ESTIMATION OF ABOVEGROUND BIOMASS OF CATCH CROPS USING NDVI MEASUREMENTS

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Abstract: For the fulfilment of the positive effects of catch crops it is necessary to create a sufficient amount of biomass. The amount of biomass of catch crops is traditionally evaluated by destructive sampling that are labour and time consuming and may not represent the whole monitored area. Within the period of 2013–2014, the aboveground biomass of catch crops was evaluated using ground measurements of vegetation index NDVI and the results were compared with traditionally carried sampling of plant matter. The study took place on a small-plot field trial established in 2006 at the experimental field station in Žabčice (South Moravia, Czech Republic). The experiment included nine kinds of catch crops. Catch crops growths were set up after every harvest of winter wheat (in mid-August). The experiment included control variant without catch crop sowing. Regression analysis for both years of monitoring showed positive dependence between the amount of vegetable matter (fresh and dry matter) and vegetation index NDVI. The accuracy of the measurement depends on the state of growths, particularly with regard to the lower sensitivity of the NDVI when a certain degree of leaf area index is reached. Despite these shortcomings, the spectral measurement is a good alternative to traditional methods, mainly due to rapid and simple measurement and its easy repeatability without damaging the crop.

Key Words: growth, vegetation index, spectral measurement

INTRODUCTION

Catch crops are crops grown between two main crops. Catch crops are valued for reducing the risk of soil erosion and leaching of nitrates (Chen et al. 2010, Valkama et al. 2015). Other important benefits include improved balance of organic matter, weed control, and reduction of the spread and incidence of diseases and pests (Rudokas, Rainys 2005, Caner, Tuncer 2001, Murakami et al. 2000, Leskovšek et al. 2013). The importance of these benefits is dependent on the total amount of generated above-ground biomass (Brant et al. 2009). Traditionally, the evaluation of the amount of biomass is carried out based on destructive sampling of above-ground plant parts, which is arduous and time consuming. In addition, in the case of larger plots, survey can be concentrated on a few places that may not accurately represent the whole monitored area (Fitzgerald et al. 2010). There is growing interest in the use of sensors, alongside traditional methods, which in most cases use measuring of spectral properties of plants and vegetation. Vegetation has a specific reflectance in particular bands of electromagnetic radiation. In this connection, we can use the normalized difference vegetation index – NDVI. NDVI evaluates the growth via ratio of the reflectance in the red (R) and in near infrared spectrum (NIR) using the formula $NDVI = (NIR - R) / (NIR + R)$. The NDVI value indicates the total amount of biomass (Yang et al. 2011, Johansen, Tømmervik 2014). The result of NDVI calculation is a dimensionless value which ranges between −1 and 1. Positive NDVI values represent green vegetation while high values indicate higher growth density. NDVI values around zero indicate bare soil and rocks, while negative ones suggest bodies of water and buildings (Astsatryan et al. 2015, Johansen, Tømmervik 2014). According to the results of some studies (Cao et al. 2015, Gnyp et al. 2014), the relationship between the density of vegetation and NDVI is not perfect. The vegetation index shows a negative trait, the so-called saturation at high density of the growth. When reaching a certain degree of leaf area index (LAI), the NDVI value does not increase anymore, so the growth density is not indicated. The reason is lack of sensitivity to changes of the NDVI to chlorophyll content, especially for medium and higher concentrations. Rating growths of agricultural crops on the basis of NDVI measurements is historically documented by number of studies, but monitoring of catch crops is only marginal. The aim of this study was to evaluate the amount of aboveground biomass of selected species of crops using ground measurements of vegetation index NDVI and compare the results with those carried out by traditional methods of sampling plant matter.

MATERIAL AND METHODS

The study took place on a small-plot field trial established in 2006 at the experimental field station in Žabčice (South Moravia, Czech Republic; 49° 1' 19" N, 16° 36' 52" E). Table 1 lists the nine species of stubble catch crops included in the experiment. Catch crops growths were set up after every harvest of winter wheat (in mid-August). The experiment included control variant without catch crop sowing. To determine the amount of biomass, traditional sampling of fresh vegetable matter of catch crops was used in October from 0.25 m^2 surface with four replications and then it was dried. Simultaneously, contactless measurements of normalized difference vegetation index (NDVI) were made using a handheld Trimble GreenSeeker device. This instrument uses an active radiation LEDs for measuring reflected radiation above the growth in the red (660 nm, bandwidth ~25 nm) and near infrared (780 nm, bandwidth ~25 nm) spectrum. The sensor displays the measured value in terms of an NDVI reading (ranging from 0.00 to 0.99) on its display screen. Three measurements were made for each replication of catch crops. The results were statistically processed using the Statsoft Statistica 12 software package.

RESULTS AND DISCUSSION

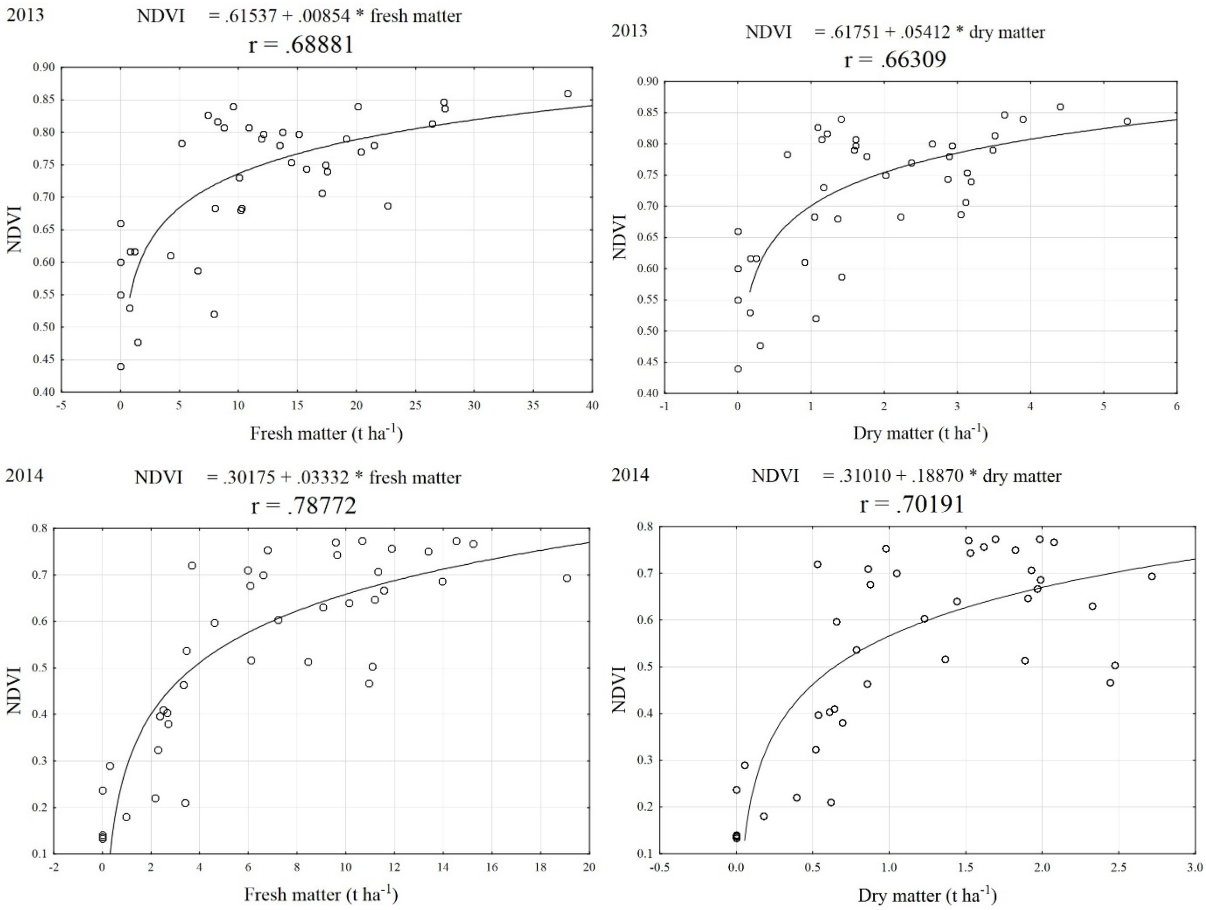
Table 1 shows the results of monitoring yields of catch crops and NDVI values for 2013 and 2014. On the control variant without catch crops, the measured value was greater than zero due to the presence of weeds and natural reflectance of soil background, which on the site was NDVI = 0.1 to 0.2.

Table 1 Aboveground biomass of catch crops and NDVI

Catch crop	2013			2014		
	Fresh matter ($t\ ha^{-1}$)	Dry matter ($t\ ha^{-1}$)	NDVI	Fresh matter ($t\ ha^{-1}$)	Dry matter ($t\ ha^{-1}$)	NDVI
Sinapis alba	17.38	3.16	0.75	9.14	2.04	0.50
Raphanus sativus v. oleifera	15.57	2.09	0.67	11.94	1.70	0.65
Phacelia tanacetifolia	21.44	2.49	0.78	13.75	1.87	0.76
Secale cereale v. multicaule	8.90	1.92	0.66	4.40	1.13	0.47
Panicum miliaceum	1.08	0.22	0.56	1.71	0.31	0.23
Crambe abyssinica	19.47	2.59	0.81	10.32	1.76	0.66
Malva verticillata	9.03	1.33	0.82	5.62	0.81	0.72
Phalaris canariensis	8.88	1.16	0.76	2.69	0.61	0.42
Carthamus tinctorius	19.14	3.70	0.82	9.12	1.45	0.75
Control variant – without catch crops	0.00	0.00	0.56	0.00	0.00	0.16

Regression analysis for both years of monitoring showed positive dependence between the amount of vegetable matter (fresh and dry matter) and vegetation index NDVI (Figure 1). Higher values of NDVI in selected catch crops correspond with greater weight of aboveground biomass, which correlates with the described growth density effect (Astsatryan et al. 2015, Johansen, Tømmervik 2014). The exception in both years was *Malva verticillata*, where the measured NDVI values were at almost the highest levels (NDVI 0.82 in 2013, 0.72 NDVI in 2014), but at the same time its yields were lower. This can be related to the formation of large leaves, which increase reflectance in the near infrared spectrum. The results show a lower sensitivity of NDVI to changes in the amount of biomass in the species of catch crops with a high increase of vegetable matter. This corresponds with the described saturation effect of NDVI (Cao et al. 2015, Gnyp et al. 2014), when after reaching a certain degree of leaf area index, the NDVI does not change. This phenomenon can be eliminated by using vegetation indices of measurement in narrow spectral bands (Mutanga, Skidmore 2004).

Figure 1 Regression analysis between the vegetable matter of catch crops and vegetation index NDVI



CONCLUSION

The results of this study demonstrate the potential of using ground NDVI measurements in assessing the amount of aboveground biomass of catch crops. The accuracy of the measurement depends on the state of growths, particularly with regard to the lower sensitivity of the NDVI when a certain degree of leaf area index is reached. Despite these shortcomings, the spectral measurement is a good alternative to traditional methods, mainly due to rapid and simple measurement and its easy repeatability without damaging the crop.

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