

Impact of Climate Change on Biodiversity: A Challenge to Agro-ecosystems in South Asia

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1. Introduction

Climate change poses a formidable challenge levying widespread impacts on human and natural systems. According to the IPCC (2014), each of the last three decades has been successively warmer at the Earth's surface than any preceding decade since 1850. Over the period 1880-2012, the average of the combined land and ocean surface temperature at global scale has shown a warming of 0.85 °C [0.65 to 1.06 °C]. The IPCC (2014) further highlights the human influence on the climate system. The recent anthropogenic emissions of greenhouse gases (GHGs), which largely determines the global warming, have been the highest in the history. The recent report of the Asian Development Bank (Ahmed and Suphachalasai, 2014) stated that South Asia, where nearly 33 % of the population of 1.5 billion is still living in poverty, faces a major challenge due to climate risks resulting in a significant economic, social, and environmental damage thus, compromising their growth potential and poverty reduction efforts.

Biological diversity (biodiversity) is the variety of all life. The Convention on Biological Diversity CBD defines biological diversity as “the variability among living organisms from all sources including, *inter alia*, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems” (SCBD, 2005). Biodiversity is determined by many factors, including mean climate and climate variability, as well as disturbance regimes caused by changes of tectonic, climatic, biological, anthropogenic and other origin. It is now generally accepted that global biodiversity will be significantly affected by climate change, although its precise impacts are still vague.

This paper mainly deals with the agricultural biodiversity (agrobiodiversity) in the Asia and South Asia regions, and Sri Lanka, and highlights the impact of climate change on the precious genetic resources in agro-ecosystems in the selected regions.

2. Biodiversity in Asia, South Asia and Sri Lanka

Asia occupies only 8.6 % of the world's land area but is the home to over 60 % of the world population. South Asia covers about 4.4 million km², which is 10 % of the Asian continent or 3.3% of the world's land surface area, and accounts for about 45 % of Asia's population (or over 25 % of the world's population). The population in Asia and South Asia grows fast and many of the countries are considered poor.

The countries in Asia have great biodiversity importance and richness, ranking with South America as the richest place on earth for variety of living forms. Hence, Asia contains some of the most important biodiversity hotspots in the world. Specifically, an area to be considered a biodiversity hotspot it must (i) contain at least 1,500 species of vascular plants as endemics (species found nowhere else on earth) and (ii) have lost at least 70 % of its original habitat (CI, 2012). Of the world's 34 recognized biodiversity hot spots, eight are in Asia (Fig. 1; Mittermeier et al., 2004). These hot spots cover the entire ASEAN (Association for South East Asian Nations) region plus the Western Ghats of India, Sri Lanka, southwest China and the eastern Himalayan countries of Nepal, Bhutan and India. The Hengduan Mountain area of China is the richest temperate ecosystem in the world.

Biodiversity in Sri Lanka is considered to be the richest per unit area in the Asian region with regard to mammals, reptiles, amphibians, fish and flowering plants, surpassing several mega diversity countries such as Malaysia, Indonesia and India. Sri Lanka's exceptional biodiversity is due to the high ecosystem diversity it carries and the diverse species those ecosystems harbor (MERE, 2014). It is a remarkable centre of endemism where the endemism of both flora and fauna species are very high. For instance around 28 % of Sri Lanka's 3,154 species of indigenous angiosperm flora (as reported in 2008) are endemic to the country, and among the faunal species, the highest endemism is seen among amphibians, freshwater fishes and reptiles (GOSL, 2008). The global importance of Sri Lanka's biodiversity could be highlighted by the fact that, it has four forests recognized as Natural World Heritage Sites based on their exceptional biodiversity value due to high endemism, four Biosphere Reserves within the UNESCO's World Network based on their exceptional biodiversity value due to high endemism. Furthermore, six (06) Ramsar sites identified in Sri Lanka shows the importance of country's wetlands ecosystem.

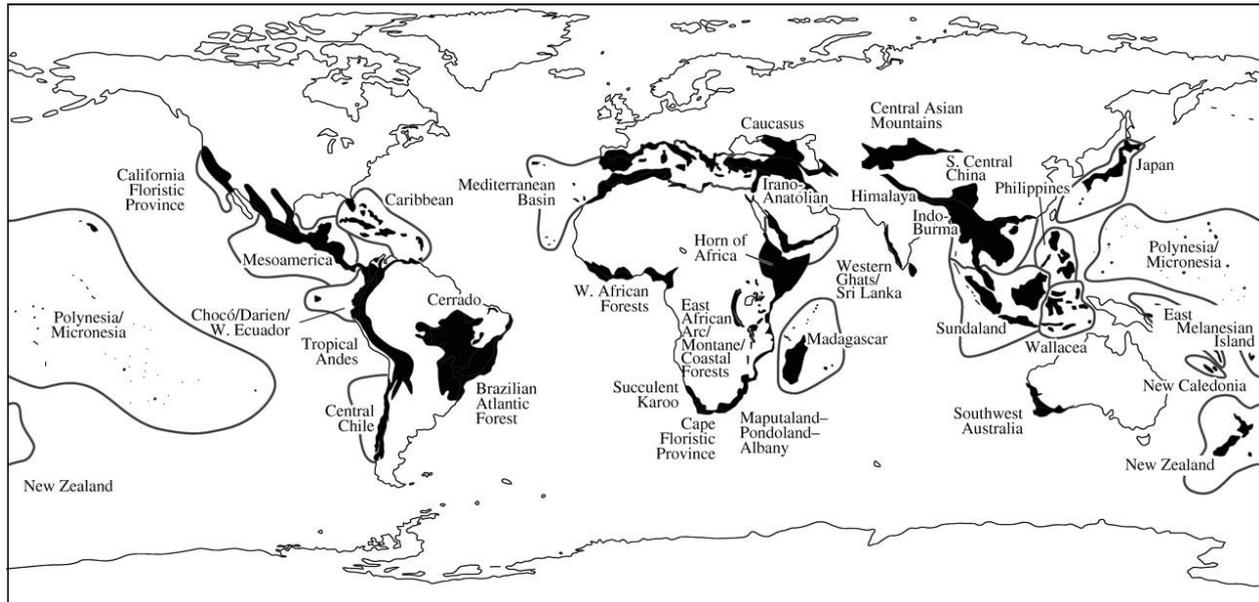


Fig. 1. Biodiversity hotspots (adopted from Mittermeier et al., 2004)

Humans mobilize approximately 40 % of the total primary production on land per annum exerting a heavy pressure on biodiversity. Estimates show that more than 40 % of the world's economy and 80 % of the needs of the world's poor are derived from biodiversity (http://www.icem.com.au/documents/biodiversity/bioplan/bio_status.pdf). This alone emphasizes the huge dependency on biodiversity and the need for its wise management. In addition, biodiversity of the region is increasingly threatened by the demand generated by rapid economic development. With pressures on biodiversity escalating, it is not surprising that one-third of all the threatened species are found in Asia (IUCN, 2009). Table 1 shows the status of plant and animal species in Asia's hotspots.

3. Benefits and Value of Biodiversity in Asia and South Asia

Benefits derived from biodiversity can be grouped into four categories namely, (a) Direct harvesting, including plants or animals for food, fodder, medicine, fibre, dyes, fuel, construction materials and other uses, (b) Social values, including aesthetic, cultural, recreational, education and research benefits, (c) Environmental services of ecosystems, such as climate regulation, flood and drought control, consistent water supply, nutrient recycling, natural pest control, pollution cleansing and soil generation, and (d) Development potential, through domestication, development and improvement of genetic resources and biotechnology. The total value of these products and services is enormous, and as a whole it contributes substantially to the economy. For example, in 2009, Asia provided wood products valued at \$28.4 billion, representing 27.4 % of the world's total, and non-timber forest products (NTFPs), such as rattan and bamboo, valued at \$7 billion, representing 37.8 % of the world's total (FAO 2010a). The value of biodiversity for China alone has been estimated at US\$ 257-421 billion per annum (CCICED 1996), which totals to \$5000 billion (SEPA 1998). Asia also has the most productive freshwater fisheries in the world, which makes a significant contribution to the national economies, improves food security as a source of protein, and a livelihood for the rural poor (Baran et al., 2008). According to the FAO (2010a), Asia contributes about two-thirds (66.4 %) of global inland fisheries production. The marine ecosystems in Asia provide significant economic goods and services that contribute to the livelihoods, food security, and safety of millions of people (WRI, 2011).

Components of biodiversity provide us with freshwater for domestic and industrial uses, and underpin the socio-economically vital areas of agriculture and livestock production, fishery, forestry, tourism, traditional medicine and several important manufacturing industries. For example, Sri Lanka's biodiversity provides a wide range of ecosystem services, which include providing fresh water, ameliorating the climate, containing soil erosion, regulating surface runoff and providing bio-resources for subsistence use as well as domestic and export oriented markets. Biodiversity of the coastal and marine ecosystems of Sri Lanka provides over 65 % of the animal protein requirement of the country. Thus, many components of biodiversity are vital to meet the consumptive and economic needs of the society

Table 1. Status of plant and animal species in Asia's biodiversity hotspots

Land Area and Species	Indo-Burma	East Melanesian Islands	Himalaya	South West China Mountains	Philippines	Sundaland	Western Ghats and Sri Lanka	Wallacea
Area (km ²)	2,373,057	99,304	741,706	262,446	297,179	1,501,063	189,611	338,494
Plants								
Species (#)*	13,500	8,000	10,000	12,000	9,253	25,000	5,916	10,000
Endemic (#)	7,000	3,000	3,160	3,500	6,091	15,000	3,049	1,500
Endemism (%)	52	38	32	29	66	60	52	15
Birds								
Species (#)	1,266	360	977	611	535	769	458	647
Endemic (#)	64	149	15	2	186	142	35	262
Endemism (%)	5	41	2		35	18	8	41
Mammals								
Species (#)	433	86	300	237	167	380	140	222
Endemic (#)	73	39	12	5	102	172	18	127
Endemism (%)	17	45	4	2	61	45	13	57
Amphibians								
Species (#)	286	42	105	90	89	244	178	48
Endemic (#)	154	38	42	8	76	196	130	33
Endemism (%)	54	91	40	9	85	80	73	69
Reptiles								
Species (#)	522	117	176	92	237	452	267	222
Endemic (#)	204	54	48	15	160	243	174	99
Endemism (%)	39	46	27	16	68	54	65	45
Freshwater fish								
Species (#)	1,262	52	269	92	281	950	191	250
Endemic (#)	553	33	33	23	67	350	139	50
Endemism (%)	44	12	12	25	24	37	73	20
Extinct Species	1	6	-	-	2	4	20	3

* # = Number; Source: CI (2012)

4. Biodiversity in Agroecosystems

Agriculture is the largest global user of biodiversity. Selection and value addition to wild biodiversity have taken place for more than 10,000 years of agrobiodiversity-management. Agro-biodiversity remains the main raw material for agroecosystems to cope with climate change because it contains the reservoir of traits for both plant and animal breeders and farmers to select resilient, climate-ready germplasm and produce new cultivars or breeds. For example, the traditional farming systems in Sri Lanka are the results of centuries long evolution of production systems to suit local conditions. Agrobiodiversity in any form can only be effectively maintained and adapted with the human management systems that created it, including indigenous knowledge systems and technologies, specific forms of social organization, customary or formal law, and other cultural practices (Marambe et al., 2012). Sri Lanka has a high diversity of traditional varieties of rice, vegetables and cash crops that are clearly resistant to diseases and insect pests, and are well suited for varied conditions of soil and climate in the island. Sri Lanka also has many wild relatives of rice and other crops in farmer's holdings, forests and wetlands amounting to 410 species (Fonseka and Fonseka, 2010). Of these, 289 species are indigenous and 77 are endemic to the island. This diverse gene pool can be used in crop breeding programmes to enhance crop production and food security for the nation. The development of the livestock sector in Sri Lanka is based on cross-breeding or grading up of local stocks of cattle, goat, swine and poultry with imported high yielding breeds. The main target of this effort is to preserve the characteristics of local poultry and livestock as much as possible while improving the productivity. Local livestock breeds are more resistant to pests and disease than imported breeds, are well adapted to local conditions, and have low nutritional requirements.

5. Loss of Biodiversity and Drivers of Biodiversity Loss

The loss of biological diversity reduces the ecosystem's ability to adapt to change and is an issue of profound concern for its own sake. Biodiversity also underpins the functioning of ecosystems which provide a wide range of services to human societies. Hence, its continued loss therefore, has major implications for current and future human well-being. This is of concern to nations in South Asia such as Sri Lanka, where the country's exceptionally rich biological diversity is central to its national identity and for maintenance of numerous ecosystem services essential for the 21 million people at present and for their future generations.

Habitat destruction, such as habitat conversion, degradation and fragmentation, are linked to biodiversity decline in South Asia. Deforestation and the associated fragmentation of natural habitats are expected to accelerate biodiversity decline in the coming years. The underlying drivers include population growth, poverty, urbanization, policy failures, institutional failures, trade and globalization, as well as climate change and variability. In contrast to proximate factors, the underlying drivers of biodiversity decline can operate at scales ranging from the national to the global. Other processes that contribute to biodiversity loss in the region include biodiversity overexploitation and the introduction of invasive species (Marambe et al., 2014).

Over the period 2002-2009, nearly 2,500 species of flora and fauna in Asia and the Pacific were recorded in the Red List of the IUCN as "critically endangered", "endangered" or "vulnerable" (UNEP, 2010). Thirteen of the 34 biodiversity hotspots designated by Conservation International are also to be found in this area (East Melanesian Islands, Himalayas, Indo-Burma, Japan, mountains of south-west China, New Caledonia, New Zealand, Philippines, Polynesia-Micronesia, south-west Australia, Sundaland, Wallacea, Western Ghats and Sri Lanka). Mammals have suffered the steepest increase in risk in South and South-East Asia compared to the global average.

6. Climate change and biodiversity loss in Asia and South Asia

The potential impact of climate change is of considerable concern worldwide and has been given due consideration by both the Convention on Biological Diversity (CBD) and the United Nations Framework Convention on Climate Change (UNFCCC). The findings of the IPCC and the attention given to this subject by the Conference of Parties to the CBD suggest that there are potential of serious threats to biodiversity as well as there are potential for adapting to climate change while enhancing the conservation of biodiversity. Climate change is likely to be an additional threat to agricultural biodiversity, increasing genetic erosion of landraces or ecotypes and threatening wild species, including wild relatives. The IPCC has reported that, globally, up to 30 % of species are at increasing risk of extinction, whereas approximately 15 - 40 % of ecosystems are being affected by climate change. Climatic factors can affect biodiversity directly and indirectly. Direct effects are mostly related to temperature and precipitation changes that affect individual organisms, populations, species distribution, and ecosystem compositions and functions.

Rice production in Asia could decline by 4% due to altered timing and magnitude of rainfall leading to drought or flood injury to rice crop. Further, since wheat is also a temperature dependent crop, reduction in agricultural productivity in wheat growing areas could also be expected. Thomas et al. (2004) predicted that 15–37 % of wild plant biodiversity is threatened with extinction due to climate change by 2050. Jarvis et al. (2008) predicted that up to 61% of *Arachis* species, 12% of potato (*Solanum* spp) species, and 8 % of *Vigna* species could become extinct within 50 years. Hence, analogue crop areas for many future climates should be promising locations to focus future collecting and conserving of crop genetic resources. FAO (2010b) predicts that climate change could cause up to 10 % reduction for staples such as rice more than 10 % reduction in millet and maize production. Localized extreme events and sudden pest and disease outbreaks are already resulting in greater unpredictability of production from season to season and year to year and require rapid and adaptable management responses. Grain harvests in China may also drop by 37 % by 2050 due to weather extremes, whereas extreme drought (i.e. doubling severity and frequency) in north-east China could result in 12 % crop losses (or 13.8 million t) by 2030.

Climate change will cause heat stress and reduce feed intake of farm animals influencing both growth and reproduction. As observed high output breeds, on which the more than 90 % of world's livestock and poultry production depend on are more susceptible to heat stress (IPCC, 2014). The areas and incidence of pests and diseases will be increased making greater exposure of farm animals. Nevertheless, adverse effects expected on crop yields and quality will seriously affect animal diet composition. Changes in micro-organisms and crop pests and diseases will create additional problems. Impact of climate change on freshwater ecosystems will change the habitat characteristics and alter the distribution and abundance of species now found in these environments. This threat exacerbates the ongoing threat to river systems in Asia due to existing dams and plans for more dams in the future. Sea level rise is another consequence of global warming that will influence freshwater ecosystems and species as saltwater intrudes upon freshwater areas and only salt-tolerant species will be able to adapt to these changes. Climate change can change flowering/fruitleting and flushing in forest species and crops and to disrupt the breeding and reproduction of wild fauna and livestock (Silva, 2009; MERE, 2014), and greater spread of invasive species (Marambe, 2008,

Marambe et al., 2009; 2014), inevitably leading to an increase in the number of threatened indigenous species, and species extinctions. Changes in rainfall regimes due to climate change could lead to pronounced water scarcity, droughts and unpredicted heavy rains that will disrupt cropping cycles and cause socio-economic upheavals among farming communities, affect human wellbeing and impede national development (MENR, 2014).

In the context of South Asia, climate change will have a major impact on the biological resources of the region, including agricultural biodiversity and availability of water. A 2 °C temperature rise and 7% increase in precipitation is estimated by scientists to cause 3% loss in net farm revenues. This can seriously undermine the economy of the South Asian region. Grain harvests in South Asia have also been predicted to drop by 30 % by 2050 due to weather extremes. For example in Bangladesh, reductions in production could potentially be as high as a 17 – 28 % for rice and 31 – 68 % for wheat (Karim et al., 1999) due to increased temperature. Studies carried out in Sri Lanka have shown that a reduction of monthly rainfall by 100 mm could reduce productivity by 30–80 kg of tea per hectare (Wijeratne et al., 2007). Eriyagama et al. (2010) reported that extended dry spells and excessive cloudiness during the wet season in Sri Lanka could reduce coconut yield, with annual losses of US \$ 32 million to US \$ 73 million, however, during a high rainfall year, the economy could gain by US \$ 42 million to US \$ 87 million due to high coconut yields. Future projections on coconut yield suggest that production after 2040 may not be sufficient to cater to local consumption. World Bank (Mendelsohn, 2004) estimated that at the aggregate level, a change in net revenues in smallholder agriculture in Sri Lanka could vary between –23 % and + 22 % depending on the climate change scenario. These effects will vary considerably across geographic areas from losses of 67 % to gains that more than double the current net revenues.

Fisheries production is one of the many ecosystem services that disappear when a reef are affected. In the central Indian Ocean, bleaching has been shown to have direct impacts on 90 % of the traditional artisanal fishing communities. Initial studies estimate that dead, crumbling reefs could lose 50% of their fisheries value. In 1998, the coral bleaching was estimated to cost as much as US\$8 billion in the Indian Ocean in terms of fisheries, tourism loss and reduced coastal protection (Ceasar, 2004).

7. Synthesis

Agro-ecosystems are characterized by high diversity at both, species and gene levels, and have much greater potential to adapt to climate change. A high crop genetic diversity is especially useful to adapt to climate change. Over-reliance on a handful of crops places global food security at a higher risk, especially in the context of climate change. It is imperative to manage agrobiodiversity in a sustainable way and to use it systematically to cope with environmental challenges. Collecting samples of endangered species to be preserved in gene banks will be the primary step, but also protecting the habitats where they thrive should be a must to ensure the in situ evolutionary processes of wild species contributing to agrobiodiversity.

Minimal efforts are in place with respect to mainstreaming of agricultural activities towards conservation of agro-biodiversity and to eliminate rural poverty. There is a need to provide traditional varieties of both plants and livestock in order to promote biodiversity conservation, and there exists a need to strengthen community level crop improvement programs (e.g. participatory plant breeding) towards establishing Community Seed Banks. Lack of responsible institutions with coordinated action, together with necessary funds and staff, makes it difficult to mainstream these activities. Habitat modifications due to changing rainfall patterns and temperature threaten the range, distribution, and diversity of terrestrial species. Rising temperatures affect flowering and seasonality and have particularly significant impact on high latitudes and altitudes. High temperature and prolonged drought may increase the risk of forest fire, which will also threaten species and habitats.

The wealth of traditional knowledge that exists in South Asia, especially Sri Lanka, had hardly been recognized or harnessed in the past for development (e.g. agriculture) or biodiversity conservation. It is now increasingly recognized that for sustainable development and the conservation of nature and its riches, traditional wisdom and the lifestyles of people with minimal demands on natural resources, could perform a vital role. This aspect is of particular importance in the areas of agriculture, control of pests and plant diseases, and curative purposes for humans and livestock, especially to face the exigencies of climate change. Climate change will therefore have a disproportionate impact on alpine and high elevation areas, including significant impact in the Himalayas and the Tibetan plateau, the sources of much of Asia's freshwater supply. Food is very much a product of biodiversity, and biodiversity can play a major role in the development of national agriculture and livestock in the future, especially in the face of climate change, by using the rich genetic diversity of indigenous crops and livestock breeds that offer much potential for genetic improvement. Traditional varieties of crops that are acclimatized to varied climatic conditions, wild relatives of crops, and indigenous livestock breeds offer potential to address challenges that may arise for agriculture in the future. Conserving agro-biodiversity and the systems they occur, as well as conserving traditional knowledge associated with agriculture and livestock rearing, are increasingly important for developing the agriculture sector in the face of climate change.

The consequences of biodiversity erosion of this magnitude are profound. Most significant is the destruction of species and ecosystems that are vital for the functioning of global life support systems. Others are loss of wild

relatives of crop plants and domesticated animals that serve as ‘gene banks’ when economically valuable breeds have to combat disease or adapt to climate change. Many species with potential medicinal or economic value may also become extinct before they are discovered. Developing countries, which are the main repositories of global biodiversity, do not have the financial and technical resources to manage and conserve their indigenous biological resources, and this exacerbates biodiversity loss. Developed countries contribute to biodiversity loss by providing lucrative markets for timber from tropical forests, ornamental fish and other endangered species. While the ultimate prerogative for conservation and management of a country’s biodiversity lies with its national government, the global implications of continued biodiversity loss has resulted in increased international cooperation to strengthen national efforts. International efforts comprise bilateral and multilateral financial assistance for biodiversity conservation, international treaties and conventions such as the Convention on International Trade in Endangered Species (CITES), the Convention on Wetlands of International Importance (RAMSAR Convention) and, most significantly, the Convention on Biological Diversity (CBD).

One of the most important ways of coping with impact of climate change on food security was to maintain diversity of crop plants and farm animals, and their wild relatives. This will not only protect from total failure of the agriculture system, but also this gene pool could be used by plant and animal breeders to develop new crop varieties and animal breeds to cope up with the challenges that will be brought by the changing climate.

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