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# Identification of agricultural soils suitable for afforestation in the Czech Republic using a soil database

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**ABSTRACT**: Afforestation of agricultural lands may be a positive action in many cases. Especially, it is a beneficial feature for waterlogged soils, stony soils or for soils which are less fertile for any other reason and thus unsuitable for farming. Afforestation can be a very important action even in the agricultural landscape – afforested belts of agricultural land divide large farm blocks into smaller ones, or act as windbreakers and biological corridors. The value, quality and fertility of soil can be assessed in different ways. The study aims to determine the identification soil criteria of agricultural land which is suitable for afforestation. This evaluation process is based on Evaluated Soil Ecological Units (ESEU), in the Czech Republic known as BPEJ, database which is available for all agricultural land in the Czech Republic. The results are represented by a complete list of ESEU codes suitable for afforestation. The list of codes is supplemented by an explanation why such an ESEU code, representing a soil group with similar properties, is suitable to afforestation.

**Keywords**: soil survey; Evaluated Soil Ecological Units; soil quality; climatic change; water retention

The development of the agricultural land structure in the world is an ongoing process which has been present since the mankind started the colonization of land. In the Czech Republic, the first colonization of the land dates back to the late 5$^{th}$ millennium BC (Ložek 1999). The first Neolithic farmers were likely to create an agricultural landscape due to deforestation, building settlements, growing crop plants and breeding farm animals (Špulák, Kacálek 2011). According to the historical records and research (Williams 2000; Špulák, Kacálek 2011) the largest forested areas were cleared during the medieval colonization. The structure of land use had changed several times due to economic and political conditions or landowners' will. Nevertheless, the land use structure was particularly influenced by consequences of wars. One of the first significant afforestation efforts was after the 30-Year War (1618–1648) when the forested areas significantly increased due to the population decline. However, the first written proof of afforestation in the Czech lands dates back to the end of the 16$^{th}$ century AD (Špulák, Kacálek 2011).

Later, the forested area decreased again, which led to the fact that the largest agricultural area was registered in the Czech lands during the years 1860–1880. Undoubtedly, the most extensive afforestation effort took place after the Second World War (1939–1945), when large areas were afforested within confiscated or abandoned land of the Germans who were expelled from Czechoslovakia (Macků 2006). All these changes are well documented by the military and cadastral (the stable land registry) mapping that has been carried out since the 18$^{th}$ century AD (Skaloš et al. 2012). The area of forest land continued to increase during the rest of the 20$^{th}$ century reaching the peak in 1991 after a huge transformation of the agricultural sec-

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tor in 1990. The afforestation of agricultural land is an ongoing process even in this century. From 1994 to 2005, 8,085 ha of agricultural land were afforested. According to Macků (2006), this effort could have been encouraged by subsidies.

Both the Czech government and the European Union support a change in land use by providing subsidies for afforestation of less-productive agricultural land. As Hlaváč et al. (2006) summed up, the main purposes of the support – according to Jarský and Pulkrab (2013) declared as public interest – regarding the afforestation of agricultural land are as follows: reduction of agricultural overproduction, improvement of social and economic conditions in rural areas where farming on less productive and fertile soils is unprofitable, improvement of biodiversity and an improvement in the ecological stability of the landscape.

The impacts of afforestation or any other land use changes in landscape vary according to the ecological habitat and its biodiversity. Afforestation of agricultural land is utilised to deliver environmental benefits and to provide ecosystem service (Blanco-Canqui, Lal 2008; Barry et al. 2014). According to Buytaert et al. (2005), Porto et al. (2009) or Stoate et al. (2009), afforestation can achieve positive benefits for water, soil and air protection. The benefits are mainly due to the stabilization of hydrological and mesoclimatic conditions in the landscape as well as the protection of soil and water sources. Numerous analyses of changes in soils and water regime following the afforestation of non-forest and agricultural land have been published, e.g.: positive changes in water transpiration, water balance and impact on the hydrological cycle (Křovák et al. 2004; Blanco-Canqui, Lal 2008); or changes in the soil structure and physicochemical soil properties by increasing the water holding capacity of soil, reducing surface runoff and eliminating the effects of water and wind erosion (Macků 2006; Porto et al. 2009).

Another positive effect of afforestation (which is in relation to the climate change issue) was described by Winsten et al. (2011), who considered afforestation as a relatively promising approach to reduce carbon dioxide ($CO_2$). Trees and other forest plants convert $CO_2$ to carbon through photosynthesis, thereby reducing concentrations of $CO_2$ in the atmosphere (Kacálek et al. 2013). As forests typically store more carbon than land in other uses (e.g. agriculture, soil erosion degraded areas etc.), the expansion of forests onto non-forest land (i.e. afforestation) has a potential to reduce $CO_2$ concentrations and mitigate effects of climate change (Blanco-Canqui, Lal 2008; Zomer et al. 2008; Shi et al. 2013).

Observations of climate in the Czech Republic, according to Středová et al. (2010), have shown a slight increase of air temperature (0.33°C/10 years). On the other hand, (annual and monthly) precipitation has not had a statistically significant trend since 1961. However, there are significant changes in the temporal and spatial distribution of precipitation (Středová et al. 2010). Spatially bounded rainfall of high intensity, flood situations and prolonged droughts are becoming more frequent, which is related to the overall increase of the climate extremes. Without taking any actions, climate change will impact all levels of society (Zomer et al. 2008). Therefore, mitigation measures (e.g. afforestation) are required, aimed especially at limiting greenhouse gas emissions, at all levels of society, on a global, European and national scale. Thus, there is a growing need to modify and supplement the criteria for selection of land suitable for afforestation in view of improving soil hydrological functions and climate change mitigation.

This article aims to provide a simple solution of identifying suitable areas for afforestation, i.e. to identify areas where the change of land use from agricultural land to forest is appropriate and where it is not. This new approach to the identification of areas suitable for land use changes (conversion from agricultural use to forest use) targets to support decision makers (i.e. government authorities) and any other stakeholders (i.e. owners).

## MATERIAL AND METHODS

Basically, the selection of suitable agricultural land for afforestation can be done in two possible ways: (*i*) scientific classifications and soil systematics associated with soil characteristics (i.e. parent material, soil texture, stoniness, depth of soil profile etc.) and climate conditions (i.e. moisture and temperature regime of soil), (*ii*) an evaluation system, i.e. the Evaluated Soil Ecological Units (ESEU, in the Czech Republic known as BPEJ), which includes most of the required data (climate conditions, stoniness, soil depth etc.).

Using ESEU seems to be more advantageous than soil and habitat evaluations carried out up to now, these are: Less Favoured Areas (LFA), point scoring (Novák et al. 2010) or economic land evaluation in terms of price etc. This is due to the fact that these evaluation systems are based on ESEU system. Hence, it is logical to use the base of all soil or land evaluation systems in the Czech Republic. Moreover, the added value of using ESEU is that it is fully digitized in the graphical and numerical part and continuously updated soil database. As it is fully digitized, it can provide a very good detail allowing the use of analysis in the Geographical Information System (GIS) environment.

If ESEU is chosen as the system in which the identification of suitable areas to afforestation is to be done, it is necessary to decide whether the selection of individual ESEU codes will be implemented according to:

– the monetary evaluation of individual ESEU codes in CZK;
– point index scoring of individual ESEU codes based on the Gross Annual Rental Effects (GARE) (Němec et al. 2001; Novák et al. 2010);
– solely according to soil and site-environmental characteristics based on the real nature of the ESEU code (Novák et al. 2010; Novotný et al. 2013).

It has been decided to make a selection according to soil and site-environmental characteristics in combination with point index scoring. Choosing the variant of the price evaluations of individual ESEU codes (first option) has been rejected because the price values of ESEU codes reflect neither the soil productivity nor the ecological quality of the soil.

**Soil information system and the evaluated soil ecological units database.** The soil information system is based on information obtained from research directly on the land or after sampling and laboratory analysis. This system provides a range of information about soil-ecological conditions, including soil evaluation. Main components of the soil information system are: base of digitised soil-ecological maps and ESEU units. The soil database that is elaborated and permanently updated by the Research Institute for Soil and Water Conservation (RISWC, in the Czech Republic known under the abbreviation VUMOP), includes immense data holdings on soil and associated components of the environment. The starting point for the evaluation of agricultural soils was the Complete Soil Survey carried out in the 1970s for the whole of former Czechoslovakia, using a unified methodology of detailed pedological surveys, while the most important soil properties were ascertained and incorporated into maps (soil morphological units, subtypes and soil textural categories, percentage of humus and carbonates, soil pH, stoniness and parent material etc.).

These activities resulted in the formation of a permanently updated (Novotný et al. 2013) and detailed Soil Evaluation Information System that is based on supplementary land surveys, according to the requirements of soil users and owners. The evaluation information system uses a 5-digit code to express the evaluation of each Evaluated Soil-Ecological Unit (ESEU). Each ESEU is determined by its soil-climatic properties, which are expressed by the code combination (Novotný et al. 2013):

– The first number indicates the climatic region (labelled 0–9). Each climatic region is characterized by the sum of temperatures above 10°C, mean annual temperature and mean annual precipitation, probability of dry growing seasons, rainfall uncertainty based on long-term (1901–1950) observations by the Czech Hydrometeorological Institute (CHMI).
– The second and third digits indicate the Main Soil Unit (MSU), which groups soils based on soil taxonomy classification (Němeček et al. 2011), texture, parent material and water regime.
– The fourth number in the code defines the morphological characteristics of the relief such as slope and exposure to cardinal points.
– The fifth digit is the code of the depth of soil profiles and stoniness (content of stones and gravel).

The database of the ESEU includes X, Y co-ordinates of polygons describing the borders of the ESEU areas and identified by ESEU numeric codes. The ESEU codes are characterized according to the Methodology for Defining and Mapping ESEU (Novotný et al. 2013).

The whole system currently comprises 78 evaluated Main Soil Units (MSU), and in total 2,278 assessed ESEU codes. Chemical, physical and morphological characteristics and properties of MSU are digitized and stored in a database administered by the Research Institute for Soil and Water Conservation (RISWC).

The MSU is a synthetic agronomic unit characterized by purposeful (agronomic) grouping of genetic soil types, subtypes, soil-forming substrates, texture, soil depth, type of soil, the degree of hydromorphic processes and topography of the relief. The classification system represents 78 evaluated MSU that, from the genetic and agronomical point of view, consists of 13 basic soil groups.

**The point-index value of agricultural land.** The basis for determining the point-index scoring value of agricultural land has become a total range of the Gross Annual Rent Effect (GARE), which according to the Institute of Agricultural Economics and Information (IAEI) survey (Němec et al. 2001; Novák et al. 2010) is the value ranging from 2,500 CZK to 10,750 CZK on agricultural lands in the Czech Republic.

The Gross Annual Rent Effect (GARE) is a difference between the production from 1 ha in CZK at a given

Table 1. Indicators and its threshold values to identify areas suitable for afforestation

| Indicator | Suitable for afforestation | |
|---|---|---|
| | variant A | variant B (extension of variant A) |
| Slope | > 12° (very steep slope) | > 7° |
| Exposure to cardinal points/ slope direction (aspect) | north or south according to climate region for slope > 10° | |
| Stoniness | > 50% (very high content) | > 25% |
| Depth of soil profile | < 30 cm (shallow soil) | < 30 cm (shallow soil) |
| Waterlogged soil | main soil unit 64–76 | main soil unit 64–76 |
| Gullies | main soil unit 77–78 | main soil unit 77–78 |

crop structure and yields from the given crop structure on the one hand and the sum of inputs (costs) for crop production on the other. The range of GARE was transferred into one hundred-point scale in which the point value is expressed by an index of soil in the range from 6 to 100 points. The lowest value of 6 points is attributed to the cold grassland, humid climate region with an average annual temperature below 5°C (for climate region in the ESEU code) in deep gullies (MSU 77, 78). Haplic Chernozem on loess, loamy, with deep soil profile and favourable water regime in a warm, slightly humid climate region (for this climate region), on flat surface (Němec et al. 2001; Novák et al. 2010), has the highest value of 100 points.

The system of point-index values of agricultural land is generally used for evaluation of soil-climatic and economic conditions of a farming system. It is used as a basis for the determination of Other Less Favoured Areas (LFA-O). The ESEU maps and database were calculated with an average point value of agricultural land at the scale of cadastral level on the basis of performance. The average is 42.2 points of crop yield from all agricultural land in the Czech Republic. The threshold for the determination of "Other Less Favoured Areas" is the crop yield amounting to 38 points.

**The procedure of ESEU evaluation.** The process of selecting ESEU codes for the proposed land use changes has stemmed from the logical structure and content of the ESEU code. Firstly, the preliminary selection of ESEU codes was conducted for proposed land use changes based on the general characteristics of the Main Soil Units (Novotný et al. 2013). Afterwards, the soil-climatic conditions (point-index value) of selected MSUs were taken into consideration (Novák et al. 2010). Based on the above described procedure, the "Major Soil-Climatic Units" (MSCU) were obtained and other agronomical and environmentally important functions and properties of soils of each selected ESEU code were taken into consideration. These were mainly: slope, soil depth and stoniness, infiltration and permeability, or even slope direction. Main indicators and determination of the thresholds of ESUE codes are described in Table 1.

## RESULTS AND DISCUSSION

Novák (2002) summarized the criteria which are essential to be considered for selection of habitats and soils suitable for afforestation. These are: climatic conditions, nature and properties of soils, slope and vulnerability to erosion, waterlogging, soil pollution, economic and private or public interest.

The results of the proposed land use changes are presented in two variants: variant A and variant B, which is the extension of variant A. Selected ESEU codes of variant A are in Table 2. As it can been seen in the table, very suitable areas for afforestation are identified by: (*i*) very shallow soils (the fifth number of the code is 5 or 6) and MSU code 37 (lithic Cambisols) and 39 (Leptosols); (*ii*) MSU code 40 and 41 represents different soil types ranging from Cambisols to Chernozems. However, all soils in this category are on a steep slope (designated by 8 or 9 in the fourth place of the code) higher than 17°; (*iii*) and the third group is represented by ESEU codes with MSU 77 or 78. Both codes represent degraded soil by erosion where MSU 77 is a gully of less than 3 m in depth while MSU 78 is a deep gully with diverse spatial distribution of hydromorphic soil. Spatial distribution of suitable land for afforestation selected on the basis of ESEU codes according to variant B is shown in Fig. 1.

Among the major reasons for the afforestation of agricultural and other non-forest soils in the Czech Republic are the following: improving the economics compared to fallow land, soil erosion control, water management conditions, influence on microclimate, possibility of the recreational use of landscape, use of anthropogenically affected soils**,** areas after mining raw materials (Černý et al. 1995; Simon et al. 2004; Hatlapatková, Podrázský 2011). Another important feature appears to be transformation and accumulation of organic material to the soil after afforestation. These processes are influenced by a wide range of factors which need to be taken into account: (*i*) previous use and possible soil cultivation; (*ii*) type of woody plants; (*iii*) soil character of the site (texture, pH, sorption, etc.); (*v*) afforestation method; (*vi*)

Table 2. Recommended ESEU suitable for afforestation (variant A)

| Soil groups | ESEU codes | Reason | Remarks |
|---|---|---|---|
| Shallow soils | 9.37.45 | shallow profile | |
| | 9.37.46 | climate | |
| | 9.37.55 | | |
| | 9.37.56 | | |
| | 0-9.39.XX | leptosols | all ESEU with main soil units 39 |
| Soils on steep slopes | 0-9.40.89 | shallow profile | slope code 5, 6 |
| | 0-9.40.99 | steep slope | |
| | 0-9.41.89 | | |
| | 0-9.41.99 | | |
| Gullies | 0-9.77.XX | gullies | impossibility of agriculture use |
| | 0-9.78.XX | | |
| Contaminated soils | different | contamination | special selection |

XX – all possible code variants

topography and climate of the site (Guo, Gifford 2002; Shi et al. 2013).

Table 3 shows variant B where the selection criteria are slightly different from variant A (see Table 1). The total area suitable for afforestation in variant A is approximately 813 thousand ha of arable land, i.e. 16%, while the total area suitable for afforestation in the extended variant (Table 3) is approximately 1,820 thousands ha, i.e. 36% of agricultural land (arable land, grassland). It is due to changes in the slope threshold value and stoniness when the selection procedure contains ESEU regions with slope higher than 7° instead of 12°and stoniness higher than 25% instead of 50%.

Given the conditions of developed countries in Europe, the effort has been made to increase the forest area in the last few decades. In addition, agricultural production on less fertile soils has become unprofitable, a large amount of agricultural soils has become so called marginal ones. Therefore, afforestation is performed in both ways, i.e. targeted and spontaneously – succession actions (Vacek, Slavík 2006). The selection of tree species suitable for afforestation of agricultural land, or the fertilizing requirements of chosen species have been described in many publications, e.g. Bartoš and Kacálek (2013) or Kacálek et al. (2013).

It is necessary to realize, when practically using the proposals presented in this study, that these are only suggestions of possible/potential (or recommended) changes. These proposals are based on the expertise of land use with regard to its agricultural production potential, in relation to non-productive functions of soil (especially infiltration, retention and transport

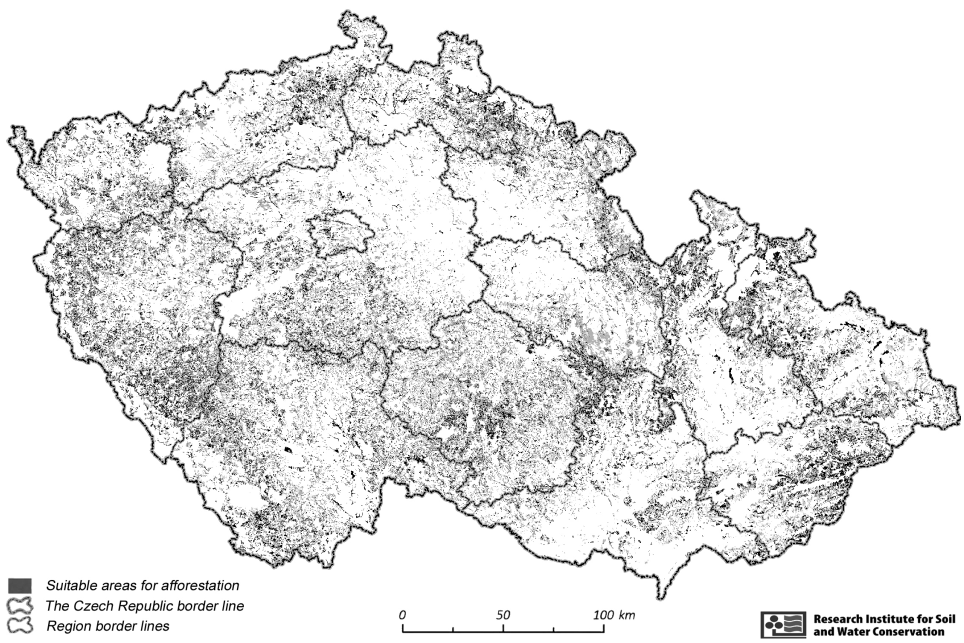


Fig. 1. Identification of suitable areas for afforestation based on selection criteria of variant B (extension of variant A)

Table 3. Recommended ESEU suitable for afforestation (variant B – extension of variant A)

| Soil groups | ESEU codes | Reason |
|---|---|---|
| Sandy soils | 8-9.18.41<br>8-9.18.44<br>8-9.18.51<br>8-9.18.54 | steep slope<br>stoniness |
| Hydromorphic soil and soil catenas | 0-9.73.41<br>0-9.73.43<br>0-9.74.41<br>0-9.74.43<br>0-9.75.41<br>0-9.75.43<br>0-9.76.41<br>0-9.76.43 | hydromorphic conditions<br>steep slope<br>stoniness |
| Soil on steep slopes | 5-9.40.67<br>5-9.40.68<br>5-9.40.77<br>5-9.40.78 | steep slope<br>stoniness |
| | 5-9.41.67<br>5-9.41.68<br>5-9.41.77<br>5-9.41.78 | steep slope<br>stoniness |

of water) and protection of the soil from erosion. Concerning the actual use of the land, it is the owner (or user) who decides with restrictions which are stipulated by higher interests (especially protected areas, water protection zones, etc.). These interests may force a land use change at relatively good localities where the soil is more suitable for crop production. Concerning the transfers of land to another type of land use (afforestation, grassing, and ponds), these are always decided given the specific and local situation. The change in land use can be sensibly (economically and environmentally) carried out in a good manner even on soils (ESEU) that are not listed as appropriate. It may be difficult accessible plots, small enclaves and sites distant from the operations centre, even though these might be highly productive soils. Furthermore, for example, even afforestation of high-quality soil which borders with forest complexes or soils which are periodically flooded around some watercourses is suitable.

## CONCLUSION

When a culture change takes place, it is necessary to consider conditions of area homogenization. This means the logical and pragmatic creation of production blocks. This also means that when the culture is changed, it is not only plots with poor soil conditions (i.e. suitable for land use change) that can be changed but also the adjacent plots with relatively good properties, if it is appropriate for a given situation at a particular locality. Financial issues are decisive in all implemented changes/actions. The owner or user has to know that the change is worth it, or that it will be adequately compensated.

This presented list of proposed amendments contains essentially lands (habitats) which are agriculturally and economically less productive. The following shall be focused on areas with the defined ESEU codes; all building construction, mining and raw materials and similar events exempting the land from the agricultural land resources in order to protect agricultural land with higher production potential. In each climatic region the best soils of the particular region shall be maintained as arable land. Therefore, proposals for changes in cultures cannot be judged only based on the absolute index-point value. However, land consolidation or other major culture changes have to be sometimes made due to technical reasons, i.e. afforestation or changes in grasslands of such regions and habitats (ESEU) that are not in the presented list of results.

The ESEU code can be transferred from agricultural fund onto non-agricultural fund in two possible ways resulting from non-production and production functions of soil. Based on non-production and production soil functions, it is possible to propose a land use change in specific areas, such as grassland or forest. At the moment Research Institute for Soil and Water Conservation is working on detailed specification of thresholds for selecting suitable land for afforestation. In this regard, the main emphasis is put on improving hydrological conditions in the landscape.


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## References


Bartoš J., Kacálek D. (2013): Přihnojení mladého porostu jedle bělokoré na zemědělské půdě. Zprávy lesnického výzkumu, 58: 213–217.

Barry L.E., Yao R.T., Harrison D.R., Paragahawewa U.H., Pannell D.J. (2014): Enhancing ecosystem services through afforestation: How policy can help. Land Use Policy, 39: 135–145.

Blanco H., Lal R. (2008): Principles of Soil Management and Conservation. Ohio, Springer: 617.

Buytaert W., Iñiguez V., De Bièvre B. (2007): The effects of afforestation and cultivation on water yield in the Andean páramo, Forest Ecology and Management, 251: 22–30.

Cremene C., Groza G., Rakosy L., Schileyko A.A., Baur A., Erhardt A., Baur B. (2005): Alterations of steppe-like grasslands in Eastern Europe: a threat to regional biodiversity hotspots. Conservation Biology, 19: 1606–1618

Černý Z., Lokvenc T., Neruda J. (1995): Zalesňování nelesních půd. Praha, Institut výchovy a vzdělávání Ministerstva zemědělství ČR: 55.

Guo L.B., Gifford R.M. (2002): Soil carbon stocks and land use change: a meta analysis. Global Change Biology, 8: 345–360.

Hatlapatková L., Podrázský V. (2011): Obnova vrstev nadložního humusu na zalesněných zemědělských půdách. Zprávy lesnického výzkumu, 56: 228–234.

Hlaváč V., Hofhanzl A., Červenka M., Beran V. (2006): Zalesňování zemědělské půdy z pohledu ochrany přírody. In: Neuhöferová P. (ed.): Zalesňování zemědělských půd, výzva pro lesnický sektor. Sborník referátů, Kostelec nad Černými lesy, Jan 17, 2006: 43–46.

Jarský V., Pulkrab K. (2013): Analysis of EU support for managed succession of agricultural land in the Czech Republic, Land Use Policy, 35: 237–246.

Kacálek D., Dušek D., Novák J., Bartoš J. (2013): The impact of juvenile tree-species canopy on properties of new forest floor. Journal of Forest Science, 59: 230–237.

Křovák F., Pánková E., Doležal F. (2004): Vliv lesních ekosystémů na hydrický režim krajiny. Aktuality šumavského výzkumu, II: 44–48.

Ložek V. (1999): Zemědělská kolonizace a její dopad. Ochrana přírody, 54: 227–233.

Macků J. (2006): Strategie a kritéria pro výběr pozemků pro ZZP. In: Neuhöferová P. (ed.): Zalesňování zemědělských půd, výzva pro lesnický sektor. Sborník referátů, Kostelec nad Černými lesy, Jan 17, 2006: 240.

Němec J. (2001): Aktualizace podkladů pro novelizaci úředních cen zemědělské půdy v roce 2001. Tematický úkol MZe ČR. Praha, VÚZE: 97.

Němeček J., Mülhanselová M., Macku J., Vokoun J., Vavříček D., Novák P. (2008): Taxonomický klasifikační systém půd České republiky. Praha, Česká zemědělská univerzita: 94.

Novák P. (2002): Stanovení kritérií a potenciálů kvality půdy z hlediska jejich významu pro plnění jednotlivých produkčních a mimoprodukčních funkcí půdy. Výstup V 01 projektu QD 1300. Praha, VÚMOP: 35.

Novák P., Vopravil J., Lagová J. (2010): Assessment of the soil quality as a complex of productive and environmental soil function potential. Soil and Water Research, 5: 113–119.

Novotný I., Vopravil J. et al. (2013): Metodika mapování a aktualizace bonitovaných půdně ekologických jednotek. Praha, Výzkumný ústav meliorací a ochrany půdy: 174.

Porto P., Walling D.E., Callegari G. (2009): Investigating the effects of afforestation on soil erosion and sediment mobilisation in two small catchments in Southern Italy. Catena, 79: 181–188.

Shi S., Zhang W., Zhang P., Yu Y., Ding F. (2013): A synthesis of change in deep soil organic carbon stores with afforestation of agricultural soils. Forest Ecology and Management, 296: 53–63.

Simon J., Müller Š., Čížek J. (2004): Tvorba stabilizačních prvků v krajině zalesněním zemědělských půd. Lesnická práce, 83: 462–463.

Skaloš J., Engstová B.,Trpáková I., Šantrůčková M., Podrázský V. (2012): Long-term changes in forest cover 1780–2007 in central Bohemia, Czech Republic. European Journal of Forest Research, 131: 871–884.

Stoate C., Báldi A., Beja P., Boatman N.D., Herzon I., van Doorn A, de Snoo G.R., Rakosy L., Ramwell C. (2009): Ecological impacts of early 21st century agricultural change in Europe – a review. Journal of Environmental Management, 91: 22–46

Středová H., Fukalová P., Rožnovský J. (2010): Specifics of temperature extremes under the conditions of urban climate. Contributions to Geophysics and Geodesy, 40: 249–261.

Špulák O., Kacálek D. (2011): Historie zalesňování nelesních půd na území České Republiky. Zprávy lesnického výzkumu, 56: 49–57.

Vacek S., Slavík M. (2006): Zalesňování zemědělských půd. Praha, Česká zemědělská univerzita v Praze: 108.

Williams M. (2000): Dark ages and dark areas: global deforestration in the deep past. Journal of Historical Geography, 26: 28–46

Winsten J., Walker S., Brown S., Grimland S. (2011): Estimating carbon supply curves from afforestation of agricultural land in the Northeastern U.S. Mitigation and Adaptation Strategic Global Change, 16: 925–942.

Zomer R.J., Trabucco A., Bossio D.A., Verchot L.V. (2008): Climate change mitigation: A spatial analysis of global land suitability for clean development mechanism afforestation and reforestation, Agriculture, Ecosystems and Environment, 126: 67–80.

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