Climate Change and Invasive Alien Species threatening the globally significant biodiversity of Sri Lanka

Buddhi Marambe[1], Siril Wijesundara[2], Pradeepa Silva[3] and Ajith Silva[4]
[1]Department of Crop Science & [3]Department of Animal Science, Faculty of Agriculture, University of Peradeniya, Sri Lanka
[2]Royal Botanic Gardens, Peradeniya, Sri Lanka
[4]Ministry of Environment and renewable Energy, Battaramulla, Sri Lanka

Introduction

Climate change demands a shift to a much less carbon intensive pattern of economic growth (ADB, 2009) and the incorporation of adaptation measures to help cope with its adverse effects (Marambe et al. 2013; Punyawardena et al. 2013). Climate change is threatening food production systems, livelihoods, and the food security of billions of people across Asia where more than 60% of the people are actively involved in agriculture. According to the IPCC (2007), the average global temperature increased by about 0.76 °C and global mean sea level rose by 12 to 22 cm during the last century. These changes are affecting the entire world, from low-lying islands in the tropics to the Polar Regions. The global average temperature increased between about 0.15°C and 0.3°C per decade for 1990 to 2005. This can now be compared with observed values of about 0.2°C per decade (IPCC 2013).

Climate change, among other factors, is already forcing biodiversity to adapt either through shifting habitat, changing life cycles, or the development of new physical traits (MEA 2005). The Figure 1 shows the projected area to change by 2100 in relation to how much area is currently protected (Conservation Risk). Many of the tropical, but not temperate regions, with greatest risk (red) are also of highest conservation value as indicated by their higher number of globally unique amphibians, birds, mammals and reptiles. This provides baseline information on a global scale to quantitatively demonstrate the urgent need to plan reserves and other conservation efforts in view of future global change impacts.

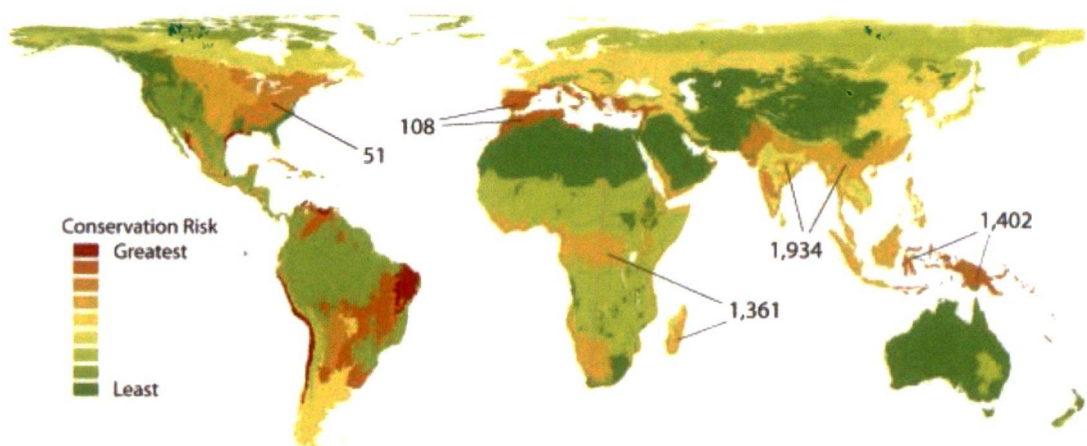

Figure 1. The global Conservation Risk area in 2100 (Source: University of California, San Diego, USA)

Globally Significant Biodiversity in Sri Lanka

Sri Lanka, along with the Western Ghats of India, has been identified by Conservation International (CI) as one of the 34 global biodiversity "hotpots" considering not only the high concentration of endemic species, but also the loss of over 75% of the primary vegetation

(Mittermeier et al. 2000). Moreover, Sri Lanka together with Western Ghats, has also been identified as one of the eight Global Biodiversity Hotspots (Myers et al. 2000) based on the number of endemic plants and vertebrates, their density, and remaining primary vegetation relative to the original extent. The globally significant biodiversity and agro-biodiversity of Sri Lanka (Gunatilleke et al. 2008, Pushpakumara and Silva 2008, Marambe et al. (2012) and the impacts of the changing environments on biodiversity (Marambe et al. 2006) are well documents.

Invasive Alien Species (IAS)

Invasive alien species (IAS) are species whose introduction and/or spread outside their natural past or present distribution threaten biological diversity of the new environment (http://www.cbd.int/invasive/WhatareIAS.shtml). The spread of IAS is a significant and growing threat to the country's globally significant biodiversity and reflects concerns raised in the Millennium Ecosystem Assessment (MEA), which identified IAS as one of the five major drivers of global biodiversity loss and ecosystem change. As an island, Sri Lanka is particularly susceptible to the spread of IAS, particularly their negative impacts. According to an analysis carried out by Vié et al. (2009) on the 2008 IUCN red list of threatened species, IAS has been identified as (a) the fifth most severe threat to Amphibians, following habitat loss, pollution, disease and fires, (b) the third most severe threat to bird species after agriculture and logging, (c) the third most severe threat to mammals after habitat loss and utilization (mostly for food and medicine), (d) the fourth most severe threat to Reptiles after pollution, persecution and natural disasters, and (e) a major threat to a broad range of marine species facing extinction. An overall assessment of the impact of IAS on the biodiversity of Sri Lanka is reported in Marambe et al. (2010).

Climate Change vs Invasive Species

The global impact of IAS has been recognized by the Convention on Biological Diversity (CBD), which calls for the control and monitoring of alien species that threaten ecosystems, habitats and species. The article 8(h) of the CBD requests all member governments to "as far as possible and appropriate, prevent the introduction of, control or eradicate those alien species which threaten ecosystems, habitats or species." The problems faced by the countries due to the presence of IAS are not new. The IAS present in Sri Lanka and their impact on the ecosystems of Sri Lanka ecosystem are well documented (Marambe et al. 2001; Marambe et al. 2010; Marambe et al. 2011; Ranwala et al. 2011). With no pressure from natural enemies, rapid reproduction, adaptable to new and changing environments, and mature early with aggressive growth and spread, thus out-compete native species are the specific characteristics of aliens that can be invasive. The IAS has continued to affect the natural (terrestrial, aquatic and marine) and agro-ecosystems of Sri Lanka affecting its biological diversity and food security (Marambe and Gunawardena 2010).

Climate change and IAS present two of the greatest threats to biodiversity and the provision of valuable ecosystem services. Apart from the human induced habitat destruction, IAS are the second most significant factor that controls environmental change worldwide, resulting in negative impacts on environmental conservation, economic growth, and sustainable development. Combined, the complexity of their interactions dramatically increases, and evidence is rapidly growing on how climate change is compounding the already devastating effects of invasive species. Climate change impacts, including warming temperatures and

changes in CO2 concentrations, are likely to increase opportunities for IAS because of their adaptability to disturbance and to a broader range of bio-geographic conditions (Figure 2).

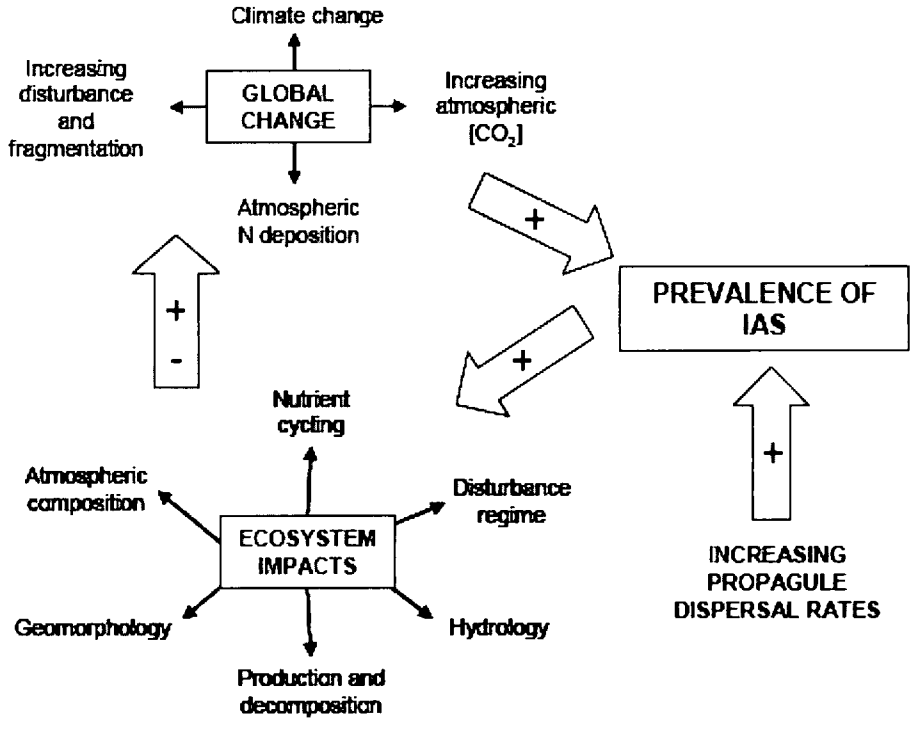

Figure 2. Impact of climate change on IAS (a modified version from Dukes and Money, 1999)

The predicted climate changes would have following impacts on the IAS in Sri Lanka thus resulting in significant negative impacts on the globally significant biodiversity of the country.

(a) Longer growing season - influencing the species' reproductive capacity (increased seed production and biomass),

(b) Higher environmental temperatures - improving plants' fertility resulting in increased population sizes (e.g. *Echinochloa crusgalli*; Marambe and Amarasinghe 2002) and increased fruit and seed set due to enhanced activity of insect pollinators activity,

(c) Increasing seasonality and marked wet and dry cycles - benefitting aquatic invasive alien plants where fluctuations of water levels help expansion of the free-floating IAS such as *Eichhornia crassipes*, extreme climatic events supporting the escape of exotic pet animals from captivity (e.g. *Chitala ornata* and *Hypostomus plecostomus*; Silva and Kurukulasuriya, 2010) that would likely to benefit from rising temperatures, and prolonged droughts supporting enhanced insect pest incidence (e.g. *Paracoccus marginatus*; Wijesekara, 2010),

(d) Higher CO_2 levels - supporting the prevalence of C_3 invasive species that are reported from Sri Lanka such as *Mimosa pigra* and *Prosopis juliflora* (Wijesundara, 2010), and

(e) Changes in atmospheric circulation – affecting the dispersion pathways of IAS making warmer-water alien species become more abundant where established and helping their expansion.

It is important to note that the present distribution of IAS may not be in equilibrium with the current climate, nor indeed their potential establishment and/or spread may not necessarily be determined primarily by climate. For example, Marambe et al. (2002), in an attempt to identify the relationship of pest and diseases outbreaks in rice cultivation over a period of 40 years from 1960 to 2000 (using proxy data cost of control efforts) in relation to change in environmental temperature, concluded that there is no clear relationship between the two parameters. However, this conclusion was drawn using limited data available on the pest and disease incidence both spatially and temporally. Accurate prediction of the effect of climate change on IAS and native biological diversity is difficult, due to the complexities involved in. Accurate prediction of the future scenarios of climate change/global warming is essential in order to establish the potential impacts of climate change on IAS and the resulting effects on natural and agro-ecosystems.

Recent research have indicated that mathematical models has indicated sustained multi-year periods of "cooling" embedded within the longer-term warming produced in the 21st century simulations (Easterling and Wehner, 2009). Therefore, it is reasonable to expect that the natural variability of the real climate system can and likely will produce multi-year periods of sustained 'cooling" or at least periods with no real trend even in the presence of long-term anthropogenic forced warming, which would no doubt have different impacts on the biodiversity and IAS of a given ecosystem. Continuous research for better understanding and information use from key sources of climate predictability, and interactions between the ocean and atmosphere, atmosphere and land, as well as volcanic eruptions, greenhouse gases and land use changes is essential in this regard. Hansen et al. (2010) recently updated the Goddard Institute for Space Studies (GISS) analysis of global surface temperature change and concluded that the rate of global warming has not declined despite year-to-year fluctuations associated with *El Nino-La Nina* cycle of the tropical ocean temperature.

Recent research has allowed a better understanding of some of the mechanisms that could act as a trigger in promoting invasions. However, predictions are feeble in this regard due to the existing gaps on the biology of the IAS, susceptibility to invasion of the host ecosystem, vulnerability of native species to climate change and impacts of IAS, and dynamism of changes in the interactions within ecosystems and human activities. The IPCC (2007) links the warming worldwide with poleward and altitudinal shifts in plant and animal ranges. It is forecasted that many ecosystems will become vulnerable to biological invasions as climatic barriers are removed. The IPCC (2007) concludes that a temperature increase of greater than 1.5 °C–2.5 °C of the global average temperature will cause dramatic changes to species distributions and ecosystem structure and function. This would result in overwhelmingly negative consequences for global biodiversity and ecosystem goods and services.

Conclusions:

Climate change is global environmental problem that will alter distributions and abundances of many species, including increasing the ranges, establishment opportunities and consequent impacts of IAS. Invasive alien species threaten biodiversity and livelihoods across the globe and must be considered when planning climate change adaptation strategies. Found in terrestrial, freshwater and marine environments, IAS adversely affect the livelihoods, lifestyles and health of island dwellers and cause harm to ecosystems and biodiversity. Islands are extremely vulnerable to the impacts of invasive species, and

introduced pests, weeds and diseases have caused biodiversity loss and ecosystem disturbance on islands worldwide. The synergy of climate change and invasive species, though complex and poorly understood, could be devastating for some native plants and animals as well as for food security, international trade and other economic activities in the Pacific. Despite physical and natural resource limitations, important consideration will need to be given to integrated planning, social cohesion, increased attention to managing biodiversity (in particular, IAS), and a strengthening of territorial planning if islands are to become economically, socially, and ecologically resilient and self-sufficient.

References

ADB (2009): Addressing climate change in the Asia and the Pacific – Impacts on food, fuel and people. Asian Development Bank. 14 pp.

Dukes JS and Mooney HA (1999): Does global change increase the s uccess of biological invaders ? Trends in Ecology and Evolution, 14:135-139

Easterling, DR. and Wehner MF (2009): Is the climate warming or cooling. Geophysical Research Letters: 36, DOI:10.1029/2009GL037810

Gregory PA, Scott RL and Heyder U. (2010): Combined effects of climate and land-use change on the future of humid tropical forests. Conservation Letters; DOI: 10.1111/j.1755-263X.2010.00133.x

Gunatilleke N, Pethiyagoda R and Gunatilleke S (2008): Biodiversity of Sri Lanka. J Natn Sci Foundation of Sri Lanka 36 (Special Issue): 25-62

Hansen J, Ruedy R, Sato M and Lo K (2010): Global Surface Temperature Change. Review of Geophysics. DOI: 10.1029/2010RG000345

http://www.cbd.int/invasive/WhatareIAS.shtml (accessed on 7th May 2014)

IPCC (2007): Fourth Assessment Report – Working Group 1. Inter-governmental Panel on Climate Change.

IPCC (2013): Summary for Policy Makers. In: Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M. Tignor and H.L. Miller (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

Kurukulasuriya P and Ajwad MI (2007): Application of the Ricardian Technique to Estimate the Impact of Climate Change on Smallholder Farming in Sri Lanka, Climatic Change, 81: 39-59

Marambe B, Bambaradeniya C, Pushpa Kumara DK and Pallewatta N (2001): Human dimensions of invasive alien species in Sri Lanka. *In:* The Great Reshuffling; Human Dimensions of Invasive Alien Species (Ed: JA McNeely), IUCN, Gland, Switzerland and Cambridge, UK. 135-142.

Marambe B, Pushpakumara DKNG, Silva P, Ratnayake HD and Widanage S (2006): Impacts on Biodiversity. An Addendum to the Biodiversity Conservation in Sri Lanka – A Framework for Action. A Publication of the Biodiversity Secretariat, Ministry of Environment, Sri Lanka. 27 pp.

Marambe B, Pushpakumara G, Silva P, Weerahewa J and Punyawardena BVR (2013) Climate change and household food security in homegardens of Sri Lanka. In: HPM Gunasena, HAJ Gunathilake, JMDT Everard, CS Ranasinghe, and AD Nainanayake (eds). Proc Int Conf Climate Change Impacts and Adaptation for Food and Environmental Security In proceeding of: International Conference on Climate Change Impacts and Adaptation for Food and Environmental Security, Colombo, Sri Lanka. pp 87-99.

Marambe B, Silva P, Ranwala S, Gunawardena J, Weerakoon D, Wijesundara S, Manawadu L, Atapattu N and Kurukulasuriya M (2011): Invasive alien fauna in Sri Lanka: National list, impacts and regulatory framework. In: Island invasives: Eradication and management. IUCN (Eds: Veitch, CR, Clout, MN and Towns DR). pp 445-450. International Union for Conservation of Nature, Gland, Switzerland.

Marambe B, Silva P, Wijesundara S and Atapattu N (Eds) (2010): Invasive Alien Species – Strengthening Capacity to Control Introduction and Spread in Sri Lanka Biodiversity Secretariat of the Ministry of Environment, Sri Lanka

Marambe B. and Amarasinghe L. (2002): Propanil-resistant barnyardgrass (*Echinochloa crus-galli* L. Beauv) in Sri Lanka: Seedling growth under different temperatures and control. Weed Biology and Management, 2: 194-199.

Marambe B., Basnayake BRSB, Punyawardena BVR., Dinuka KR and Thambawita GD (2002): Assessment of Evidence, Causes and Implications of Change in Daily Temperature Regimes in Sri Lanka. (http://www.meteo.slt.lk/Researches.htm)

Marambe, B. and Gunawardena, J. (2010): Institutional coordination, legal regime and policy framework for management of invasive alien species in Sri Lanka. In: Invasive Alien Species – Strengthening Capacity to Control Introduction and Spread in Sri Lanka (Eds: Marambe B, Silva P, Wijesundara S and Atapattu N), Chapter 6. pp 63-76. Biodiversity Secretariat of the Ministry of Environment, Sri Lanka.

Marambe, B., Pushpakumara, G. and Silva P. (2012): Biodiversity and Agro-biodiversity in Sri Lanka: A case in Village Tank Systems. In: Biodiversity Observation Network in the Asia-Pacific Region: Towards Further Development of Monitoring (Eds: S-I Nakano, T. Yahara, T. Nakashizuka and S. Yamamoto). Springer, Japan. pp 403-430

MEA (2005): The Millennium Ecosystem Assessment, Island Press.

Mittermeier RA, Myers N and Mittermeier CG (2000): Hotspots - Earth's Biologically Richest and Most Endangered Terrestrial Ecoregions, Conservation International.

Myers N, Mittermeier RA, Mittermeier CG, da Fonseca GAB and Kent J (2000): Biodiversity hotspots for conservation priorities. Nature 403: 853-858

Punyawardena R, Dissanaike T and Mallawathanthri A (2013) Spatial variation of climate change induced vulnerability in Sri Lanka: An analysis of the components of vulnerability at district level. Department of Agriculture, Sri Lanka and UNDP/GEF Sri Lanka.

Pushpakumara DKNG and Silva P (2008): Agrobiodiversity of Sri Lanka (In Sinhala). Biodiversity Secretariat, Ministry of Environment and Natural Resources, Sri Lanka, 80p.

Ranwala S, Marambe B, Wijesundara S, Silva P, Weerakoon D, Atapattu N, Gunawardena J, Manawadu L and Gamage G (2011): Post-entry risk assessment of invasive alien flora in Sri Lanka: Present status, gap analysis and the most troublesome alien invaders. Pakistan J Weed Science 18: 863-871

Silva P and Kurukulasuriya M (2010): Invasive Alien Fauna in Sri Lanka. In: Invasive Alien Species: Strengthening Capacity to Control, Introduction and Spread in Sri Lanka (Eds: Marambe B, Silva P, Wijesundara S and Atapattu N). Chapter 5 .Ministry of Forestry and Environment of Sri Lanka and UNDP-Sri Lanka.

Vié J-C, Hilton-Taylor C and Stuart SN. (eds.) (2009): Wildlife in a Changing World – An Analysis of the 2008 IUCN Red List of Threatened Species. Gland, Switzerland: IUCN. 180 pp.

Wijesekara A (2010): Invasive alien species of agricultural importance in Sri Lanka: Have we managed them properly? In: Invasive Alien Species – Strengthening Capacity to Control Introduction and Spread in Sri Lanka (Eds: Marambe B, Silva P, Wijesundara S and Atapattu N), pp 115-122. Biodiversity Secretariat of the Ministry of Environment, Sri Lanka.

Wijesundara S (2010): Invasive alien plants in Sri Lanka. In: Invasive Alien Species – Strengthening Capacity to Control Introduction and Spread in Sri Lanka (Eds: Marambe B, Silva P, Wijesundara S and Atapattu N), pp 27-38. Biodiversity Secretariat of the Ministry of Environment, Sri Lanka.