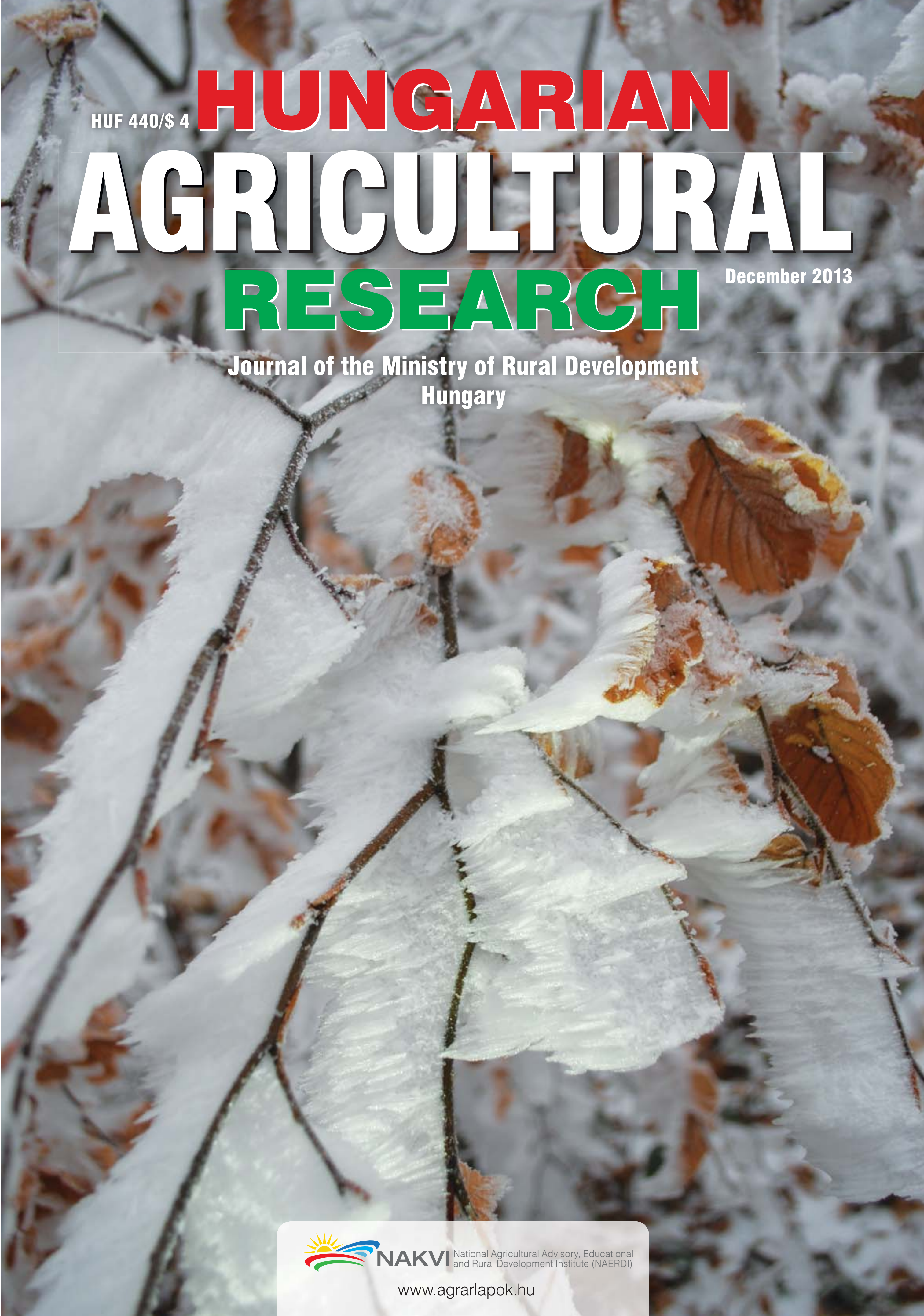

HUF 440/$ 4

HUNGARIAN AGRICULTURAL RESEARCH

December 2013

Journal of the Ministry of Rural Development
Hungary

NAKVI National Agricultural Advisory, Educational and Rural Development Institute (NAERDI)

www.agrarlapok.hu

Szent István University

Faculty of Agriculture and Environmental Sciences

Selection of Available Courses

Bachelor Degree Programs (BA/BSc)

Agricultural Engineering
Agricultural Environmental Management
Animal Husbandry
Crop Production
Environmental Engineering
Horticultural Engineering
Nature Conservation
Wildlife Conservation and Management

Master Degree Programs (MA/MSc)

Agricultural Biotechnology
Agricultural Engineering
Agricultural Environmental Management
Animal Husbandry
Animal Nutrition and Feed Safety
Crop Production
Environmental Engineering
Ecotoxicology
Nature Conservation
Plant Protection
Wildlife Conservation and Management

Postgraduate Specialist Training Programs

Agricultural Water Management
Alternative Energy Management Counselling
Alternative Energy Production Systems Expert
Animal Nutrition and Feed Management
Bachelor Level in International Agriculture
Fish Culture and Management
International Agricultural Expert
Kynologyst
Master Level in International Agriculture
Plant Genetics and Plant Breeding
Renewable Energy Production and Utilization
Seed Management
Soil Science
Soil Protection

Our purpose is YOUR FUTURE!

SZENT ISTVÁN UNIVERSITY
FACULTY OF AGRICULTURE AND ENVIRONMENTAL SCIENCES, GÖDÖLLŐ

H-2100 Gödöllő, P.O.Box 3. HUNGARY
Phone: +36-28/522-059, +36-28/522-005
Fax: +36-28/410-804
E-mail: dekan@mkk.szie.hu
www.mkk.szie.hu

Winter *(Photo by János Bakk)*

HUNGARIAN AGRICULTURAL RESEARCH

Vol. 22, No. 4.
December 2013
Journal of the Ministry of Rural Development Hungary

Published by

NAKVI National Agricultural Advisory, Educational and Rural Development Institute (NAERDI)

Owner

Ministry of Rural Development

H-1223 Budapest, Park u. 2. Hungary
www.agrarlapok.hu | info@agrarlapok.hu

Editorial Office
Deparment of Mechanics and Engineering Design
Szent István University, Gödöllő | H-2103 Gödöllő, Hungary

Subscription request should be placed with the Publisher (see above)
Subscription are HUF 1200 (only in Hungary) or
$16 early plus $5 (p & p) outside Hungary

HU ISSN 1216-4526

Gergely Hunyadi –Csaba Juhász –János Tamás[1]

Advanced methods to examine the process of composting

Introduction

The political, economic and social changes in the early 1990's in Hungary brought considerable changes also in agriculture, resulting in a major transformation of ownership and farm structure. Most of the large-scale farms were replaced by micro, small and medium-sized enterprises, or private entrepreneurs, leading to the fragmentation of the land property (*Molnár and Farkasné, 2003*).

By the changes in the ownership structure, the two main sectors of agriculture, crop production and animal husbandry were separated, which further reduced the profitability of enterprises. The decrease in efficiency was accompanied with the drastic decline in livestock. As compared to the 1970's, both the cattle stock and the pig stock reduced by over 40% (*Baranyai and Takács, 2007*).

The reduction in livestock brought forth the reduction in manure quantity as well. In the 1970's, about 15 million tons of manure was used annually. By 2000, this value decreased to 5 million tons. This change was enhanced up to the early 1990's also by the spreading of artificial fertilizer usage. The increased amount of artificial fertilizer, however, influences not only the soil characteristics but soil life as well.

Although the artificial fertilizer doses adjusted to the nutrient demand of crops can cover the needs of crops, they do not contribute to the maintenance of the soil organic matter content. Also, the calculations regarding the amount of active ingredient to be supplied exclude the nutrient demand of soil microorganisms which thus have to cover their needs from the soil reserves, further reducing the nutrient base and nutrient supply capacity of the soil. The removing of organic compounds, humus materials can lead to the deterioration of soil characteristics and soil degradation, which may make cultivation impossible (*Dobos, 1999*).

To prevent the above consequences and to maintain the favourable soil characteristics, the supplementation of organic matters is essential. One possible way of organic matter supply is composting. By the proper selection of raw materials, the controlling of degradation processes, and the monitoring of determining parameters, a stable end product suitable to be used for nutrient replenishment can be obtained (*Filep, 1999*). In addition, composting – performed in accordance with strict conditions – enables the disposal of various organic wastes as well.

The efficiency of composting is determined primarily by the amount and composition of additives (sawdust, wood cuttings, wheat straw, reed chips, etc.) added to the material to be degraded. The quality of the end product is influenced also by the compost's homogeneity, particle distribution, oxygen balance, moisture content and C/N ratio (*Petróczki and Késmárki, 2003*).

The degradation process, the amount of toxic gases produced and the rate of toxic gas production are highly affected by the compost mixture, i.e. the mixing rate of the initial materials as well as the application of proper pre-treatment technologies (*Kocsis, 2005*).

The development of advanced methods to examine the composting process

In the last decade, the research activity of the Department of Water and Environmental Management has been largely focused on the treatment alternatives – such as biogas production and composting – of various biodegradable organic wastes.

A wide range of choice of composting technologies is available in both national and international practice, therefore, the primary aim is not the development of new technological solutions but the further improvement of the procedures used in order to make them more efficient and to produce an end product with consistent quality. Efficiency can only be increased if the degradation processes are known in detail and accurately. This requires measurement methods that provide information quickly, cost-

[1] *University of Debrecen, Centre of Agricultural Sciences and Engineering, Department of Water and Environmental Management*

effectively and directly from the compost pile.

The Department of Water and Environmental Management performs examinations and methodology improvement in connection with the measurement of surface temperature, the determination of the pore gas composition in the compost pile and the applicability of reflectance.

The examination of pore gas composition

Pore gas composition, on the one hand, provides information on the efficiency of degradation and, on the other hand, enables the examination of compost homogeneity and compost maturity. In practice, usually only oxygen concentration is measured for closed technologies, however, the amount of carbon dioxide and oxygen should be both known to evaluate aerobic/anaerobic processes. In case the concentrations of ammonia and methane are also determined, the efficiency of degradation can be analysed even more precisely.

The measurements are carried out using the portable outdoor multigas detector OLDHAM MX 21 (*Figure 1 [A]*). The instrument can measure various gases in different categories: combustible gases, toxic gases (carbon dioxide, hydrogen sulphide, chlorine, ammonia, etc.) and oxygen. Using special detection cells (*Figure 1 [A/3]*) each corresponding to one channel, it can measure four different gases at a time (*Figure 1 [A/2]*), one combustible and three other freely chosen gases. The results are displayed in an alphanumeric display (*Figure 1 [A/1]*) in cm^3/m^3 for toxic gases and in volume percent for combustible gases. The measuring principle is based on infrared refraction. The instrument is equipped with a pump system and a gas injection cap (*Figure 1 [B]*), enabling it to detect gas quantity in less accessible places.

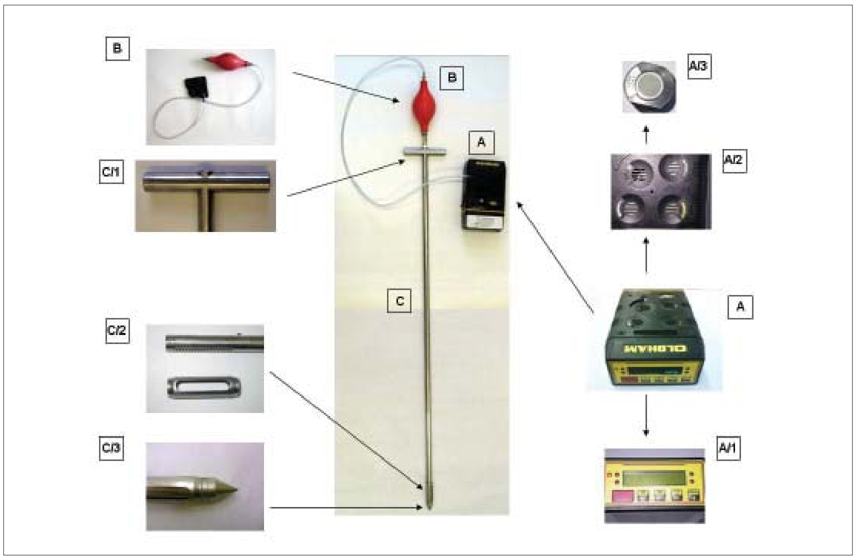

Figure 1: OLDHAM MX 21 portable gas analyser

An accessory was required for the direct measurement of the gas component concentration of the compost pile (*Figure 1 [C]*), which is a special stainless steel acid-proof stick developed by our Institute with an inner diameter of 14 mm, and a maximum measuring depth of 1.5 metres. The pointed tip (*Figure 1 [C/3]*) and the special grip (*Figure 1 [C/1]*) enable easier application. The end of the probe stick is protected from contamination by a filter (*Figure 1 [C/2]*).

Legend:

A: OLDHAM MX 21 gas analyser

A/1: Alphanumeric LCD display

A/2: Top of the instrument with 4 measuring cells

A/3: Measuring cell

B: Pump system

C: Measuring stick

C/1: Special grip

C/2: Pointed tip

C/3: Special metal filter

The instrument can examine 4 gases at a time, thus the oxygen, carbon dioxide, ammonia and methane content of pore air can be measured simultaneously. To assess the efficiency of degradation, it is practical to examine oxygen together with carbon dioxide. The rate of oxygen and carbon dioxide is a non-dimensional number that expresses the amount of carbon dioxide relative to oxygen in the pore gas mixture. This ratio not only enables the examination of the relation between these two gases but provides an overall picture of aerobic/anaerobic degradation, too. The development of anaerobic conditions is confirmed also by the increasing quantities of ammonia and methane.

The amount of gases in the compost pore is influenced by several parameters (e.g. moisture content, temperature, C/N ratio, homogeneity etc.), but it can be stated that the gas composition of the pore is invariable in the last stage of degradation. Accordingly, the maturity and stability of compost is indicated by the gradual decrease in the carbon dioxide and ammonia content of the internal gas space.

The four maturity stages of composting cannot be clearly separated from each other on the basis of the graphs showing the changes in ammonia, carbon dioxide and oxygen content, however, the continuous decrease in ammonia and carbon dioxide content demonstrates compost maturity. It is advised, therefore, to measure gas content more frequently during the last stage of degradation. The continuous measurement of gases is not recommended to examine compost maturity but rather to reveal homogeneity and aerobic/anaerobic conditions.

The applicability of thermographic camera in the examination of compost

One of the most frequently used methods to examine the progress of composting is the measurement of the compost pile inner temperature. Temperature is usually measured with a stick thermometer or a probe thermometer. The method is suitable to monitor degradation, however, the number of sampling points is advised to be increased in order to have a better image on the entire pile. Another disadvantage of the method is that surface temperature cannot be evaluated with it.

In the case of open air windrow composting, which is a wide-spread method in Hungary, surface temperature can be measured with thermo-cameras (*Figure 2.*).

When assessing the thermal images, it is apparent that the temperatures of certain surface points significantly differ (Figure 3).

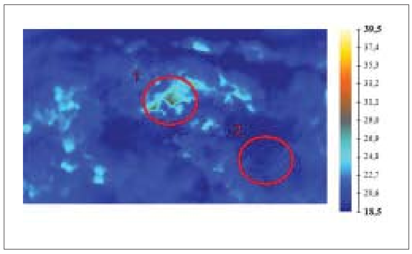

Figure 3: Surface points with different temperatures

These differences may reach 15-20 °C. The objectives of using a thermo-camera was to examine the surface and to investigate these differences. The application of thermo-cameras enabling quick assessment may become cost-effective if the causes of such temperature differences are revealed in order to replace expensive or time-consuming methods.

Thermo-cameras help identify the points where a feature of the certain compost pile differ. To uncover the causes of the difference, samples were taken from points with differing temperature and from those with average temperature and were examined for organic matter content, C/N ratio and moisture content. Surface temperature showed close correlation only with the loss on ignition, indicating that temperature was influenced by the organic matter content of the compost. C/N ratio and moisture content had an indirect relation with surface temperature, which leads to the conclusion that temperature variance is the result of improper mixing. By the application of a thermo-camera to identify the points with different temperature, it is not required to remix the entire pile.

The effect of surface temperature variance on the temperature of inner layers was also examined. It was found that the distribution of surface temperature affects the inner pile temperature depending on the additive used. In piles created using wood cuttings a crust of 20-30 cm is formed, as a result of which the inner temperature does not follow the changes in surface temperature. The inner temperature of piles created using wheat straw or other materials that provide less stability has close correlation with the surface temperature up to the depth of 60 cm.

By using a thermo-camera, it is not required to remix the entire pile only the segments with critical temperature. The largest disadvantage of the method is the high acquisition cost, therefore, it is recommended to be used in cooperation with several other composting plants.

The applicability of reflectance in the examination of compost

Reflectance can be used to determine the mixing rate of compost and to evaluate the decomposition process and compost maturity. The examination of reflectance provides an efficient solution if sampling and measurement can be made in the same place. Field measurement can be performed using for instance the portable spectrophotometer ALTA II (Figure 4).

The determination of mixing rate is based on the different reflection features of various raw materials; the reflectance of dark raw materials (e.g. sewage sludge)

Figure 2: Thermo-camera PYROLATER 12

Figure 4: Portable field spectrophotometer ALTA II

on various wavelengths differs from that of bright materials (e.g. sawdust, straw). Infrared regions are the most suitable to examine compost mixtures, however, if the rate of sewage sludge is higher than 60 v/v%, there is no significant difference between the mixing rates on any wavelength. This does not considerably influence the applicability of the measuring method as the rate of sewage sludge cannot exceed 50 v/v% to ensure maximum composting efficiency.

Increasing the rate of brighter additives caused an increase in reflectance, too. Moisture content has a negative effect on reflectance: drying results in an increased reflectance. The method can be used for both dry and wet samples. Wet samples can be analysed without drying, so the samples taken from the pile can be examined directly.

Reflectance analysis is an efficient and quick way to determine compost maturity in open air windrow composting based on sewage sludge. However, it is advised to be carried out along with temperature measurement to obtain more precise results on the stage of maturity. The frequency of measurements should be increased in the second stage of degradation (as of the 25th day) because the increase and the subsequent decrease in reflectance provide information on the integration of humus materials and the formation of mature compost (*Figure 5*).

Assessing the trend on the basis of reflectance values, the degradation of organic matters can be divided into four processes, similarly to temperature changes. The values change because of the different reflection features of organic matters. In the initial stage, complex organic matters with long carbon chain are present in large quantities, which is indicated by high reflectance. In the second stage, simpler compounds are formed due to intensive degradation, resulting in reduced reflectance. In the third stage, complex organic compounds are formed again by the integration of humus materials, as a result of which reflectance rises. At the end of the process, reflectance is reduced to an almost constant value, indicating that compost is mature.

The applicability of reflectance for the examination of degradation process is based on the structure of organic compounds and the colour of the compost substance examined. The reflection features of more complex organic compounds differ from those of simpler compounds. Due to the higher reflectance of more complex organic compounds, the measured reflectance values will be higher in the initial stage (because of complex organic raw materials) and at the end of the process (because of the formation of humus compounds). The end product of degradation is compost, a soil-like dark material with a reflectance lower than that of the raw materials.

Summary

Effective composting and product oriented composting cannot be imagined without knowing the degradation process and examining the factors affecting it. By monitoring and controlling the parameters, the efficiency of degradation and thus the quality of end product can be influenced. The aim is to apply and develop measurement methods that enable the direct in-situ evaluation of these parameters (particularly temperature and the gas components of pore) to avoid the separation of sampling and measurement which is typical of laboratory investigations.

Using a thermo-camera and thermo-images provides information on the pile surface in open air windrow composting, revealing the points where different degradation processes take place. Considering the high costs attached to the use of a thermo-camera, it is recommended to be used in cooperation with other composting plants.

The examination of the pore gas composition provides information on aerobic/anaerobic conditions. Although a special instrument is required, it can be automated easily in closed technologies, and also enables the investigation of the presence of oxygen, homogeneity and compost maturity.

Reflectance allows the examination of compost mixing rate and homogeneity as well as of compost maturity, however, it is advised to

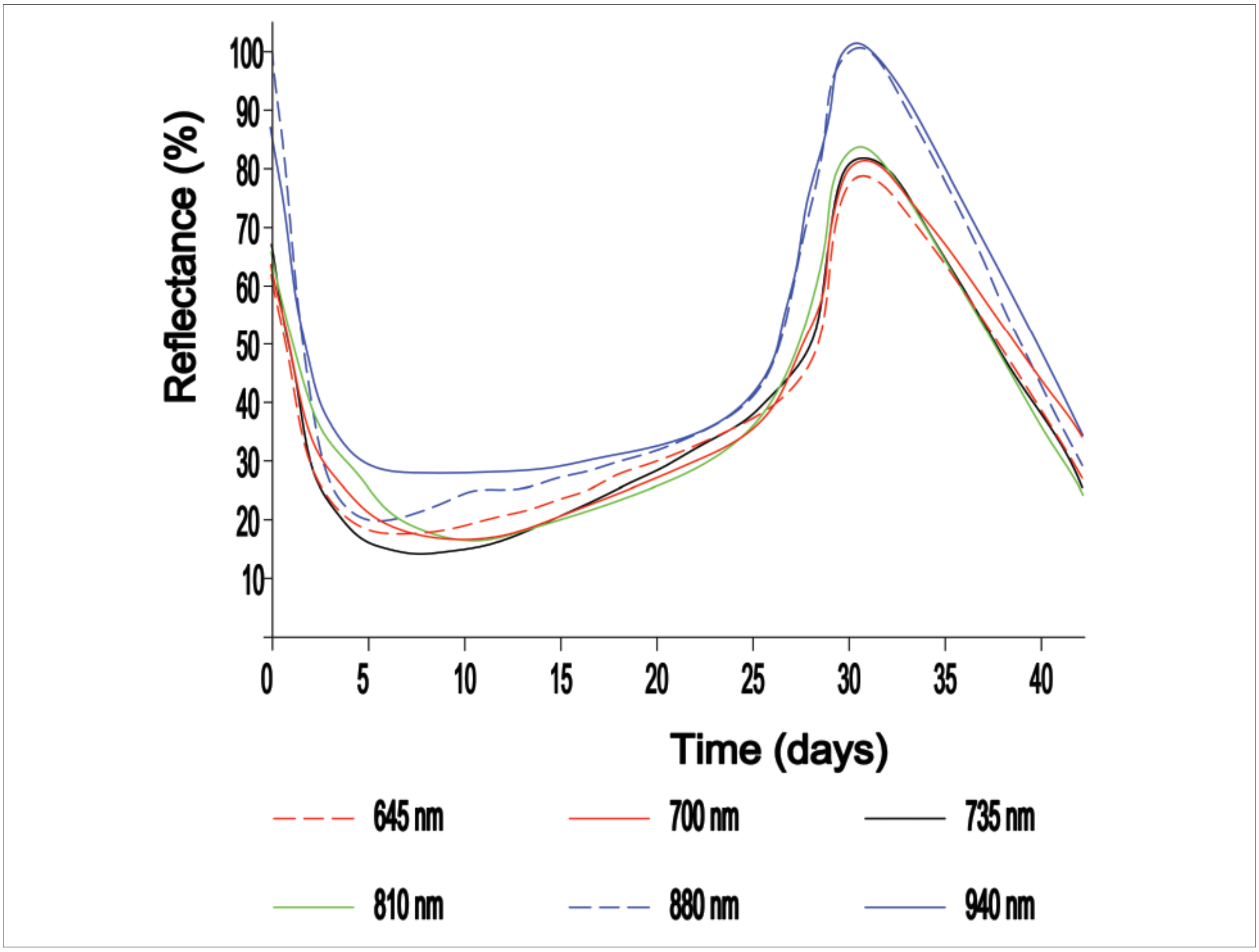

Figure 5: Changes in reflectance over time

be used along with the measuring of temperature or gas composition. Reflectance measurements should be carried out more frequently in the last stage of the process. It would also be practical to examine the values of absorbance in the future to determine compost maturity and end product stability even more efficiently.

References

Baranyai Zs.–Takács I. (2007): A rendszerváltás hatása a mezőgazdasági termelés hatékonyságára Magyarországon (The effect of the change in the regime on the efficiency of agricultural production in Hungary). AVA Nemzetközi Konferencia. Debrecen. Konferencia CD. 1–15.

Dobos E. (1993): Talajtan–Talajvédelem (Pedology-Soil protection). Ökológiai Intézet a Fenntartható Fejlődésért Alapítvány. Miskolc. 34.

Filep Gy. (1999): Talajtani alapismeretek I. Általános talajtan (Pedology basic knowledge). DATE Mezőgazdaságtudományi Kar. Debrecen. 64.

Kocsis I. (2005): Komposztálás (Composting). Szaktudás Kiadó Ház. Budapest. 207.

Molnár J.–Farkasné Fekete M. (2003): A makrogazdasági környezet néhány meghatározó elemének hatása az agrárgazdaságra. Birtokviszonyok és mérethatékonyság (The effect of some determining factors of macroeconomic environment on agriculture. Land property and efficient production depending on farm size). Agroinform Kiadó és Nyomda Kft. Budapest. 9–26.

Petróczki F.–Késmárki I. (2003): A komposztálás jelentősége (The importance of composting). Acta Agronomica Óváriensis. 45. 2: 203–213.

Vasa, Laszlo[1]

Diversification opportunities in agriculture: chances of rural tourism in Hungary

Despite the growing interest in rural tourism in rural communities, there has been little investigation of how to introduce this new activity into conventional farm management while taking advantage of multifunctionality in agriculture. Actually rural tourism as a new farming activity that transforms a positive externality of multifunctionality into an income-generating opportunity (or the internalization an of externality). In many rural regions, tourism is accepted as a natural part of the socio-economic system connected with agriculture. It is clear that rural tourism is based on rural amenities; however, it is not clear how this relates to agriculture. Are these interrelationships of mutual benefit, in the sense that while rural tourism provides the farmer with auxiliary funding to continue his/her agricultural activity, the latter is an important or even necessary component of rural tourism? Do active farms with rural tourism enjoy economies to scope and run their businesses more efficiently than firms with only a single activity?

Rural tourism is a segment of the total tourist industry which could be particularly important in Hungary, in a country with no spectacular natural attractions, without seaside, high mountains or rainforest. However, its attractive cultural landscapes with small villages, thermal springs, rivers and lakes, combined with the traditional hospitality, are able to offer pleasant experiences to the kind of tourist who is looking for relaxation and recreation in a calm setting.

Literature review

The demarcation between farm tourism and rural tourism is somewhat hazy. Nilsson (2002), in his work on farm tourism, defines farm tourism as a subset of rural tourism. According to him, rural tourism is based on the rural environment in general whereas farm tourism is based on the farm and the farmer. This means that within the framework of rural tourism, farm tourism enterprises are more closely related to agriculture than other rural tourism operations. Clarke (1996) elaborates further and claims that there is a difference between tourism on farms and farm tourism. When accommodations are divorced from the farm environment then it is .farm tourism. while in .tourism on the farm., the farm environment and its essence are incorporated into the product. These links not only differ, they also change over time. Busby and Rendle (2000) claim that the link between farm tourism and agriculture is getting weaker. They describe the transition from tourism on the farms to farm tourism. This transition occurs as farmers who got engaged in tourism on their farms as an alternative source of income to agriculture, slowly divorced themselves from agricultural activities. According to Busby and Rendle (2000), with this transition the active farm is no longer a necessary component. Clough (1997) extends this argument further by claiming that most of the visitors would be happy not seeing the active farm. It seems that many

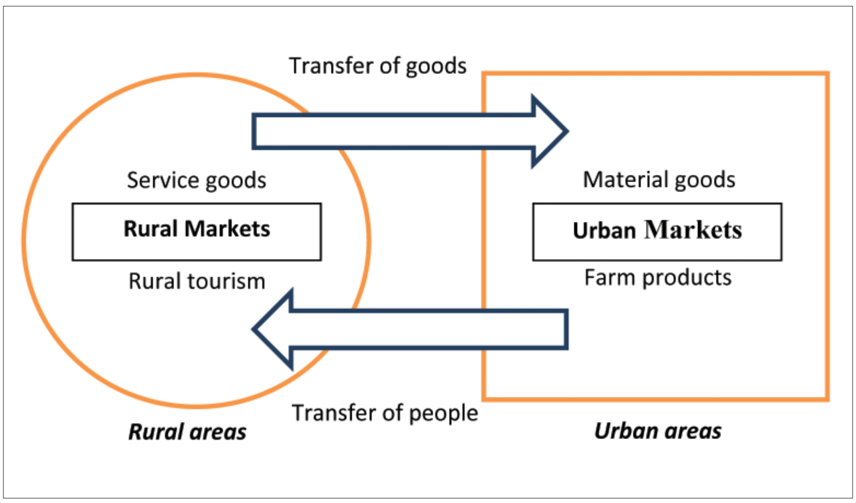

Figure 1. Rural-urban relationship between two products
Source: Yasuo, 2007.

[1] *PhD, associate professor, Szent Istvan University,Faculty of Economics and Social Sciences, Gödöllő, Hungary*

researchers agree that the role of the farm and the farmer is to supply the background that provides farm tourism with its unique features (Pearce, 1990; Nilsson, 2002). This is strengthened by Walford's (2001) findings that successful farm accommodations are located in an aesthetically pleasing, tranquil countryside environment; there is no reference to farm activities. These observations lead to the conclusion that there is a range of links between agriculture and tourism and that these links are getting weaker, especially from the visitor's point of view. If benefits do not accrue to the farmer from the demand side, then they may accrue from the supply side. That is, farmers involved in tourism and agricultural production might do it more efficiently and thus have an incentive to continue the farm's activity. Farming problems have given a big push to farmers and policymakers to seek alternative activities, tourism being one of them (Ilbery et al., 1998). The diversification of farm activities to tourism has in some cases fulfilled expectations, whereas in other regions it has not: this issue has been the predicate of many works. Fleischer and Pizam (1997) depict different cases and elaborate on the causes of their success or failure. However, the topic at issue here is not the success of tourism as an alternative activity but the level of symbiosis between tourism and agriculture from the supplier side.

Multifunctional agriculture, although less performing from the strict point of view of production and profit, is preferred from other points of view (tourism, landscape, ecological, social, etc.). In principle, multifunctional agriculture carries out the same economic functions as the super intensive and specialized agriculture, yet it takes over new functions, such as:

– Production of energy raw materials – bioenergy, as a new and extremely important function in the areas with surplus production of agricultural raw materials with food destination;

– Increase of tourism potential by the preservation and improvement of the landscape heritage;

– Conservation of vital elements and biodiversity (soil, air, water, flora, fauna), through their sustainable use in an environment-friendly agriculture that should ensure agro-eco-system stability;

– Harmonization of the social and cultural functions of the rural area in close connection to a healthy and diverse agriculture.

Multifunctional agriculture growth presupposes the use of an increased number of people, for longer periods of time throughout the agricultural year, compared to the conventional, intensive and highly specialized agriculture.

As agriculture has multiple functions, it seems obvious that the society, as their beneficiary, should pay not only for the agri-food products, food respectively, but also for the indirect services that contribute to the improvement of habitat or landscape quality, etc. The present price system, as well as the removal of subsidies so as to produce cheaper food, without using any financial compensation forms for the subsidiary services of agriculture, will adversely impact the farmers on the medium term, and will indirectly have negative consequences with regard to food security on longer term. We consider that it is necessary to evaluate these compensations (for tourism, for maintaining the less-favoured areas into economic and social "operation" conditions, for organic production, environment protection, diminution of chemical fertilizer and pesticide application, etc.) and it is the government's duty to find funding sources for these.

Emerging rural markets and conceptual consideration

The recent surge in rural tourism and direct selling by farmers from stands or shops in rural areas creates a new possibility for forming other markets in addition to the markets for farm products in the cities (Figure 1).

Figure 1 illustrates that, in addition to the traditional route of farm products from rural areas to urban markets depicted by the arrow from left to right, another arrow emerges from right to left. This arrow exists because urban dwellers have begun to purchase farm products that often have the features of service goods such as rural tourism. Therefore, I assume that there are two spatially segregated

Characteristics	Rural-tourism goods	Ordinary farm products
Location of markets	Rural areas	Urban areas
Who pays transportation costs	Consumers (visitors)	Producers
Types of demand	Recreation, purchase of local foods	Food purchase
Types of goods	Service goods	Physical goods
Types of market	Niche, up-market	Mass market
Possibility of internalising multifunctionality into farm activity	Positive	Neutral

Table 1. *Comparison of two different farm goods*
Source: Yasuo, 2007.

Types of multifunctionality	Content of multifunctionality	Possibility of farm business
Environmental function	Land preservation: preventing flood water and soil erosion	Low
	Nurturing water resource: preserving underground water	Low
	Preserving natural environment: purifying water and air, ameliorating climate change, preserving bio-diversity and eco-system	Low
	Landscape formation	Low
Cultural and social function	Preserving cultural heritage	Middle
	Health and recreational function	High
	Educational function	High

***Table 2.** Multifunctionality and possibility of internalization as farm activity,*
Source: Yasuo, 2007.

markets in rural and urban areas, and these are termed here "urban markets" and "rural markets", respectively. This is because prices for traditional farm products are formed in urban markets, while prices for rural tourism are formed in rural markets. In other words, the difference is based on whether or not price formation is done at the point of production. This is why we should consider two spatially independent markets. Profiles of the two products, which we call "rural tourism goods" and "ordinary farm products", are characterised and contrasted in Table I. The profiles show two different goods dealt in spatially different markets.

First, in the case of the urban market, ordinary farm products are traditionally shipped to urban markets for consumption. Generally, these products are for a mass market utilising a mass distribution system conducted by retailers or agricultural cooperatives. Transportation costs are usually borne by producers.

Conversely, in the case of rural markets, products are demanded mainly by urban inhabitants and partially by rural inhabitants. The following are included in the category of rural tourism goods: accommodation, rural cuisine, farm and farming experiences, pick-your-own, etc., and these have some of the characteristics of service goods. In addition, products from farmers' shops and ordered by telephone or e-mail and delivered through the postal service or other carriers are also included in this category. Products sold in this manner are considered to be purchased by urban consumers who pay transportation costs. A common factor with these products is that those who demand them pay the costs of coming to the rural markets or the delivery costs.

The markets for rural tourism goods are not large, and are considered to be niche markets, as is often pointed out (OECD, 1995a, OECD, 1995b). Thus, it is assumed that these characteristics result in larger income elasticity of demand compared with that for ordinary farm products such as food.

In connection with multifunctionality, a positive externality such as landscape formation, land preservation, maintenance of a rural heritage, provision of a recreational opportunity and so on caused by a farm activity can be internalized or transformed into a farm business such as rural tourism activity by farmers as described below in detail. Otherwise farmers cannot receive payment for the benefit that they provide to society.

In this sense rural tourism can take advantage of multifunctionality by internalizing an externality caused by multifunctionality. On the contrary, ordinary farm products can create multifunctionality, although they are considered to be neutral for utilizing multifunctionality by internalization into the farm business. It is presumed that these two markets are not substitutable, but are complementary to each other for farmers. When we consider the two possible markets, it is easier to extend perspectives towards farm diversification.

Internalizing multifunctionality into rural tourism

Here, I evaluate multifunctionality from the viewpoint of internalization into an on-farm activity. I summarize types and features of multifunctionality from the perspective of Japanese agriculture in Table II; yet, we can recognize that there is variation in what aspects are emphasized from one country to another. With regard to the impact of agriculture on the environment from each aspect, agriculture has both naturally positive and negative impacts depending on the intensity of the agricultural activity. However, this paper focuses on positive externalities in farming activities.

First, we classified multifunctionality into two functions: one related to the environment and another related to cultural and social aspects as shown in Table II. Concerning functions related to the environment, since externalities are widely exerted, these are not easy to entirely internalize at an individual farm level because these functions require collective efforts, for instance, at the local community level for complete internalization.

In contrast, health and recreational functions and educational functions are interpreted as social functions rather than environmental functions and can be internalized into a farm level activity more easily than other functions, as they are easier to transform into service goods such as rural tourism by a farm activity. Thus, in multifunctionality, there are functions that are easily internalized at the farm level and ones that are not. For this reason, health, recreational and educational functions have greater possibilities to be utilized as new farm activities.

To summarize, from the farm policy perspective, the significance of multifunctionality issues is the chance to enlarge the activity domain for farm diversification by taking into account environmental impacts. In this case, it should be noted that there are differences in terms of the ease in internalizing an externality into a farming activity among types of multifunctionality. Hereafter, in the following section, I am focusing on the recreational function to examine how a rural tourism activity was generated.

Rural tourism opportunities in Hungary

The development of rural tourism has been included in regional development plans since the 1960's, without too much success (Kõszegfalvi, 1991). According to Rátz and Puczkó (1998) it has to be added that the majority of the Hungarian population living in urban areas still has relatives in the countryside, so VFR (Visit Friends and Relatives) is an existing form of rural tourism, but as the motivations are different (to visit relatives, not to become familiar with farming communities' lifestyle), on their behalf a demand for an organised supply of rural tourist products is basically nonexistent. So their need for staying in a rural environment is mostly satisfied by their relatives without any expenses, so very often they are not willing to spend any additional amount of money on similar holidays in other rural areas of the country.

Another important factor to consider is that the majority of middle-class Hungarian families have their own small holiday homes somewhere in the countryside where they can spend weekends and their summer holidays. Nowadays the domestic image of rural tourism (cheap, aimed for the least affluent, relatively boring) does not help to attract visitors to rural areas. In order to change this image, we have to create value and experience for customer. The development of rural tourism (including active nature holidays or participation in farm activities) is still in an early stage and the profitability of rural tourism is very low in Hungary (Kovács, 1993). The presupposition of the author of this paper is that the rural (village) tourism in Hungary can be competitive only if it creates value both for demand and supply side and if service providers cooperate in concern of success and the destination competitiveness.

Comparative factors for competitiveness are suitable in the Hungarian rural areas. Most of the rural areas (villages) possess various natural and cultural attractions. Among these, the most important ones are the clean natural environment, fresh air, quiet, the hospitality of the local people, the gastronomy, the rural lifestyle, and to a certain extent, the preserved traditions and heritage. On the other hand, the old architectural styles that made our villages so distinctive are disappearing, the construction boom in the '60s and '70s resulted in relatively similar village appearances all over the country, less and less young people know and practice the old traditions, and the general modernisation has changed the rural lifestyle (Rátz – Puczkó, 1998). Rural lifestyle and the closeness of nature are important factors of competitiveness of rural tourism in Hungary, our on-going survey2 certifies that the interest of rural tourists mainly looking for authentic rural experiences, for quiet, for sport activities and for nostalgia (for example vacation with grandmother). Certain attractions typical of rural tourism, like the opportunity for participation in farm activities or involvement in the hosts' everyday life, are missing in the majority of destinations. Altogether, the overall attractiveness (supply-competency) of the rural areas in Hungary is acceptable, the potential for rural tourism development seems to be existing, but there is a need for a marketing approach (communicational competency) in the development of complex tourist products, and for further diversification and development of attractions based on the needs of different tourist segments. Rural destination should acquire these 2 main parts (Piskóti et al., 2002) of competency to attract visitors. The first is the supply-competency being responsible for creatively packing the touristic products of rural area, and the second as communicational-competency which is responsible for a harmonizing communication and image building.

On the other hand, *competitive advantage* relates to tourism infrastructure, the quality of management, the skills of the workforce, government policy etc. This side of rural competitiveness is less organized still in Hungary, so it is a great problem, which is in the way of tourism success. We can see earlier that the touristic supply is rather fragmented, composed by small and medium sized touristic enterprises facing with low financial standing, and lack of marketing skills. In order to satisfy the demand of experience-chain3 and to deliver experience-based, complex touristic products are needed, the service suppliers of a destination should think and work together in different degrees of collaborative network.

According to the author, in cases like rural areas of Hungary, where the culture of cooperation has not been developed, or has been inflated in the centrally planned economy, the top-down initiation possibly with the assistance of the government is needed to raise community awareness. The solution and the right way for success are, if this coordination task can be fulfilled by the local touristic association or by the nowadays fashionable Destination Management Organization (DMO). Rural touristic associations' or DMOs' responsibility is to create the inventory analysis about the attractions of the destination, and measure the given resources and source of new ones. The product packages of the destination should be put together on the base of the inventories and demand forecasts, with the help of supplier. DMOs or associations should encourage the entrepreneurial sphere to think and work together to create complex supply packages. Building the image of the destination and finding the best way for promoting and selling the destination is vital in the steep competition. DMOs should realize the need of horizontal cooperation with other regions, to carry out cross-regional actions. DMOs' are responsible for the development in the destination. To reach a balanced and legitimate development, the relevant participants of the suppliers and representatives of the host population should be involved. The DMOs' role is to bring attention to the innovative technologies and methods which can create value for the destination and assure training and education for the participants for successful adaptation. And finally is rather useful to reach and maintain the community awareness, and to assure the stable support of the host population and the suppliers. By interactive communication, the negative effect of tourism can be prevented, and a prospering development and competitiveness maintained.

Conclusions

The study brings together the main elements of rural tourism destination competitiveness in Hungary, it provides a realistic display of the linkages between the various elements. Rural tourism in Hungary is a developing area, but there is a lack in necessary factors of success and competitiveness. The reason of the problem is mainly the lack of organizational competency and the lack of cooperative business culture. To solve this problem we should create value both for demand and supply side, but value creation is possible only with cooperation of tourism suppliers and local government and local communities in form of association or DMO. The topic is calling for further research, therefore, as a continuation of this work, further empirical study will be realized, with tools of both qualitative and quantitative methods.

Rural tourism created a personal network of people outside the local community and this network stimulated discovery of new local resources and eventually the creation of a new activity

Literature

Busby, G. and Rendle, S. (2000). The transition from tourism on farms to farm tourism. *Tourism Management*, 21(8):635-642.

Clarke, J. (1996). Farm accommodation and the communication mix. *Tourism Management*, 17 (8):611-620.

Clough, M. (1997). Profiting from farm tourism. *Western Morning News*, 11 June

Fleischer, A. and Pizam, A. (1997). Rural tourism in Israel, *Tourism Management*, 18(6):367-372.

Ilbery, B., Bowler, I. Clark, G., Crockett, A. and Shaw, A. (1998). Farm-based tourism as an alternative farm enterprise: A case study from the Northern Pennines, England. *Regional Studies,* 32(4):355-364.

Kovács, D. (1993): A falusi turizmus korlátai és lehetõségei Magyarországon. *Településfejlesztés,* Vol.5. pp. 7-17.

Kőszegfalvi, Gy. (1991): Falusi turizmus és urbanisztika. Regionális összefüggések. *Településfejlesztés*, Vol. 6. pp. 7-9.

Nilsson, P.A.(2002). Staying on farms . an ideological background. *Annals of Tourism Research,* 29(1):7-24

OECD (1995a) Niche Markets and Rural Development. OECD, Paris.

OECD (1995b) Niche Markets as a Rural Development Strategy. OECD, Paris.

Pearce, P.L. (1990). Farm tourism in New Zealand: a social situation analysis. *Annals of Tourism Research*, 17(3):337-352.

Piskóti, I. – Dankó, L. – Schupler, H. (2002): *Régió- és településfejlesztés*. KJK, Budapest

Rátz, T - L. Puczkó (1998): Rural Tourism and Sustainable Development in Hungary.In: D. Hall - L. O'Hanlon eds.: *„Rural Tourism Management: Sustainable Options"* International Conference, Conference Proceedings; Scottish Agricultural College, Auchincruive, Ayr, Scotland, UK, pp. 450-464.

Walford, N. (2001). Patterns of development in tourist accommodation enterprises on farms in England and Wales. *Applied Geography* 21:331-345.

Yasuo Ohe Multifunctionality and rural tourism: A perspective on farm diversification. Journal of International Farm Management Vol.4. No.1 June 2007

Márton Jolánkai, Csaba Gyuricza, Katalin M. Kassai, Ferenc H. Nyárai, Ákos Tarnawa[1]

The impact of water availability on yield quantity and quality of maize crop

Introduction

Water availability highly influence the performance of field crops. Water deficiencies of live systems trend from scarcity to drought. Drought is a physiological water stress causing irreversible changes in live structures (Várallyay 2008). Drought is the result of an extended period of months or years when a region notes a deficiency in its water supply. Generally, this occurs when a region receives consistently below average precipitation. It can have a substantial impact on the ecosystem and agriculture of the affected region. Although droughts can persist for several years, even a short, intense drought can cause significant damage and harm the local economy.

Definition of droughts can be assessed in three main ways:

(1) Meteorological drought is brought about when there is a prolonged period with less than average precipitation. Meteorological drought usually precedes the other kinds of drought.

(2) Agricultural droughts are droughts that affect crop production or the ecology of the area. This condition can also arise independently from any change in precipitation levels when soil conditions and erosion triggered by poorly planned agricultural endeavours cause a shortfall in water available to the crops. Drought is a phenomenon when a plant suffers irreversible physiological damages.

(3) Hydrological drought is brought about when the water reserves available in sources such as aquifers, lakes, and reservoirs fall below the statistical average. Hydrological drought tends to show up more slowly because it involves stored water that is used but not replenished. Like an agricultural drought, this can be triggered by more than just a loss of rainfall.

Life is based on water fluxes within the habitat as well as that of the specific organism. Water availability profoundly influences all physiological processes of plant life. Water transport of individual plants as well as water budget of the crop site determine growth and development and ultimately quality.

Crop water use, consumptive use and evapotranspiration, are terms used interchangeably to describe the water consumed by a crop. This water is mainly used for physiological processes; a negligible amount is retained by the crop for growth. Water requirements for crops depend mainly on environmental conditions. Plants use water for cooling purposes and the driving force of this process is prevailing weather conditions. Different crops have different water use requirements, under the same weather conditions (Várallyay 2008, Pepó 2010). Crops will transpire water at the maximum rate when the soil water is at field capacity. When soil moisture decreases, crops have to exert greater forces (energy) to extract water from the soil. Usually, the transpiration rate doesn't decrease significantly until the soil moisture falls below 50 percent of available water capacity. Information regarding seasonal crop water requirements are crucial for planning crop species planting especially during drought years. In Hungary, the seasonal water use of maize crop is 550 mm while cereal grain crops use some 400. These water requirements are net crop water use (the amount a crop will use, not counting water losses such as deep percolation and runoff) in an average year, given soil moisture levels don't fall below critical levels. Under ideal conditions, this net water requirement is reduced by the effective rain (Pásztorová et al. 2011).

Maize provides a basic staple for mankind as well as a most widely used feed for animals. This crop is one of the most important ones in Hungary, and has a high economic value. The production of the crop normally exceeds one million hectares annually. Almost two thirds of the crop is used as fodder mainly for cattle and pig husbandry. The alimentary use of maize is rather small in Hungary, since sweet corn, popcorn, processed maize products are preferred. Maize flour and other direct milling products are

[1] *Szent István University, Crop Production Institute, 2100 Gödöllő, Páter Károly utca 1., e-mail: jolankai.marton@mkk.szie.hu*

Picture 1. *Wintersteiger maize plot drill*

secondary aliments in comparison with other grain crops. Industrial uses of maize is increasing. Starch, bio-ethanol, and invert sugar are the major branches of industrial output. Utility, market and alimentation value of the crop is highly affected by climatic conditions, specifically annual weather performances, as well as soil moisture conditions (Ács et al., 2008; Várallyay 2008). The aim of maize production is twofold; to provide quantity and quality. Maize is a major source of protein and carbohydrates for human and animal nutrition. At the same time maize is a valuable industrial raw material providing bases for biofuels, sugar, oil etc. Maize performance is mainly determined by the genetic basis, however it can be influenced by management techniques (Nagy et al., 1997). The aim of this study was to determine the role of water availability impacts on maize production.

A study on the impact of water availability on the performance of maize

In long term field trials high starch maize (*Zea mays* L) hybrids were tested in a 9 year period of 2002-2010. The small plot trials were run at the Nagygombos experimental field of the Szent István University, Crop Production Institute, Hungary. The soil type of the experimental field is chernozem (calciustoll). Soil tillage of the experimental field is done in a regular system; after the subble operations of the precrop the field is ploughed to a 20-25 cm depth in autumn, and then closed with a roller. Spring time seedbed preparation is done by the use of a cominator. Annual precipitation of the experimental site is representing the Hungarian average. Annual values are displayed int he tables attached. The site is located in the 550-600 mm precipitation belt of the Northern edges of the Great Plain (Figure 1), while the average depth of groundwater varies between 2 to 3 metres (Figure 2).

Experiments were conducted in split-plot design with four replications. The size of each plot was 10 m^2. The maize experiment is run in a maize-winter wheat biculture system. The optimum planting time vary from 15th April to the 15th of May, in accordance with the optimum soil temperature. Harvest of maize plots is implemented usually at full ripen stage in the second half of September. Plots were planted and harvested by plot machines (Standard Wintersteiger maize specific experimental plot machinery series). Various identical agronomic treatments were applied to plots. All plots were planted with identical series of maize hybrids

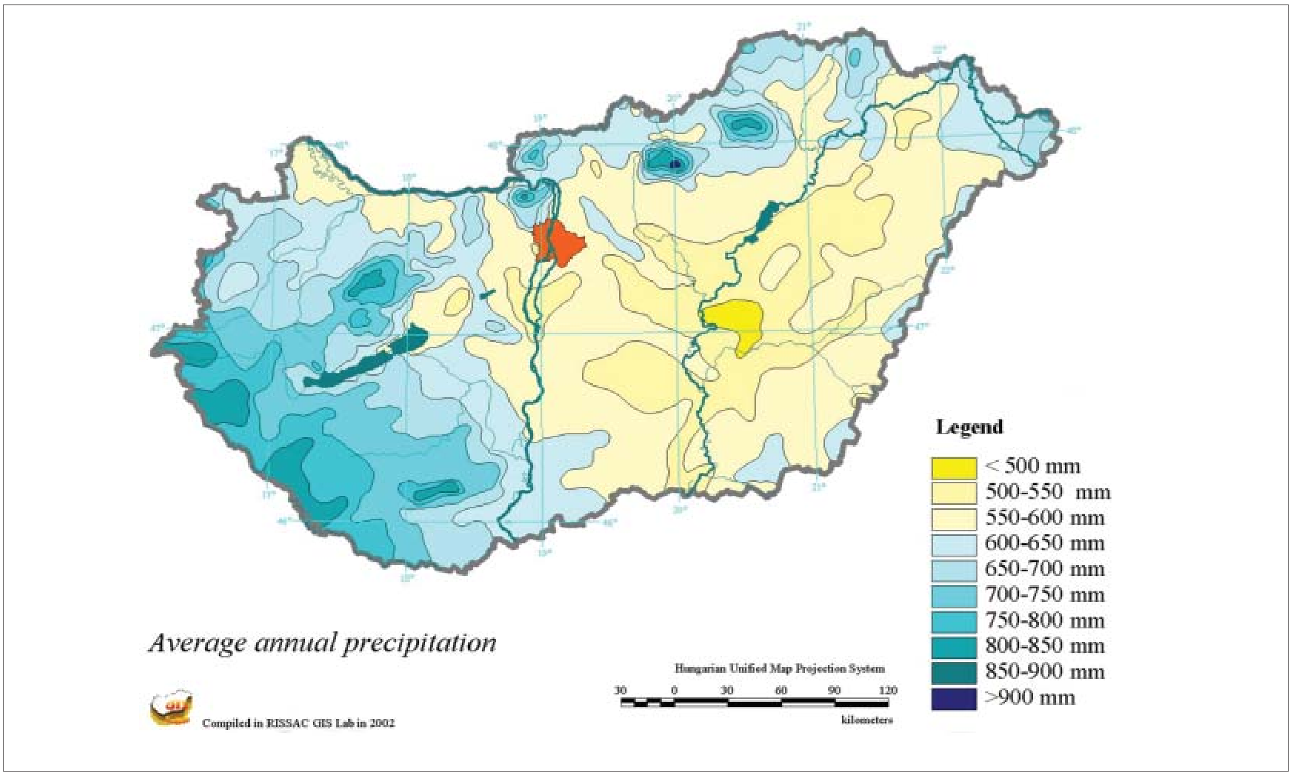

Figure 1 *Average annual precipitation spatial distribution in Hungary*

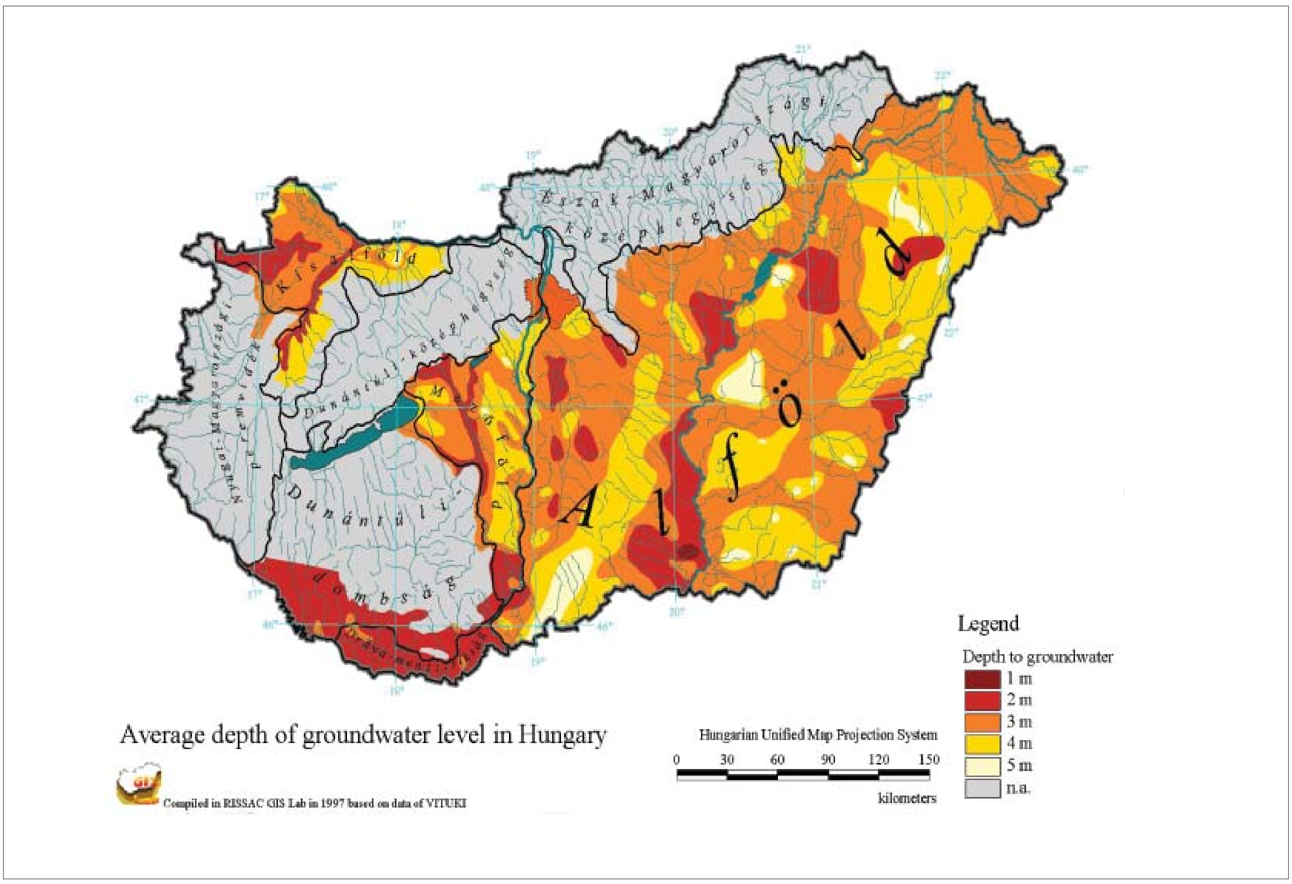

Figure 2. *Average depth of groundwater level in Hungary*

for studying their performance in relation with agronomic impacts.

Regarding water availability impacts, experimental mean values of respective treatments and homogenized bulk yield samples were used only. Precipitation records have been evaluated in relation with yield quantity and quality. Quality tests were done at the Research Laboratory of the SIU Crop Production Institute, according to Hungarian standards (MSZ 1998). Grain yield samples and quality figures were correlated with water availability parametres. Analyses were performed using Microsoft Office 2003 statistical programmes.

year	Precipitation, mm	Yield, tha^{-1}	Protein, %	Starch, %	Ethanol, lha^{-1}
2002	426	5,44	9,2	63,5	2245,4
2003	442	4,12	7,63	72,2	1933,5
2004	463	5,60	8,43	68,8	2504,3
2005	705	5,22	7,1	74,5	2527,8
2006	593	7,40	6,7	74,1	3564,2
2007	545	8,24	8,5	65,8	3524,3
2008	612	6,28	7,9	64,3	2624,7
2009	623	7,34	6,8	63,3	3020,0
2010	847	4,09	8,2	70,5	1874,2

***Table 1.** Annual precipitation, grain yield and alcohol production figures of a maize trial*
Nagygombos, 2002-2010

r	Precipitation, mm	Yield, tha^{-1}	Protein, %	Starch, %	Ethanol, lha^{-1}
Precipitation, mm	1				
Yield, tha^{-1}	0,76210	1			
Protein, %	-0,50219	-0,22311	1		
Starch, %	0,22297	-0,36296	-0,46314	1	
Ethanol, lha^{-1}	0,80224	0,58342	-0,36783	0,48741	1

***Table 2.** Correlation figures of a maize trial*
Nagygombos, 2002-2010

The results of the study

Annual amounts of precipitation and maize yields have been examined in a 9 year period at the Nagygombos experimental field of the Szent István University, Gödöllő. Table 1 and 2 illustrate annual changes of yield and precipitation mean values. Yields, protein and starch content, as well as ethanol processing values have been correlated with water availability. Yield figures covered a wide range (4.09 – 8.24 tha^{-1}) showing 100 per cent differences even, during the experimental period.

Maize yields and annual precipitation figures were in a close non linear correlation. Yields were smaller in drought years (2002, 2003 and 2004) and extremely moist years (2005 and 2010). The highest yields were obtained in crop years with average precipitation (2006, 2007, 2008 and 2009).

The protein content of grain samples showed slight negative correlation with the amount of annual precipitation. Starch figures have not been affected by water availability. Protein content was smaller, and starch values were higher in moist years in, however neither of the correlation was strong enough to provide a basis to formulate a general statement. Alcohol production exhibited strong correlation with yield figures and with the amount of annual precipitation as well. The highest ethanol yields were obtained in average precipitation years.

Conclusions

According to the results obtained it can be concluded, that maize is high yielding and high utility crop in Hungary, however it is susceptible to water deficiencies. Water availability is a basic factor related to yield quality and quantity performance of grain crops. In an agronomic long term trial run at the Szent István University's Nagygombos experimental site impact of water availability on maize crop has been evaluated. Various crop years have had different impacts on crop yield quantity. Yield figures were in correlation with annual precipitation figures in general. However two years of extremely high precipitation resulted in lowest yields. High precipitation induced various diseases deteriorating yield. Moisture availability had diverse influence on quality manifestation. Drought stress reducing the amount of yield has induced non significant quality improvement in a few cases. Protein values were smaller, and starch values higher in rainy years. Ethanol processing values were in strong correlation with yield figures. The amount of annual precipitation had a significant impact on ethanol yield.

There have been two parameters in this study with less chance to observe; once the soil impacts on water availability, since the trials were designed in a *ceteris paribus* agronomic layout. The other is the varietal differences between maize hybrids. The results obtained suggest, that late maturity maize hybrids represent a higher yield potential in comparison with the early ones, however their vulnerability seems to be higher as well. These fields are to be evaluated in further studies.

Acknowledgements

The authors are indebted regarding the financial support of TÁMOP and KTIA project fundings.

References

Ács F., Horváth Á., Breuer H. 2008: The role of soil in variations of the weather. Agrokémia és Talajtan. 57. 2. 225-238.

MSZ 6383:1998, 824/2000/EK Grain quality standards, Hungary.

Nagy J. - Huzsvai L. (1997): The effect of precipitation on the yield of maize (Zea mays L.). In: Soil, plant and environment relationships. Ed.: J. Nagy. DATE, Debrecen, 78-88 pp.

Pásztorová M., Skalová J., Vitková J. 2011: Analysis of impact of management on groundwater level of abrod wetland. Növénytermelés. 60. Suppl. 361-364.

Pepó P. 2010: Adaptive capacity of wheat (*Triticum aestivum* L.) and maize (*Zea mays* L.) crop models to ecological conditions. Növénytermelés. 59. Suppl. 325-328.

Várallyay G. 2008: Extreme soil moisture regime as limiting factor of the plants' water uptake. Cereal Research Communications, 36. Suppl. 3-6.

***Ákos Tarnawa, Csaba Gyuricza, Barnabás Pósa, István Balla, Márton Jolánkai*[1]**

The impact of climatic factors on the quantity of crop production and the yield stability

Introduction

Since the beginning of the human civilization, when man first tried to cultivate plants and recognized that crop plants do not give the same yield in each year, moreover sometimes the differences could be very high, there is a profound interest to seek and learn possible reasons of that. According to the level of that age, this variance was explained by some supernatural forces. The only thing that could be done in favour of preventing them was giving gifts to placate them. In accordance with the progress of society, more and more rational explanations were found up to now. On the basis of rationality, only scientifically approved causes could be accepted. In this way crop science and practice become reasonable gradually. There are numerous factors that are having effect on yield and among them there are some that could be influenced by the farmer and also some, that could not be. The first group is the set of elements of agronomic management the second group is the set of factors of environment. In the set of environmental factors there are some with more or less impact on yield, but according to former observations, weather plays a significant role (Várallyay et al 1985). Even because crop production is not an indoor practice but mostly outdoor; the weather and climate may have high impact on that. Climate change processes may have an impact on agricultural production. Climate change impacts on crop production are due to weather anomalies and uncertainities (Varga-Haszonits et al. 2003).

As the yields still show lower or higher fluctuation from the long term averages or trends, it should be more than useful to explore how they depend on each element of climate (Pepó, 2010). Certain crop species respond to climatic impact in different ways. The performance of maize crop is highly influenced by radiation and temperature (Anda and Lőke 2004). The grain yield of maize is rather influenced by precipitation. Grain yield of wheat may vary in accordance with the weather conditions of the crop year. Yield stability depends on the optimum distribution of precipitation during the vegetative phenophases. Grain yield of wheat may vary in accordance with the weather conditions of the given crop.

The modelling of climatic impacts regarding cropping

[1] *Szent István University, Crop production Institute, 2100 Gödöllő, Páter Károly utca 1.,e-mail: jolankai.marton@mkk.szie.hu*

|r|	wheat	maize	barley	rye	oat	peas	sunflower	Oilseed rape	alfalfa	sugar beet	potato
high	2	7	3	3	2	4	1	1	8	7	3
moderate	4	3	5	10	4	5	5	9	5	8	8
low	10	14	7	6	12	9	16	11	10	8	11
lowest	16	8	17	13	14	14	10	11	9	9	10

Table 1: *The effect of climatic factors on crop species by categories*

systems is extensively studied worldwide. Modelling the climate system depends on the probability assessment of tipping points (Hall et al. 2009). Optimum precipitation patterns, physiologically adequate temperature and radiation are the most influential basic parametres in crop performance (Ladányi et al. 2001, Adams et al. 2003). Climate variability is one of the most influential factors for crop yield alterations in the Carpathian Basin. Water availability is essential for all forms of life.

A study on the impact of climatic factors

The present study is intended to obtain information on the performance of the major field crop species produced in Hungary. The work was based on the use of long term databases covering a 40 years period between 1960 and 2000. Such an assessment has a twofold nature. Once it is beneficial regarding the abundance and the duration of baseline data. On the other hand it is restricted to the available structure, moreover it is bound to annual figures giving less chance for deep layer evaluations. However, the study could provide some novel specific information on crop yield performance.

Regarding the changes in the yield figures of the main crops of last decades an ascending tendency was recorded. It is a normal trend which can be due to the impact of agronomic and genetic advance. But that could also be detected, that there are some years when yield is under the trend line and also some when it

Picture 1. *SIU Experimental field at Nagygombos*

Group of crops	Susceptibility to climatic impacts	Reason
Cereals, peas, oil seed crops	Low	Good climatic adaptability, these crops can tolerate extremities even
Maize and potato	Medium	Crops with higher environmental demand. Agronomic failures may contribute to the harm induced by weather anomalies
Alfalfa and sugar beet	High	Diverse performance reasons. Alfalfa is a most extensive crop of the region with no other major influencing factor for yield than weather. Sugar beet is a most intensive crop within the species observed. Only the weather can induce differences in yield, since there are less regular agronomic management failures.

Table 2: *Susceptibility of crop species to climatic impacts*

is above it. In this study the yield of crops with the highest total cultivated area in Hungary were observed in the period of 1960 to 2000 (KSH – Hungarian Statistical Office). The crops studied were the following:

- Wheat *Triticum aestivum* L.,
- Maize *Zea mays* L.,
- Barley *Hordeum vulgare* L.,
- Rye *Secale cereale* L.,
- Oat *Avena sativa* L.,
- Peas *Pisum sativum* L.,
- Oilseed rape *Brassica napus* L.,
- Sunflower *Helianthus annuus* L.,
- Sugar beet *Beta vulgaris* L.,
- Potato *Solanum tuberosum* L.,
- Alfalfa *Medicago sativa* L.

The yield of studied crops was in a close correlation with a linear trend along the observed period. Our aim was to find, how the formation of yield under or above the trend depends on the crop-year's weather.

The following 32 parameters are collected regularly by the Hungarian Meteorological Service

Picture 2. *Harvestin winter wheat trial at Nagygombos*

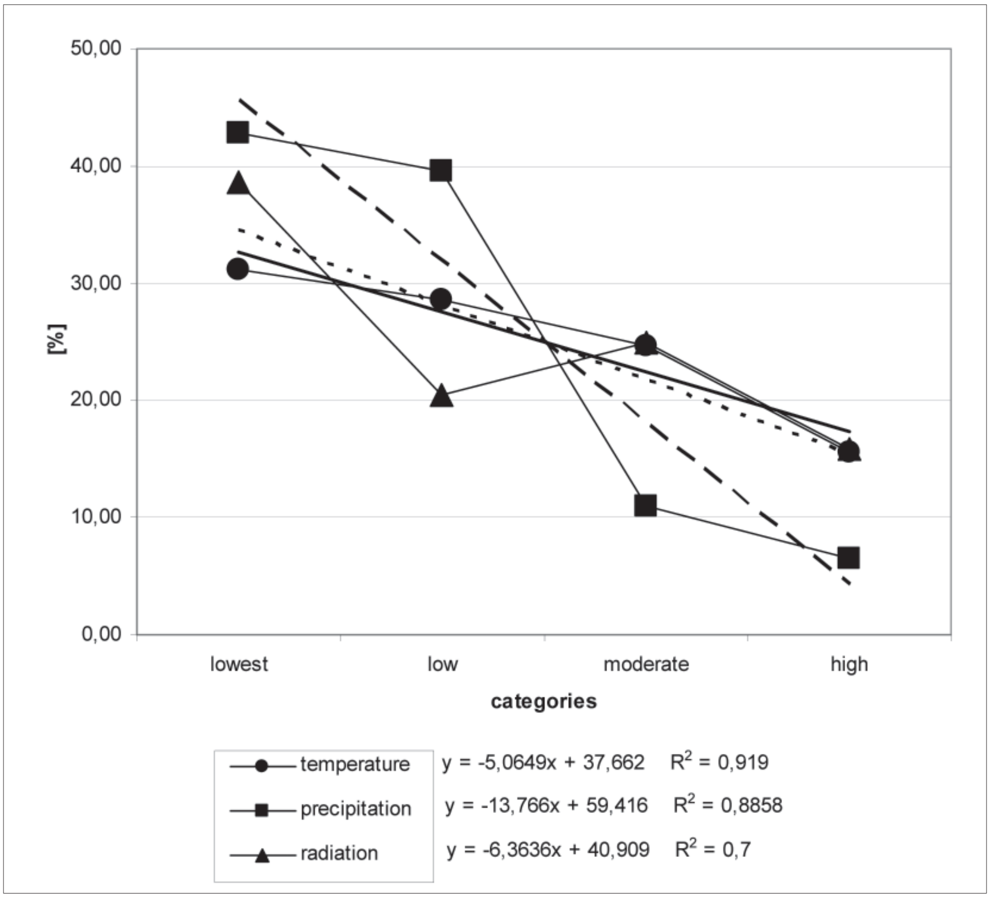

Figure 1. *The average level of correlation by the main categories of weather parameters*

(OMSZ): Referring to temperature: average annual temperature, highest daily temperature in the year, lowest daily temperature in the year, highest mean temperature in the year, annual average of daily maximum temperatures, number of days with a maximum below 0 °C, number of days with a maximum above 25 °C, number of days with a maximum above 30 °C, number of days with a maximum above 35 °C, lowest temperature in the year, annual average of daily minimum temperatures, number of days with a minimum below 0 °C, number of days with a minimum below -10 °C, number of days with a minimum above 20 °C. Referring to precipitation: annual total precipitation, annual precipitation as snow, maximum daily precipitation, daily precipitation above 0,1 mm, daily precipitation above 1 mm, daily precipitation above 5 mm, daily precipitation above 10 mm, daily precipitation above 20 mm, daily precipitation above 30 mm, daily precipitation above 50 mm, number of snowy days, number of frost days, number of rain stormy days, number of sleety days. Referring to radiation: total annual duration of sunlight, maximal daily sunlight radiation, daily duration of sunlight less than 20% of likely value, daily duration of sunlight more than 80% of likely value.

Statistical analysis has been performed by using recent standard MS Excel program packages. For each crop the yield trend was calculated and also the deviations from trend for each year. The connection between deviations and given year's climatic factors was analysed. In that way 32 relations were given for each of the 11 crop species. The relation of these connections has been determined by the Pearson's correlation coefficient ("r") and that was calculated for each item. The absolute value of that coefficient refers to the role played by each of the meteorological factors in the formation of the deviation of the given crop yield from the trend.

In case of Hungary, in relation with climate two facts can be observed in the Carpathian basin. Hungary is a country in the centre of Europe with a most peculiar geographic location regarding the possible impacts of any sort of climatic changes. On the other hand, this geographic formation provides the basin a sort of protection against extreme weather anomalies. However the climate of the region has always been highly variable.

The cropping stucture of the country is rather stable concerning the observed period (1960-2000). The 11 field crop species involved in this study represent over 90 % of the arable plant production area of the country. Crop yield of all species have been correlated with all of the meteorological database figures annually.

It can be stated that the absolute values of correlation coefficients obtained are not so high, never more than 0.5 in general. As there are so many figures, a summary table is the best way to represent them. Four categories of the data were set up with the following intervals:

- owest ($0.1>|r|$),
- low ($0.2>|r|\geq0.1$),
- moderate ($0.3>|r|\geq0.2$),
- high ($|r|\geq0.3$)

In Table 1 that number of $|r|$ referring to climatic factors can be seen that falling into these categories by crops.

Picture 3. *Small plot trial sowing at Nagygombos*

The weather parameters could be sorted into three major groups (temperature, precipitation, radiation). On Figure 1 the rate of them can be seen as the respective correlation coefficient's absolute value is in decline in each of the categories. The trends and the fittings of trend lines are shown as well.

Figure 1 also demonstrates, that temperature and radiation have more significant effect and precipitation has weaker correlation in average. It could be a surprise for first, but as there is no tool to change radiation in connection with field crops, and not much for defending crops from the extreme and rapid changes in temperature, and as most of researches aim to explore and treat the effects of extremities of precipitation and soil water regime as well, it is not a surprise for the second view. Most of tools and methods that can change the climatic milieu of arable fields are connected with water management, and as farmers usually rely on them, so that is the reason why precipitation seems to have less effect.

On Figure 1 it can also be seen, that trends have strong correlation, and as these are gained as averages, they can be used as a base of comparison, representing a fictive reference crop (abbreviated as "φ"). If real crops' attributes are compared with that of "φ", it can be seen, that cereal species', peas and oil crops' trend lines are very similar to "φ" precipitation trend line and other crops' trend lines show more similarities to "φ" temperature trend line. According to these observations, at least under the climatic conditions of Hungary, the yield of crops domesticated under our climate or similar to that are mostly formed by precipitation in the first place; and the yield of crops domesticated under tropical or subtropical climate are primarily formed by the climatic factors connected with temperature.

Table 2 summarizes susceptibility of crop species to climatic impacts. The results obtained were in accordance with previous observations. Alfalfa and sugar beet proved to be highly susceptible. Maize and potato have shown moderate susceptibility, while cereals, peas and oilseed crops have been less affected by climatic impacts.

However, this study as it has been described in the introduction, had less chance to highlight two crucial fields in relation with the crop adaptabilities. The average annual crop yield figures proved to be characteristic for the given crop species, and were reliable regarding interspecific performance, but did not allow intraspecific evaluations, since there were no available data in relation with crop varieties and hybrids. Also, there was no chance to evaluate the influence of genetic and agronomic advance in crop yields, an important factor in precising the probability assessment of tipping points (Hall et al. 2009).

Conclusions of the study

With higher "r" absolute value the connection is stronger, and the effect of weather parameter is bigger. The variance of yield figures is primarily not depending on the changes in climatic factors in most grain crops, in cereals, peas and oil crops. It is due to the good climatic adaptability of these crops as they can tolerate even extreme weather situations. However changes in agronomic management may have a profound effect on the performance of this group.

The determinating effect of climate is much stronger concerning maize and potato. These cultures are more demanding, so mistakes in agronomic management occurs by not protecting them from the effect of weather anomalies. For these two crops it should be marked that the original gene centers of them are the most distant from Hungary, and also the climate of those areas is different.

The strongest effect could be detected in the case of alfalfa and sugar beet. The reason of it for these two is diverse. Alfalfa is one of the most extensively cropped plants in Hungary. In this case there's almost no other factor than the climate to make significant effect on yield. The reason for sugar beet results is almost the opposite. Farmers dealing with beet are technologically highly equipped and so can solve on high level almost all the agronomical problems occurring hence climatic parameters as affecting factors may be secondary only.

After all, it can be stated that some of the climatic factors may have profound influence on crop production but the factors of agronomic management cannot be ignored. Researches and developments in agronomy play a significant role in the reduction of fluctuation in yield caused by climatic factors.

Further studies are needed to obtain information regarding intraspecific evaluations in relation with crop varieties and hybrids. Also, there is a need to evaluate the influence of genetic and agronomic advance in crop yields in favour of precising the probability assessment of crop-climate relations.

Acknowledgements

This project was carried out at the Crop Production Institute of the Szent István University by the support of TÁMOP and KTIA projects.

References

Adams P.T., Sinha P.G., Markovic M., Nguyen S.D., Fedoseev V.V. 2003: Climate change assessment in spatial cropping systems. Field Crops Newsletter, 17. 2. 117-123 pp.

Anda A., Lőke Zs. 2004: A sugárzás- és a hőháztartási mérleg komponenseinek alakulása eltérő sűrűségű kukorica hibridekben. Növénytermelés. 35. 4. 389-398 pp.

Hall, J., Held, H., Dawson, R., Kriegler, E., Schellnhuber, H. J. 2009: Imprecise probability assessment of tipping points in the climate system. PNAS 106. 5041-5047 pp.

Ladányi M., Horváth L., Gaál M., Hufnagel L. 2001: An agro-ecological simulation model system. Applied Ecology and Environmental Research. 1. 1-2. 47-74 pp.

Várallay Gy., Szűcs L., Zilahy P., Rajkai K., Murányi A. 1985: Soil factors determining the agroecological potential of Hungary. Agrokémia és Talajtan. 34. Suppl. 90-94 pp.

Varga-Haszonits Z. 2003: Az éghajlatváltozás mezőgazdasági hatásának elemzése, éghajlati szcenáriók. AGRO-21 Füzetek. 31. 9-28 pp.

www.agrarlapok.hu