

PUBLIZIERBARER ENDBERICHT

A) Projektdaten

Kurztitel:	ClimAllergy
Langtitel:	Climate change induced invasion and socio-economic impacts of allergy-inducing plants in Austria
Programm:	ACRP 2 nd Call for Proposals
Dauer:	24 Monate
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Projektübersicht

1 Summary (German)

Es gibt zahlreiche Hinweise darauf, dass der Klimawandel die Pollensaison verlängert und die Menge an Pollen sowie ihre Allergenität nachhaltig beeinflusst. Gleichzeitig fördert der Klimawandel die Einwanderung und Ausbreitung wärmeliebender Pflanzen mit starkem allergenen Potenzial. Die Kenntnisse über die Ausbreitungsdynamik solcher Pflanzenarten und ihre potenziellen Auswirkungen auf die Gesundheit der österreichischen Bevölkerung sind jedoch zurzeit begrenzt. In dem Projekt ClimAllergy haben wir die allergenen Pflanzen Dreispaltiges Traubenkraut (*Ambrosia trifida*), Einjähriger Beifuß (*Artemisia annua*) und Rispenkraut (*Iva xanthiifolia*) als Modellpflanzen verwendet. Alle drei Arten sind Neophyten, d. h., sie sind nicht heimisch in Österreich. Das Dreispaltige Traubenkraut und das Rispenkraut stammen ursprünglich aus Nordamerika und der Einjährige Beifuß aus Asien. Diese wärmeliebenden Arten haben ihre Vorkommen und ihr Areal insbesondere in den Nachbarländern (z. B. Ungarn, Italien) in den letzten Jahren deutlich vergrößert. Daher ist zu erwarten, dass sich diese Arten – verstärkt durch den Klimawandel – auch in Österreich ausbreiten werden mit potenziellen gesundheitlichen Folgen für die Bevölkerung. Das Ziel des Projekts war es, die aktuelle Verbreitung der drei Modellpflanzen in Österreich und seinen Nachbarländern zu dokumentieren, ihr zukünftiges Areal zu prognostizieren sowie effektive und kostengünstige Maßnahmen zur Eindämmung und Kontrolle zu erarbeiten.

In den Arbeitspaketen 1 und 2 haben wir alle Verbreitungsdaten der drei Modellpflanzen in Österreich und den Nachbarländern (Deutschland, Tschechien, Slowakei, Norditalien, Kroatien [Mittel- und Ostkroatien], Slowenien, Schweiz, Serbien [Vojvodina], Ungarn) von ihrem Erstauftreten bis zum Jahr 2011 gesammelt (Quellenbasis: floristische Datenbanken, nationale Kartierungsprojekte und Herbarien, floristische Literatur und länderübergreifende Expertenbefragung). Die räumliche Auflösung der Funddaten folgt dem Quadrantenraster der floristischen Kartierung (5 x 3 geografische Minuten, ca. 33 km²). Basierend darauf haben wir die aktuelle Verbreitung dieser drei Arten kartografisch dokumentiert und ihre räumlich-zeitliche Ausbreitungsdynamik in Mittel- und Osteuropa analysiert. Insgesamt konnten wir für das Dreispaltige Traubenkraut 324 (Österreich: 8), den Einjährigen Beifuß 1804 (41) und für das Rispenkraut 1603 (44) Funde zusammentragen. Alle drei Arten sind zum ersten Mal im 19. Jahrhundert in Mittel- und Osteuropa aufgetreten. Die Arten blieben selten, erst ab Mitte des 20. Jahrhunderts sind Neufunde des Einjährigen Beifußes und des Rispenkrauts deutlich angestiegen, was bis heute anhält. Das Dreispaltige Traubenkraut breitete sich deutlich langsamer aus. In Österreich sind die Arten bis heute jedoch nur selten zu beobachten. Sie besiedeln vorwiegend ruderale Standorte (u. a. Müllplätze, Ödland), Straßenränder, Eisenbahnwege und landwirtschaftliche Flächen. Das Dreispaltige Traubenkraut und das Rispenkraut gelten als bedeutende landwirtschaftliche Unkräuter. Des Weiteren haben wir eine Literaturrecherche zu den Auswirkungen aller drei Pflanzen auf die Gesundheit und die Landwirtschaft durchgeführt als Basis für das Arbeitspaket 4.

Im Arbeitspaket 3 haben wir für die drei Arten mit Hilfe einer Habitatmodellierung ihre geeigneten Habitate (auf Basis des Quadrantenrasters der floristischen Kartierung) unter aktuellen

klimatischen Bedingungen in Mittel- und Osteuropa sowie eine Prognose ihres zukünftigen Ausbreitungsverhaltens unter Klimawandelszenarien abgebildet. Für die Habitatmodellierung wurden vier verschiedene Regressionstechniken ausgewählt und kombiniert ausgewertet (ensemble forecast): Generalized Linear Models (GLM), Generalized Additive Models (GAM), Boosted Regression Trees (GBM) und Multiple Adaptive Agression Splines (MARS). Dabei wurde ein umfassendes Set an Klimavariablen (WorldClim; <http://www.worldclim.org/bioclim>) und Umweltvariablen verwendet (topografische Daten, Infrastrukturinformationen, Landbedeckungsdaten, Fließgewässernetz). Der gewählte Prognosezeitraum war 2020 und 2050. Für die Vorhersagen wurden fünf globale Zirkulationsmodelle (CGCM2, EchAM5, HadCM3, HadCM3, HadGEM1) und drei Emissionsszenarien (moderate [B2] und stärkere [A1, A2] prognostizierte Erhöhung der globalen Durchschnittstemperatur) herangezogen. Die Ergebnisse der Habitatmodellierung liegen als Habitateignungskarten vor, wobei die Habitateignung für jeden Quadrant und jede Art in „ungeeignet“ und „geeignet“ eingeteilt wurde.

Die Ergebnisse zeigen, dass die gegenwärtigen Invasions-Hotspots für alle drei Arten in Norditalien und in Gebieten mit einem kontinentalen und wärmeren Klima liegen. In Österreich sind unter gegenwärtigen Klimabedingungen 7,85 %, 10,53 % bzw. 12,75 % der Fläche (östliches Donautiefland, Wiener Becken) für das Dreispaltige Traubenkraut, den Einjährigen Beifuß und das Rispenkraut geeignet. Das Ausmaß der Zunahme der besiedelbaren Fläche ist mit der Intensität des vorhergesagten Klimawandels und dem Zeithorizont eng korreliert. Die geeignete Fläche erhöht sich für den Einjährigen Beifuß und für das Rispenkraut um nahezu das Dreifache bis 2050, während das Invasionsrisiko des Dreispaltigen Traubenkrauts je nach gewähltem Szenario eher gleichbleibt oder gar abnimmt. Die Ergebnisse lassen den Schluss zu, dass alle drei Arten zurzeit keine Gefahr für die Gesundheit (und Landwirtschaft) darstellen, da sie nur selten in Österreich auftreten. Allerdings zeigt die Habitatmodellierung ein großes bisher nicht realisiertes Invasionspotenzial für alle Arten unter gegenwärtigen Klimabedingungen. Hinzu kommt, dass insbesondere der Einjährige Beifuß und das Rispenkraut vom Klimawandel stark profitieren werden. Daher ist eine Strategie zur Eindämmung und Kontrolle der Arten notwendig. Dabei ist wichtig, die Kosten für die Gesundheit und Landwirtschaft abzuschätzen, weil sie in Relation gesehen werden müssen zu den Kosten, die eine Eindämmung der Pflanze verursacht.

Im Arbeitspaket 4 wurde eine Kosten-Nutzen-Analyse für Österreich durchgeführt unter dem Gesichtspunkt, ob Ressourcen (Kosten) für ein vorsorgliches Management gegen die weitere Ausbreitung der drei Arten verwendet werden sollen und ob die Kosten geringer als die Nutzeffekte (für das Gesundheitswesen und die Landwirtschaft) dieser Maßnahmen sind. Die Pollenbelastung für die Bevölkerung in einem Quadranten wurde für zwei Klimawandelszenarien („konservativ“ [CGCM2 B2] vs. „worst case“ [HadCM3 A1]), zwei Ausbreitungsmodelle („realistisch“ mit einer radialen Ausbreitung um bestehende Populationen und zufallsbedingte Besiedlung von Quadranten durch eine Fernausbreitung vs. „maximal“ d. h., alle geeigneten Habitate werden besiedelt) und zwei Maßnahmenzenarien („keine Bekämpfung“: ungehinderte Ausbreitung, Pollenbelastung durch lokale Populationen und Pollenzuflug aus den Nachbarländern; „vollständige Bekämpfung“: Ausrottung auftretender Populationen in Österreich, Pollenzuflug nur aus den Nachbarländern) simuliert. Diese acht Ausbreitungsmodelle lieferten Daten für die Pollenbelastung und den Befall der Quadranten im Dreijahresintervall für den Zeitraum bis 2050. Für die Berechnung der Pollenbelastung wurde ein einfacher isotroper Gaußscher Kern verwendet mit der höchsten

Belastung im Kern selbst und einer Abnahme zur äußeren Grenze. In einem weiteren Schritt wurde die betroffene Bevölkerung in jedem Quadranten berechnet, indem diese mit Bevölkerungsdaten verschnitten wurde. Dabei wurde auch die zukünftige Bevölkerungsentwicklung berücksichtigt. Daraufhin wurden die Kosten für ein Managementprogramm (Aktionsplan: Koordination, Training des Personals, Präventionssystem u. a., GIS-Datenbank zur Dokumentation der Verbreitung, Kosten für die direkte Bekämpfung der Arten in jedem Quadranten) und die Nutzeffekte für das Gesundheitswesen (vermiedene Kosten pro Patient) und die Landwirtschaft (vermiedene Ertragsverluste pro ha) abgeschätzt. Die durchschnittlichen Behandlungskosten für einen Patienten haben wir auf 700 € („konservatives“ Szenario) bzw. 1.683 € („worst case“ Szenario) geschätzt. Um die Mehrkosten für die Behandlung von Allergien verursacht durch unsere Modellpflanzen abzuschätzen, haben wir angenommen, dass diese Arten die Pollensaison um zwei Monate verlängern (die Pflanzen blühen im Spätsommer und bis in den Herbst). Anders ausgedrückt besteht der Nutzeffekt darin, dass die Pollensaison in ihrem derzeitigen Ausmaß bleibt. Die damit verbundenen Mehrkosten belaufen sich daher auf 2/12 der durchschnittlichen Behandlungskosten eines Patienten. Für die Landwirtschaft wurde entsprechend ein „konservatives“ (1 % Ertragsverlust) und ein „worst case“ Szenario (5 %) gewählt, um die Auswirkungen auf ausgesuchte landwirtschaftliche Kulturen (Mais, Sojabohne, Sonnenblume) zu simulieren. Die Nutzeffekte für die Landwirtschaft wurden auf Basis der gefährdeten Anbaufläche in jedem Quadranten (Input von den Ausbreitungsmodellen, Daten zur Anbaufläche) und den Erzeugerpreisen und Erträgen berechnet.

Die Ergebnisse der Kosten-Nutzen-Analyse zeigen, dass (1) für alle Szenarien Nutzeffekte generiert werden. Sogar für das „konservativste“ Szenario (d. h. unter der Annahme eines moderaten Klimawandels, geringen Behandlungskosten und Ertragsverlusten in der Landwirtschaft) liegen die Nutzeffekte bei 96,4 Mio. € (0 % Diskontsatz) bzw. 34,5 Mio. € (5 %). Beim „worst case“ und dem am wenigsten wahrscheinlichen Szenario liegen die Nutzeffekte entsprechend deutlich höher 2.747,7 € Mio. (0 % Diskontsatz) bzw. 884,4 Mio. € (5 %). Darüber hinaus (2) beruht der überwiegende Teil dieser Nutzeffekte auf der Vermeidung allergiebedingter Erkrankungen und (3) bei einer Einzelbetrachtung der drei Arten würde die Bekämpfung des Einjährigen Beifußes die größten Nutzeffekte erbringen. Des Weiteren (4) deuten die Ergebnisse darauf hin, dass eine zeitnahe Bekämpfung des Einjährigen Beifußes und des Rispenkrauts zu positiven Nutzeffekten führt.

Bei der Interpretation der Ergebnisse sind einige Limitierungen zu berücksichtigen. Zuverlässige Daten zur Auswirkung der drei Arten auf die Gesundheit waren nur unzureichend vorhanden, daher mussten wir auf Daten naher verwandter Arten derselben Pflanzenfamilie (*Ambrosia artemisiifolia*, *Artemisia vulgaris*) zurückgreifen. Die Auswirkungen auf die landwirtschaftlichen Kulturen stellen nur eine grobe Schätzung dar und beruhen nicht auf experimentellen Untersuchungen. Die Modellierung der Pollenbelastung wurde relativ vereinfacht durchgeführt. Schlussendlich beruhen die Kosten für die polleninduzierten Krankheiten auf sehr spezifischen Annahmen. Besonders schwierig erwies es sich, die resultierenden Mehrkosten zusätzlich zu den bestehenden Kosten zu quantifizieren, weshalb wir einen konservativen Kostensatz veranschlagt haben.

Das Projekt vermittelt einen Eindruck der Kostendimension des Problems der allergenen Pflanzen und es unterstreicht, dass durch proaktive, zeitnahe und konzertierte Maßnahmen gegen solche Pflanzen zukünftig anfallende Kosten deutlich begrenzt werden können. Darüber hinaus zeigt das Projekt, dass Kosten-Nutzen-Analysen ein geeignetes Instrument sind, um Auswirkungen und ökonomische Kosten von aufkommenden invasiven Pflanzenarten zu erfassen.

2 Executive Summary

There is much evidence that global warming increases pollen quantity, pollen allergenicity and induces longer pollen seasons. One of the key issues, however, is that climate change may alter the distribution of allergy-inducing plant species. At present there is a lack of knowledge on the range dynamics of allergy-inducing plant species in relation to climate change and to what extent the human population in Austria will be affected. There is a strong need for adaptive strategies for their control and containment. We have chosen the allergy-inducing species *Iva xanthiifolia* (burweed marshelder), *Artemisia annua* (annual mugwort) and *Ambrosia trifida* (giant ragweed) as model plants for this project.

Based on distribution data of the species studied, we analysed the reasons and underlying mechanisms of their invasion in central and eastern Europe (CEE) in order to better understand the spatial-temporal invasion pattern and the factors which govern the current distribution in the region studied. Moreover, we conducted an extensive literature review (ELR) on management options and impacts on human health, agriculture and environment. We assessed the current and future distribution of the species studied in CEE by means of species distribution models (SDMs). We used several different climate change scenarios to account for differences in Global Circulation Models and Emission Scenarios. Moreover, a cost-benefit-analysis (CBA) was applied. Based on the current and future plant distribution and expected pollen load, we estimated management costs (for surveillance and eradication of the target species) as well as agricultural and health benefits (in terms of avoided allergy induced health costs and yield loss) in Austria. Recommendations were produced based on discussion and results were disseminated to target groups.

The species studied were first recorded in the 19th century, remained rare until the mid-20th century, but particularly *A. annua* and *I. xanthiifolia* have spread strongly in recent decades in parts of CEE. In Austria, the plants have been rarely found so far. At present, it seems that all three species do not represent an urgent threat for human health and agriculture. However, the SDMs showed that there is substantial non-realized invasion potential for *A. trifida*, *A. annua* and *I. xanthiifolia* in the area studied including Austria. Our results suggest that climate warming leads to a considerable acceleration of the spread of *A. annua* and *I. xanthiifolia* and only to a lesser extent of *A. trifida* in Austria and neighbouring countries. The likely associated effects on human health and agriculture call for the development of a pro-active management strategy focused on surveillance, systematic prevention and early control/eradication.

The CBA demonstrated that a timely and coordinated control strategy is beneficial in all simulated scenarios. Even in the most conservative case that assumes limited spread of the species, a moderate climate change effect as well as prudent parameters for socio-economic impacts the estimated net benefits would amount to €96.4 mio (0% discount rate) or €34.5 mio (5% discount rate). If we were to assume a stronger climate change effect and more dire consequences for human health and agriculture these net benefits could be as high as €2.747,7 mio (0% discount rate) or € 884.4 mio (5% discount rate). We conclude that it is wise to act early and determined to halt further spread of the species studied and emerging invasive alien plants (IAP) in Austria in general.

3 Hintergrund und Zielsetzung

In recent years, increasing risks to public health associated with climate change have gained much attention. Amongst others major concerns for human health are allergic diseases (Beggs & Bambrick 2005). Rhinitis, asthma and conjunctivitis are major causes of loss of productivity and increasing healthcare costs. In Europe, the prevalence of allergic disorders has constantly increased during the second half of the 20th century, which inter alia can be attributed to climate change (Beggs & Bambrick 2005). There is much evidence that global warming increases pollen quantity, pollen allergenicity and induces longer pollen seasons (Beggs 2004). One of the key issues, however, is that climate change may alter the distribution of allergy-inducing plant species (e.g. Emberlin et al. 1994, Levetin & Van De Water 2008). Particularly, the establishment of new populations of allergy-inducing plant species in the immediate vicinity of human population centres may increase local pollen load and hence, the (local) risk of allergenic disorders. At present there is a lack of knowledge on the range dynamics of allergy-inducing plant species in relation to climate change and to what extent the human population in Austria and in the neighbouring European countries will be affected. There is a strong need for adaptive strategies for their control and containment. This present interdisciplinary project proposal considered the socio-economic costs of an invasion of allergy-inducing plants by exploring the consequences of contrasting options of action versus inaction, and it identifies strategies for reducing their impact.

We have chosen *Iva xanthiifolia* (burweed marshelder), *Artemisia annua* (annual mugwort), and *Ambrosia trifida* (giant ragweed) as model plants for this project, because they are highly allergyinducing weed species causing hay fever, asthma, and dermatitis and they are still rare or very rare in Austria (Fischer et al. 2008), but already established and currently expanding their range in several neighbouring European countries (Jehlik 1998, Follak 2009). It can be expected that climate change triggered spread of these species would severely aggravate problems for the public health sector in Austria.

The objectives of the project were:

- (1) to reconstruct the invasion history of *A. trifida*, *A. annua* and *I. xanthiifolia* in Austria and neighbouring European countries (work package [WP] 1)
- (2) to map the current distribution of *A. trifida*, *A. annua* and *I. xanthiifolia* in Austria and neighbouring European countries (WP 2),
- (3) to projected the distribution of *A. trifida*, *A. annua* and *I. xanthiifolia* under current climate and climate change in Austria and neighbouring European countries (WP 3),
- (4) to evaluate the costs and benefits of controlling the spread of *A. trifida*, *A. annua* and *I. xanthiifolia* under climate change in Austria (WP 4),
- (5) to develop a cost-efficient management strategy to reduce invasion risk of the species studied and to disseminate the results to different target groups (WP 5).

4 Projektinhalt und Ergebnis(se)

Work packages 1 & 2

Invasion history and current distribution

The three species: *Ambrosia trifida*, *Artemisia annua* and *Iva xanthiifolia*

Ambrosia trifida L. (giant ragweed)

Giant ragweed is summer annual species of 30–150(–400+) cm height, fibrous-rooted with a relatively short taproot (Fig. 1). The plant is characterised by its temporal emergence pattern, rapid and aggressive growth, and persistence over a range of soil disturbances. *A. trifida* is native to riverbanks and lakeshores north of the Ohio River. The plant has a high economic impact on crop yields and the allergenic pollen is causing considerable problems for public health in the United States and Canada.



Fig. 1: Flowers are growing in bunches and leaves are three-lobed. Large population of *Ambrosia trifida* in a cereal field (right) (Photos: © S. Follak; Velký Osek, CZ, 28.07.2012).

Artemisia annua L. (annual wormwood)

Annual wormwood is an annual herbaceous aromatic plant of 30–200(–300) cm height (Fig. 2). The plant is pioneer species and is characterised by a high degree of morphological and reproductive plasticity and a high seed production. The plant is native to East Asia, most probably to Inner Mongolia in China. Pollen from *A. annua* is an important cause of allergic disorders in its native and introduced range.



Fig. 2: Inflorescence of *Artemisia annua* (left) and a large population on a ruderal place (right)
(Photos: © Pavol Eliáš; Kameničná, SK, undated).

Iva xanthiifolia Nutt. (burweed marshelder)

Burweed marshelder is a summer annual species of 30–200(–300) cm height arising from a taproot (Fig. 3). The plant is native to North American prairies. Today, the species can be found southwards near to the Mexican border and to the west coast and east of the Mississippi River and adjacent Canada. Since the middle of the 19th century, and in particular the middle of 20th century the plant was introduced to many countries throughout Europe. The plant is an agricultural weed and an important inducer of hay fever.



Fig. 3: *Iva xanthiifolia* before flowering (left). Large population behind a warehouse (right)
(Photos: © S. Follak; Galanta, SK, 15.08.2012)

Invasion history and distribution

We collated 1,804 records of *A. annua*, 1,063 records of *I. xanthiifolia*, and 324 records of *A. trifida* in CEE. All species were first recorded in the 19th century, but remained rare until the mid-20th century. The cumulative number of records of *A. trifida*, *A. annua* and *I. xanthiifolia* in CEE has

increased over time since their introduction into CEE (Fig. 4). *A. trifida* showed only a moderate increase. For *A. annua*, there was a constant increase of records already from the 1890s onwards until the 1970s. Then records increased distinctly and spread became particularly pronounced after 1995 with the number of records more than duplicating. Our data indicate a distinct lag phase for *I. xanthiifolia*, since records were scarce until 1950, but have sharply increased since then (>80% of all records have been made since then).

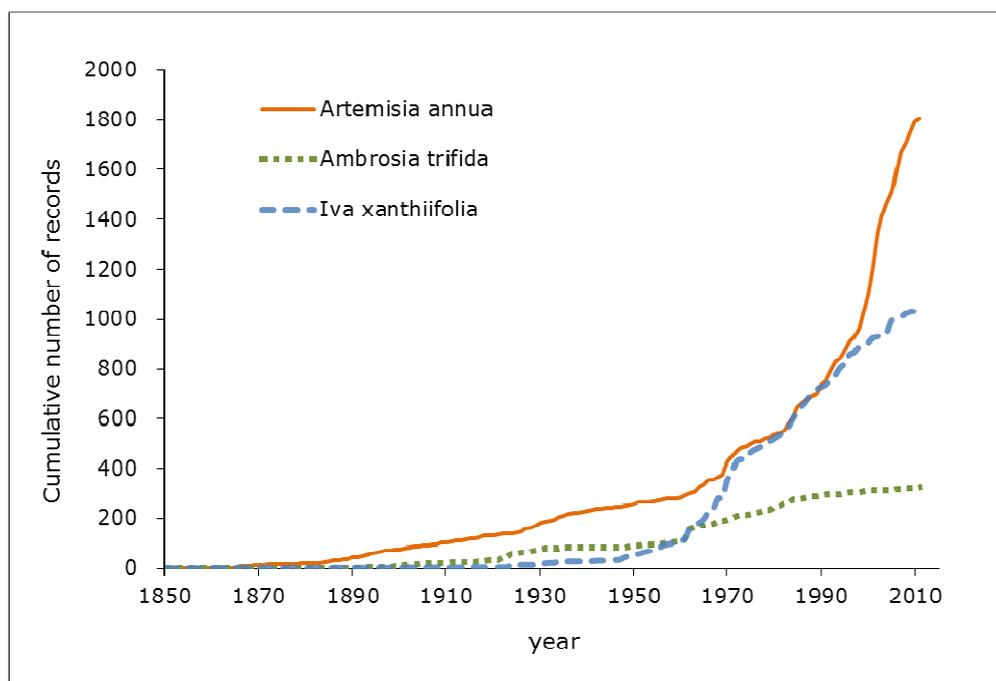
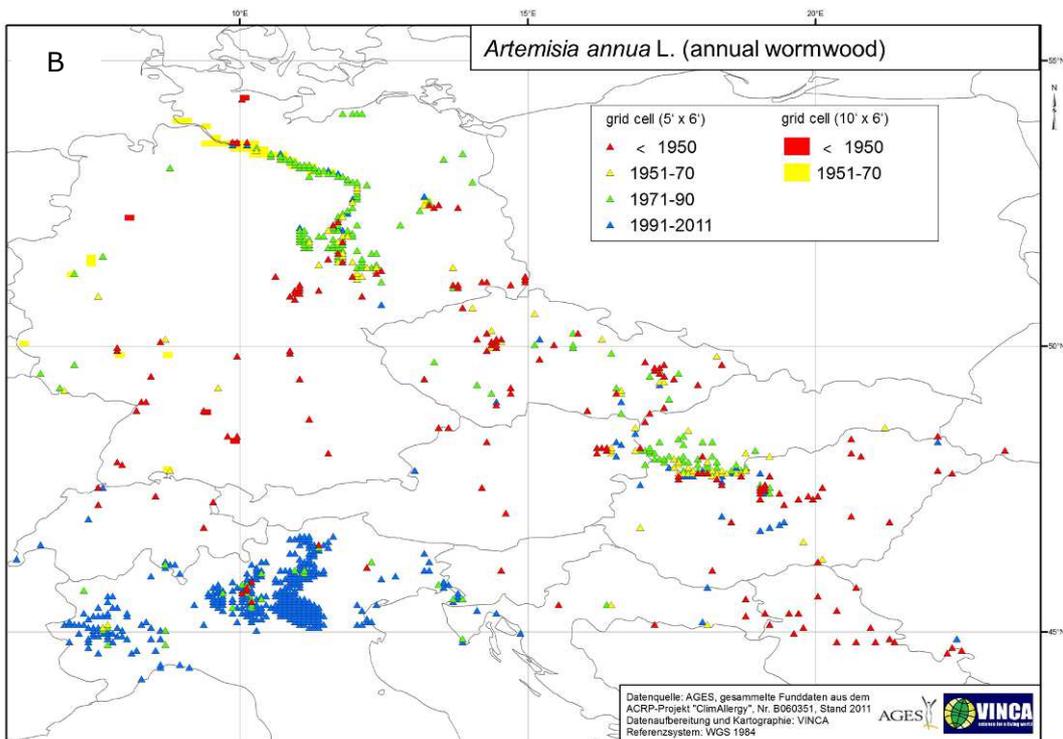
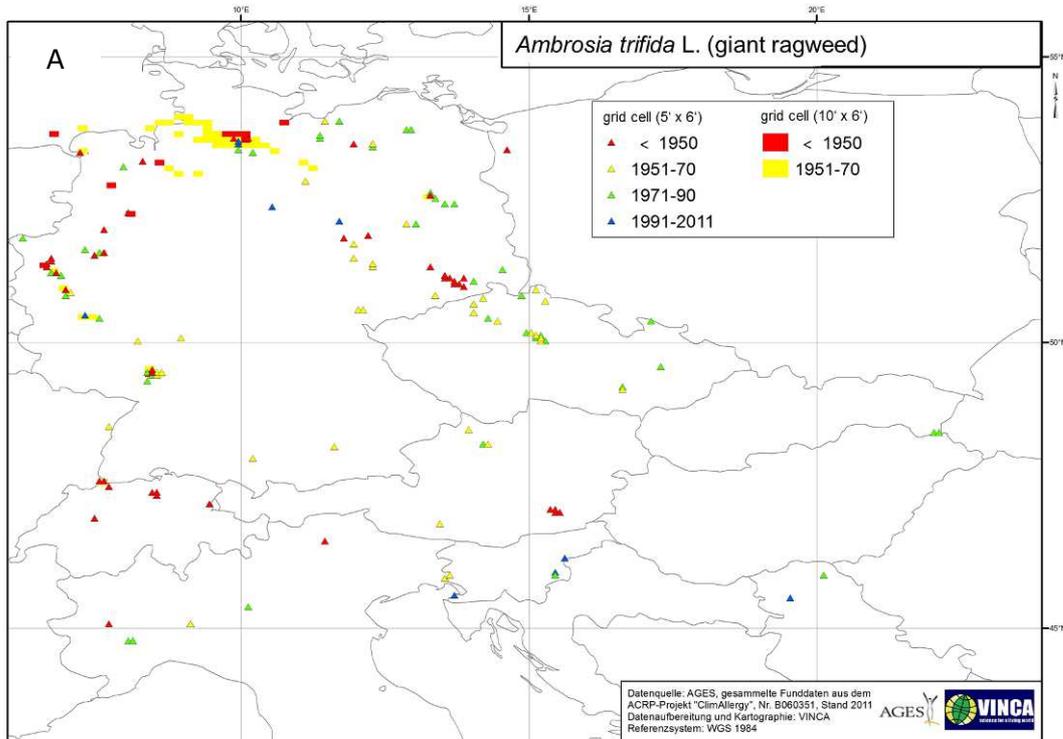


Fig. 4: Curves of the colonization (i.e. cumulative number of records) by *Ambrosia trifida*, *Artemisia annua* and *Iva xanthiifolia* of central and eastern Europe (adapted from Follak et al. 2013).

The current distribution of *A. trifida* consists of only few localities (Fig. 5A). It is most widespread in northern parts of CEE, in particular in Germany, Switzerland and the Czech Republic where it has been predominantly recorded in larger cities along the rivers Rhine and Elbe (i.e. Basel, Dresden, Hamburg, Mannheim Ruhr). A few established populations are currently found e.g. in Serbia, Italy and in the Czech Republic. It is presumed that there are presently no actual populations of *A. trifida* in Austria. *A. annua* is present in all countries of the study region, but the distribution is very uneven with several regions being heavily invaded (Fig. 5B). These invasion hotspots are mostly associated with large river valleys in particular in Germany (Elbe and Saale), in Slovakia and Hungary (Danube) and N-Italy (e.g. Adige). Populations can be found in larger cities and their vicinities in the Czech Republic, Germany, Hungary and northern Italy. In the remainder of CEE, records are sparse. *A. annua* occurs currently mostly in the Eastern part of Austria. At present, *I. xanthiifolia* is most widespread in warm continental lowlands in the eastern part of the study region (Fig. 5C). Throughout most of the remaining CEE, *I. xanthiifolia* is uncommon except for some larger cities and areas along the rivers Rhine (Ruhr, Mainz, and Mannheim) and Elbe (Hamburg). In

Austria, the plant is rare and has been occasionally found in Graz, Linz and Vienna and in the eastern lowlands (Lower Austria, Vienna, and Burgenland).



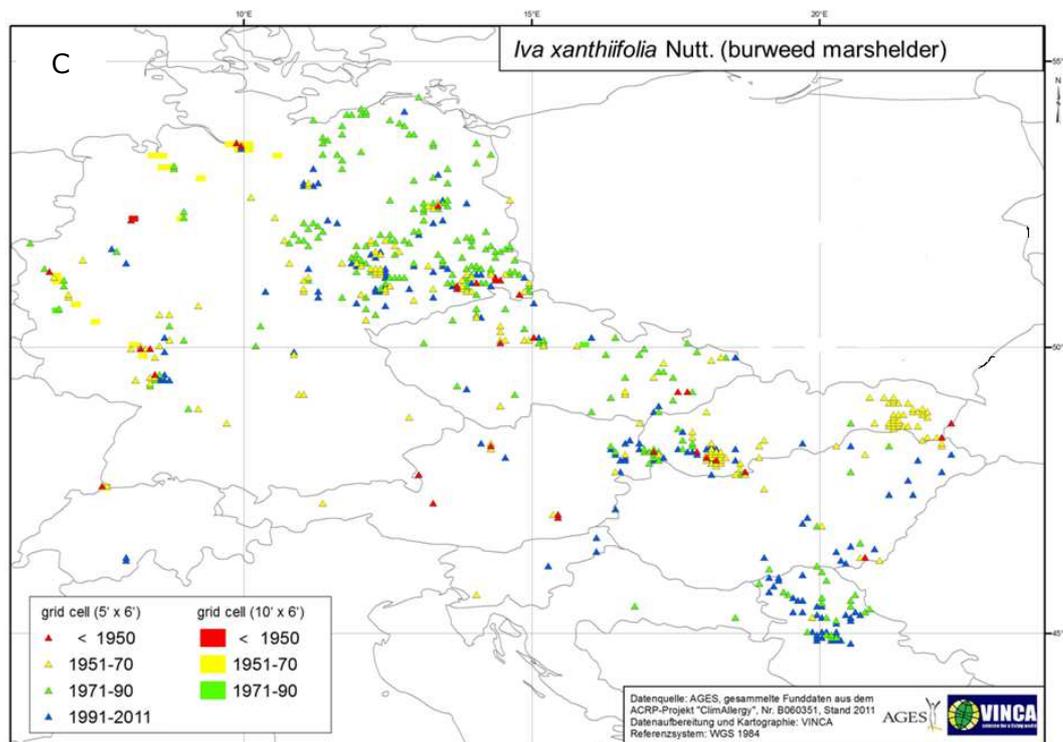


Fig. 5: Distribution maps of *Ambrosia trifida* (A), *Artemisa annua* (B) and *Iva xanthiifolia* (C) in central and eastern Europe for the periods < 1950 (red triangle), 1951–1970 (yellow), 1971–1990 (green), and 1991–2011 (blue). Records have been assigned to a grid cell (5 × 3 geographic minutes) of the Floristic Mapping Project of Central Europe. Few records in Germany could only be assigned to larger grid cells (6 × 10 geographic minutes) (Follak et al. 2013).

Work package 3

Projected distribution under current climate and climate change

Currently, the three species studied occupy less than 1.5% of all suitable grid cells of the FMCE raster across CEE (Table 1). However, SDMs show that under current climatic conditions approximately 16%, 28% and 26% of all grid cells are suitable for *A. trifida*, *A. annua* and *I. xanthiifolia*, respectively. The spatial pattern of suitable habitats in CEE is rather similar for the three study species, with lowland regions in the east and south being most suitable. In Austria, 7.85%, 10.53% and 12.75% of all grid cells are suitable for *A. trifida*, *A. annua* and *I. xanthiifolia*. All climate change scenarios predict increasing invasion risk for *A. annua* and *I. xanthiifolia*. The magnitude of increase, however, depends on the climate change scenario and the time horizon. For *A. annua* and *I. xanthiifolia* the suitable area in CEE increases almost 3.0-fold in 2050. The invasion risk of *A. trifida* is predicted not to rise strongly or even declines in CEE.

Table 1: Potential occupied grid cells by the species studied in CEE under different climate change scenarios.

Scenario	<i>Ambrosia trifida</i>			<i>Artemisia annua</i>			<i>Iva xanthiifolia</i>		
	un-suitable	suitable	suitable [%]	un-suitable	suitable	suitable [%]	un-suitable	suitable	suitable [%]
real	28564	50	0.17	28178	436	1.52	28402	212	0.74
current climate	24115	4499	15.72	20531	8083	28.25	21176	7438	25.99
cgcm2b2a 2020	25529	3085	10.78	6709	21905	76.55	8575	20039	70.03
cgcm2b2a 2050	22258	6356	22.21	5386	23228	81.18	6320	22294	77.91
echam5a1b 2020	25253	3361	11.75	5091	23523	82.21	6671	21943	76.69
echam5a1b 2050	24310	4304	15.04	1888	26726	93.40	3964	24650	86.15
hadcm3a1b 2020	22276	6338	22.15	4302	24312	84.97	5799	22815	79.73
hadcm3a1b 2050	21660	6954	24.30	1821	26793	93.64	3823	24791	86.64
hadcm3a2a 2020	25548	3066	10.72	7744	20870	72.94	10252	18362	64.17
hadcm3a2a 2050	23928	4686	16.38	3422	25192	88.04	6689	21925	76.62
hadgem1a1b 2020	24683	3931	13.74	4969	23645	82.63	6182	22432	78.40
hadgem1a1b 2050	24683	3931	13.74	4969	23645	82.63	6182	22432	78.40

At present, it seems that all three species do not represent an urgent threat for human health and agriculture. However, the SDMs showed that there is substantial non-realized invasion potential for *A. trifida*, *A. annua* and *I. xanthiifolia* in the area studied including Austria. Moreover, our results suggest that climate warming leads to a considerable acceleration of the spread of *A. annua* and *I. xanthiifolia* and only to a lesser extent of *A. trifida* in Austria and neighbouring countries. The likely associated effects on human health and agriculture call for the development of a pro-active management strategy to halt further spread of the species studied. Hence, a CBA was applied where we estimated management costs as well as agriculture and health benefits (see WP 4).

Work package 4

Evaluating the costs and benefits of controlling the spread of *A. trifida*, *A. annua* und *I. xanthiifolia* under climate change in Austria

In this WP, a CBA was applied. Based on the current and future plant distribution we estimated management costs (for the control/eradication of the target species) as well as agriculture and health benefits (in terms of avoided allergy induced health costs and agriculture yield loss).

The results of the CBA suggested that a timely and coordinated response to the spread of the three species studied is beneficial in all simulated scenarios (Table 2, Table 3). Even in the most conservative case that assumes limited spread of the species, a moderate climate change effect as well as prudent parameters for socio-economic impacts the estimated net benefits would amount to €96,4 mio (0% discount rate) or €34,5 mio (5% discount rate) for the whole period. If we were to assume a stronger climate change effect and more dire consequences for human health and agriculture these net benefits could be as high as €2.747,7 mio (0% discount rate) or € 884,4 mio (5% discount rate) (Table 2 & 3). The major share of the net benefits is derived from avoiding pollen-induced allergies. This is less surprising as we have taken a rather prudent approach in modelling the agriculture impacts. The greatest impact is generally associated with limiting the pollen allergy potential of *A. annua*. In contrast, impacts associated with *A. trifida* and *I. xanthiifolia* tend to be smaller, although under some specific scenarios they can also become substantial. Moreover, leaving the background scenarios aside and focusing only on the limited plant spread scenarios supports the case for a systematic eradication of the plants. Even an isolated perspective - comparing the management costs for all plants and the benefits for each plant - suggests that a timely intervention would yield into positive net benefits, except for one specific case of *A. trifida* (b2a-limit assuming conservative agriculture and health impacts and a 5% discount rate).

Some limitations should be highlighted and need to be taken into account when interpreting our results. Firstly, our estimates on agriculture related impacts of the three species studied constitute only a rough approximation without reflecting the results of experimental yield loss studies. Secondly, we used available data on health impact from close relatives (i.e. *Artemisia vulgaris*, *Ambrosia artemisiifolia*) within the same species family because data on the health impact for our species studied was lacking. Thirdly, modelling of the pollen load data and its impact in terms of pollen allergies might be exhibited more sophisticatedly. Lastly, the cost of pollen-induced allergies is based on very specific assumptions. As most patients tend to be poly-sensitized it is difficult to link costs to one specific allergy source. Hence, we assumed that controlling the three plants would spare the poly-sensitized patients two months of additional suffering. The annual average cost of pollen allergy is at the lower end of estimates as some direct health costs, particularly private household expenses for medication, are likely to be higher. Also specific indirect costs (e.g. reduced productivity at the workplace) were not considered in our model.

Despite these limitations the results of our study give an estimate on the dimensions of costs linked to allergy-inducing plants (and weed species) and they underline that the socio-economic benefits, which can be captured by a concerted effort of public authorities, are substantial.

Therefore, it is highly advisable to act preventively to stop the spread of *A. trifida*, *A. annua* and *I. xanthiifolia* in Austria and beyond.

Table 2: Net benefits under conservative and worst-case assumptions for the period 2011-2050 (in mio. €, undiscounted).

Scenario	Conservative Assumptions (Discount Rate: 0%)			
	a1b-limit	a1b-max	b2a-limit	b2a-max
Management Costs	20.5	188.3	11.0	66.9
<i>A. annua</i> : Health Benefits	95.0	151.5	64.4	80.5
<i>A. trifida</i> : Health Benefits	70.5	119.8	15.9	94.0
<i>A. trifida</i> : Agriculture Benefits	7.1	n/a	0.2	n/a
<i>I. xanthiifolia</i> : Agriculture Benefits	54.7	n/a	26.9	n/a
<i>Net Benefits</i>	206.8	82.9	96.4	107.7
Scenario	Worst-Case Assumptions (Discount Rate: %)			
	a1b-limit	a1b-max	b2a-limit	b2a-max
Management Costs	20.5	188.3	11.0	66.9
<i>A. annua</i> : Health Benefits	1,641.1	2,617.8	1,113.7	1,392.1
<i>A. trifida</i> : Health Benefits	818.1	1,390.7	184.4	1,091.7
<i>A. trifida</i> : Agriculture Benefits	35.5	n/a	1.2	n/a
<i>I. xanthiifolia</i> : Agriculture Benefits	273.5	n/a	134.3	n/a
<i>Net Benefits</i>	2,747.7	3,820.1	1,422.6	2,416.9

Table 3: Net benefits under conservative and worst-case assumptions for the period 2011-2050 (in mio. €, 5% discount rate).

Scenario	Conservative Assumptions (Discount Rate: 5%)			
	a1b-limit	a1b-max	b2a-limit	b2a-max
Management Costs	6.0	61.5	3.8	23.4
<i>A. annua</i> : Health Benefits	30.1	57.8	23.0	30.5
<i>A. trifida</i> : Health Benefits	20.0	45.8	3.0	38.4
<i>A. trifida</i> : Agriculture Benefits	3.2	n/a	0.1	n/a
<i>I. xanthiifolia</i> : Agriculture Benefits	24.6	n/a	12.1	n/a
<i>Net Benefits</i>	71.9	42.0	34.5	45.5
Scenario	Worst-Case Assumptions (Discount Rate: 5%)			
	a1b-limit	a1b-max	b2a-limit	b2a-max
Management Costs	6.0	61.5	3.8	23.4
<i>A. annua</i> : Health Benefits	519.4	998.2	398.3	527.4
<i>A. trifida</i> : Health Benefits	231.8	531.3	34.7	445.5
<i>A. trifida</i> : Agriculture Benefits	16.0	n/a	0.6	n/a
<i>I. xanthiifolia</i> : Agriculture Benefits	123.2	n/a	60.5	n/a
<i>Net Benefits</i>	884.4	1.468.0	490.2	949.5

5 Schlussfolgerungen und Empfehlungen

It is an enormous challenge to take effective steps to prevent the spread and to contain or eradicate the species studied and IAP in general. Early detection and containment of invading and expanding populations of allergy-inducing plants should be an essential component of a successful adaptive strategy, and it is the most cost-effective management option for plants at an early stage of invasion.

Our results of the project suggest a strategic approach for emerging IAP, which may consist of the following parts:

1) Temporal, geographical, and biological information regarding the demographics of a given IAP is an obvious factor in devising suitable containment or eradication strategies for that species (see point 3). This information can be gathered by analysing retrospectively the plants' invasion history and providing data on the actual distribution. These data allows evaluating the spread dynamics, invasion hotspots, and introduction pathways of an IAP. Certainly, this is a time-consuming effort and often there is a lack of information in the scientific literature for most of IAP. However, it provides valuable information on the plants' behaviour in its new range and this information is a prerequisite for the evaluation of effective management options to halt or slow down its future spread.

2) Species distribution modelling (SDM) has become an important tool for assessing the species' potential range under current and potential future environmental and climatic conditions. This ability enables strategic control efforts to be maximized, as land owners and public authorities can be alerted to detect new infestations sufficiently early to implement effective containment, control or eradication strategies.

3) Management strategy could consist of the following components:

- Training system for municipal workers, maintenance service workers in infested regions
- Adoption of a "prevention system" including a GIS-database, maintenance of a detection system, public relations, training and reporting
- Establishment of coordination position which acts as a focal point for different stakeholders, including municipalities, the media and the general public
- Control/eradication of small and incipient populations (i.e. *via* hand pulling, brush cutter/lawn trimmer, herbicide application). However, in areas with established and larger populations of a certain IAP, more intensive and strategic control ("action plan") efforts may be needed and management should concentrate on containment and limiting the species' spread into previously uncolonized areas. The most effective way to limit the spread of IAP is to select grid cells for surveillance and management based on environmental suitability as predicted by SDMs (see point 2). Information from point 1) can provide additional information where to monitor. For example, transportation corridors may serve as means for rapid dispersal of a certain IAP. Hence, the placement monitoring stations along key transportation corridors, particularly near large ports, could be an efficacious strategy to identify incipient populations.

4) Cost-Benefit-Analysis can accurately and effectively highlight the impacts and costs of an IAP invasion. Management of IAP is often costly, however a CBA can demonstrate that costs of management may be below the additional would-be costs if a certain IAP spreads and expands its

range. We know that - in our case - the calculation of the impact on human health and agriculture and management costs is based on a range of assumptions and simplifications (e.g. methodology, scale of impact, pollen load), but our results suggest that it is necessary to act early and in a concerted action to halt further spread of the species studied (“an ounce of prevention is worth a pound of cure”).)

Future priorities:

- We generally need better public and governmental awareness of the impacts of biotic invasions (brochures, scientific publications, lectures, media articles, exhibitions etc.). In this respect, few tools are as effective as time-series maps showing the course of an on-going and future invasion and its corresponding potential impact.
- We need cost-benefit analyses that accurately and effectively highlight the impacts and costs of an IAP invasion or just “costs of non-action”. Members of the society (public, governmental and agricultural sector) become aware of invasions only through first-hand experience or (potential) economic costs.
- We need sufficient resources and funding for a long time (even decades). Effective prevention and control of any biotic invasion requires a long-term, large-scale strategy rather than a tactical, short-lived and even local approach. This includes clear competencies among the different authorities and political will in Austria.
- We need to know what IAP to expect. Successful control and containment (even eradication) is only feasible at an initial stage of invasion. Hence, the early identification of an emerging IAP and its introduction pathways is an urgent need by e.g. using risk assessment tools (e. g. EPPO 2012; see also Essl et al. 2011 for review) and/or conducting pathway analyses (e.g. Brunel et al. 2010).
- We need to coordinate activities regarding IAP and exchange experiences with neighbouring countries.

B) Projektdetails

6 Methodik

Work packages 1 & 2

Invasion history and current distribution

Conducting detailed analyses of the invasion history of alien species is a well-established way of gaining new insights into biological invasions (Pyšek & Hulme 2005, Essl et al. 2009). The data was a prerequisite for WP 3.

We collected all available records of *A. trifida*, *A. annua* and *I. xanthiifolia* in central and eastern Europe (CEE) up to 2011 from a wide range of sources. We searched global (<http://www.gbif.org>), national and subnational (i.e. floristic mapping projects) databases and important national herbaria. These data were supplemented by an extensive literature search using appropriate keywords in indexed (Web of Science, CAB Abstracts, Agris, AGRICOLA) as well as in non-indexed journals, monographs, and in the internet. Additionally, we contacted 38 key country and regional experts for further records. All records have been assigned to a grid cell (5 × 3 geographic minutes, ~ 33 km²) of the Floristic Mapping Project of Central Europe (= FMCE; Niklfeld 1998). The date (= year) of the records was extracted from the original source. We analysed the invasion of the three species over time in CEE by constructing invasion curves (Follak et al. 2013).

Work package 3

Projected distribution under current climate and climate change

Distribution and rates of spread of invasive plants are controlled by the interplay of environmental, climatic and anthropogenic factors. In this respect, niche-based distribution modelling (e.g. species distribution models, SDMs) has become an important tool for identifying environmental factors affecting a species' distribution and for assessing the species' potential range under current and future environmental and climatic conditions (Dullinger et al. 2009).

Spatially explicit data on climatic conditions (selected bioclimatic variables from WorldClim, <http://www.worldclim.org/bioclim>), major infrastructure (highways) and natural (rivers) networks, which represent potential invasion corridors, and land use were collected from various sources. All GIS data were pre-processed to match the resolution of the raster of the FMCE, i.e. aggregation by means of averaging (topographical data) or summarizing (street and river length). For calibrating the SDMs, records of the study species were partitioned into those of established and casual populations (Dullinger et al. 2009). We used SDMs (Guisan & Zimmermann 2000) for identifying the factors governing the current distribution of the study species. We used the BIOMOD-framework implemented in the R software (R Development Core Team 2012) for fitting SDMs. BIOMOD allows combinations of several modelling techniques in an ensemble forecast (Thuiller et al. 2009). Here, we combined generalized linear models (GLM), generalized boosting models (GBM), generalized additive models (GAM), and multiple adaptive regression splines (MARS). Projected occurrence probabilities were transformed into presence/absence predictions per grid cell, based on the threshold that maximizes model accuracy (Liu et al. 2005). To assess variable

importance in explaining the current distribution of a study species and to assure comparability among models, BIOMOD provides a permutation procedure to extract a measure of relative importance for each predictor variable that is independent of the model. High values imply high importance of the predictor variable (Thuiller et al. 2009).

Climate change predictions incorporated are based on calculations of four General Circulation Models (GCM), run for different SRES (Special Report on Emission Scenarios) and storylines for 2020 and 2050, respectively (IPCC 2007):

GCM	SREC	
CGCM2	B2a	Coupled Global Climate Models, V.2
EchAM5	A1b	European Centre for Medium-Range Weather Forecasts + MPI-M
HadCM3	A1b	Hadley Centre Coupled Model, V.3
HadCM3	A2a	Hadley Centre Coupled Model, V.3
HadGEM1	A1b	Hadley Centre Global Environment Model V.1

The strongest mean annual temperature increase is forecasted with emission scenario A1 whereas B family scenarios predict a moderate increase and A2 ranges in the middle (IPCC 2007).

Projected distribution and pollen load under climate change in Austria

We used the BIOMOD-framework implemented in the R software (R Development Core Team 2012) for fitting SDMs. For modelling details see above as well as Follak et al. (2013). Future projections were based on the 30 year running mean forecasts of changing climatic conditions available at http://www.ccafs-climate.org/statistical_downscaling_delta/). We contrasted two different scenarios, the CGCM2 B2a dataset and the HadCM3 A1b scenario. The high resolution (ca. 1km) climate datasets were rescaled to the FMCE raster by averaging the values of the smaller grid cells within a larger FMCE cell. For each species, we projected the probability of occurrence within each FMCE cell of the study system under both current and future climatic conditions as a weighted sum of occurrence-probability projections made by the three modelling techniques (Marmion et al. 2009). The weighting scheme was proportional to the TSS statistics for each modelling technique (i.e. the techniques that delivered the most accurate models had the highest weights). For calculating the pollen load within Austria in 2020 and 2050 we first calculated the projected distribution of the species. We contrasted a maximum and a realistic dispersal scenario: (a) As a maximum scenario we assumed that all suitable sites will be occupied instantly as projected by the SDM models for the two different climate change scenarios. (b) However, since these projections are models of site suitability rather than occurrence, and as an immediate colonization of all newly available suitable sites was assumed to be unrealistic, we simulated the range changes of the study species by means of a simple spread model. Starting with the current distribution, species were dispersed to all suitable neighbouring cells in 3 years steps, whereupon population density was not considered. This means, that a new site can be colonised only in the proximity of already occupied sites and the distribution area grows radially. To simulate long distance dispersal and occasional establishment, a small fraction of 0.1 % of colonized cells were randomly distributed across the whole simulation area. Since, climate projections and hence SDM projections were only

available for every 10th year, occurrence probabilities for the intermediate years were linearly interpolated between these 10th year values. The simulation area was Austria plus a buffer zone of 100 km. The final pollen load was then calculated for the 2 (two climate change scenarios) x 2 (two dispersal models) x 2 (2020 and 2050) = 8 different plant distribution models using 2 different management scenarios: (a) a “full eradication” assuming all plant occurrences within Austria were destroyed and only pollen from outside Austria was interspersed and (b) a “no intervention” scenario where plant growth is not restricted within Austria and pollen was assumed to come from both, Austria and neighbouring countries.

We applied a simple isotropic Gaussian dispersal kernel with a distance of 5 FMCE cells to calculate the local pollen load for Austria. Since our model did not generate population densities, the pollen load was calculated relatively [0, 1], with maximum load in the direct vicinity of a cell; decreasing to the outer limit. We calculated the pollen load of every cell in Austria as the sum of all interspersed pollen from neighbouring cells and finally rescaled the values between 0 and 1.

Work package 4

Evaluating the costs and benefits of controlling the spread of *A. trifida*, *A. annua* und *I. xanthiifolia* under climate change in Austria

A number of different studies have been conducted dealing with the economics of invasive alien species (IAS). In a comprehensive survey, Born (2008) lists more than 30 economic studies that tackle the issue of IAS. The impacts investigated range from the negative consequences on biodiversity and ecosystem services to effects on economic sectors, particularly agriculture and fisheries, as well as human well-being. The methodological approach in this project consists of a cost-benefit analysis (CBA), which evaluates the different outcomes over the period from 2011 to 2050. The CBA builds on a simulation model elaborated in this project (see WP 3).

We could not identify any studies in the literature that report on prevalence rates for *I. xanthiifolia* and agricultural impact of *A. annua* in Austria and CEE. Hence, we excluded from our CBA *I. xanthiifolia* for health benefits and *A. annua* for agricultural benefits, respectively.

Model assumptions of the CBA

The simulation model provides us with four scenarios for the period 2011-2050 which are centered on two key variables. The first key variable is the degree of climate change that is either assumed as “mild” (SRES B2) or “severe” (SRES A1) (see WP 3). The second key variable influencing the distribution is the spread of the respective species. It can be “limited” meaning that a plant can only spread a certain distance per period or take a “maximum” value. In the latter case such a limitation does not apply and it is assumed that all suitable habitats are invaded by the respective species. The two maximum spread scenarios serve as background scenarios indicating of what could theoretically happen if all suitable habitats would be infested. The main focus was to put on the two limited-spread scenarios (a1b-limit and b2a-limit).

For each of those four baseline scenarios the model further distinguishes between control options that can either take the value “full eradication” or “no intervention”. For the CBA, we were provided with eight different outcomes regarding pollen load data as well as plant distribution per quadrant and time period for each of the three species (WP 3).

Management costs

The management costs were classified into fixed and variable costs. The former encompass costs that are independent of the projected invasion pattern of the respective species and, hence, are constant for all scenarios. They consist of costs for trainings of municipal staff, a coordination position, and a prevention system (Table 4). Variable costs are the eradication costs (i. e. personnel, material, travel costs) per quadrant infested for one year and for a 3-year control period. Populations of our target species will generally be small (less than 1000 plants per location), hence, the most sustainable control option in our case is assumed to be “hand pulling”.

Table 4: Fixed annual management costs and variable management costs per quadrant.

	2011	2012ff
Training Costs (initial year only)	10.106,00	-
Coordination	9.918,00	6.612,00
Prevention System	100.000,00	100.000,00
<i>Total</i>	<i>120.024,00</i>	<i>106.612,00</i>
Average variable eradication costs / year	748.14	1.904,76
Average variable eradication costs / 3-year control period	2.992,56	7.619,04

Health benefits

Prevalence rates of closely related *Ambrosia artemisiifolia* and *Artemisia annua* serve as input for our scenarios for the estimation of health benefits of *A. trifida* and *A. annua*, respectively, based on available literature (e. g. Gabrio et al. 2010, Weber 2012).

The health benefits were obtained by comparing the projected pollen-induced allergy pattern of the “full eradication” option with the “no intervention” option. First, we calculated the potentially affected population per quadrant for the period 2011-2050. Our point of departure was the population data from the Census 2001 at the household level which was mapped to the quadrants from the FMCE. The population projections from the Austrian Conference on Spatial Planning (<http://www.oerok.gv.at/>) were used as proxies to estimate the average population growth per year.

We set two scenarios for allergies induced by *A. trifida* and *A. annua* pollen: (i) a conservative one assuming a modest increase of and a limited impact on allergic persons and (ii) a worst-case scenario with a strong rise of allergies as well as health costs per patient (Table 5). We assume an average pollen allergy cost of €700 per patient and year in the conservative scenario while in the maximum scenario the average cost goes up to €1.683. Thus far, the available evidence suggests that a primary sensitization by our study plants is not very widespread among pollen allergy sufferers. Hence, we presume that the major health impact – in terms of avoided health costs – will result from keeping the pollen season within its current time period. Put differently, the eradication of our species plants should spare poly-sensitized patients two additional months of suffering. Therefore, we take 2/12 of the average annual costs of pollen allergies as IAS related costs per patient.

Table 5: Variables for the “conservative” and “worst-case” scenario for *A. trifida* and *A. annua* health impacts.

	“Conservative”	“Worst-Case”
Current rate of Ambrosia allergies	4.38%	4.38%
Current rate of Artemisia allergies	6.63%	6.63%
Maximum rate of Ambrosia & Artemisia allergies	8.75%	12.5%
Rate of clinical manifestation	25%	65%
Annual health cost per patient	€700	€1.683
Additional IAS related health costs per patient	€700 × (2/12) = €116.67	€1,683 × (2/12) = €280.5

To estimate the impact of the pollen load on the population in the respective quadrant and time period we use the average pollen load data as weighting factor in the following way:

$$AP(t,i) = P(t,i) \times [CRA + APL(t,i) \times (MRA - CRA)]$$

AP(t,i) ... number of allergic persons in quadrant i at t

P(t,i) ... Population in quadrant i at t

CRA ... Current rate of allergy

MRA ... Maximum rate of allergy

APL(t,i) ... Pollen load in quadrant i at t

As the pollen load APL(t, i) might fluctuate from year to year we use average values for the time periods [2011-2020], [2020-2030], [2030-2040] as well as for [2040-2050]. These average values are derived from the model simulations that deliver pollen load data for every third year (2011, 2014, ..., 2050). In this way, we obtain the number of allergic persons per quadrant and year which is subsequently used to calculate the health costs using the rate of clinical manifestation and the average additional costs of IAS related pollen allergy per patient.

Agriculture benefits

Agriculture benefits are estimated by evaluating and comparing the outcomes for the “full eradication” option and the “no intervention” option. Similar to estimating health benefits we used a conservative and a worst-case scenario to assess the impacts on selected field crops (i.e. grain maize, soybean and sunflower) for which negative impact by these two species has been published. Under the conservative projections we set the average yield loss of *A. trifida* and *I. xanthiifolia* at 1%. In the worst-case scenario, the average yield loss caused by the two species was set at 5%. We used data from Statistik Austria (Statistik Austria 2011) to assess the cultivated area of the selected field crops by quadrant (Table 3).

As our model only allows distinguishing between “affected” or “not affected” for every third year we calculate the degree of affectedness by dividing the number of cases in which the respective quadrant has been affected over the total number of periods. This rate of affectedness is used a weighting factor to calculate the yield loss per quadrant:

$$YL(i,c) = AY(c) \times AA(i,c) \times AYL(c) \times DA(i)$$

YL(i,c)	...	Yield loss in quadrant i of field crop c
AY(c)	...	Average yield of field crop c
AA(i,c)	...	Agricultural area in quadrant i used for field crop c
AYL(c)	...	Average yield loss factor for field crop c
DA(i)	...	Degree of affectedness in quadrant I

The monetary valuation of the respective yield loss per quadrant is based on the average producer prices for each field crop concerned. Finally, these annual yield losses are aggregated for the period 2011-2050 to obtain the total yield loss for each species.

Work package 5

Dissemination to target groups

We specifically prepared the scientific results for each target audience (agricultural and health sector, scientific community, general public). We launched a project homepage (<http://www.ages.at/ages/en/research-international-cooperation/current-research-projects-in-english/austrian-climate-research-program-acrp/climallergy/>) where we will additionally provide our project results and requirements for action. Results of the project have been already disseminated to the following target groups (see for further details and web links paragraph 8: Publikationen und Disseminierungsaktivitäten).

1. Agricultural and health sector

This sector includes members of the Federal Ministries of Agriculture and Health as well as municipal authorities, consultants, farmers and practitioners as well as industry representatives (e.g. area of plant protection). Here, we put emphasis on the descriptions of the target plants and problems of rising allergies (and yield loss in crops) connected with their occurrence and we presented results on their current and potential distribution (maps, graphs) and management options. We published two articles in the journal “Der Pflanzenarzt”, the leading agricultural journal (magazine) in Austria. The project coordinator participated in a national plant protection conference (52. Österreichische Pflanzenschutztag 2011) and gave a talk on the distribution of

the target plants and management options. Results (distribution dynamics of the target plants and their potential future impact on human health and management options) will be presented at the 3rd National Neobiota Conference in Vienna (Theme: "Neobiota und Gesundheit") in September 2013 (members of Austrian organisations and institutions who work on health impacts will most likely participate).

2. Scientific community

We presented our results and recommendations for action as a poster or oral presentation at three international, four national conferences (including 13. and 14. Österreichischer Klimatag) and one international expert meeting group (EPPO Panel on Invasive Alien Species) to the scientific community including experts from various disciplines (economists, botanists, weed scientists, climatologists etc.) and stakeholders. Further dissemination activities are still to come (e.g. peer-reviewed publication in an international economic journal).

3. General Public

We informed the general public (i.e. citizens) via a press release, media and internet articles (e.g. FALTER Heureka!, Kurier, AGES homepage) in a more general way about the problems of rising allergies connected with the migration of allergy-inducing plants and what each citizen can do to limit the spread of the target species.

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7 Arbeits- und Zeitplan

ClimAllergy consisted of six work packages (WP) (Table 2), which were the following: "invasion history (WP 1)", "current distribution (WP 2)", "projected distribution (WP 3)", "socioeconomic impact assessment (WP 4)", "recommendations & dissemination activities (WP 5)", "project management (WP 6)" (Table 6).

Table 6: Timetable for project meetings, milestones and deliverables within ClimAllergy.

Project month	WP	Item	Notes
1	6	Kick-off Meeting	held by AGES (19.01.2011)
10	6	1 st Project Meeting	held by UBA (19.10.2011)
12	1 & 2	WP 1 & 2 completed	distribution data of the target species completed, raster maps & datasheets produced
13	6	Interim report	on 19.01.2012 delivered
16	6	2 nd Project Meeting	held by TU Wien (19.04.2012)
18	3	WP 3 completed	maps visualizing invasion risk in the study region & maps of expected pollen loads in Austria produced
22	6	3 rd Project Meeting	held by TU Wien (19.10.2012)
22	4	WP 4 completed	cost-benefit analysis (CBA) completed
24	5	WP 5 completed	recommendations & dissemination activities (partly) completed
24	6	Final report	on 19.04.2013 delivered

8 Publikationen und Disseminierungsaktivitäten

Peer-reviewed

Follak, S., Dullinger, S., Kleinbauer, M., Moser, D. & Essl, F. (2013): Invasion dynamics of three allergenic invasive Asteraceae (*Ambrosia trifida*, *Artemisia annua*, *Iva xanthiifolia*) in central and eastern Europe. *Preslia* 85, 41-61, <http://www.preslia.cz/>

Presentations

Getzner M., Plank L., Zak, D. (2013): Climate change and socio-economic impacts of invasive alien species. 10th International Conference of the European Society for Ecological Economics, Lille (France) 17.06-21.06.2013, Book of Abstracts: http://esee2013.sciencesconf.org/conference/esee2013/boa_en.pdf, pages 235-236.

Follak S., Dullinger S., Essl F., Gattringer A., Getzner M. Kleinbauer I., Moser D., Plank L., Zak D. (2013): Climate change induced invasion and socio-economic impacts of allergy-inducing plants in Austria. 14. Österreichischer Klimatag, Universität für Bodenkultur, Wien, 04.04.2013, Book of Abstracts: http://ccca.boku.ac.at/?page_id=880, page 45.

Follak, S., Essl, F., Dullinger, S., Getzner, M., Kleinbauer, M., Moser, D. & Zak, D. (2012): A new wave of allergenic weeds knocking at the door? EPPO Panel on Invasive Alien Species, Mèze, France, 05.06.2012, http://www.eppo.int/MEETINGS/2012_meetings/IAP_meze.htm.

Follak, S., Essl, F., Dullinger, S., Getzner, M., Kleinbauer, M., Moser, D. & Zak, D. (2011): Zum Vorkommen und zur Verbreitung neuer, allergener Unkräuter in Österreich. 52. Österreichische Pflanzenschutztag, , Wirtschaftsförderungsinstitut Niederösterreich, St. Pölten, 30.11.-01.12.2011, Book of Abstracts: <http://www.oeaip.at/>, p. 24.

Follak, S., Essl, F., Dullinger, S., Getzner, M., Kleinbauer, M., Moser, D. & Zak, D. (2011): ClimAllergy – Climate change induced invasion and socio-economic impacts of allergy-inducing plants in Austria. Klimafolgenforschung in Österreich: Aktuelle Projekte im Überblick, MuseumsQuartier, Wien, 17.05.2011, <http://www.klimafonds.gv.at/veranstaltungen/veranstaltungen/klimafolgenforschung-in-oesterreich-aktuelle-projekte-im-u-berblick/#&slider1=12>

Poster

Follak S., Dullinger S., Essl F., Kleinbauer I. & Moser D. (2013): Spread dynamics and agricultural impact of emerging *Iva xanthiifolia* in Central and Eastern Europe. 16th EWRS Symposium, Samsun (Turkey), 23.06-27.06.2013, Book of Abstracts: <https://www.ewrs2013.org/>, page 29.

Follak, S., Essl, F., Dullinger, S., Getzner, M., Kleinbauer, M., Moser, D. & Zak, D. (2012): A new wave of allergenic weeds knocking at the door? NEOBIOTA 2012 Halting Biological Invasions in Europe: from Data to Decisions, 7th European Conference on Biological Invasions, Pontevedra, Spain, 12.09.-14.09.2012, Book of Abstracts, p. 143. Book of Abstracts: <http://neobiota2012.blogspot.co.at/p/book-of-abstracts.html>, page 143.

Follak, S., Essl, F., Dullinger, S., Getzner, M., Kleinbauer, M., Moser, D. & Zak, D. (2012): Climate change induced invasion of allergenic plants in Austria. 13. Österreichischer Klimatag "Klima, Klimawandel, Auswirkungen und Anpassung sowie Klimaschutz in Österreich", Universität für

Bodenkultur, Wien, 14.-15.06.2012, Book of Abstracts:
<http://www.austroclim.at/index.php?id=klimatag2012>, page 14.

Popular Science

Follak, S. (2012): Dreilappige Ambrosia: Bisher nur seltenes Auftreten aber Vorsicht ist geboten. Der Pflanzenarzt 9-10, 17–18.

Follak, S. (2011): Das Rispenkraut – allergen und konkurrenzstark. Der Pflanzenarzt 11-12, 10–11.

Internet

ClimAllergy – Project Homepage; <http://www.ages.at/ages/en/research-international-cooperation/current-research-projects-in-english/austrian-climate-research-program-acrp/climallergy/>

Iva xanthiifolia – fact sheet; <http://www.ages.at/ages/landwirtschaftliche-sachgebiete/pflanzengesundheit/invasive-pflanzen/rispenkraut/>

Newspaper/press releases

Neue Immigranten in Österreich, FALTER Heureka! 5/12, (print) 21.11.2012,
<http://www.falter.at/heureka/2012/11/neue-immigranten-in-osterreich/>

Die stille Invasion aus dem Osten, Kurier, (print) 13.08.2011.

Einjähriger Beifuß und Rispenkraut: Allergen und konkurrenzstark, AGES, 22.09.2010,
<http://www.ages.at/ages/presse/presse-archiv/2010/die-verwandten-der-ambrosia/>

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