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Benefits and costs of controlling three allergenic alien species under climate change and dispersal scenarios in Central Europe

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ABSTRACT

Climate change is likely to exacerbate the negative effects of invasive alien species (IAS) as it will foster their further spread. This paper analyses the potential socio-economic effects of three emerging IAS (giant ragweed, *Ambrosia trifida*; annual wormwood, *Artemisia annua*; and burweed marshelder, *Iva xanthiifolia*), which are known to cause substantial harm to human health and to have negative effects on agricultural production. The novelty of the study consists in an integrated approach that combines several aspects of IAS research and management. We model the future spread of the study species in Central Europe by the year 2050 under several climate change, management and spread scenarios. The costs and benefits of controlling the expansion of these IAS are based on this forecast. The results show that an early and coordinated response to the spread of these IAS yields substantial net benefits under all scenarios. Under the conditions of moderate climate change (+1.5 °C), discounted net benefits range from €19 to €582 million. Assuming more severe climate change (+2.4 °C), total savings over the full period are projected to add up to €1063 million. These large socio-economic benefits provide compelling evidence that public authorities should act preventively to restrict the spread of these three IAS.

1. Introduction

The proliferation and spread of invasive alien species (IAS) is threatening biodiversity and thus the provision of ecosystem services, and may also affect economic development and human well-being (Pimentel et al., 2005; Olson, 2006; Vilà et al., 2010, 2011). Conservative monetary value estimations of these effects for Europe indicate that the costs of IAS amount to roughly €12.5 billion per year, including the damage to crops and harm to human health amounting to €9.8 billion, and €2.7 billion for the costs to control invasions (Kettunen et al., 2009; Vilà et al., 2010).

Climate change is very likely to further exacerbate these developments (Walther et al., 2009). The increase of atmospheric CO_2-concentrations and the associated rise in temperature will most probably alter habitat conditions. In particular, climate change in temperate regions might assist the spread of IAS to hitherto unaffected areas as their current spatial distribution is often limited by physiological constraints (ibid.). In addition, climate change fosters plant growth and thus intensifies the negative effects they may have on human health (Ziska et al., 2009). Research on common ragweed (*Ambrosia artemisiifolia)* – one of the most prominently discussed IAS in Europe – is indicative in this regard, as pollen production and concomitantly human allergies increase under higher temperature levels. Several studies have drawn attention to the accelerated invasion of this species, the increase in pollen production (Ziska and Caulfield, 2000; Rogers et al., 2006; Wayne et al., 2002; Essl et al., 2009; Bullock et al., 2012; Chapman et al., 2013) as well as extended flowering seasons with negative effects on human well-being through earlier and longer pollen seasons (Beggs and Bambrick, 2005; Eis and Helm, 2009).

To our knowledge, this is the first paper that addresses the potential socio-economic effects on public health and on the agricultural production of three emerging alien species closely

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related to *A. artemisiifolia*: *Ambrosia trifida* L. (giant ragweed), *Iva xanthiifolia* Nutt. (burweed marshelder) and *Artemisia annua* L. (annual wormwood). This interdisciplinary study complements the literature on bio-economic modelling of IAS in two ways. First, we bring together several aspects of IAS, including species distribution modelling and spread, health and agriculture effects as well as climate change. Second, we apply the framework to the management of three IAS simultaneously. Specifically, an analysis was made of the costs and benefits of controlling the expansion of these species in Austria under several scenarios of climate change, management and spread.

The methodological approach consists of a cost-benefit analysis (CBA) in which the different outcomes of the invasion process over the period from 2011 to 2050 are evaluated ex-ante. The CBA is based on the current species' distribution within Austria and adjacent countries[1] (Follak et al., 2013) and on species distribution models (Guisan and Thuiller, 2005) to forecast how they are likely to spread in the future.

The paper is structured as follows: Section 2 summarizes the literature on the socio-economic effects of the three IAS, while a more detailed review can be found in Appendix A. Section 3 introduces the bio-physical model framework as well as the climate change and spread scenarios that provide the input for the CBA. The CBA methodology is detailed in Section 4. The CBA results are presented in Section 5, while they are discussed and conclusions are drawn in Section 6.

2. Socio-economic effects of invasive alien species

2.1. Economic valuation of IAS

In view of the potentially negative socio-economic effects of IAS a number of studies on the economics of IAS has been done. The focus of these studies falls into three broad categories: estimation of the invasion dynamics, damage costs and optimal management strategies, and policy instruments (see reviews by Born, 2008; Marbuah et al., 2014). Much of the research has dealt with a single IAS employing a range of methodological approaches (Hastings et al., 2006; D'Evelyn et al., 2008; Taylor & Hastings, 2004; Cacho et al., 2008; Blackwood et al., 2010). In the case of jointly managing several IAS only little literature is available (see for instance, Carrasco et al., 2010; Nghiem et al., 2013).

We add to this literature by simultaneously analysing three emerging IAS in an integrated framework combining bio-physical and socio-economic dimensions with the ultimate aim of assessing the costs and benefits under different scenarios of climate change and dispersal.

2.2. Ecology of the study species

Besides being closely related (i.e., belonging to the same tribe), the species treated within this paper share a range of traits typical of these species (wind-pollinated, herbaceous, annual species found in open habitats with vigorous growth) and introduction characteristics (e.g., invasion started in the 19th century after accidental introduction into Central and Eastern Europe). *A. trifida* is characterized by rapid growth and relatively moderate seed production (Abul-Fatih and Bazzaz, 1979). It is native to riverbanks and lakeshores north of the Ohio River in the United States (Basset and Crompton, 1982). *A. annua* is native to East Asia, most probably to Inner Mongolia in China, where it is part of the grassland and steppe vegetation (Ferreira et al., 1997). *A. annua* has become widespread in temperate regions worldwide (FNA Editorial Committee, 2006). *I. xanthiifolia* is characterized by rapid growth and high seed production (Hodi and Torma, 2002). It is native to the North American prairies where it grows on alluvium, and occasionally on moist places. The species has spread by human means in North America; now it covers large fractions of the lower United States and parts of the southernmost region of Canada (FNA Editorial Committee, 2006). The three study species were introduced in the 19th century to Europe, but they began to proliferate only after World War II. They are, however, still rare in Austria and the surrounding countries (Follak et al., 2013).

2.3. The effects on human health

The main effects of study species on human health are caused by pollen allergens. Individuals allergic to pollen suffer from a reduced quality of life owing to the negative physical and psychological effects, as well as from reduced productivity at work (Juniper, 1999; Crystal-Peters et al., 2000; Burton et al., 2001; Szeinbach et al., 2007). *A. trifida* and *I. xanthiifolia* pollen were reported to cause allergic diseases, including rhinitis, conjunctivitis, asthma and also contact dermatitis (Huber and Harsh, 1932; Wodehouse, 1971; Frain-Bell and Johnson, 1979; Gadermaier et al., 2004). Pollen from *Artemisia* spp. is a predominant cause of allergies in Central and Eastern Europe (CEE) in late summer and autumn (D'Amato et al., 1998). In China, the pollen of *A. annua* is considered to be one of the most virulent allergens in autumnal hay fever (Liu et al., 2010). Studies on the prevalence rates of *Ambrosia* spp. draw attention to two different trends. Whereas in regions with high infestation (e.g., Hungary) prevalence rates of around 50% are observed, lower prevalence rates of ca. 12% prevail in many Central and Western European countries (Burbach et al., 2009a; Hemmer et al., 2009; Gabrio et al., 2010). The prevalence rates of *Artemisia* spp. range between 10 and 15% (Stach et al., 2007; Gioulekas et al., 2004; Gadermaier et al., 2004; Hemmer et al., 2009). *I. xanthiifolia* was not included in the CBA with regard to human health effects as we could not identify studies on prevalence rates.

Not every patient that is otherwise allergic to pollen automatically reacts with clinically relevant allergy symptoms. Hence, in addition to prevalence rates it is also necessary to estimate the proportion of clinically manifested symptoms. The EU-wide GA(2)LEN study suggests that the rate of clinical manifestation among patients allergic to *Ambrosia* and *Artemisia* species is 62.4% and 65.1% in Austria, and 64.6% and 84.9% in Germany, respectively (Burbach et al., 2009b). These figures might overestimate the actual rate of clinical manifestation as the major part of this study was based on patient self-reporting during the pollen seasons (Grosskopf, 2010). A more conservative figure is put forward by Behrendt et al. (2010) who suggest that the rate of clinical manifestation caused by *A. artemisiifolia* is more likely to range between one quarter and one third in Germany.

2.4. The effects on agriculture

As for the negative effects on agriculture, *A. trifida* and *I. xanthiifolia* qualify as competitive weeds. In many crops, *A. trifida* is a predominant weed, and it is most prevalent in maize and soybean fields in the United States, Canada and China (Basset and Crompton, 1982; Baysinger and Sims, 1991; Kong et al., 2007; Williams et al., 2008). In North America, *I. xanthiifolia* can be found mainly in sunflower and soybean fields in the Midwestern States (USDA, 1972; Olson et al., 2011). In CEE, both species occur as a weed in several countries, including Hungary, the Czech Republic,

[1] Czech Republic, Germany, Hungary, Slovakia, Slovenia, Switzerland and northern parts of Croatia and Italy (i.e., the regions Aosta Valley, Friuli-Venezia Giulia, Liguria, Lombardy, Piedmont, Trentino-Alto Adige, Veneto) and Serbia (Vojvodina, parts of central Serbia).