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Author(s): Md. Sajjad Hossain Tuhin

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Supervisor(s): Md. Sharif Hasan Limon, Associate Professor, Forestry and Wood Technology Discipline, Khulna University

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Md. Sajjad Hossain Tuhin
Student ID: 100510

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Supervised by

27.04.16

Md. Sharif Hasan Limon

Associate Professor

Forestry and Wood Technology Discipline

Life Science School

Khulna University

Khulna-9280

Bangladesh

Submitted by

27.04.16

Md. Sajjad Hossain Tuhin

Student ID: 100510

Forestry and Wood Technology Discipline

Life Science School

Khulna University

Khulna-9280

Bangladesh

Declaration

I Md Sajjad Hossain Tuhin, declare that this thesis is the result of my own works and that it has not submitted or accepted for any degree in any university.

I, hereby, give consent for my thesis, if accepted, to be available for photocopying and for interlibrary loans, and for the title and summary to be made available to outside organizations.

Signature and Date: 27.04.16

Name of the candidate: Md. Sajjad Hossain Tuhin

Dedicated to my beloved Parents,

And

My friend Sheikh Mohammad Hadiul Islam

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Abstract

Khulna university campus acquires a land area of 106.75 acres (432001.923 m^2) and just 7 m above the mean sea level. This area is highly modified and has created different topographic variations. Due to many topographical variations and many land-use classes it contains a large number of plant species. To assess the diversity of herbs in Khulna University, 50m × 50m gridlines were created and each intersection point was center of 1m × 1m sample plot. A total of 6717 individuals were counted that belonged to 163 species of 112 genera and 46 families. Simpson (1-D), Shannon (H) and Dominance (D) were 0.946, 3.619 and 0.054 for the total area that indicate a high diversity of herb species in the campus. Built up area (Shannon H=3.334, Dominance D=0.068, Simpson 1-D=0.9317, Evenness e^H/S=0.2418) and fallow land (H=3.382, Dominance D=0.065, Simpson 1-D=0.935, Evenness e^H/S=0.2803) shows higher diversity indices than plantation (H=2.876, Dominance D=0.0937, Simpson 1-D=0.9063, Evenness e^H/S=0.4328), cropland (H=2.486, Dominance D=0.1988, Simpson 1-D=0.8012, Evenness e^H/S=0.1793) and aquatic (H=2.056, Dominance D=0.2168, Simpson 1-D=0.7832, Evenness e^H/S=0.4598) land-use. The diversity pattern of the campus can be ordered as built-up areas > fallow land > plantation> cropland>aquatic.

Keyword: Khulna University, Plant diversity, Herbs, Simpson index, Shannon index

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List of abbreviation

1.	BBS	Bangladesh Bureau of Statistics
2.	DNA	Deoxyribonucleic acid
3.	Km	Kilometer
4.	Ha	Hectare
5.	Cm	Centimeter
6.	IUCN	International Union for Conservation of Nature
7.	CBD	Convention on Biological Diversity
8.	CITES	Convention on International Trade in Endangered Species
9.	CMS	Convention on the Conservation of Migratory Species
10.	RAMSAR	Convention on Wetlands; popularly known as the Ramsar Convention
11.	WHC	World Heritage Convention
12.	M	Meter
13.	h	Hour

Chapter one: Introduction

1. Introduction

1.1 Background

Urbanization is changing natural habitats worldwide. The rate of urbanization is faster and fragmenting the natural ecosystems into a highly modified anthropogenic hybrid system. The anthropogenic modification and transformation of land-use lead to habitat destruction, land conversion and other consequences over time. In recent times, faster urban infrastructural development is one of the major issues for biodiversity loss and biotic homogenization by exotic species introduction (Clergeau et al, 1998; Araújo, 2003; McKinney, 2002; DeFries et al, 2007; Forman, 2008). Urban areas have expanded over 2% of the total land surface of the world in the previous century (1900-2000) (Grimm et al, 2000; Vimal et al, 2012). If urban areas increase at this rate, by 2050 global urban population should be reached to 70 % and the earth will lose its valuable genetic variety in a very short time (Elmqvist et al. 2013). Most of the biodiverse zones of the earth are in the developing countries and that are urbanizing rapidly even near biological hotspots. This process is endangering the biodiversity and the resilience of earth system (Wang et al, 2007; Pauchard et al, 2006). Like other developing countries, urbanization in Bangladesh is also rapid and interfering with natural environment (Uz Zaman et al, 2010). Educational institutions are important part of urban settlement in Bangladesh like many other countries. Especially the universities have large land area if compared to other settlements and subjected to less modification than most settlements in the urban areas for a considerable amount of time. Universities are more promising for biodiversity conservation as these areas are comparatively large, has academicals research support and easier management. On an average a public university of Bangladesh is acquiring 50 acres of lands (Ahmmed, 2010). Most of the university's campuses are situated in and around natural ecosystems. So, establishment of universities in those areas is distracting the biodiversity and also can be a prominent place for conservation as well. Khulna University is situated in the south western part of the country. The university has 432001.923 m^2 of lands that are historically low laying areas and were later modified through landfilling and other construction works. Considering the landuse pattern, the area has built-up area, agricultural land, aquatic habitat and fallow land. This pattern of land-use has created habitat differences. Generally habitat differences bring about changes in vegetation communities. Herb species are more sensitive to habitat variation and vary even at micro-topographic variations. Herb species contains about 50% of the total floral species (Rahaman, 2003). So herb species plays vital role in ecosystem functioning. Herb species assessment in Khulna university campus will provide quantitative information to set conservation strategy at university scale as well as national scale.

1.2 Objectives of the study

1. To identify the herbs of Khulna University campus at species level.

2. To measure biodiversity indices for herb species in Khulna University Campus.

Chapter two: Literature Review

2. Literature review

2.1 Biodiversity

Biodiversity is an important terminology that has received immense attention both in the scientific and political community for its pivotal role especially in a natural system. After signging the Convention on Biological Diversity in 1992 the word "Biodiversity" received prime importance to nations and scientific community agenda (O'Rourke, 2006; CBD, 2001).

The word "Biodiversity" was first introduced by an American ecologist E. O. Wilson in 1980 (Reaka-Kudla et al., 1996). Some other scholars also synonymously used "Biological Diversity' for expressing biodiversity (Mace et al, 2005). In 1984 the word was discussed as a society agenda in the "National Forum on BioDiversity". The proceedings of the forum were published in 1988 under the title "BioDiversity" (later to be cited with less than bibliographical accuracy by most authors as Biodiversity). After that it has got priority and become a concerning issue in the Earth Summit of Rio in 1992 (Reaka-Kudla et al, 1996).

The term Biodiversity was defined in different ways in different literatures. O' Rourke (2006) defined biodiversity as the biological variability either at the level of species, ecosystem diversity and genetic varitatio which is widely accepted as biodiversity. Australian Department of Environment (2001) consider Biodiversity as the variety of all life forms: the different plants, animals and microorganisms, the genes they contain and the ecosystems of which they form a part. It is not static, and constantly changing; it is increased by genetic change and evolutionary processes and reduced by processes such as habitat degradation, population decline and extinction (Carlton et al., 2001). According to Convention on biological diversity biodiversity means 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 a part; this includes diversity within species, between species and of ecosystems (Bell, 1992). Therefore, Biodiversity of the world is primarily classified into genetic, species and ecosystem levels (Haila and Kouki, 1994).

2.1.1 Species diversity

Species is one of the major divisions of all described taxonomic strata having same common genetic characteristics or qualities and have capabilities of breeding with the other individuals of the opposite sex (Pearce and Moran, 1994). Darwin (1859) proposed that species are similar in kind to groupings at lower and higher taxonomic levels and most identifiable and fundamental taxon. Measurement of these taxonomic strata in a particular unit of area or ecosystem is known as species diversity. Species diversity is the assessment of biodiversity at the species level. Generally it is defined as the number of particular species present in a particular time within a particular ecosystem. It is often termed as species diversity and defined as the function of the number of species present (species richness or species abundance) and the evenness with which the individuals are distributed among these species (Hurlbert, 1971). Species richness synonymously used with species diversity and considered as one of several possible measures of species diversity (Hill, 1973; Whittaker, 1972). However, scientific communities have disagreements about the utility of species richness measurement. Some consider it as important tool for biodiversity measurement and management and other consider it as only a measurement process without explanatory output (Fisher et al., 1943; Sheldon, 1969).

2.1.2 Ecosystem diversity

An ecosystem is a complex set of relationship among all interacting living organism and their surrounding environmental units on a specific unit of space in a specific time. The amount of differences in species content and their arrangement or other parameters between ecosystems is known as "Ecosystem diversity". Ecosystem diversity concept was introduced to compare the total ecosystem with other corresponding ecosystems. According to Pearce and Moran (1994) ecosystem diversity relates to the variety of habitats, biotic communities and ecological processes in the biosphere as well as the diversity within ecosystem and diversity can be described at different levels and scales. Diversity of an ecosystem is influenced by habitat, species content, ecological processes, trophic level and many others. It can be used to compare diversity among ecosystems and calculated based on numerous parameters. This concept was first proposed by Fisher in (1943), but it was widely accepted after the description of Whittaker in 1972 (Fisher et al., 1943; Whittaker, 1972).

2.1.3 Genetic diversity

By the discovery of DNA double helix by Watson and Crick in 1953 a new level of biodiversity assessment emerged. This diversity is measured by the DNA pattern analysis within and between several taxonomic strata. This is measured by the number of genes or chromosomes or the structure and number of DNA per cell. Based on the theory of evolution all organisms are developed from DNA recombination by changing over time for several ecosystem functioning. This diversity improves the ecosystem resilience, so very important for the survival in this earth system (Hedrick and Miller, 1992; Hamrick and Godt, 1996; Lammi et al., 1999; Reed and Frankham, 2003).

2.2 Status of World Biodiversity

Biodiversity is being considered as the prime element of the ecosystem. According to Darwin (1859) the diversity of life is due to the result of ecosystem functioning from the beginning of the earth which termed as evolutionary process or evolution. This evolutionary ongoing process has contributed to evolve new species and diversity of life. Thus, we are always in a process of losing and gaining the new species (Purvis and Hector, 2000; Pereira et al, 2010). Earth has homed around 1.8-1.6 million described species. With variation and in-specific taxon, it was 1.868 million species with 7000 fungi and 0.27 million terrestrial plant species (Reaka-Kudla et al, 1996). But this number is decreasing with time, recently it is reported that earth's ecosystem consists of 1,629,516 living species and 5,654 species are extinct from the earth (Roskovet al, 2016). It includes 107,116 species of bacteria and 370739 species of plant including 51 Anthocerotophyta, 13373 Bryophyta, 6000 Charophyta, 8000 Chlorophyta, 15 Glaucophyta, 788 Marchantiophyta, 7000 Rhodophyta and 335512 Tracheophyta. Faunal diversity contributes 0.45 million species with the largest class insecta (Hilton-Taylor, 2000; Roskov et al, 2013). Recent assessment shows that about 7% species of the world ecosystems are at risk of high rate of extinction possibilities (Baillie et al, 2004).

Biodiversity varies with spatial and temporal variations, viz. tropical and temperate region have different types of species and then assemblage (Kerr, 2001). Global forests are the major contributor to most of the terrestrial flora and fauna. Tropical and subtropical forest consists of approximately 1.39 trillion individuals of tree species, boreal forest consists of 0.74 trillion and temperate forest has 0.61 trillion individuals (Crowther et al., 2015).

As mentioned earlier, global terrestrial biodiversity is not equally distributed all over the world rather they are distributed in biological zones of the world commonly known "Biological hotspot". The concept of biological hotspot came in 1999. In 1999, 25 hotspots covered 12% of the total earth surface and supports 131399 endemic vascular plants that accounts 43.8% of the world's total and 9681 endemic non-fish vertebrates (35.5% of the global total) (Mittermeier et al., 1999). Every "Biological hotspot" contain over 1,500 endemic vascular plants or >0.5% of the world's total vascular plant. The number of hotspots is increasing with more assessment. In 2011, the number of hotspot reached at 35 covering only 15.9% of Earth's land surface and home of 152,000 plant species (over 50% of the world's total) (Mittermeier et al., 2011). Among all hotspots of the earth, Brazilian hotspots are the home of the highest number of endemic vascular plant species (Morales-Hidalgo et al., 2015).

2.3 Biodiversity conservation

Biodiversity conservation is a multidimensional concerted effort to conserve a species at genetic, species and ecosystem levels. Simply it is the process by which, any or all organisms of the ecosystem is protected in or outside ecosystem with several strategies (Miller, 2005). Protected area management is one of the oldest and widely accepted strategies for conserving biodiversity. The first formal protected area of the world is Yellowstone National Park of USA declared in 1872. According to United Nations List of Protected Areas in 2002 there were 12,754 protected areas (PAs) worldwide, which covers 13.2 million km^2 (Pretty and Smith 2004). Besides, additional 17,600 PAs (Protected areas) are present, which are not fulfilling the UN 1000-ha minimum (for declaration of hotspots minimum thousand ha of land required) requirement with 28,500 km^2 land surface (Pretty, 2002). The Protected area concept has guided the biodiversity conservation in their natural habitat. Most of the protected areas (54%) are strictly protected where any local people make use of wild resources for food, medicine, fuel, and feed (Nash, 1973; Gomez-Pomp and Kaus, 1992; Pretty, 2002). Currently, developing countries are managing the most of the biodiversity rich zones of the earth (Berkes et al, 1995).

2.4 Importance of Biodiversity Conservation

Biodiversity conservation has got utmost priority to the scientific community for its importance. Since the beginning of human civilization, people depend on 7,000 species of plants for food, of which 150 are commercially important and just 100 account for 90% of the world's food crops

(Chivian et al, 2002). People also depend on biodiversity for their medicine. It was estimated by the "World Health Organization" that approximately 80% of the world's population of developing countries rely on traditional medicines (mostly derived from plants) for their primary health care and 20% of the developing countries use traditional medicine for major health care. In the United States from 1959 to 1980, 25% of pharmaceutical chemicals were extracted from plants. 74 % medicines were discovered during attempts to isolate the active chemicals from plants used in traditional medicines (Chivian et al, 2002). Faunal diversity is also contributing in this sector. Now five thousand bacterial species out of more than forty thousand and about seventy thousand fungi out of 1.5 million species are used in pharmaceuticals (Young, 1999).

Of all goods and services provided by biodiversity, ecosystem service is considered as the most important service (Costanza, 1997; MEA, 2005; Chan et al, 2006; Sachs et al, 2009). In 1997, the global value of ecosystem services was estimated to average $33-46 trillion/year and in 2011 it was $125 trillion/year- $145 trillion/year. Only land use change decreased ecosystem services up to $4.3–20.2 trillion/year from 1997 to 2011(Costanza et al., 2014). Anthropogenic intervention and habitat destruction are the major causes of the extinction of biodiversity (Szwabiński and Pekalski, 2006; Nakagiri et al 2010). Poverty and financial crisis act as a background driver of this situation. Biodiversity conservation can be used for improving the local environment and used as a tool for poverty elevation as well (Adams, 2004).

2.5 Biodiversity loss

Biodiversity loss is one of the most concerning environmental problems (Asafu-Adjaye, 2003). There is a debate about the key factor of biodiversity loss. Some argues that all species are not equally important for ecosystem functioning and extinction of species is a natural process (Walker, 1992). But extinction is accelerated due to human intervention. They hypothesized that biodiversity might influence ecosystem processes (Tilman, 2000) meaning biodiversity is the result of ecosystem functioning. Therefore, a particular ecosystem determines how and which species will survive in a place. But biodiversity loss also can be a driver of ecosystem change (Hooper et al. 2012). So, both are related among themselves in a complex manner. Meanwhile, most of the scholars marked it as a dangerous content for environmental degradation (Asafu-Adjaye, 2003).

There is a race between the extinction and nomenclature of the species and urbanization played a key role there (Sala et al., 2000; Costello et al, 2013; Pimm et al., 2014). Now species are being lost at a fast rate. The current extinction rate of the species at the global scale is near 1% per year (Purvis and Hector, 2000). But the threat of extinction rate due to climate change and other drivers can increase up to 5-20% in the near future where only climate change can extinct 7.9% of the total diversity (Urban, 2015). Until now over 46% of plant resources are lost since the start of human civilization (Crowther et al., 2015). From 1600 to 1990s, 83 species of mammal and 113 species of bird and 384 species of our vascular plant have been lost (Whitmore et al., 1992). According to Wilson (1989), 10,000 species become extinct every year, which is calculated by species-area relationship. Recent estimate shows 27,000 species become extinct annually and for a single species every twenty minutes is enough for extinction (Purvis and Hector, 2000).

Biodiversity loss is not equal in all areas. The 25 biological hotspots accounts only 1.4% of the total land surface, but contains 44% of the total plant species and 35% of vertebrate species. These hotspots already lost 70% of their original geographic extent (Helmer et al., 2002; Books et al, 2002). As most of the endemic species are present in biological hotspots, degradation of this habitat is expediting extinction of species (Midgley et al., 2002) and urbanization has made contribution (Lu and Li, 2003).

2.5.1 Habitat destruction

Habitat destruction is the most important direct causes of biodiversity loss. It is one of the primary causes of recent mass extinction of species, even in a small scale (Nakagiri et al., 2010). Many species have gone extinct already and many of them are in a high probability of extinction because of habitat destruction (Tilman and Downing, 1996; Seabloom et al., 2002; Montoya et al., 2008; Nakagiri et al., 2010). Studies prove that the indirect effect of habitat destruction is much more alarming than direct effect of it. The cause and effect relationship of species extinction or biodiversity loss and habitat destruction is very much complex (Yokozawa et al., 1999). Most discussed and accepted theory for biodiversity loss by habitat destruction is the "Meta-population theory". According to this theory, habitats are fragmented in different patches through habitat destruction which change or modify the genetic information of the population. This phenomenon is considered an indirect but, a vital cause of biodiversity loss (Szwabiński and Pekalski, 2006; Levins, 1969). Though nature plays a role in habitat destruction, but mainly human interventions in the natural system are destroying the habitat of other organisms (Foley, 2005).

2.5.2 Land Conversion

Land conversion is another vital cause for losing the earth's biodiversity. Land conversion and habitat fragmentation are complementary. Land surface is converted from one land type criteria to another by both natural and anthropogenic factors, but human influences play the most important role. Urban development and agriculture is the most important driver for land conversion (Bruinsma, 2003; Gibbs et al., 2010). Humans have expanded their agricultural land with population expansion. Population expansion and economic needs play the main role in the land conversion and agricultural extension (Bruinsma, 2003; Alexandratos 1999; Gibbs et al., 2010). Land conversion and agricultural extension is much higher in developing countries than developed countries due to high population pressure and economic crisis. For example, in the 1980s and 1990s developing countries converted their 629 million ha of land into croplands where developed countries lost 335 million ha of land for agricultural expansion (Alexandratos, 1999; Gibbs et al., 2010). The highest rate of land conversion is experienced by tropical countries and it is estimated that over 10 billion ha of new land will face land conversion by 2050 and most of them will be converted into cropland from forest and natural ecosystems (Bruinsma, 2003). 55% of all land which is converted to croplands from 1980 and 2000 came from the forest and 28% came from disturbed forests (Gibbs et al., 2010). This agricultural expansion and land conversion phenomenon are decreasing the genetic diversity and increasing homogenization. The loss of biodiversity genetic diversity and increasing homogenization is increasing the threat of extinction of species (Geist and Lambin, 2001).

2.5.3 Invasive species

According to Beck (2008) invasion simply denotes the uncontrolled or unintended spread of an organism outside its native range with no specific reference about the environmental or economic consequences of such spread or their relationships to possible societal benefits. Introduction of non-native species is a severe problem. Invasive species are non-native organisms that harm other native organisms of an ecosystem. Invasive species are the cause of and invasion effect of an ecosystem. Anthropogenic influences are the prime factor of introducing invasive species and invasion in an ecosystem. Human are introducing those species for cultivation, pets, ornamental use and other human uses (Mack and Lonsdale, 2001). But those species become a pest for that ecosystem after a time and causes severe damage to ecosystem by biotic homogenization (McKinney 2006). Biotic homogenization is the replacement of local biotas with non-indigenous species, a process that often replaces unique endemic species with already widespread species (McKinney et al., 2005). So this process decreases the taxonomic diversity between two ecosystems. With the introduction of invasive species, Alpha (α) diversity is increased in the primary stage, but later it can cause biotic homogenization and decrease Ecosystem diversity (β diversity). This complex effect with rapid urbanization, the rise of invasive species introduction is increasing damage the ecosystem functioning and its resilience by raising the level of biotic hominization (Olden, 2006; McKinney, 2006; Clavero and Garciaberthou, 2005).

2.5.4 Deforestation

Deforestation is directly related with biodiversity loss (Rosenzweig, 1995; Gaston, 2000). Half of the temperate broadleaf and mixed forest and nearly one quarter of the tropical rainforest and 4% of the total boreal forest is already removed and that caused significant loss of biodiversity (Wade et al, 2003). In 1990-1997 worlds have lost its 5.8±1.4 million hectares of humid tropical forest which increase possibilities of extinction of a large number of species (Achard, 2002). In the new century world are losing its forest as well. From 2000-2005 the rate of deforestation was 0.6% per year and 1,011,000 km^2 forest area is lost already (Hansen et al., 2010). Between 1900-2015 world has lost its 3% (128 million ha) forest land and (Keenan et al., 2015). This phenomenon not only destruct the habitat of the organism but also play an important role in climate change by emitting 12% of anthropogenic carbon emission, which is a great threat to biodiversity (Kurz, 2010).

2.5.5 Pollution

Environmental pollution is an important driver in biodiversity loss. Source of environmental pollution is mostly concentrated in urban areas (Tarr, 1996). Industrialization, infrastructural development, cultivation, habitat modification and others are constantly influencing physical and biological components of the environment, while development of urban areas and cause damage to ecosystem functioning (Zhao et al, 2006). A number of negative effects can be attributed to this urban environmental carbon cycling, primary productivity, water cycling, nutrient cycling and other fundamental cycles of ecosystems (Grimm et al., 2008). If any of these fundamental cycles affected, the total ecological functions get affected. Air pollution of the cities reported to affect 1,300 species, including 11 mammals, 29 birds, 10 amphibians, 398 higher plants, 305 fungi, 238 lichens and 65 invertebrates worldwide (Dudley and Stolton, 1996).

2.5.6 Climate change

Climate change is the process of changing the earth's climate with time by several anthropogenic and natural causes. Deforestation, fossil fuel use, urbanization is significant driver for climate change (Bazrkar et al, 2015). Greenhouse gas release increased by 1.6% from 1974 to 2007 and contributed to rise of the temperature up to 0.6° C since 1850 and rise sea level to 10-20 cm (Melnychuk, 2013). This modification of the environment causes several problems to ecosystem functioning and biodiversity. Migration of several groups of animal are reported to be affected for this modification of the environment. A large scale migration has been observed by several species, due to climate change in recent times. Migration can affect negatively to other ecosystem whom they are taking shelter and whom they left. So both ecosystem get affected which reduce ecosystem resilience. For example, recently it has been observed that 90% of the British birds have differed their habitat and migrated to other nearby ecosystems due to climate change and they became a pest (Araujo and Rahbek, 2006). Recently studies also proved that climate change is the main factor for the extinction of golden toad and spotted antelope Montevideo (Melnychuk, 2013).

2.6 Urbanization and biodiversity loss

Urbanization or industrialization is one of the most significant reasons of environmental problem. Urbanization and industrialization is the outcome of land-use change and source of pollutants and greenhouse gases. In the last century (1900-2000) urban areas have been extended over 2% of the total land surface of the earth (Grimm et al., 2000; Vimal et al., 2012). These urban areas are expanding in and around biological hotspots in a very high rate than other land-use change (Seto et al., 2012; Clergeau et al., 1998; McKinney 2002). Urbanization affects an area physically and biologically and plays direct role in biodiversity loss. Indirectly, urbanization can be the background cause of the habitat destruction and exotic species introduction which declines the biodiversity of an area through infrastructure and built-up area (Clergeau et al, 1998; Araújo, 2003; McKinney, 2002; DeFries et al, 2007; Forman, 2008).

2.7 Biodiversity of Bangladesh

Bangladesh is influenced by tropical and subtropical climate. Historically, the region is rich in biodiversity. It is estimated by several studies that 5000 - 7000 species of angiosperm plants were found in Bangladesh (Rahaman, 2003). There are 750–800 tree species, including indigenous, exotic and naturalized ones. The number of shrubs and woody climbers is 1500–2000 species and the remaining are herbs. Bangladesh has approximately 15 % tree, 35% shrub and woody climber, and 50% herb species (Rahaman, 2003). Most accepted checklist of Bangladeshi flora, "Encyclopedia of Flora and Fauna of Bangladesh" by Asiatic Society of Bangladesh reported seven gymnosperm species, 195 pteridophyte species and 3611 angiosperm species (excluding Bacteria and fungi) in 2007-2009 (Ahamed et al, 2007; Ahamed et al, 2008a; Ahamed et al 2008b; Ahamed et al, 2008c; Ahamed et al, 2008d; Ahamed et al, 2009a; Ahamed et al, 2009b; Irfanullah, 2011). Hilly region of Chittagong is the most biodiverse region of the country with 68 woody legume species, 130 fibers yielding plant species, 500 medicinal plant species, 29 orchid species, three gymnosperm species and 1,700 pteridophytes and 2,260 endemic plant species (Mukul et al, 2008).

Table 1: Biodiversity of Bangladesh

Category	No. of Reported Species	Reference
Angiosperm plants	5,000 – 7,000	(Mukul et al, 2008; Chowdhury and Koike, 2010)
Mammal	113 (110 inland and 3 marine)	
Reptiles	126 (109 inland and 17 marine)	
Birds	>628 (388 resident and 240 migratory)	
Fish	708 (266 freshwater and 442 marine)	
Amphibians	22	
Insects	2,493	
Mites	19	
Corals	66	
Echinoderms	4	
Crabs	15 (4 freshwater and 11 marine)	

Bangladesh is the most densely populated countries of the world and experiencing a fast urbanization rate. Over exploitation of natural resources is the major cause of biodiversity loss in Bangladesh. Urbanization can be the background cause of the habitat destruction and exotic species introduction by humans which can indirectly decline the biodiversity of an area or can directly affect the biodiversity through infrastructure and built-up area (Clergeau et al., 1998; Araújo, 2003; McKinney, 2002; DeFries et al., 2007; Forman, 2008).

2.8 Urbanization

Urbanization is one of the most dominant drivers of land use change in the world. Urbanization is defined as "a multidimensional process that manifests itself through rapidly changing human population and changing land cover" (Elmqvist et al., 2013). It brings about temporal, spatial and sectorial changes in the demographic, social, economic, technological and environmental aspect of life in a given society (Misra, 1978). Urban areas are increasing very rapidly all over the world. The rate of urbanization is very fast in developing countries than developed world in the present (Bazrkar et al., 2015).

In the era of industrialization, in the 17^{th} century, urban growth rate has increased significantly. But urban growth was highest in the last century (20^{th} century). At the beginning of the century, the total urban population of the world was 13%. In 2010, half of the world's population was living in urban areas and it is predicted to reach at 70% in 2050 (Desa, 2010; Elmqvist et al., 2013). Not only urban population, but also urban lands are increasing as well. We are building more cities and megacities. Now the world has 19 megacities with the population of over 10 million for each. (Seto and Shepherd, 2009; Elmqvist et al., 2013). Distribution of cities or urban areas do not equal all over the world. Asia and Africa is urbanizing at a fast rate. About 40% population of Asia and Africa and 80% people of North America and Europe live in an urban area (Elmqvist et al., 2013).

The process of urbanization indicates the progress of human settlement, but it tends to damage some vital resources of the earth which are essential for human life. Habitat destruction and biodiversity loss due to habitat destruction and deterioration are one of these problems (Arunachalam et al., 2004). Studies presume that by 2030 urban expansion will take up 1.8 % of all biodiversity hotspot areas (Seto et al, 2012) and almost 90 % of the protected areas likely to be impacted by future urbanization (McDonald et al., 2008). Both developing and developed countries are expanding the urban built-up areas near its biological hotspots (Wang et al., 2007; Pauchard et al., 2006).

2.9 Urban Bangladesh

Urbanization rate in Bangladesh has increased in the last century. Due to rapid industrialization and economic activity, urbanization has taken place all over the country. At the beginning of that 19th century the urban population of Bangladesh accounted only 2.43% of the total population (Chowdhury, 1980; Laskar, 1983; Jordan, 1993; Rouf and Jahan, 2007). In the middle of that century urban population reached to 4.33% and in 2001 it was 23.10% of the total population. Some studies predicted that urban areas of Bangladesh can be resident for 37-40% of the population in 2050 (Jordan, 1993; Laskar, 1996; Rouf and Jahan, 2007).

Dhaka division is the most urbanized division of the country with more than 47% of urban population. Chittagong Division stood second with 20-22% urban population and Rajsahi, Khulna, Barisal and Shylhet stood 3rd, 4th, 5th and 6th respectively (Rouf and Jahan, 2007). Like other developing countries, migration is one of the key factors of urban expansion and urban population growth here (Hossain 2013). Scenarios of urbanization of Bangladesh are given below,

Table 2: Tent of urban population

	1974	1981	1991	2001	2011
Urban population (%)	7.7	14.9	19.8	25.0	31.1
Urban growth in Bangladesh (%)	3.74	2.0	2.49	2.56	2.76
Urban population of Dhaka division (%)	46	40	44	47	52

Source: (BBS, 1984; 1987; 1994; 2004; Hossain, 2013)

2.10 Urbanization in Khulna

Khulna division is one of the most urbanized divisions after Dhaka and Chittagong. This area is not showing the consistence of urban growth like other divisions of the country. The urban population of this region is increasing, but little lower than other divisions of the country. The population of this division contributes 14% of the total population of the country in 1974. But this contribution is decreasing with time (Uz Zaman et al., 2010; Rouf and Jahan, 2007; BBS, 1994).

Table 3: Urban population of Khulna Division:

	1974	1981	1991	2001	2011
% of total country	14%	13%	11%	10%	11%
Urban population	14.99%	17.6%	18.99%	20%	33.54%

Source: (BBS, 1994; Rouf and Jahan, 2007; Uz Zaman et al, 2010; BBS, 2011)

Khulna, Jessore and Satkhira are the most populated districts of this division. Khulna district is contributing the highest amount of urban growth in Khulna division. The urban growth of Khulna district is much higher in 1970s and 1980 today over 33.54% of the total population living in urban areas of Khulna (BBS, 2011).

Khulna City Corporation is being the 3rd largest city in Bangladesh. Khulna is also a divisional headquarter of Khulna Division (Rouf and Jahan, 2007). It is situated on the bank of "Rupsha" and "Bhairab" river. It covers 45.65 square kilometer area. Khulna was first own the status as a city in 1884 by declared as the municipality. During 1950s and 1960s, it became the center of industrialization. In 1990 Khulna city got declared status of City Corporation (Adhikari et al., 2006; Uz Zaman et al., 2010). Like all other divisional city Khulna is also a densely populated city. In 1981 the population of the Khulna city corporation was 0.51 milion, which increased to 0.61 million and 0.88 million in 1991 and 2001 but in 2007 it grows to 1.4 million (BBS 2013). Khulna City Corporation is losses its natural ecosystem and fallow land with increasing of built-up areas. In 1989, built up area of Khulna city was 16%, but increased to 18% and 31% in the year 1999 and 2009 (Ahmed, 2011). Still, this city has a 48.59% vegetation cover and it can be a well-designed green city if we start working from now (Billah and Rahman, 2004).

2.11 Biodiversity loss in Bangladesh

The Bangladeshi land surface holds two biological hotspots out of 25. However, Bangladesh is losing its biodiversity at a high rate due to economic growth. Last 100 years (1900-2000) Bangladesh has lost about 10% of its mammals, 3% of avifauna and 4% of the reptiles (IUCN, 2006). It was also reported that in last 10 years, 10 mammals, 1 reptile, 2 birds species has been lost from Bangladesh (Chowdhury and Koike, 2010). Floral diversity is also in threat due to ecosystem degradation. Bangladesh still lacks a complete list of plant species. According to 'Red Data Book of Vascular Plants of Bangladesh' Volume-1 only 4 angiosperm species are threatened, one of which is critically endangered, one is endangered and other two are vulnerable (Khan et al, 2001; Irfanullah, 2011). Some other statistics said that nearly 50% of all the total wildlife species of the country will be marked as threatened in a very short time. Some 27-plant species are listed threatened now.At present, 129 species, including 37 mammals, 21 reptiles, 69 birds and 2 amphibians are on the IUCN Red List of endangered (IUCN, 2006).

2.12 Biodiversity conservation in Bangladesh

Biogeographically Bangladesh is situated between Indo-Gangetic plains and the eastern Himalayas and some part of the Indo-Chinese sub region of the Oriental realm (Sobuj and Rahman, 2011). This is a vital part of tropical climate and very rich in biodiversity because of this environmental setting and biogeography. This country has about 17.5% forest land, but only 7% of this is under forest cover and the annual deforestation rate in the country ranges between 1% to 3.3% (Biswas and Choudhury, 2007). Through this degradation of forest lands and other ecosystems, Bangladesh lost it's a vital portion of the biodiversity and this process is still continuing. Bangladesh government and private sector are trying to protect its biodiversity through several strategies. According to Basurco (2006) about 20.9% forest areas of Bangladesh were primarily annexed for conservation purpose which, 12% are officially protected (Managed by Forest Department alone) and other 8.9% was under participatory management. Until 2011, the Bangladesh government has declared 24 protected areas on the basis of ecological importance (Uddin, 2011). For ex-situ conservation several botanical gardens, arboretum, preservation plots clone banks and parks are established in several regions of this country. For example, alone Mirpur Botanical Garden has 255 tree species, 310 shrub species and 385 herb species of 114 families (Mukul, 2007). Bangladesh has signed the five major conventions and agreements related to biodiversity conservation (CBD, CITES, CMS, RAMSAR, WHC) (Brown et al. 2003) and trying to comply with the agreements.

Several legislations have been adopted by Bangladesh government for conserving its natural resources and biodiversity. First, adaptation of legislation for conserving biodiversity was immerged in 1986 and named it as National Conservation Strategy (NCS). It was specified the strategies for sustainable use, development and management of natural resources in 18 different sectors. This strategy was implemented through National Conservation Strategy Implementation Project I (1994–1999) by the Ministry of Environment and Forest. At this time Bangladesh was experienced its first Environment Conservation Act in 1995 (Mukul, 2007). Besides this act Bangladesh has a legal and policy tools, while first Wildlife Preservation Act was come in 1974 after the great liberation war of Bangladesh and its Amendment came in 2012. Forest act and policies are also used as a tool for biodiversity conservation in Bangladesh. Bangladesh forest act 1927 was amendment in 2000 for accelerating the conservation (Millat-e-Mustafa, 2002).

Chapter three: Materials and Methods

3. Materials and Methods

3.1 Study area

3.1.1 Geographical information

The plant species (Herbs) assessment was carried out in Khulna University campus during August to October 2015. The university campus lies between 22°47′57″N to 22°48′18″N and 89°31′38″E to 89°32′21″E. These land areas are managed by the Khulna University authority since the establishment of Khulna University in 1991. The total university area is 106.75 acres (432001.923 m^2) and is just 7 m above the Mean Sea Level (Ahmed, 2011). The area is more or less an alluvial plain of Ganges deltaic plain. Most of the area was wetlands before the establishment of the University (Ahmmed, 2010). This area is a true representative of the urban built-up area of Khulna and managing under several habitats and land use classifications, but most of the area is modified by different degrees of land development.

3.1.2 Soil

Soil of Khulna University is a mixture of the Late Holocene/Recent alluvium of the Ganges deltaic plain in and Ganges estuarine plain. Stratigraphically this area shows seven cycles of sedimentation from Upper Miocene to Recent age. This area has a well-developed soil. Average depth of soil in this area is estimated around 300m. The area is composed of course to very fine sand, silt, silty clay and clay in several sites. The Standard Penetration Test (SPT) value of this region is ranging between 1 and 9 from surface to 5m deep and 1 to 27 from 5m to 15m below of the surface. Soil parameter varies to several limits here the liquid limit ranges from 38 to 59%. Plasticity index lies between 9 to 30% and the natural moisture content (NMC) range from 16.5% to 42% respectively. But in marshy or semi aquatic land shows moisture content up to 192%. Upper soil horizon shows low shearing strength with compressive index from 0.123 to 0.335 (Adhikari et al, 2006). Organic content also varies here, it ranges from 5% to 38% (Rabbee and Rafizul, 2012). The soil of this area is slightly alkaline and dominated by peat soil. Soil pH varies to 6.5-7.9 here. Top soil of this area experienced a low salinity ranges from 2-15 ECe:ds/m (Electrical Conductivity of the extract:decisiemens per meter). This salinity level varies by the year round. January-June salinity level of this area is much higher than other part of he year. April and May shows highest salinity in this region up to 10-15 ECe:ds/m. During \ugust-October this show lowest soil salinity of 1-6 ECe:ds/m (Rasel et al, 2013). As built up ırban area this land surface is subjected to modification.

3.1.3 Climate

The climate in Khulna is typically tropical with a mild winter from October to March, hot and humid summer in March to June and humid, warm rainy monsoon in June to October. Maximum and minimum temperature is variable all the year round. In the month of January and December temperature falls to the lowest around 12-15 °C and it reaches to the months of April, May and June to the maximum around 41-45 °C. Monthly average lowest temperature is 11.7 °C in January and average highest temperature is 35.4 °C in April. The average daily temperature is around 20-27 °C. Daily relative humidity lies between 50-90%, which is lowest in evening and height in morning. A humid, warm rainy monsoon occurs here from June to October. The precipitation reaches height in July and August. Maximum monthly precipitation occurs in July around 393mm. In the months of July and August this area experience 20-25 days of rain. December and January are the driest months here. In those months the precipitation reaches lowest around 6mm. Average annual precipitation is around 368 mm here. Wind speed is also variable here. Wind speed shows higher in the months of April, May, June July and August. In those months average wind speed is over 5 Km/h. In the month of May the average wind speed reaches height around 8 km/h. Maximum wind speed also reaches higher in this month is around 80-90 km/h. December is the calmest month of the year, wind speed is lowest here. Average daily wind speed during this month is 2 km/h and maximum reaches only 26 km/h (BBS, 2013, 2014).

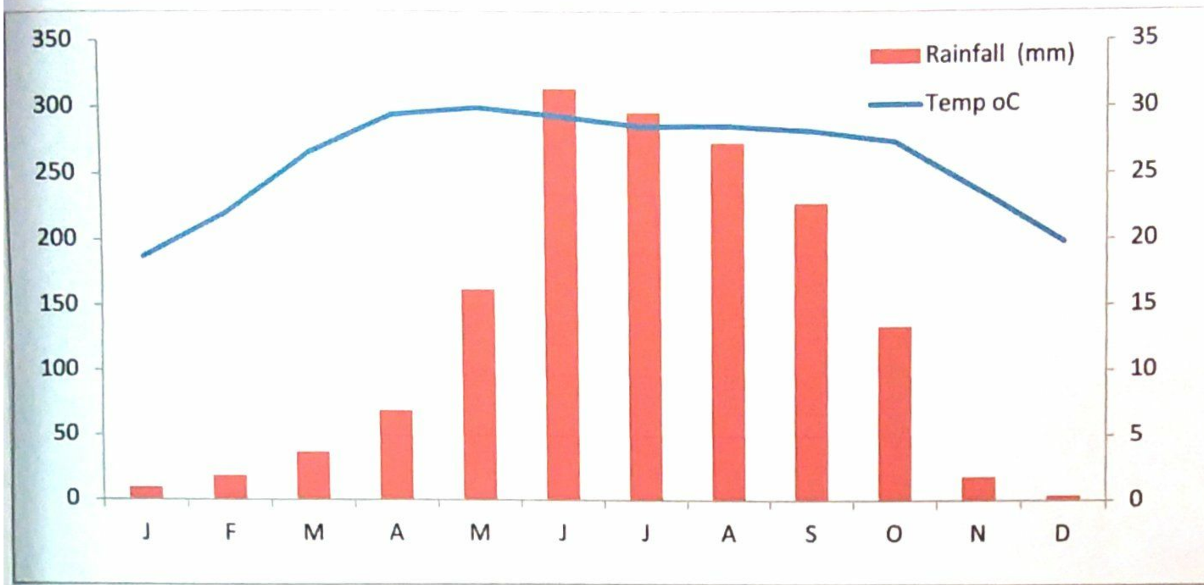


Fig. 3.1: Climate map of Khulna

3.2 Sampling Design

For the sampling, Khulna University Campus was selected and gridlines of 50 m × 50 m were made. Gridlines were created along the north and east lines. Each intersect point of the gridlines were selected as the center-point of the plot. From the intersect point 0.5m on each side (North, East, South and West) were taken and 1m^{2}square shape plot was created. The intersect point of the plot was identified using GPS (Garmin GPSMAP 76CSx.). The identified plots were plotted in Google Map and a baseline map of the sampling was prepared. A total of 207 plots were prepared and assessed.

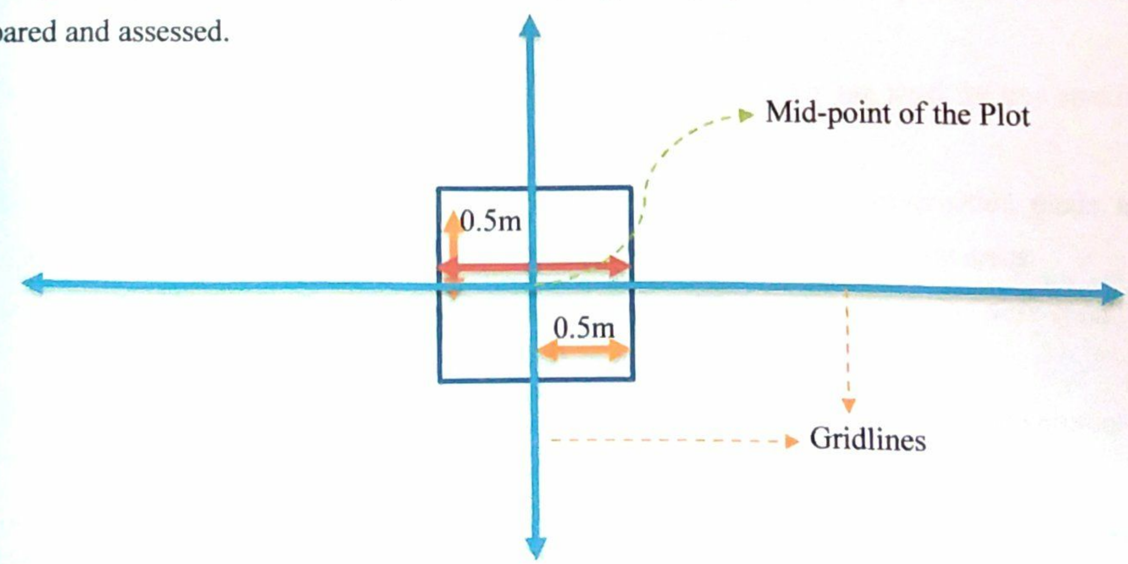


Fig 3.2 Plot Demarcation

Fig. 3.3: Grid Plot of Khulna University Campus.

After selecting the plots the total area is divided into several land-use areas. Mainly croplands, built-up areas, fallow lands, aquatic lands or permanent wetlands and plantation. The plots which fall into any of this area is treated as a representative of this land use area for analysis.

A. Croplands: The land surface area which uses at least one season for paddy production or any other Agricultural crops is treated as Agricultural lands.
B. Fallow lands: Land surface area of the selected site which are not used for any specific use, but fallow all-round the year are defined as fallow lands.
C. Built-up areas: the site areas in and around 5 meters of any construction made any construction materials (Bricks, stones or concrete) are defined as Built-up areas.
D. Aquatic Lands: the Land surface which is submerged in water for all the year round id termed as aquatic lands or permanent wetlands.
E. Plantation: the land surfaces which contain two or more numbers of rows and columns of trees which are planted by management authority.

3.3 Data Collection

'rimary data were collected from field surveys during August-October 2015. All species were dentified and counted in the plot. For creepers and the species which are difficult to separate in iumbers (Poaceae, Cyperaceae and Commelinaceae) are counted as occurrence data. When the vatches of species were separately identifiable, they are counted as separate in number also. As he field survey was in the pick monsoon period.

3.4 Identification

dentification of the herbs is done in three steps for this study. In first step most common and asily identifiable taxa was identified by all available taxonomic key (structure of flower, leaf tructure, root structures and others). Most of the family and genera level identification was done hrough these steps. In second phase the unidentified taxa are collected directly and capture their ll possible structural images and compared with several Encyclopedias, books, databases and ther reliable materials. In most of the cases the Encyclopedia of flora and fauna of Bangladesh ublished by Asiatic society was used as a key reference. The species which were not dentifiable from the Encyclopedia of flora and fauna of Bangladesh, other materials like Kew otanical garden database, World plant database, Flora of India, Missouri Botanical Garden latabase, Flora of Pakistan, Species 2000 were consulted.

3.5 Data Processing and analysis

After collection of literatures and field survey information from primary and secondary sources, hose were vigilantly reviewed and sorted according to the requirements of the study. Data were nalyzed to determine the diversity index for determining the evenness and richness of the study ite. For measuring evenness Simpson's Diversity Index and Shannon-Wiener Diversity Index vere used.

3.5.1 Simpson's Diversity Index

Simpson Diversity Index is a popular diversity index in biology. It is developed by Edward Hugh Simpson a British statistician in 1949 which was later favored by Whittaker (1965) and Pielou 1969). It indicates the probability of selecting same species in two different random sample Roghair and Dolloff, 2013). Mathematically Simpson's Diversity Index (D) = $\frac{\Sigma n(n-1)}{N(N-1)}$

Where, D = Simpson's Diversity Index

n = Total number of individuals of a given species

N = Total number of species collected

3.5.2 Shannon-Wiener Diversity Index

The Shannon index is another popular way of measuring biodiversity in the ecological literature, which is also known as Shannon's diversity index. The measure was originally proposed by Claude Shannon and Warren Weaver the two American scientists in the year of 1949. This Index is based on communication theory and it represented how to predict the next species in a site to a particular similar species (Spellerberg and Fedor, 2003). It is indicated by "H".

Shannon-Wiener Diversity Index, H = $\sum_{i=p}^{n} pi\ lnpi$

Where, H = Shannon-Wiener Diversity Index

n = Total number of species

pi= The proportional abundance of species i

$pi = \frac{ni}{N}$ (where ni = Total number of species of i and N = Total number of all species)

3.5.3 Species Evenness

Species evenness refers to the closeness of number of species in an ecosystem or a specific land surface.. This index can be calculated from Shannon-Wiener Diversity Index. Species evenness is indicated by "J' and values lies between 0 to 1. Higher value of species evenness indicates the lower diversity (Molles and Cahill, 1999).

Species evenness, J = $\frac{H}{Hmax}$

Where, H = Shannon-Wiener Diversity Index and,

H_{max} = Maximum Shannon-Wiener Diversity Index

3.6 Software

Several soft-wares are used to fulfill the requirements of the study. Google Earth Pro 4.2 used for map preparation and sampling outline. GEPath 1.4.6 is used for guidelines creation and identification of plots. Microsoft Excel 2013 is used for statistical analysis of the data in several stages of the study. PAleontologicalSTatistics (PAST) Version 3.10 is used for calculating diversity indices.

Chapter four: Result and Discussion

l.1 Result

l.1.1 Species content

\ total of 6423 individuals belonging to 163 species were found throughout the sample plots. [These 163 species belonged to112 genera and 46 families. The highest number of species was 'ound in Poacea and Cyperaceae and they contained 23 and 19 species in number (Fig.4.1). Dicot ınd monocot species were 72% and 28% respectively among the sampled data (Fig.4.2). Out of l7 families, Amaranthaceae, Acanthaceae, Asteraceae, Poaceae, Linderniaceae, Cyperaceae, and \raceae contributed 85% of the total individuals and the rest of the 39 families contributed about 5% of the total individuals sampled (Fig. 4.3).

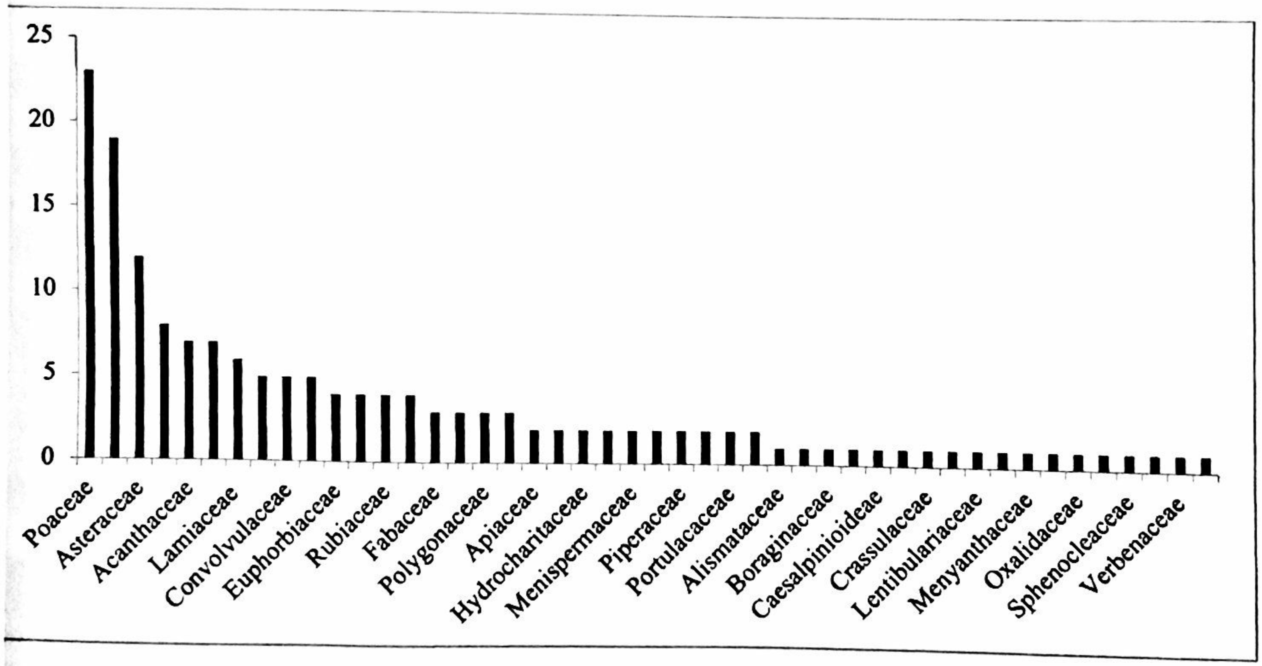


Fig .4.1 Species in different families

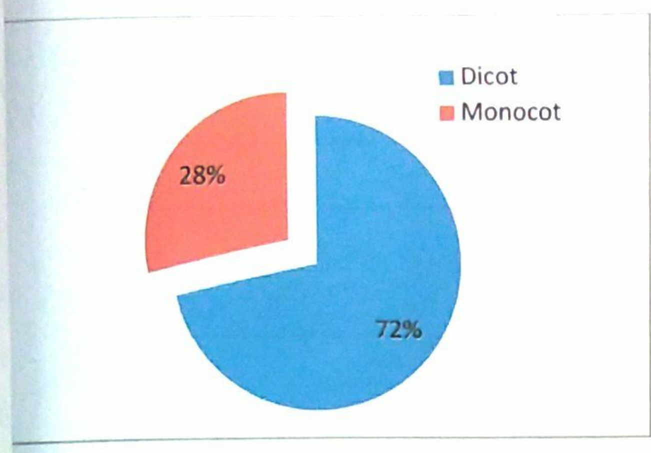


Fig. 4.2 Monocot and dicot in Khulna University campus

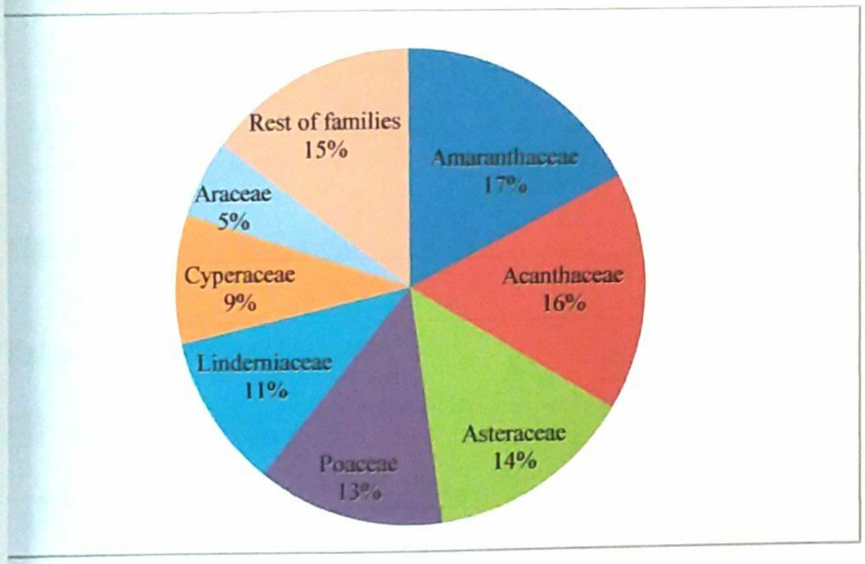


Fig. 4.3: Dominant families

The total individuals were dominated by many species. Most (10) dominated species accounts 63% of the total individuals and the rest of 153 species contributed to 37% of total. Only 18 species accounts over 1% of the total individuals. Among the total species, *Alternanthera paronychioides* Kunth (14%), *Lindernia crustacea* (L.) F. Muell (9%), *Ruellia tuberosa* L. (8%) *Synedrella nodiflora* (L.) Gaertn. (7%), *Rungia pectinata* (L.) Ness. DC. (7%) and *Oryza sativa* L. (6%) were the most dominated species, which are contributing over 5% of the total individuals (Fig. 4.4) .

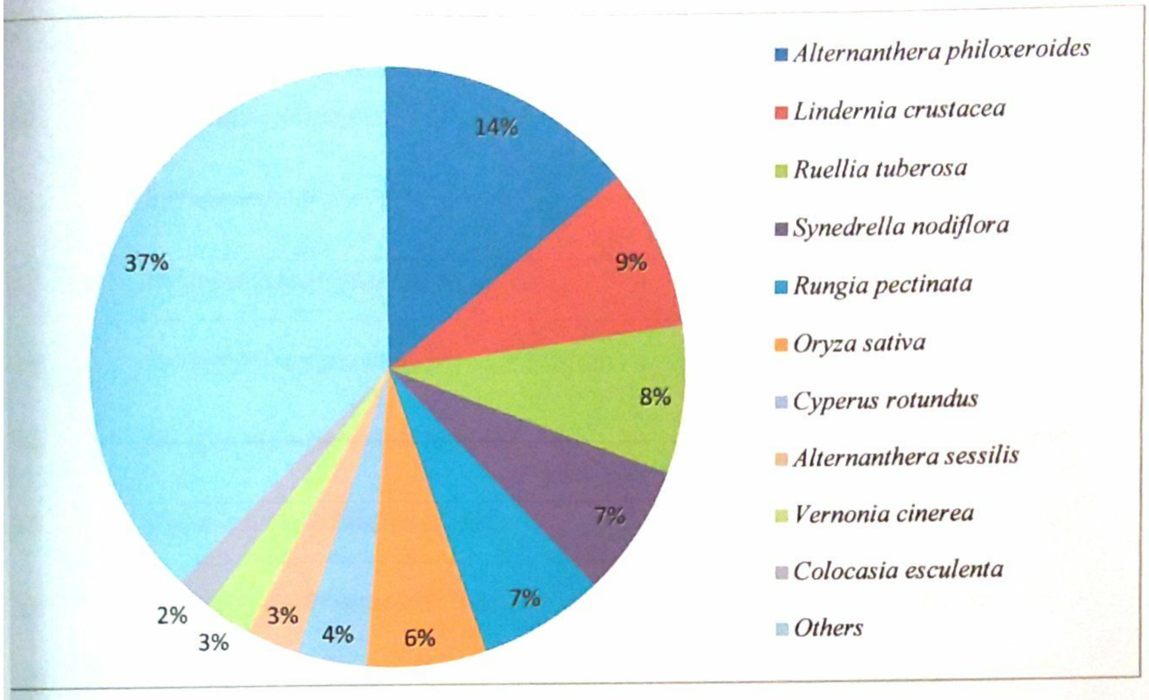


Fig. 4.4: Dominant species

Table 4: List of the Species

Sl. No	Scientific name	Family
1	*Acalypha indica* L.	Euphorbiaceae
2	*Achyranthes aspera* L.	Amaranthaceae
3	*Aerva lanata* (L.) Juss. ex Schult.	Amaranthaceae
4	*Alocasia macrorrhizos* (L.) G.Don	Araceae
5	*Alternanthera philoxeroides* (Mart.) Griseb.	Amaranthaceae
6	*Alternanthera paronychioides* Kunth.	Amaranthaceae
7	*Alternanthera sessilis* (L.) R. Br. ex Roem. & Schult	Amaranthaceae
8	*Amaranthus spinosus* L.	Amaranthaceae

9	*Amaranthus viridis* L.	Amaranthaceae
10	*Ammannia baccifera* L.	Lythraceae
11	*Ammannia coccinea* L.	Lythraceae
12	*Antigonon leptopus* Hook. & Arn.	Polygonaceae
13	*Axonopus compressus* (Sw.) P.Beauv.	Poaceae
14	*Bacopa monnieri* (L.) Pennell	Scrophulariaceae
15	*Blumea lacera* (Burm.f.) DC.	Asteraceae
16	*Blumea membranaceae* Wall. *ex.* DC.	Asteraceae
17	*Brachiaria brizantha* (A.Rich.) Stapf.	Poaceae
18	*Brachiaria mutica* (Forssk.) Stapf	Poaceae
19	*Centella asiatica* (L.) Urban	Apiaceae
20	*Cleome rutidosperma* DC.	Cleomaceae
21	*Coccinia grandis* (L.) Voigt	Cucurbitaceae
22	*Colocasia esculenta* (L.) Schott	Araceae
23	*Commelina benghalensis* L.	Commelinaceae
24	*Commelina diffusa* Burm.f.	Commelinaceae
25	*Commelina longifolia* Lamk.	Commelinaceae
26	*Croton bonoplandianum* Bail	Euphorbiaceae
27	*Cyanotis axillaris* (L.) D.Don ex Sweet	Commelinaceae
28	*Cynodon arcuatus* J. S. Presl ex. C. B. Presl.	Poaceae
29	*Cynodon dactylon* (L.) Pers.	Poaceae

30	*Cyperus corymbosus* Rottb	Cyperaceae
31	*Cyperus cuspidatus* Kunth in Humb	Cyperaceae
32	*Cyperus difformis* L.	Cyperaceae
33	*Cyperus distans* L. f.	Cyperaceae
34	*Cyperus exaltatus* Retz.	Cyperaceae
35	*Cyperus imbricatus* Retz.	Cyperaceae
36	*Cyperus rotundus* L.	Cyperaceae
37	*Dactyloctenium aegyptium* (L.) Willd.	Poaceae
38	*Dentella repens* (L.) J. R. & G. Forst.	Rubiaceae
39	*Dentella serpyllifolia* Wall. ex. Craid	Rubiaceae
40	*Desmodium triflorum* (L.)DC.	Fabaceae
41	*Digitaria bicornis* (Lam.) Roem. & Schult.	Poaceae
42	*Digitaria sanguinalis* (L.) Scop.	Poaceae
43	*Dioscorea alata* L.	Dioscoreaceae
44	*Echinochloa colonum* (L.) Link.	Poaceae
45	*Eclipta alba* (L.) Hassk.	Asteraceae
46	*Eichhornia crassipes* (Mart.) Solms	Pontederiaceae
47	*Eleocharis acutangula* (Roxb.) Schult.	Cyperaceae
48	*Eleocharis dulcis* (Burm.f.) Trin. ex Hensch.	Cyperaceae
49	*Eleocharis obtuse* (Willd.) Schult.	Cyperaceae
50	*Eleusine indica* (L.) Gaertn.	Poaceae

51	*Emilia sonchifolia* (L.) DC. ex Wight	Asteraceae
52	*Enhydra fluctuans* Lour.	Asteraceae
53	*Euphorbia serpens* H. B. & K.	Euphorbiaceae
54	*Euphorbia thymifolia* Forssk., sensu auct.	Euphorbiaceae
55	*Evolvulus nummularius* (L.) L.	Convolvulaceae
56	*Fimbristylis dichotoma* (L.) Vahl.	Cyperaceae
57	*Fimbristylis miliacea* (L.) Vahl	Cyperaceae
58	*Fimbristylis ovata* (Burm.f.) J.Kern	Cyperaceae
59	*Hedyotis corymbosa* (L.) Lam.	Rubiaceae
60	*Hedyotis racemosa* Lam.	Rubiaceae
61	*Heliotropium indicum* L.	Boraginaceae
62	*Hemigraphis hirta* (Vahl) T. Anders.	Acanthaceae
63	*Hemigraphis sp.* ***	Acanthaceae
64	*Hydrocharis dubia* (Blume) Backer	Hydrocharitaceae
65	*Hygrophila ringens* (L.) R. Br.	Acanthaceae
66	*Hygrophila schulli* (Buch.-Ham.) M.R. Almeida & S.M. Almeida	Acanthaceae
67	*Hyptis brevipes* Poit.	Lamiaceae
68	*Hyptis suaveolens* (L.) Poit	Lamiaceae
69	*Imperata cylindrical* (L.) Raeusch	Poaceae
70	*Ipomoea aquatica* Forsk.	Convolvulaceae

71	*Ipomoea pandurata* (L.) G.F.W. Mey.	Convolvulaceae
72	*Kalanchoe pinnata* (Lam.) Pers.	Crassulaceae
73	*Kyllinga brevifolia* Rottb.	Cyperaceae
74	*Kyllinga nemoralis* (J.R.Forst. & G.Forst.) Dandy ex Hutch. & Dalziel	Cyperaceae
75	*Leersia hexandra* Sw.	Poaceae
76	*Lemna perpusilla* Torr.	Araceae
77	*Leonurus sibiricus* L.	Lamiaceae
78	*Leucas aspera* (Willd.) Link	Lamiaceae
79	*Lindernia antipoda* (L.) Alston	Linderniaceae
80	*Lindernia ciliata* (Colsm.) Pennell	Linderniaceae
81	*Lindernia crustacea* (L.) F. Muell	Linderniaceae
82	*Lindernia pusilla* (Willd.) Merrill	Linderniaceae
83	*Ludwigia adscendens* (L.) Hara.	Onagraceae
84	*Ludwigia hyssopifolia* (G. Don) Exell apud A, & R. Fernandes	Onagraceae
85	*Ludwigia prostrate* Roxb.	Onagraceae
86	*Marsilea quadrifolia* L.	Marsileaceae
87	*Mecardonia procumbens* (Mill.) Small	Scrophulariaceae
88	*Melochia corchorifolia* L.	Malvaceae
89	*Mentha viridis* (L.) L.	Lamiaceae

90	*Merremia hederacea* (Burm. fil.) Hall. fil.	Convolvulaceae
91	*Mikania cordata* (Burm.f.) B.L.Rob.	Asteraceae
92	*Momordica charantia* L.	Cucurbitaceae
93	*Monochoria hastata* (L.) Solms	Pontederiaceae
94	*Murdannia nudiflora* (L.) Brenan	Commelinaceae
95	*Nicotiana plumbaginifolia* Viv.	Solanaceae
96	*Nymphaea nouchali* Burm. fil.	Nymphaeaceae
97	*Nymphoides hydrophylla* (Loureiro) Kuntze	Menyanthaceae
98	*Ocimum tenuiflorum* L.	Lamiaceae
99	*Oenanthe javanica* DC.	Apiaceae
100	*Operculina turpethum* (L.) S. Manso	Convolvulaceae
101	*Oplismenus burmannii* (Retz.) P. Beauv	Poaceae
102	*Oryza rufipogon* Griff.	Poaceae
103	*Oryza sativa* L.	Poaceae
104	*Ottelia alismoides* (L.) Pers.	Hydrocharitaceae
105	*Oxalis corniculata* L.	Oxalidaceae
106	*Panicum maximum* Jacq.	Poaceae
107	*Panicum miliaceum* L.	Poaceae
108	*Panicum paludosum* Roxb.	Poaceae
109	Paspalidium flavidum (Retz.) A. Camus	Poaceae
110	*Paspalum conjugatum* Bergius	Poaceae

111	*Paspalum distichum* L.	Poaceae
112	*Passiflora foetida* L.	Passifloraceae
113	*Peperomia pellucida* (L.) Kunth	Piperaceae
114	*Persicaria glabra* (Willd.) Gomez de la Maza	Polygonaceae
115	*Phyla nodiflora* (L.) Greene	Verbenaceae
116	*Phyllanthus niruri* L.	Phyllanthaceae
117	*Phyllanthus urinaria* L.	Phyllanthaceae
118	*Physalis minima* L.	Solanaceae
119	*Pilea microphylla* (L.) Liebm.	Urticaceae
120	*Piper betle* L.	Piperaceae
121	*Pistia stratiotes* L.	Araceae
122	*Polygonum effusum* Meisn.	Polygonaceae
123	*Portulaca oleracea* L.	Portulacaceae
124	*Portulaca quadrifida* L.	Portulacaceae
125	*Pouzolzia zeylanica* (L.) Benn. & R. Br.	Urticaceae
126	*Pycreus polystachyos* (Rottb.) P. Beauv	Cyperaceae
127	*Rorippa indica* (L.) Hiern	Brassicaceae
128	*Rottboellia cochinchinensis* (Lour.) Clayton	Poaceae
129	*Ruellia prostrate* Poir.	Acanthaceae
130	*Ruellia tuberosa* L.	Acanthaceae
131	*Rungia pectinata* (L.) Ness. DC.	Acanthaceae

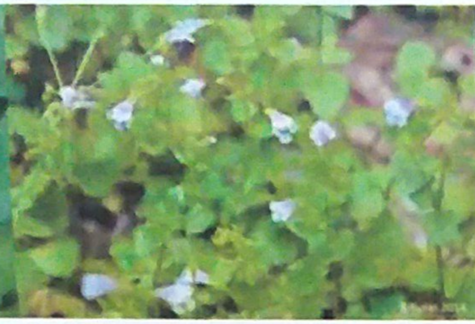
132	*Saccharum spontaneum* L.	Poaceae
133	*Sagittaria sagittifolia* L.	Alismataceae
134	*Schoenoplectus articulates* (L.) Lye.	Cyperaceae
135	*Schoenoplectus juncoide* (Roxb.) Palla	Cyperaceae
136	*Scoparia dulcis* L.	Scrophulariaceae
137	*Senna tora* (L.) Roxb.	Caesalpinioideae
138	*Sesbania sesban* (L.) Merr.	Fabaceae
139	*Sida acuta* Burm. F.	Malvaceae
140	*Sida cordata* (Burm. F.) Borss.	Malvaceae
141	*Sida cordifolia* L.	Malvaceae
142	*Sida rhombifolia* L.	Malvaceae
143	*Solanum nigrum* L.	Solanaceae
144	*Solanum villosum* Miller	Solanaceae
145	*Sphenoclea zeylanica* Gaertn.	Sphenocleaceae
146	*Spilanthes calva* DC. In Wight	Asteraceae
147	*Spilanthes uliginosa* (Sw.) Cass.	Asteraceae
148	*Spirodela polyrhiza* (L.) Schleid.	Araceae
149	*Spirodela punctate* (G.Mey.) C.H.Thomps.	Araceae
150	*Stephania japonica* (Thunb.) Miers	Menispermaceae
151	*Synedrella nodiflora* (L.) Gaertn.	Asteraceae
152	*Tetrastigma angustifolium* (Roxb.) Planch	Vitaceae

153	*Tinospora cordifolia* (Willd.) Miers	Menispermaceae
154	*Tridax procumbens* L.	Asteraceae
155	*Typha domingensis* Pers.	Typhaceae
156	*Typhonium trilobatum* (L.) Schott	Araceae
157	*Utricularia gibba* L.	Lentibulariaceae
158	*Vernonia cinerea* (L.) Less.	Asteraceae
159	*Vigna luteola* (Jacq.)Benth.	Fabaceae
160	*Wedelia chinensis* (osbeck) Merr.	Asteraceae
161	*Wedelia trilobata* (L.) A. S. Hitche,	Asteraceae
162	*Xanthosoma violaceum* (L.) Schott	Araceae
163	*Zephyranthes grandiflora* Lindl., nom. illeg.	Amaryllidaceae

(*** not identified at species level)

Fig 4.5: Major herbs of Khulna University Campus

Alternanthera philoxeroides

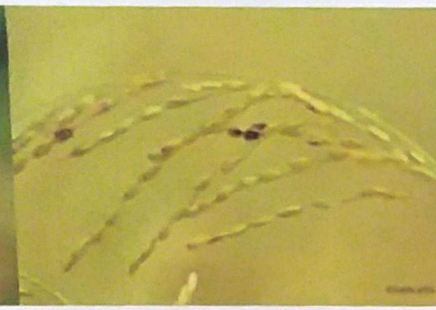


Lindernia crustacea

Synedrella nodiflora

Ruellia tuberosa

Rungia pectinata



Oryza sativa

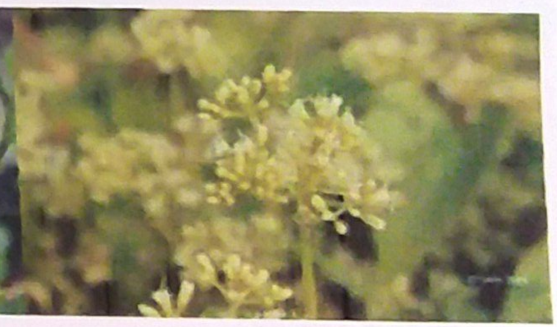
Cyperus rotundus

Alternanthera sessilis

Colocasia esculenta

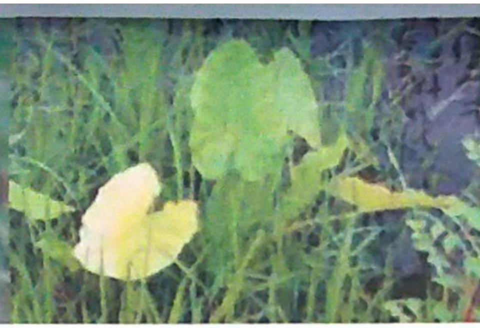
Vernonia cinerea

Lindernia pusilla



Mikania cordata

Eleusine indica



Alocasia macrorrhizos

Marsilea quadrifolia

Cyperus exaltatus

Phyla nodiflora

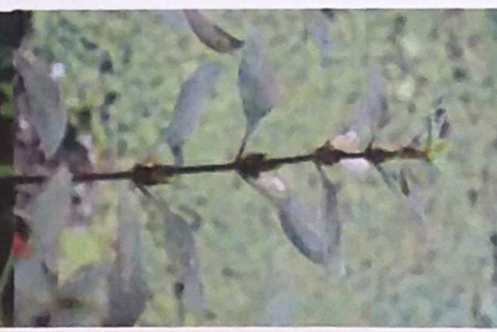
Pistia stratiotes

Cyperus difformis

Brachiaria mutica

Ipomoea aquatic

Eclipta alba



Hygrophila ringens

Paspalum distichum

4.1.2 Diversity

Simpson (1-D), Shannon H and Dominance (D) were recorded 0.946, 3.619 and 0.054 for the total area irrespective of different landuses. The high value of Simpson (1-D) indicates greater sample diversity in Khulna University campus. High Shannon H (3.619) low value of Dominance (0.054) and low evenness (0.2289) indicate all taxa have considerable contribution (Tab. 5).

Table 5: Diversity indices for Khulna University

	Total
Taxa (S)	163
Dominance (D)	0.054
Simpson (1-D)	0.946
Shannon (H)	3.619
Evenness (e^H/S)	0.2289

The diversity of plant diversity of major landuses of Khulna University varied. High plant diversity was found for Built up area (Shannon H=3.334, Dominance D=0.068, Simpson 1-D=0.9317 and Evenness e^H/S=0.2418) and fallow land (H=3.382, Dominance D=0.065, Simpson 1-D=0.935 and Evenness e^H/S=0.2803). For plantation (H=2.876, Dominance D=0.0937, Simpson 1-D=0.9063 and Evenness e^H/S=0.4328) and cropland (H=2.486, Dominance D=0.1988, Simpson 1-D=0.8012 and Evenness e^H/S=0.1793) the diversity indices is lower than built-up area and fallow land. The lowest diversity was observed in aquatic landuses (H=2.056, Dominance D=0.2168, Simpson 1-D=0.7832 and Evenness e^H/S=0.4598) (Fig. 4.6)

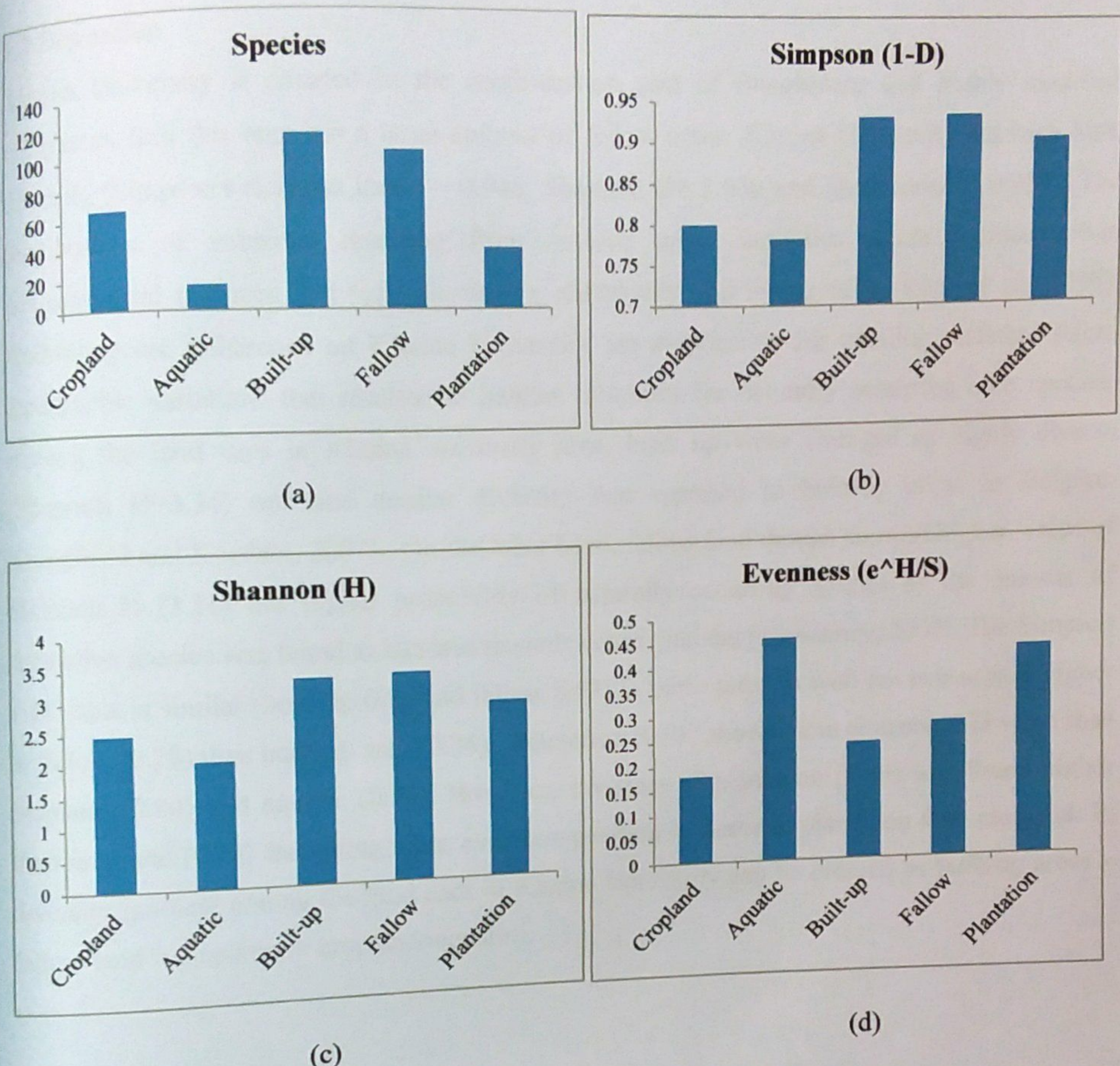


Fig. 4.5: Diversity indices for herbs in different landuses. (a: Number of species in land classes, b: Simpson 1-D indices for land use class, c: Shannon H indices and d: Evenness indices)

4.2 Discussion

Khulna University is situated in the north-eastern part of Bangladesh and highly modified ecosystem. Still this area has a large amount of fallow areas. Khulna University has high herb diversity (Simpson's richness index = 0.946, Shannon H= 3.619 and Dominance = 0.054). The distributions of substrate resulting from various urban activities create various urban environmental matrices that vary physically, chemically and biologically (Kent *et al.*, 1999). Anthropogenic influences on Khulna University are responsible for creating different micro topographic variations that resulted in habitat variations for naturally occurring herb species. Among the land uses in Khulna university area, built up areas emerged as highly diverse (Shannon H=3.34) one and similar diversity was reported in built-up areas in Belgium (Godefroid and Koedam, 2007). On the other hand, fallow land though showed higher value of Shannon H (3.38) has higher probability of naturally occurring species as the number of nonnative species was found to increase towards urban gradient (McKinney, 2002). The Simpson 1-D value is similar (built-up 0.93 and fallow 0.93) in those areas as well but evenness is higher in fallow (0.28) than built-up area (0.24). Plantation (0.91) shows more simpson 1-D value than cropland (0.80) and aquatic (0.78). However, evenness of plantation (0.46) was found higher than cropland (0.18) indicating more even composition of herbs in plantation than cropland. In diversity gradient among the land uses in Khulna University can be ordered as built-up areas > fallow land > plantation> cropland>aquatic.

Chapter five: Conclusion and Recommendations

5. Conclusion and Recommendations

5.1 Conclusion

After this work, it can be concluded the Khulna university campus is a unique ecosystem with a large diversity of herbs. In just one seasons it was found 163 species and it should be a huge number if we go for total enumeration it is predicted that this area is habitat for 700-800 angiosperms. Built up areas are multidimensional and subjected to changes through time and space (Alberti *et al.*, 2003) and it provide variable urban matrix that contain elements of biodiversity deserving the attention of the conservationist (Miller and Hobbs, 2002). At present condition plant diversity in Khulna University was found to vary spatially and temporally for herbs. Built-up areas, fallow land and Plantation area can be brought under conservation strategy to increase native species pool and conservation for existing.

5.2 Recommendations

There is no proper listing of species for this area but it has a vital contribution in biodiversity of this regions. So, proper identification and listing should be done for future research and conservation. Due to rapid land use changes, the habitats of those species are degraded and fragmented day by day. If this situation continues, there is a big chance of extinction of those species before identification or conservation. So some conservation measures should be taken with proper documentation to conserve this valuable genetic diversity of this area.

Bibliography

Achard F. 2002. Determination of Deforestation Rates of the World's Humid Tropical Forests. Science 297: 999–1002.

Adams WM. 2004. Biodiversity Conservation and the Eradication of Poverty. Science **306:** 1146–1149.

Adhikari DK, Roy MK, Datta DK, Roy PJ, Roy DK, Malik AR, Alam AB. 2006. Urban geology: a case study of Khulna City Corporation, Bangladesh. Journal of Life and Earth Science **1:** 17–29.

Ahamed ZU, Begum ZNT, Khondokar M, Kabir SMH, Ahmed M, Ahmed ATA, Rahaman AKA, Haque EU. 2007. (eds). *Encyclopedia of Flora and Fauna of Bangladesh, Monocotyledon: (Agavaceae-Najadaceae).* Asiatic Society of Bangladesh. Dhaka, Bangladesh. **11.** 1-457

Ahamed ZU, Begum ZNT, Khondokar M, Kabir SMH, Ahmed M, Ahmed ATA, Rahaman AKA, Haque EU. 2008a. (eds). *Encyclopedia of Flora and Fauna of Bangladesh, Bangladesh Profile.* Asiatic Society of Bangladesh. Dhaka, Bangladesh. **1.**1-230

Ahamed ZU, Begum ZNT, Khondokar M, Kabir SMH, Ahmed M, Ahmed ATA, Rahaman AKA, Haque EU. 2008b. (eds). *Encyclopedia of Flora and Fauna of Bangladesh, Dicotyledons (Acanthaceae-Asteraceae).* Asiatic Society of Bangladesh. Dhaka, Bangladesh. **6.**1:408

Ahamed ZU, Begum ZNT, Khondokar M, Kabir SMH, Ahmed M, Ahmed ATA, Rahaman AKA, Haque EU. 2008c. (eds). *Encyclopedia of Flora and Fauna of Bangladesh, Dicotyledons (Balsaminaceae- Euphorbiaceae).* Asiatic Society of Bangladesh. Dhaka, Bangladesh. **7.**1-546

Ahamed ZU, Begum ZNT, Khondokar M, Kabir SMH, Ahmed M, Ahmed ATA, Rahaman AKA, Haque EU. 2008d. (eds). *Encyclopedia of Flora and Fauna of Bangladesh, Dicotyledons (Fabaceae-Lythraceae).* Asiatic Society of Bangladesh. Dhaka, Bangladesh.**8.**1-578

Ahamed ZU, Begum ZNT, Khondokar M, Kabir SMH, Ahmed M, Ahmed ATA, Rahaman AKA, Haque EU. 2009a. (eds). *Encyclopedia of Flora and Fauna of Bangladesh, Dicotyledons (Magnoliaceae - Puniaceae).* Asiatic Society of Bangladesh. Dhaka, Bangladesh **9.**1-488

Ahamed ZU, Begum ZNT, Khondokar M, Kabir SMH, Ahmed M, Ahmed ATA, Rahaman AKA, Haque EU. 2009b. (eds). *Encyclopedia of Flora and Fauna of Bangladesh. Dicotyledons (Orchidaceae - Zingiberaceae).* Asiatic Society of Bangladesh. **10.**1-580

Ahmed B. 2011. Modelling spatio-temporal urban land cover growth dynamics using remote sensing and GIS techniques: A case study of Khulna City. Journal of Bangladesh institute of Planners **4**: 15–32.

Ahmmed MM. 2010. Higher education in public universities in Bangladesh. Pakistan Journal of Social Sciences (PJSS) **30**: 293–305.

Alberti M, Marzluff JM, Shulenberger E, Bradley G, Ryan C, Zumbrunnen C. 2003. Integrating humans into ecology: opportunities and challenges for studying urban ecosystems. BioScience **53(12)**:1169-1179.

Alexandratos N. 1999. World food and agriculture: outlook for the medium and longer term. Proceedings of the National Academy of Sciences **96**: 5908–5914.

Araújo MB. 2003. The coincidence of people and biodiversity in Europe. Global Ecology and Biogeography **12**: 5–12.

Araujo MB, Rahbek C. 2006. How Does Climate Change Affect Biodiversity? Science **313**: 1396–1397.

Arunachalam A, Sarmah R, Adhikari D, Majumder M, Khan ML. 2004. Anthropogenic threats and biodiversity conservation in Namdapha nature reserve in the Indian Eastern Himalayas. Current Science **87**: 447–454.

Asafu-Adjaye J. 2003. Biodiversity Loss and Economic Growth: A Cross-Country Analysis. Contemporary Economic Policy **21**: 173–185.

Baillie JE, Hilton-Taylor C, Stuart S. 2004. A Global Species Assessement: 2004 IUCN Red List of Threatened Species. IUCN Species Survival Commission. IUCN.

Basurco A, Groothousen CA, Howard J, Mestre M, Beliard CA. 2006. Global forest resources assessment 2005: progress towards sustainable forest management. FAO, Rome.

Bazrkar MH, Zamani N, Eslamian S, Eslamian A, Dehghan Z. 2015. Urbanization and Climate Change. Handbook of Climate Change Adaptation. Springer, Berlin Heidelberg. Pp. 619-655.

BBS. 1984. Bangladcsh Population Cerrsus 1981 National series, analytical findings and national tables. Bangladesh Bureau of Statistics, Statistics Division. Dhaka.Bangladesh.

BBS. 1987. Bangladcsh Population Cerrsus 1981 (Report on Urban Area). Dhaka, Bangladesh: Bangladesh Bureau of Statistics, Statistics Division. Dhaka. Bangladesh.

BBS. 1994. Bangladesh Population Census 1991, vol. I, (Analytical Report). Dhaka, Bangladesh: Bangladesh Bureau of Statistics, Statistics Division. Dhaka. Bangladesh.

BBS. 2004. Banglude.sh Population Census 2001, (Preliminary Report). Dhaka, Bangladesh: Bangladesh Bureau of Statistics, Statistics Division. Dhaka. Bangladesh.

BBS. 2011. Population and housing census 2011. Dhaka, Bangladesh: Bangladesh Bureau of Statistics, Statistics Division. Dhaka. Bangladesh.

BBS. 2013. District Statistics 2011 Khulna. Dhaka, Bangladesh: Bangladesh Bureau of Statistics, Statistics Division. Dhaka. Bangladesh.

BBS. 2014. Statistical Pocketbook of Bangladesh – 2013. Bangladesh Bureau of Statistics. Ministry of planning. People's Republic of Bangladesh. Dhaka. Bangladesh.

Beck KG, Zimmerman K, Schardt JD, Stone J, Lukens RR, Reichard S, Randall J, Cangelosi AA, Cooper D, Thompson JP. 2008. Invasive species defined in a policy context: Recommendations from the Federal Invasive Species Advisory Committee. Invasive Plant Science and Management **1**: 414–421.

Bell DE. 1992. 1992 Convention on Biological Diversity: The Continuing Significance of US Objections at the Earth Summit, The George Washington Journal of International Law and Economics. **26**: 479.

Berkes F, Folke C, Gadgil M. 1995. Traditional ecological knowledge, biodiversity, resilience and sustainability. Springer. Berlin, Heidelberg.

Billah M, Rahman GA. 2004. Land cover mapping of Khulna city applying remote sensing technique. Geoinformatics: 707–714.

Biswas SR, Choudhury JK. 2007. Forests and Forest Management Practices in Bangladesh: The Question of Sustainability 1. International Forestry Review **9**: 627–640.

Books TM, Mittermeir CG, Mittermeir RA, Fonseca GAB da, Rylands AB, Konstant WR., Flick P, Pilgrim J, Oldfield S, Magin G, Hilton-Taylors C. 2002. Biodiversity can eleminate proverty. Biodiversity can eleminate proverty **16**: 909–923.

Brown C, Durst PB. 2003. State of forestry in Asia and the Pacific- 2003: Status, changes and trends. RAP Publication 2003/22 edn. Asia-Pacific Forestry Commission. Food and Agriculture Organization (FAO) of the United Nations. Bangkok, Thiland.

Bruinsma J. 2003. World agriculture: towards 2015/2030: an FAO perspective. Food and Agriculture Organization (FAO). Earthscan, UK.

Carlton C. 2001. Community biodiversity survey manual. Sydney South, N.S.W.; Hurstville, N.S.W.: National Parks Association of NSW Inc. ; NSW National Parks and Wildlife Service. New South Wales National Parks and Wildlife Service. New South Wales, Australia.

Chan KM, Shaw MR, Cameron DR, Underwood EC, Daily GC. 2006. Conservation planning for ecosystem services. PLoS Biol **4**:379.

Chivian E, others. 2002. Biodiversity: its importance to human health, Interim Executive Summary. Center for Health and the Global Environment, Harvard Medical School, Johnson & Johnson generously. Cambridge, MA.

Chowdhury MSH, Koike M. 2010. An overview on the protected area system for forest conservation in Bangladesh. Journal of Forestry Research **21**: 111–118.

Chowdhury RH. 1980. Urbanization in Bangladesh. Centre for Urban Studies. Dhaka, Bangladesh.

Clavero M, Garciaberthou E. 2005. Invasive species are a leading cause of animal extinctions. Trends in Ecology and Evolution **20**: 110–110.

Clergeau P, Savard J-PL, Mennechez G, Falardeau G. 1998. Bird abundance and diversity along an urban-rural gradient: a comparative study between two cities on different continents. Condoc: 413–425.

Convention on Biological Diversity (CBD). 2001. Assessment, conservation, and sustainable use of forest biodiversity. Montreal: Secretariat of the Convention on Biological Diversity. Himalayan journal of sciences. **4**:43-45.

Costanza R, de Groot R, Sutton P, van der Ploeg S, Anderson SJ, Kubiszewski I, Farber S, Turner RK. 2014. Changes in the global value of ecosystem services. Global Environmental Change **26**: 152–158.

Costanza R, d, Arge R, de Groot R, Farber S, Grasso M, Hannon B, Limburg K, Naeem SO, Neill RV, Paruelo J, Raskin RG, Sutton P, van den Belt M. 1997 The value of the world' s ecosystem services and natural capital. Nature **387**: 253.

Costello MJ, May RM, Stork NE. 2013. Can we name Earth's species before they go extinct? Science **339**: 413–416.

Crowther TW, Glick HB, Covey KR, Bettigole C, Maynard DS, Thomas SM, Smith JR, Hintler G, Duguid MC, Amatulli G, Tuanmu M-N, Jetz W, Salas C, Stam C, Piotto D, Tavani R, Green S, Bruce G, Williams SJ, Wiser SK, Huber MO, Hengeveld GM, Nabuurs G-J, Tikhonova E, Borchardt P, Li C-F, Powrie LW, Fischer M, Hemp A, Homeier J, Cho P, Vibrans AC, Umunay PM, Piao SL, Rowe CW, Ashton MS, Crane PR, Bradford MA. 2015. Mapping tree density at a global scale. Nature **525**: 201–205.

Darwin CR. 1859. The Origin of Species by Means of Natural Selection, or the Preservation of Favoured Races in the Struggle for Life,. London: John Murray.

DeFries R, Hansen A, Turner B, Reid R, Liu J. 2007. Land use change around protected areas: management to balance human needs and ecological function. Ecological Applications **17**: 1031–1038.

Desa U. 2010. World urbanization prospects: the 2009 revision. Population Division of the Department of Economic and Social Affairs of the United Nations Secretariat, New York.

Dudley N, Stolton S. 1996. Air pollution and biodiversity: a review. Switzerland: WWF International.

Elmqvist T, Fragkias M, Goodness J, Güneralp B, Marcotullio PJ, McDonald RI, Parnell S, Schewenius M, Sendstad M, Seto KC, Wilkinson C. 2013. Urbanization, Biodiversity and Ecosystem Services: Challenges and Opportunities. Dordrecht: Springer Netherlands.

Fisher RA, Corbet AS, Williams CB. 1943. The relation between the number of species and the number of individuals in a random sample of an animal population. The Journal of Animal Ecology: 42–58.

Foley JA. 2005. Global Consequences of Land Use. Science **309**: 570–574.

Forman RT. 2008. The urban region: natural systems in our place, our nourishment, our home range, our future. Landscape Ecology **23**: 251–253.

Gaston K. 2000. Global patterns in biodiversity. Nature. **405**: 220–227.

Geist HJ, Lambin EF. 2001. What drives tropical deforestation. Land-Use and Land-Cover Change (LUCC) Report series.**4**: 116.

Gibbs HK, Ruesch AS, Achard F, Clayton MK, Holmgren P, Ramankutty N, Foley JA. 2010. Tropical forests were the primary sources of new agricultural land in the 1980s and 1990s. Proceedings of the National Academy of Sciences **107**: 16732–16737.

Godefroid S, Koedam N. 2007. Urban plant species patterns are highly driven by density and function of built-up areas. Landscape Ecology **22.8**: 1227-1239.

Gomez-Pompa A, Kaus A. 1992. Taming the wilderness myth. BioScience **42**: 271–279.

Grimm NB, Faeth SH, Golubiewski NE, Redman CL, Wu J, Bai X, Briggs JM. 2008. Global change and the ecology of cities. Science **319**: 756–760.

Grimm NB, Grove JG, Pickett ST, Redman CL. 2000. Integrated Approaches to Long-Term Studies of Urban Ecological Systems Urban ecological systems present multiple challenges to ecologists—pervasive human impact and extreme heterogeneity of cities, and the need to integrate social and ecological approaches, concepts, and theory. BioScience **50**: 571–584.

Haila Y, Kouki J. 1994. The phenomenon of biodiversity in conservation biology. Annales Zoologici Fennici. **31**:5–18.

Hamrick JL, Godt M. 1996. Effects of life history traits on genetic diversity in plant species. Philosophical Transactions of the Royal Society of London B: Biological Sciences **351**: 1291–1298.

Hansen MC, Stehman SV, Potapov PV. 2010. Quantification of global gross forest cover loss. Proceedings of the National Academy of Sciences **107**: 8650–8655.

Hedrick PW, Miller PS. 1992. Conservation genetics: techniques and fundamentals. Ecological Applications **2**: 30–46.

Helmer E, Ramos O, López T del M, Quinones M, Diaz W. 2002. Mapping the forest type and land cover of Puerto Rico, a component of the Caribbean biodiversity hotspot.

Hill MO. 1973. Diversity and Evenness: A Unifying Notation and Its Consequences. Ecology **54**: 427.

Hilton-Taylor C. 2000. 2000 IUCN red list of threatened species. IUCN.

Hooper DU, Adair EC, Cardinale BJ, Byrnes JEK, Hungate BA, Matulich KL, Gonzalez A, Duffy JE, Gamfeldt L, Connor MI. 2012. A global synthesis reveals biodiversity loss as a major driver of ecosystem change. Nature **486**: 105–108.

Hossain S. 2013. Migration, urbanization and poverty in Dhaka, Bangladesh. Journal of the Asiatic Society of Bangladesh (Hum.) **58**: 369–382.

Hurlbert SH. 1971. The Nonconcept of Species Diversity: A Critique and Alternative Parameters. Ecology **52**: 577.

Irfanullah HM. 2011. Conserving threatened plants of Bangladesh: Miles to go before we start? Bangladesh Journal of Plant Taxonomy **18**: 81–91.

IUCN. 2006. Bangladesh National Capacity Self-Assessment for Global Environmental Management. Dhaka, Bangladesh.

Jordan D. 1993. Urbanization in Bangladesh and Dhaka. Working Paper, Dhaka Metropolitan Development Plan. Ministry of planning. Dhaka, Bangladesh.

Keenan RJ, Reams GA, Achard F, de Freitas JV, Grainger A, Lindquist E. 2015. Dynamics of global forest area: results from the FAO global forest resources assessment 2015. Forest Ecology and Management **352**: 9–20.

Kent M, Stevens RA, Zhang L. 1999. Urban plant ecology patterns and processes: a case study of the flora of the City of Plymouth, Devon, UK. Journal of Biogeography **26.6**: 1281-1298.

Kerr J. 2001. Global biodiversity patterns: from description to understanding. Trends in Ecology & Evolution **16**: 424–425.

Khan MS, Rahaman MM, Ali MA. 2001. Red data book of vascular plants of Bangladesh. Dhaka, Bangladesh: Bangladesh National Herbarium.

Kurz WA. 2010. An ecosystem context for global gross forest cover loss estimates. Proceedings of the National Academy of Sciences **107**: 9025–9026.

Lammi A, Siikamäki P, Mustajärvi K. 1999. Genetic diversity, population size, and fitness in central and peripheral populations of a rare plant *Lychnis viscaria*. Conservation Biology **13**: 1069–1078.

Laskar SI. 1983. Urbanization in Bangladesh, 1901-1981. Bangladesh Institute of Development Studies. Dhaka, Bangladesh.

Laskar SI. 1996. Urbanization in Bangladesh: some contemporary observations. The Bangladesh Development Studies **24**: 207–216.

Levins R. 1969. Some demographic and genetic consequences of environmental heterogeneity for biological control. Bulletin of the Entomological Society of America **15**: 237–240.

Lu F, Li Z. 2003. A model of ecosystem health and its application. Ecological Modelling **170**: 55–59.

Mace G, Ricketts T, Abell R. 2005. Ecosystems and Human Well-Being: Volume 1: Current State and Trends: Biodiversity. PLoS Biology. **4**:1300-1337.

Mack RN, Lonsdale WM. 2001. Humans as Global Plant Dispersers: Getting More Than We Bargained For Current introductions of species for aesthetic purposes present the largest single challenge for predicting which plant immigrants will become future pests. BioScience **51**: 95–102.

McDonald RI, Kareiva P, Forman RT. 2008. The implications of current and future urbanization for global protected areas and biodiversity conservation. Biological conservation **141**: 1695–1703.

McKinney M, Lockwood J, Sax D, Stachowicz J, Gaines S. 2005. Community composition and homogenization–evenness and abundance of native and exotic plant species. Species invasions–insight into ecology, evolution and biogeography: 365–380.

McKinney ML. 2002. Urbanization, Biodiversity, and Conservation The impacts of urbanization on native species are poorly studied, but educating a highly urbanized human population about these impacts can greatly improve species conservation in all ecosystems. BioScience **52**: 883–890.

McKinney ML. 2006. Urbanization as a major cause of biotic homogenization. Biological Conservation **127**: 247–260.

Mellinium Ecosystem Assessment (MEA). 2005. Ecosystems and human well-being: desertification synthesis. World Resources Institute. Washington DC, USA.

Melnychuk M. 2013. BIODIVERSITY AND CLIMATE CHANGE. International Scientific Electronic Journal Earth Bioresources and Life Quality Founded by National University of Life and Environmental

Sciences of Ukraine (NUBiP of Ukraine) and Global Consortium of Higher Education and Research for Agriculture (GCHERA).

Midgley GF, Hannah L, Millar D, Rutherford MC, Powrie LW. 2002. Assessing the vulnerability of species richness to anthropogenic climate change in a biodiversity hotspot. Global Ecology and Biogeography **11**: 445–451.

Millat-e-Mustafa M. 2002. A review of forest policy trends in Bangladesh. Policy trend report **2002**: 114–121.

Miller JR. 2005. Biodiversity conservation and the extinction of experience. Trends in Ecology & Evolution **20**: 430–434.

Misra RP. 1978. Million cities of India. Vikas Publication House. New Delhi, India.

Mittermeier RA, Myers N, Mittermeier CG, Robles Gil P. 1999. Hotspots: Earth's biologically richest and most endangered terrestrial eco-regions. CEMEX, S.A., Agrupación Sierra Madre, S.C. Mexico City, Mexico.

Mittermeier RA, Turner WR, Larsen FW, Brooks TM, Gascon C. 2011. Global Biodiversity Conservation: The Critical Role of Hotspots. In: Zachos FE, Habel JC, eds. Biodiversity Hotspots. Springer. Berlin Heidelberg, pp3–22.

Molles MC, Cahill JF. 1999. *Ecology: concepts and applications*. WCB/McGraw-Hill Dubuque, IA.

Montoya D, Zavala MA, Rodríguez MA, Purves DW. 2008. Animal versus wind dispersal and the robustness of tree species to deforestation. Science **320**: 1502–1504.

Morales-Hidalgo D, Oswalt SN, Somanathan E. 2015. Status and trends in global primary forest, protected areas, and areas designated for conservation of biodiversity from the Global Forest Resources Assessment 2015. Forest Ecology and Management 352: 68–77.

Mukul SA, Uddin MB, Uddin MS, Khan MASA, Marzan B. 2008. Protected areas of Bangladesh: current status and efficacy for biodiversity conservation. Proceedings of the Pakistan Academy of Sciences **45**: 61–68.

Mukul SA. 2007. Biodiversity Conservation and Sustainable Development in Bangladesh. An overview of the present status, management problems and future prospects. Department of Forestry and Environmental Science. Sylhet, Bangladesh.

Nakagiri N, Sakisaka Y, Togashi T, Morita S, Tainaka K. 2010. Effects of habitat destruction in model ecosystems: Parity law depending on species richness. Ecological Informatics **5**: 241–247.

Nash R. 1973. Wilderness and the American. Mind. New Haven, CT.

O'Rourke E. 2006. Biodiversity and land use change on the Causse Méjan, France. Biodiversity and Conservation **15**: 2611–2626.

Olden JD. 2006. Biotic homogenization: a new research agenda for conservation biogeography. Journal of Biogeography **33**: 2027–2039.

Pauchard A, Aguayo M, Peña E, Urrutia R. 2006. Multiple effects of urbanization on the biodiversity of developing countries: the case of a fast-growing metropolitan area (Concepción, Chile). Biological conservation **127**: 272–281.

Pearce DW, Moran D. 1994. The economic value of biodiversity. London: Earthscan.

Pereira HM, Leadley PW, Proença V, Alkemade R, Scharlemann JP, Fernandez-Manjarrés JF, Araújo MB, Balvanera P, Biggs R, Cheung WW. 2010. Scenarios for global biodiversity in the 21st century. Science **330**: 1496–1501.

Pielou EC. 1969. An introduction to mathematical ecology. An introduction to mathematical ecology. ohn Wiley & Sons. **13**: 219–220.

Pimm SL, Jenkins CN, Abell R, Brooks TM, Gittleman JL, Joppa LN, Raven PH, Roberts CM, Sexton JO. 2014. The biodiversity of species and their rates of extinction, distribution, and protection. Science **344**: 1246752.

Pretty J, Smith D. 2004. Social capital in biodiversity conservation and management. Conservation biology **18**: 631–638.

Pretty JN. 2002. Agriculture: Reconnecting people, land, and nature. Earthscan Publication Ltd. London, UK.

Purvis, A, Hector A. 2000. Getting the measure of biodiversity. Nature **405**: 212–219.

Rabbee T, Rafizul IM. 2012. Strength and Compressibility Characteristics of Reconstituted Organic Soil at Khulna Region of Bangladesh. International Journal of Engineering and Technology **2**: 1672–1681.

Rahaman MM. 2003. Forest resources of Bangladeshwith reference to conservation of biodiversity and wildlife in particular for poverty alleviation. Seoul, Korea: RAP Publicatiion, 139–147.

Rasel HM, Hasan MR, Ahmed B, Miah MSU. 2013. Investigation of soil and water salinity, its effect on crop production and adaptation strategy. International Journal of Water Resources and Environmental Engineering **5**: 475–481.

Reaka-Kudla ML, Wilson DE, Wilson EO. 1996. Biodiversity II: understanding and protecting our biological resources. Joseph Henry Press. United States.

Reed DH, Frankham R. 2003. Correlation between fitness and genetic diversity. Conservation biology **17**: 230–237.

Roghair CN, Dolloff CA. 2013. Application of Diversity Indices and an Index of Biotic Integrity to a Basin Area Stream Survey (BASS) Fish Dataset Collected on the Ouachita National Forest. United States Department of Agriculture Forest Service. Blacksburg.

Rosenzweig ML. 1995. Species diversity in space and time. Cambridge University Press. Cambridge, United Kingdom.

Roskov Y, Abucay L, Orrell T, Nicolson D, Flann C, Bailly N, Kirk P, Bourgoin T, DeWalt RE, Decock W, De Wever A eds. 2016. Species 2000 & ITIS Catalogue of Life, 29th January 2016. *Digital resource at www.catalogueoflife.org/col. Species 2000: Naturalis*, Leiden, the Netherlands. ISSN 2405-8858.

Roskov Y, Kunze T, Paglinawan L, Orrell T, Nicolson D, Culham A, Bailly N, Kirk P, Bourgoin T, Baillargeon G. 2013. Species 2000 & ITIS Catalogue of Life. 2013 Annual Checklist [http://catalogueoflife. org/annual-checklist/2013/].

Rouf MA, Jahan S. 2007. Spatial and temporal patterns of urbanization in Bangladesh. Urbanization in Bangladesh: patterns, issues and approaches to planning. Bangladesh Institute of Planners, Dhaka: 1–24.

Sachs JD, Baillie JE, Sutherland WJ, Armsworth PR, Ash N, Beddington J, Blackburn TM, Collen B, Gardiner B, Gaston KJ. 2009. Biodiversity conservation and the millennium development goals. Science **325**: 1502–1503.

Sala OE, Chapin FS, Armesto JJ, Berlow E, Bloomfield J, Dirzo R, Huber-Sanwald E, Huenneke LF, Jackson RB, Kinzig A. 2000. Global biodiversity scenarios for the year 2100. science **287**: 1770–1774.

Salafsky N, Wollenberg E. 2000. Linking livelihoods and conservation: a conceptual framework and scale for assessing the integration of human needs and biodiversity. World development **28**: 1421–1438.

Seabloom EW, Dobson AP, Stoms DM. 2002. Extinction rates under nonrandom patterns of habitat loss. Proceedings of the National Academy of Sciences **99**: 11229–11234.

Seto KC, Güneralp B, Hutyra LR. 2012. Global forecasts of urban expansion to 2030 and direct impacts on biodiversity and carbon pools. Proceedings of the National Academy of Sciences **109**: 16083–16088.

Seto KC, Shepherd JM. 2009. Global urban land-use trends and climate impacts. Current Opinion in Environmental Sustainability **1**: 89–95.

Sheldon AL. 1969. Equitability indices: dependence on the species count. Ecology **50**: 466–467.

Sobuj N-A, Rahman M. 2011. Comparison of Plant Diversity of Natural Forest and Plantations of Rema-Kalenga Wildlife Sanctuary of Bangladesh. Journal of Forest and Environmental Science **27**: 127–134.

Spellerberg IF, Fedor PJ. 2003. A tribute to Claude Shannon (1916–2001) and a plea for more rigorous use of species richness, species diversity and the "Shannon–Wiener"Index. Global ecology and biogeography **12**: 177–179.

Szwabiński J, Pe,kalski A. 2006. Effects of random habitat destruction in a predator–prey model. Physica A: Statistical Mechanics and its Applications **360**: 59–70.

Tarr JA. 1996. The search for the ultimate sink: urban pollution in historical perspective. University of Akron Press.

Tilman D, Downing JA. 1996. Biodiversity and stability in grasslands. Ecosystem Management. Springer, 3–7.

Tilman D. 2000. Causes, consequences and ethics of biodiversity. Nature **405**: 208–211.

Uddin HMB. 2011. Exotic species invasion and biodiversity in Bangladesh forest ecosystems. Vorgelegt der Fakultät für Biologie. Bayreuth.

United Nations. 2006. World urbanization prospects: the 2005 revision. Department of Economic and Social Affairs. Population Division of the United Nations Secretariat, New York.

Urban MC. 2015. Accelerating extinction risk from climate change. Science **348**: 571–573.

Uz Zaman H, AKM K, Alam T, Islam JI. 2010. Urbanization in Bangladesh: Present status and policy implications. ASA University Review **4**.

Vimal R, Geniaux G, Pluvinet P, Napoleone C, Lepart J. 2012. Detecting threatened biodiversity by urbanization at regional and local scales using an urban sprawl simulation approach: Application on the French Mediterranean region. Landscape and Urban Planning **104**: 343–355.

Wade TG, Riitters KH, Wickham JD, Jones KB. 2003. Distribution and causes of global forest fragmentation.

Walker BH. 1992. Biodiversity and ecological redundancy. Conservation biology **6.1**: 18-23.

Wang G, Jiang G, Zhou Y, Liu Q, Ji Y, Wang S, Chen S, Liu H. 2007. Biodiversity conservation in a fast-growing metropolitan area in China: a case study of plant diversity in Beijing. Biodiversity and Conservation **16**: 4025–4038.

Whitmore TC, Sayer J, International Union for Conservation of Nature and Natural Resources, International Union for Conservation of Nature and Natural Resources, IUCN Forest Conservation Programme (Eds.). **1992.** Tropical deforestation and species extinction. London ; New York: Chapman & Hall.

Whittaker RH. 1972. Evolution and measurement of species diversity. Taxon: 213–251.

Wilkins DA. 1999. Assessing ecosystem health. Trends in ecology & evolution **14**: 69.

Wilson EO. 1989. Threats to biodiversity. Scientific American **261**: 108–116.

Yokozawa M, Kubota Y, Hara T. 1999. Effects of competition mode on the spatial pattern dynamics of wave regeneration in subalpine tree stands. Ecological Modelling **118**: 73–86.

Young RN. **1999**. Importance of biodiversity to the modern pharmaceutical industry. Pure and Applied Chemistry **71**: 1655–1661.

Zhao S, Da L, Tang Z, Fang H, Song K, Fang J. **2006**. Ecological consequences of rapid urban expansion: Shanghai, China. Frontiers in Ecology and the Environment **4**: 341–346.