Effect of Climate Change on the Invasive Alien Plant Species

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Abstract. The introduction of invasive alien plant species (IAPS), which have strong competitiveness will outcompete the native species, destroy the ecological balance and results in loss of biodiversity. Under staggering changes of climate scenarios, the damage brought by invasion could be even more unpredictably severe. To better protect the original biodiversity, possible evolution process of distribution and mechanisms of some invasive species, and some efficient approaches that could deal with invasive organisms is concluded below. The results illustrate that based on their dominant biological mechanisms, the invaded geographical regions will increase in the future and with different species, the rate of expansion may vary. The elevational changes of invaded regions will also occur due to rising temperature. With increasing rate of globalization and climate change, there will be more frequent species exchange in the future. Controlling or preventing the presence of IAPS out of natural range, especially the presence caused by anthropogenic activity will still be extremely crucial. It is also necessary to keep carrying out experiment, modelling and analysis to comprehend the nature of invasive species. The paper summarizes the possible effect and mechanisms of typical species that can be used by the authorities, in order to develop effective control and management strategies in the nearly future.

Keywords: Climate change, IAPS, geographical distribution, risk analysis.

1. Introduction

Species invasions have wreaked havoc on China. According to data recorded from the Ministry of Agriculture, 2012, the invasive alien organisms endanger the survival of local organsissms, damage ecosystems, and cause gigantic economic losses every year [1]. Under strict regulatory conditions, some notorious invasive alien species (IAS) are under control. However, there are still some that are wild or cultivated.

Under the new climate scenario, weather patterns will be more difficult to extrapolate, extreme weather and increased temperatures may lead to greater negative impacts on the environment, as they are better suited to high temperatures and can develop more advanced mechanisms to survive and compete with other local populations. In future, the situation of biodiversity will be even more serious. In order to better implement the principle of "early detection and rapid response" when faced with non-native species, thereby saving the abundance and richness of species, accurate estimation of the impact and distribution changes of Invasive alien plant species (IAPS) is essential.

The timeliness of reviews has been a big issue in invasive species research. At present, the existing reviews are relatively scattered, not only have no in-depth research and summary for a representative species, but most of the existing scattered literature still has problems such as incomplete description, incomplete content or insufficient credibility of references, and the publication time of the literature. Especially in the past five years, when research on invasive species responses to climate change has increased significantly, there is not much review literature on climate change, so it is completely impossible to summarize progress against invasive species in a timely and effective manner.

Based on the emerging topic of climate change response, this paper summarizes the prediction of the geographical location of invasive plant species in the past five years and its related basic mechanisms. The major purpose of this paper is to turn out the impact of changing environmental factors on invasive species, in the changing climate scenarios in recent decades. First, this paper will briefly introduces the causes and manifestations of recent climate scenarios, and then we elaborate and summarize the changes of invasive species under climate change from the aspects of invasion mechanism, geographical distribution, species composition in invading sites and ecological niche.

Finally, in view of the current situation of invasion and biodiversity reduction, possible preventive measures and efficient approaches to prevent and control invasion are concluded.

2. Climate Change and Reasons

2.1. Climate Change

Climate change could be measured as the changes in overall weather pattern of a particular geographical region over a period. With staggering increases in anthropogenic activities, the climate condition globally varies significantly. China, as a vast country with tremendously variable weather condition, may occurred with even more complicated pattern of climate. As long-term weather pattern is always considered as a drivinng forces of geographical distribution of species, which may also positively impact the invasion of nonnative species, it is essential to investigate the condition of climate in China.

2.2. Types and Reasons

Climate change could be mainly concluded in three major issues, which are manifested as global warming, acid deposition, and the depletion of ozone layer. Among the three aspects, global warming is the most urgent issue for humanity, and is suggested as the most related to future one.

Over the past few decades, fossil fuel resources, such as oil and coal are utilized as the vast majority of energy resource in oerder to give rise to the production, infrastructure and daily life. Correspondingly, huge amount of greenhouse gases, such as carbon dioxide and other toxic gases is emitted. As the key cause of enhancing greenhouse effect is the greenhouse gases emission, the increase in greenhouse gases has positively impacted the greenhouse effect.

The long-wavelength wave emitted nowadays from the earth surface and the non-environmentally friendly gases has exceeded the past levels. Due to deforestation and construction of concrete jungle, a large amount of farmland or field that used to grow crops has been constructed into cities and factories. Original vegetation has been damaged and the availability of fixing free carbon into organic matter is significantly reduced. In addition, the surface area of availible water resources and overall precipitation gradually shrink, obviously decreases the quantity of carbon dioxide dissolved and originally assumed by aquatic autotrophs. As a result, the original dynamic equilibrium of carbon element in ecosystem is destroyed, which makes the atmospheric level of greenhouse gases increase over times and lead into warming problems in recent stages.

Also, sulfur dioxide nitrogen oxides are emitted from the combustion of fossil fuel, from the burning of resources for housing, heating or car engineering, react with water vapor in the air to generate nitric acid and enter the atmosphere. Finally, during the process of the formation and falling of droplet-like substance, such as rain, snow, and others, the droplets may absorb and dissolve the two toxic chemicals in the air, forming acidic precipitation with a pH lower than 5.6, which is harmful to vegetation in ecological aspect and also significantly affect the human normal life.

The last type of environmental problems is the ozone depletion, which can be literally seen as the result of the use of CFCs as refrigerants. CFCs is composed of carbon, chlorine and fluorine. When chlorine ions are emitted from the surface of earth into the atmosphere, they can contiuously distort the ozone layer without being using up. Therefore, although the molecule is in a small quantity, they can also result in the formation of a lager cavity situated in the ozone layer. This has led to more ultraviolet radiation than the previous level from the sun onto the earth, which will destructively interfered the balance and homeostasis of the ecological environment, and finally, threaten the normal survival of human beings and other creatures.

3. Effect of Climate Change on Invasive Species

3.1. Change in Invasion Mechanism

In the past-hundred years, temperature has risen more dramatically and with more unpredictable weather conditions. The rising in temperature and increased occurrence of extreme weather has impacted both the abiotic and biotic factors. However, these changes may positively affect the introduction and establishment of invasive species in new geographical regions.

Invasive organisms have higher tolerance to the stricter weather condition, as they are advanced in biological mechanisms, such as rate of utilizing the soil, unique metabolisms of carbon or nitrogen fixation or enzyme activity when facing higher temperature, etc. For instance, a IAPS species, Vachellia farnesiana (L.) increased the genetic abundance compared to local species, when responding to the changed amount and condition of precipitation, as a result, it will have greater resistance to water stress [2]. With similar situation, in those area that are experiencing high level of nitrogen concentration in soil when facing global hot climate, there have been simultaneous decreases in wheat production, but increases in Aegilops tauschii coss, which is also an IAPS grass species [3].

For another example, an adaptable *annual herb that is called* Field sandbur (Cenchrus spinifex Cav.), is native to Northern regions of America in previous times, and now scattered all around the world in types of sandy soils, within the tropical and sub-tropical zone [4]. It has shown great ability of adaptation to survive and reproduce in places such as fields or farmland that is already unable to cultivate crops, or sites along the tramline and lane. With high adaptation to earth quantity and drought resistance, as the soil are available condition, this species can normally undergo metabolic process and complete its lifecycle, even during the warmer season [5-7]. Furthermore, as the seeds produced are contained in the spiny bur with sharp edges, they can still main highly viable in suitable condition (if not contaminated) for several years, which also ensure a higher germination rates of plants. In general, IAPS organisms will usually occured with reproductive ability [8]. With more advanced biological mechanisms, they can outcompete previous residential speciesl by outcompeting them in several aspects like sunlight or water. The introdution of IAPS without controll will bring severe impact on agro-ecosystems, and the invasion will often result in reduced native productivity, or species richness [6, 7]. Meta-analysis surprisingly indicates that an IAPS community has been found with 17% higher soil nitrate (NO_3) quantity and an extra amount of 83% of the aboveground net primary production (ANPP) across the systems, compared to non-invaded systems [9]. The result could be in line with a other research on sandy soils, in this investigation, some exotic plants can replace the local residents, and even alter the original pattern of succession within a community [10]. All those results explain the establishment of a new ecological structure, especially for autotrophic producers, that will benefit the IAPS in the invaded sites.

3.2. Change in Distribution

Fig. 1 is illustrated based on the information from the previous field investigation and on-air datapool [11]. The main approach used to simulate the distribution scenarios of four typical alien plant beings in China is the Maximum Entropy model (Maxent). Under current and future climate in two shared socio-economic pathways, scientists found out that all the appropraite sites for these IAPS to live will increases, however, with different expansion levels in the nearly future [11]. Among the four plants, Mikania micrantha is occuring with the largest degree of expansion in distribution (61–120%) in future. Second largest expanding, A. philoxeroides will exband by 12% to 74%. A. adenophora sinensis, will also increase by one-third in extra, at last and the least, regions that suits A. artemisiifolia will rise by 8% to ultimately 27%. Additionally, except the central sites of both A. adenophora and A. artemisiifolia is shifted into the southwest under one particular weather pattern, the central regions of four habitat will move to the north, northwest, or northeast seperately. In complex climate situationm, it will be more accurate to describe the distribution by selecting some important abiotic factors, such as slope, temperature, and precipitation.

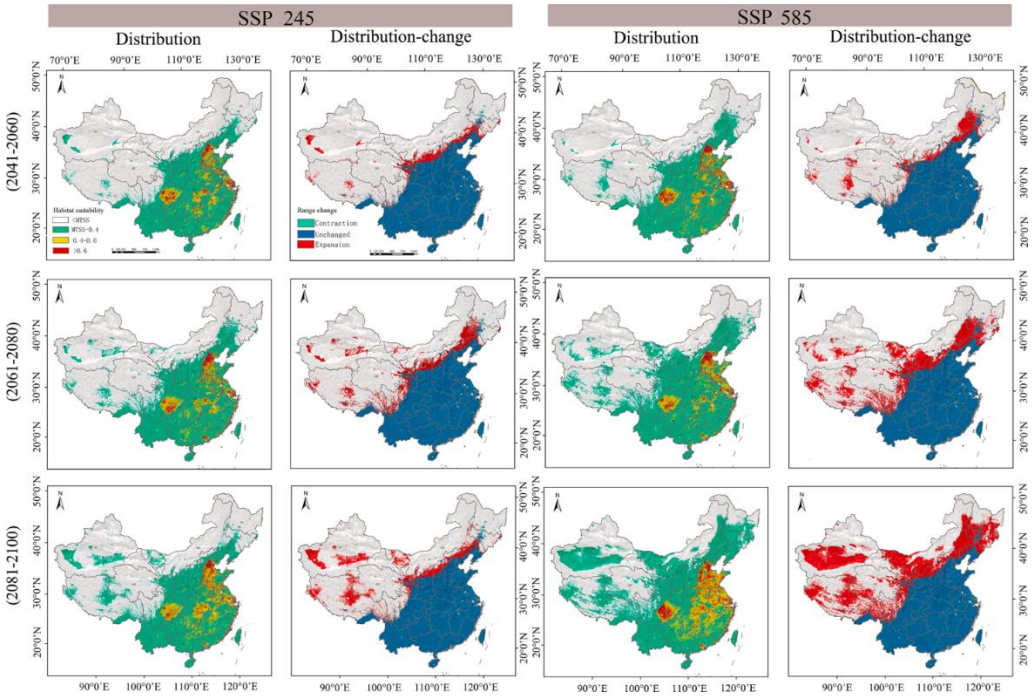

Figure 1. Projected futural distributions of periods of typical IAPS species and the gradual changes between current and future distributions.
https://www.sciencedirect.com/science/article/pii/S1470160X21005847

3.3. Species Composition of Invaded Habitats

Shrub verbenae (Lantana camara L.) is known as one of the most notorious IAPS in the eastern China [12]. The photosynthetic physiological indexes of Lantana camara and its main companion species Bidens pilosa L., Urena lobata L., Achyranthes aspera L. under different effective photosynthetic radiation (PAR) and different CO_2 concentrations were measured. The results ilustrated that both the light compensation point (LCP) and the light saturation point (LSP) of Lantana were both lower than the accompanying species and significantly different from the accompanying species. Also, the increase in effective photosynthetic radiation and CO_2 concentration did not significantly affect neither the transpiration rate (Tr) nor the stomatal conductance (Gs) of Lantana, but greatly improved its water use efficiency (WUE), indicating that this plant has good adaptability to changes in light intensity and CO_2 in the environment. This information is a supplement to the understanding of the physiological and ecological characteristics of Lantana camara, shows this species is highly competitive when overlapped in niche, but firmly adapted and corporated with organisms of other niches in environments.

3.4. Advancement of Dominant Niche

Lantana camara is a typical example of invasive species. Some basic research on its advanced mechanism of invasion to get to a dominant niche will be carried illustrates that in recent decades, many invasion hypotheses have evolved, such as 'Diversity Resistance Hypothesis', 'Enemy Release Hypothesis' or 'Evolution of Competitiveness Enhancement Hypothesis'. These theories indicate that the mechanisms of invading organisms are extremely complex and are still unclear to the academic yet. Meanwhile, another analysis has indicated IAPS will significantly impact the soil physical-chemical structures through the process of invasion [13].

However, despite those mechanisms above, such as exceedingly utilizing the soil or fix harmful mineral component, allelopathy has been focused since some chemicals (allelochemicals) that can inhibit the growth of other organisms have been found in a variety of invasive plants, allelopathy is taken as a starting point to explore why IAS could inhibit the growth of other companion species, and ultimately defeat local species.

In addition to the enhancement caused by chemical substances, IAPS also has a strong ability to utilize and tolerate the root system of soil. The research shows that Lantana camara has a good tolerance to the combined effects of pollution with cadmium, lead and zinc elements, and can reduce the damage to cells by transforming heavy metals into low toxic forms through aerial parts [12]. At the same time, the researchers mentioned that the invasion of Lantana camara increased the content of organic matter, level of nitrogen and potassium, nitrogen (that can be hydrolyze in alkali conditions), available phosphorus and potassium, and carbon, nitrogen and phosphorus in the soil [13]. There is also significantly increased the content of urease, protease, invertase, cellulase catalase activity, metabolic activity, carbon source utilization efficiency and diversity index of soil microbial community, and its promoting effect on rhizosphere soil is higher than that on non-rhizosphere soil. This kind of research shows the potential of Lantana camara in vegetation restoration and improving soil utilization. But at the same time, Lantana camara is conducive to further invasion and diffusion of its own in the process of improving soil fertility and accelerating soil nutrient cycle.

Recent studies have shown that water extracts from certain parts of plants, including leaves, fruits and stems, have significant side effects on seed germination and coleoptile elongation [14]. The experiments found that the essential oil and some effective chemicals in the extract were harmful to the adult rice whitefly, the fourth instar larvae of Aedes aegypti, and the reticulate yellow fin. The existing research results still show that the essential oil and extract of Lantana camara leaves have significant evading effects on at least three pests. This finding provides evidence for the successful and successive invasion of IAPS.

4. Controlling Measures

To meet the criteria of early detection and rapid response (EDRR) in order to protect the biodiversity, despite the corresponding risk analysis or management that have been done, punch of policies and guidelines are promulgated by the government. There have been several international conferences in China and abroad, discussed on the topic of preventing biodiversity reduction from the aspect of invading species. China's Ministry of environmental protection (EPA) completed the establishment of the borders of priority areas for biodiversity conservation (Biodiversity Committee, Chinese Academy of Sciences, n.d.) These facts have declared a strong attitude of alien invasive species, and announced and implemented a series of control measures. The available approaches include mechanical crushing, manual removal (such as large-area salvage, cutting), chemical control (such as chemical agent) or biological control (such as introduce corresponding predators to restrict species).

There are also a lot of studies on the distribution and community characteristics of Lantana camara, introducing models to analyze the hazards of Lantana camara from the ecological perspective. Through the simulation of suitable habitat and the community characteristics, the risk assessments and warning system of invasion, and ideas of managing the invasion from different perspective and policy recommendations for managing IAS were proposed. This part of the content digitizes and visualizes the impact of alien invasive species, providing many corresponding ideas for the part of this paper 'improving the current limited management mode.

5. Conclusion

Invasive organisms show negative ecological impacts on invading sites, so they are highly correlated to the biodiversity. As they destroy the eco-balance, invading is also a key issue of environmental protection. It is found that the biological mechanisms of invasion will be enhanced in several aspects with rising temperature. First, invasive plants will maximize its ability to utilize soil, in order to absorb nutrition content as much as possible. These behaviors will outcompete the species with similar ecological roles within the community but could also be beneficial to the surrounding organisms whom with no overlaps in niches. Correspondingly, a new ecological structure is

established and will be continuously enhanced by other co-effect, such as the rising photosynthesis efficiency. As a result, the suitable living regions of IAPS will increase. However, different species will expand to different content, and will expand to different elevation due to, different density, degree of drainage and temperature, which has been considered as more realistic factors when modelling or extrapolating the futural geographical patterns of IAPS. In nearly future, the protection of species diversity and richness should still be emphasized. There should be more risk analysis and management based on IAPS distribution, and the understanding of evolution of IAPS biological functions, through field research, models or experiments are still needed to be enhanced.

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