der Praxis getestet werden, um ihre Genauigkeit und Komplexität mit anderen Methoden zu vergleichen.

Stichwörter: Ernteschäden, Verbiss, wilde Pflanzenfresser, Schadensquantifizierung

Introduction

Wild herbivores, in accordance with the theory of optimal nutrition, are looking for food that will ensure optimal energy gain (Westoby, 1974; Bleier et al., 2017). Therefore, animals at certain times prefer agricultural crops for their high nutrients, and thus, cause a significant damage to the crops. The extent of the damage is the result of several factors. However, the extent of damage is most related to the number of large herbivores that caused significant increase in the amount and cost of environmental damage in recent decades. In extreme cases, the damage was so great that it limited the business management and did not allow cultivation of more attractive crops (Conover et al., 2018; Hohbein & Mengak, 2018). One of the reasons of these persistent problems is the complexity of determining the amount of damage. The affected enterprises are thus in a situation, where they are unable to quantify the damage, and thus, cannot request financial compensations.

In current practice, two methods are most used to determine the amount of damage to agricultural crops. The first is based on inspection of the observed area and estimating the damage extent in sub-areas. The second method uses aerial photography to estimate the damage. For both of these methods, the primary data source for subsequent damage calculations is the size of the damaged area expressed in absolute terms in m^2, or a in relative terms by proportion of the damage.

Estimating the extent of damage by visual inspection method is the most used method, especially since no special equipment is needed to work in the field. The stands are inspected in a way that the inspected area is representative of the damage distribution. However, the method has several drawbacks. In particular: it is a time consuming method; there is a risk of secondary physical damage to the crops; there is a high risk of results being influenced by the evaluator; it is impossible to use in impenetrable crop areas; and there is also a risk of a significant underestimation of the damage in poorly visible parts (Bayani et al., 2016). On the other hand, Remote Survey Methods (Puri et al., 2017) are done by drone imaging. For this, the damage assessment is based either on a simple photograph viewing or on automated 3D-point analysis and subsequent identification of different crop height categories, or on recognition of crops colour changes caused by the herbivore's food behaviour. The advantage of remote survey is that there is no damage to crops during the damage assessment and data collection, and the damage evaluation is not time consuming due to the option of automatic categorisation. The disadvantage of aerial photography, in addition to the demands on technology, is that it can underestimate some types of damage even more than the visual inspection method. While drones would prevent increased damage made to crops by walking in it, there is a high risk of overlooking the cases where damage occurred in early stages of the growth and the damaged plants were able to regenerate and reached a similar height to the surrounding vegetation. However, the earlier damage is manifested by a decrease or complete absence of crops production (Kamler et al., 2009; Bayani et al., 2016). It is, therefore, common to have a significant difference between the estimated damage and the compensation received (Ogra & Badola, 2008; Haney & Conover, 2013). The cost of taking aerial pictures and partly the time spent for photo-processing also limits the usability of this method, although it is becoming more and more affordable.

Practical application of both above mentioned methods encounters some difficulties, and therefore, other methods are sought to estimate the amount of damage in a less demanding way while maintaining the necessary accuracy. Comparing yields could be one potentially good method, where the amount of damage could be estimated by comparing the yields in damaged and undamaged areas. The yield is either measured by weighing the crop, or directly during harvesting using sensors on the harvesting machines and GPS for monitoring the harvested area. This procedure is mainly used for machine-harvested crops, however, can also be applied to crops harvested by hand (Srivastava et al., 2018). One great advantage of this method is that it minimizes the demanding collection of damage data in the field and uses yield data that can only be obtained quite easily. At the same time, this Comparison Method also eliminates the usual underestimation of damage due to poor visibility. Under ideal conditions, the damage can be estimated with high accuracy and minimal difficulty. In practice, however, this method is dependent on correct selection of the reference area. It is best to use a damaged field, on which undamaged parts are selected for comparison as reference areas. Animal damage is usually unevenly distributed, where the damage is usually highest near the shelter from which the animals come to the field (Bleier et al., 2017). Therefore, it is often possible to find a continuous undamaged area of the field. At the same time, however, it is necessary to respect possible unevenness in the yield (for example due to shading, dampness, erosion or other influences) that could be significant in large fields. Therefore, the reference area must be of such a size and distribution as to represent the yield of the observed field with sufficient accuracy. Failure to respect this condition could result in errors and might even result in the damaged area having a higher yield than the undamaged reference area. Nevertheless, to have an ideal model for systematic distribution of reference areas throughout the field is practically impossible (Kovács et al., 2020) as damaged areas cannot be avoided and pure undamaged harvest would be technically too demanding. Thus, it is necessary to find a reasonable compromise, which would include a parameter of "reasonable labour" to determine the yield on the reference area, including consideration for the harvesting technique, in particular the width of the harvesting machine. The proposed method was created as a thought experiment based on the study of literature review and experience with other methods. For implementation it needs to be tested and statistically evaluated.

Proposed Comparison method of Yields in One Area

The amount of damage is calculated from the difference between the yields of the damaged area and the undamaged reference area. Undamaged parts of the observed field are used as reference areas, but only if there is a comparable yield potential. To determine the similarity of yield potentials, it is recommended to use map data of average potential yields (Fig. 1). This data is becoming more available thanks to the growing precision agriculture and is mostly available online (for example for the Czech Republic they can be found at www.agrihub.cz). In the selected area, we use GIS to determine the standard deviation or a coefficient of variation, which determines the homogeneity degree of the particular field. Based on these quantities and the required accuracy, we then determine the size of the compared area. We placed the reference area in the field outside the damaged areas while taking into account the potential yield according to the yield map. This increased the accuracy of the damage quantification even further (Fig. 2).

For risk areas, where severe damage is very likely, an undamaged part can be fenced off in advance. At the same time, care should be taken to ensure that the crop yield conditions on the reference area are the same as on the damaged area and that the reference area is clearly defined in size and is easily harvestable, e.g. a multiple width of the harvesting machine. The yield of the reference area can also be determined manually from small experimental areas, which should be spaced with regard to field variability. These small areas should be checked in the reference area and also in the damaged areas and the aim is only to compare the yield potential. Thus, it is possible and preferable to present the result of such a comparison in relative values (%), rather than in absolute yield. This eliminates any possible errors in the yield estimation for the manual experimental method and also for the standard harvesting technique. If the yield and the damage are inhomogeneous in the observed field, then it would not be possible to set a sufficiently large reference area there, and thus, this method would be unsuitable.

Fig. 1. **Example of a yield potential map.**