Agriculture, Ecosystems and Environment 138 (2010) 348–354

Contents lists available at ScienceDirect

Agriculture, Ecosystems and Environment

journal homepage: www.elsevier.com/locate/agee

Short communication

Cropmarks in stands of cereals, legumes and winter rape indicate sub-soil archaeological features in the agricultural landscape of Central Europe

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ARTICLE INFO

Article history:
Received 27 March 2010
Received in revised form 2 June 2010
Accepted 4 June 2010
Available online 26 June 2010

Keywords:
Aerial prospection and survey
Brassica napus
Hordeum vulgare
Triticum aestivum
Medicago sativa
Logging
Oblique photographs
Plant nutrition

ABSTRACT

Small-scale variability in biomass production of crops (cropmarks) can be used for mapping of former human activity in the agricultural landscape. The aim of this study was to assess the suitability of the most frequently planted crop species for identification of sub-soil archaeological features in the agricultural landscape in the NW of the Czech Republic. During 17 years of aerial surveys, 635 archaeological localities were discovered based on cropmarks. The mean number of archaeological features in each locality was approximately 30, ranging from 1 to more than 300. The age of the features ranged from 7500 years (Neolithic) to the modern day, the latter having no archaeological importance. In the contemporary agricultural landscape, the density of archaeological localities was 0.59 per km^2. Over all discovered localities, 95% of archaeological features were positively cropmarked and only 5% were negatively cropmarked. Point features like settlement pits, semi-sunken buildings and graves were substantially more frequent than linear features such as ditches, palisade fortifications and dikes. Negative and positive cropmarks were the best developed in stands of cereals, especially in barley, followed by wheat, rye and oat from tillering up to full ripeness. Lucerne was the best crop for indicating sub-soil archaeological features during the dry summer. Cropmarks in winter rape were substantially less conspicuous than those in cereals. Sugar beet, potatoes and maize did not indicate the presence of any archaeological features.

1. Introduction

An unwanted result of scientific specialization is the lack of communication between relatively unrelated scientific disciplines, even though they may use the same or similar research methods and collect similar data. A good example is agronomy, which aims to optimize field crop production (Šíp et al., 2009; Valkama et al., 2009; Černý et al., 2010; Hejcman and Kunzová, 2010), and aerial archaeology, which looks for signs of former human activity in the agricultural landscape (Bewley, 2003; Bourgeois and Meganck, 2005; Smrž and Hluštík, 2007). Both scientific disciplines are highly connected through their study of the variability in soil physical and chemical properties and the resulting spatial variability in crop production (Challis et al., 2009). Any disturbance of the sub-soil layers is irreversible and therefore regardless of age, such disturbance can generate clear visually detectable changes in crop growth known as "cropmarks" (Edis et al., 1989; Smrž, 1999). Cropmarks photographed from the ground, kites, aircraft or satellites can be used to identify near-surface archaeological features of different age and origin (Smrž, 1996; Lasaponara and Masini, 2007; Gojda and John, 2009; Verhoeven, 2009). Cropmarks are generally divided into positive and negative (Rajani, 2007). Negative cropmarks are characterized by shorter plants and the light green or yellow color of the crop, probably due to water shortage and nutrient deficiency, in comparison with the dark green color of the surrounding vegetation, which is better supplied with water and nutrients during "green phenological stages". Negative cropmarks are most frequently identified above stone wall foundations and former roads (Doneus, 2001; Braasch, 2005). Positive cropmarks are characterized by taller plants and the dark green color of the crop during "green phenological stages", due to improved water and nutrient supply above buried pits, ditches, graves, etc. In addition to changes in plant height and color, a shift in the phenological development of the crop has frequently been recorded above archaeological features compared to the surrounding vegetation (see Hašek and Kovárník, 1999; Kershaw, 2003). Cropmarks and their use for the identification of sub-soil archaeological features have been known since the 18th century and their practical use was first described by "the father" of aerial archaeology, Crawford (1924). In the Czech Republic and other post-communist countries

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doi:10.1016/j.agee.2010.06.004

Fig. 1. Map of the NW part of the Czech Republic with indication of the study area. Prague (Praha)—capital of the Czech Republic.

of Central and Eastern Europe, rapid development of aerial archaeology was enabled after the end of "the cold war" in the 1990s (Gojda, 1996, 2004; Hašek and Kovárník, 1999; Szajlik, 2007). To date, little attention has been paid to the question of which crop species can be used to identify sub-soil archaeological features in the conditions of Central Europe or the frequency of cropmarks that indicate sub-soil archaeological features in the contemporary agricultural landscape of the Czech Republic. The aim of this study was therefore to assess the suitability of the most frequently planted crops for the identification of archaeological features in the NW part of the Czech Republic. This area was selected because it is sufficiently representative and directly comparable with other lowland areas of Central Europe that have been densely inhabited since the Neolithic period.

2. Materials and methods

2.1. Study area

Photographs of cropmarks were collected by Zdeněk Smrž in the NW part of the Czech Republic (Fig. 1) in an old settlement area that has been densely inhabited by humans since the Neolithic period (5500 BC, Pavlů and Zápotocká, 2007). The study area covered approximately 1500 km^2 at an altitude ranging from 170 to 400 m a.s.l. The average annual temperature ranged from 8 to 10 °C and the average annual precipitation ranged from 450 to 600 mm (Tolasz, 2007). In the investigated area, forests covered up to 10% of the study area and more than 95% of the agricultural land was arable. Cover by permanent grasslands and orchards was negligible.

According to the Czech national classification, the study area belongs to the sugar beet growing area and partly to the cereal growing area (Šnóbl and Pulkrábek, 1999). The main soil types are highly productive Chernozems, covering approximately 60% of the study area. Less frequent soil types include Pararendzins (syn. Calcic Leptosols), Fluvisols near the main rivers and Cambisols on substrates of various fertility (Tomášek, 2000).

2.2. Data collection

Aerial surveys of the study area were performed from April to August in the period from 1993 to 2009 during approximately 240 flight hours. Low-altitude oblique aerial photographs of cropmarks were collected from a small aircraft (Cessna 172) from a height of 300–500 m above ground. During the collection of photographs, the speed of the aircraft was approximately 170 km per hour. At the start of the growing season, aerial surveys were performed from early morning to late evening. In June, July and in August, when the height of the crop increased and the crop height differed markedly between the cropmarks and the surrounding vegetation, aerial surveys were performed in the morning and in the evening when the sun was low above the horizon and the differences in crop heights were the most obvious. Surveys were preferentially carried out on sunny days with no wind.

After collecting the aerial photographs of cropmarks, individual localities were visited and crops were recorded. Identified archaeological localities were marked on high resolution maps (1:10 000 and 1:50 000) of the study area. In the majority of cases, the dating of archaeological features at the discovered localities was based on ground-collected pottery or rescue excavation in several cases. Some localities remained undated as no valid pottery was collected during surface surveys.

2.3. Data evaluation and presentation

No "hard" biological data were collected therefore no statistical evaluation was used within the paper. Suitability of the most frequently planted crop species for identification of sub-soil archaeological features was demonstrated according to photographs and long-term personal experiences of authors as no other exact method was available. During aerial survey, only photographs of cropmarks which improved information about former human activities in the landscape were collected. Therefore if good cropmarks (with high resolution of archaeological features) were photographed in stands of cereals, there was no reason to photograph bad cropmarks in stands of other crops in the same place in different years. Therefore to present photographs of the same place with different crops in different years was not possible although we selected photographs from a large archive of photographs collected over 17 years. Further, photographs of the same place with different crops do not present cropmark indication value of crops as weather conditions in different years were different. We tried to demonstrate cropmark indicating value of crops by presenting aerial photographs with several crops together on one photograph as this was the only possible way how to do it exactly. Further, we selected photographs to present wide scale of cropmarked archaeological features discovered in the study area. To evaluate distribution of cropmarked archaeological localities with respect to the soil substratum, we compared maps used for documentation of archaeological localities with pedological maps (Tomášek, 2000) and counted number of discovered cropmarked localities on each soil substratum.

3. Results

During 17 years of aerial surveys, 635 archaeological localities were discovered based on cropmarks in the study area—447 on sands or sandy substrates, 141 on loess and 47 on other substrates. The mean number of archaeological features at each locality was approximately 30, ranging from 1 to more than 50 features (sometimes more than 100–300 features, especially in the case of prehistoric settlements). The age of the cropmarked archaeological features ranged from 5500 BC (Neolithic) up to modern-day features of no archaeological importance (pipelines, drains and drainage, set-aside hop-fields, roads, etc.; these are not discussed further). In the contemporary agricultural landscape of the investigated area, the density of discovered archaeological localities was 0.59 per km^2 (1 locality per 1.7 km^2). The high density of discovered localities is clearly visible from a scan of a small sector of the map used for the documentation of archaeological localities (Fig. 2). Over all discovered localities, 95% of archaeological features were positively cropmarked and 5% were negatively cropmarked (Fig. 3).