BIOLOGICAL DIVERSITY IN LOWLAND RICE FIELDS: SRI LANKAN CONTEXT

Buddhi Marambe[1], Gamini Pushpakumara[1] and Pradeepa Silva[2]
[1]Department of Crop Science and [2]Department of Animal Science
Faculty of Agriculture, University of Peradeniya, Sri Lanka
(bmarambe@pdn.ac.lk; Tel/Fax +94-777-900948)

Abstract: Rice is interwoven with the culture of Sri Lankans. Being the major staple food crop, rice cultivation has maintained its priority status in the agricultural sector of the country. The intensive management practices adopted by the practitioners have resulted in genetic erosion, thus affecting the species composition of the rice field ecosystems in Sri Lanka. This paper presents a review on the work carried out on the biological diversity of lowland rice field ecosystems of Sri Lanka, and proposes the need for conservation strategies to ensure the sustainability of these rice growing ecosystems in the long run.
Keywords: Rice field ecosystem, biodiversity, Sri Lanka

Introduction

Sri Lanka, being a small island economy registered a growth of 6.6 % in real terms during the first half of 2008 in comparison to 6.3 % recorded during the first half of 2007. The economic growth during the first half of 2008 was broad based with significant contributions from all key sectors. With land extent of 65,525 sq km (SLEO, 2009), and located between 5° 54' and 9° 5 north latitude of the equator and 79° 39' and 81° 53' east longitude. The country is divided into three broad climatic zones, namely dry zone (av. Annual rainfall < 1750 mm), intermediate zone (av. Annual rainfall between 1750 – 2500 mm) and wet zone (av. Annual rainfall > 2500 mm) and is further divided into 46 agro-ecological regions based on rainfall expectancy, altitude, soil class and landform. The physiography of the country comprises of three peneplains, and the major part of the country is made of crystalline rocks. The lowest peneplain that covers the entire northern and eastern parts of the island has an altitude of 0-125 m amsl. The second highest peneplain is at 448-762 m amsl and the highest is at 1524-2200 m. This highest mountain region is referred to as the central massif. The rivers originating in the central hill country provide a diverse system of irrigation with multiple uses such as hydro-electricity, agriculture and other development purposes.

The varied climatic conditions and topography of Sri Lanka has given rise to the unique biological diversity of the country. Biodiversity, which means diversity of the life forms and the variety of systems in which life exists, is defined at four levels, namely, species diversity, genetic diversity, ecosystem diversity and cultural diversity. It is significant that more than 35% of the flora of Sri Lanka is endemic to the country, while more than 65% of those found in the wet zone are endemic. Standing out among the fauna are 59 endemic species of land/fresh water crabs, while more than 50% of land snails, amphibians, and reptiles are endemic. The majority of the endemic species are found in the wet zone. Sri Lanka, along with the Western Ghats of India has been classed as one of the 35 "Biodiversity Hotspots". Sri Lanka recognizes the uniqueness of its biological diversity, but also expects urgent action for reversal of the current deteriorating trend. The conservation status of flora and fauna of Sri Lanka are given in Tables 1 and 2.

Sri Lanka's population, now reaching 20 million, places the island among the most densely populated countries in the world, and a substantial proportion of the population live under poverty. This is the most potent underlying factor that has brought about the changes in Sri Lanka's environment, threatening to undermine the nation's natural resource base. The nation's effort to advance its pace of development, while maintaining the essential freedom of the people to make choices, has had adverse impacts on the four primary natural resources namely, the land, water, atmosphere and living resources, and on the living environment.

Rice Environment in Sri Lanka

Rice cultivation has been the pride of Asian societies, and Sri Lanka is no exception. With a per capita consumption recorded as 108 kg in 2007 (www.agridept.gov.lk/content/admin/pdf/Rice.pdf), Sri Lanka's rice sector alone contributes about 30 % to the agricultural GDP (gross domestic production), which accounted for 16.8 % of the national GDP in 2007. The annual value of the rice production is about Sri Lankan Rs 49 billion (US $ 1 = Sri Lankan Rs 114), which is at an increasing trend, although the relative contribution of the rice sector to the GDP is diminishing. About 20 % of the total population and 32 % of the labour force in Sri Lanka are directly engaged in this sector. Approximately 45% of the calorie and 40% of the protein requirement of average Sri Lankans are obtained from rice. Rice has not only influenced human culture, but also the social system, and has helped creating

a number of systems of irrigation and other aquatic habitats. The high biodiversity of rice field ecosystems have assisted its sustainability. This is more visible in the developing economies of south Asia. Understanding the rice field biodiversity in the context of Sri Lanka will enable communities to sustainably manage their natural resources, while maintaining the ecosystem functions and ensuring food security.

Table 1. Summary of conservation status of fauna of Sri Lanka.

Taxon	Total evaluated species	CR	EN	VU	Total threatened species	Extinct species
INDIGENOUS VERTEBRATE						
Mammals	91 (16)	09 (02)	20 (08)	12 (04)	41 (14)	
Birds	227 (33)	9 (02)	15 (06)	21 (10)	46 (16)	
Reptiles	171 (101)	10	23 (16)	17 (09)	56 (37)	
Amphibians	106 (90)	16 (12)	34 (34)	06 (05)	52 (51)	21 (21)
Freshwater fishes	82 (44)	12 (12)	07 (04)	11 (08)	28 (20)	
Sub total	**677 (284)**	**57 (34)**	**99 (68)**	**67 (36)**	**223 (138)**	
INDIGENOUS INVERTEBRATE						
Butterfly	243 (20)	21 (2)	29 (09)	16 (02)	66 (13)	
Dragon Flies	120 (57)	13 (13)	05 (05)	02 (02)	20 (20)	
Fresh water Crabs	51 (51)	23 (23)	08 (08)	06 (06)	37 (37)	
Theraphosid Spiders	07 (05)	00 (00)	00 (00)	01 (01)	01 (01)	
Land Snails	246 (204)	16 (15)	12 (12)	05 (05)	33 (32)	
Sub total	667 (337)	73 (53)	54 (34)	30 (16)	157 (103)	
Grand total	**1344 (621)**	**130 (87)**	**153 (102)**	**97 (52)**	**380 (241)**	

Source: MENR (2008)
Note: CR-Critically endangered EN-Endangered VU-Vulnerable Values in parenthesis are the number of endemic species.

Table 2. Summary of conservation status of flora of Sri Lanka.

Taxon families	Total evaluated species	Threatened species				NT	DD	Extinct	Extinct from wild
		Total	CR	EN	VU				
Orchidaceae	181	122	22	47	53	23	07	04	00
Rubiaceae	168	99	25	36	38	02	06	15	00
Acanthaceae	101	51	20	17	14	04	09	04	00
Dipterocarpaceae	58	42	18	09	15	06	00	01	00
Pyllanthaceae	63	31	08	09	14	08	02	02	00
Other families (63 Nos.)	571	330	158	68	104	26	31	26	01
Total	**1099**	**675**	**251**	**186**	**238**	**69**	**55**	**42**	**01**

Source: MENR (2008)
Note: CR - Critically endangered; EN – Endangered; VU – Vulnerable; NT - Not threatened; DD - Data deficient

Rice (*Oryza sativa* L.) being the major staple food crop cultivated with a history of two thousand years in Sri Lanka, and it is reported that there are over 4,000 accessions of indigenous rice varieties (Marambe and Pushpakumara 2007), containing about 1,000 distinct cultivars. The rice fields in Sri Lanka fall into three major categories based on the water regime where 41% of the extent fall in the major irrigation schemes, 25% fall under the minor irrigation schemes while 34% is rainfed (Gunatilleke and Somasiri, 1995). The majority of rice fields in the wet zone are rainfed, while the ones in the intermediate and dry zones are irrigated, by minor or major irrigation schemes. Most of the irrigated rice fields are usually successors of shallow marshes or a lowland area that can be supplied with adequate water (Fernando, 1993). They are characterized by the presence of a standing water body, which is temporary and seasonal. Hence, scientists have viewed flooded rice fields as agronomically managed marshes (Fernando, 1996), or a type of freshwater marsh with a cultivated grass (Odum, 1977). Temporary fresh waters are generally defined as bodies of fresh water that experience a recurrent dry phase of varying length that is sometimes predictable in both its time of onset and duration (Williams, 1996). Therefore, rice fields, being temporary aquatic habitats with a generally predictable dry phase, can be scientifically defined as an agronomically

managed temporary wetland ecosystem (Bambaradeniya, 2000). They are temporary and seasonal aquatic habitats, managed with a variable degree of intensity (Halwart, 1994).

According to Bambaradeniya *et al* (2004), the rice ecosystem consists of two physically and morphologically distinct habitats namely, the rectangular or similar shaped flooded fields comprising mainly of the rice plants, and the surrounding bunds (levees), which harbour weeds or cultivated plants. Under the irrigated conditions, this mosaic system is connected with irrigation canals and ditches, while sump ponds, marshes and tanks serve as contiguous aquatic habitats. Although being a monoculture agro-ecosystem, a rice field undergoes three major ecological phases; aquatic, semi-aquatic and a terrestrial dry phase, during a single paddy cultivation cycle (Fernanado, 1995). Physically, the aquatic phase has a shallow fluctuating water depth of 5–30 cm. Fernando (1993) reported that the physical status of floodwater is variable during a cycle and that there is consecutive flow through, stagnation and drying off in the aquatic habitat as the seasons progress. Accordingly, the physico-chemical composition of the floodwater changes, which are made more complex by the agronomic practices such as application of fertilizer and pesticides. As a whole, the ecology of rice fields is characterized by rapid physical, chemical and biological changes (Bambaradeniya, 2000).

Biodiversity in Rice Fields

Biodiversity of rice fields can be grouped into four categories as indicated earlier. The ecosystem diversity of rice field is due to the variation of the environmental conditions (wet to dry condition, irrigated to non irrigated systems, low elevation to high elevation, variation of soil condition such as salinity, etc.) and management conditions (management through indigenous knowledge, and with high technology such as fertilizer application, pest and disease control methods, etc.). Further, the availability of large area of paddy fields (*yaya* system) and isolated pockets also contribute to the ecosystem variation in rice fields in Sri Lanka. In hilly areas of the country, a unique system has been developed to avoid land slides *i.e.* terraced paddy fields. All such techniques allow to develop various rice field agro-ecosystems throughout the country. Although categories of different ecosystems in rice fields have been identified, characterization of such systems has not been done in terms of extent and their components.

Being a dynamic ecosystem as a result of various human activities, the rice fields have been able to house a wide variety of living organisms. Approximately 75% of rice lands in Sri Lanka are located within inland valley while the rest are found in alluvial plains and also on terraced uplands in the interior. Being an ecosystem that experiences alternate wetting and drying cycles frequently, the fauna in the Sri Lankan rice field ecosystems are dominated by micro, meso and macro invertebrates (especially arthropods) who inhabits the vegetation, water and soil sub-habitats of the rice fields, while vertebrates are also associated with rice fields (Bambaradeniya, 2004). The aquatic phase of rice fields generally harbours a varying group of aquatic animals. Those that inhabit the vegetation are mainly the arthropod insects and spiders.

The species diversity of rice field ecosystems is mainly due to that the various species of mammals, reptiles, insects, amphibians, avian fauna and pisces that are inhabiting paddy field ecosystems as well as visits the rice fields for feeding from surrounding area. The species diversity of flora is mainly due to the presence of flowering plants (grasses including rice, sedges and broad leaves), ferns and fern-allies, and mosses. The rice field biodiversity is usually synonymous to species diversity due to the easiness of assessment of the species category, which is also identified as insect pests, weeds, natural enemies and neutral forms. This aspect, which has been studied in detail at various levels, is discussed below.

Several published reports provide details on the work carried out on the rice field biota in Sri Lanka, mainly dealing with the agronomic aspects. In these reports provide results of extensive survey carried out on the rice pests, their natural enemies and weeds. A brief account on the ecology of the rice field animals in Sri Lanka have been provided by Weerakoon (1957) has given a brief popular account on the ecology of rice field animals in Sri Lanka. Bambaradeniya *et al.* (1998) documented 77 species of invertebrates, 45 species of vertebrates and 34 species of plants in a rice field ecosystem. Several researchers have worked on specific groups of rice field organisms in Sri Lanka, such as aquatic invertebrates (Fernando, 1977; Neale, 1977; Amerasinghe, 1993), terrestrial invertebrates (Rajendram and Devarajah, 1990), fish (Fernando, 1956) and flora (Velmurugu, 1980; Weerakoon and Gunawardena, 1983; Chandrasena, 1987; 1988; 1999; Seneviratne *et al*., 1992).

The rice-field landscapes along the traditional home gardens and other agro-ecosystems in Sri Lanka provides a variety of food resources, resting and nesting/breeding sites for numerous species of animals, thus acting as a refugee for wild animals who are threatened due to habitat loss. A survey on vertebrate fauna that inhabit and/or visit the traditional home garden-rice field managed landscapes in Sri Lanka (IUCN, 1999) has enabled to document

a total of 250 species, which represents about 40% of the total inland native vertebrate species in Sri Lanka. Among the vertebrate species recorded, 29 (12%) are endemic, while 40 (16%) are nationally threatened. In addition to 133 species of native birds observed, 30 species of winter migratory birds that visit Sri Lanka from other countries were also documented.

Bambaradebiya *et al.* (2004) reported 494 species of invertebrates belonging to 10 phyla, 103 species of vertebrates, 89 species of macrophytes, 39 genera of microphytes and 3 species of macrofungi from an irrigated rice field ecosystem in Sri Lanka. The aquatic organisms found in the rice fields of Sri Lanka covers the entire spectrum of fresh water invertebrates, and that arthropods are the main terrestrial faunal species. About 130 species of phytophagous insects have been recorded in Sri Lanka's rice fields. More than 50% of the terrestrial arthropod species in Sri Lankan rice fields consisted of predators, with spiders being the dominant predatory group. About 103 species of vertebrates recorded from an irrigated rice field ecosystem in Sri Lanka. Rice fields in Sri Lanka have also been recorded as important man-made habitats for amphibians. Among flora, more than 340 species of weeds have been recorded from the Sri Lankan rice fields.

The vertebrate fauna and the macrophytes reported from a comprehensive survey carried out by Bambaradeniya *et al*. (2004) are presented in Tables 3 and 4. Studies on the biodiversity of rice field ecosystems in Sri Lanka have revealed that arthropod natural enemies of rice pest insects are ubiquitous in these ecosystems. Bambaradeniya *et al*. (2004) reported that almost 50% of the arthropod species consisted of predators and parasitoids. Heong *et al*. (1991) and Ooi and Shepard (1994) have also reported of high species richness among arthropod natural enemies in rice ecosystems. This rich composition of arthropod predators and parasitoids of rice insect pests in tropical rice fields highlights the potential of natural biological control in such countries. The findings of Bambaradeniya *et al.* (2004) clearly highlighted the contribution of the irrigated rice ecosystems in towards sustaining a rich biodiversity.

Table 3. Vertibrate fauna reported from rice field ecosystems at Batalagoda, Sri Lanka.

Phylum/class/order	Sub-family/family	Genus/species
Pisces	Cyprinidae	*Rasbora daniconius* (Hamilton) *Esomus thermoicos* (Valenciennes) *Puntius bimaculatus* (Bleeker)* *Amblypharyngodon melettinus* (Valenciennes)
	Channidae	*Channa punctata* (Bloch) *Channa guchua* (Bleeker)
	Cobitidae	*Lepidocephalichthys thermalis* Valenciennes
Amphibia	Ranidae	*Euphlyctis cyanophlyctis* (Achneider) *E. hexadactylus* (Lesson) *Limnonectes limnocharis* (Gravenhorst) *Hoplobatrachus crassus* (Jerdon)
	Microhylidae	*Microhyla ornata* (Dumeril & Bibron) *M. rubrum* (Jerdon)
	Bufonidae	*Bufo melanostictus* (Schneider)
Reptilia	Agamidae	*Calotes versicolor* (Daudin) *C. calotes* (L.)
	Varanidae	*Varanus salvator* (Deraniyagala) *V. bengalensis* (Daudin)
	Scincidae	*Mabuya carinata* (Deraniyagala)
	Bataguridae	*Melanochelys trijuga* (Lesson)
	Trionychidae	*Lissemys punctata* (Laccapede)
	Elapidae	*N. naja* (L.)
	Colubridae	*Amphiesma stolata* (L.) *Coluber mucosus* (Deraniyagala) *Xenochrophis piscator* (Schneider) *Atretium schistosum* (Daudin) *Ahaetulla nasatus* (Lacapede)
	Viperidae	*Daboia russelli* (Gray)
Aves	Ciconnidae	*Anastomus oscitans* (Boddaert) *Mycteria leucocephala* (Pennant)
	Ardeidae	*Egretta garzetta* (L.) *Mesophoyx intermedia* (Wagler) *Casmerodius albus* (Gray) *Ardea cinerea* (Gould) *Ardeola grayii* (Sykes) *Bubalcus ibis* (Boddaert) *Ixobrychus cinnamomeus* (Gmelin)
	Threskiornithidae	*Threskiornis melanocephalus* (Latham)
	Charadridae	*Vanellus indicus* (Boddaert)

	Scolopacidae	*Tringa hypoleucos* (L.)** *T. glareola* (L.)** *Gallinago stenura* (Bonaparte)**
	Rallidae	*Amauromis phoenicurus* (Pennant) *Gallicrex cinerea* (Gmelin) *Gallinula chloropus* (Blyth)
	Phalacrocoracidae	*Phalacrocorax niger* (Vieillot) *P. fuscicollis* (Staphens)
	Anatidae	*Dendrocygna javanica* (Horsfield)
	Alcedinidae	*Halcyon smyrnensis* (Boddaert) *Alcedo atthis* (Kleinschmidt) *Pelargopsis capensis* (Pearson)
	Recurvirostridae	*Himantopus himantopus* (Whistler)
	Larridae	*Sterna nilotica* (Gmelin)** *Chlidonias hybridus* (Stephens)**
	Accipitridae	*Spilornis cheela* (Blyth) *Haliaster indus* (Boddaert) *Accipiter badius* (Gmelin)
	Caprimulgidae	*Caprimulgus macrurus* (Ripley)
	Strigidae	*Otus bakkamoena* (Pennant) *Glaucidium radiatum* (Tickell)
	Meropidae	*Merops orientalis* (Whistler) *M. leschenaultii* (Vieillot)
	Coraciidae	*Coracias benghalensis* (L.)
	Cuculidae	*Centropus sinensis* (Stresemann)
	Psittacidae	*Psittacula eupatria* (L.) *P. kramerii* (Bechstein) *P. cyanocephala* (L.)
	Columbidae	*Streptopelia chinensis* (Reichenbach) *Columba livia* (Strickland)
	Muscicapidae	*Turdoides affinis* (Dumont) *Cisticola juncidis* (Blyth) *Prinia inornata* (Legge) *P. socialis* (Legge) *Orthotomus sutorius* (Pennant) *Saxicoloides fulicata* (Lesson) *Copsychus saularis* (Sclater)
	Dicruridae	*Dicrurus caerulescens* (Blyth)
	Sturnidae	*Acridotheres tristis* (Legge)
	Corvidae	*Corvus macrorhynchos* (Sykes)
	Artamidae	*Artamus fuscus* (Vieillot)
	Ploceidae	*Passer domesticus* (Ripley) *Lonchura punctulata* (Hodgson) *Lonchura striata* (L.)
	Hirundinidae	*Hirundo daurica* (Blyth) H. rustica (L.) **
	Pycnonotidae	*Pycnonotus cafer* (L.)
	Motacillidae	*Motacilla cinerea* (Pallas)** *Anthus rufulus* (Eyton)
Mammalia	Soricidae	*Suncus murinus* (L.)
	Muridae	*Bandicota bengalensis* (Gray & Hardwick) *Rattus rattus* (L.) *Mus cervicolor* (Blyth)
	Sciuridae	*Funambulus palmarum* (L.)
	Viveridae	*Herpestes fuscus* (Waterhouse) *H. edwardsii* (Wroughton) *Paradoxurus hermaphroditus* (Pallas)
	Carnivora	*Felis viverrina* (Bennett)
	Mustellidae	*Lutra lutra* (F. Cuvier)
	Canidae	*Canis aureus* (Wroughton)
	Suidae	*Sus scrofa* (Wagner)
	Leporidae	*Lepus nigricollis* (Wroughton)
	Bovidae	*Bubalus bubalis* (L.)
	Vespertilionidae	Unidentified spp.

Source: Bambaradeniya *et al.*(2004).

Table 4. Floristic composition of the macrophytes in rice fields in Batalagoda, Sri Lanka.

Group	Family	Geneus/Species
Monocotyledons	Poaceae	*Axonopus affinis* (Chase) *A. compressus* (Sw.) Beauv. *Chloris barbata* (L.) *Cyanodon dactylon* (L.) *Dactyloctaenium aegyptium* (L.) Richt. *Digitaria ciliaris* (Schumach) *D. longiflora* (Retz) Pers. *Echinochloa colonum* (L.) Link *E. crus-galli* (L.) Beauv *E. stagnina* (Retz.) Beauv. *Eleusine indica* (L.) Gaerth. *Eragrostis unioloides* (Retz.) Nees ex Steud *Isachne globosa* (Thunb.) Kuntze *Ischaemum rugosum* Salisb. *I. timorense* (Kunth) *Leptochloa chinensis* (L.) *Leersia hexandra* (Sw.) *Paspalum conjugatum* (Berg.) *P. commersonii* (Lam.) *Panicum repens* (L.) *Setaria geniculata* (Lam.) Beauv.
	Cyperaceae	*Cyperus rotundus* (L.) *C. iria* (L.) *C. difformis* (L.) *C. pilosus* (Vahl) *C. tenuispica* (Steud) *C. haspan* (L.) *F. miliaceae* (L.) Vahl *F. dichotoma* (L.) Vahl *F. schoenoides* (Retz.) Vahl *Kyllinga brevifolia* (Rottboell) *K. nemoralis* (J.R. & G.Forst) Dandy ex Hutchins. *Pycreus polystachyos* (Rotboell) Beauv P. pumilus (L.) Schoenoplectus juncoides (Roxb.)
	Commelinaceae	*Commelina diffusa* (Burm.f.) *C. benghalensis* L. *Cyanotis axillaris* (L.) *Murdania spirata* (L.) Bruckner
	Pontederiaceae	*Eichhornia crassipes* (Mart.) *M. vaginalis* (Burm.f.) Presl
	Eriocaulaceae	Eriocaulon thwaitsii Koern.
Dicotyledons	Asteraceae	*Epaltes divaricata* (L.) *Tridax procumbens* (L.) *Ageratum conyzoides* (L.) *Eclipta prostrata* (L.) *Eleutheranthera ruderalis* (Swartz) Sch. Bip *Eupatorium odoratum* (L.) *Emilia sonchifolia* (L.) DC *Mikania cordata* (Burm) Robinson *Spilanthes iabadicensis* (A. H. Moore) *Sphaeranthus indicus* (L.) *Vernonia cinerea* (L.) Less
	Scrophulariaceae	*Dopatorium junceum* (Roxb.) Buch.-Ham.ex Benth. *Lindernia rotundifolia* (L.) Alston *L. anagallis* (Burm.f.) Pennell *L. pusilla* (Willd.) Boldingh *L. antipoda* (L.) Alston *L. crustacea* (L.) F.Muell *L. hyssopioides* (L) Haines
	Malvaceae	*Abutilon asiaticum* (L.) *Sida rhombifolia* (L.) *Urena lobata* (L.)
	Onagraceae	*Ludwigia decurrens* (Walt.) *L. perennis* (L.) *L. hyssopifolia* (G.Don) Exell
	Fabaceae	*Desmodium triflorum* (L.) DC *Alyssicarpus vaginalis* (DC.) *Cassia tora* (L.)
	Euphorbeaceae	*Euphorbia hirta* (L.) *E. hypericifolia* (L.) *E. rubicunda* (L.)

		E. indica (Lam.) *Phyllanthus debilis* (Klein ex Willd.)
	Convolvulaceae	*I. aquatica* (Forsk.) *I. triloba* (L.) *I. pes-tigridis* (L.)
	Rubiaceae	*Borreria laevis* (Lamk.) Griseb. *Hedyotis corymbosa* (L.) Lamk. *Spermococe assungera* (L.)
	Lamiaceae	*Basilicum polystachyon* (L.) *Leucas zeylanica* (L.) R.Br.
	Amaranthaceae	*A. sessilis* (L.) DC
	Mimosaceae	*Mimosa pudica* (L.)
	Sphenocleaceae	*Sphenoclea zeylanica* (Gaertn).
	Elatinaceae	*E. triandra* (Schkuhr.)
	Apiaceae	*C. asiatica* (L.) Urb.
Pterydophytes	Salviniaceae	Salvinia molesta (D.S.Mitchell)
	Marsiliaceae	*Marsilia quadrifolia* (L.)

Source: Bambaradeniya *et al.* (2004).

Species diversity of paddy fields also includes cultivation of *O. sativa* and existence of wild rice in close proximity to paddy fields. Occurrence of five wild rice species namely *O. nivara, O. rufipogon, O. granulate, O. eichingeri* and *O rhizomatis* have been reported in Sri Lanka. Among these, *O. rhizomatis* has been identified as an endemic wild rice species to Sri Lanka. *Hygroryza aristata* is a species belonging to the related genera of *Oryza*, and is present in Sri Lanka adding to the species diversity of rice. The characteristics of "*sativa*" and "*officinalis*" groups are given in Tables 5 and 6.

Table 5. A comparison of selected characters that distinguish taxa of "*sativa*" complex in Sri Lanka.

Character	***O. sativa***	***O. nivara***	***O. rufipogon***
Distribution	Island wide	Low country dry zone	Low country wet zone
Form of Habit	Annual – erect habit	Annual - erect habit	Perennial - usually prostrate habit
Panicle	Compact	Short and semi open or compact	Erect, lax branches, open
Grain	Persistent at maturity	Deciduous at maturity - high shattering	Deciduous at maturity - high shattering
Awns	Awnless or short awn	Long awns	Long awns
Seed Dormancy	Less	High	High
Nodal tillering	No or rare	No or rare	Common and extravaginal branching

Source: Liyanage (2009).

Table 6. A comparison of selected characters that distinguish taxa of "*officinalis* "complex in Sri Lanka.

Character	***O. eichingeri***	***O. rhizomatis***
Distribution	Intermediate zone	Low country dry zone
Habitat	Partial shade	Seasonally dry open habitat
Habit	Erect	Semi erect to erect
Panicle	Semi open	Open
Stigma	White	Purple
Awn	Usually awns and more than 1.4 cm	Often awnless or less than 1.5 cm
Rhizomes	Non rhizomatous	Rhizomatous

Source: Liyanage (2009).

The genetic diversity of rice field ecosystems is due to the genetic variation of rice crops, which has been identified as a mechanism to resists to pest and diseases, environmental stresses, management conditions etc. The genetic

diversity of rice in Sri Lanka has been enormous, recording more than 2800 varieties over time (Pushpakumara and Silva, 2008). Some of them show tolerance to drought, submergence and flash floods, high salinity and other adverse soil conditions, and low temperatures. Some varieties are highly resistant to pests and diseases. Rice fields are associated with rich wetland flora and fauna, including many endemic species (SOE, 2002).

These varieties, originating from landraces and developed into traditional varieties through selection and then to new improved varieties through selection and breeding, have adapted to different rice-growing ecosystems. Interwoven with this, the cultural diversity involved in paddy farming has helped utilizing the ecosystem services provided by the biodiversity of the rice-growing ecosystem in Sri Lanka in a judicious manner, ensuring harmony with the environment.

Although traditional rice cultivation has been carried out in a sustainable manner over many millennia, there is growing evidence that modern rice cultivation that depends heavily on machinery and chemical inputs, together with short term rice varieties, has disrupted the balance of these efficient trophic linkages (Bambaradeniya *et al*., 2004). Agricultural development through the use of genetically improved modern varieties often involves the replacement of more diverse genetic resources and thereby resulting in genetic erosion (Marambe and Pushpakumara, 2007). In addressing the requirements for both conservation and development, it is clear therefore, that ways must be found to allow agricultural development while conserving diversity of the rice growing ecosystem.

Cultural diversity of paddy field are due to the involvement of various races of human in rice culture along with different environmental conditions. Evolution of ploughs, mammoties, sickles and other equipments are due to variation of social and cultural systems and cultivated varieties. For example, evolution of sickle is mainly due to the response to silica content and height of the paddy varieties. Indigenous knowledge has been evolved as a mechanism of various cultural activities. The cultural diversity in rice fields consist with a language unique to paddy field activities. Kem systems, rituals, chanting based on religion, and starting activities based auspicious times related to the movement of moon, are some of the local initiatives that have been inherited through generations. Lack of proper documentation has hindered the conservation of local knowledge in this regard.

The agricultural sector in many low income countries such as Sri Lanka is large, neglecting its adverse affect on the rest of the economy. Better use of biodiversity in the rice growing ecosystem will be a pre-requisite to meeting these challenges of development and poverty alleviation of a country like Sri Lanka. In particular, greater use of biodiversity will be required in order to produce varieties adapted to the adverse environments of the low productivity areas and use of natural resources for sustainable management of the ecosystem while minimizing the external inputs. With the need to combine productivity with sustainability, and the concomitant pressures to reduce the use of agrochemicals and improve the efficiency of utilization of limited water and nutrient resources, there is likely to be an increased reliance on the biodiversity found in high productivity areas (Marambe and Pushpakumara, 2007). The rich biodiversity associated with the rice field agro-ecosystems could be compatible with conservation objectives and meets the requirements/interests/emphases of agroecologists as well as conservation biologists (Bambaradeniya *et al* 2004). Bambaradeniya *et al.* (2004) further stated that flooded rice fields serve as ecotones that lie between land and water and hence, they provide an important feeding habitat for fauna and could contribute to enhance the biodiversity especially in the urban and sub-urban areas. McNeely and Scherr (2001) reported of the growing interest in concepts of eco-agriculture where agricultural systems are managed as both a food production and biodiversity conservation system.

Conservation of biodiversity of rice fields needs an integrated approach to include ecosystem, species, genetic and cultural diversity aspects. Conservation of this ecosystems is essential. In this regard the water logged rice field ecosystems in the wet zone of Sri Lanka would be the priority concern due to high level of siltation and conversion to other land uses. Species diversity of rice fields has been addressed to some level where as genetic diversity of rice has been approached via *in situ*, *ex situ* and *circa situm* mechanisms. The surveys on biodiversity associated with the rice field agro-ecosystem conducted to-date have clearly demonstrated that the rice field ecosystem contributes to sustain a rich biodiversity, including unique as well as threatened species. The sustenance of the rice field ecosystem could be assured only by developing and adopting environmentally friendly technologies that would help minimizing the loss of biodiversity due to human and other interventions in the era of modern agriculture.

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