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Comparison of artificial neural networks and logistic regression as potential methods for predicting weed populations on dryland chickpea and winter wheat fields of Kurdistan province, Iran

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ABSTRACT

This study was carried out in 2013 and 2014 to compare the potential of artificial neural networks and logistic regression to predict dominant weed presence on dryland chickpea and winter wheat fields in Kurdistan province, Iran. In both models, climatic and soil characteristics were defined as independent variables and presence/absence of the dominant weeds as the dependent variable. The geographical coordinates of each field was overlaid on georeferenced map of the province for producing the distribution of weed species maps in ArcGIS. Also, the zonation maps developed by using GIS based on LR models. Demographic indices of weed species were calculated, and the dominant weeds were determined. In the area under study, 61 and 74 weed species were identified on chickpea and winter wheat fields, respectively. The results indicated that *Galium aparine* L., *Convolvulus arvensis* L., *Scandix pectinveneris* L. and *Tragopogon graminifolius* DC. at three-leaf stage (99, 81, 71 and 70, respectively), *Convolvulus arvensis* and *Tragopogon graminifolius* at podding stage of chickpea (96 and 77, respectively); and *Convolvulus arvensis*, *Tragopogon graminifolius*, *Turgenia latifolia* (L.) Hoffm. and *Carthamus oxyacantha* M. B. at heading stage of winter wheat (95, 80, 78 and 72, respectively) were the dominant weeds with the highest abundance indices. The logit models did not show good fitness and could not fit any models for *Galium aparine* at three leaf stage and dominant weeds at podding stage of chickpea. However, ANN could develop the best suited models for prediction all dominant weeds with high MSE values. Sensitivity analysis on the optimal networks revealed that altitude and rainfall were the most significant parameters. The results demonstrates the potential of ANN as a promising tool for survey of weed population dynamics.

1. Introduction

Wheat (*Triticum aestivum* L.), the second most important cereal in the world and chickpea (*Cicer arietinum* L.), the third most relevant legume have main roles in worldwide agricultural economy (FAO, 2013). They are most important crops in dryland agricultural regions of Iran (Abdulahi et al., 2012). Iran is ranked four and eleven in chickpea and wheat production in the world, respectively (FAO, 2013). Kurdistan Province with the common crop rotation of chickpea-wheat has the first and fourth position in Iran production rank, respectively.

Compared to developed countries in the world, Iran has low productions of chickpea and wheat per unit area (FAO, 2013). The average yield of rain-fed chickpea and winter wheat in Kurdistan are 265 and 750 kg/ha, respectively. Many factors are responsible for reduction of yield in chickpea and wheat in Iran from which the most important factor are weeds. Weeds occurring on dryland chickpea fields represent a major production loss and impact on chickpea grain yield because of slow growth of chickpea seedlings, smaller leaf area and weak interspecific competition at early growth stages. Yield loss in Iranian wheat and chickpea due to weed is more than 25% and 66%, respectively. Weeds are more competitive when moisture is limited and also wheat seedlings are

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not able to compete well enough with weeds (Abdulahi et al., 2012).

Therefore, weed identification on dryland crops is the most important operation for weed management (Hassan et al., 2010). Mapping of weed distribution and their demographic indices would be an important step forward in weed management on chickpea and wheat fields. Monitoring of weed species will provide great help to make a decision on applying suitable control methods (Minbashi Moeini et al., 2008). Weed distribution on fields is not uniform and limited to different size of patches on field (Weis et al., 2008) and since there is significant difference in weeds among different fields, site-specific weed monitoring and management are necessary (Moran et al., 2004). Weed researchers need to predict weed populations by developing models that help to: (i) estimate the presence of weeds on fields relating their population dynamics with the expenses and profits of their control, (ii) estimate the effects of new management before field implementation, and (iii) simulation weed populations responses to changes in the environment or managing. Many factors influence weed specie presence and abundance, such as soil and climate properties (Fried et al., 2008), crop interference (Caussanel, 1989), other competing weed species and agricultural practices (Dale et al., 1992) among others. Nowadays computer knowledge has been widely applied to design application systems for weed management to estimate current and predict future infestations (Memon et al., 2011). Some researchers applied geographic information system (GIS) (Lamb and Brown, 2001), logistic regression (LR) (Goslee et al., 2003) and artificial neural networks (ANN) (Irmak et al., 2006) to determine and rank the relative importance of the soil and climate factors in different situation and crops on weed presence. GIS as a powerful tool can provide full information to weed researchers (Minbashi Moeini et al., 2008) and can integrate layers of information in one habitat. Mitchell and Pike (1996) developed a potential map of weed presence based on the logistic regression equations within a GIS environment for weed management. Logistic regression models cover the case of binary dependent variables. It can take only two values (presence/absence of weed). Nowadays, artificial neural networks are presented as powerful weed modelling tools for solving non-linear ill-defined problems (Gonzalez-Andujar et al., 2016). ANN models are inspired by biological neural networks which can accurately predict complex nonlinear procedures at a desired level (Torrecilla et al., 2004). An ANN contains of simple processing elements called neurons and synapses are the connections between neurons. At each neuron, the input signals are summed and this input is processed via a nonlinear transfer function, i.e., sigmoid (Irmak et al., 2006) and tangent hyperbolic (Heidari et al., 2011) to produce the output of the neuron. Previous research in the field of crop science indicate that ANN provide reasonable and reliable results. For example, ANN were applied for: (i) spectral classification of grass weed species in winter wheat (Lopez-Granados et al., 2008), (ii) to discriminate between Cruciferous weeds in winter wheat and legume crops (Castro et al., 2012), (iii) to develop herbicide application map (Yang et al., 2003). Further, ANN were used to predict the effect of soil fertility on soybean yield (Irmak et al., 2006) and to discriminate between sunflower and weeds (Kavdir, 2004). Therefore, the ANN approach is presented as a useful and feasible technique for species discrimination and site-specific control in weed science.

In Iran, much research is needed in order to assess weed flora in cultivated crops. This gap in our knowledge led us to start a survey in order to find an appropriate method to study weed distribution. The objectives of this study were to accurately identify weeds and to develop distribution maps of the dominant weed species on dryland chickpea and winter wheat fields by using GIS. In addition, we aim to determine the importance climatic and soil factors on weed field presence by using LR and ANN approaches and ultimately compare the relative accuracy of such models.

2. Materials and methods

2.1. The study area

Kurdistan province, Iran, comprises of 28 203 km^2 area being located between 34°44′-36°30′N and 45°31′-48°16′E. Weed samples were collected during 2013 and 2014 cropping seasons from 33 dryland chickpea and wheat fields in 5 counties (Sanandaj, Kamyaran, Dehgolan, Divandareh and Saqez) of Kurdistan province in Iran (Fig. 1). The selection of the counties was done based on cultivation acreage and production of chickpea and wheat in Kurdistan. The number of fields in each county was selected based on its area under dryland chickpea and wheat cultivations (Table 1) (Minbashi Moeini et al., 2008).

2.2. Weed sampling and determination of population indices

Weed sampling time in different counties was performed at two stages of chickpea growth, (three-leaf and the podding stages of chickpea) and heading stage of winter wheat (Minbashi Moeini et al., 2008). According to McCully et al. (1991), weed sampling pattern was "W shape" and five quadrats were used in selected fields where the area was between 1 and 5 ha (Hassan et al., 2010). The species of weeds were identified and separately counted in each quadrat of 0.25 m^2 (Nordmeyer and Dunker, 1999).

After weed species identification and counting, population indices (frequency, uniformity, density, mean field density and abundance index) were calculated to determine the dominant

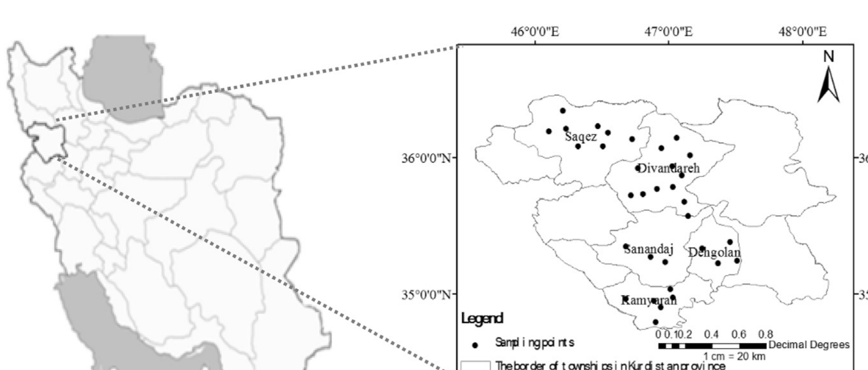

Fig. 1. Geographic distribution and sampling points of dryland chickpea and winter wheat fields in Kurdistan province, Iran.