Multifunctionality of agriculture and joint production

Multifunkční zemědělství a sdružená produkce

L. GREGA

Mendel University of Agriculture and Forestry Brno, Czech Republic

Abstract: There is growing the importance of the concept of multifunctionality of agriculture both in the Czech Republic and in the whole European Union. Multifunctionality reflects the fact, that agriculture produces many food and non-food commodities, while some of them have the character of externalities and public goods. The methodological framework for analysis of extra-production benefits of agriculture must include both production relationships between commodity and non-commodity products and the view on multifunctional agriculture from the demand side, e.g. it must consider the solution of externalities and public goods. This article is dealing with joint production, e.g. with the supply side view on multifunctional agriculture. Presented are the possible methodological approaches to optimisation of joint production in agriculture if commodities are produced in fixed proportions, the possibility, that non-commodity product is provided in fixed amount and finally the possibility, that joint production may be realised with variable proportions of individual products. However, to assess multifunctionality of agriculture, it is necessary to analyse not only production relationships between commodities and non-commodity outputs, but also externalities and public goods connected with this production must be valuated.

Key words: multifunctionality of agriculture, joint products, agricultural policy

Abstrakt: Nejen v České republice, ale v celé Evropské unii stále roste důležitost otázek multifunkčnosti zemědělství. Multifunkčnost odráží skutečnost, že zemědělství produkuje nejen řadu komodit potravinového i nepotravinového charakteru, ale také externality a veřejné statky. Metodologický rámec pro analýzu mimoprodukčních přínosů zemědělství musí postihovat jak produkční vztahy mezi produkty komoditního a nekomoditního charakteru, tak musí zahrnovat i pohled na multifunkčnost zemědělství z poptávkové strany, tzn. musí uvažovat řešení externalit a veřejných statků. Tento příspěvek se zaměřuje na sdruženou produkci, tzn. věnuje se pohledu na multifunkční zemědělství z nabídkové strany. Jsou v něm analyzovány možné metodologické přístupy k optimalizaci sdružené produkce v zemědělství, a to v případech, kdy jsou jednotlivé komodity vyráběny v neměnných proporcích, kdy nekomoditní produkt je poskytován v neměnném rozsahu a konečně situace, kdy jednotlivé produkty mohu být produkovány v různých vzájemných proporcích. Pro hodnocení multifunkčnosti zemědělství je však nutné analyzovat nejen produkční vztahy mezi produkty komoditní a nekomoditní povahy, ale musí být také hodnoceny externality a veřejné statky, spojené s touto produkcí.

Klíčová slova: multifunkční zemědělství, sdružená produkce, zemědělská politika

INTRODUCTION

Considering the development of agriculture both in the Czech Republic and in the whole European Union, the concept of multifunctionality has a growing importance. Because of the frequency of the use of this term it could seem, that multifunctionality is a traditional and typical concept for Europe. It is true, that many aspects of this concept have been discussed and taken into account by agricultural policymakers for a long time. Nevertheless, the term "multifunctionality" in its complexity was presented for the first time at the OECD meeting of ministers of agriculture in March 1998, as a concept considering all functions of agriculture, not only production, but also extra-production functions.

In spite of the non-existence of any unified definition of the multifunctionality, all authors agree, that multifunctionality reflects the fact, that agriculture produces many food and non-food commodities, while some of them have the character of externalities and public goods. Individual products are joint in the sense that the change in output of the main product automatically leads to changed output of other products. Multifunctionality is perceived as a characteristic of production.

However, any economic activity, where the result is a few different products contributing to different social

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objectives, may be considered as multifunctional. The question is, if multifunctionality concept is specific only for agriculture. There are many other economic activities, where together with primary product, there are produced externalities and public goods. However, in comparison with these industries, agriculture has some characteristics, which may justify why multifunctionality of agriculture has attracted political interest. Among these characteristics, there belong especially colligation of agricultural production and land, the fact that agriculture in Europe has been for many years subsidised and protected, and last but not least, that agricultural land usually represents most of the area of individual states.

To analyse multifunctionality, two different views of the concept must be considered. Multifunctionality may be perceived as a characteristic of economic activity, where the output may be of primary objective and at the same time, it produces by-products, with possible positive or negative social impact. As for their requirements for inputs, these main and by-products may be complementary or competitive. This look on multifunctionality may be indicated as a positive concept of multifunctionality. However, multifunctionality may be also considered as a goal, which the state marked out for agriculture, to be able to fulfil the desired social functions. From this point of view, multifunctionality is not only a characteristic of production activity, but has its own value. If multifunctionality is a political objective, it becomes a normative concept.

An important precondition for support of multifunctionality is that some of the produced non-commodity products have a character of an externality or a public good, which do not have a market or in case of existence of a market, this market does not function properly. However, the existence of an externality need not automatically mean that there is a market failure. If for example market equilibrium corresponds with the output, which is higher than the output where positive externality is produced, there is not any market failure.

The methodological framework for analysis of extra-production benefits of agriculture must include both production relationships between commodity and non-commodity products and the view on multifunctional agriculture from the demand side, e.g. it must consider solution of externalities and public goods. This article is dealing with joint production, e.g. with the supply side view on multifunctional agriculture.

METHODOLOGY AND OBJECTIVE

An important aspect of multifunctionality is the existence of joint production of market and non-market goods. If production of some positive externality or public goods does not have the character of joint production, this non-commodity product could be supplied independently on agricultural activity. Important from this viewpoint is the question, if multifunctional production is cheaper or brings a higher quality of individual products than if these products and services would be produced as a main product. Decisive is the character and the degree of jointness when producing commodity and non-commodity products. Joint production is from this point of view usually desirable if there is a high degree of complementarity between the individual products.

From the cost point of view, it is important, that jointness of products may be accompanied by scope efficiencies with positive impact on cost of the main commodity production. Cost of joint production of commodity and non-commodity products may be lower, than if these products are produced separately.

For joint products, it is typical, that together with the change of commodity, output also output of non-commodity product is changed. Incentives for a change of commodity production volume may be of market or political character. That is why any political measure influencing commodity production will also have an impact on provision of non-commodity product.

Another important aspect of multifunctionality as a normative concept is the question of locality. Emphasis on multifunctionality will depend and will be different according to the suitability of particular locality for agricultural production. The difference will be not only in the level of social demand for non-commodity outputs of agriculture, but also the structure of this demand will be different. In less favourable areas for intensive agricultural production, there may be expected social interest for such non-commodity outputs as for example landscape creation, landscape and environmental protection and biodiversity support. On the other hand, in areas favourable for intensive agricultural production, there may be expected social interest for such extra-production benefits of agriculture as food security and animals welfare.

Finally looking on multifunctionality from the supply side, it is important to ask, if somebody else, different from agricultural producer producing non-commodity product as an extra-production benefit, could not produce this non-commodity product cheaper. From this point of view, it is important, if the provided extra-production benefit is separable from primary agricultural production and if it may be provided independently on this production.

Joint production in agriculture

For joint production, it is typical, that agricultural enterprise produces two or more products, while production of these products is interrelated. The change in output of one product has an impact on the volume of production of other ones. OECD (2001) distinguishes three basic reasons for existence of joint production:

a) *technical interdependencies of production process* – which is typical for most negative externalities, greenhouse gas emissions, problems of animal welfare, however, it is typicall also for many positive benefits, as for example pest controlling effects or the impact of crop rotations on nutrient balances and soil productivity;

b) *non-allocable inputs* – production of more products of one input. Typical examples are production of mutton and wool, meat and manure, landscape creation and extensive production systems etc.;
c) *allocable inputs with fixed character at firm's level* – such factors are available to the firm in fixed amount, however, they are allocable to various productions, while these productions compete in their needs to the use of these factors.

For agriculture, there are typical variable production relationships between commodity and non-commodity joint products. Only exceptionally have these relationships a fixed character. Similarly, reactions to market incentives and state interventions may vary to a great extent. Usually, there exists the whole set of possible reactions. In case of environmental products, the improvement may be also reached by change of production technology. Sometimes provision of non-commodity goods may be separated from agricultural production.

Commodity and non-commodity agricultural products may have both complementary and substitution character. Usually, there exists mutual interdependence of more non-commodity products. That is why any effort to fulfil social demand for non-commodity products may have also impact on commodity production, while this impact may be both positive and negative. An effort to maximise social welfare requires to take into account also the impact, which have political decisions primarily oriented on non-commodity products on markets with agricultural commodities.

An effort to optimise combination of agricultural commodity and non-commodity goods from social point of view also requires optimal allocation of extensive and intensive forms of agricultural production, support of agricultural research and its practical implementation and last but not least corresponding information flow to individual agricultural producers. All these aspects may have in long-term view an impact on existing proportions of joint agricultural production.

Landscape creation and protection

Probably the most frequent attribute of extra-production benefit of agriculture is its impact on landscape. Many authors consider this term in the broader sense, including also such positive benefit of agriculture as its impact on biodiversity, quality of soil, water and air (Hellerstein et al. 2002). In narrower sense, there is by landscape benefit considered the aesthetic value of picturesque views, as well as enjoyment and quiet obtained by stay in such areas. These goods enable to gain utility from open-air recreation activities (fishing, swimming, tourism, cyclo-tourism, camping, game watching, hunting etc.). In this sense, landscape is the benefit of agriculture as a public good, because with these activities, there is not connected neither exclusivity, nor overload effect. However, landscape benefit may also have a character of positive externality and does not reach the level of public good. An example may be the growing price of building plots in an area positively affected by this benefit (Geoghegan, Lynch and Bucholtz 2003).

Rural development and employment

Especially in economically developed countries, there is important the social-economic benefit of agriculture for rural areas. By support of social-economic function, agriculture contributes to the attractiveness of living in these areas, both for rural and urban communities. Agriculture in rural areas contributes to the income of individuals, offers employment and generates income in the given region, thus having impact on the level of consumer demand not only for food commodities. Agriculture creates preconditions for agricultural community to stay on land and to participate in the economic and social life in rural areas.

Position of agriculture in rural areas has been changing in the last decades. From dominant industry, both from economic point of view and because of its share, in employment, agriculture got, especially because of technological progress, to the role, where it lost its leading position in the country. Looking into future, it is possible to expect that technological progress will lead to further structural changes in agriculture and further decline of employment in agriculture.

In spite of the fact, that various authors differ in their opinions, whether economic viability of rural areas is real economic value above the framework of value added in market products and services provided by agricultural producers, agriculture remains an important factor of social and economic life (also thanks to the linkage to land) in rural area. From this aspect, there is often mentioned the fact (Abler 2003), that market deformations may lead to lower level of social opportunity cost for work in rural regions than is the wage level in these areas. In this case, calculations of economic benefit of agriculture in rural areas, based on market level of wages, undervaluate this benefit.

Regarding the benefit of agriculture for employment, there is important the fact, that agricultural production creates preconditions for development of employment in industries like rural tourism, agro-tourism, processing of agricultural products with higher share of added value, manufacture of local specialities and direct sale of agricultural products on local agricultural markets.

Food security

Food security is often defined as a regular access to the sufficient amount of food of corresponding quality, leading to healthy and productive life. However, in context of multifunctionality of agriculture, food security is often defined in the sense of national security, e.g. access to the sufficient amount of food of desired quality and nutrition value even in time of national and international crisis. Domestic food production creates a securi-

ty against the possible import dropouts because of wars, blockades or any other international events.

Agriculture contributes both to domestic and international food security by increase of food products supply, decrease of food prices on import markets, stimulation of food production in areas with comparative advantages for agricultural production and by increase of the rate of economic growth thanks to the efficient allocation of inputs (OECD 2001). However, there never may be eliminated a possibility of food market breakdown because of political problems or natural catastrophes. Unfortunately such a collapse of market with great probability would bring problems also in the market with imported inputs, with negative impact on domestic production.

Risk of food shortage because of uncertainty of food supply from abroad may be reduced by domestic food production independent on foreign inputs. However, an effort to ensure agricultural production at the level, which would be above the production level at liberalised markets, could bring problems with production quality and increase the danger of instability of domestic supply in periods of bad crops.

As optimal from the point of view of food security, there may be considered the combination of domestic production, stocks and import. Part of this strategy could be the extensive form of domestic agriculture, with conserved production capacity, which could be used in case of need (OECD 2001).

Environmental benefit

Agricultural production may have a substantial impact on environment. Environmental impact may be both negative and positive, while usually this impact has a multidimensional character. The character of the impact of agricultural production on environment depends to the great extent on the intensity of agricultural production and farming practices. Intensive agricultural production may lead to soil degradation and erosion, reduced biodiversity or pollution of water sources. On the other hand, proper crop rotation may even in case of intensive agriculture reduce the danger of negative environmental impacts, respectively it may bring positive environmental effects. Environmental impacts of animal production depend especially on the concentration of animals, grazing practices and systems of manure management.

Extensive production systems, based on traditional forms of agricultural production, generally support increase of environmental quality. They contribute to the increase of biodiversity, reduce the danger of soil erosion and increase the quality of ground and surface water. In the whole Europe, there is growing the share of ecologically friendly agricultural practices, based on production technologies, which are especially sensitive to the environment.

Any analysis of extra-production benefits of agriculture for environment must evaluate both positive externalities and public goods connected with agricultural production, and possible negative externalities.

Animal welfare

Animal welfare is associated with production of meat, milk and eggs. Animals can be used to the benefit of humans, but this use must fulfil some criteria (Blandford, Fulponi 1999). The main aspects of agricultural production that influence animal welfare are buildings in which the animals are housed, access opportunities to outdoor areas and feeding, transportation and slaughter practices. The interest in animal welfare is aimed especially at the character of production technologies. By the tendency to use production technologies contributing to careful care of animals, agriculture contributes to ethical interests of the society.

ANALYSIS OF JOINT PRODUCTION IN AGRICULTURE

The objective of this article is to analyse joint production in agriculture if commodities are produced in fixed proportions, the possibility, that non-commodity product is provided in fixed amount and finally the possibility, that joint production may be realised with variable proportions of individual products.

In joint production, there generally exists technological interdependence of individual products. This production may have either more main products, or one main product and one or more by-products. There are more main products, if they are realised in the market at the similar price level. If this condition is not fulfilled, the product has a character of by-product.

On the assumption that there is a market for both products, the problem is to set optimal prices and volume of production, respectively sale. The application of the same principles as for determination of price and output in case of one product would not lead to the optimal solution. Optimal pricing requires calculation of joint production costs. Many authors (Needham 1978) consider any calculation of costs based on technological principles as artificial and therefore inefficient. As optimal is considered a methodology taking into consideration the fact, that any price of output change of one product brings not only a change in marginal revenues and marginal costs of this product, but also a change in marginal revenue and marginal cost of other main products and by-products. For profit maximization, a firm must choose such a level of joint production, which maximises the difference between total revenues and total costs. Necessary condition of profit maximisation is

$$\Sigma MR_i = \Sigma MC_i$$

where $i = 1, 2, 3, \ldots\ldots, n$.

Considering two products, where *JMC* is joint marginal cost, it must hold

$$MR_1 = JMC - MR_2 = MOC_1$$

$$MR_2 = JMC - MR_1 = MOC_2$$

where *MOC* is marginal opportunity cost of production of individual products. For the output maximising profit it must hold, that marginal revenue from both products must equal marginal opportunity cost. Marginal opportunity cost cannot be calculated without the knowledge of demand curves for both products. Joint marginal cost of joint production cannot be optimally calculated only on technical basis, because marginal opportunity cost of each of products depends on marginal revenue of these products. For determination of the optimal level of joint production, it must hold that net effect of marginal production change of any of joint products on firm's total profit must be equalled to zero.

Joint products in fixed proportions

If products *A* and *B* are produced in fixed proportions, for determination of optimal production level of both products the same process may be used as for determination of optimal price and output for single product. On assumption of independent demand curves, the situation is depicted in Figure 1. Demands for the products are D_A and D_B, and corresponding marginal revenues are MR_A a MR_B. *B* is by-product. Joint marginal cost is depicted *JMC*. Σ*MR* represents vertical summary of marginal revenues. On horizontal axis, there is the volume of joint production and because of fixed proportions also production of products *A* and *B*. If this proportion does not equal one, demand and marginal revenue of one product must be expressed in units of the other one. Maximal profit corresponds with production Q_1, because $\Sigma MR = JMC_1$. Corresponding prices are p_A a p_B.

If the composite product is higher than *Q*, than for production above *Q*, e.g. when marginal revenue of *B* is negative, a different approach must be chosen for product and price optimisation. For example for joint marginal cost JMC_2, the optimal output is Q_2. The price of *A* should be p_A'. However, optimal price of product *B* is the price, which maximise revenue from this product (p_B') and optimal quantity is *Q*. Sale of all *B* production would decrease the total revenue while cost would remain the same. The result would be decreased profit. The amount $Q_2 - Q$ should not be sold.

In case of multifunctional agriculture, the final set of products includes also externalities and public goods. If the level of commodity production corresponds with market conditions and at the same time the sufficient amount of non-commodity joint products is produced, there is not any problem with externalities and public goods, because these are provided in socially required amount. However, if the society is wiling to pay for bigger amount of produced non-commodity goods, market equilibrium is not optimal from social point of view.

Joint production of commodity and non-commodity product in fixed amount

For agriculture, it is often typical, that joint production includes main commodity product or products and a non-commodity product, which is fixed for the rational levels of productions of commodity product. An example could be meat production and landscape creation and protection as a non-commodity benefit of extensive agriculture. The situation is depicted in Figure 2. D_c represents demand for commodity product, which is sold in the market. Horizontal line S_N corresponds with the supply of non-commodity good, for which there is not any market. The farmer would ignore the supply of landscape amenities in his meat production decisions. To encourage a greater supply of landscape, a payment to the farmer could be made at a constant rate per unit of the amenity, somehow measured. The distance between the origin and the line would reflect the level of the payment, which would be added to the farmer's average revenue. As a result, supply of meat would shift to the right to S_{C+N}, and output of meat would increase to Q_C^2. For the market for meat to clear, the price would have to fall to p_C^2.

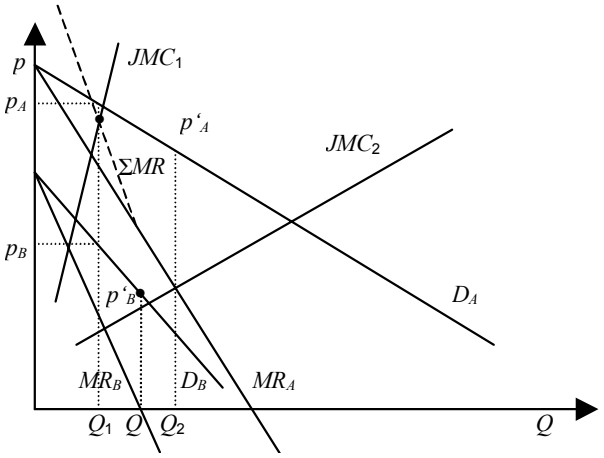

Figure 1. Joint production in fixed proportions

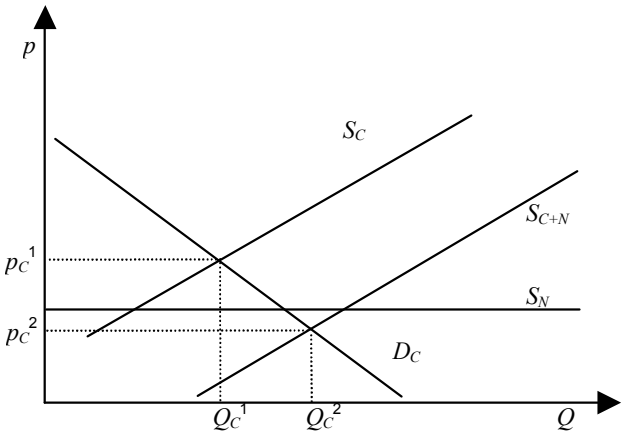

Figure 2. Joint production of commodity and non-commodity product in fixed proportions

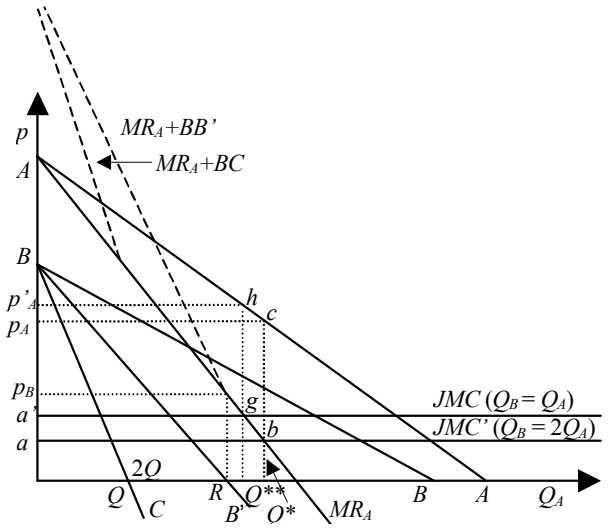

Figure 3. Joint products with variable production proportions

Joint production with variable proportions

Products in joint production may be often produced in proportions, which may vary to some extent. In such case, managers must decide not only about the optimal level of composite product, but also about the optimal proportion of joint products. Furthermore, the cost need not vary only with the change of composite good, but also with the change in proportion of joint products. This is typical for example in case, if there is a possibility of intensive and extensive form of farming.

Determination of output and price in case of variable proportions is presented in Figure 3. Suppose two products *A* and *B*, which may be produced in two different proportions. First possibility corresponds with one to one ratio between products *A* and *B* (Q_A=Q_B), while in the second case, the technology provides one unit *A* and two units *B* (Q_B=$2Q_A$). At the horizontal axis, there is output at the same proportions. *AA* and MR_A are demand and marginal revenue curves of product *A*, while *BB* and *BB'* are demand and marginal revenue curves of product *B*. Joint marginal cost is *JMC*. A change in production proportions to Q_B=$2Q_A$ means a relatively lower production of main product and more of by-product. This may lead to some savings in cost. Then joint marginal production cost will be lower, at the level *JMC*. If the share of products is not the same, and using one diagram, the curves of demand and marginal revenue of one product must be expressed in units of the other one. In this case, demand for *B* and marginal revenue from sale of *B* are *BB*', respectively *BC*. In the figure, there is also depicted vertical summary of marginal revenues for both alternatives.

At the production ratio 1 : 2, there is optimal level of joint product *Q**, which corresponds with the intersection of *JMC'* and MR_A+*BC*. Output of product *A* is *Q** and output of product *B* is twice higher *(2Q*)*. Amount of *B* for sale, given by *Q*, equals 2*Q*, because *Q* denotes amount of product *A*. Optimal prices for product *A* and *B* are p_A a p_B.

If both products are produced at the ratio 1 : 1, optimal production level is *Q***, which corresponds with the intersection of curves *JMC* and MR_A+*BB'*. Then output of product *A* would be *Q*** and the product *B* would be 2*Q***. However, sale of *B* will be *R*, which equals 2*Q*, because at this level of sale is maximised profit. Corresponding prices are p_A' a p_B. The price of *B* remains the same, however, the total production is lower. The amount of *B*, which must be liquidated, is reduced.

For comparison of both alternatives, it is possible to calculate the level of profit for both alternatives. On assumption, that fixed cost remains the same regardless the share of products and because revenue from sale of product *B* is in both cases the same, it is sufficient to consider only profit from product *A*. In the case of the same proportions, the area of profit is *a'ghp*$_A$' and in the case of ratio 1 : 2, *abcp*$_A$ > *a'ghp*$_A$'. Optimal proportion in this example is thus 1 : 2.

This analysis could be extended to include all technically possible combinations of two products. Generally, it is possible to state that on assumption of independent demand curves for joint products the optimal production mix, volume of sale and price will depend on the following factors:

– relative cost increase with change of production proportion;
– price elasticity of demand for main product;
– and relative size of price elasticity of by-products' demands.

CONCLUSION

In economic theory, we have to know the value of multifunctionality in order to know how much of it should be optimally produced. In a market economy, the external multifunctions have to be internalised in order to assure that the right amount is produced. We need to know the value of agricultural multifunctions not only because it is interesting but also in order to compare it with other potential activities in choice situations.

For the possibility to assess multifunctionality of agriculture, it is necessary to analyse not only production relationships between commodities and non-commodity outputs, but also externalities and public goods connected with this production must be valuated. Considering relationship between commodity and non-commodity outputs, it relates mainly to the supply side, while externalities and public goods aspects relate mainly to the demand side. Analysis of production relationship may provide a methodological framework to analyse how multifunctionality could or should be supported by the state. Analysis of externality and public goods aspects may provide a methodological framework to analyse how the benefits of multifunctionality could or should be distributed in society. Any political discussion on externalities requires an analysis of the type and amount of demand that exists for each externality that is jointly produced with a marketable good.

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Contact address:

Doc. Ing. Libor Grega, PhD., Mendelova zemědělská a lesnická univerzita v Brně, Zemědělská 5, 613 00 Brno, Česká republika
e-mail: grega@mendelu.cz