation tillage systems, especially on a large number of soil types on which the production of crops takes place in Croatia, is still a lot of unknowns, primarily with the physical, chemical and biological aspects. There are a lot of negative examples of unsuitable application tillage systems, but that has great potential to be used. In this regard, investigations of conservation tillage should be extended to all main soil types and all crops, especially to those who are expecting a positive response from conservation tillage (*Photo 48*).

In **chernozems** soils a thick black surface layer (rich in organic matter) was found. We may find well- and lower managed soils in Baranja region depending on the existing land use (*Photo 49-52*). We may outline that these soils – as the saying this soil is best in the world – are vulnerable to insufficient use (over-irrigation, tillage and traffic-induced compaction), so preservation of the crumby structure and organic material content is the great evidence.

Central Croatia

Stagnosol are periodically wet with or without concretions and/or bleaching (along rivers Sava and Drava). A common name in many national classification systems for most Stagnosols is **pseudogley**. Periodically stagnating water above dense and settled subsoil is really resulted aeration deficiency. The subsoil requires draining in spite of this solution is often insufficient. We found settled subsoil in many fields in *Baranja, Virovitica and Podravina, Sisak and Moslavina, Bjelovar and Bilogora counties* which may call attention to use subsoil conditioning tillage. In most cases ratio of silt and clay were about 30:20 % in the ploughed layer, for this reason that is ranged to loamy soils. Soil erosion is a high and destructive process of soil damage, caused by soil properties (unstable structure, high content of silt), topographic conditions, an adverse land management practices. These findings strengthen the importance of the use adequate, field-adapted crop rotation and catch crops (green manure plants). In plantations it is necessary to change traditional direction of rows with the slope to contour one. In the case of row orientation with the slope (from top to the bottom) is really necessary to obligate land owners/users to grass the inter-row spaces. There is also a serious problem of narrow crop rotation or monoculture.

One of the locations examined during the project is in Potok – Popovaca with Stagnosols, and with A_{ch}+E_{cg} – E_{cg} – B_{tg} sequence of soil horizons. Due to its physical (high content of fine sand, silt and clay) and chemical properties (calcium deficiency, low content of organic matter), this soil type has limited fertility (*Photo 53-56*). Data from *Table 7* indicates that this is a poorly porous soil of a medium water holding capacity.

Table 7 Physical properties of the soil

Soil horizon	Depth, cm	Porosity, (% Vol.)	Water capacity, %	Air capacity, %	Specific density, g cm^{-3}	
					Bulk	**Real**
A_{ch}+E_{cg}	0-32	43,7	39,7	4,0	1,54	2,74
E_{cg}	32-52	40,0	39,2	0,8	1,65	2,74
B_{tg}	52-97	43,0	41,2	1,6	1,58	2,77

The soil is loam in A and E horizons, and sandy clay loam in B horizon. It is characterized by a high content of the fine sand and silt. The clay content is increased in the B_{tg} horizon (*Table 8*).

Table 8 Soil texture

Soil horizon	Depth cm	% particle size distribution, mm				Texture
		Coarse sand (2-0.2)	**Fine sand (0.2-0.02)**	**Silt (0.02 - 0.002)**	**Clay (< 0.002)**	
A_h+E_g	0-32	0,15	48,55	30,80	20,50	Loam
E_g	32-52	0,18	45,17	31,40	23,25	Loam
B_{tg}	52-97	0,04	51,11	24,50	24,35	Sandy clay loam

Soil reaction is acid in the topsoil and slightly acid in the B_{tg} layer (*Table 9*). There is low humus and medium nitrogen content in the plough layer, supply of soil by plant available phosphorus is good, and by plant available potassium medium.

Table 9 Chemical properties of the soil

Soil horizon	Depth cm	pH in nKCl	Humus %	N – total %	mg/100 g soil	
					P_2O_5	**K_2O**
A_{ch}+E_{cg}	0-32	4,84	1,01	0,15	17,72	10,45
E_{cg}	32-52	5,12	0,91	0,10	5,20	7,15
B_{tg}	52-97	6,02	0,35	0,04	7,68	6,43

Good fertilization practice and conditioning of soil pH can be also decisive for good management, together with improved soil tillage.

Photo 53 **Gleyic soil in dry condition**

Photo 54 **Gleyic soil in wet condition**

Photo 55 **Pan compaction close to the surface**

Photo 56 **Adequate soil condition of ploughing for wintering**

Photo 57 **Marta Birkas in a discussion with farmer (10 July, 2010)**

Cultivation of Stagnosols is not simple, because of short period of optimal moisture for different tillage operations. Although the machinery available to advanced farmers is today out of question, level of knowledge is not adequate for successful combat against unexpected weather deviations that became very complex in last few years. It will be important to develop new educational programs for the farmers, and they are ready to discuss all new information regarding modern approach to soil tillage (*Photo 53-57*).

Problem of soil acidity was studied in a field trial with different liming rates. At location Lepoglava soil examination was carried out in a corn field (*Photo 58*) during summer 2010.

Photo 58 **Marta Birkas examine Stagnosols at Lepoglava area**

Negative influence of acidity is one of the main causes of poor soil fertility and relatively low yields of grown crops. Mineral and organic fertilizers very often are not applied in the correct manner, while liming, as the key soil-improvement measure, is generally not practiced. The differences in the yields of grown crops in different years and different treatments point to the conclusion that liming, combined with mineral fertilization had statistically significant positive influence on the correction of the excessive acidity and on the yields of the grown crops.

Gleysols occur mainly in lowland areas where groundwater comes close to the surface and the soil is saturated (the spaces in the soil are filled) with groundwater for long periods of time. This pattern is essentially made up of red, brown or yellow colours both in lower and upper soil layers, in combination with grey or blue colours. Parent material has wide range of unconsolidated materials, mainly fluvial, marine and limnic sediments with basic to acidic mineralogy. We found gleysol showed about 48:47 % of silt and clay in the upper 0-35 cm layer. This type of soil is silty clayey. Soil swelling and shrinking properties are determined by the percentage and type of clay minerals in soil, together with humus content. The depth of groundwater table is 1.2-1.3 m, which strongly fluctuates by precipitation and drainage. During dry periods Gleysol has a high proportion of large blocky aggregates (See *Photo 53, 55*), and large cracks, by this means rainwater can easily percolate through the soil. When soil is wet, clay particles swell and water retention is very low. As it is, told evidence of reduction processes with segregation of Fe compounds within 50 cm of the soil surface. The main obstacle to utilization of Gleysols is drainage to lower the groundwater table (*Photo 59, 60*). While we found soil structure destroyed by cultivation in wet conditions, we call attention to turn a well-timing soil tillage including soil loosening. Liming and draining of soils that are high in organic matter and/or of low pH value creates a better habitat both for microbial and earthworm activity.

Photo 59 **Drainpipe installation in a field near Popovaca**

Photo 60 **Subsoiling of the field with drainage for water percolation**

Soils under influence of Mediterranean climate

The Adriatic area of Croatia is a typical example of Mediterranean ecosystems, as shown by the economy, culture and civilization. This area covers more than one third of the entire territory of Croatia (2.020.000 ha or 35.7%). Agricultural areas within the Adriatic littoral represent more than one third (34.3%) of the total agricultural area of Croatia. In contrast, arable lands of the Adriatic Region represent only 16.4% of the total arable lands of Croatia (*Photo 61, 62*). Rangelands account for a greater portion of the agricultural and forest lands within the Adriatic Region compared to other agricultural regions of Croatia.

Over 1.7 million hectares are considered as rangelands, and these lands represent a significant natural resource for livestock development. The lack of grazing has allowed the growth of bushes and small trees that form very dense and almost impenetrable thickets. The fire-prone bushes and small trees increase the risk and the danger of fires, prevent livestock access to the existing range plants, and suppress the growth of more desirable plant species.

Even though livestock production in the Croatian littoral has a long tradition, extensive and systematic investigation of the economic value and proper utilization (i.e., grazing systems) of Mediterranean rangelands has not been conducted (*Rogosic,* 2008).

Photo 61 **Small vegetable gardens in a valley at Lubenice (Cres)**

Photo 62 **Sampling of the potato garden soil (Lubenice, Cres)**

Leptosol is a shallow soil over hard rock, very gravelly or highly calcareous (lime-rich) material. We found this formation in (mountainous) areas where the soil has been eroded to the extent that hard rock comes close to the surface.

Because of limited soil forming development they do not posses much structure while contains less than 20 percent (by volume) fine earth. Leptosols on limestone are commonly called Rendzinas, while those on acid rocks, such as granite called Rankers (WRB). Continuous rock at the surface is considered non-soil in many soil classification systems.

We found Leptosols having a resource potential for wet-season grazing and as forest land. They may vulnerable to the tourism pressure through increasing environmental pollution. However we found good solution e.g. terracing and planting vineyards, preserving old olive tree plantations, building (or preserving) low stone walls decreasing water erosion on the slopes. *Photo 63-68* represents variable and special landscape formations.

Regosols are very weakly developed mineral soils in unconsolidated materials while located in eroded lands, particularly in mountainous terrain. Profile development is minimal as a consequence of slow soil formation, e.g. because of aridity and low moisture holding capacity. We found extensive grazing, abandoned pastures and naturally growth bushes (*Photo 69-70*).

Photo 63 **Abandoned vineyard at Lubenice (Cres)**

Photo 64 **Soil and water preserving stone wall (Lubenice, Cres)**

Photo 65 **Landscape panorama from the hill at Novigrad na Dobri**

Photo 66 **Typical landscape at Mala Kapela**

Photo 67 **Stone-mulch in a vineyard at Korlat**

Photo 68 **Natural mint field in the island Cres**

Photo 69 **Abandoned pasture at Lubenice (Cres)**

Photo 70 **Bush rooting into stony soil (Ustrine, Cres)**

Islands

Basic rocks of island **Cres** are limestone and dolomite which may include water reservoir layers (*Photo 71, 72*). Limestone rocks split by shafts, rifts and sink holes (*Photo 73*). Karst fields are surrounded with steep rock walls encircled karst fields (*karstic polje*) and small dry valleys covered by fertile red soil (*terra rossa*). Karst covers 48.9 % of the land area or 27,265 km^2 of Croatia (*Bogunovic,* 2006). There sandy (*lumbarda*) and clayey sand (*blatsko polje*) soils on the rocks in some field of island covered by grass for grazing and or mowing. Left pastures have shortly occupied with bushes (*garrigue, macchia*) and their habitat quality has also transformed. Many centuries ago steep hillsides were divided into smaller parts with stone walls slowing down water flows and reducing erosion damages.

Photo 71 **Typical limestone formation on the island Cres.**

Photo 72 **Vrana lake, the most important water reservoir of the island Cres**

The forests are very important parts of the original vegetation. In the northern part of the island where bare limestone and dolomite is dominant the main species of tree are *Quercus petraea*, *Quercus cerris* and *Quercus pubescens* associated with *Carpinus orientalis*, *Ulmus minor*, *Pinus pinea*, *Pinus nigra* and *Quercus ilex*, while central and southern part of the island pastures and dense *macchia* are found. As it told, from some 1100 plant species is about 939 plants are indigenous.

Macchia is a shrub land biome in this region, typically consisting of densely growing evergreen shrubs, such as holm oak, juniper, buckthorn, spurge olive, myrtle etc. – are mostly aggressive plants – which may 3-8 m high. This shortly occupied uncultivated and or deforested fields and abandoned pastures. Basic rocks of limestone and dolomite coupling some water conserving soil give favourable habitat for the native, evergreen olive (*Oliva europea*).

Photo 73 **Utilising of a sink-hole for vegetable garden (Rakovica).**

Photo 7**4 Brnistra (Weaver Broom, *Spartium junceum* L.) a typical perennial plant in the region**

The typical perennial plant of the dry and warm slopes the Spanish Broom or Weawer Broom (*Spartium junceum* L.; in Croatian *brnistra*) which 2 to 3 meters high scrub with junk shaped branches and fragrant flowers are yellow blooming from spring (*Photo 74*). There are many native herbs in the island that is rosemary (*Rosmarinus officinalis*, in Croatian *ruzmarin*), laurel (*Laurus*, in Croatian *lovor*), sage (*Salvia pratensis*, in Croatian kadulja), mint (*Mentha piperita* L., in Croatian *metvica*), a levendula, lavander (*Lavandula angustifolia*, in Croatian *lavanda*), and thyme (*Thymus vulgaris*, in Croatian *timijan*).

The most important agricultural activities are sheep breeding, bee-keeping and maintaining olive plantations and vineyards. Sheep being small area for fodder plant production are grazed in pastures of stony meadows soils. For this reason sheep grazing is a factor of the soil loss and water erosion. Soil fertile layer has really been narrowed for centuries therefore that are unsuitable for crop production but adequate habitat for native plants (*Photo 75, 76*).

Changes in land use in islands Cres and Losinj. The original land use patters were meadow, pasture, or producing arable crops, vegetable and garden plants. These methods are mostly decreased or disappeared. Olive growing is still important, but grapevine production is almost vanished. However, as it is told, tourist involvement assists local inhabitants in maintaining traditional agricultural activities and methods that have been used by local inhabitants for centuries. Agricultural activities may provide an exciting experience for visitors living in urban areas.

Photo 75 **M.Birkas and I. Kisic near Beli, island Cres**

Photo 76 **Mediterranean type of land use, island Cres**

Climate in island Losinj is very favourable for many native and imported plants including herbal plants. Native and planted forests represent high values, maintaining their health state is very important. Considering shallow layered stony and rocky soils the state of the existing and abandoned pastures and gardens are also stressed.

Forest Dundo is the most beautiful Mediterranean forest (1040 ha) located in the island **Rab.** Typical tree species of the forest are *Quercus ilex*, *Quercus kelloggii, Quercus coccinea*, *Fraxinus ornus*, *Phillyrea latifolia*, *Pinus nigra*, *Pinus leucodermis*). Moreover *Erica arborea*, *Pistacia lentiscus, Arbutus unedo, Myrtus communis*, *Viburnum tinus* and *Asparagus acutifolius* are also found in the Dundo forest. Soil of this forest is skeleton covers liming, and karst basic rock. Although humus content of soil is low, soil compaction problem – being a conserved area where traffic is slight – is insignificant.

Pines, as allochthonous and pioneer species, were used to afforest degraded and devastated areas on the island because of their important role in the process of progressive vegetation succession. Degradation of forest sites on the island of Rab goes back several hundred years. The causes include in the first place negative anthropogenic impacts, followed by climatic conditions that are hostile to natural regeneration of vegetation. In a part of the island, devastation has led to the disappearance of forests or the preservation of only degraded forms of the basic autochthonous forest vegetation, the forest of holm oak and manna ash (*Fraxino orni-Quercetum ilicis*). The beginning of the twentieth century saw intensive reforestation activities aimed at halting site degradation processes. The main task of the pines was to create site conditions for the return of original vegetation (*Photo 77*). There are about 1000 hectares of pine cultures on the island Rab, yet climate zonal vegetation has been re-established in a small part of these forest cultures.

The island itself is a karst mountain and one part is covered by Mediterranen pine forests (e.g. peninsula Kalifront), and other part is indeed covered by bare cliff. Agricultural activity is limited to smaller and greater plane valleys (Lopari, Kampori, Supetari) where grapes, olives, vegetables and fruits are produced. We found very small maize parcels, too. Sheep breeding is limited to the valley's pastures. Bee-keeping is an old-new farming method.

Highland in **island Dugi Ot**ok is similarly covered pine forests. Vineyards, olive plantations, fruit and vegetable gardens cover about 1500 ha. Area of pastures cover about 750 ha (about 300 ha left pasture is reoccupied by macchia.

Photo 77 **Both natural and planted forests are of high value in the islands**

Photo 78 **Karst-limestone formations (Kornati)**

National Park Telašćica (N 43˚ 53' 35,80" E 15˚ 10' 37,85") is situated in SE part of island **Dugi Otok** and some 13 smaller and larger islands (area covers 70.5 km^2). In one side of the park are peaceful bays, cliffs, pine and oak groves, and the others side vineyards and olive plantations are found.

National Park of Kornati (bigger part of the Kornati island**s)** has been declared in 1980, considering its exceptional landscape beauty, interesting geomorphology, diversity of the coastline and rich biocoenoses of the marine ecosystem. It occupies an area of about 220 km^2, includes 109 islands, islets and cliffs, with a coastline about 238 km long. Most of the terrain in the Kornati islands is karst-limestone which (*Photo 78*), in the distant geological past, arose from sea sediment. In the stone there are numerous fossils of crustaceans and fish. This area has examples of the typical forms of karst that is bizarre shapes formed by the atmosphere, unexplored caves, areas of flat rock and, above all, cliffs. The islands have no spring water, only rainwater collected in water holes. Due to the unfavourable dynamics of rainfall and air temperatures during the vegetation period, and because of limestone formation, the *vegetation* on the islands is very sparse. There are some 200 known varieties of Mediterranean plants, and they have sufficiently degenerated.

The most common plant is a tough variety of grass, and are many scented and medicinal herbs, e.g. sage, feather grass and xeranthemum giving a fragrant spring, and providing the best country for bees. The landscape of chalk limestone is covered with bushes of rosemary, juniper, lavender, thyme, myrtle and sage. Olive trees account for about 80% of the land under cultivation, followed by vineyards, figs, orchards and vegetable gardens. It is though that the Kornati islands were once covered with forests of Mediterranean holm oaks (*Quercus ilex*). Over the time erosion (*Photo 79*) has been caused by the sea, over grazing by sheep and fire. This erosion has deprived the islands of their primeval luxurious vegetation, and the people have moved to more hospitable islands. The predominant type is rocky ground with sparse pastures. Only on the NE side of the Kornati islands are some areas under holm oaks.

Red soil fields, mild slopes and coves provide good opportunities for the cultivation of olives, figs, vines and citrus fruit. It is told that islands Kornati have no permanent inhabitants, although the present owners from nearby larger islands periodically visit here to tend their vineyards and olive groves, bringing their sheep to graze.

Photo 79 **Water erosion in the karst-limestone rocks (Kornati)**

Factors limiting agricultural production in soil relation

Soil degradation processes in Croatian relation were listed by *Husnjak et al.* (2011), include water and wind erosion (46% of agricultural land is exposed to high or moderate risk of soil erosion by water, and 45% of forest land to moderate risk), land reallocation, depletion of humus content (humus content in soils on agricultural land of Slavonia and Baranja is approximately two times lower compared to the same soils in the forest ecosystem), acidification, salinization and alkalization, human-induced compaction, soil biogenity decrease, contamination by heavy metals, by pesticides and petrochemicals, forest fires and war damages.

Croatian partners of the S&T project summarised the major types of natural or anthropogenic limitations of agricultural production and those are as follows: soil depth, depth of fertile layer, depth of tilled layer, soil quality deteriorating tillage, acidity, salinity, alkalinity, clay content, drainability, excess water, skelet of rocks, terrain slope, erosion, rock outcrop, stoniness, as well as specific degradation processes of pedophysical, pedochemical and pedobiological properties in conditions of intensive ploughland farming.

Destruction of facilities, devastation of natural ecosystems and unregistered waste are the consequences of war activities. There are undefined quantities of polychlorinated biphenyles (PCB) in the soil from damaged power transformers and military vehicles.

These factors may be determined both the agricultural chance in the future and the mission of the participants of the concerning sectors.

Potential risk of soil erosion by water is defined as the inherent soil susceptibility to erosion by water, not accounting for the vegetation cover or mode of utilization. This risk is thus the worst possible case; namely, assessment of the potential soil erosion risk is based on the assumption that the entire area under study is used as arable land. Major characteristics of a terrain that have dominant influence on the potential soil erosion risk include soil erodibility, precipitation erosivity and terrain slope, for which respective maps were made, and their further integration resulted in the map of potential soil erosion risk. Inventory of areas under particular degrees showed that the most wide-spread class is the one indicating low actual risk of soil erosion by water, which accounts for 3,020,690.3 ha or 53.3% of the Croatian territory. The degree of moderate actual soil erosion risk covers 1,796,921.0 ha or 31.5%, while the degree of high actual erosion risk occurs on 746,474.8 ha or 13.4% (*Husnjak et al.,* 2008).

Factors promoting agricultural production in soil relation

Partners of the S&T project note that depth of the soil layer may be utilised its adaptability to the different land use (arable, forest, grass, pasture etc., e.g. *Photo 80*).

Depth of the fertile layer in one hand is to preserve (erosion control), and in other hand it can be developed by adaptable fertilisation and organic material intervention. *Depth of the tilled layer* is a question in small farms where usual ploughing depth extended to the depth of 22-25 cm (or less). Soil condition in these farms requires improvement in the near future.

- The typical ploughing experience that is leaving a furrow in the central line of the parcel removing the water surplus during winter time may qualify as water loss system. We found that cause of the periodical water surplus is the thick plough pan compaction which limits water infiltration in deeper layers of the soil (*Photo 81*).
- Subsoiling that is soil state remedying method is to initiate and spread widely (c.f. *Photo 82*). Soil conservation tillage methods have to obtain greater publicity. Soil conservation is the basis of the nature preservation (*Photo 83*).
- Acidity and salinity may solve regional chemical and biological methods. Impact of the high content clay and silt in soils may require using organic material conservation tillage completing farmyard and green manuring.
- Exact practice of the green manure crop production is also necessary. Drainability of soils can be improved in harmony of water table management, water storing and irrigation.
- Old terraces built many decades ago may be renovated in sloped areas for a minimum conservation state. Sink holes were or are used for crop production may be maintained or improved (at best case grassing). Rocky areas as the part of the landscape in some

regions in Croatia are worthy of conservation. Learning and using climate threat mitigation crop production methods are adequate in the near future.

Photo 80 **Natural and human-induced landscape in Zagorje region**

Photo 81 **Shallow ploughing; soil is deteriorated by pan compaction**

Photo 82 **Preserved landscape in Krbavsko polje**

Photo 83 **Sink-hole in Istria, sown with winter wheat; stowed stone wall at the side of the hole**

Results of the project

Results of chemical soil analyses

Although it was not originally planed, soil chemical analyzes were performed in soil samples taken during the project. Results are presented in *Table 10.*
Methods used for analyses were; for soil pH - HRN ISO 10390:2005, KCl (1:2,5), for P_2O_5 and K_2O - AL-method, and for humus content Tjurin/bicromate method.

According to the results, soil pH in samples taken in Hungary is decreasing from east to west, and same goes for humus content. Content of phosphorus and potassium is mainly result of natural fertility combined with mineral and organic fertilizers application. In case of chernozem soil from Mezőhegyes (Lok 1 and 2) it is possible to make conclusion that phosphorus and potassium status is very good and there are excellent potentials for high yields of grown crops. This statement is partly based on results from deeper soil horizons, even if the amount of nutrients in plant available form is decreasing with depth. In samples taken in Karcag (KAR 1) content of P_2O_5 is much smaller, while content of K_2O is even higher that in samples form Mezőhegyes. Samples form Szentgál clearly describes different land use patterns. In the case of arable field, soil pH value, phosphorus and potassium status are higher compared to the grassland, while humus content is higher in soil samples from grassland.

Table 10 Results of chemical analyses from soil samples taken during the project

Location	Basic chemical properties			
	pH	P_2O_5	K_2O	Humus
		mg/100g		%
Lok 1 0-30 cm	7,35	37,4	26,5	4,0
Lok 1 30-60 cm	7,46	31,9	27,3	4,0
Lok 1 60-90 cm	7,61	6,7	18,0	2,3
Lok 2 0-30 cm	7,47	35,2	30,3	4,5
Lok 2 30-60 cm	7,45	34,1	28,8	3,6
Lok 2 60-90 cm	7,44	10,8	17,6	3,1
KAR-1 0-30 cm	5,64	10,5	31,1	3,1
KAR-1 30-60 cm	6,72	7,8	28,4	2,9
KAR-1 60-90 cm	7,32	3,7	19,5	2,1
Szentgal 0-30 cm	7,08	15,6	15,1	2,3
Szentgal 30-60 cm	7,22	15,8	10,4	1,8
Szentgal 60-90 cm	6,48	9,9	11,2	0,7
Szentgal grassland 0-30 cm	5,30	4,2	11,5	2,9
Szentgal grassland 30-60 cm	5,50	2,8	9,7	1,9
Szentgal grassland 60-90 cm	5,32	4,7	13,0	0,9
Lub 1 0-30 cm	6,95	34,6	> 45,0	4,4
Lub 2 0-30 cm	7,38	14,9	30,4	2,5
Lub 3 0-3 cm	5,89	1,0	> 45,0	9,1
ML -1 0-3 cm	6,27	1,6	> 45,0	12,3
ML -2 0-3 cm	6,04	0,8	> 45,0	13,5
B12 0-3 cm	5,50	1,49	>40	5,8
B12 3-10 cm	5,46	0,13	>40	4,5
B13 0-30 cm	6,82	14,25	25,4	5,3
B14 0-3 cm	4,97	0,00	19,7	5,2
B14 3-10 cm	5,04	0,00	12,4	3,0
B15 0-3 cm	7,27	0,00	39,2	5,0
B15 3-10 cm	7,28	0,25	31,9	4,7
B16 0-30 cn	7,17	>40	>40	6,3

Soil samples from Croatia were collected at islands Cres and Losinj, and it is possible to conclude that pH is generally not a problem, while phosphorus content is very low in all samples taken from soils under native vegetation. Relatively high content of phosphorus is recorded in 3 samples taken from cultivated soils - garden (Lub 1), abandoned vineyard (Lub 2) and olive orchard (B 13). Content of potassium is commonly very high, as a result of pedogenetic processes and natural richness inherited from parent material. Highest humus content is recorded in samples taken from Čikat reforested area. This is clear evidence of positive influence of forests on carbon sequestration in Mediterranean conditions.

Project goals performance

The results are **important for both the partners** in 1) higher education, especially in MSc trainings; 2) joint publications in scientific and applied topics (soil compaction; climate threat etc.); 3) formation of a common opinion on measures that should be taken in agricultural practice of both the countries (adaptation to climate change, climate threat mitigating soil management practices etc.) and 4) supporting a European-scale common research platform in the Region involving young scientists.

The expected benefits are similar in both the countries. 1) preparation and publish of papers as well as giving of scientific presentations in Croatia and Hungary using data obtained in both the countries. 2) Evaluation of a precedent setting collaboration in the Region. 3) Involvement of young scientists in international co-operations. 4) the problem of soil tillage induced soil compaction that increases the climate threats will have increased publicity in the agricultural press of both the countries; the stake-holders and the decision-makers would get practical advises for threat recognition as well as for prevention and mitigation of the damages. 5) The joint research would contribute to the development and distribution of site-specific, sustainable soil management systems that ensure soil structure and moisture content conservation. 6) Improvement of the competitiveness of the Croatian and Hungarian science and technology.

The most important results of the project

1. Collecting and analysing the concerning thematic literature – in the field of soil tillage, land use, N-fertilisation, climate-impact – at Partners, and apply the findings in the collective publication in the past and in the future.
2. Assessing soil physical and biological state on similar – chernozem, meadow, forest, pasture (stony, shallow fertile layered) that is Chernozem, Luvisol, Cambisol, Calcocambisol, Leptosol –, and different – gleyic, alluvial, that is Stagnic Luvisol – and determining their vulnerability and sensitivity to the climate.
3. Evaluating of the environmental impacts of the similar – arable, pasture, plantation –, and different – abandoned ploughed field, plantation, and pasture – land use formations.
4. Assessing of the possible dangerous climate impact on Partners' lands, mainly in arable soils.
5. Evaluation of the extreme precipitation consequences that wreaked havoc in the Pannonian region in 2010 on chernozem (HU) and gleyic (HR) soils: Publication in press (*Növénytermelés*, 2012 61. 1: Birkas, M., Kalmar T., Kisic I., Jug D., Smutny V., Szemok A.: Impact of the extreme precipitation phenomena in 2010 on soil physical state.
6. Revealing the possible interactions between soil tillage practice and climate stress increasing or decreasing effects.
7. Studying and stating of experiences in soil compaction occurrence, and its consequences on arable soils at Partner' lands, and proposing adaptable alleviation methods.
8. Defining changes in nitrogen and carbon content and C/N ratio in the same soil type under different site conditions. As it was found, the management of agricultural fields, grasslands, meadows, orchards and forests has great influence on soil carbon content and on C/N ratio. Therefore the depletion of SOC is not an option for sustainable land use.
9. On soils originally rich in SOM stating five influencing factors, e.g.: (1) number and extent of soil disturbance (affecting CO_2 emission); (2) crop residue mass and handling (incorporate, mulch, or mix as recycle); (3) soil moisture storage or loss (affecting soil disturbance); (4) correct/incorrect-timing of primary tillage; (5) depth and method of soil disturbance in summer (affecting CO_2 emission).
10. Soil data collection and analyses (28) and soil condition assessment (56) and land use (6) evaluation (as a basis of the new publications).
11. Outlining that both in Pannonian and Mediterranean region it is very important to protect soils and to apply sustainable land management in terms of tillage, fertilization and crop rotation.

12. Project results appearance in the education processes: Marta Birkas (in Zagreb): 14-15 January, 2010: *Environmentally-sound adaptable tillage*, 25 November: *Soil tillage and climate change*; Milan Mesic (in Gödöllő): 22 April, 2010: *Efficiency of nitrogen fertilization on arable crops grown and influence of fertilization on soil and water properties*, Ivica Kisic (in Gödöllő): 18 April, 2011: *Water and wind erosion – prevention and alleviation*.
13. Delivering cooperative presentations in the regional conferences, e.g. Vukovar (31 May-2 June, 2010; 1-3 June, 2011), Plitvice (5-8 July, 2010), Osijek (9-11 Sept, 2010), Opatija (14-18 March, 2011), Pruhonice (31 Aug.-2 Sept. 2011*), Photo 84, 85*).

Photo 84 **M. Birkas presents plenary paper at Agroglas Conference (Vukovar, 1 June, 2010).**

Photo 8**5 M. Birkas and I. Kisic as moderators at 11th Congress of CSSS (Plitvice lakes, 8 July, 2010).**

14. Meeting regional farmers, discussion of the research result adoption, and attending soil tillage demonstration (*in Croatia*: 7 July, 2010: Krvabsko Polje; 9 July, 2010: Lepoglava; 10 July, 2010: Popovaca; 19, 5-6 June, 2011: Cres, Losinj, Rab; 15-16 June, 2011: Telascica and Kornati; 19 July, 2011: Cacini; 20 July, Osijek; 21 July, 2011: Otok; *in Hungary*: 1 August, 2009: Botykapterd, 21 April, 2010: Mezőhegyes; Karcag; 15-17, July, 2010: Szentgál and Balaton highlands; 27 July, 2010: Szigetvár-Dencsháza, 12-13 June, 2011: Karcag, Nagykunság, and Mezőhegyes, 20-21, June, 2011: Bekecs and Borsod basin, 7-9 July, 2011: Hatvan, Tisza lake region, and Hortobágy (*Photo 86, 87*).

Photo 86 **M. Milan assesses the growth of maize in Lepoglava**

Photo 87 **M. Jolankai and M. Mesic at the statue of Ambroz Haracic (in island Losinj**

15. Widening of young researchers experiences in the bilateral cooperation, and contribution to their research progress; ***in Hungary***: Laszlo Bottlik, Tibor Kalmar and Barnabás Posa PhD students acquired the absolutorium (2010, 2011), and their dissertation will be defended till 2013, Szilveszter Csorba (2nd year corresponding PhD student) has just written his first research publication (Water retention curves of heterogeneous pore- structured soil in soil conserving tillage systems; Agrokémia és Talajtan, 60.2.325-342); ***in Croatia***: Zeljka Zgorelec (PhD, 2010), Ivana Sestak (PhD, 2011), Aleksandra Jurisic (PhD exam, 2011), and Darija Capka will be defended their dissertations till 2013.

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2. Summarising of the project results in a closing booklet: Birkas M., Mesic M. (eds): Impact of tillage and fertilization on probable climate threats in Hungary and Croatia, soil vulnerability and protection, initiated authors were cooperated to the project (12 papers, with figures, tables and pictures).

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