

Unraveling the Impact of Global Warming on *Phragmites australis* Distribution in Egypt

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ABSTRACT

Climate change is a critical worldwide concern that affects every aspect of existence and all living beings. The study of climate change's impact on invasive species has piqued the interest of researchers worldwide due to the possible ramifications for biodiversity and vulnerable species protection. *Phragmites australis* (Cav.) Trin. Ex Steud. (Poaceae) is regarded as one of the most crucial invaders with a high tolerance for climate change impacts, particularly increased salinity, temperature, and atmospheric CO₂, which may alter the surrounding ecosystems, and its uncontrolled spread may result in biodiversity deterioration. Because of its ecological importance and applications, common reed requires sustainable management to reap the majority of its benefits without damaging the environment, which requires a thorough understanding of its behavior in light of climate change. The following review article intends to investigate the response of the common reed to significant climate change factors including as salinity, temperature, and atmospheric CO₂ in Egypt, as well as to highlight rehabilitation solutions. Therefore, it is projected that the common reed population would continue to grow under the current climate change key drivers in Egypt, necessitating greater mitigation and adaption procedures from the government, academia, and society.

Keywords: Atmospheric CO₂; Climate change; Global warming; Invasive species; *Phragmites australis*; Salinity.

INTRODUCTION

Understanding, predicting, and mitigating climate change is a major ecological challenge (IPCC, 2014). Climate change is going to alter species interactions, community structure, plant phenology, biodiversity and geographic ranges (Post, 2013; Visser, 2016) in addition it affects different species differently (Springate and Kover, 2014). In a changing environment, globally dispersed species may have the genetic variety to adapt to a wide range of environmental and climatic gradients (Jump and Peñuelas, 2005). Yet, most efforts to study species transitions have focused on climate modelling (Thuiller *et al.*, 2005; Munguia-Rosas *et al.*, 2011) or trials with plants that are unlikely to have extensive effects on community diversity or ecological functions (Chapman *et al.*, 2014; Springate and Kover, 2014). Since 1950, the worldwide average temperature has risen at a rate of roughly 0.13 degrees Celsius each decade, with the global mean surface temperature rise projected to be between 0.3 and 0.7 degrees Celsius by the mid-twentieth century. The emissions scenario has a substantial impact on the extent of projected climate change (IPCC 2014).

Phragmites australis, sometimes known as common reed, is a prolific flooded grass that dominates aquatic emergent vegetation worldwide. Its success may be attributed in large part to its vast ecological range (Haslam, 1972; Lissner *et al.*, 1999a&b), high genetic variety (Saltonstall, 2002; Fer and Hroudova, 2009; Lambertini *et al.*, 2006), and effective dispersion via strong clonal and sexual reproduction (Kettenring and Mock, 2012; Meyerson *et al.*, 2012). Not unexpectedly, significant drivers of global climate change, including projected temperature rises of more than 3.5 °C (Warren *et al.*, 2011; Meehl *et al.*, 2012) and an estimated doubling of atmospheric CO₂ concentration by the end of this century, have a

favourable effect on this species (Solomon *et al.*, 2007). Consequently, invasive *Phragmites australis* is thought to spread and become more productive in North American coastal marshes as a result of global climate change (Chambers *et al.*, 1999; Saltonstall, 2002; Brisson *et al.*, 2008), where *Phragmites australis* invasion affects species diversity, geochemical cycling and ecology, as well as greenhouse gas emissions (Chambers *et al.*, 1999; Meyerson *et al.*, 2000; Brix *et al.*, 2001). Thus, this review paper focuses on the reaction of *Phragmites australis* populations in Egypt to major global climate change drivers like temperature, atmospheric carbon dioxide concentrations, and salinity, as well as advice for dealing with the consequences.

Location and Climate of Egypt

Egypt is geographically located between longitudes 24° and 37° east of the Greenwich line, as well as latitudes 22° and 32° north of the equator. It shares borders with the Mediterranean Sea to the north, Palestine to the east, the Red Sea to the south, and Sudan and Libya to the west. With a land area exceeding one million km², Egypt is situated in the northeastern part of Africa.

The climate data provided on The World Bank's website on climate change (<https://climateknowledgeportal.worldbank.org/country/egypt/climate-data-historical>) characterizes Egypt's climate as hot, dry, and predominantly desert-like. The country experiences a scorching and arid summer season alternating with a milder winter season accompanied by coastal showers occurring between May and September. Daytime temperatures are influenced by prevailing winds, resulting in seasonal fluctuations. Along the coast, temperatures range from an average high of 30°C during summer to a typical low of 14°C during winter (May to October). Inland desert regions



exhibit more extreme temperature swings, particularly during summer when nighttime temperatures drop to around 7°C while daytime temperatures soar up to 43°C. Although desert areas may experience nighttime lows of 0°C and daytime highs of 18°C over winter months, temperature variations are less pronounced compared to other seasons.

Egypt is a desert territory with minimal precipitation each year. With Alexandria receiving the greatest precipitation annually-roughly 200 mm-rainfall falls mostly in a shoreward direction. During the summer months, precipitation declines southward, and Cairo receives less than 10 mm of rain per year. In comparison to other desert regions, Sinai receives substantially more rainfall, and the region's wells and oasis support little settlements that were formerly trade routes. Water is an extremely limited resource in the nation due to the high evaporation rate and the near lack of permanent surface water over broad areas of the country. The main challenges are scarcity of water supplies, changing precipitation patterns, and rising population demands.

***Phragmites australis* geographical distribution and ecology**

Phragmites australis is common in Egypt. It is found in water and wet areas throughout all phytogeographical zones, including the Nile Valley and Delta, Oases, the Mediterranean shore, the shore of the Red sea, deserts and Sinai (Täckholm, 1974; Zahran and Willis, 1992) (Figure 2). It is found in the open water bodies, beach, and islands of Lake Bard-awil, but being a rare species, it can be found exclusively in wet salt marshes and dry sand sheets. (Khedr and Lovett-Doust, 2000; El-Bana *et al.*, 2003). According to Khedr (1989) *Phragmites australis* is a distinctive component of the reed-swamp vegetation of Manzala Lake, where it flourishes in 1.5 m of water deep.

P. australis is a semi-aquatic species that thrives in a variety of environments and in fresh or brackish water (Figures 3, 4). It is resistant to saltwater circumstances, as evidenced by its presence in salt marshes, although common reed's performance declines as salinity increases (Batterson and Hall, 1984). *P. australis* likes slower currents and rich silted and muddy bottoms, but it is also found in reed swamp environments, along ditches, and in moist cultivated fields. It ranks as one of the most important emerging aquatic plants on the sudd (floating islands of vegetation) along the Nile within central Sudan (Holm *et al.*, 1977). According to Chapman (1960), it is a widespread plant in oligotrophic, mesotrophic and some eutrophic reed wetlands and acts as an originator and stage of hydrosere. According to Haslam (1973) the common reed is a major nuisance in shallow drainages in the flat alluvial plains of the northern hemisphere.

In Egypt, Batanouny *et al.* (1991) identified three *P. australis* ecotypes: a hydrophytic ecotype, which lives on the flooded shores of the Nile and fresh water canals; a mesophytic ecotype, which lives on the levat-

ted Nile shores and wasteland in the Nile Delta; and a halophytic ecotype, which lives in salt marshes.

Economic importance and uses of *P. australis*

Current reed applications can be neatly classified as industrial, energy production, agricultural use, and water treatment.

Industrial uses

Reed is used in enormous quantities for thatching, papermaking, construction, insulation, and polymer synthesis. It is most famously used throughout Europe for roofs thatching. Until the late 1800s, the only roofing materials near the beach were reed and straw (Iital *et al.*, 2012). In Europe, reed stems gathered in the winter are used to build garden fences, floor, blinds and wall coverings, panels, and screens. They can be employed in a house's walls, floors, and ceilings.

Reeds provide cellulose and hemicellulose in which its cellulose could be utilised for semi-chemical and chemical pulps (Rodewald-Rudescu, 1958). Semi chemical pulp requires only the leaves, while papermaking can use all above-ground plant parts (Chivu, 1968a). *P. australis* has a high concentration of short fibres, making it ideal for paper manufacturing (Chivu, 1968b). For practically all purposes, paper with up to 30 percentage reed content is of acceptable quality (Chivu, 1968a; Hurter, 2001), whilst paper containing up to 80 percentage could be used as wrapping paper (Haslam, 2010). Reed and other biomass may be used to make bio-plastics. Its high ligno-cellulose content, like that of wood and bamboo, makes it suitable for the production of functional polymers such as stimuli-responsive polymers and biomimetic materials (FNR, 2012). Pulp, paper, and textiles are some of the other applications for cellulose. Lignin (22-23% extract) with pentosan (23-27% extract) (Holzmann and Wangelin, 2009).

Energy

Reed biomass can be burnt, biogased, or biofuelled, and any length or diameter of stems or leaves can be used (Wichmann and Wichtmann, 2009; ELP and Ash, 2010). To create heat and power, simple burners and gasification power plants may burn winter-harvested *P. australis* with less moisture content. Harvesting in late winter (March-April) gives the lowest moisture content (15-20%) (Paist *et al.*, 2003; Komulainen *et al.*, 2008).

Reed can serve as an energy source in a biogas plant, primarily during the green summer period (May-October) when it exhibits high nutrient content. However, it is important to note that reed's biogas potential is reduced at the beginning of summer or fall due to its higher lignin concentration (Kask, 2011). Through anaerobic digestion, bacteria break down chopped reed and generate methane gas which can be utilized for heat and electricity production. Additionally, reed offers opportunities for biofuel manufacturing. It can be used to produce bioethanol, biodiesel, or biohydrogen as alternative fuels for automobiles (Wichmann and Wichtmann, 2009). Notably, unlike "first-generation" biofuels derived from food

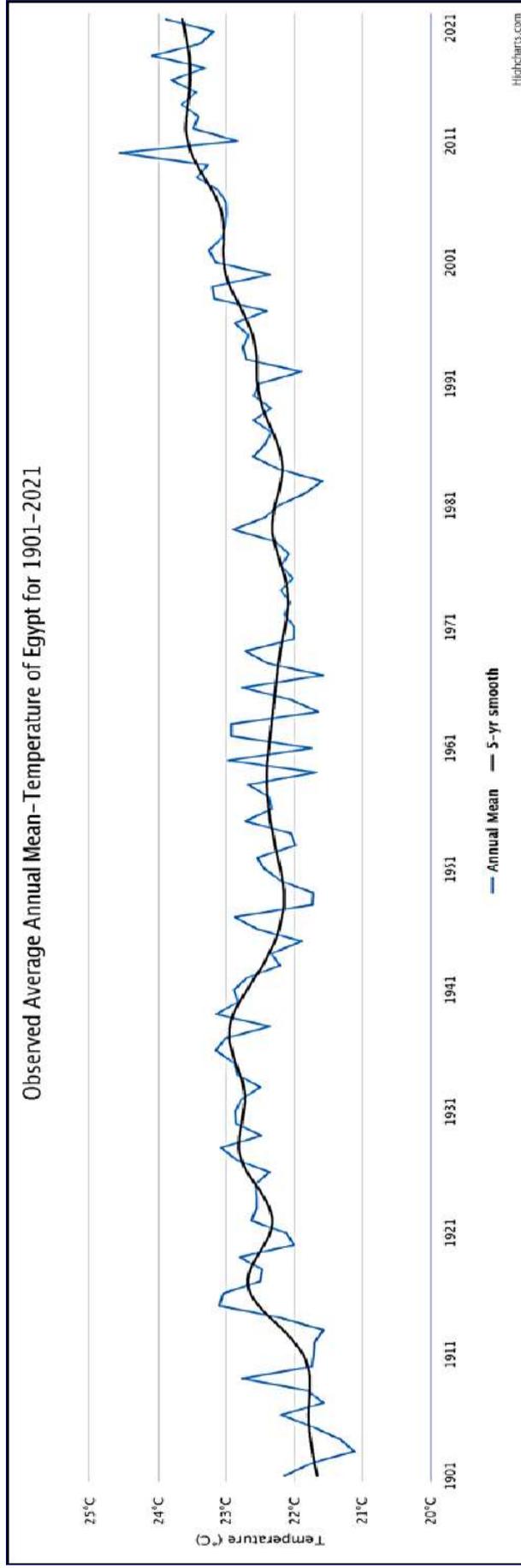


Figure (1): Observed average annual mean temperature of Egypt for 1901-2021, (climate change knowledge portal of the World Bank, 2022).

crops, reed represents a second-generation biofuel sourced from non-food biomass or agricultural waste such as maize. With pre-treatment to remove the lignin seal and hemicellulose sheathing, reed cellulose (31.5% hemicellulose and 49.4% cellulose) yields glucose for the production of biofuel (Tutt and Olt, 2011).

Agriculture

The third most important application for reed biomass is agriculture. Reed has been utilised for millennia as a natural wetland plant for animal grazing and as a fodder plant. In Scandinavia, the Netherlands, and China, reed is still used to feed sheep, water buffalo, goats, cows, donkeys and cattle (Häkkinen, 2007; Thevs *et al.*, 2007; Hansmann, 2008; Huhta, 2009; White, 2009). Ruminants prefer it because of its high nitrogen, potassium, and manganese levels (Baran *et al.*, 2002). 13.31 Kg of reed has the same nutritional value as one Kg of oats (Rodewald-Rudescu, 1974). While its nutritional value is lower than that of other fodder plants, huge animals may consume shoots up to 50 -75 centimeters tall (Haslam, 2010). In rice growing, reed may manage soil (Thesiger, 1964). Exclusively summer-harvested reed has enough nutrients to act as fertiliser (Hansson and Fredriksson, 2004), but harvesting it during summer eliminates nutrients from the biomass, perhaps causing oligo-trophication and lower biomass growth the following year.

Wastewater treatment

Wastewater treatment often uses artificial wetlands (Vymazal, 2010). Water flows through aquatic plant beds to remove non-point source pollution (primarily N and P) (Kusler and Kentula, 1990; Brix, 1994; Wild, 2001; Sarafraz *et al.*, 2009). Reed beds purify water in two ways. The aerenchyma in intact reed stalks brings oxygen to the roots, which starts bacterial activity (Kronbergs *et al.*, 2006). Phosphorus is removed via chemical adsorption and biological transformation, while Nitrogen is largely eliminated by denitrification, nitrification, ammonia volatilization, ammonification and cation exchange for ammonium (Sarafraz *et al.*, 2009). Collecting above-ground biomass depletes the wetland of nutrients. The top part of the common reed plant stores nutrients until July or August, when they are back to the roots and sediment to be stored until the following growth season (Hansson and Fredriksson, 2004; Komulainen *et al.*, 2008). Just 10-20% of August nutrients are retained by winter dead above-ground shoots (Graneli, 1990; Hedelin, 2001).

Because the concentrations of various heavy metals accumulated in wetland plants at the same areas and receive the same amounts of pollutants varied, *Phragmites australis* and *Cyprus papyrus* can be employed jointly in the treatment beds of artificial wetland systems for effective heavy metal removal (Dewedar *et al.*, 2018a).

Major drivers and Key Factors in Global Climate Change

Increases in soil salinity, atmospheric temperature, and atmospheric carbon dioxide have been seen as a result of excess heat in the climate system induced by

the addition of greenhouse gases to the atmosphere, influencing seasonal rainfall conditions.

Recent study on plant invasion has offered *P. australis* as a model species (Meyerson *et al.*, 2016; Packer *et al.*, 2017). *P. australis* may offer insights into how other plant species may adapt to climate change due to its extremely variable morphological and physiological responses to interrelated global climate change elements (Eller and Brix, 2012; Mozdzer and Megonigal, 2012; Eller *et al.*, 2014; Caplan *et al.*, 2015). A number of interacting human-caused global change factors threaten tidal wetland ecosystems and the ecosystem services they provide. *P. australis* grows in 15-foot-tall dense clusters, altering both the structure and function of wetlands. As it becomes an increasingly dominant wetland species, it is crucial to comprehend its response to global change (Smithsonian Environmental Research Centre website <https://serc.si.edu/>). North American and European common reed exhibited contrasting interactions to the global climate change drivers (Eller *et al.*, 2017). *P. australis* of other territories such as in Egypt has gotten little notice; consequently, their reactions to these drivers are not completely understood.

Salinity

Global sea level rise is endangering brackish salt-marshes and freshwater tidal wetlands with saltwater intrusion (Beckett *et al.*, 2016). Moreover, areas with elevated salinity and elevated evaporation rates will grow more salty, while areas with decreased salinity and high precipitation rates will get fresher, increasing salinity extremes in wetlands worldwide (IPCC, 2014). Several models of climate change forecast an elevation in tropical storms and hurricanes, which might flood near-coastal ecosystems and bring salt into the environment (Bender *et al.*, 2010; Knutson *et al.*, 2010). As a result of shifting soil salinity regimes, coastal biotic communities are becoming increasingly salt resistant. In 2021, it was reported that common reed can survive in Burullus areas of Egypt with salinities as high as 65 ‰ or as low as 22.5‰; however, it has been reported that young plants of common reed can tolerate salinities as high as 35‰. Also, during 2010 it was discovered that young and old stand morphotypes varied in all biomass and morphometric variables in the near-shore lagoon of Burullus. At the northern sites, the density of younger stands was not connected with salinity levels, whereas the density of older stands rose considerably with higher salinity levels

Yang *et al.* (2014) studied the physiological interactions of *P. australis* to soil water content and NaCl salinity in the delta of Yellow River, China. According to the findings, the combined impacts of soil water and NaCl saltiness had a considerable effect on this species' light-saturated photosynthetic rate, intercellular CO₂ concentration, and stomatal conductance during light saturation. Stress resistance in the *P. australis* was connected to the preservation of a considerably higher water status and a higher potassium ions (K⁺) content in the leaves. Water stress and NaCl salt stress both increased.

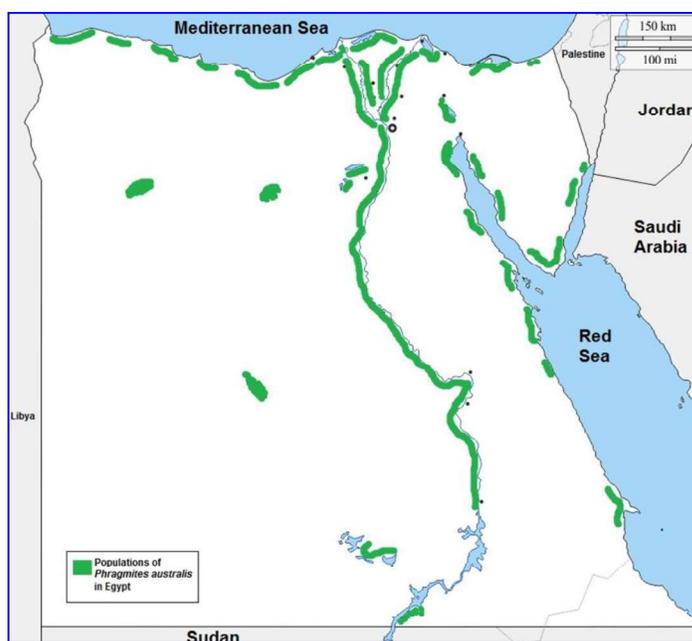


Figure (2): Map of Egypt showing distribution of *Phragmites australis* populations.

sodium ions (Na^+) and proline content, and leaf proline concentration was strongly related to leaf Na^+ content.

According to Heather *et al.* (2011) genotypic richness of *P. australis* was adversely linked with soil potassium content. Lexuan *et al.* (2012) discovered substantial negative relationships between the genetic diversity of *P. australis* and soil salinity. In a field study, Burdick *et al.* (2001) discovered a relationship between natural variability in soil salt levels over time and geography and the vigour and spread rates of *P. australis*. Despite the fact that canopy height was decreasing at all but two of the research sites, *P. australis* stands were spreading into salt marsh at a rate of 0.35 meter per year and increasing in cover (8 percent per year). The salinity of artificially controlled wetlands was lower (11- 16 ppt versus 19- 24 ppt in wild marshes), and one of these locations had fast *P. australis* growth.

P. australis was found to spread more slowly in areas with natural hydrology, shading out marsh species and possibly escaping salt stress by accessing natural sources of fresher water at various soil levels and seasons. Serag (1996) discovered that *P. australis* grows abundantly in non-saline environments, particularly along irrigation and drainages, in the north-eastern Delta of the river Nile. In salty settings, *P. australis* frequently recorded alongside halophytes such as *Arthrocnemum macrostachyum*, *Halocnemum strobilaceum*, and *Symphytotrichum squamatum* (Spreng.) G.L.Nesom.

It has been proposed that increased chlorophyllase activity reduces leaf chlorophyll concentration in response to a range of environmental stressors, including salt and floods (Mihailovic *et al.*, 1997). There were no appreciable differences in the total chlorophyll content in any of the studied habitats, with the exception of brackish water habitats along the northern

the exception of brackish water habitats along the northern Nile Delta of Egypt, where the combined effects of hypoxia and salinity may have a detrimental effect on chlorophyll content. *P. australis*, on the other hand, has the capacity to maintain its chlorophyll content under stress conditions (Nada *et al.*, 2015). Hellings and Gallagher (1992) studied *Phragmites australis* in vitro for the impacts of salinity and flooding. The data suggest that controlling *P. australis* numbers in wetlands by managing water tables/flooding and salt levels.

Temperature and CO_2

The growth, development, and function of plants are influenced by changes in temperature and atmospheric CO_2 levels. Over recent years, there has been a significant shift from pre-industrial CO_2 levels of 280 parts per million to 390 parts per million (Barnola *et al.*, 1995; IPCC, 2007). Projections indicate that atmospheric CO_2 is expected to continue rising and reach 700 parts per million by the end of this century. Furthermore, it is anticipated that the global mean surface temperature will increase by approximately 0.6-4.8 degrees Celsius since the beginning of this century (IPCC, 2007). These changes in temperature and CO_2 levels have profound implications for plant growth and ecosystem dynamics.

Phragmites australis space expansion techniques in a harsh environment complimented classic cloning plant ecology hypotheses. Furthermore, the environmental factors that clonal plants in inland river wetlands are driven by were discovered, which is critical for the restoration and management of damaged wetlands in dry and semi-arid environments. Eller *et al.* (2017) studied the ecophysiology and ecology of significant common reed lineages, as well as their interactions to various kinds of global change. The key outcomes of the review were as follows: (1) *P.*

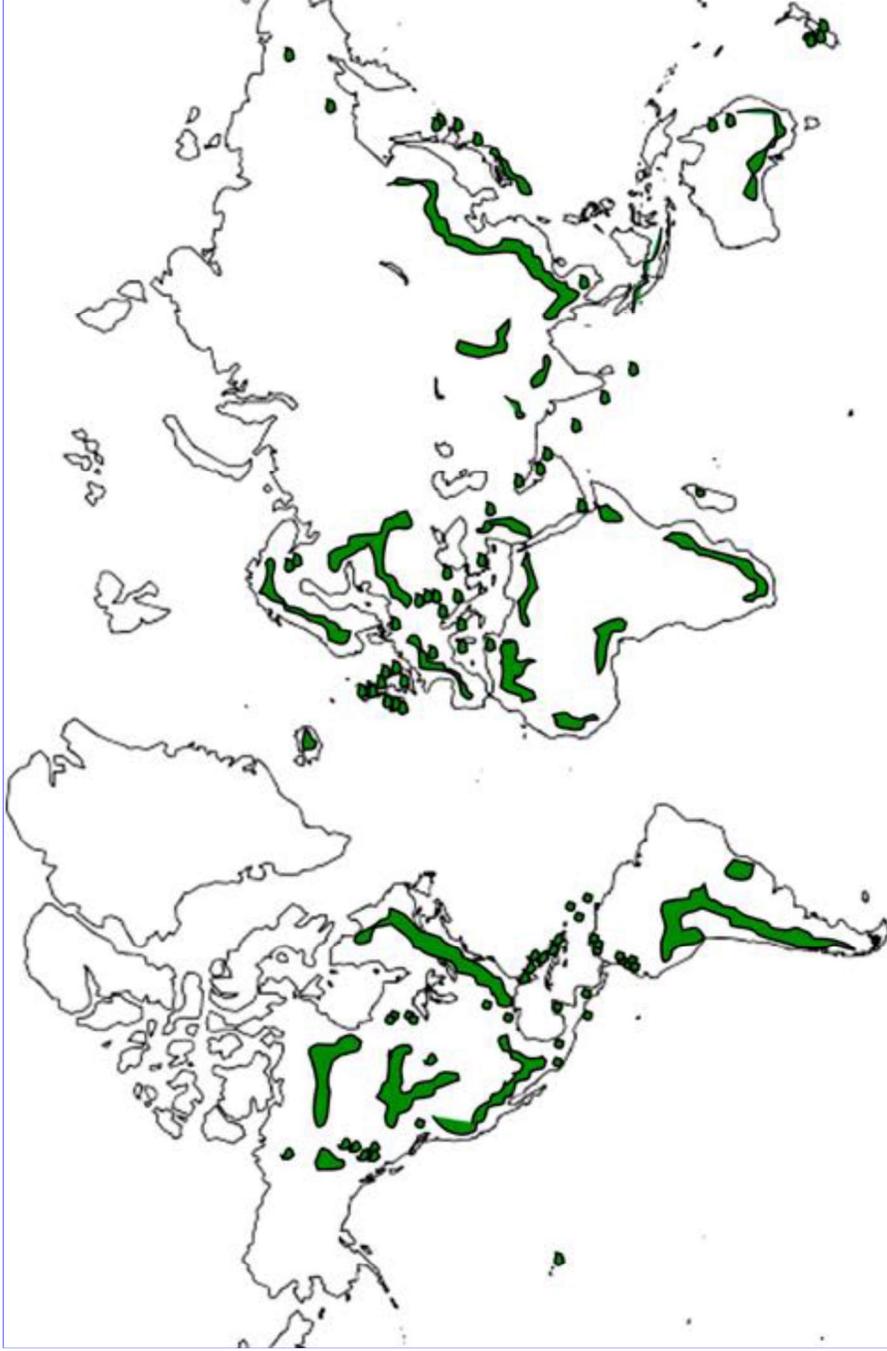


Figure (3): World map showing the distribution of *Phragmites australis* over the continents. Green strips show the global infestation of *Phragmites australis* (Srivastava *et al.*, 2014).



Figure (4): Assessment of habitat variability and distribution patterns of *Phragmites australis* in Different ecological settings across Egypt: Insights from Field Surveys and Remote Sensing Data Analysis" (a) Saline soil habitat near to salt marshes, (b) At the edge of irrigation fresh water canal habitat, (c) Salt marsh habitat, (d) Habitat where plant roots are completely submerged inside water body, (e) Agricultural field habitat

australis lineages interact differentially to changes in climatic variables, such as temperature or atmospheric CO₂, since they are well-adapted to their phylogeographic origin regions; (2) each lineage includes of populations with diverse genotypes that may exist in geographically dissimilar settings; and (3) The reactions to climatic changes on a global scale are determined by the phenotypic variation of functional and wellness features of a genotype. These trends suggest that the diverse *P. australis* lineages will be subject to strong selection pressure in the face of global change, which is expected to alter the distributions and interactions of co-occurring lineages as well as the genotypes within lineages.

In addition to a theoretical framework for using *P. australis* lineages to forecast plant responses to climate change generally and its effects, Eller *et al.* (2017) suggested that significant latitudinal clines within and between common reed lineages could be used to forecast plant responses to climate change specifically. Eller *et al.* (2012) also found that despite of the atmospheric Carbon dioxide content, a rise in temperature induced a rise in soil surface vegetation, suggesting that *P. australis*'s vast distribution will endure in a warmer future. The soil surface production of the two *P. australis* clones under study, however, was shown to be relatively unaffected by a potential increase in atmospheric Carbon dioxide to 700 ppm, with most of their photosynthetic characteristics staying unchanged.

With enough nutrition, elevated CO₂, a photosynthetic resource, is predicted to increase plant growth (Poorter, 1993; Wolfe *et al.*, 1998). Experiments provide inconclusive evidence (Ainsworth and Long, 2005; Rasse *et al.*, 2005; Kirschbaum, 2011). Plant exposure over time to increased carbon dioxide levels has been found in certain experiments to boost growth and productivity (Wand *et al.*, 1999), but not in others (Milla *et al.*, 2006). Long-term CO₂ exposure may acclimatise leaf photosynthesis, reducing it. Light-saturated photosynthesis and carbon absorption, on the other hand, are promoted by carbon need and growth capacity (Ainsworth *et al.*, 2003; Tuba and Lichtenthaler, 2007). Yet, the effects of CO₂ on plant development are less apparent than the impacts of temperature (Ojala *et al.*, 2002). The effects of Carbon dioxide and temperature on photosynthesis and respiration may cancel each other out, especially in C3 plants (Morison and Lawlor, 1999).

Phragmites australis demonstrates lineage-specific interactions with temperature levels, impacting its morphology, growth, and to some extent, photosynthetic features (Clevering *et al.*, 2001; Lessmann *et al.*, 2001; Eller and Brix, 2012; Eller *et al.*, 2014; Mozdzer *et al.*, 2016). In regions with warmer temperatures and longer day durations at lower latitudes, there are observed higher rates of common reed growth, particularly in terms of shoot height and length. Additionally, these regions exhibit increased rates of transpiration and photosynthesis (Haslam, 1975; Lissner *et al.*, 1999;

Zemlin *et al.*, 2000; Lessmann *et al.*, 2001; Karunaratne *et al.*, 2003; Mozdzer *et al.*, 2016).

Higher temperatures are necessary to stimulate development in lineages originating in lower latitudes, and when transplanted to higher latitudes, panicles emerge late or do not blossom at all (Brix, 1999; Karunaratne *et al.*, 2003; Lambertini *et al.*, 2012). Climate adaptation in the origin region has a substantial influence on plant species performance and plasticity (Bhattarai *et al.*, 2017a and b; Münzbergová *et al.*, 2017). As a result, *P. australis* from the MED lineage may be used to represent subtropical, Mediterranean and even tropical plant species, whereas *P. australis* from the EU-lineage can be used to model temperate species located at higher latitudes.

In a study done by Clevering *et al.* (2001) proposed a hypothesis suggesting that *Phragmites australis* has developed adaptations to synchronize its growth and development with seasonal environmental changes. They conducted investigations to explore these adaptations and found notable variations among *P. australis* populations regarding to: a. growing season duration, b. timing of blooming, and c. shape and biomass allocation. These findings hold significant implications for understanding the impact of global warming on population dynamics and functioning.

Concurrently, Lessmann *et al.* (2001) conducted a study examining the influence of climatic variations on photosynthetic interactions within four distinct populations of *P. australis*. The findings revealed remarkable phenotypic flexibility in the photosynthetic response to environmental changes across these genetically diverse populations. Notably, *P. australis* genotypes exhibited substantial levels of photosynthetic flexibility surpassing genetic variations observed in European populations. These results are discussed in relation to projections of global climate change, highlighting the implications for understanding and predicting plant responses to future climatic conditions. Researchers observed that temperature throughout the main growth phase had a large effect on shoot growth but a limited influence on the variance of morphological characteristics towards the conclusion of the growing season on the beaches of four separate lakes in Berlin and Brandenburg of Germany. This suggests that fast spring shoot elongation due to high temperatures did not always result in higher shoots at the conclusion of the growth season (Zemlin *et al.*, 2000). To further investigate this phenomenon and its ecological implications, additional research is needed in Egypt to assess the direct effects of rising temperatures and CO₂ levels on the development and proliferation of *P. australis* (common reed).

DISCUSSION

Regional climate change, that has recently been identified as a critical component in global terrestrial ecosystem change, is particularly vulnerable to vegetation (Yang and Piao, 2006; Kelly *et al.*, 2011; Li

et al., 2019). As a result of climate change, vegetation's reaction to various climate conditions varies drastically from one site to the next, particularly in dry and semi-arid regions (Zhengchao *et al.*, 2011; Zhang *et al.*, 2013; Jin *et al.*, 2014). Variations in the geographical and temporal distribution of vegetation indicate ecological features that are important for natural resource research and management. Genuinely global species like *Phragmites australis* (Cav.) Trin. ex Steud., have vast ranges high levels of genetic and phenotypic diversity, and may be found in a variety of environments, mostly wetlands. *P. australis* populations often have high levels of intraspecific variety, which may allow the species to adapt to and benefit from a fast changing climate (Jump and Peuelas, 2005; Kettinger *et al.*, 2010, 2011).

Wetlands are one of the world's three basic ecosystems, and they are more vulnerable to climate change than some other terrestrial ecosystems (Johnson *et al.*, 2016). Wetlands' ecological role aids in mitigating the detrimental consequences of climate change (Ma and Zhang, 2015; Moomaw *et al.*, 2018). Wetlands have recently been identified as one of the largest unknowns in terms of material flux and the dynamics of elements in the context of climate change (IPCC, 2001; Paul *et al.*, 2006). According to research, the global area covered by wetlands is rapidly shrinking as a result of climate change and human activities such as, urban expansion, land reclamation and aquaculture. Although many nations have set goals to restore the ecosystem, the downward trend is expected to continue (Leadley *et al.*, 2014), and since data changes frequently, determining global trends is difficult (CBD, 2014). In wetland ecosystems, there are intricate interactions between the atmosphere, land, water and plants.

Elevation of major global driving factors generally was found to enhance the production continuity of common reed populations especially the young stands, those factors including the salinity increase, atmospheric CO₂ concentration up to 700 ppm over the short term, while in long term exposure some studies have discovered that long-term CO₂ exposure boosts plant growth and productivity, while others have not.

As an impact of the climate change within Egypt, soil salinity levels may be enhanced by sea level intrusion, increased evaporation rates of wetlands by the effect of elevated temperature and the waterlogged areas poor drainage (Arnous *et al.*, 2017), this may stimulate the spatial expansion of the *P. australis* populations throughout the Egyptian dry and wetlands preferred them against less salinity-tolerated species, except in a potassium rich soil it may has a negative impact on the genetic diversity and richness of the common reed.

Egypt's overall GHG emissions increased from 193.3 million tonnes of equivalent CO₂ in 2000 to 318.2 million tonnes of equivalence CO₂ in 2010. The energy, manufacturing, agricultural, and waste sectors contributed the most (Nakhla *et al.*, 2013). Egypt's

contribution to the world's emissions of greenhouse gases, on the other hand, is merely 0.57% (Selim, 2009; UNFCCC, 2010). According to the IPCC (2014), the global average surface temperature change for the period 2016- 2035 will likely be in the range of 0.3 °C to 0.7 °C by the mid-twentieth century; these records and predictions are consistent with the increased salinity deductions that stimulate the growth and invasion of *P. australis* populations over other less plastic species.

CONCLUSION

Phragmites australis is recognized as one of the most invasive plant species worldwide, exhibiting remarkable adaptability to various extreme conditions resulting from climate change. Unless effective adaptation and mitigation measures are implemented through collaborative efforts among nations, we may witness uncontrolled proliferation of common reed, posing significant threats to ecosystem goods and services. Therefore, it is crucial to expand research on the impact of *P. australis* invasion on local biodiversity in Egypt. Further research should focus on developing strategies for mitigating current populations in order to conserve biodiversity effectively. Additionally, there is a need to explore innovative techniques for sustainable utilization of common reed resources. By addressing these concerns, we can strike a balance between managing *P. australis* invasions and minimizing their negative ecological impacts while also harnessing its potential benefits in ways that promote sustainability and preserve biodiversity within Egypt's unique ecosystems.

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تأثير التغير المناخي على انتشار نبات البوص في مصر

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الملخص العربي

يعد تغير المناخ مصدر قلق عالمي بالغ الأهمية يؤثر على كل جانب من جوانب الوجود وجميع الكائنات الحية. أثارت دراسة آثار تغير المناخ على الأنواع الغازية اهتمام الباحثين في جميع أنحاء العالم بسبب التداعيات المحتملة على التنوع البيولوجي وحماية الأنواع المعرضة للخطر. ويعتبر نبات البوص أحد أهم الأنواع الغازية الذين يتمتعون بدرجة عالية من التحمل لتأثيرات تغير المناخ ، وخاصة زيادة الملوحة ودرجة الحرارة وثاني أكسيد الكربون في الغلاف الجوي ، مما قد يغير النظم البيئية المحيطة ، وقد يؤدي انتشاره غير المنضبط إلى تدهور التنوع البيولوجي . بسبب أهميتها البيئية وتطبيقاتها ، يتطلب نبات البوص إدارة مستدامة لجني معظم فوائده دون الإضرار بالبيئة ، الأمر الذي يتطلب فهماً شاملاً لسلوكه في مواجهة تغير المناخ. تهدف مقالة المراجعة التالية إلى التحقيق في استجابة نبات البوص لعوامل تغير المناخ الهامة بما في ذلك الملوحة ودرجة الحرارة وثاني أكسيد الكربون في الغلاف الجوي في مصر ، بالإضافة إلى تسليط الضوء على حلول إعادة التأهيل. لذلك ، من المتوقع أن تستمر أعداد نبات البوص في النمو في ظل الدوافع الرئيسية الحالية لتغير المناخ في مصر ، مما يستلزم مزيداً من إجراءات التخفيف والتكيف من قبل الحكومة والأوساط الأكاديمية والمجتمع.