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Robinia pseudoacacia as a valuable invasive species for the restoration of degraded croplands

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ABSTRACT

Deforestation was, for many years, a common practice in Greece in order for the old forest sites to be used as croplands. These deforestations had a very negative influence on soil fertility, especially in the cases where soil depth was restricted, and very sharp inclinations occurred. All these cases were followed by increase of soil surface runoff and extended soil erosion. The continuously decreased crop yields led very often to the abandonment of cultivation. In order to restore such areas and to enhance agricultural development, different rules from the European Agricultural Fund for Rural Development (EAFRD), in the frame of axis 4 "Forestation of Agricultural Lands" were applied. For the study of the influence of restoration on soil fertility, a research project was performed in the whole community area of Gomati (Chalkidiki, Macedonia, Northern Greece), and soil chemical properties have been determined in: i) degraded agricultural sites, ii) restored with *Robinia pseudoacacia* (black locust) lands, as well as: iii) in mixed native forests. The results showed that the restoration of the degraded agricultural lands with *R. pseudoacacia*, 20 years after the establishment of these plantations, led to 1.3–3 times greater (depending on soil layer) organic matter content, 1.2–2.5 times greater N quantity, and in many cases to significantly higher P and K concentrations, compared to the degraded agricultural lands and to the native forest areas, respectively. The highest exchangeable Ca and Na concentrations were recorded in the mixed native forest soils, while the highest DTPA extractable Fe and Mn concentrations were found in the degraded agricultural soils, compared to the other two land use types. Finally, most leaf nutrient concentrations in black locust plantations were adequate to optimum for plant growth and nutrition, with the exceptions of those of K, Cu and Fe, which were deficient, critical and excessive, respectively.

1. Introduction

Restoration of degraded agricultural lands was chosen as a valuable tool for environmental protection, and particularly for protection from erosion, for conservation of biodiversity, for biomass production, etc. (Clemente et al., 2004). In order to fulfill all these requirements, absolutely necessary is the expansion of forest areas, together with the attenuation of pressure from agricultural activities on natural resources and biodiversity. The land use change from agricultural crops to forest restoration is combined with amelioration of physical, chemical and biological soil properties (Nouvellon et al., 2008). After this change, soil organic C of surface soil horizons and nutrient availability are enhanced (Cao et al., 2007), while soil structure is considerably ameliorated due to the accumulation of vegetal residues on surface horizons (Hazlett et al., 2007). Nowadays, the necessity for restoration of degraded areas and for expansion of forest resources, via the reforestation of abandoned agricultural lands, is considered as imperative (Croitoru, 2007).

Robinia pseudoacacia L. was one of the first invasive species used in order to create new forested (from old degraded agricultural sites) lands in Greece, and especially under marginal environments. It is a deciduous tree, belonging to the *Fabaceae* family, its geographical origin is northern America, and it was introduced in Europe in the 17th century (Barrett et al., 1990). Black locust plantations were used as an attractive alternative and successful technique to increase soil C contents in reclaimed, disturbed, mine soils, as well as to protect soil from erosion, to improve its quality and to restore the environment (Hatzistathis et al., 2003; Zhang et al., 2015). Due to the high ability of black locust to fix atmospheric N, it was repeatedly used for restoration of many degraded areas (Yuksek and Yuksek, 2011). Despite the fact that *R. pseudoacacia* was largely expanded for cultivation and it was often used for different purposes, there are not enough data concerning change in soil chemical properties after its use. It is, however, largely known that that *R. pseudoacacia* may influence soil chemical properties, as well as the composition of local vegetation species (Tateno et al., 2007). Black locust was also found to increase soil available P, Ca and Mg (Gillespie and Pope, 1990; Malcolm et al., 2008), as well as to ameliorate soil structure (Ussiri et al., 2006).

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Despite the large areas that were planted with *R. pseudoacacia*, there is little information on the changes of soil properties (usually the studies were focused only on surface soil properties, like those of Yuksek (2012), and Yuksek and Yuksek (2011)) after planting; for example, the study of Chang et al. (2012) described the effects of restoration with *R. pseudoacacia* of some degraded crop sites, suffering from high soil erosion, on the enhancement of soil organic C. Furthermore, Yuksek (2012) studied the restoration effects of black locust plantations on surface soil properties on lower hillslopes, in Turkey. According to our knowledge, there is not, until now, any triple comparative study presenting and discussing soil properties among three land use types, i.e. among degraded (eroded) agricultural lands, mixed native forests and *R. pseudoacacia* plantations. Berthold et al. (2009) made a comparison concerning soil properties between black locust plantations and adjacent planted oak stands (*Quercus cerris* L. and *Quercus pubescens*) – and not between *Robinia* and mixed native forests (*Arbutus unedo*, *Quercus coccifera*, *Calicotome villosa*, *Phillyrea latifolia*, *Erica manipuliflora*, *Erica arborea*, *Pistacia terebinthus*, *Pistacia lentiscus*, *Myrtus communis* and *Quercus ilex*), as those existed in our study area – and found that the elevated biomass accumulation resulted in significantly higher C, N, P and S contents under *Robinia* plantations. Yuksek and Yuksek (2011) studied the effects of black locust, stone pine and black locust + stone pine (*Pinus pinea* L.) on surface soil properties, in eroded clayey soils. Particularly, the novelty in our study is that we compared soil chemical properties and fertility among: i) degraded (eroded) agricultural lands (converted many years ago to crop fields from old forest sites, after extended deforestation), cultivated with wheat and barley crops, ii) sites with mixed native forest vegetation, quoted above, and iii) old, degraded agricultural lands, like those of the case i), which were restored 20 years ago with *R. pseudoacacia*, and are currently reforested. We observed macroscopic differences in soil color, quality and structure among the three land use types in the community area of Gomati (Chalkidiki, northern Greece).

The objectives of our investigation were: i) to study and evaluate the effect of restoration of degraded agricultural croplands with black locust on soil organic C and fertility, 20 years after the establishment of these plantations, as well as: ii) to compare the three land use types concerning organic matter content, soil chemical properties and nutrient availability. In order to provide some useful information on the nutrient status of black locust plantations, iii) the leaf nutrient concentrations of N, P, K, Ca, Mg, Na, Fe, Zn, Mn and Cu were also determined. For these purposes, we assessed the hypothesis that the restoration of the degraded croplands with *R. pseudoacacia* plantations (20 years after their establishment) would have better performance results, i.e. it could better increase organic matter content and improve soil chemical properties and nutrient availability (especially concerning N and P content), than the mixed native forests of the studied area, since it is a N-fixing tree (Yuksek and Yuksek, 2011) and a fast-growing species, suitable for biomass production. In addition, it has great ability to increase soil available P, while it also presents long-term benefits on the improvement of soil properties in eroded hilly areas (Wang et al., 2012).

2. Materials and methods

2.1. Description of the study area and land use types

For the implementation of this research project, the community area of Gomati, in Chalkidiki, northern Greece, was chosen (Fig. 1). The whole area consists of three land use types: i) mixed native forestlands, some of which were cut-off many years ago due to the necessity for expansion of cultivated lands, ii) croplands (always cultivated only with wheat and/or barley crops), which were created after the deforestation of some native forest areas, and iii) black locust plantations, which were established 20 years ago, in order to restore some of the degraded (eroded) croplands. Apart from environmental restoration, within the primary purposes of establishing black locust plantations, was biomass production. *R. pseudoacacia* is an invasive species, previously found to show very good adaptation at the climatic and soil conditions of this area, since it may sufficiently grow up and produce in marginal, nutrient poor, and dry soils. Among the three land use types, black locust plantations cover about 10% of the total vegetation, wheat and barley crops cover approximately 20%, while mixed native forests cover about 70%. Concerning the meteorological data of this region, its bio-climate has strong semi-Mediterranean characteristics; the average temperatures are 5 °C in the winter period and 26.5 °C during the summer months. The annual precipitation varies from 430 to 591 mm (Mauromatis, 1980).

The mixed native forests consisted of *A. unedo*, *Q. coccifera*, *C. villosa*, *P. latifolia*, *E. manipuliflora*, *E. arborea*, *P. terebinthus*, *P. lentiscus*, *M. communis* and *Q. ilex* plantations. Despite the difficulties that existed in the determination of the relative cover percentages among the native species (due to the existence of many factors which influence their appearance and distribution, such as soil depth, altitude, humidity, northern or southern inclination of slopes, and distance from the sea), we can certainly say that the three species which prevail in the study area are: *Q. ilex*, *Q. coccifera*, and afterwards *A. unedo*. All these mixed native forests were not seriously disturbed, burnt, or modified by anthropogenic processes (like wood cutting) during the last 50 years. Concerning the degraded (eroded) agricultural lands that were not restored with black locust plantations and are still cultivated with wheat and barley, it should be pointed out that these crops are annually fertilized with N, P and K, in a quantity of 30 kg/ha. All the soils of the whole area of Gomati are originated from parent material Gneiss; the altitude in this community area varies from 70 to 120 m.

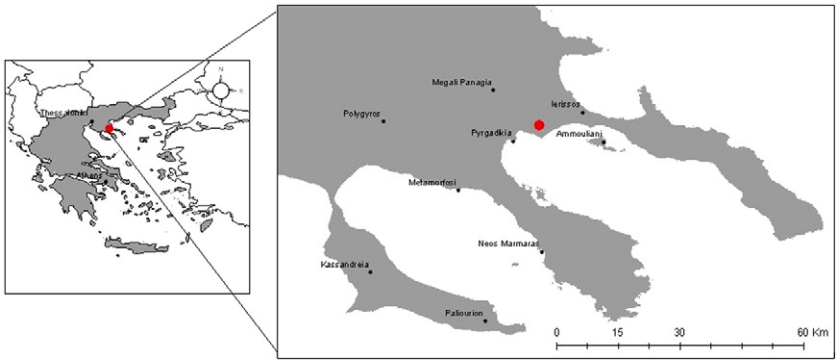

Fig. 1. Study area location of the *Robinia pseudoacacia* plantations.