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Inventory and prioritization for the conservation of crop wild relatives in The Netherlands under climate change

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ABSTRACT

Crop-related wild plant species are a rich source of genetic diversity and are potentially useful in plant breeding for the development of varieties with novel traits. However, many crop wild relatives are poorly represented in gene banks, while their continued survival *in situ* is by no means ensured. Here we introduced a methodology to inventory relevant taxa and to assess their threat levels for continued survival *in situ*, including the expected effects of climate change, and applied it to crop wild relatives in The Netherlands. A total number of 214 taxa of wild relatives of economically important agricultural and horticultural crops were identified, of which 53 are included in the Dutch red list of plant species. The group of 53 red list species was studied in more detail to prioritize species for conservation. Based on recent distribution data, the number of Dutch populations consisting of at least 50 individuals varied strongly among the red list species. The majority of these 'large' populations were found to be located in protected areas. Furthermore, niche modelling was used to study the expected effects of climate change on the future distribution of the red list species. These analyses predicted a reduced distribution area for the majority of species, although also positive effects of climate change were observed for several species. Similar patterns of change were observed when only protected areas were considered. Results of the study were used to prioritize the conservation of crop wild relatives in The Netherlands.

1. Introduction

Crop wild relatives (CWR) are wild plant taxa related to cultivated species, and hence form a potential source of genetic diversity for cultivar improvement by plant breeding when the variation of interest is no longer present, or difficult to find, in the cultivated species (Hajjar and Hodgkin, 2007; Van de Wouw et al., 2010). To classify crop relatedness, the gene pool concept was introduced by Harlan and de Wet (1971). According to this concept, taxa of the primary, secondary and tertiary gene pool are distinguished based on their level of inter-fertility with the cultivated species. However, for many crop species the crossing ability with its wild relatives has not been established yet. As a proxy for inter-fertility, the taxon group concept was developed by Maxted et al. (2006), classifying taxa in five taxon groups based on existing taxonomic hierarchy. Gene pool and taxon group data have been collected for 173 globally important crops, comprising 1667 CWR taxa (Trust, 2014; Vincent et al., 2013). However, data on crop relatedness are rather scarce for less well-known crops or crops only important at the regional or national level.

Despite the fact that the importance of CWR for crop improvement and food security is well recognized, wild relatives are poorly conserved in gene banks (Castañeda-Álvarez et al., 2016; Khoury et al., 2010). This under-representation makes CWR less accessible for utilization, while their survival solely relies on persistence *in situ*. In the European Union, a system of conserved areas in individual member states has been developed into the Natura 2000 network of protected sites (Evans, 2012). Nature reserves may protect species against present-day threats, such as habitat destruction, pollution and urbanisation, but climate change is increasingly being considered a serious problem for the continued *in situ* survival of populations in the forthcoming decades (Dempewolf et al., 2014). Statistics on climate variables, such as temperature and precipitation, have shown that the climate has changed since the 1950s, while climate models predict these changes to continue in the forthcoming decades (Stocker et al., 2013).

Niche modelling, also known as species distribution modelling, is commonly used to estimate climatic effects on future species distribution. These models relate geographic occurrence data of a species to the local environmental conditions to predict the probability of occurrence over a wider area. When combined with climate change scenarios, the models predict at which locations favourable or unfavourable conditions can be expected for the species in the future. The modelling results for the present and future are then compared to investigate expected

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changes in distribution range (Jarvis et al., 2008). Niche modelling studies have predicted substantial reductions in distribution range, or even extinctions, such as for many wild relatives of peanut and potato in South America and cowpea in Africa under climate change (Jarvis et al., 2008). Aguirre-Gutiérrez et al. (2017) investigated eight CWR in Europe under different climate change scenarios, in general predicting a shift towards Northern locations and a net loss of distribution area. Considering its predicted effects on species distribution, climate change cannot be ignored when developing sound conservation strategies.

Considering their importance for crop improvement and food security and the threats they are facing, conservation efforts for CWR are urgently needed (Maxted et al., 2010). Under the auspices of the European Cooperative Programme for Plant Genetic Resources (ECPGR) a conservation concept has been developed for CWR in Europe (Maxted et al., 2015). This concept primarily focusses on *in situ* conservation, while *ex situ* conservation is regarded a complementary strategy to facilitate germplasm users in the short term. The first implementation steps of the proposed conservation strategy include the inventorying of CWR and examination of their threat status at the national level, taking into account the expected effects of climate change. Here we introduce a methodology to achieve these goals for CWR in The Netherlands.

In a recent analysis of the global distribution of 1076 taxa related to 81 crops, Western Europe appeared as one of most critical collecting gaps (Castañeda-Álvarez et al., 2016). In The Netherlands about 2300 vascular plant species are known to occur in the wild, of which 1450 are considered native (FLORON, 2014). In the present paper we report on an inventory of CWR occurring in The Netherlands focussing on agricultural and horticultural crops. CWR that are part of the Dutch red list of plant species were studied in more detail by quantifying their occurrence and abundance in Dutch nature reserves and by examining the expected effects of climate change on their future distribution. The aim of the study was to establish a priority list for the conservation of CWR in The Netherlands.

2. Material and methods

2.1. Crop domain

Agricultural and horticultural crops were considered that are economically important worldwide or to The Netherlands in particular. An initial short list of globally important crops, excluding unspecified rest groups (*e.g.* other melons or other fibre crops), was based on the FAO world primary crop list (FAO, 2014). This shortlist was supplemented with crops of economic importance to The Netherlands based on data about crop production areas (CBS, 2014) and economic revenues per hectare (LEI, 2014). The inventory was further supplemented with crops or taxa included in Annex 1 of the International Treaty on Plant Genetic Resources for Food and Agriculture (ITPGRFA, 2014), the EU database of registered plant varieties (EU, 2014), the Dutch variety list and the technical questionnaires for vegetables and agricultural crops of The Netherlands Inspection Service for Horticulture (Naktuinbouw, 2014). The resulting crop domain comprised 207 crops (Table A1), which were grouped according to the FAO crop classification system (FAO, 2015).

2.2. CWR inventory

Using species distribution data from the 'Verspreidingsatlas', which are based on validated observations from the Dutch National Databank Flora and Fauna (NDFF), wild taxa were inventoried that belong to the genus of the crop and that occur in The Netherlands (FLORON, 2014). Synonyms, unaccepted taxonomies and taxon combinations as indicated by the Verspreidingsatlas were disregarded. Taxon names presented by the Verspreidingsatlas were verified through GrinTax (2014) and the Plant List (2014). Accepted names presented by these taxonomic databases were recorded in case of inconsistencies. The Verspreidingsatlas was also used to collect data on indigeneity in The Netherlands and on trends in occurrence since 1950. In case of incompleteness, data were supplemented by the Dutch Species Catalogue (Soortenregister, 2014), the website '*Wilde Planten in Nederland en België*' (2014) and the 'Flora van Nederland' (Heukels and van Ooststroom, 1977). Extinctions and exotics and taxa introduced or naturalized after 1900 were disregarded.

The 'Harlan and de Wet Crop Wild Relative Inventory' of the Global Crop Diversity Trust (Trust) was used to collect data on the relationship of the identified taxa with the cultivated species, classifying taxa according to either the (provisional) gene pool concept or the taxon group concept (Trust, 2014). In case of missing data, the crop relationship was denoted by 'same genus'. Crop gene pools described in the 'Harlan and de Wet Crop Wild Relative Inventory' were also used to identify related taxa from genera other than that of the crop. Such taxa were added to our inventory in case of occurrence in The Netherlands. Other representatives of the genus of those taxa were not considered.

2.3. Current conservation status

The IUCN classification system for species conservation status includes the categories 'extinct', 'extinct in the wild', 'near threatened', 'least concern', 'data deficient', 'not evaluated', and the threatened categories 'critically endangered', 'endangered' and 'vulnerable' (IUCN, 2012). Data on CWR conservation status in The Netherlands were collected from the Verspreidingsatlas (FLORON, 2014) that largely follows the IUCN classification system. Red list species indicated by the Verspreidingsatlas include taxa belonging to one of the three threatened IUCN categories or a fourth category denoted as 'susceptible'. This classification was followed throughout our study, denoting susceptible taxa as 'near threatened'. To prioritize CWR for conservation, also their conservation status in neighbouring countries was examined. Data for Germany were collected from the 'Bundesamt für Naturschutz' that in addition to the IUCN categories also uses the classification 'extremely rare' (FloraWeb, 2015). In Germany also the classifications 'potentially endangered', 'declining' and 'plausible threat' are used, which were combined into the category 'near threatened'. However, such cases were not encountered for the examined taxa. A number of CWR were listed as 'not occurring in Germany', in which case 'absent' was denoted. Data for Flanders (Belgium) were collected from the Research Institute for Nature and Forest that in addition to the IUCN categories also uses the classification 'rare' (Van Landuyt et al., 2006). Data for Flanders also include the classification 'declining' that for the purposes of the present study was included in the category 'near threatened'. Data for England were collected from the Botanical Society of Britain and Ireland, which also largely follows the IUCN classification system (Stroh et al., 2014). For these data, the classification 'waiting list' was treated as 'not evaluated'. A number of taxon names presented by the Verspreidingsatlas were missing from the data sources used to determine the conservation status in neighbouring countries. In cases where such taxa were listed under alternative, accepted names by GrinTax or the Plant List, the presented information for those species was used. Otherwise, 'no data' was denoted.

2.4. Distribution analysis of Dutch red list CWR in The Netherlands

To prioritize threatened CWR for conservation, the identified Dutch red list species were examined in greater detail. For these species, distribution data spanning the period 2000–2015 were obtained from the NDFF in April 2015. Data included the observed species occurrence and abundance per 1 km × 1 km square. For each 1 km × 1 km square in which a species was recorded to occur, the percentage overlap was calculated with areas belonging to the Dutch network of protected areas, which includes existing and planned nature reserves in The Netherlands.