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Trends of a Plant Invasion: Challenges and Outcomes

Akinkuolie A. O[1], Oke S.O[2], Sanni R.O[3], Olugbemiro A.O[4]

**Department of Biology, Adeyemi College of Education.*
***Department of Botany, Obafemi Awolowo University, Ile Ife, Osun State, Nigeria.*

Abstract: *Biological invasions are considered to be important drivers of global change and receiving increased attention in many countries, some of which have already set in place comprehensive legislation or natural strategies to deal with various aspects of invasion in particular concerning their management.*
There is nevertheless a lively debate within the scientific community regarding the most appropriate strategies to adopt for managing invasive alien species. Aspect of this debate offer important points to dimensions that need to be better studied and then measures needed to make the phenomenon of biological invasion better understood by all stakeholders. This actually informed the need to have a basic knowledge of the trends followed in a plant invasion and the outcomes with a view to managing the problem effectively and hence this paper.

Keywords*: Biological-Invasion, Legislation, Invasive alien species, natural strategies.*

I. INTRODUCTION

The process of invasion by exotic species has been naturally occurring f=\]or thousands of years. It can be described as an initial colonization of a system, followed by the establishment of a viable population within the system. In addition, biological invasions have negative socio-economic and human health impact (Shakleton *et al* 2018, Potgeiter *et al* 2019, Roy *et al* 2019.). invasion of exotics species is among the most important global scale problems experienced by natural ecosystem.

An exotic species means a non-native plant or animal introduced into a new location by human activity either intentionally or by accident. The United States of America National Park Service (NPS) defines an exotic species as those that occur in a given place as a result of direct or indirect, deliberate or accidental actions by humans. The NPS policy generally prohibits the introduction of exotic species into natural areas of national parks. Introduction is a terminology used in invasion biology to describe the movement by human agency of species, sub-species or lower taxon (including any part gametes or propagules that might survive and subsequently reproduce) outside its natural range. This movement can be either within a country or between countries (Shine et al., 2000; Richardson and Pysek, 2012).

An indigenous plant means a species that reached its location without assistance from humans.(Akinkuolie 2014). Invasive are those plant species that continue to spread rapidly and widely. They are capable of moving aggressively into a habitat and monopolizing resources such as light, nutrients, water and space to the detriment of other species. Those plant species that have become thoroughly enmeshed in the native ecosystem are referred to as naturalized (Tellman, 2002). Vascular plants are among the most common invasive organisms, as they are often introduced for agricultural ,agroforestry and ornamental purposes (D'antonio, Jackson ,Horvitz, and Hedberg,2004;Daehler,2003;Pysek *et al.,*2012*).*

Alien or non-indigenous species are now considered a major element of global environmental change (Mack *et al.,* 2000).they form one of the major threats to global and local bio-diversity(IUCN. Council, 2000). Exotic, invasive species have the potential to affect the structure of native plant communities ecosystem

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functions and services (Vitousek 1990, Mack *et al.,* 2000; Woitke and Dietz 2002;Reaser *et al.,*2007;Spotswood,Meyer & Bar tolome,2012 ;Rojas-Sandoval,Melendez-Ackerman,&Angles-Alcazar,2016). Invasive exotics have brought about various types of ecological changes, some of which are perceived as negative (Simberloff 1981, Williamson and Brown 1986). Impacts include changes in the diversity or relative abundance of native species and alteration of the successional dynamics of communities over time (Wllcove *et al.,* 1999; Parker et al., 1999; Cronk and Fuller, 2001). Chemical impacts include the release of allelochemicals which impact the regeneration of neighboring tree seedling directly (Rusterholz *et al* 2018). Specifically, Chemical impacts also include the ability of alien plants to alter chemical and biochemical soil properties, which in turn can cause changes in the native species richness above and below the ground (Rusterholz *et al* 2018).Structural impacts refers to alien plants causing changes in the structural biotype characteristics of native environment ,nutrient or water cycles disturbance regime or natural succession (Campagnaro,*et al* 2018). The threats caused by IAS in forest ecosystems include hybridization, transmission of diseases and species competition (Vilà et al., 2011; Medvecká et al., 2018). In general, invasive plants are characterized as being highly adaptable to a broad range of environmental parameters (Moughalu and Chuba 2005). Economic losses attributed to widespread invasives are high. Invasive exotic plants usurp forest productivity, hinder forest-use activities and limit diversity on millions of acres of forest land. Some exotic species are capable of rapidly colonizing areas, altering community composition and even displacing native species. (Belcher and Wilson 1989, Tyser and Key 1988). They expand their ranges and invade new areas. Therefore, several policies, risk assessments and legislations are now in place to regulate the spread of IAS in forest ecosystems (Heywood and Brunel, 2009; Brundu and Richardson, 2016; Pötzelsberger et al., 2020).

II. Steps to a Successful Plant Invasion

The probability of introduction, establishment and spread of invasive plant species (the introduction-naturalization invasion continuum) is affected by geographical, ecological and socioeconomic features of the invaded area (i.e., climate, resource availability and demand for certain goods and services; Catford, Jansson & Nilsson,2009;Pysek&Richardson 2006; Reaser *et al*.,2007;Richardson & Pysek,2012),by external factor such as the initial population size, residence time and propagule pressure (Lockwood, Cassey, & Blackburn, 2005; Trueman *et al* 2010; Catford, Vesk, White, & Wintle, 2011) and by inherent species traits influencing its ability to survive ,reproduce, disperse and interact with other species, native or alien, already resident in the area (Pysek & Richardson ,2006;Rojas-Sandoval&Acevedo-Rodriguez,2015).

The invasion potential of an exotic species can be partially predicted by examining its life history, attributes, geographic and ecological distribution. There are several important steps to a successful plant invasion which include seed dispersal, initial seedling establishment and the establishment as well as the persistence of a viable population. Seed dispersal is one of the most important factors that influences the ability of a species to colonize new areas (Bedunah 1992). For an invasion to occur, seeds must first be dispersed to a potential habitat. Seeds have an entire array of morphological and structural adaptations which allow them to be dispersed by wind, water and animals (Bedunah, 1992).

Human activities are other important vectors for seed dispersal. For instance, cultivation has promoted the spread of exotics as a number of exotic plants were intentionally introduced for use as crops or as ornamentals. More recently, exotic plants have been introduced as part of erosion control programmes or accidentally by park visitors. Exotic plants continue to be unintentionally introduced and dispersed by clinging to clothing and mud on hiking boots and by attaching to motor vehicles. Once seeds reach a new potential habitat, climatic and biotic factors may affect the establishment of seedlings. For a seeding to successfully become established, the temperature and precipitation regimes of the area must fall within the tolerance ranges of that species. However, many invasive species may be “pre-adapted” to the climatic and abiotic conditions of the new habitats (Newsome and Noble 1986). These species may have evolved under similar climatic conditions or may have broad tolerance range that allows them to occupy a variety of habitat types.

The establishment of a single plant in an ecosystem generally does not constitute a successful invasion. Instead, an invasive species must establish with a self-sustaining population. Bazaaz (1984) points out that

colonizing species are more likely to become established with a large number of repeated introductions of a large number of seeds. The establishment of invasive species is rare with single introductions of a small number of seeds (Bazaaz 1984). Species that are capable of producing and dispersing a large number of seeds have a higher probability of a successful invasion. Species which have a high number of propagules in close proximity to natural areas also have a high invasion potential. Species that are good competitors for soil moisture and nutrients have a higher chance of establishment and persistence in ecosystems than other species. Characteristics of good competitors include plants that hold their leaves higher than other plants in light limited environments or push roots deeper into the soil in water- limited environments. Good competitors often possess rapid early growth, leading to a rapid development of the root system which may allow the plant to access available resources; the exotic plant may then become established in the ecosystem.

III. Factors Contributing to Invasiveness

Biological factors that have been suggested as contributing to invasiveness fall into the following categories;

Species characteristics:- Here, factors such as breeding system and seed ecology may be important. Most plants are outbreeders with some capacities for self-fertilization and this seems to be the case for invasive plants (Cronk and Fuller 1995). For introduced trees, outbreeding may not be a constraint if many species have been introduced in large numbers. Furthermore, many of the introduced trees produce large quantities of seeds (e.g. Pines, Eucalyptus, Woody legumes) and Richardson et al., (1994) through their work on pines, have suggested that propagule pressure is an important factor contributing to invasiveness. Greater reproductive potential of an invading species tend to aid rapid invasion. The prodigious quantity of seeds produced by *Tithonia rotundifolia* leaves so much seeds in the soil. Such seed banks are usually larger than those of other native species (Holmes et al., 1987; Londsdale et al., 1986)

Some invasive have aggressive root systems that can spread long distances from single plant. These root systems often grow so densely that they smother the root system surrounding vegetation. Some species produce chemicals in their leaves or root system which inhibit the growth of other plants around them. Most invasives cast dense shades beneath which native vegetation cannot survive.

Seed dispersal mechanism:- Cronk and Fuller (1995) collated information that the dispersal of many invasive plants is facilitated by vertebrates. In New Zealand, over half of the woody invaders have fruits that are adapted for dispersal by birds (Haysom and Murphy, 2003). Most invasive species produce copious amounts of seed. This seed is often bird or wind-dispersed allowing it to cover great distances in a short period of time.

Ecosystem disturbance: Most invasions by forestry trees occur in semi-natural ecosystems and disturbance has frequently been identified as anessential prerequisite for invasion byan introduced species (Hayson& Murphy 2003). Further support for this idea come from Hughes and Styles (1989) who cited examples from south American of introduced trees that were unable to invade natural ecosystems. Large gaps created by logging operation appear to be more readily invaded by exotics than natural tree fall gaps.

The shrubs*Chromoleanaodorata*is readily found in selectively logged forest of Western Ghats (India) but absent from natural forests (Chandrashekara and Ramakrishnan, 1994).

In heavy exploited and degraded forests of lowland of Southwestern Sri Lanka; *Alstonamarcropylla*of the family Apocynaceae is commonly found in large gaps but appear tobe absent from unlogged forest (Bingelli 1999). In Tanzania *Maesopsiseminii*becomes dominant in logged forest but is capable of regenerating in natural forests in large treefall gaps. In the same forest shrubs *Clidemiahirta*is also becoming quite commoninnatural forest gaps (Bingelli 1999).

Potential rapid climate change results in increased intensity of disturbance; increased human pressure for firewood and forest products will as lead to conditions more favourable to know invasive woody plants. Most of these species require a substantial amount of disturbance to spread extensively.

Absence of Herbivorous/Competitors/Pest:-There are many studies that show that trees in their native ranges are attacked by a wide variety of co-evolved micro-organisms and herbivores (both insect and vertebrates). However, when trees are introduced, they are often relieved of this pressure, as the herbivores e.t.c. in the area of introduction are not co-evolved and are usually less diverse (Haysom et al., 2003). In Nigeria, *Tithoniadiversifolia*does not have a specialist pest and diseases inspite if its large population which ordinarily should attract such. This more or less predator free status may be one reason among others for its competitive advantage over native flora with which it shares similar ecological requirements. invasive exotics also continue to spread because natural predators were not imported from the plant home range.

At present, it's unclear whether environmental factors or species specific characteristics are more important in determining the tendency of a species to become invasive. This problem has led to substantial research efforts over the past 15 years to try to identify those factors that might result in a tree becoming invasive (Richardson, 1998). This has been part of a wider effort to understand the general basis of invasiveness in plants (Rejmanek 2001). Rapid growth rate, particularly in relation to poor soil has often resulted in emergency of trees that seed heavily and can survive and can survive under a wide range of environmental conditions; these very qualities can lead to a tree becoming invasive. There are many causes in which a species known to be highly invasive in at least one country has not shown the same trait when introduced elsewhere (Haysom and Murphy, 2003). It is well known that most invasive tree species have taken something like 50 years or more to attain that state (Hughes, 1995). Time is thus a very a very important variable that needs to be taken into account when recording whether or not a species in invasive. Richardson et al., (1994) cited some examples of naturalized pines that have subsequently become invasive whereas others have remained merely naturalized.

IV. Sources of Invasion

Horticultural activity:-This is responsible for about 60% of invasive species introductions, into arboretum, botanical gardens, and gardens. A numbers of species introduced to botanical gardens have becomes invasive but there is no evidence to show that scientists responsible for their introductions were aware of the potential problems (Bingelli, 1999). The appearance of articles warning that tropical botanical gardens could be the source of invasive species in a very recent development. Exotic plants can spread rapidly because of our mobile society with "hitch-hiking" seeds and the intentional transportation of ornamental and forage plants (Randall and Marinnelli, 1996).

Conservation Activity :-(Soil Conservation Service, United States Department of Agriculture) introduced about 30% of invasive plant, mostly for screening, windbreak, and erosion control, but also to supply food and cover for wildlife.

Accidental Introductions:-Make up the remaining 10% for example, *Chromolaenaodorata*was accidentally introduced to Nigeria and has become an aggressive invasive weed. Siam weed forms dense stands, which prevents establishment of other species, both due to competition and allelopathic effects (Muniappan 2000). It is also a problem in agricultural land and commercial plantations. Also the case of purple loose strife which was first brought to the U.S in the hold of a ship via ballast water, then later introduced for horticultural purposes is an example of accidental introduction. Some species may be indigenous to certain regions of North America where they are not invasive, but arrive in new regions through assisted range expansion or transportation in other parts of the country for ornamental purposes, where they can become invasive (black locust, for example).

V. Outcomes of a Plant Invasion

After an exotic plant is introduced there is a "lag phase": of decades to decades to centuries before an exponential spread phase (Baskin, 1996). Thus, some species that currently appear non-invasive may eventually begin to spread rapidly. Most invasive exotic plants spread through abundant seed production and perennial species spread by well-protected, below-ground rhizomes (Miller, 1996). Invasive exotic plants can prevent or retard natural succession and reforestation by forming dense infestations, often in mixtures.

Once an exotic plants population becomes established, there are three potential outcomes of invasive-nutralization, facilitation and species replacement through succession. Naturalization refers to a species that is more or less in equilibrium with the other plants in the community. If a species invades an ecosystem and does not expand its range within that ecosystem, it might be considered “naturalized”. However, naturalization may only be a short term phenomenon.

Facilitation can occur when a disturbance alters the community. Following the disturbance the exotic species may then begin to invade larger areas. In a sense, the subsequent invasions were “facilitated by the disturbance”. An exotic species can be facilitated to spread by the introduction of a suitable seed dispersal agent or pollinator, or the provision of disturbance (Cronk and Fuller, 1995). Facilitation helps to complete the invasion cycle by allow the species to disperse seeds and establish plants in new areas. In the absence of any natural controls, such pathogens or herbivores these invasive species may continue to expand their range (Bedunnah 1992).

Finally, the process of succession can affect the invasion cycle by altering the availability of resources overtime. The changes in species composition from a simple plant community comprising of a few colonizing species to more complex plant communities overtime is called succession.

Succession is driven by stressors or disturbance, which can affect the availability of resources to plants. These changes in resources availability influence which plants are able to persist in the ecosystem and may provide an initial opportunity for invasion. Over time, plants that are best adapted to the biotic and abiotic conditions replace the plants that are not well adapted to the conditions. Horn (1976) distinguished three major ways in which succession may occur in disturbed forest. The first, simply involves the invasion of gaps by species which are well established in the surrounding forests, succession is thus complete in one generation. In the second which is called “obligatory succession” by Horn, the ground is first pioneer communities in the shade of which a second wave of species, becomes established and so on until a mature community is re-established at the end of the succession. In Horn’s third way many species invade simultaneously but only the long-lived persist into the matured community. The species involved are said to form a “competitive hierarchy”. In some cases, all the three processes are likely to play part if there is a “ competitive hierarchy” we can envisage species which invade the fresh gap as pioneers, but nevertheless persist to become components of the mature forest although they may not regenerate under canopy. These have been recognized as “persistent serial” (Keay 1957) but because they do not fit easily into the obligatory succession model, they have usually been ignored.

VI. Conclusion

It has long been recognized that biological invasions threaten the conservation of indigenous biodiversity resulting in severe global ecological and economic impacts plants invasions particularly follow some trends which make the entire process a success. Knowledge of the trends following a plant invasion can assist conservationist, scientists, foresters, ecologist and other concerned stakeholders to predict the invasion potentials of exotic species with a view to reducing the rate of invasion across the globe.

VII. Recommendations

1. Biological invasion is more a human-driven environmental problem than a strictly biological one. Inherent uncertainties remain about what species will be introduced and which will become invasive. Consequently making decisions may be very challenging and difficult.
2. The overall complexity of the problem, its interdisciplinary the scientific uncertainties and the large number of stakeholders that need to be informed and involved together need to study the trend followed by plant invasions and use it in decision making that will enhance the effective management of invasive alien species.
3. As regard the management of invasive alien species it is widely agreed that presenting biological invasion or tackling them at a very early stage is the most efficient and cost effective approach.

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