SCIENCE VISION

BI-ANNUAL

ISSN 1027-961X

Vol. 18 No. 1&2 (January to December 2012)

A Journal of Science for Development

Commission on Science and Technology for Sustainable Development in the South

COMSATS Secretariat: 4th Floor, Shahrah-e-Jamhuriat,
Sector G-5/2, Islamabad, Pakistan.
Tel : (+92-51) 921 4515-7 Fax : (+92-51) 921 6539
Email: info@sciencevision.org.pk, Website: www.sciencevision.org.pk

SCIENCE VISION

An International Bi-annual Journal of the Commission on Science and Technology for Sustainable Development in the South (COMSATS)

EDITORIAL BOARD

EDITORIAL ADVISORY COMMITTEE

SCIENCE VISION is published by COMSATS as a bi-annual journal that contains articles relevant to the impact of science and technology on the socio-economic uplift of developing countries.

Manuscripts may be sent to the Managing Editor at the following address:

COMSATS Secretariat, 4th Floor, Shahrah-e-Jamhuriat, Sector G-5/2, Islamabad - 44000, Pakistan.
Tel: (+92-51) 9204892, 9214515-7, Fax: (+92-51) 9216539, Email: comsats@comsats.org, info@sciencevision.org.pk
Websites: www.sciencevision.org.pk; www.comsats.org

Subscription	Pakistan	Other Countries
Annual	= Rs. 1,000.00	US$ 50.00
Single Copy	= Rs. 500.00	US$ 25.00

Published by Mr. Tajammul Hussain, Advisor (Programmes)
COMSATS Secretariat, Islamabad, Pakistan

SCIENCE VISION

ISSN 1027-961X

Vol. 18, No. 1&2
(January to December 2012)

A Journal of Science for Development

December 2013

Commission on Science and Technology for
Sustainable Development in the South

EDITORIAL

The publication team of 'Science Vision' has been making strenuous efforts to implement two major decisions taken by COMSATS' Coordinating Council in its 12th meeting held in Nigeria in 2009. One of these was related to resuming publication of the journal after a gap of several years. This effort is still on-going because of the necessity of providing content for the missing issues, which is time consuming. The publication schedule is gradually catching up with the calendar year and hopefully it would be fully in step with effect from 2014.

The second decision was concerned with the types of articles that would be accepted for publication in 'Science Vision'. That decision represented a major policy revision, whereby the focus of the journal was shifted from purely technical research papers to those that elaborate social and economic impact of the scientific and technological developments. We now invite authors to elaborate the significance of their overall research activity, rather than reporting the technical results of a specific research project. By necessity, this category of articles does involve technical details and review of the relevant field, but the author is expected to relate it to requirements of the society in general. Owing to the nature of such papers, the authorship is considerably narrowed to senior researchers. This aspect also has a bearing on getting sufficient number of contributions for new issues of the journal. However, considering that there are over 10,000 scientific staff members in 18 Centres of Excellence of COMSATS, the new scope and reduced frequency of the journal should be sustainable, provided there is strong interest and support of the Heads of Centres of Excellence, who are all ex-officio members of the Editorial Advisory Committee.

The present volume of the journal is a thematic issue in the sense that it comprises of research articles presented in the 4th International Conference on Environmentally Sustainable Development (ESDev), organized by COMSATS Institute of Information Technology (CIIT). The Conference is aimed at exploring linkages among environment and sustainable development; finding technological solutions for the environmental problems; renewable energy resources and management of natural resources; and promoting integration among these in support of the 'UN Decade of Education for Sustainable Development', adopted for 2005-2014.

The papers included in this edition broadly touch upon the impact of climate change on food-security, eco-systems and water resources; the importance of international cooperation on environment; making use of indigenous know-how to complement modern knowledge; and development of green systems and structures. The Organizing Committee of ESDev working under the chairmanship of Dr. Iftikhar Ahmed Raja, Professor, Department of Environmental Science, CIIT, was responsible for the highly professional job of soliciting well-written manuscripts from authors. Their efforts are appreciated with gratitude. Sincere thanks are also due to the authors for their consent to publish their papers in 'Science Vision'.

The editorial committee is conscious that this volume is again a compromise in the sense that the contents of articles are not strictly in line with the new focus of the journal. However, COMSATS is continuously making serious efforts to rejuvenate the journal and meet the requirements of its scope and frequency. One of the steps taken in this regard is to start an intensive campaign of identifying suitable authors and inviting them to write scholarly articles for the journal. Another initiative taken is to expand the membership of Editorial Board by approaching outstanding scientists and engineers in different fields of S&T, and requesting them to join the Board.

A small but very dedicated editorial team of 'Science Vision' is hard at work to enhance the quality and usefulness of this journal. What is needed most for their success is the cooperation of the members of scientific communities in COMSATS' Member States in the form of contributing high-quality relevant articles that reflect their scientific services for the benefit of society. The vision of scientists in the developing countries for the socio-economic development of the South is what the 'Science Vision' is committed to project. It is hoped that this volume will serve the purpose of elucidating multiple aspects around the specific theme of environmental issues.

Dr. I. E. Qureshi
Executive Director COMSATS
Patron & Editor-in-Chief, Science Vision

SCIENCE VISION

Patron and Editor-in-Chief: Dr. Imtinan Elahi Qureshi

Vol. 18, No. 1&2
(January to December 2012)

CONTENTS PAGE

ENERGY EFFICIENCY AND ENVIRONMENTAL CONSIDERATIONS FOR GREEN DATA CENTERS

Mueen Uddin and Asadullah Shah***

ABSTRACT

The advancement of business and social practices based on information and communication technologies (ICTs) in the last few decades has transformed many, if not most, economies into e-economies and businesses into e-businesses. For economies, ICTs are increasingly playing a critical role in transforming and generating economic opportunities. Technology has a potential to create sustainable business and society both in grim and green economic times. Especially, the recovery from the current economic crisis is going to lead to more greener and energy efficient industries. Data centers are found to be major culprits in consuming too much energy and generating higher level of CO_2 in their overall operations. In order to handle the sheer magnitude of today s data, servers have become larger, denser, hotter, and significantly more costly to operate using more power than being used earlier. This paper determines the properties and attributes of green IT infrastructures and the way they will be helpful in achieving green sustainable businesses. The proposed attributes and characteristics of green IT using Virtualization technology are very productive and efficient for data centers in making them more energy efficient and green, hence reducing the emission of greenhouse gases so that their overall effect on global warming can be reduced or even eliminated. The proposed attributes indicate the qualities of green IT to enhance the proper utilization of hardware and software resources available in the data center.

Keywords: *Energy Efficiency, Green IT Attributes, Green IT, Environmental Sustainability*

1. INTRODUCTION

Seldom does a day pass in which we do not hear or read about sustainability or going green. Environmental concerns are constantly in news headlines, and the impact of technology on our environment is significant. Large technology organizations such as, Dell, HP, IBM, Sun, Hitachi, and Fujitsu have introduced green and sustainable initiatives. Green is generally understood to mean Friendly to the environment and energy efficient. Sustainable implies planning and investing in a technology infrastructure that serves the needs of today as well as the needs of tomorrow while conserving resources and saving money. Organizations are quite concerned with environmental issues, but they have also come to realize that sustainable business practices can significantly enhance the bottom line.

Data centers have become an increasingly important part of most business operations in the twenty-first century. With escalating demands and rising energy prices, it is essential for the owners and operators of these critical facilities to assess and improve their performance. In contexts ranging from large-scale data centers to mobile devices, energy use is an important concern. In data centers, power consumption in the U.S has doubled between 2000 and 2006, and will double again in the next five years [1]. Server power consumption not only directly affects a data center s energy costs, but also necessitates the purchase and operation of cooling equipment, which can consume one-half to one Watt for every Watt of power consumed by the computing equipment [2]. As new servers are being added continuously into data centers without considering the proper utilization of already installed servers, it will cause an unwanted and unavoidable increase in the energy consumption, as well as increase in physical infrastructure, like over-sizing of heating and cooling equipments. This increased consumption of energy causes an increase in the production of greenhouse gases that are hazardous for the environment. Hence it not only consumes space and energy, but also costs environmental stewardship [3]. The continued growth of data center power consumption impacts everything from business enterprises, and power supply companies to the environment. With more efficient energy use in data centers, power supply companies will face less demand and the possibility of excess power, which could help limit blackouts, reduce carbon dioxide emission and cut other greenhouse gases. In addition, energy use has implications for reliability, density, and scalability. As data centers house more servers and consume more energy, removing heat from the data centers becomes increasingly difficult [4]. Since the reliability of servers and disks decreases at high temperatures, the power consumption of servers and other components limits the achievable density of data centers, which in turn limits their scalability. Furthermore, energy use in data centers is starting to prompt environmental concerns of pollution and excessive load placed on local utilities [5]. These concerns are sufficiently severe for the large companies that are starting to build data centers near electric plants in cold weather environments [6]. For

* Universiti Teknologi Malaysia (UTM), Malaysia. Email: mueenmalik9616@gmail.com
** Kulliyyah of Information Communication Technology, International Islamic University Malaysia

the business enterprise, an increase in data center efficiency can save significant energy costs. However, even with the global presence of many companies, these metrics are often not applied consistently at a global level. All of these factors are increasing the public s awareness and global concerns of these current power consumption trends.

The world is in the biggest data centre construction boom in history. The U.S. is spending $16 billion a year building additional data centers, with another $6 billion on refurbishing existing ones. Experts say that $3 billion a year should be spent to build new electrical power plants to meet the supply needs of these data centers except it is not being spent thus [7]. The Smart 2020 report published by the Climate Group and GeSI revealed that in 2002, the global data centre footprint, including equipment use and embodied carbon, was 76 million metric tons of carbon dioxide ($MtCO_2e$) and this is expected to increase more than three times by 2020 to 259 $MtCO_2e$, making it the fastest-growing contributor to the ICT sector s carbon footprint, at 7 per cent per annum in relative terms. If growth continues in line with the demand, the world will be using 122 million servers in 2020, up from 18 million today [8]. With energy prices increasing worldwide, the operational costs of data centers continues to increase steadily. Besides the cost, availability of electrical power is becoming a critical issue for many companies whose data centers have expanded steadily.

Enterprises, governments, and societies at large have a new important agenda: tackling environmental issues and adopting environmentally sound practices. Over the years, the use of IT has exploded in several areas, improving our lives and work, and is offering convenience along with several other benefits. We are passionate about advances in and widespread adoption of IT. However, IT has been contributing to environmental problems, which most people do not realize. Computers and other IT infrastructure consume significant amounts of electricity, placing a heavy burden on electric grids and contributing to greenhouse gas emissions. Additionally, IT hardware poses severe environmental problems both during its production and its disposal. IT is a significant and growing part of the environmental problems of today s world. There is a need to minimize or eliminate, where possible, the environmental impacts of IT to help create a more sustainable environment. To reduce environmental problems related to IT and to create a sustainable environment, the IT sector and individual computer users should green their IT systems, as well as the way they use these systems [9].

Legally, ethically, and socially speaking, it is required to green our IT products, applications, services, and practices. Green IT benefits the environment by improving energy efficiency, lowering greenhouse gas emissions, using less harmful materials, and encouraging reuse and recycling. Factors such as environmental legislation, the rising cost of waste disposal, corporate images, and public perception give further impetus to the green IT initiatives. Green IT is a hot topic today and will continue to be an important issue for several years to come. To foster green IT, one should understand: What are the key environmental impacts arising from IT? What are the major environmental IT issues that need to be addressed? How can we make our IT infrastructure, products, services, operations, applications, and practices environmentally sound? What are the regulations or standards with which we need to comply? How can IT assist businesses and society at large in their efforts to improve environmental sustainability? This paper highlights some of these issues, and then presents a holistic approach to greening IT in e-businesses, especially data center industry. A green IT strategy for data centers is proposed and specific ways to minimize IT s environmental impact have been outlined.

2. ENVIRONMENTAL IMPACT OF INFORMATION TECHNOLOGY

For over 25 years, researchers have been cognizant of the potential for the rise in trade to negatively impact the environment. There is a global change in the world s climate due to intensifying emissions of greenhouse gases and other fuel combustions, causing potentially disastrous consequences, and as these problems become global, a new spotlight appears on IT. IT is turning out to be both a solution and problem for environmental sustainability. Unfortunately, it is contributing enormously towards environmental problems causing gigantic problem of global warming. Its immense use has exploded in almost all areas of business activities offering great benefits and convenience and at the same time transforming businesses and societies into a global village [10]. IT affects our environment in several different ways. Each stage of a computer s life from production, use to disposal presents environmental challenges. Manufacturing computers and their various electronic and non-electronic components consume electricity, raw materials, chemicals, water, and generate hazardous waste. The increased

number of computers in use and their frequent replacement make the environmental impact of IT a major concern. This increase in energy consumption results in increased emission of greenhouse gases as most of the electricity is generated by burning coal, oil, or gas. All these factors contribute towards environmental problems. As businesses balance their growth and production with environmental risks, they are baptized to innovate and implement greener solutions to make IT systems and work practices energy efficient and environment friendly [11].

Data center operational managers need to implement green IT techniques and policies to reduce greenhouse gas emissions by improving energy efficiency, thereby reducing the rate of energy consumption by improving the utilization of already installed equipments [12]. Other policies, like the use of lower emission, clean fuels, such as wind, solar, biomass, or hydroelectric, would reduce total emissions by reducing emission intensity, while maintaining the rate of energy consumption [13]. Today global warming is a much-debated issue amongst the scientific society. The consensus among most of the scientific community is that the problem of global warming is largely due to an increase in greenhouse gases in the atmosphere as a result of human activities [14]. Energy savings play a key role in reducing the overall cost of ownership of data center, and is being discussed everywhere for doing businesses with due consideration towards sustainable development WITH ITS economic, social and environmental dimensions. One of the ways, organizations can reduce their carbon footprints and lessen their harmful environmental impact is through adopting environmental friendly Information Technology (IT) practices, frequently referred to as green IT [15].

These practices mitigate environmental risks associated with the emergence of a green economy. Organizations that mitigate these risks more effectively than their competitors would be able to gain a competitive advantage. Global warming is a matter of high concern for all inhabitants living on this planet. Individuals, organizations and governments are doing their best to control the warming and make this tiny planet a livable place. Information Technology and telecom/data networks can play an equally important role along side other direct means for solving this menace. Many technologies are in place and others are to be developed or fine tuned to make them ready for use in reducing the emission of greenhouse gases into atmosphere [16]. It has taken more than 30 years for data center industry to evolve to a point of modularity that is conducive to alignment of efficiencies in use and design across disparate infrastructures. The green movement has been around for many years to evolve to a point where the economics of sustainable practices are well understood. Traditionally, environmentalism has been perceived to be at odds with economic prosperity. Environmental stewardship encompasses the notion of balancing current resource consumption with the resource requirements of future generations. The landmark Brundtland report defines sustainable development as meeting the needs of the present without compromising the ability of future generations to meet their own needs [17].

The use of green IT extends to many areas and activities, including power management; data center design, layout, and location; the use of biodegradable materials; regulatory compliance; green metrics and green labeling; carbon footprint assessment tools and methodologies; and environment related risk mitigation. A growing number of IT vendors and users have begun to turn their attention towards green IT triggered by the imminent introduction of more green taxes and regulations; there will be a major increase in demand for green IT products and solutions. Green IT is becoming a hot topic these days and for years to come, as it becomes imperative to develop environmentally sustainable IT, from both economic and environmental viewpoints [18].

3. CHALLENGES FACED BY DATA CENTERS

There is no single factor that can be blamed for IT inefficiency. Worse, inefficiency seems to grow incrementally over time as environment becomes older and more complex. Each new application being added seems to require another server, which requires administrative time to keep running, while it also consumes power, space, and expensive network ports in data centers. The data center industry has a number of related problems such as:

3.1 Inconsistent Measuring Metrics and Benchmarking

It is highly important for data center managers to measure the performance of their data centers regularly so that efficiency measures should be taken to make data centers energy efficient and green. But unfortunately there is no industry standard metric available acceptable worldwide to measure the performance in terms of energy efficiency and CO_2 emissions. Data center managers are currently

equally split between using external benchmarks, home grown tools, financial analysis, and commercial asset/financial management tools, with no clear leader and metric. It is evident from different discussions that measuring IT performance is difficult.

3.2 Large Number of Underutilized Servers

Servers are the major components responsible for performing most of the processing being performed in data centers. There number is continuously increasing as the demands from businesses grow. Due to their increased number, they are the leading consumer of IT power in any data center. Data centers are plagued with thousands of servers mostly underutilized having utilization ratio of only 5 to 10% consuming huge amount of energy and generating a lot of greenhouse gases [3].

3.3 Power Efficiency of IT Equipment

Data center comprises many types of equipment like servers, UPS, PDU s, Chillers, Cracks, etc. All of these components consume enormous amount of power to provide services to end users. Most of the data managers think that IT equipments are significant source of electrical waste. Proper efficiency measures can reduce these consumptions and help data center managers implement environment friendly and green data centers.

3.4 Establishing Performance Requirements and Maximizing IT Operations

Effective application service delivery requires a continuous understanding of end-to-end application performance requirements. In a data center environment, with rapidly changing dynamic workload and resource allocation, continuous measurement to establish performance requirements is especially vital. This understanding should start when the applications are still in development, so that IT can avoid any surprise performance problems during and immediately after production deployment. As application usage changes, continuous measurement is required to adapt workload and resource allocation and maintain desired service levels. When application changes are made, or new features are added, performance requirements will need to be re-established to again avoid potential disruption.

3.5 Environmental Issues and Problems

The growing accumulation of greenhouse gases is changing the world s climate and weather patterns, creating droughts in some countries and floods in others. It is slowly pushing global temperatures higher, posing serious environmental problems to the world. For instance, 2005 was the warmest year on record, and the 10 warmest years have all occurred since 1980. Global data shows that storms, droughts, and other weather-related disasters are growing more severe and frequent. To stop the accumulation of greenhouse gases in the atmosphere, the growth of global emissions should be watched. Electricity is a major cause of climate change, because the coal or oil that helps generate electricity also releases carbon dioxide, pollutants, and sulphur into the atmosphere. These emissions can cause respiratory diseases, smog, acid rain, and global climate change. Reducing electric power consumption is the key to reducing carbon dioxide emissions and their impact on environment and global warming. With this in mind, IT professionals, members of the IT industry, and IT users should focus on individually and collectively creating a sustainable environment. In the following sections, environmental impact and proposed green IT measures are given.

4. PROPOSED WORK AND ENERGY EFFICIENCY ATTRIBUTES FOR GREENING DATA CENTERS

The continued rise of Internet and Web applications is driving the rapid growth of data centers. Enterprises are installing more servers or expanding their capacity. The number of server computers in data centers has increased six fold to 30 million in the last decade, and each server draws far more electricity than earlier models. Aggregate electricity use for servers doubled between 2000 and 2005, most of which came from businesses installing large numbers of new servers. [19]. One problem with the greening of IT is that it forces organizations to buy more. Plans usually call for things like more energy efficient servers, intelligent sensors for data center cooling, server virtualization software, low power monitors and devices that turn off dormant computers [20]. The social, financial, and practical constraints involved will force businesses and IT departments to reduce energy consumption by data centers. Efficiency of the data centers can be improved by using new energy-efficient equipment, improving airflow management to reduce cooling requirements, investing in energy management software, and adopting environmental-friendly designs for data centers and new measures to curb data centers energy consumption.

The proposed energy efficient green IT attributes help to achieve energy consumptions, underutilization, emission of greenhouse gases, environmental concerns, global warming issues and intensive administrative labor that contribute towards data center inefficiency. The proposed attributes highlight top IT improvements in data center spanned across data center energy efficiency, infrastructure consolidation, reduced administrative labor, better IT process, improved service time, and reduced greenhouse gases, to reduce the effects of global warming on environment. These benefits may vary significantly across businesses of different types. In particular, companies with less than $1 billion in revenue said that they benefited more from physical consolidation of IT assets, whereas companies with $5 billion or more in revenue benefited the most from improving the energy efficiency of their data centers. These attributes are:

- Baseline Environment;
- Virtualize Servers;
- Consolidate IT;
- Improve Data Center Efficiency;
- Update IT Processes.

4.1 Baseline Values

The first step in greening of the data centers is to baseline all the requirements to get the maximum value out of data center greening programme. Now more than ever, energy efficiency seems to be on everyone s minds. Faced with concerns such as global warming and skyrocketing energy costs, more and more companies are considering if and how to increase efficiency. E-businesses that rely on data centers must make hard decisions to accommodate growing demands without creating a negative impact on their finances or the environment. The data center baseline study report must be based on in-depth interviews with engineers and data center managers. These professionals represent a cross-section of companies in terms of industry type, size, number of servers being used, storage capacity, age, geography, etc.

The baseline study provides measures to boost efficiency, as well as the incentives for making changes to make data center energy efficient. The growth in IT demand is among the most common obstacles in becoming more energy efficient. Data centers must contend with constant expansion in data volume, along with new and extended application requirements. The study also gets awareness about how to calculate the power load of individual IT devices. The data center baseline report also outlines helpful strategies for approaching energy efficiency in the data centers. The discussion covers virtualization, airflow management, server decommissioning, equipment upgrades, storage consolidation and optimization, and use of fresh-air cooling and renewable energy sources. The report also includes tips on how to improve energy efficiency in the data center so that other data center professionals can evaluate their options and identify the most appropriate steps for their particular organizations.

The process of creating the baseline of a data center starts by creating an inventory of all resources including servers, resources they require, available resources and their associated workloads, this process is called discovery process. The inventory process includes both utilized and idle servers. It also includes information related to [21]:

- Make and Model of the Processor;
- Types of processors (socket, Core, Threads, Cache);
- Memory size and speed;
- Network type (Number of ports, speed of each port);
- Local storage (number of disk drives, capacity, RAID);
- Operating system and their patch levels (service levels);
- Applications installed;
- Running services.

4.1.1 Inventory Process

It is very important for an organization to know in advance the total content of its infrastructure before implementing green IT techniques. This is the most important step in Green IT projects. There are many tools available from different vendors for performing initial analysis of an organization. Microsoft Baseline Security Analyzer (MBSA) tool provides different information like IP addressing, Operating System, installed applications and most importantly vulnerabilities of every scanned system. After analyzing, all generated values are linked to MS Visio, which generates a complete inventory diagram of all components and also provides details about each component being analyzed [22]. Microsoft Assessment and Planning toolkit (MAP) is another tool for the assessment of network resources. It works with Windows Management Instrumentation (WMI), remote registry service or with simple network

management protocol to identify systems on network [23]. VMware, the founder of X-86 virtualization, also offers different tools for the assessment of servers that could be transformed into virtual machines. VMware Guided Consolidation (VGC) is a powerful tool that assesses network with fewer than 100 physical servers. Since VGC is an agent-less tool, it does not add any overhead over production server s workload [24].

4.1.2 Categorize Server Resources

After creating server inventory information, the next step is to categorize the servers and their associated resources and workloads into resource pools. This process is performed to avoid any technical political, security, privacy and regulatory concern between servers, which prevent them from sharing resources. Once analysis is performed, each server role can be categorized into groups. Server roles are categorized into following service types:

- Network infrastructure servers;
- Identity Management servers;
- Terminal servers;
- File and print servers;
- Application servers;
- Dedicated web servers;
- Collaboration servers;
- Web servers;
- Database servers.

Aggregate utilization data helps initially to target particular servers and storage devices as candidates for consolidation. But it does not tell the whole story, since many servers are busy for short periods of time on a periodic basis. In that case system management tools should be used to collect trends for the entire cycle of systems with applications that run on a weekly, monthly, or quarterly basis. Some capacity or consolidation planning tools can simplify this task by superimposing historic data for multiple systems to simplify analysis. To optimize the consolidation scenarios, consider using performance modeling and consolidation planning tools to analyze different consolidation and virtualization scenarios. Different consolidation strategies can be followed to consolidate different components of data center depending on the workloads and nature of consolidation. Modern planning tools take mathematical approach to optimizing capacity while minimizing configuration conflicts between dissimilar systems or those that will compete for resources at the same time.

4.2 Virtualization Process

Virtualization promises to dramatically change how data centers operate by breaking the bond between physical servers and the resource shares granted to customers. Virtualization can be used to slice a single physical host into one or more virtual machines (VMs) that share its resources. This can be useful in a hosting environment where customers or applications do not need the full power of a single server. In such a case, virtualization provides an easy way to isolate and partition server resources. The abstraction layer between the VM and its physical host also allows for greater control over resource management. The CPU and memory allocated to a virtual machine can be dynamically adjusted and live migration techniques allow VMs to be transparently moved between physical hosts without impacting any running applications.

Server virtualization has become popular in data centers since it provides an easy mechanism to cleanly partition physical resources, allowing multiple applications to run in isolation on a single server. It categorizes volume servers into different resource pools depending on the workload they carry and then server consolidation is applied. This technique decouples software s from hardware and splits multi processor servers into more independent virtual hosts for better utilization of the hardware resources, allowing services to be distributed one per processor. In server consolidation many small physical servers are replaced by one large physical server to increase the utilization of expensive hardware resources, reducing the consumption of energy and emission of CO_2 [3]. Server virtualization complements overall IT consolidation projects by allowing firms to share capacity across multiple underutilized systems and shrink the hardware footprint of applications that cannot be completely eliminated. Data center managers focus on reducing hardware and operational costs with virtual servers, yet overlook significant improvements they should make to disaster recovery and time lapses to market for applications. By offering improved service levels for virtualized servers, internal customers migration to virtual infrastructure can be accelerated, while improving overall satisfaction with IT services.

4.2.1 Physical to Virtual Live Migration

This is the most critical, time-consuming and painful operation when performed manually, since it includes cloning the existing operating system and restoring it

on an identical machine, but at the same time changing the whole underlying hardware, which can lead to driver reinstallation or possibly the dreadful blue screen of death. To avoid these ambiguities, virtualization vendors started to offer different physical to virtual (P2V) migration utilities. This utility software speeds up the movement of operation and solves on the fly driver incompatibilities, by removing physical hardware dependencies from server operating systems and allowing them to be moved and recovered. Instead of having to perform scheduled hardware maintenance at some obscure hour over the weekend, server administrators can now live migrate a VM to another physical resource and perform physical server hardware maintenance in the middle of the business day. Virtuozzo for Windows 3.5.1 SWsoft itself introduced a physical to virtual (P2V) migration tool called VZP2V. This tool can remotely install P2V knowing machine administrative username and password.

4.2.2 Management to Increase Utilization Ratio

Server consolidation increases the utilization ratio of underutilized volume servers from 10% to 50% or even more by proper management of workloads to be virtualized to increase the productivity of data center and reduces the total cost of ownership. There is always a room for improvement, however, as many data centers leave a substantial amount of headroom on their virtual server hosts. Today, some data centers are consolidating the load of 5 to 10 virtual machines (VMs) on single server, while more experienced organizations are putting 25 to 30 VMs on a single server. Many administrators are reluctant to run servers at maximum capacity because they are concerned about the possibility of performance problems that could affect multiple applications simultaneously. In order to get to higher levels of hardware utilization, it is important to improve the administrator s visibility into the performance and availability of the virtual infrastructure with management tools designed for virtual servers. Active power management software can be used to help power your server infrastructure up and down depending on the demand for applications. This is particularly useful in virtual environments where live migration is used to consolidate VMs onto as few physical servers as necessary to maintain service levels, shutting down the rest.

4.3 Consolidate IT Resources

The best way to reduce the costs of hardware, software, labor, and facilities is to unplug unneeded infrastructures. But it is a complex task that requires a lot of legwork and detailed information on your assets to do it right. One needs to assess data center from all aspects and then categorize it into measurable units so that, consolidation can be applied and then benchmarking can be set properly to reduce the consumption of energy and emission of greenhouse gases. IT consolidation involves the consolidation of servers, storage devices, applications running, and operating systems. Virtualization increases the capability of the already installed equipments by increasing their utilization ratio and thus reduces the overall operational costs. Many data center managers tend to measure the consolidation success rate by the percentage reduction in their IT budget, while it is important to note that consolidation success rates should be measured another basis of percentage reduction in operational costs. Virtualization complements IT consolidation but cannot replace it. Even after virtualizing, one will still be paying for the maintenance of the same number of application instances, even if they use less equipment to run. As a result, companies frequently struggle to reduce operational costs on the basis of virtualization alone. Direct-attached storage is usually blamed for data centers low storage utilization. However, networked storage can also suffer because of over-provisioning and isolated storage area networks (SANs). One may already be paying for intelligent arrays with virtualization, thin provisioning, or reduplications features waiting to be turned on.

4.4 Improve Data Center Efficiency

Considering the power consumption in data centers, the main problem is the minimization of the peak power required to feed a completely utilized system. In contrast, the energy consumption is defined by the average power consumption over a period of time. Therefore, the actual energy consumption by a data center does not affect the cost of the infrastructure. On the other hand, it is reflected in the electricity cost consumed by the system during the period of operation, which is the main component of a data center's operating costs. Furthermore, in most data centers, 50% of consumed energy never reaches the computing resources; it is consumed by the cooling facilities or dissipated in conversions within the UPS and PDU systems. With the current tendency of continuously growing energy consumption and costs associated with it, the point when operating costs exceed the cost of computing resources themselves in few years can be reached soon. Therefore, it is crucial

to develop and apply energy-efficient resource management strategies in data centers. Data center power and cooling infrastructures should be upgraded so that energy efficiency can be achieved. There are many opportunities to reclaim capacity (and reduce electrical costs) in data centers by making both small and large adjustments. Improving data center efficiency is especially important for large data centers.

4.4.1 Prevent Hot and Cold Air Mixing

When hot exhaust air mixes with cold air, it increases the intake temperature of equipments installed in the data center. This means that it is necessary to set the temperatures even lower, to accept the intake temperatures. It is necessary to isolate the exhaust air with a hot aisle containment system or ceiling to reduce the load on cooling system and increase the power density of racks. Because it is relatively inexpensive compared to new infrastructure, upgrades off facilities to prevent hot/cold air mixing were one of the top choices among the data centers. Before overhauling anything, one should start small improvements like eliminating under-floor obstructions to airflow, plugging cable cut outs, and installing blanking panels in racks (to improve the amount of air delivered to racks). Older, uninterruptable power supplies and power distribution units may have older, less efficient transformers that are responsible for a sizable portion of the wasted electricity in data center. It is important for data centers to replace these older systems with newer, more efficient systems. Most data center infrastructures are network-oriented, allowing collecting usage statistics from a variety of energy management softwares.

4.5 Update IT Processes

Consolidation and virtualization helps to optimize hardware and software investments, reduce the number of systems being managed, and free up or close some underutilized volume servers. However, IT processes remain unchanged and probably are a major source of IT inefficiency. Many data centers are implementing more formalized IT processes, while others suffer from IT processes that have too many steps and depend on manual labor to get them done. Therefore it now becomes obvious for data center managers to revise their IT processes to achieve green data centers. The focus should be on those processes that are most critical to running reliable and efficient IT services; in particular, problem management and incident management issues in data center followed by financial management and configuration management issues. IT processes ensure more reliable services, but with added records and data, formalized processes do not get better efficiency because of the added overhead. The efficiency can be achieved by upgrading the system management tools that integrate with service desk software and provide more task-level automation to free up administrators time.

5. CONCLUSIONS

Green IT is constantly becoming more relevant, and many organizations are working towards reducing the carbon footprint of their data centers. This reduction in carbon footprint is achieved by reducing the data centers power consumption, which in turn results in one being savings for the organization. Many new techniques have been used to achieve this reduction in power. One of them is virtualization. It helps to consolidate multiple servers onto a few physical machines, which increases their utilization, and decreases their power consumption. This paper proposes green IT attributes as solution for implementing green data centers. The proposed attributes provides a solution based on virtualization technology to overcome the issues and challenges of data centers like energy efficiency and CO_2 emissions to reduce the effects of global warming.

REFERENCES

1. U.S. Environmental Protection Agency, 2006. ENERGY STAR Program. Report to Congress on server and data center energy efficiency. Online, Aug 2006.
2. Rivoire, S. M., 2008. Models and Metrics for Energy-Efficient Computer Systems, PhD diss., Stanford University
3. Mueen Uddin., and Azizah A. R., 2010. Server consolidation: An Approach to make Data Centers Energy Efficient & Green, *International journal of Scientific and Engineering Research*,1(1).
4. Patel. C.D., 2003. A vision of energy-aware computing from chips to data centers. In Proceedings of the International Symposium on Micro-Mechanical Engineering (ISMME), December 2003
5. Patel, C.D., and Ranganathan.P., 2006. Enterprise power and cooling. Tutorial at the International Conference on Architectural Support for Programming Languages and Operating Systems (ASPLOS), October 2006.
6. Markoff, J., and Hansell, S., 2006. Hiding in plain

sight, Google seeks more power. New York Times, 14, 1-2.
7. EPA, 2009, EPA ENERGY STAR Program Requirements for Computer Systems Draft 4, Environmental Protection Agency, Washington, DC
8. Webb, M., 2008. Smart 2020: Enabling the low carbon economy in the information age, The Climate Group. London, 1(1), 1-1. Available at : http://www.smart2020.org/_assets/files/02_Smart2020Report.pdf
9. M. Uddin., and A. A. Rahman., 2012. Energy efficiency and low carbon enabler green IT framework for data centers considering green metrics. *Renewable and Sustainable Energy Reviews*, 16 (6), pp. 4078- 4094
10. Molla, A., 2008. GITAM: A Model for the Adoption of Green IT, 19th Australasian Conference on Information Systems, Christchurch, New Zealand.
11. Fuchs, C., 2008. The implications of new information and communication technologies for sustainability. *Environment, Development and Sustainability*,10(3), pp. 291-309.
12. Petrucci, V., Loques, O., and Mossé, D., 2009. A dynamic configuration model for power-efficient virtualized server clusters, in: Proceedings of the 11th Brazillian Workshop on Real-Time and Embedded Systems, WTR 2009, Recife, Brazil.
13. Bhutto, A.W., and Karim, S., 2007. Energy-poverty alleviation in Pakistan through use of indigenous energy resources. *Energy for Sustainable Development*, 11(1), pp. 58-67.
14. Packard, K. O., and Reinhardt, F. L., 2007. What Every Executive Needs to Know About Global Warming. In Harvard Business Review on Green Business Strategy (pp. 21-39). Boston, MA: Harvard Business School Press.
15. Tracy, A., Jenkin. T. A., Webster, J., and McShane, L., 2011. An agenda for Green information technology and systems research. *Information and Organization*, 21(1), pp. 17-40.
16. Jacobson, M.Z., 2009. Review of solutions to global warming, air pollution, and energy security. *Energy Environment Science*. 2(2), pp.148 73.
17. Benjamin, K.S., and Marilyn, A.B., 2010. Competing Dimensions of Energy Security: An International Perspective. *Annual Review of Environment and Resources*, 35, pp. 77-108.
18. Murugesan, S., 2008. Harnessing Green IT: Principles and Practices, IT Professional, 10(1), pp. 24-33.
19. Pritchard,S., 2007. IT Going Green: Forces Pulling in Different Directions, Financial Times, 30 May 2007.
20. Baines, S., 2007. The Greening of IT: Why Less is More. Silicon.Com. 13 Aug. 2007. Accessed 18 Jan. 2008 <hardware.silicon.com/servers/0,39024647,39168119,00.htm>.
21. Mueen Uddin and Azizah A.R., 2010, Pre Requisites for implementing energy efficient & cost effective data centers using virtualization. *Journal of Computing*, 2(11), pp. 95-101
22. Microsoft, 2007. Visio Connector for Microsoft Baseline Security Analyzer. [online] Available at <http://technet.microsoft.com/en-US/security/cc184925#mbsa20>
23. Microsoft, 2008. Upgrading to Windows Server 2008. [online] Available at <http:www.microsoft.com/downloads/detail.aspx?familyID=67240676-3148-4e49-943d-4d9ea7f77730&displaylang=en>
24. VMWare, 2008. VMware Server User s Guide: VMware Server 2.0. [online] Available at <http://www.vmware.com/pdf/vmserver2.pdf>

FULFILLING ENVIRONMENT RELATED INTERNATIONAL COMMITMENTS THROUGH IMPLEMENTATION OF MULTILATERAL ENVIRONMENTAL AGREEMENTS (MEAS) IN PAKISTAN

Ahmad Hussain and Zaheer A. Gillani**

ABSTRACT

Multilateral Environmental Agreements (MEAs) help address the environmental problems being faced by the international community as a whole. The ultimate goal of reaching MEAs is to realize sustainable development across the globe. According to World Bank (2006), Pakistan's economy loses Rs. 365 billion annually to environmental hazards. A key mechanism available under international law for countries to work together on global environmental issues is through MEAs. Pakistan is signatory to several MEAs and has acceded to other non-legally binding instruments, such as Agenda-21, Rio Principles and Johannesburg Plan of Implementation aiming at sustainable development of natural resources. As a party to various Conventions and Protocols, Pakistan has been participating in different Conferences of Parties (COPs), Meetings of Parties (MOPs), and international consultative and technical meetings regarding MEAs organized by the United Nations and other international fora. Pakistan has been actively participating in and keeping liaison with institutional elements of each of these MEAs, i.e. COPs, the secretariat, advisory bodies, subsidiary bodies, clearing-house mechanisms, for effective decision-making regarding the overall implementation and development of programme of work and strategic plans, budget and the revision of annexes to the treaties. Priorities and objectives of MEAs vary significantly from one international instrument to another while the common aspects include the sustainable development and use of natural resources and the protection of the environment in such a way as to ensure its judicious use. Based on different stages of implementation of these MEAs, the spectrum in priorities of Pakistan has been quite broad. Pakistan attaches greater emphasis to crosscutting themes for MEAs that are primarily of a functional nature, such as strengthening of the capacities to meet the country's obligations or responsibilities under these agreements; enhancing coordination among implementing agencies; public education and awareness; strengthening scientific basis for decision-making; and strengthening international partnerships.

Keywords: *Multilateral Environmental Agreements (MEAs), Conference of Parties (CoPs), Meeting of Parties (MoPs), Environment Hazards, Sustainable Development, Environmental Governance.*

1. INTRODUCTION

Environment related challenges and issues of Pakistan are associated primarily with an imbalanced social and economic development in the recent decades. This challenge is further compounded with rapid urbanization due to a shift of population from rural to urban areas. Environmental problems are no longer defined as discrete problems, but are increasingly being understood as symptoms of disorder associated with a particular development path [1]. Climate change is really a problem of the ecological burden of human activity [2]. Environmental degradation is considered fundamentally linked to poverty in Pakistan. Approximately one-fourth of the country's population, like that of most developing countries, is poor and directly dependent on natural resources for their livelihoods whether agriculture, hunting, forestry, or fisheries. Poverty combined with a rapidly increasing population and growing urbanization, is leading to intense pressures on the environment. This environment-poverty combination cannot be ignored if effective and practical solutions are to be taken to remedy environmental hazards. In Pakistan, the deterioration of environment continues to affect livelihoods and health, thus increasing the vulnerability of the poor to disasters and environment-related conflicts. The current cost of environmental degradation is considerably high. According to an assessment made by the World Bank [3], the cost of environmental neglect and degradation to Pakistan's economy amounted to Rs. 365 billion per year.

Multilateral Environmental Agreements (MEAs) address the environmental problems being faced by the international community as a whole. The MEAs vouch for common responsibility among nations for environmental protection. The ultimate goal for the MEAs is sustainable development across the globe. Most environmental problems have a transboundary nature and often a global scope, and they can only be addressed effectively through international co-operation. The main method available under international law for countries to work together on global environmental issues is to implement a multilateral environmental agreement (MEA). The importance of cooperation among countries to work together in an integrated manner through various conventions/protocols cannot be overemphasized.

* National MEAs Secretariat, Ministry of Environment, Islamabad. Email: ahmaddof@yahoomail.com

This research study aims to investigate the degree of awareness about the environment related international commitments and effectiveness of the focal agencies regarding the execution of decisions on various MEAs as a solution to problems encountered by Pakistan in implementation of MEAs. Specific objectives of this study were to: (i) evaluate the coordination and cooperation between stakeholders for compliance to MEAs; and (ii) make recommendations for implementation of MEAs in Pakistan.

2. METHODOLOGY

The survey was carried out using participants' experience method, structured interviews and informal discussion technique. International experiences on information management in implementation of MEAs were investigated through a literature survey of various reports, record of the Ministry of Environment and secondary data. Primary data were collected from the focal points in the Ministry of Environment, stakeholders of MEAs (twenty five members), and another twenty from various workshops organized by the Ministry from 2007-2010. The functions, role and the institutional mechanism of MEAs were analyzed in relation to their implementation problems identified by previous studies. Twenty potential stakeholders from the private sector and NGO sector were also selected for the survey. The private sector and NGO representatives were selected from the participants of workshops organized by the Ministry of Environment during 2007-2010. The respondents of the survey were asked questions regarding: i) Obligations of Pakistan under various international conventions/ protocols and the purpose of MEAs ratification; ii) their opinion on the effectiveness of MEAs Secretariat, and iii) the problems faced by Pakistan in implementing MEAs according to their perception and suggestions. Interviews were carried out during two months period from January to February 2011. The interviewees were requested to make recommendations as a way forward to improve information management of MEAs in Pakistan.

3. RESULTS AND DISCUSSION

3.1 Multilateral Environmental Agreements Ratified by Pakistan

Pakistan is signatory to several MEAs and has

Table-1: List of International Environment Conventions/Protocols Signed and Ratified by Pakistan

Sr. No.	Name of Convention	Date of Signing	Date of Ratification	Main Theme
1.	Ramsar Convention on Wetlands	1971	July 1976	Conservation and wise use of all wetlands through local, regional and national actions and international cooperation.
2.	Convention of Migratory Species (CMS)	1971	Dec. 1987	Conservation and protection of terrestrial, aquatic and avian migratory species.
3.	Convention on International Trade in Endangered Species (CITES)	1973	April 1976	Cooperation among the signatory countries for protection of certain endangered species of wild animals and plants to prevent their over exploitation through international trade.
4.	Convention on the Law of Seas	Dec. 1982	Feb. 1997	Peaceful uses of the seas and oceans; the equitable and efficient utilization of its resources; the conservation of their living resources; and study, protection and preservation of the marine environment.
5.	Vienna Convention on the Protection of the Ozone Layer	Jan. 1989	Dec. 1992	Protecting Ozone layer for conserving environment for the present and future generations.
6.	Montreal Protocol on Ozone Layer Depleting Substances	Jan. 1989	Dec. 1992	Protecting human health and the environment by reducing the emissions of certain substances that deplete or change the Ozone layer.
7.	Basel Convention on the Control of Trans-boundary Movement of Hazardous Wastes	May 1992	July 1994	Controlled trans boundary movement of Hazardous Wastes.

continue...

...continued

8.	Convention on Biological Diversity	June1992	26th July 1994	Conservation of biological diversity, the sustainable use of its components and the fair and equitable sharing of the benefits arising out of the utilization of genetic resources
9.	United Nations Convention to Combat Desertification	15th Oct. 1994	24th Feb. 1997	To combat desertification and mitigate the effects of drought in countries experiencing serious drought and /or desertification, supported by international cooperation and integrated approach for sustainable development in the affected areas.
10.	United Nations Framework Convention on Climate Change (UNFCCC)	June1992	June 1994	Stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system
11.	Kyoto Protocol to UNFCCC	Dec. 1997	Jan. 2005	It covers: 1. Mitigation of climate change so as to reverse the pace of climate change. 2. Promote the carbon sequestration and carbon credits, i.e. Certified Emission Reduction (CER) trading.
12.	Rotterdam Convention on Prior Informed Consent (PIC) for certain Hazardous Chemicals and Pesticides	Sept. 1999	July 2005	Promotes shared responsibility and cooperation among parties in the international trade of certain hazardous chemicals in order to protect human health and the environment from potential harm and to contribute to their environmental sound use.
13.	Cartagena Protocol on Bio-safety to the CBD	4th Jun. 2001	May 2009	A Protocol to CBD that deals with the safe handling, storage and trans-boundary movement of the Genetically Modified Organisms (GMO).
14.	Stockholm Convention on Persistent Organic Pollutants (POPs)	Dec. 2001	April 2008	Protecting human health and the environment from the harmful impacts of persistent organic pollutants (POPs).

acceded to other non-legally binding instruments, such as Agenda-21, Rio Principles and Johannesburg Plan of Implementation aiming at sustainable development of natural resources. A detailed list of the Conventions/Protocols related to environment signed and ratified by Pakistan is given in Table-1. In this way, Pakistan acknowledged that sustainable management of environmental resources required acceptance of relevant international treaties in the field of the environment and the concurrent development of effective legal, institutional, and regulatory frameworks.

A review of MEAs shows that more than 120 global conventions have relevance to the Asian countries. Many of these have attracted significant levels of ratification or accession by Asian States [4]. The record of acceptance of MEAs (as given in Table-1) are of particular significance to the Asian countries and reveals that majority of the countries in South Asia has ratified these.

3.2 Key Obligations of Various Conventions/ Protocols

Multilateral environmental agreements (MEAs) are global treaties whose geographic scope varies widely. Obligations in an MEA are considered to be legally binding for the Parties to the international environmental instruments. A legal obligation is authoritative, prescriptive and binding under international law. As a treaty, an MEA creates binding international obligations between parties to it. All the parties to an MEA perform their obligations in good faith and no party may invoke the provisions of its own domestic law to justify its failure to comply with an obligation under MEA. A list of key obligations under various Conventions and Protocols ratified by Pakistan is given in Table-2.

In the Millennium Report, the Secretary-General of the United Nations highlighted, “Support for the rule of law would be enhanced if countries signed and ratified international treaties and conventions”, but many countries are unable to engage effectively owing to

Table-2: Key Obligations of Various International Conventions/Protocols

Sr. No.	*Name of Conventions*	Main Obligations
1.	Ramsar Convention on Wetlands	i. Designate at least one Wetland to be included in the list of Ramsar sites when signing the convention. ii. Contracting Parties shall endeavor through management to increase waterfowl populations on appropriate wetlands. iii. Contracting Parties shall promote the training of personnel competent in the fields of wetland research, management and wardening. iv. Contracting Parties have to formulate National Wetland Policies as an important step towards facilitating conservation and wise use of wetlands v. Contracting Parties to establish procedures which guarantee that the local communities are involved in the decision-making process related to wise use of wetlands vi. Contracting Parties have to establish National Committees according to their needs to provide a focus at national level for implementation of the convention. vii. Every contracting party will develop management plan for wise use of Wetlands of Ramsar sites. viii. Every contracting party has to develop Communication, Education, and Public Awareness (CEPA) programme task force.
2.	Convention of Migratory Species	i. Provide immediate protection for migratory species included in Appendix-I of the Convention. ii. Develop Agreements covering the conservation and management of migratory species included in Appendix-II of the Convention. iii. Range States for migratory species listed in Appendix-I or Appendix-II should inform the COP through the Secretariat about the measures that they are taking to implement the provisions of this Convention for these species. iv. Any dispute on application or interpretation of this Convention, which may arise between two or more Parties, should be solved through negotiation between the Parties involved in the dispute. v. Keep the Secretariat informed with regard to which of the migratory species listed in Appendices I and II they consider themselves to be Range States.
3.	Convention on International Trade in Endangered Species (CITES)	i. Export, import, permit and re-export certificates for specimen enlisted in CITES should be granted by specific procedure and format. ii. Permit should be issued by designated Management Authority of the country with its stamp control number for six month. Separate permit or certificate should be issued for each consignment of specimen. iii. To take appropriate domestic measures like Penalize trade, possession of such species. To confiscation, or return to state of export of such specimen to enforce the convention & prohibit trade violation. iv. Designate ports of exit & port of entry for clearance of specimen. v. During transit, specimen should be given a proper care to minimize the risk of injury, damage to health or cruel treatment. vi. A rescue centre must be organized for confiscated living specimen for look after by management authority of the state. vii. Each party should nominate management and scientific authorities. viii. Management authority of the state of import of any specimen shall cancel & retain the export permit or re-export certificate and any corresponding import permit presented in respect of the import of that specimen.
4.	Convention on the Law of Seas	i. Establishment of National and Regional Marine Scientific Technological centers. ii. Cooperation among international organizations that will take all appropriate measures to ensure, either directly or in close cooperation among themselves, the effective discharge of their functions and responsibilities. a. Ensure Sustainable use of Marine Biodiversity as a common concern of human kind.

continue...

...continued

		b. It covers the rapidly expanding field of Biotechnology and Scientific Research. c. Illegal, unreported and unregulated fishing, including as it might relate to international organized crime; d. Piracy and armed robbery; maritime safety and security; e. Oceans and climate change; f. Climate Preservation of the marine environment; g. Safety of navigation and the production of nautical charts; iii. Cooperation and coordination among flag states, coastal states and port states in the implementation of the convention.
5 & 6	Vienna Convention on the Protection of the Ozone Layer & Montreal Protocol on Ozone Layer Depleting substances	i. The Parties shall take appropriate measures in accordance with the provisions of this Convention and of those protocols in force to which they are party to protect human health and the environment against adverse effects resulting or likely to result from human activities that modify or are likely to modify the ozone layer. ii. To this end, the Parties shall, in accordance with the means at their disposal and their capabilities: a. Co-operate by means of systematic observations, research and information exchange in order to better understand and assess the effects of human activities on the ozone layer and the effects on human health and the environment from modification of the ozone layer; b. Adopt appropriate legislative or administrative measures and co-operate in harmonizing appropriate policies to control, limit, reduce or prevent human activities under their jurisdiction or control should it be found that these activities have or are likely to have adverse effects resulting from modification or likely modification of the ozone layer; c. Cooperate in the formulation of agreed measures, procedures and standards for the implementation of this Convention, with a view to the adoption of protocols and annexes; d. Co-operate with competent international bodies to implement effectively this Convention and protocols to which they are party. iii. The provisions of this Convention shall in no way affect the right of Parties to adopt, in accordance with international law, domestic measures additional to those referred to in paragraphs i and ii above, nor shall they affect additional domestic measures already taken by a Party, provided that these measures are not incompatible with their obligations under this Convention. iv. The application of this article shall be based on relevant scientific and technical considerations.
7.	Basel Convention on the control of Trans-boundary movement of Hazardous Wastes	i. Reduce transboundary movements of hazardous wastes; ii. Minimize the production of hazardous and toxic wastes; iii. Ensure that disposal of wastes is done in environmentally sound manner and as close to the possible source as possible; and iv. Assist developing countries in the environmentally sound management of hazardous and other wastes they generate.
8.	Convention on Biological Diversity	i. In-situ conservation ii. Ex-situ conservation iii. Sustainable use of components of Bio diversity iv. Research and training on ecosystem management v. Public education and awareness Exchange of information with parties vi. Technical and scientific co-operation among parties
9.	United Nations Convention to Combat Desertification	i. Prepare National Action Programmes and to cooperate in implementation of Sub-Regional Action Programme (SRAP) and Regional Action Programme (RAP). ii. Give due priority to combating desertification and mitigating the effects of drought, and allocate adequate resources in accordance with their circumstances and capabilities.

continue...

...continued

		iii. Establish strategies and priorities, within the framework of sustainable development plans and/or policies, to combat desertification and mitigate the effects of drought. iv. Address the underlying causes of desertification and pay special attention to the socio- economic factors contributing to desertification processes. v. Promote awareness and facilitate the participation of local populations, particularly women and youth, with the support of non-governmental organizations, in efforts to combat desertification and mitigate the effects of drought; and vi. Provide an enabling environment by strengthening, as appropriate, relevant existing legislation and, where they do not exist, enacting new laws and establishing long-term policies and action programs.
10 & 11	United Nations Framework Convention on Climate Change (UNFCCC) & Kyoto Protocol to UNFCCC	i. Designation of National Implementing Entity (NIE) ii. Grant of host country approval to CDM Projects and endorsement for registration with CDM-Executive Board. iii. Preparation of Climate Change Policy and National Adaptation Plan. iv. Research and development and new projects in the field of Climate change. v. Development of Institutional mechanism. vi. Inventory of GHG Emissions. vii. Preparation of National Communication. viii. Capacity Building Framework ix. Technology Transfer Mechanism (Framework). x. Mitigation & Adaptation Strategy. xi. Coordination and liaison with maximum stakeholders at federal and provincial levels. xii. Participation in COP/MOP Meetings. xiii. Strengthening of compliance with Multilateral Environmental Agreements. xiv. Identification of linkages of climate change with all other MEAs and streamlining the climate change policies and plans with the National Policies.
12.	Rotterdam Convention on Prior Informed Consent (PIC) for certain Hazardous Chemicals and Pesticides	i. The parties shall implement appropriate legislative and administrative measures to comply with the decisions ii. The parties will provide an export notification to the importing party regarding the banned or severely restricted chemicals. iii. The exchange of scientific, technical, economic and legal information including toxicological, eco-toxicological and safety information to be furnished. iv. To implement the convention, the suggested measures mention in the convention.
13.	Cartagena Protocol on Bio-safety to the CBD	i. Application of Precautionary Principle ii. Risk Assessment of LMOs/GMOs iii. Establishment of Bio-safety Clearing House by parties iv. Advance Informed Agreement between Parties
14.	Stockholm Convention on Persistent Organic Pollutants (POPs)	The Convention: i. Bans Production and Use of chemicals. ii. Measure to reduce or eliminate releases from unintentional production iii. Measure to reduce or eliminate releases from stockpiles and wastes iv. National Implementation Plan (NIP)

"the lack of necessary expertise and resources."

The analysis revealed that as focal points are dealing with these international environmental instruments at domestic and international levels, they (60%) are aware of major obligations under various conventions and protocols (Figure-1). Provincial government agencies are not as conscious of obligations under various international environmental instruments as academic institutions. This may be due to lack of access to information relating to MEAs at government level. The higher awareness in academic institutions may be attributed to emerging concepts of MEAs as solution to environmental problems and queries posed in brainstorming sessions in academia.

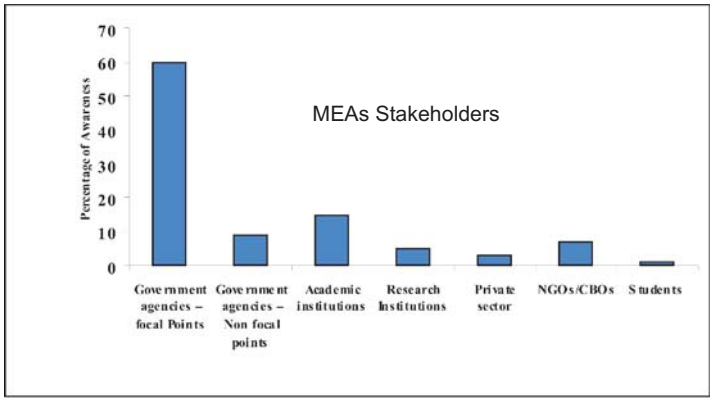

Figure-1: Comparison of Awareness of Stakeholders about their Obligations w.r.t Signed MEAs

3.3 Coordination and Cooperation between stakeholders for compliance to MEAs

As a party to various conventions and protocols, Pakistan has been actively participating in different Conference of Parties (CoP), Meeting of Parties (MoP), and international consultative and technical meetings organized by the United Nations and other international fora. In addition, Pakistan has adopted major declarations in the field of environment (the Stockholm Declaration; Dubai Declaration; Nairobi Declaration; and the Rio-Declarations). Pakistan also adheres to the Charter of the United Nations; the Statute of the International Court of Justice (ICJ); and the 1969 Vienna Convention on the Law of Treaties. Pakistan is an active member of the South Asian Co-operative Environment Programme (SACEP), South Asia Association of Regional Cooperation (SAARC); Economic Cooperation Organization (ECO) Plan of Action; Strategic Approach to International Chemicals Management (SAICM); and South Asia Regional Seas Programme.

The Government of Pakistan accords high priority for implementation of international legal instruments in the country. National focal points which are responsible for decision making on respective treaties have been designated for each international treaty ratified. Ministry of Environment, Government of Pakistan is the focal Ministry to deal with 14 environment related conventions and protocols. Respective focal points in the Ministry of Environment have taken several important measures, such as legislations, policies and action plans to implement MEAs in Pakistan. However, the implementation of these measures is not exemplary. The main problem is the lack of access to technical information relating to MEAs, understanding of the complexities of mechanics of MEAs and lack of coordination among implementing agencies as faced by Sri Lanka [5].

The focal points are not able to meet their commitments because obviously they do not know what their commitments are and what benefits Pakistan may derive out of compliance to the particular MEA. This is a serious problem. Due to frequent changes of the subject areas of government agencies, focal points also change very often. In this changing process, in some cases, the focal points of some MEAs may not be clear about their role and function. Another disadvantage of this phenomenon is lack of networking with technical community of other parties and secretariats of the conventions. If there is a dedicated center for MEAs implementation, one can find remedy for these issues.

Therefore, as a solution to these problems and to serve the purpose of institutional memory of UN meetings, high level segments and development of Pakistan's response to various issues, the National MEAs Secretariat has been established at the Ministry of Environment. It started functioning in April 2007. It is the centrum/focal organization for major environment and sustainable development related international conventions and treaties for coordination and enhancement of implementation of MEAs in the country.

As strategy for management of information on MEAs, the Ministry of Environment and Forestry, Government of Bangladesh, planned to establish a MEA Cell in the Ministry to coordinate the activities on MEAs [6]. National Environment Commission Secretariat (NECS) is working in Bhutan for this purpose [7]. The Ministry of Environment and Natural Resources of Sri Lanka established the Environmental Treaties Reference Centre (ETRC) as a strategy for management of information on all MEAs [5].

In Pakistan, the National MEAs Secretariat involves all focal points of MEAs and stakeholders, such as government agencies professionals, academics, NGOs, CBOs and the public in updating Pakistan's stance and decision making. Through this Secretariat, the government raises public awareness and consults stakeholders on the legal instrument that the country undertakes or plans to sign/ratify. It functions as a related information source, which stores reference materials and documents relevant to all MEAs, and update them frequently for the benefit of the Federal and Provincial partners.

3.4 Analysis of Policies and Strategies/ Action Plans to implement MEAs

The analysis revealed that the area-wise key policies and strategies/Action Plans have been developed to implement MEAs in Pakistan. These policies include National Environment Policy (2005); National CDM Policy; National Forestry Policy (2011); National Sanitation Policy (2006), National Drinking Water Policy (2009); Pakistan Trade Control of Wild Fauna and Flora Act (2010); Pakistan Energy Conservation Bill (2010); National Rangeland Policy (2011); National Wetlands Policy (2011); Climate Change Policy (2011); Trade Policy (2009-10); Pakistan National Policy and Strategy for Fisheries and Aquaculture Development in Pakistan (2009) and its derivative - Sindh Fisheries and Aquaculture Strategy (2010-2013), as well as the Merchant Marine Policy (2000-2001).

Major plans included National Land Use Plan (NLUP); National Environment Action Plan (NEAP), which is a multi-donor national level plan covering 4 core areas, namely: Clean water, Clean air, Energy Efficiency, Ecosystem Management; Forestry Sector Master Plan (1995); Biodiversity Action Plan; National Action Plan to Combat Desertification; the National Environment Action Plan - Support Programme (NEAP-SP); National Action Plan for Wetlands (2002); Pakistan Clean Air Programme (PCAP); and Building Energy Code of Pakistan for Energy Efficiency & Conservation Measures.

Among the important strategies are Poverty Reduction Strategy (2001); Mid-Term Development Framework (2005-2010); Pakistan National Operational Strategy for Clean Development Mechanism (CDM 2006); National Conservation Strategy (1992) and Provincial and District Conservation Strategies, i.e. Sarhad Conservation Strategy, Balochistan Conservation Strategy and Northern Areas Conservation Strategy; National Bio-safety Guidelines; WAPDA's Vision (2025); and First National Communication on Climate Change.

Pakistan has also developed National Standards for Drinking Water Quality; and National Environmental Quality Standards (NEQS) for Noise, Ambient Air, Motor Vehicle Exhaust and Noise (Amended) to protect public health through ensuring provision of healthy environment to the people of the country. Though some of these plans have been developed before the establishment of National MEAs Secretariat, the respondents have stated that all these action plans have benefited in the implementation phase and when they are updated.

The survey revealed that a large number of projects and activities have benefited from the National MEAs Secretariat. Such activities include preparation for COP / MOP meetings of various Conventions and Protocols; preparation for National Capacity Self Assessment (NCSA); and preparation and processing

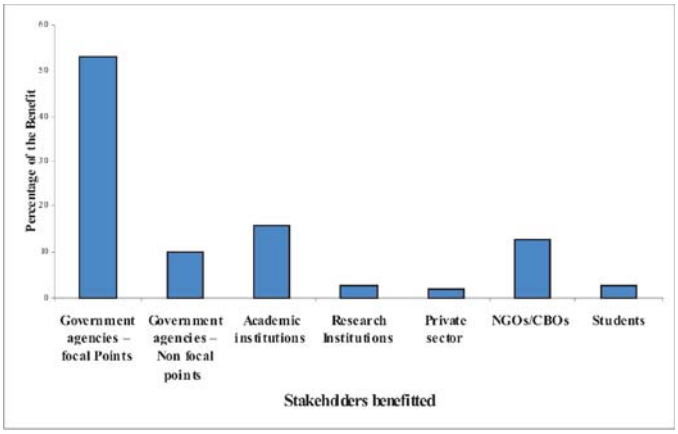

Figure - 2: Comparison of Benefits to Stakeholders from National MEAs Secretariat

of GEF proposals and facilitation of project implementation; enhancement/development of Protected Area Management; and preparation of concept papers / PIF for GEF Programme. It was also revealed that the National MEAs Secretariat has supported activities related to broad subject areas, including desertification and land degradation, biodiversity, forestry and chemical management [8].

Based on the respondents' perception and inputs, the National MEAs Secretariat benefited various categories / groups as presented in Figure-2.

4. CONCLUSIONS

Priorities and objectives of MEAs vary significantly from one international instrument to another, while the common aspects include the sustainable development focus of the three Rio Conventions (CBD, UNCCD and UNFCCC), the sustainable use of natural resources and the environment, and the protection of the environment in such a way as to ensure its sustainable use. Based on different stages of implementation of these MEAs, the spectrum in priorities of Pakistan has been quite broad. Pakistan is attaching greater emphasis on cross-cutting themes for many that are primarily of a functional nature, such as strengthening of the capacities to meet the country's obligations or responsibilities under these agreements, enhancing coordination among implementing agencies, public education and awareness, strengthening scientific basis for decision-making, and strengthening international partnerships.

Main institutions of Pakistan have been participating in MEAs activities include: Conference of the Parties (COP), the secretariat, advisory bodies, subsidiary bodies, and clearing-house mechanism for effective decision-making regarding the overall implementation and development of programme of work and strategic plans, budget and the revision of annexes. The record of Pakistan participation in MEAs has improved significantly over the years. Environmental treaty acceptance has been driven by Pakistan's interface with the global environmental institutions, the demands of international financial and donor institutions and states, and increasingly, the emergence of local environmental actors and interests.

REFERENCES

1. WRI, 2007. Restoring Nature's Capital: An Action Agenda to Sustain Ecosystem Services. World Resources Institute.
2. Parry, M., 2009. Climate change is a development issue and only sustainable development can confront the challenge, Climate and Development, 2009.
3. World Bank, 2006. Pakistan: Strategic Country Environment Assessment. Report No. 36946-PK. Aug 2006. South Asia Environment and Social Development Unit. South Asia Region. http://siteresources.worldbank.org/SOUTHASIAEXT/Resources/Publications/448813-1188777211460/pakceavolume1.pdf
4. United Nations Environment Programme and Development Alternatives, 2008. South Asia Environment Outlook 2009: UNEP, SAARC and DA.
5. Kumar, P., 2005. Market for Ecosystem Services. International Institute for Sustainable Development. Ministry of Environment and Natural Resources, Govt. of Sri Lanka.
6. DoE., 2006. National Biodiversity Strategy and Action Plan (NBSAP) for Bangladesh. Department of Environment, Ministry of Environment and Forests, Government of Bangladesh.
7. National Environment Commission Secretariat (NECS), 2004. Brief Report on State of the Environment, Thimphu, May 2004.
8. Economic Advisors Wing, 2010. Pakistan Economic Survey (2009-2010). Ministry of Finance, Government of Pakistan. Statistical Yearbook 2010.

MODELING OF CLIMATE CHANGE IMPACTS ON AGRICULTURE, FORESTRY AND FISHERY

B. K. Bala, M. A. Munnaf**, F. Y. Ruma*** and M. S. Alam*****

ABSTRACT

Changes in climate affect agriculture, forest and fisheries. This paper examines the climate change impacts on crop production, fishery and forestry using state-of-the-art modeling technique. Crop growth model InfoCrop was used to predict the climate change impacts on the yields of rice, wheat and maize in Bangladesh. Historical climate change scenario has little or no negative impacts on rice and wheat yields in Mymensingh and Dinajpur but IPCC climate change scenario has higher negative impacts. There is almost no change in the yields of rice and maize for the historical climate change scenario in the Chittagong, Hill Tracts of but there is a small decrease in the yields of rice and maize for IPCC climate change scenario. A new statistical model to forecast climate change impacts on fishery in the world oceans has been developed. Total climate change impact on fishery in the Indian Ocean is negative and the predictor power is 94.14 % for eastern part and 98.59 % for the western part. Two models are presented for the mangrove forests of the Sundarbans. Total bole volumes of the pioneer, intermediate and climax are simulated for three different logging strategies and the results have been discussed in this paper.

Keywords: *Climate Change, Crop Production, Forestry, Fishery, Modeling, Simulation, Adaptation, Management Strategies.*

1. INTRODUCTION

Many studies have been reported on modeling of forest growth, management strategies and climate change (Bossel, 1991; Bossel and Kreiger, 1991; Huth and Ditzer, 2000; Ito and Oikawa, 2002; Phillips, et al., 2003; Masera, et al., 2003; Wallman et al., 2004; Köhler and Huth, 2004; Tietjen and Huth, 2006; Fyllas et al., 2007 and Drouet and Pages, 2007). Bala, et al., (2003, 2004 & 2008) adopted the process based cohort model of Kohler (2000) and Kohler and Huth (1998) to simulate the mangrove forest growth of the Sundarbans and also applied the aggregate model CO2FIX (Masera, et al., 2003).

2. MODELING AND SIMULATION

2.1 Modeling of Climate Change Impacts on Crop Growth

Computation of climate change impacts on crop yields are based on the crop growth model, InfoCrop, developed by Aggarwal, et al. (2006 a & b). Computation of canopy photosynthesis from the incoming photosynthetically active radiation forms the central part of the crop-growth simulation models. The crop development and growth processes and their relationships with the crop growth model, InfoCrop, are shown in Figure-1, where light and temperature are the independent variables, and photosynthetic parameters are constants. Rectangles represent quantities (state variables), valve symbols indicate flows (rate variables), circles are auxiliary variables (converters), full lines are flows of material, and dashed lines are flow of information. Development and growth processes are dry matter production, dry matter partitioning, leaf area growth and phenology. The growth rate of the crop is calculated as a function of radiation use efficiency; photosynthetically active radiation; total leaf area index; and a crop/ cultivar specific extinction coefficient. The growth rate of the crop is calculated as follows:

$$GCROP = RUE * PAR * (1 - EXP(-KDF * LAI)) \quad \text{Eq. (1)}$$

Where GCROP = net crop growth rate;
RUE = radiation use efficiency;
PAR = photosynthetically active radiation;
KDF = extinction coefficient; and
LAI = leaf area index.

Under favorable growth conditions, light, temperature, and the crop characteristics for phenological, morphological, and physiological processes are the main factors determining the growth rate of the crop on a specific day. The net dry matter available each day for crop growth is partitioned into roots, leaves, stems, and storage organs as a crop-specific function of development stage. Allocation is made first to roots, which increase in case the crop experiences water, or nitrogen stress. The remaining dry matter is allocated to the above ground shoot, from which a fraction was allocated to leaves and stems. The balance dry matter is automatically allocated to the storage organs. The model follows a daily calculation scheme for the rates of dry matter production of the plant organs, the rate of leaf area development, and the rate of phenological development (growth stages). By integrating these rates over time, dry-matter production of the crop is simulated throughout the crop growing season and the yield of the crop is computed. Radiation use efficiency changes for the changes in temperature and CO_2 concentrations in the atmosphere as a result of climate

* Universiti Putra Malaysia, Malaysia. Email: bkbalabau@yahoo.com. ** Hajee Mohammad Danesh Science and Technology University, Bangladesh. ***Bangladesh Agricultural Development Corporation, Bangladesh. ****Sher-e-Bangla Agricultural University, Bangladesh.

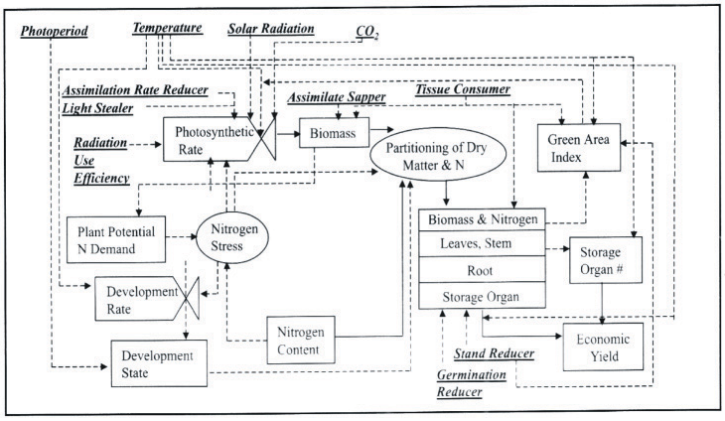

Figure - 1: Simple representation of crop growth model

change and these changes are incorporated in the crop growth model to compute the climate change impacts on crop productions.

2.2 Modeling of Climate Change Impacts on Fishery in the Oceans

Several studies reported that fishing in the oceans is affected by surface water temperature. Greenhouse and other effects contribute to global warming and the global warming in turn affects the fish catches. A knowledge of the impact of the temperature on fish catches in world fishery is essential for sustainable management of the world fishery resources, and a new method for prediction of climate change impact in the world oceans is described as follows.

Two categories of data were analyzed and processed to assess the dynamics of spatial temperature distribution and fish catches for the oceans of the fishery resources. The predictor is a rule, in accordance with which the dynamics of fish catch w(t) for the future, i.e. for new values of m1,...,m4 (moments of a future temperature distribution) can be predicted. Assuming that the values of w(t) (both for previous years and for future) can be presented in the form:

$$w(t) = \sum_{k=1}^{4} \alpha_k m_k(t), t = 1,..., n \qquad \text{Eq. (2)}$$

With n=32>>4, system can be considered as an over-determined linear algebraic system with respect to α_k which can be solved by the Gauss method (the method of least squares (Hoel, 1966).

Now assuming that the solution of Equation (2) is: {α_k; k=1,2,3,4}. It is obvious that :

$$u(t) = \sum_{k=1}^{4} \alpha_k^* m_k(t) \neq w(t), t = 1,..., n \qquad \text{Eq. (3)}$$

Where u(t) is the relative deviation of predicted total fish catch.

Finally, the decision rule with the predictor s power is that:

> if u(j) > 0, then the fish catch would be higher than the amount predicted by the curve of the mean growth (climate change has a positive influence); this statement is true with probability P^+;
> If u(j) < 0, then the fish catch would be lower than predicted by the curve of the mean growth (FF has a negative influence); this statement is true with probability P^-.

The details of the construction of the predictor and predictor power are given by Biswas, et al. (2005).

2.3 Modeling of Mangrove Forest

The tree geometry and canopy development of mangrove forests are not well defined and are highly variable. Based on critical reviews on previous efforts on modeling and search for a simple but realistic model, two approaches of modeling of the mangrove forests are considered and these are aggregate modeling and individual based growth modeling. The aggregate model consists of three successional tree species of Keora (Sonneratia apetala), Gewa (Excoecaria agallocha) and Sundari (Heritiera fomes). The individual based growth curve model proposed by Chen and Twilley (1998) is adapted for modeling of the

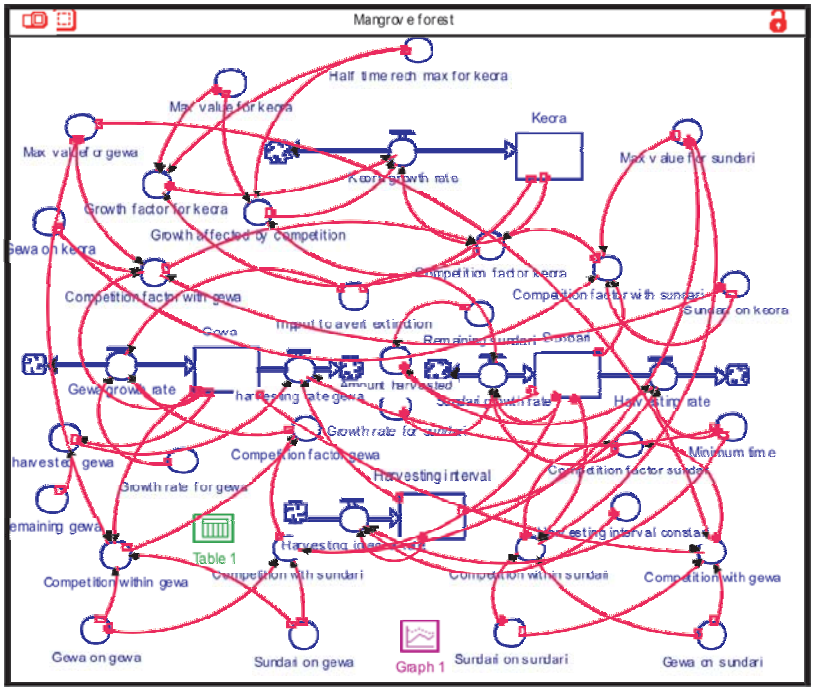

Figure-2: STELLA Flow Diagram for Forest Growth Model with Logging Operations

mangrove forests of the Sundarbans incorporating the salinity multiplier, temperature multiplier, and dominance effect or basal area multiplier. The aggregate model is based on a system of three coupled equations, which describe the stem volume changes of the three successional groups of Keora, Gewa and Sundari for every time step. The model in STELLA flow diagram is shown in Figure-2 and these equations are solved using Runge Kutta method of order 4.

There are few individual based ecological simulation models describing the structural and functional characteristics of mangrove forests. The FORMAN model based modifications of the JABOWA and FORET models (Shugart, 1984; Botkin, 1993) was developed to simulate demographic processes of mangroves in a 0.05 ha plot. This model is adapted for mangrove forest of the Sundarbans and the growth equation of the mangrove forest is as follows:

$$\frac{dD}{dt} = \frac{GD(1 - DH / D_{\max}H_{\max})}{(274 + 3b_2D - 4b_3D^2)} \times A \qquad \text{Eq. (4)}$$

Where A= $(SALT) * N(NUT) * T(DEGD) * D(BA)$ and
D = Diameter at breast height, m;
H = height, m;
t = Time, year;
G, b_2 and b_3 are constants.

Furthermore, the height of the tree is related to the diameter at breadth height as follows:

$$H = 197 + b_2D - b_3D^2 \qquad \text{Eq. (5)}$$

The SIMILE flow diagram of the individual based growth curve model is shown in Figure-3.

3. RESULTS AND DISCUSSIONS

3.1 Climate Change Impacts on Rice, Wheat and Maize Production

As the global warming continues, the weather parameters are also changing in conjuncture, gradually creating a new unacquainted ambient environment for the field crops. What will be the yield, duration and spatial dispersion of the field crops in the changing scenarios of climate change, are the burning issue to the global intellectual community.

The simulated climate change impacts on the yields of rice and wheat in Mymensingh and Dinajpur for historical and IPCC trends of the temperature and CO_2 changes for a period of 2020-2050 are shown in

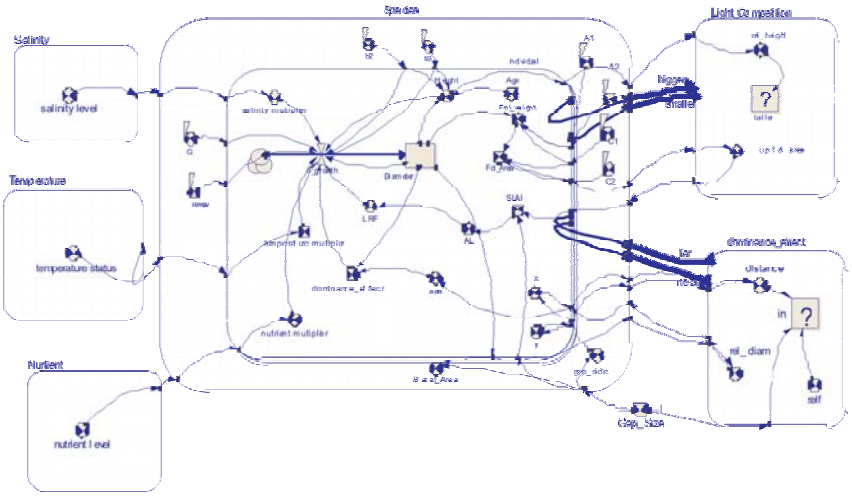

Figure-3: SIMILE Flow Diagram of the Mangrove Forest

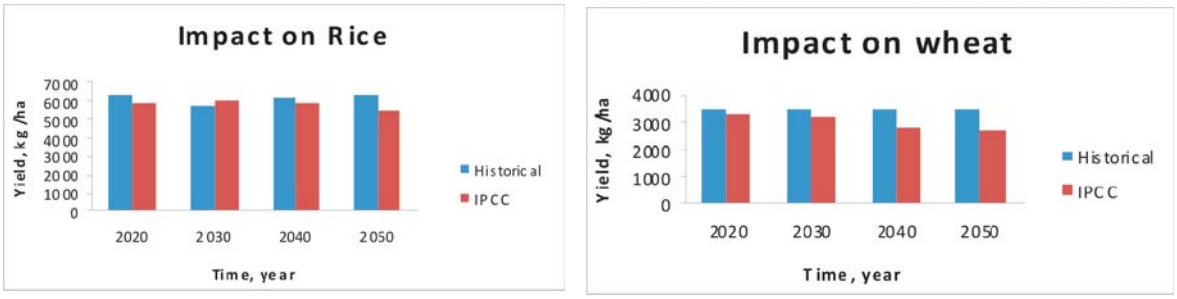

Figure-4(a): Changes in the Yields of Rice & Wheat for Historical & IPCC Climatic Scenarios (Mymensingh)

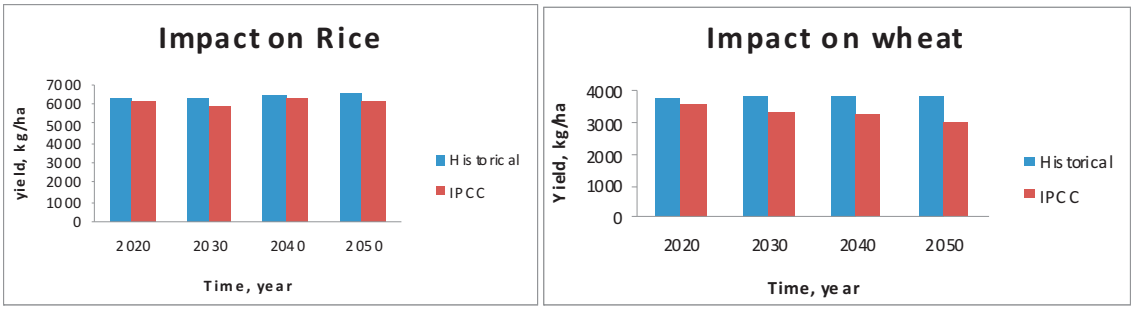

Figure-4(b): Changes in the Yields of Rice & Wheat for Historical and IPCC Climatic Scenarios (Dinajpur)

Figure-4. From the simulation studies, it is clear that there is almost no change in the yields of rice and wheat for the historical climate change scenario, but there is small decrease in the yields of rice for IPCC climate change scenario. Rice yield decreases from 5,780.9 kg/ha to 5,449.3 kg/ha and from 6,222.1 kg/ha to 6,110.8 kg/ha in Mymensingh and Dinajpur, respectively, and wheat yield decreases from 3,263.8 kg/ha to 2,648 kg/ha and 3,573.9 kg/ha to 2,933 kg/ha in Mymensingh and Dinajpur, respectively. Climate change impacts are more effective for wheat yields than the rice yields. Rice yields will be more affected by the climate change in Mymensingh in comparison to Dinajpur, while wheat yields will be more affected by climate change in Dinajpur in comparison to Mymensingh. The simulated results in Figure-5 show

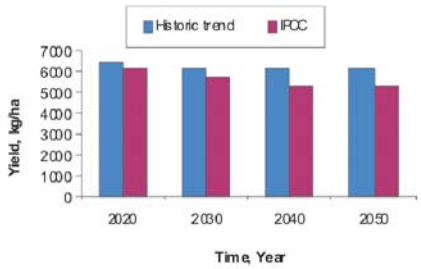

Figure-5(a): Changes in the Yields of Rice for Historical and IPCC Climate Scenarios

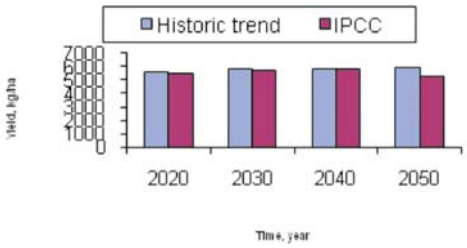

Figure-5(b): Changes in the Yields of Maize for Historical and IPCC Climate Scenarios

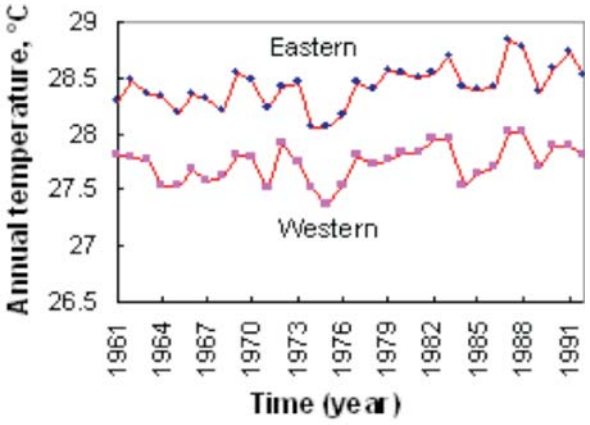

Figure-6(a): Temperature Changes in the Western and Eastern Parts of the Indian Ocean.

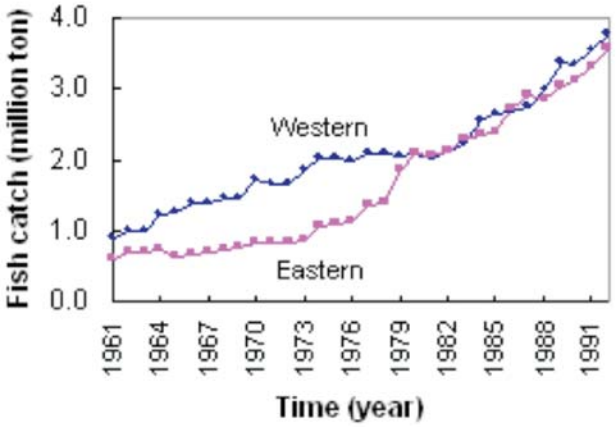

Figure 6(b). Fish Catch in the Western and Eastern Parts of the Indian Ocean.

that there is almost no change in the yields of rice and maize in the Chittagong Hill Tracts for the historical climate change scenario, but there is small decrease in the yields of rice and maize for IPCC climate change scenario. The predicted climate change impacts on rice yields in Bangladesh by different researchers vary considerably and it is as high as 50 %. This might be due to difference in climate change scenario considered and hence climate change scenario predicted by GCM or IPCC should be considered for consistency in the prediction of climate change impacts. More recently, Rosenzweig, et al. (2010) reported preliminary outlook for effects of climate change on Bangladeshi rice, and this study shows that Aus rice crop is not strongly affected and Aman rice crop simulations project highly consistent production increase.

3.2 Climate Change Impacts on Fish Catch In the Oceans

Temperature changes and fish catch in Indian Ocean, from the years 1961-1992, are shown in Figure-6. Based on these data, the dynamics of fish catch w(t) for next time, i.e. for new values of m1,..,m4 (moments of a future temperature distribution), are predicted and the solutions of equation (2) are also obtained for computing the u(t)-values.

The model CLIMBER-2 (CLIMate-BiospheRE model), developed by Petoukhov, et al. (1998) is applied for prediction of the future temperature changes. The future temperature differences of every 10-year interval are taken from the CLIMBER-2 Simulated Sea Surface Temperature Anomalies 2000-2100 for the Indian Ocean and these differences also increase for every interval. From these data, the future average of Indian Ocean are calculated. The predicted temperature and u(t)-values from the years 2000-2100 are shown in Figure-7. Figure-7(b) shows that the u(t)-values for the eastern part of the Indian Ocean decreases with time from positive to negative values, and the u(t) values for the western part of the Indian Ocean also decreases with time (totally negative values). This means that the global climate change will negatively influence fish catch in the Indian Ocean from the year 2005 to 2100 and also the influence of

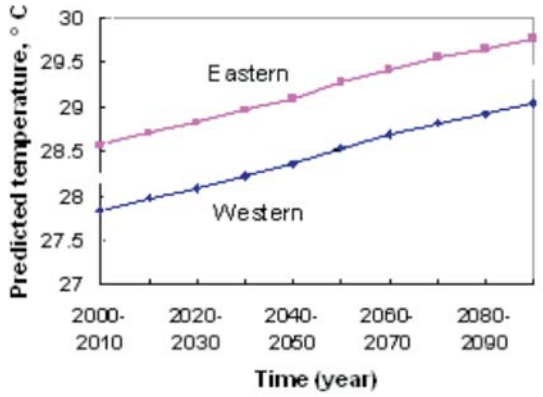

Figure-7(a): Predicted Temperature in the Western and Eastern Parts of the Indian Ocean.

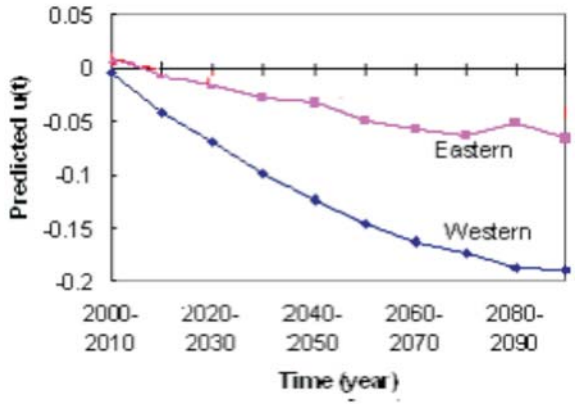

Figure 7(b): Predicted u(t)-values in the Western and Eastern parts of the Whole Indian Ocean.

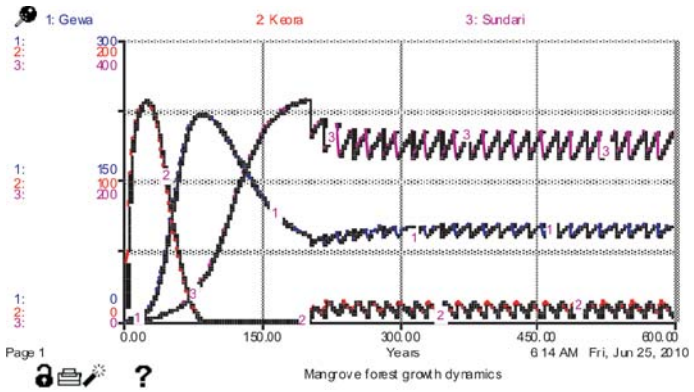

Figure-8: Simulation results For the Development of Volume of Mangrove Forests for 16 Years Logging Cycle.

climate change will be negative for the western part of the Indian Ocean, from the year 2000 to 2005.

Validation of a model is a process by which confidence in the model is to be developed for some particular purpose. In this statistical forecasting model the predictor power is the probability with which the prediction is made. The total climate change impacts on fish catch in the Indian Ocean is negative and the predictor power is 94.14 % for eastern part and 98.59 % for the western part.

3.3 Forest Growth Model

Simulated total bole volumes of pioneer, intermediate and climax tree species for logging cycle of 16 years with time are shown in Figure-8. The first logging is practiced after the forest reached a steady state condition. For the undisturbed forest growth model, the pioneer tree species (Keora) disappears after a certain period due to competition with climax and intermediate tree species, but after a logging operation it reappears. If the logging operation continues at a certain interval, the pioneer species never disappear. The maximum volume of the climax tree species for undisturbed model is 320 m^3/ha but for 16 years logging cycle it cannot reach its maximum volume, rather the volume changes in cyclical manner with a mean volume of 195 m^3/ha, while a maximum volume is 275 m^3/ha.

4. CONCLUSIONS

InfoCrop model based on radiation energy use efficiency in photosynthesis was used to simulate crop growth and to predict climate change impacts on rice, wheat and maize yields. Historical climate change scenario has little or no negative impacts on rice and wheat yields in Mymensingh and Dinajpur, however IPCC climate change scenario has higher negative

impacts than historical climate change scenario. IPCC climate change scenario is more negative for wheat yields than rice yield. There is almost no change in the yields of rice and maize for the historical climate change scenario in the Chittagong Hill Tracts, but there is a small decrease in the yields of rice and maize for IPCC climate change scenario. A new method has been applied for prediction of climate change impacts on world fishery. The impacts may be positive or negative depending on the climate scenarios. This model can predict the climate change impacts on fish catch in the different world oceans, at least qualitatively with a probability statement. An individual based gap model using SIMILE has been developed and simulated to address the cutting cycles and further study is underway to refine the model and update data and predict the climate change impacts on mangrove forests for climate change scenarios.

REFERENCES

- Aggarwal, P.K., Kalra. N., Chander, S., and Pathak, H.,2006a. InfoCrop: A dynamic simulation model for the assessment of crop yields, losses due to pests, and environmental impact of agro-ecosystems in tropical environments. I. Model description. *Agricultural Systems,* 89(1), pp. 1-25.
- Aggarwal, P.K., et al., 2006b. InfoCrop: A dynamic simulation model for the assessment of crop yields, losses due to pests, and environmental impact of agro-ecosystems in tropical environments. II. Performance of the model. *Agricultural Systems,* 89(1), pp.47-67.
- Aggarwal, P.K., Kropff, M.J., Cassman, K.G., and Berge, H.F.M., 1997. Simulating genotypic strategics for increasing rice yield potential in irrigated, tropical environments. *Field Crops Research,* 51, pp. 5-17.
- Bakun, A.1990. Global climate change and intensification of coastal ocean upwelling. *Science,* 247, p. 4939.
- Bakun, A., and Broad, K.,2003. Environmental Loopholes and fish population dynamics: Comparative patter recognition with focus on El Niño effects in the Pacific. *Fisheries Oceanography,* 12(415), pp. 458-473.
- Bala, B.K., et al., 2000. Computer Modelling of Integrated Farming Systems and Environment: The Case of Bangladesh. Proceedings of the Ninth National Conference on System Dynamics, December 26-29, 2000, Hyderabad, India.
- Bala, B.K., Matin, M.A., and Hossain, M.A., 2003. Modeling of Forest Dynamics of the Sundarbans. Proceedings of the International Conference on Mechanical Engineering at BUET, Dhaka, 2003
- Bala, B.K., Matin, M. A., and Hossain, M. A., 2004. Modeling of forest dynamics of the Sundarbans. Proceedings of the International Conference on Modeling Forest Production, held on 19-21 April 2004, Vienna, Austria, 2004.
- Bala, B.K., Matin, M.A., and Hoque, A.K.F., 2008.Simulation of forest dynamics of the Sundarbans. Proceedings of the national Conference on systems thinking and system dynamics (NCSD-2886), held on 29 February-01 March 2008, Baranas Hindu university, Varanasi, India, pp. 30-44.
- Biswas, B.K., Svirezhev, Yu.M., and Bala B.K.,2005. A model to predict climate change impact on fish catch in the world oceans. IEEE Transactions on Systems, Man and Cybernetics, Part A., 35(6), pp. 773-783.
- Bossel, H., 1991 Modelling forest dynamics: moving from description to explanation. *Ecological Management,* 42, pp. 129-142.
- Bossel, H., and Krieger, H.,1991. Simulation model of natural tropical forest dynamics. Ecological Modelling, 59, pp.37-71.
- Botkin, D.B., 1993. Forest Dynamics: An Ecological Model. Oxford University Press, New York.
- Chen, R., and Twilley, R., 1998. A gap dynamic model of mangrove forest development along gradients of soil salinity and nutrient resources. *Journal of Ecology,* 86, pp. 37-51.
- De Silva, C.S., Weathearhead, E.K., Knox, J.W., and Rodriguez-Diaz, J.A., 2007.Predicting the impact of climate change- A case study of paddy irrigation water requirements in Sri Lanka. *Agricultural Water Management,* 93, pp. 19-29.
- Drouet, J., and Pages, L.,2007.GRAAL-CN: A model of GRowth, Architecture and ALlocatio for Carbon and Nitrogen dynamics within whole plants formalised at the organ level. *Ecological Modelling,* 206, pp. 231-249.
- Fyllas, M.N; et al., 2007. Development and parameterization of a general forest gap dynamics for the North-eastern Mediterranean Basis (GREek FOrest Species). *Ecological Modelling,* 204, pp. 439-456.
- Hoel, P.G., Elementary Statistics. John Wiley & Sons, Inc., New York, 1966.
- Huth, A., and Ditzer, T., 2000. Simulation of the growth of a lowland Dipterocarp rain forest with FORMIX3. *Ecological Modelling,* 134, pp.1-25.
- Ito, A.,and Oikawa, T., 2002. A simulation model of the carbon cycle in land ecosystems (Sim-CYCLE): a description based on dry-matter

production theory and plot-scale validation. *Ecological Modeling,* 151, pp. 143 176.

- Klyashtorin, L.B., 1998. Long-term change and main commercial fish production in the Atlantic and Pacific. *Fisheries Research,* 37 pp. 115-125.
- Köhler, P.,2000. Modeling anthropogenic impacts on the growth of tropical rain forests using an individual-oriented forest growth model for analyses of logging and fragmentation in three case studies. Ph.D Thesis, University of Kassel, Germany.
- Köhler, P., and Huth, A., 1998. The effect of tree species grouping in tropical rain forest modelling - Simulation with the individual based model FORMIND. *Ecological Modelling,* 109(3), pp. 301-321.
- Köhler, P., and Huth, A.,2004. Simulating growth dynamics in South-east Asian rainforest threatened by recruitment shortage and tree harvesting. *Climate Change,* 67., pp.95-117.
- Magrin, G. O., Travasso, M. I., and Rodriguez, G. R., 2005. Changes in climate and crop production during the 20th century in Argentina. *Climate Change,* 72, pp. 229-249.
- Masera, O.R., et al., 2003. Modeling carbon sequestration in afforestation, agroforestry and forest management projects: the CO2FIX V.2 approach. *Ecological Modelling,* 164, pp. 177-199.
- Mati, B. M.,2000. The influence of climate change on maize production in the semi-humid-arid areas of Kenya. *Journal of Arid Environment,* 46, pp. 333-344.
- Meza, F. J., Silva, D., and Vigil, H., 2008. Climate change impacts on irrigated maize production in Mediterranean climates: Evaluation of double cropping as an emerging adaptation alternative. *Agricultural Systems,* 96(1); pp. 21-30.
- Orlowski, A., 2003. Influence of thermal conditions on biomass of fish in the Polish EEZ. *Fisheries Research,* 63, pp. 367-377.
- Pathak, H., and Wassmann, R.,2008. Quantitative evaluation of climatic variability and risk for wheat yield in India. *Climatic Change,* 93(1-2), pp.157-175.
- Petoukhov, V. et al., CLIMBER-2: A climatic system model of intermediate complexity. Part I: Model description and performance for present climate, PIK report No. 35, 1998.
- Phillips, D.P., et al., 2003. An individual-based spatially explicit tree growth model for forests in East Kalimantan (Indonesian Borneo). *Ecological Modelling,* 159, pp. 1-26.
- Rosenzweig, C., et al., Impacts on Bangladeshi Rice. Available online at: http://siteresources.worldbank.org/EXTWAT/Resources/4602122-1213366294492/5106220-1234469721549/20.2_Modeling_the_impact_of_CC_on_Agriculturet.pdf
- Saseendrain, S. A., et al., 2000. Effects of climate change on rice production in the tropical humid climate of Kerala, India. *Climate Change,* 44, pp. 495-514.
- Shugart, H. H., 1984. A Theory of Forest Dynamics: The Ecological Implications of Forest Succession Models. Springer Verlag, New York.
- Tian, Y; Akamine, T; and Suda, M. Variations in the abundance of Pacific Saury (Colobasis saira) from the Northwestern Pacific in relation to oceanic-climate changes. *Fisheries Research,* 60; 2003, 439-454.
- Tietjen, B., and Huth, A., 2006. Modelling dynamics of managed tropical rainforests - An aggregated approach. *Ecological Modelling,* 199, pp. 421-432.
- Wallman, P., et al., 2004. ForSAFE An integrated process-oriented forest model for long-term sustainability assessments. *Forest Ecology and Management,* 207, pp. 19-36.
- Yao, F., et al., 2007. Assessing the impact of climate change on rice yields in the main rice areas of China. *Climate Change,* 80, pp. 395-409.

IMPACT OF CLIMATE CHANGE ON FOOD SECURITY IN SOUTHWEST COASTAL REGION OF BANGLADESH

Md. Saiful Islam and Abdur Rahman**

ABSTRACT

This paper examines the impact of climate change on food security of the population residing in the coastal area of Bangladesh. Based on multistage random sampling technique, a survey was conducted to collect socioeconomic and food datasets of the people affected by extreme climate events in the country. The study found that climate change caused food insecurity in the region; it led to greater dependence on pond and rain water for cooking food and water intake. Catastrophe due to extreme weather events adversely affected the livelihoods and level of income. The severe cyclonic storms, Sidr (November 2007) and Aila (May 2009) severely affected the vulnerable people of this region, especially the extremely poor.

The study came out with several coping strategies to address adverse effects of climate change, including rehabilitation with income and employment generating activities and skill development training; alternative livelihood adaptation practices; access to subsidized inputs and credits; introduction of crop calendars; conservation of arable and fellow land; and innovation of saline-tolerant, heat-resistant, moderate water consuming and short-rotation crops for the coastal people.

Keywords: *Climate Change, Food Security, and Agriculture.*

1. INTRODUCTION

Climate change is sometimes used to refer to global warming, a change in climate, which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods (UNFCCC, 1994). The main causes of climate change are the burning of fossil fuels to meet increasing energy demand, as well as the spread of intensive agriculture to meet increasing food demand, which is often accompanied by deforestation. It is increasingly recognized as the most pressing issue that poses serious global threat and has the potential to irreversibly damage the natural resource base on which agriculture depends, and thus, adversely affects agricultural productivity in general.

In Bangladesh, the significant impacts of climate change is being observed in the form of hotter summer; irregular monsoon with untimely rainfall; increased river flow with inundation during the monsoon season; heavy rainfall over shorter period causing water logging, and increased frequency, intensity and recurrence of floods; very scarce rainfall in dry period; drought in summer; very short and acute cold spell; and salinity intrusion along the coastal region. All these factors have been damaging the agricultural production to a significant extent.

The geographical location and geo-morphological condition makes Bangladesh one of the most vulnerable countries to climate change, where floods, droughts, cyclones and tidal surges are common threats. Bangladesh is situated at the interface of two different environments, with the Bay of Bengal to the south and the Himalayas to the north. This particular geography of Bangladesh causes not only life-giving monsoons, but also catastrophic ravages of natural disasters. About 10 percent of the country is hardly one meter above the Mean Sea Level (MSL), and one third is under tidal excursions (Karim, 2010).

The southern part of Bangladesh consists of coastal lowland and mangrove areas, formed by the delta of large river systems. According to 2001 population census, the coastal zone of Bangladesh has a population of 35.1 million. More than a quarter of the population of the country lives in a coastal environment with multiple vulnerabilities and opportunities. Their despair and dream, their plight and struggle, their vulnerability and resilience, are exclusively dependent on an intricate ecological and social setting that makes their livelihoods distinctive from other parts of the country to a considerable extent. The combination of natural and man-made hazards seem to have adversely affected lives and livelihoods in the coastal zone, and slowed down the pace of socioeconomic developments in this region.

Since the coastal part of Bangladesh is extremely vulnerable to floods, cyclones and many different kinds of calamities, many people are affected by these calamities every year. The occurrence of Very Severe Cyclonic Storm Sidr on 15 November 2007 and Very Severe Cyclonic Storm Aila on 25 May 2009 are the relatively recent cyclonic catastrophes that have permanently altered the agricultural production in the southern region of Bangladesh to have downwards trend. The southwest coastal region is the most affected region of Bangladesh where most of the people are vulnerable. Thus, crop production in the

* Khulna University, Khulna, Bangladesh. Email: saifecon@yahoo.com

country seems to be vulnerable under climate change scenarios leading the country's food security at risk. Food security exists when all people at all times have physical or economic access to sufficient, safe and nutritious food to meets their dietary needs and food preferences for an active and healthy life (FAO, 2006).

Climate change is likely to have serious impacts on the four dimensions of food security: food availability, food accessibility, food utilization and food system stability. Effects are already being felt in global food markets, and are likely to be significant in specific rural locations where crops fail and yields decline. Impacts are more visible in southwest coastal regions where supply chains are disrupted, market prices increase, assets and livelihood opportunities are lost, purchasing power falls, human health is endangered, and affected people are unable to cope. Thus, southwest coastal region has been shaken by the devastating cyclones, Sidr and Aila, which affected millions of people, and destroyed their land, house and ways of living. Besides, see level rise flooded many areas with saline water, which is detrimental to crop production. Food is one of the fundamental rights of the people. Production and availability of sufficient qualities of safe and healthy food lay the foundation of healthy communities, culture and environment. Hence, the study regarding climate change and its impact on food security was conducted to understand ways and means to improve the quality of life of the people affected by climate change.

In order to suitably highlight the findings of the study, this paper is organized as follows: objectives of the study; data and methodology; results and discussion; and conclusion and recommendations.

2. OBJECTIVES OF THE STUDY

The following specific objectives were set forth to examine the climate change and its impacts on food security in the southwest coastal region of Bangladesh:

- To identify the affectees of climate change in the southwest coastal region of Bangladesh;
- To identify impacts of climate change on the socio-economic conditions of the target population in the area;
- To suggest appropriate policy options to address climate change and food security concerns.

3. DATA AND METHODOLOGY

The study was a survey research, based on primary data collected. To conduct the study a multistage sampling technique was adopted. In southwest coastal region of Bangladesh, there are three districts, namely Khulna, Bagerhat and Satkhira. The Khulna district has nine upazilas. The Dacope upazila of Khulna district has 10 union councils, of which three union councils, namely Bajua, Kamarkhola, and Saherabad, were purposively selected for the study. From within these three councils four villages were purposively selected keeping in view that residents from these villages were seriously affected by climatic calamities. To determine an appropriate sample size 20 households from each selected villages were randomly surveyed, and thus, the sample size stood at 80. The heads of affected households were considered as respondents to the survey.

An interview schedule containing both closed and open-ended questions was used to collect data from the respondents. The schedule was pre-tested; necessary correction and modification were made before it was run for final data collection. Data were collected through face-to-face interview during the period of March-April 2010. Collected data were analyzed using SPSS 16.

4. RESULTS AND DISCUSSION

4.1 Socioeconomic Characteristics of the Victims of Climate Change

Characteristics of individuals largely influence their behaviors. The investigated characteristics included age, education, family size, annual income, occupation and housing. The gathered information of the socioeconomic characteristics of the target population is summarized in the Table-1.

Age Distribution: Most of the respondents (37.5%) belonged to the 46 to 60 years age bracket; 30 % to the 31 to 45 years age bracket; while 20 % respondents had the age between 15 to 30 years. Only 12.5 % respondents were above 60 years of age.

Educational Status: Educational status is one of the most important indicators of social development and standard of living. Fifty percent of the respondents were found to be illiterate; 30 % had only received primary education; while 12.5 % had secondary and 7.5 % had tertiary education. Thus, the people of the region were even below the national average literacy

Table-1: Socioeconomic Characteristics of the Victims of Climate Change

Characteristics	Categories (Score)	Distribution of respondents			
		Number	(%)	Mean	Standard Deviation
Age	Young (15-30)	16	20	43.18	12.25
	Mid age (31-45)	24	30		
	Old (46-60)	30	37.5		
	Above 60	10	12.5		
Educational Status	Illiterate	40	50	0.78	0.94
	Primary education	24	30		
	Secondary	10	12.5		
	Above	6	7.5		
Occupational Status	Farmer	40	50	-	-
	Shrimp farming	16	20		
	Small business	10	12.5		
	Day laborer	6	7.5		
	Others	8	10		
Income (Taka)	< 1500	30	37.5	1705	886.63
	1501-2000	24	30		
	2001-3000	14	17.5		
	3000 above	12	15		
Expenditure (Taka)	0-1000	2	2.5	2995	1136.78
	1001-2000	12	15		
	2001-3000	38	47.5		
	3001-4000	10	12.5		
	4001-5000	12	15		
	above 5000	6	7.5		

Source: *Field Survey, March 2010*

rate of 55 % (World Bank, 2010).

Occupational Status: Most of the respondents were directly or indirectly relying on agriculture and fisheries in the absence of industry. Fifty percent of the respondents were involved in agriculture, 20 % were doing shrimp farming along with small scale of agriculture. Besides, 12.5 % of the respondents were engaged in small-scale businesses, 7.5 % were day laborers, and 10% were engaged with various service sectors, like education and NGOs.

Income Status: Most of the respondents belonged to the low-income group with little income per month. Out of the target population surveyed, 37.5 % had income below Tk. 1,500, followed by 30 % having an income bracket between Tk. 1,500 and 2,000. The surveyed group that was earning between Tk. 2,000 to 3,000 made 3, and only 15% had a monthly income of over Tk. 3,000.

Expenditure Status: The households under the study were unable to fulfill their basic needs due to high costs and low income. It was evident from the survey that most of the households (47.5%) were spending between Tk. 2,001 to 3,000 to meet their needs. Only 15 % of the respondents had family expenditure between 1,001 to 2,000; 12.5 % between 3,001 to 4,000; 15 % between Tk. 4001-5000, and merely 7.5% were spending above Tk. 5,000. Thus, there was a gulf of difference between the income and expenditure of the target populations, reflecting the extent of misery of people living in the coastal belt of Bangladesh with little opportunities and greater hardships.

4.2 Source of Income

Source of income indicates the quality of life and the level of food security. About seven years ago most of the people of the region were well-off and their main sources of earning were agriculture and fisheries. The severe cyclonic storms, Sidr and Aila, destroyed their crop lands, and many people were compelled to change their occupations.

Table-2 shows the source of income of the respondents. As per the survey conducted, the table indicates the sources of income at the time of the survey and the source of income about seven years before that. It shows that seven years ago, 62.5 % of the respondents were engaged in agriculture, while 22.5% in fisheries, and 5 % in small businesses. After the two severe cyclones, the population under study was compelled to consider changing their occupations and sources of income. After Sidr and Aila cyclones,

Table-2: Sources of Income

At the time of study	Respondent		Seven years before the study	Respondent	
	Number	%		Number	%
Agriculture	38	47	Agriculture	50	62.5
Fisheries	22	27	Fisheries	18	22.5
Small business	6	7	Small business	4	5
Day laborer	6	7	Day laborer	4	5
Sundarbans	4	5	Sundarbans	2	2.5
Others	4	5	Others	2	2.5
Total	80	100		80	100

Source: *Field Survey, March 2010*

Table-3: Daily Food Intake

Menu of Food	Respondents	
	Number	%
Rice	80	100
Wheat	30	37.5
Fish	60	75
Milk	20	25
Meat	4	5
Vegetable	60	75
Fruits	6	8

Source: *Field Survey, March 2010 (Multiple Response)*

vast agricultural land become unusable due to salinity intrusion, and people were compelled to switch to shrimp farming on agricultural land. Besides, a segment of the population opted for establishing small businesses and earning living as day laborers. The share of agriculture as source of income, drastically declined to 47 %. That of fisheries increased to 27 %, and similarly share of small businesses and day laboring increased to 7 % and 5 %, respectively.

4.3 Dietary Habits

As the surveyed inhabitants of the coastal region of Bangladesh were mostly poor, their food intake was neither enough nor nutritionally rich. They were unable to meet the minimum food requirements for a normal human body.

Table-3 reveals the dietary habits of the surveyed sample group. It was noted that all the respondents consumed rice on daily basis, 75 % took vegetable and fish, 37.5 % consumed wheat, 25 % took milk, and a very few could afford meat and fruit in their daily diet.

4.4 Frequency of Meals

Many of the surveyed people were not able afford three meals a day. They were not getting proper meals and some even went without a meal. The frequency with which the surveyed group was taking meals is shown in Table-4.

The survey showed that 30 % households were able to manage three meals a day at the time of the survey, while 62.5 % used to take three meals a day seven

Table-4: Frequency of Meals

Number of meal	Food Intake at the time of Survey		Food takings seven years ago	
	Number	%	Number	%
One time	16	20	0	0
Two times	40	50	24	30
Three times	24	30	50	62.5
More than 3 times	0	0	6	7.5
Total	80	100	80	100

Source: *Field Survey, March 2010*

Table-5: Sources of Drinking Water

Sources	At the time of survey		Seven years ago	
	Number	%	Number	%
Rain Water	40	50	36	45
Pond Water	70	80	60	75
Deep Tube-well	10	12.5	50	62.5
Others Sources	10	12.5	6	7.5

Source: *Field survey, March 2010 (Multiple Response)*

Table-6: Dynamics of Land Use Pattern

Land Use Purpose	Average Land Holding (Katha)	
	At the time of survey	Seven years ago
Dwellings	8	15
Cultivable land	45	60
Uncultivable	20	5
Shop, bazaar etc.	1.5	2.4

Source: *Field Survey, March 2010; Note: 60.61 Katha = 1 Acre*

years ago. It is also found that half of the respondents (50 %) were taking two meals a day and 20 % of the respondents managed only one meal a day. At the time of the survey none of the respondents were able to manage more than three meals a day, while 7.5 % informed that they had more than three meal a day seven years ago. Thus, climate changes lowered food intake of the coastal inhabitants.

4.5 Sources of Drinking Water

Due to extreme salinity, ground water was it is absolutely undrinkable. So the coastal people were making use of rain and pond water to drink. The water crisis was seen to be worsening due to adverse effect of climate change. Table-5 summarizes the information given by respondents indicating their source of drinking water.

Through the survey, multiple responses were found regarding the source of drinking water. The survey disclosed that a majority (62.5 %) households used to take drinking water from deep tube-well 7 years ago, but at the time of survey only 12.5 % households were able to get water from that source. Fifty percent of the households were relying on stored rain water as the chief source of drinking water. It was also noted that 80% of the households were using pond water as the main source of drinking water.

4.6 Land Use Pattern

The Table-6 provides data on the land use pattern of the inhabitants of the southwestern coastal region of Bangladesh.

The survey showed that on average 8 katha land was being used for dwelling purposes at the time of the survey, while about 7 years ago 15 katha land was used for the same purpose. The land use for cultivation purposes also decreased, on average 45 katha land was being used at the time of the survey while 7 years ago on average 60 katha land was used for the purpose. Similar, downtrend was seen in the average land use for shops and bazaars. The average size of uncultivable land was drastically increased during the same period. Thus, over the years the land use pattern had a declining trend.

4.7 Perceived Causes of Declining Land Property

Table-7 provides data on the causes of declining land property as perceived by the respondents of the study area.

Table-7 depicts that 80 % of the respondents of the survey considered river erosion as the main cause of declining land property. Three-forths of the respondents considered salinity intrusion, 50 % viewed cyclones, and 37.5 % perceived land fragmentation as the causes of declining land property.

4.8 Climatic Impact on Agriculture and Food Security

The southwest coastal region of Bangladesh being vulnerable to climate change witnessed socio-economic condition of this area altered especially after the two major cyclones, Sidr and Aila. Many crop lands, shrimp firm, trees were inundated due to cyclones, floods, and salinity intrusion. The

Table-7: Perceived Causes of Declining Land Property

Causes	Respondents	
	Number	%
River erosion	64	80
Salinity intrusion	60	75
Cyclones	40	50
Land fragmentation	30	37.5

Source: *Field survey, March 2010 (Multiple Response)*

catastrophes caused by climate change led to reduced monthly incomes of the inhabitants, degraded crop lands, reduced agricultural yield, made food inaccessible and the prices of food items went up, in a nut shell increasing food insecurity.

4.9 Changing Income Pattern

The main source of income of the southwestern coastal people has been agriculture. Due to climate change the coastal people had to change the occupations. The disaster caused by the severe cyclones changed the financial and economic status of the people.

From the Table-8, it is evident that there was a huge difference between the incomes before and after the natural disasters, and the people of the southwest coastal region were severely affected by the climate change manifested by Sidr and Aila, and their food security was threatened.

4.10 Changing Expenditure Pattern

Due to climate change expenditure pattern of the surveyed population have changed over the years.

Table-9 shows that the expenditure before and after cyclone Sidr. It is evident that the mean expenditure before major natural disaster was Tk. 4,272.5, while after the disaster the mean expenditure was reduced to Tk. 2995 only. Thus, it is evident that due to climate change the expenditure pattern of the respondents drastically declined over the years.

4.11 Dynamics of Cost of Foods

Due to climate change the source of income and food production has been on decline. The cost of food in this area has been increasing day by day. It was noticed that average expenditure on food items by the coastal people was Tk.1,000 some seven years ago, and it increased to Tk.1,500 now at the time of survey. This shows how drastically food prices went up for the vulnerable people of southwest coast of Bangladesh (Field Survey).

4.12 Vulnerability Effect on the Study Areas

Households suffer not only from natural disasters but also from a broad range of other affiliated issues. The households are vulnerable when they are unable to cope with the risk, stress, and shock. Based on the field survey in the target area, the vulnerability contexts posing several threats on the lives, property, settlements and livelihood patterns were identified. The effect for the vulnerability contexts of the study were assessed as a percentage of population affected by the problem.

Table-10 shows that cyclones left 50 % of the respondents homeless, 75 % faced food shortages, 65 % bore loss to property, 15 % got affected by diseases, 89 % faced shortage of drinking water, 42 % observed decreased production, 59 % suffered from reduced income, 70 % faced sanitation problem, and 55 % were left with damaged homes and 88 % with damaged communication system. The cyclones had severe impacts on the livelihood of people of the study

Table-8: Test of the Significance of the Differences of between Income Before and After the Natural Disasters

Method	Value	Level of Significance	Test
Z-test	3.23	0.05	Two Tailed
Category Statistics			
Variables	**Sample Size**	**Mean**	**Std. Deviation**	**Std. Error Mean**
Income Seven years ago	80	5105.00	1858.44	293.84607
Present income	80	1705.00	886.63	140.19

Source: *Author's calculation*

Table-9: Changing Expenditure Pattern

Expenditure	Before				After			
	Number	%	Mean	SD	Number	%	Mean	SD
0-1000	0	0	4272.5	1688.11	2	2	2995	1136.78
1001-2000	8	10			12	15		
2001-3000	14	17.5			38	48		
3001-4000	12	15			10	12.5		
4001-5000	30	37.5			12	15		
Above-5000	16	20			6	7.5		
Total	80	100			80	100		

Source: *Field Survey, March 2010*

area. In the same fashion, tidal surge, floods, river erosion, heavy rainfall, and salinity intrusion all had more or less similar impacts on the people of the study area as depicted in table 10. The respondents were mainly dependent on pond and rain water. Due to lack potable water 81 % of the respondents face water crises, and 44 % of them had water-borne diseases.

4.13 Vulnerability Ranking of Declining Agricultural Production

Food production is hampered when farmers are unable to cope with and respond to risk, stress and shocks. On the basis of the field survey the vulnerability contexts were prepared that interrupted the target population's food production. The vulnerability scores of food production were classified as high, medium and low.

Table-11 indicates that 100% respondents viewed that salinity intrusion and river erosion occurring throughout the year posed major risks. Cent percent respondents perceived that salinity intrusion was the major cause of declining food production, and ranked it 'high'. While 93 % of respondents viewed river erosion as a high and 30 % as a medium degree problem responsible for declining food production. All the respondents recognized cyclones as a high degree risk, which occurred 2~3 times a year. The cyclones, Sidr and Aila, carried out devastating impacts in the area under study; 90 % of the respondents perceived cyclone as a high risk and 62.5 % as a medium level threat responsible for declining food production in the region. Similarly, floods, tidal surge, and heavy rainfall had more or less similar impacts on the food production in the study area. Thus, it is evident that climate change has been causing significant impact on the food production in the study area.

4.14 Dynamics of Agricultural Production

Agricultural production was reduced tremendously due to frequent natural disasters and climatic events over the years. The following table shows agricultural production in the study area at the time of survey and

Table-10: Vulnerability Effects of Climate Change on the Study Area (Figures in terms of % of population)

Vulnerability Contexts	Homeless	Food Shortage	Property Loss	Diseases	Drinking Water Shortage	Production Decline	Reduce Income	Sanitation Problem	Snake Attack	Home Damage	Damage Communication System
Cyclone	50	75	65	15	89	42	59	70	6	55	88
Tidal Surge	29	24	47	12	51	42	33	55	7	77	61
Floods	47	47	35	35	35	59	29	59	29	29	29
River Erosion	31	0	35	0	0	21	11	3	0	47	36
Heavy Rainfall	4	29	11	2	0	24	18	4	0	4	47
Salinity Intrusion	0	35	12	0	24	47	29	0	0	0	0
Portable Water Crisis	0	0	0	44	81	0	0	0	0	0	0

Source: *Field Survey, March 2010 (Multiple Responses)*

Table-11: Average Frequency of Climatic Problems and Ranking in Declining Food Production

Climatic Problem	Respondents		Average Frequency	Ranking in Declining Food Production					
				Highly		Medium		Low	
	Number	%		Number	%	Number	%	Number	%
Salinity Intrusion	80	100	Round the year	80	100	0	0	0	0
River Erosion	80	100	Round the year	74	93	30	37.5	0	0
Cyclones	80	100	2~3 times	72	90	50	62.5	0	0
Floods	60	75	1~2 times	68	80	44	60	58	72.5
Tidal Surge	24	30	1~2times	40	50	30	37.5	20	25
Heavy Rainfall	30	37.5	2~5 times	40	50	44	55	32	40

Source: *Field Survey, March 2010 (Multiple Responses)*

seven years before it.

Table-12 depicts data on the production of major crops in the study year. It is evident from the table that production of all major crops, including vegetables, was drastically decreased due to climatic reasons, while only the production of water melon increased as it grows well in saline soils and water.

4.15 Loss of Average Food Production Due to Climate Change

Climate change mostly affected the agricultural production in southwest coastal region of Bangladesh due to adverse effects of rising sea level, chronic salinity intrusion, cyclone, tidal surge and others calamities. Thus food production was observed to be decreasing day by day.

Table-13 shows yearly loss of average food production due to climate change. Most of the respondents (30 %) claimed that loss of food production was around Tk. 2001-3000; 25 % of respondents argued that their losses remained within the range of Tk. 3001-4000; while 20 % of respondents claimed that their loss of food production was around Tk. 4001-5000. On the other hand, a small number of respondents claimed that their loss of food production was around Tk. 5001-6000 (5%), Tk. 6001-7000 (7.5%), and Tk. 7001-8000 (5%). However, the mean loss of food production was estimated to be Tk. 3,755 per year.

4.16 Price Trends of Rice

The climate is taking place severely for the last few years and its adverse effects are seen on the price of basic commodities as their productions are declining over the years. Since most of the coastal people are poor, they feel contented if they get their daily necessities at cheaper rates. Rice being the main food, the price trends of average quality rice are shown in following table:

Table-14 shows that price of rice has been increasing over the years at a faster rate. In the year 2007, when the Sidr cyclone struck, the price of rice increased by 45 %, although it came down by the next year, but again it increased in the following year when another cyclone Aila stuck. Thus, the price of rice has had increasing trend over the years because of adverse impact of climate change and a severe food insecurity was observed taking place in the southwest coastal area of Bangladesh.

5. CONCLUSIONS AND RECOMMENDATIONS

After the severe cyclonic storms that were triggered by climate change effects, the food security situation deteriorated for the coastal inhabitants. The drinking water crisis became worse due to adverse effects of climate change, and majority of the respondents were compelled to use pond and rain water as the main sources of drinking water. Most of the respondents

Table-12 : Yearly Agricultural Production (Kg/Bigha)

Crops	Before 7 years	Present
Rice	700-900	200-300
Wheat	200-250	90-120
Water melon	200-320	350-600
Brinjal	160-200	Negligible quantity
Aurum	400-500	
Vegetable varieties (Cabbage, coli flower, beans)	300-400	

Source: *Field Survey, March 2010*

Table-13: Average Loss of Food Production Due to Climate Change

Average loss (Tk)	Respondents	%	Mean	SD
0-1000	1	2.5	3755	1568
1001-2000	2	5		
2001-3000	12	30		
3001-4000	10	25		
4001-5000	8	20		
5001-6000	2	5		
6001-7000	3	7.5		
7001-8000	2	5		
Total	**40**	**100**		

Source: *Field Survey, March 2010*

were found to be illiterate and poor with low income per month. Being inhabitants of coastal belt of the country, they directly or indirectly relied on agriculture and fisheries as the source of income. The survey research showed that people in the coastal belt were unable to fulfill their daily needs as there existed a gulf of difference between their income and expenditure, reflecting the extent of misery of living in a costal line vulnerable to climate change. Many of them were not able to afford three meals a day and even went without a single proper meal. Only half of the respondents were able to take two meals a day.

The catastrophes caused by Sidr and Aila cyclones compelled the inhabitants to switch their occupations, and it affected their monthly income levels. Over the years, the land use pattern towards cultivation had a declining trend due to climate change. Many croplands, shrimp firm, trees were inundated by the severe cyclones, floods, and salinity intrusion, and many agricultural land become unusable. The subsistence farmers were compelled to switch to shrimp farming on inundated crop land. The two extreme weather events left the inhabitants homeless, caused severe shortage of food and drinking water, damaged property, caused spread of diseases, affected agricultural production and levels of income, inundated sanitation networks, and destroyed communication system.

Salinity intrusion, river erosion, cyclone, floods, tidal surge, and heavy rainfall have been causing significant declining impact on the food production of the area under study. The price and cost of food production has had an increasing trend over the years and, thus, food insecurity has been taking place in southwest coastal area of Bangladesh. Some of the policy options suggested to mitigate the effects of climate change are:

- Rehabilitation should include different measures for income and employment generating activities, including skill development trainings.
- Flood forecasting and early warning system should be made effective, and crop calendars should be kept up-to-date along with special methods to be used to grow seasonal crops after disasters caused by extreme weather events.
- Saline tolerant and heat resistant, less water-requiring and short-rotation crops should be

Table-14: Price Trends of Rice (Tk/50Kg)

Year	Price	Change rate (%)
2000	500	-
2001	510	2
2002	540	5.8
2003	550	2
2004	660	20
2005	800	21.21
2006	820	2.5
2007	1190	45
2008	875	-26.24
2009	1010	15.45

Source: *Field Survey, March 2010*

identified and harvested for the coastal areas through research and development.
- Alternative livelihood adaptation practices, such as cultivation of vegetables on floating beds of water or cultivation of beans, gourds and other vegetables on embankments surrounding, should be promoted.

REFERENCES

- FAO, 2006. Policy Brief on Food Security, Issue 2, Available at ftp.fao.org/es/ESA/policybriefs/pb_02.pdf (Accessed on June, 03, 2010).
- Karim Z., 2010. Climatic impact on agriculture and food security. The Daily Star, P 6, Wednesday, February 24.
- UNFCCC, 1994. "The United Nations Framework Convention on Climate Change", 21 March 1994. Available at:<http://unfccc.int/essential_background/convention/background/items/1349.php>
- World Bank, 2010. The World Development Indicators, Washington DC.

ANNUAL EFFECTIVE DOSE DUE TO RESIDENTIAL RADON EXPOSURE IN THE DWELLINGS OF ABBOTTABAD

S.U. Rahman, R. Muhammad**, F. Khan***, M. Rafique**** & Z. Wazir******

ABSTRACT

A study was conducted to measure indoor radon concentrations in dwellings of the Abbottabad city. In this regard, CR-39 based NRPB type radon detectors were installed in drawing rooms and bedrooms of 40 selected houses and were exposed to indoor radon for 3 months. After exposure, the CR-39 detectors were etched for 8 hrs in 6M NaOH solution at 70°C and tracks were counted under an optical microscope. The observed tracks densities were related to radon concentrations using a calibration factor of 2.7 tracks.cm^{-2}.h^{-1}/kBq.m^{-3}. The mean annual estimated effective dose received by the residents of the studied area was found to be 1.48 ± 0.47 mSv y^{-1}. Comparing the current indoor radon results with the published data of international agencies, it was found that the houses surveyed in the present study were within the safe limits.

Keywords: *CR-39 detector, indoor radon concentration, effective dose, calibration factor, dwellings.*

1. INTRODUCTION

Radon is a colorless, tasteless and chemically non-reactive radioactive gas. Radon is all around us as a part of our environment. It is a naturally occurring by-product of decaying uranium, which is scattered through all of Earth s crust. The amount of radon in soil depends on complex soil chemistry that varies from place to place [1, 2]. Radon is a unique natural element being a gas, noble and radioactive in all of its isotopes. Once produced it escapes from the soils and rocks in which it is trapped. It enters into water we drink and the air we breathe. Its concentration levels depend strongly on geological, geophysical conditions and atmospheric factors. Being a noble gas, it has greater ability to migrate freely through soil, air and water [3-5].

Radon produced in the soil and other building materials enters into the indoor environment through exhalation. Radon flows from the soil into the indoor environment from the movement of gases in the soil beneath homes. The amount of radon that escapes from the soil and enter a house depends on the weather, the soil porosity, soil moisture, and the suction within the house. Radon gas can penetrate houses from many sources and in many ways [6, 7]. In indoor air, short-lived decay products of radon may attach to aerosol particles present in the air or deposit on room surfaces. Once inside a building, the radon cannot easily escape. The sealing of buildings to conserve energy reduces the intake of outside air and worsens the situation. Radon levels are generally highest in basements because these areas are nearest to the sources of radon. Radon can seep out of the ground and build up in confined spaces, particularly in basements of buildings [8].

Radon is a known human carcinogen. Prolonged exposure to the elevated radon concentrations inside dwellings may represent a significant health problem in the form of increased cancer risk. The external dose from ^{222}Rn and its air-borne progeny is a very small fraction of the natural external radiation dose received by individuals. However, inhalation of radon and its daughters may be followed by deposition of potentially large amounts of energy, from the short-lived α and β particle-emitting decay products, primarily from ^{218}Po, ^{214}Pb, ^{214}Bi, and ^{214}Po [9-14].

The dwellings under study were built, in general, using different materials, cement, sand, stones, and bricks, iron structure, marble and concrete as the construction materials. Several of these materials are expected to contribute significantly to sources of indoor radon. The knowledge of indoor radon levels in dwellings is important in assessing population exposure. In this study, etched track detectors were used to measure indoor radon levels from Abbottabad city area.

2. MATERIALS AND METHODS

Active and passive devices are available for detection and measurement of alpha particles of radon and its daughters. In the present investigations, passive technique is used to measure indoor radon concentrations. Solid State Nuclear Track Detectors (SSNTDs), the most reliable and convenient detectors for the integrated and long-term measurement of radon in the environment were used. These detectors have the advantage to be mostly unaffected by humidity, low temperatures, moderate heating, light, and are low cost. In this regard, CR-39 track detector, which mainly detects the alpha particles, has been used for monitoring of the indoor radon level in the dwellings of Abbottabad.

* Nuclear Medicine, Oncology and Radiotherapy Institute (NORI), Islamabad. ** Federal Urdu University, Islamabad. *** COMSATS Institute of Information Technology, Islamabad. **** University of Azad Jammu and Kashmir, Muzaffarabad. ***** Riphah University, Islamabad

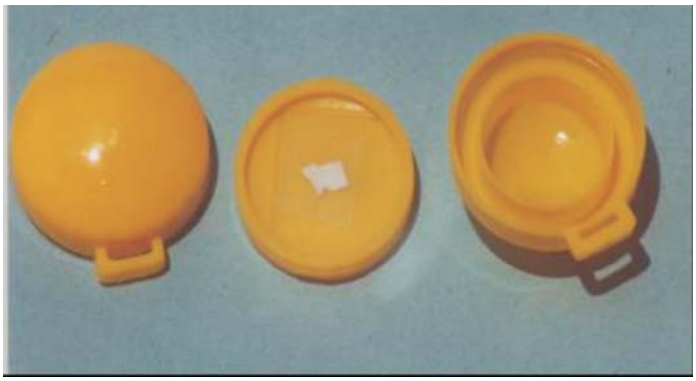

Figure-1: A photograph of the NRPB dosimeter

In order to carry out this study, large sheets of CR-39 detectors were cut and placed in the detector assembly having dimensions 1.5 × 1.5 cm^2. The detector assembly is shown in Figure-1. The design of this type of detector ensures that all the aerosols and radon decay products are kept outside and only radon diffuses into the sensitive volume of the chamber. Representative houses were selected to measure indoor radon levels at different locations. The detectors were installed at a height more than 2 meters above the ground level, about 1 meter below the ceilings and 0.5 meter away from the walls so that the direct alpha particles from the building material of the dwellings do not reach the detector films.

The detectors were installed in the bedrooms and drawing rooms of each house (all at the ground and first floors). After 90 days of radon exposure, the detectors were collected and chemically etched in 6M NaOH solution at 70°C for 8 hours. The tracks density was counted using an optical microscope at 300X magnification. After background correction, track densities were related to the radon concentrations (Bq m^{-3}) using a calibration factor 2.7 tracks cm^{-2} h^{-1}/ kBq m^{-3}[15].

3. RESULTS AND DISCUSSION

The measurements for indoor radon concentration levels were made in 30 dwellings of different ventilation conditions for three months. Table-1 summarizes the results of indoor radon concentration levels, measured in different dwellings covering drawing rooms and bedrooms of ground and first floors. The data shows that the indoor concentration obtained for the study varies from 7 ± 2 to 212 ± 15 Bq m^{-3} with an overall average value of 78 ± 25 Bq m^{-3}, which is lower than the action levels of International Commission on Radiological Protection (ICRP, 1993) recommendations, i.e., 200-600 Bq m^{-3} [16].

Mean, minimum and maximum values are also shown in the Table-1. The radon levels in the bedrooms were seen to vary from 18 ± 3 Bq m^{-3} to 178 ± 12 Bq m^{-3} with an average activity value of 84 ± 23 Bq m^{-3} for the ground floor houses. The radon concentration levels vary from 16±3 Bq m^{-3} to 167±13 Bq m^{-3} with mean values of 69 ± 26 Bq m^{-3} in the bedrooms of first floor. The indoor radon levels in drawing rooms situated on the ground floor varied from 15 ± 3 Bq m^{-3} to 212 ± 15 Bq m^{-3} with an average value of 87 ± 34 Bq m^{-3}. The values of indoor radon concentration for drawing rooms of first floor varied from 7 ± 3 Bq m^{-3} to 160 ± 14 Bq m^{-3} with an average value of 72 ± 28 Bq m^{-3}.

So far, there is no reported/approved criterion for permissible radon levels set for Pakistan. If recommendations set by the International Commission on Radiological Protection (ICRP) are followed (i.e. maximum indoor radon concentration limit of 600 Bqm^{-3}) [16], then it may be concluded that all of the houses surveyed in the Abbottabad district were within the safe limits of radon potential health hazards. On the other hand, if recommendations made by the Health Protection Agency UK and the US EPA (who suggest a maximum indoor radon concentration limit of 200 and 148 Bqm^{-3}, respectively) are followed, then only two houses had elevated value of indoor radon concentrations. The inhabitants of these dwellers were exposed to excessive radon doses. It was considered necessary for these dwellers to use more ventilation during their stay at home.

3.1 Dose Estimation

The range of dose conversion factors for radon, derived from epidemiological studies and physical dosimetry varied from 6 to 15 nSv $(Bq\ h\ m^{-3})^{-1}$. For the estimation of average effective dose [H] (mSv y^{-1}) to the inhabitants of Abbottabad due to the indoor radon

Table-1: Indoor Radon Concentrations (Bq m^{-3}) in Drawing Rooms and Bedrooms

Types of Rooms	Ground floor		Mean	First floor		Mean
	Min.	Max.		Min.	Max.	
Bedrooms	18±3	178±12	84 ± 23	16±3	167±13	69 ± 26
Drawing rooms	15±3	212±15	87 ± 34	7±3	160±14	72 ± 28

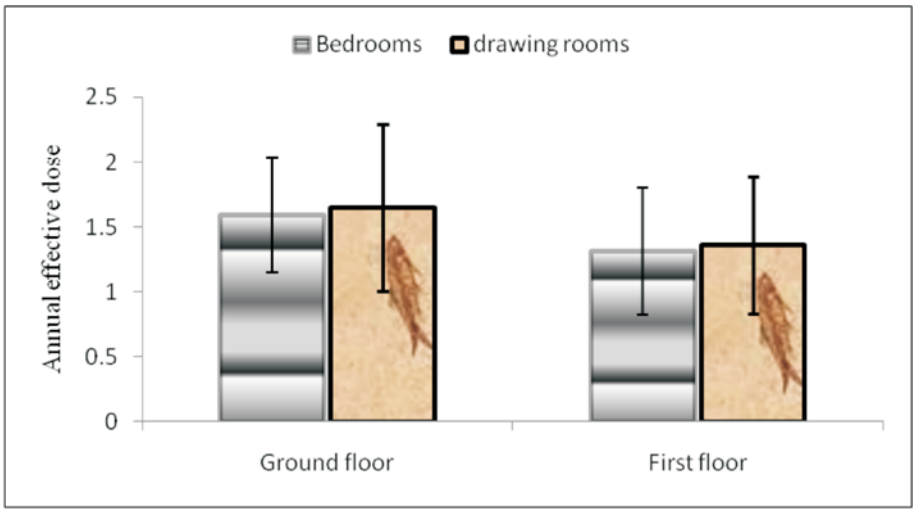

Figure-2: Annual Effective Indoor Radon Doses for Different Dwellings

and its progeny, the following model was used [15, 17,18]:

$$H = C \times F \times O \times T \times D$$

where C is the ^{222}Rn concentration (Bq m^{-3}), F is an equilibrium factor (0.4), O is the occupancy factor, T is the number of hours in a year (8760 h y^{-1}) and D is the dose conversion factor (9.0 nSv h^{-1}per Bq m^{-3}). In the study, the value of O was estimated to be 0.6, because it was assumed that out of 24 hrs per day, inhabitants of the area spend about 60% time indoors and 40% outdoors. Substituting the measured average radon concentration value of 78 ± 25 Bq m^{-3} in the above-mentioned equation, the overall average effective annual dose in the studied area came out to be 1.48 ± 0.47 mSv y^{-1}. The annual effective dose in bedrooms and drawing rooms for ground and first floor is shown in Figure-2. It can be seen from Figure-2 that annual effective doses have higher values for ground floor as compared to the first floor. It is also clear from the same figure that annual effective doses were higher in drawing rooms as compared to the bedrooms. These values were below the recommended action level (i.e. 3-10 mSv y^{-1}) [16].

4. CONCLUSIONS

Indoor radon concentrations were measured in 30 dwellings in the Abbottabad region using CR-39 based NRPB type radon detectors. Indoor radon concentrations varied from 7 ± 2 to 212 ± 15 Bq m^{-3} with an average activity concentration of 78 ± 25 Bq m^{-3}. The radon levels in drawing rooms were found to be higher than in bed rooms. It was also observed that indoor radon concentrations were higher in ground floor as compared to first floor. The mean annual effective dose equivalent due to the indoor radon concentration in the dwellings of studied area was found to be 1.48 ± 047 mSv y^{-1}, which was below the action level. Consequently, the health hazards related to indoor radon levels were found to be negligible. Occupants of these dwellings were therefore, relatively safe. Proper regulatory standards should be implemented to make the dwellings safer and it is recommended to carry out similar studies in this region.

REFERENCES

1. Faheem, M., Rahman, S., and Matiullah, 2008. A review of radon measurement studies in Pakistan. *Journal of Radiological Protection,* 28, pp. 283-

292.
2. Rahman, S.U., Anwar, J., and Matiullah, 2008. Measurement of indoor radon concentration levels in Islamabad, Pakistan. *Radiation Measurements,* 43, pp. 401-404.
3. Rahman, S.U., Rafique, M., Matiullah, and Anwar, J., 2009. Radon measurement studies in workplace buildings of the Rawalpindi region and Islamabad Capital area, Pakistan. *Building Environment,* 45(2), pp. 421-426.
4. Rahman, S., Mati, N., Matiullah, Ghauri, B.M., 2007. Seasonal indoor radon concentration in the North West Frontier Province and Federally Administered Tribal Areas of Pakistan. *Radiation Measurements,* 42, pp.1715-1722.
5. Gunby, J. A., et al., 1993. Factors Affecting Indoor Radon Concentrations in the United Kingdom. *Health Physics,* 64, pp. 2-12.
6. Rafique, M., Rahman, S.U., Jabeen, S., et al., 2009. Measurement and Comparison of Indoor Radon Levels in New and Old Buildings in the City of Muzaffrabad (Azad Kashmir), Pakistan: A Pilot Study. *Radioisotopes,* 58(11), 749-760.
7. Miles, J.C.H., 1998. Mapping Radon-prone Areas by Lognormal Modeling of House Radon Data. *Health Physics,* 74, 370 378.
8. Durrani S. A., Ilic, R., 1997. Radon Measurements by Etched Track Detectors: Applications in Radiation Protection, Earth Sciences, and the Environment. World Scientific Publishing Co. Pte. Ltd, Singapore.
9. BEIR-VI: Committee on Biological Effects of Ionizing Radiation, 1999. Health Effects of Exposure to Radon. National Academy Press, Washington, DC.
10. Rafique, M., Shahida, J., Ikram, M. S., 2008. General Public's and Physicians' Perception of Health Risk Associated with Radon Exposure in the State of Azad Jammu and Kashmir. *Public Health Nursing,* 25(4), pp.327-335.
11. Faheem, M., Rahman, S.U., Nasir, T., and Matiullah, 2010. Assessment of Lung Cancer Risk Using Weighted Average Indoor Radon levels in Six Districts of the Punjab Province of Pakistan. *Indoor Built Environment,* 19 (3), 382 390
12. Lubin, J. H., Boice, J. D., 1989. Estimating Rn-induced Lung Cancer in the United States. *Health Physics,* 57(3), pp. 417-427.
13. Matiullah, Ahad, A., Rehman, S., Mirza ,M. L., 2003. Indoor Radon Levels and Lung Cancer Risk Estimates in Seven Cities of the Bahawalpur Division, Pakistan. *Radiation Protection Dosimetry,* 107(4), pp. 269-276.
14. Lubin J. H., 2003. Studies of Radon and Lung Cancer in North America and China. *Radiation Protection Dosimetry,* 104(4), 2003, 315-319.
15. UNSCEAR: United Nations Scientific Committee on the Effects of Atomic Radiation, 2000. Source and Effects of Ionizing Radiation, United Nations, New York.
16. ICRP: International Commission on Radiological Protection, 1993. Publication 65, Annals of the ICRP 23(2). Pergamon Press, Oxford.
17. Rahman, S.U., Matiullah., and Anwar, J., 2009. Assessment of the Dose Received by Students and Staff in Schools in the Rawalpindi Region of Pakistan Due to Indoor Radon. *Journal of Radiological Protection,* 29, pp.273-277.
18. Rahman, S.U., Rafique, M., Matiullah, and Anwar, J., 2009. Indoor Radon Concentrations and Assessment of Doses in Four Districts of the Punjab Province -Pakistan. *Journal of Radiation Research,* 50, pp. 529-535.

LAND-USE CHANGE ANALYSIS OF DISTRICT ABBOTTABAD, PAKISTAN: TAKING ADVANTAGE OF GIS AND REMOTE SENSING ANALYSIS

Auriba Raza, Iftikhar A. Raja**, and Shahid Raza****

ABSTRACT

During the last decade, District Abbottabad of Pakistan has gone through extensive land-use changes due to accelerated developmental and educational advancements, urbanization, and a major earthquake in Pakistan (2005). The study was conducted to analyze and quantify the changes in land-use that occurred during 1998-2009 and the transition rate among different land-use types to better understand the complex inter-relationships and to provide a base-line for further studies of drivers of land-use change in the region. The possible causes and impacts of land-use change were discussed. Advance geographic information system (GIS) and remote sensing (RS) techniques were applied to map and analyze land-use changes. Land-use maps for the years 1998, 2005, and 2009 were developed. A transition matrix of land-use was calculated for 1998-2009. The results show an increase of 2.83 % and 9.3 % in forest and settlements areas, respectively; whereas bare land has decreased significantly by 11.4 %. Of the area converted to settlement, 34.13 % was from bare land and 32.98 % was from vegetative land. The data collected and analyzed would be useful for examining the relationship between land-use conversion and its socio-economic drivers.

Keywords: *Land-use change, Geographic information system (GIS), Remote sensing (RS), Pakistan.*

1. INTRODUCTION

District Abbottabad is located in Hazara division of Khyber Pakhtunkhwa province of Pakistan with the total area of 1,967 square kilometers [1]. With its good weather and beautiful landscape, district Abbottabad attracts people from all over Pakistan. Some come for tourism and some to seek education from a large number of emerging educational institutions. Tourism is one of the important sources of economic activity in Abbottabad [2]. In summers, when temperatures in the plains of Pakistan rise to well above 45 degrees, a large number of tourists come to Abbottabad to enjoy its pleasant climatic conditions. The district is now witnessing rapid population growth, which is affecting its environmental conditions. It is going through extensive land-use changes over the last few years. The most significant driving forces of land-use change in this region have been the 2005 earthquake [3], pleasant weather, and emerging higher education institutions, which inclined people to migrate from adjoining areas to this district. This trend has increased the need and demand of residential and commercial areas which resulted in raised prices of land available. This situation has led to deforestation and conversion of forest, grass land and agricultural land into residential colonies and commercial areas (hotels, restaurants, and markets). Due to lack of appropriate land-use planning and measures for sustainable development, these haphazard developments and construction activities led to lowering water-table, contamination of drinking water sources, flood like situations during heavy rains, increasing vehicles and recurrent traffic congestion and air pollution problems, which traditionally were not characteristic of district Abbottabad. These changes have the potential to undermine the long-term harmonious people-environment relationship. Hence, it is essential to study land-use change for the selection, planning, and implementation of land-use schemes. This study also assists in monitoring the dynamics of land-use due to the changing demands of the growing population in the district.

Remote Sensing (RS) and Geographic Information System (GIS) have been recognized as powerful and effective tools and are widely applied in detecting the spatio-temporal dynamics of land-use and land-cover (LULC) [4]. RS method cost effectively provides abundant, multi-spectral, multi-temporal, and real-time data and turns it into information valuable for understanding and monitoring land development patterns and processes and for building land-use data sets [5]. GIS has powerful function of storing, analyzing, and displaying geo-referenced data necessary for change detection [6]. The combination of RS and GIS has inestimable advantages compared to traditional methods, and is highly effective in monitoring dynamic changes of the land-use/land-cover. Based on RS, the researchers can obtain valuable multi-temporal data for monitoring land-use patterns and processes, and GIS techniques make possible the analysis and mapping of these patterns [7-8]. In this paper the land-use changes in district Abbottabad spanning 11 years from 1998-2009 have been analyzed.

* Institute of Environmental Medicine, Sweden. email: auriba.raza@ki.se. ** COMSATS Institute of Information Technology, Abbottabad Pakistan. Email: iaraja@ciit.net.pk. ***Swedish Institute of Computer Science, Sweden.

2. DATA COLLECTION AND ANALYSIS

2.1 Data Acquisition

Three Landsat TM, ETM, and ETM+ images of 1998, 2005, and 2009 were acquired from United States Geological Survey (USGS) [9]. However, these images were not of high quality. The data of land-use was acquired from Landsat image by experts interpretation. The satellite images of study area were taken in autumns of 1998, 2005, and 2009. Bands 3, 2, and 1 were used for Red, Blue, and Green, respectively. The district Abbottabad map with information of General Topography (GT), location, road network, forest, and water bodies was obtained from Survey of Pakistan [10]. The scale of the map is 1:250,000. The GT sheet was used for preparing GIS layer.

2.2 GIS Data Processing

In order to use GT sheets in GIS it is necessary to geo-reference GT sheets, i.e. to align it with existing geographically referenced data. Six ground control points were used to geo-reference the sheets. For geo-referencing Global Mapper was used [11]. Geo-referencing of GT sheets is very important to create GIS layers as it accurately sets the ground coordinates on scanned topographic map. After geo-referencing GIS layers were created in ArcView 3.1 software [12], and were later used in identifying land-use classes.

2.3 Remote Sensing Image Processing

Prior to interpretation, digital images were processed with standard procedures. The study region was clipped with the image using the software, ENVI 4.7 [13]. The satellite images were processed using methods of geo-referencing, radiometric correction [14] and image enhancement. Geo-referencing was necessary for subsequent GIS data integration. Each scene was geo-referenced by using 30 ground control points (GCPs) identified and selected from a topographic map at a scale of 1:250,000, followed by using the corrected image as a reference for image-to-image registration of all other band-images. The random distortion method was used for geometric correction of the images [15]. The study was supported with field survey investigation for having a general understanding of the area.

2.4 Satellite Image Classification

On the basis of field survey five land-use classes were identified in the district Abbottabad, i.e. settlement, vegetative land, forest, water body, and bare land. Land-use maps were acquired by classifying our satellite image. Maximum Likelihood (ML) [16] decision rule of supervised classification was applied. After applying ML classification sieved and clumped operations were carried out from post classification in order to improve the appearance of the output thematic image. The post-classification process removes high-frequency spatial variance (or noise) from the classified image. This is achieved by analyzing the neighborhood for each pixel and removing the scattered single pixels (sieve process), and then merging the small patches of pixels together to make more continuous and coherent units (clump process). This process was carried out on each satellite image using ENVI 4.7.

2.5 Accuracy Check

Each classified image was checked for accuracy by using swipe technique. Accuracy of supervised classification mainly depends upon analyst s approach to understand marked differences in land-use classes and capability of sorting out small variation occurrence in reflectance values of different land features. The images aligned perfectly when overlaid on the original images.

3. RESULTS AND DISCUSSIONS

3.1 Land-Use Distribution for the Years 1998, 2005, and 2009

The land-use change was analyzed by performing GIS and RS analysis. The integration of GIS and remote sensing techniques provided unique and useful information regarding land-use change. However, accuracy of the results obtained from the analysis depends upon expert s skills and decisions on how to separate out different pixels of different land-use features. In the present study, classified image of each year was used to determine class area. Imagery was classified for five land-use classes. Land-use classes identified were settlement, vegetation, water, forest and bare land. Table-1 presents class area and percent cover for different land-use classes for years 1998, 2005, and 2009.

Table-1 depicts increase in the area of settlement for the year 2009. This can be attributed to the upward trend of migration to the district due to its progress in education sector, increased development activities, seasonal activities and pleasant weather conditions.

Table-1: Land-use Distribution for each Land-use Class for the years 1998, 2005, and 2009

S.No.	Land use Classes	1998		2005		2009	
		Area (Km^2)	(%)	Area (Km^2)	(%)	Area (Km^2)	(%)
1	Settlement	987.8276	50.169	1064.244	54.050	1170.767	59.46
2	Vegetation	217.6335	11.053	467.95255	23.766	196.9	10
3	Water	20.4776	1.040	36.3674	1.847	26.9753	1.37
4	Forest	235.1576	11.943	299.7211	15.222	290.8213	14.77
5	Bare land	507.8838	25.794	100.7143	5.115	283.5360	14.4

Higher number of migration to Abbottabad was observed after Earthquake 2005. People from earthquake affected areas moved to the district although it was also hit by the earthquake but the damages were not as severe as they were in other affected areas. Moreover, the higher education institutions in Abbottabad have been expanding rapidly. These institutions include five new medical universities, two engineering universities, and branches of some school chains highly acclaimed in the country.

Forests and vegetation in the area first increased in 2005 and then decreased in 2009, as can be seen in Figure-1. The increase in the forest and vegetation is due to the extensive Shajar Kari Mohim (plantation campaign) conducted in 1998 to improve the forest cover of a certain area. Decrease in the later years is attributed to the increase in the human settlements and the landslides due to 2005 earthquake that eroded much of the green land and left large portions of the land barren. This is evident from the decrease in the bare land in earlier years and then increase in the later years. Whereas, the availability of water body remained almost stable throughout the study period. Figure-2 represents land-use change from 1998 to 2009.

3.2 Analysis of Land-use Classes using Transition Matrix

Transition matrix is an important aspect of land-use change as it clearly shows the direction of the change. Information extracted from transition matrix reveals desirable and undesirable changes overtime and also shows the classes that are relatively stable. Transition matrix of land-use change was calculated using RS software, ENVI 4.7. This helped to demonstrate the conversion among different land-use classes. Figure-3 shows the graph derived from transition matrix and contains information about the rate of transition that took place among different land-use classes.

As seen from Figure-3, there has been a considerable change during 11 years period. Forest and settlement has increased in the area by 2.83 % and 9.3 %, respectively, whereas bare land has decreased significantly by 11.4 %. The GIS-RS analysis further indicated that there was a clear and continuous increase in settlement from 1998 to 2009. Of the area converted to settlement, 34.129 % was bare land and 32.98 % vegetative land. Goa, et al., also found the same trend of land-use change in Manasi oasis of China [7]. There also was simultaneous decrease in the area of bare land with 20.71 % converted to vegetative land. However, 11.43 % of the forest area was converted to bare land, showing the trend of

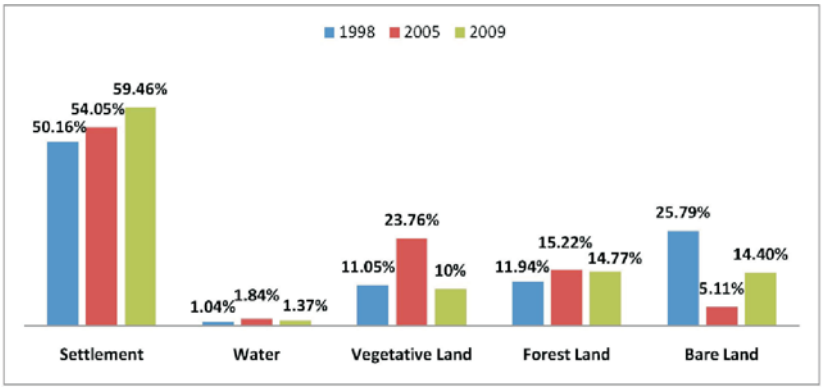

Figure-1: Land use Distribution of District Abbottabad for the years 1998, 2005, and 2009

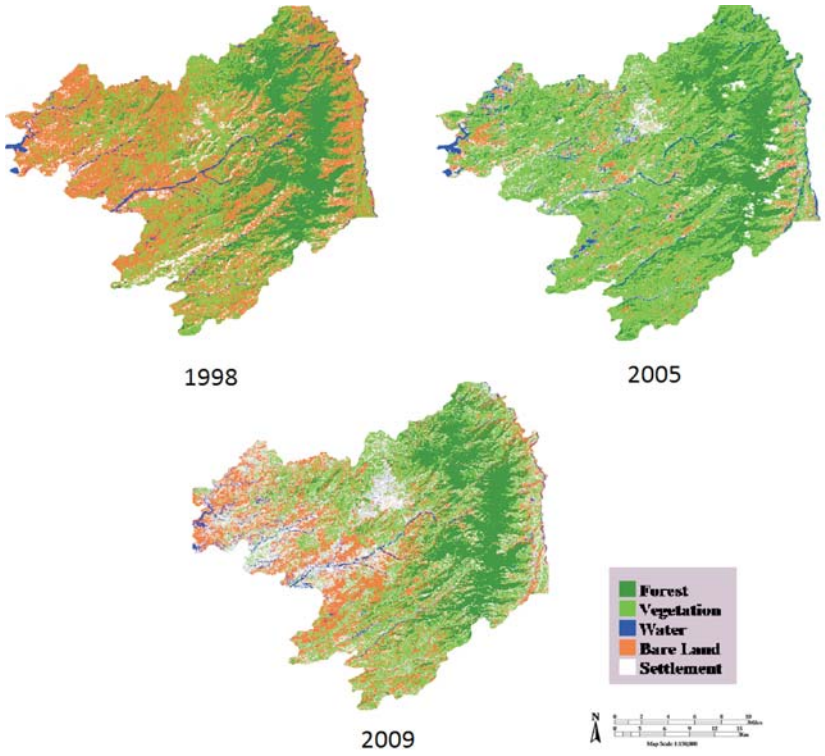

Figure-2: Land-use Pattern of District Abbottabad during 1998-2009

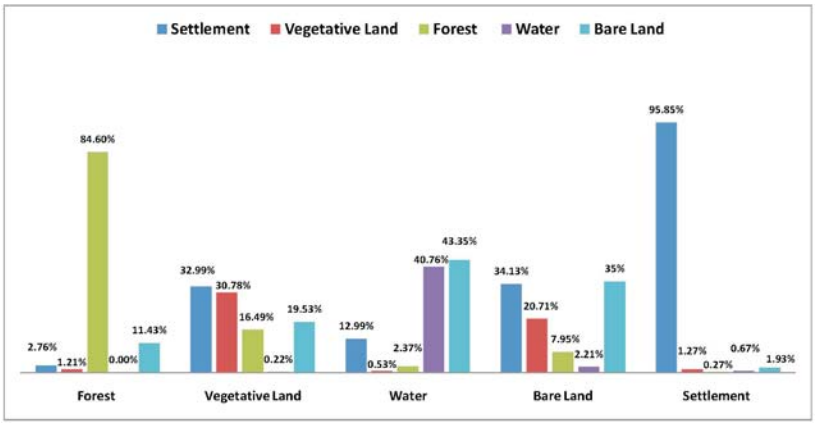

Figure-3: Conversion of Land-use Classes during 1998-2009

deforestation. These figures are useful for examining the relationship between land-use conversion and its socio-economic drivers.

4. CAUSES OF LAND-USE CHANGE

4.1 Natural Forces

Natural events directly influence the pattern of land-use. They cause changes in the natural environment and interact with the human decisions of land-use ultimately causing land-use change. The major natural

event in district Abbottabad was 2005 earthquake that has significantly altered the pattern of land-use. After earthquake, in some classes, a reverse change was observed. From 1998-2005 the pattern of land-use change was quite natural and mainly due to human activities. The results in Figure-4 show 3.8 % increase in settlement from 1998-2005 with the simultaneous increase in 12.71 % vegetative land, 0.8 % water, and 3.27 % forest cover. All these land-use changes were desirable as they were positive; the only negative trend observed was in the case of bare land, which showed 20.6 % decrease in the bare land. The other classes were increasing so the bare land converted to other land-use classes as mentioned before. After the earthquake, settlement in the area increased to 5.41 %, which is very obvious because people from the earthquake affected areas migrated to this region and became permanent residents. As far as the situation of other classes is concerned, a negative trend was observed in vegetative land, forest and water with 13.76 %, 0.47 %, and 0.45 % decrease, respectively (Figure-4). Landslides triggered by an earthquake eroded much of the green areas leaving the land barren. Another reason behind the deforestation and decreased vegetative land was the increase in the settlement. Thus, the earthquake caused land-use change in district Abbottabad.

4.2 Demographic Pressure

The changing demographic profile of the population is another major cause of land-use change. According to a census report, in 1998 the population of the district Abbottabad was 880,666, but in 2009 it has risen to 1.2 million [10]. The study shows 9.3 % increase in the settlement from 1998-2009 (Figure-1). Population increase always results in land-use change. It increases the pressure on land resources thus triggering the land-use change. Shelter is a basic need of humans. As evident from the results of this study the settlements have increased tremendously in the last decade. Forests are being converted into residential areas. The naked chalked hills are ready to be converted into a residential area and this has become a common business in the area. The famous Silk Route that runs through the main Abbottabad city now has huge plazas and wide-spread residential colonies and schools, and one can rarely find any tree along the road. Vegetative lands have been converted into residential and commercial areas. This ultimately has environmental impacts. Following are the reasons of increased demographic pressure in the District.

4.3 Establishment of Educational Institutes

In the last 10 years, many higher education institutes have been established in the district. Among the major ones are COMSATS Institute of Information Technology; Women Medical College and University; Frontier Medical College; Hazara University - Abbottabad Campus; University of Engineering and Technology - Abbottabad Campus; Abbottabad International Medical College; National Institute of Medical Sciences; Women Institute of Learning; as well as a number of schools and colleges offering intermediate level education. These institutes have attracted people from different parts of the country and contributed to the population increase of the district. These universities have also raised the value of the land. People started more developmental activities in

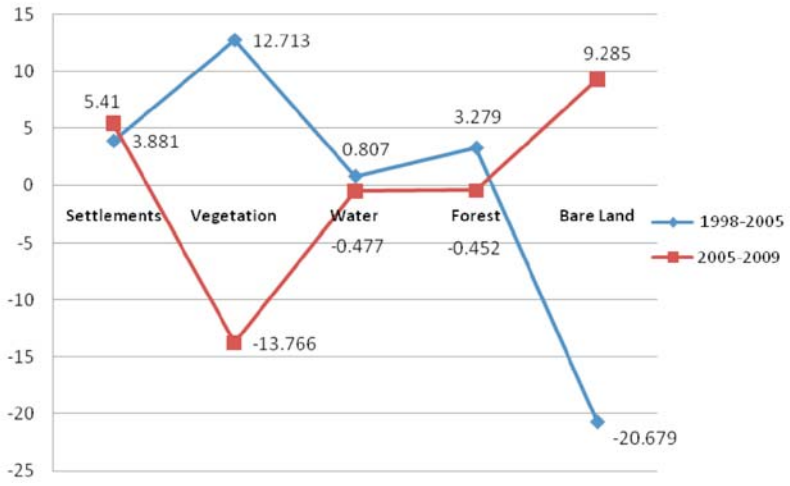

Figure-4: Percentage Change in the Land-Use Type from 1998 to 2009

the areas close to the universities and educational institutes. More residential and commercial buildings have been built, some of them transformed into hostels.

4.4 Pleasant Climatic Conditions and Human Activities

District Abbottabad is famous for its pleasant climatic conditions and breath-taking beauty. It is a hub of tourism in the country and people from all parts of the country visit this area to enjoy its weather and beauty. It has been observed that people prefer to settle in this area after retirement because of its weather, this is particularly true for armed force personnel.

Human activities that alter the land-use are agriculture, livestock raising, urbanization, deforestation, construction, and development, etc. These have some serious implications for sustainable development, climate, and livelihood systems. The study shows 9.3 % increase in settlement in district Abbottabad which is a clear sign of increased urbanization. Urbanization resulting from development, or vice versa, cause land-use change. Many new commercial plazas have been constructed on crop lands and grass lands; the study shows that 32.98 % of the vegetative land in 1998 was converted to settlement in 2009 (Figure-3). 2.75 % (Figure-3) of the forest was converted to settlements, which indicate deforestation that also results in soil erosion, and loss of biodiversity. All of these factors in turn have health, safety, and economic implications.

4.5 Mining

Mining is another cause of land-use change in district Abbottabad as it is a major mining area. According joint report of International Union for the Conservation of Nature and Natural Resources (IUCN) and Sustainable Development Policy Institute (SDPI) quarrying and mining is carried out in 108 villages, covering 4.8 % of the total land area of District Abbottabad. About 20 different minerals are excavated. A total of 308 mining licenses have been issued, of which 206 were for industrial rock and minerals (barite, clay minerals, dolomite, feldspar, graphite, gypsum, iron laterite, limestone, magnesite, phosphate, rock salt, silica sand and soapstone), 66 for dimension stone (granite, marble, serpentine), 19 for metallic minerals, 9 for gemstones and 8 for coal. About 73 % of the mines in the district are situated in hilly areas, while the remaining are on flat land. All are at a distance of less than 2 km from the water body, with the result that mine residues are polluting drinking water sources. About 18 % of these mines are located in landslide zones, posing a risk not only to the environment, but also to the safety of the local communities [17].

4.6 Cultural Changes

Cultural changes also drive land-use change. In district Abbottabad, people used to live in joint families, i.e. five to six families, live under one roof. However, due to some modern influences the trend has been changing. The extended families have been breaking down into multiple nuclear families, thus resulting in an increase in settlement area.

5. IMPACTS OF LAND-USE CHANGE IN ABBOTTABAD

The changes of land-use patterns certainly provide many social and economic benefits. However, they also come at a cost to the natural environment. In this section, the major impacts of land-use change pattern on natural environment of district Abbottabad are discussed providing key inputs to the decision-makers to make informed decisions and enforce policies to mitigate the effects of land-use change in district Abbottabad. The predicted impacts may be helpful if planning of the city is considered important to preserve the natural beauty of the district Abbottabad.

5.1 Climate Change

In district Abbottabad the settlement increase since 1998 has been 9.29 %, indicating population increase which has increased pressure on the district s natural resource; resulted in 1.94 % decrease in vegetative land; and 11.39 % decrease in bare land. The increase in population is also connected to more use of fuel in cooking, heating, and transportation. The burning of the fuel releases carbon dioxide into the atmosphere, which is resulting in increased atmospheric temperature. In the past, there were significant snowfalls in Abbottabad, but now due to increased urbanization, transportation and burning of fossil fuels, it has gradually decreased. However, the surrounding mountains are still getting enough snowfall, which has a pleasant effect on the overall temperature of the city during summers. Mining in Abbottabad is becoming very common and has resulted in complete disappearance of hills in Ghomanvan and Thandiani areas having adverse impacts on the landscape of the district and added amounts of particulates into the atmosphere. The particulates absorb radiation from

the sun and then release the absorbed energy into the atmosphere, increasing atmospheric temperatures and adversely affecting human health.

5.2 Landslides

Deforestation and removal of vegetation make soil vulnerable to soil erosion due to which landslides are more recurrent now in Abbottabad. This study shows that since 1998, 1.05 % of vegetative land has decreased due to land-use change. One additional factor contributing to landslides is agriculture practices on steep terrain, which make the soil unstable and vulnerable to erosion. Mining, which is becoming very common in district Abbottabad, also contributes to soil erosion.

5.3 Water Pollution

One of the major direct environmental impacts of land-use change resulting from urbanization is the degradation of water resources and water quality. The study shows that from 1998-2009, 9.29 % increase in the settlement has 32.98 % vegetative land, 2.75 % forest, 13 % water body, and 34.12 % bare land (Figure-3). This conversion results in increase in impervious surface, which alters the natural hydrologic condition of an area. It is well understood that the outcome of this alteration is typically reflected in increases in the volume and rate of surface runoff during heavy rainfall, and decrease in ground water recharge which is quite evident in district Abbottabad. The events of roads filled with water due to blocked drains are very commonly seen during rainy season. These eventually lead to larger and more frequent incidents of local flooding during heavy rainfall, and reduced residential and municipal water supplies. Impervious surfaces collect pollutants either dissolved in runoff or associated with sediment, such as nutrients, heavy metals, sediment, oil and grease, pesticides, and fecal coliform bacteria. These pollutants are washed off and delivered to aquatic systems by rainfall and sometimes make their way to the drinking water supplies and results in health problems. Typhoid fever and water-borne diseases are common in Abbottabad. This is because the sewage pipes and the drinking water pipes run side by side and a small leakage in the former can have adverse health impacts on the water quality.

Heavy metals are major water and sediment contaminants. The potential major urban non-point source (NPS) pollutants include fertilizer and animal waste for nutrients, roads and paints for heavy metals, and motor oil for oil and grease. These NPS pollutants make their way into water body, and underground water and deteriorate the water quality. Open drains is another problem commonly seen in the region.

Mining which is common in district Abbottabad also pose threat to the water quality. All mines are at a distance of less than 2 km from a water body, with the result that mine residues pollute drinking water sources [9].

5.4 Air Pollution

Increase in the settlement (9.29 % from 1998 to 2009) is directly linked with increase in vehicles and more fuel combustion. This eventually has adverse impacts on air quality. Vehicles are mobile source of pollution and fuel combustion in stationary sources, including residential, commercial, and industrial heating and cooling also release air pollutants. Mining releases dust particles into the atmosphere which also deteriorate the air quality. Air pollutants and particulates can penetrate deep into lungs and have adverse health effects. In Abbottabad, the situation of transport is worse. The number of vehicles has increased due to increase in population but the existing road infrastructure cannot meet the needs of the growing population which adds to the pollution caused by vehicles. In summers, a number of vehicles increase as the people from other parts of the country visit this area for recreation. Unplanned and unmonitored land-use change can make the situation worse in the coming years if necessary attention it goes unchecked. It is of great importance to deal with the present impacts of land-use change and predict the future status in an effort to restore the environmental quality of the district Abbottabad.

6. CONCLUSION

Land-use change during the last 10 years of the district Abbottabad was studied by taking advantage of GIS and RS analysis. The study showed that the region has undergone a noticeable land-use change due various factors, including demographic, anthropogenic and environmental factors. The Earthquake 2005 played a major role in land-use change. From 1998 to 2009, the vegetative and bare land decreased while the areas of settlement, forest, and water areas were observed to have increased. The vegetative land decreased by 1.053 %, bare land by 1.394 %, settlement, forest and water area increased by 9.29 %, 2.82 %, and 0.33 %, respectively. Major portion of the vegetative land and bare land

have been converted into settlements.

Most of the study results showed uneven and unchecked land-use change that has adverse impacts on the air and water quality, as well as climatic conditions of the region. This poses a risk to the health of local community. Problems of water availability, water contamination, and overall management of the region were quite apparent and on increase. This study can help in the selection, planning, and implementation of the land-use schemes to deal with the problems arising from land-use change. It can also help in monitoring the dynamics of land-use due to changing demands of increasing population, in order to ensure the environmental sustainability of the district Abbottabad.

REFERENCES

1. SMEDA, 2009. District profile Abbottabad. Small and Medium Enterprises Development Authority, Government of Industries and Production.
2. Pastakia and Firuza, 2004. Abbottabad - State of the Environment and Development. IUCN Pakistan, P.135
3. Fujiwara, S., Tobita, M., Sato, H.P., et al., 2006. Satellite Data Gives Snapshot of the 2005 Pakistan Earthquake. EOS, Transactions American Geophysical Union, 87(7), 73-77
4. Michalak, W.Z., 1993. GIS in land-use Change Analysis: Integration of Remotely Sensed Data into GIS. Applied Geography, 13(1), 28-44.
5. Green, K., Kempka, D., and Lackey, L., 1994. Using Remote Sensing to Detect and Monitor Land-Cover and Land-use Change. Photogrammetric Engineering and Remote Sensing, 60(3), 331-337.
6. Chang, K., 2004. Introduction to Geographic Information Systems. New York, NY 100206.
7. Walter, V., 2004. Object-based Classification of Remote Sensing Data for Change Detection. ISPRS Journal of Photogrammetry and Remote Sensing, 58(3), pp. 225 238.
8. Pijanowski, B.C., Brown, D.G., Shellito, B.A., and Manik, G.A., 2002. Using Neural Networks and GIS to Forecast Land-use Changes: A Land Transformation Model. Computers, Environment and Urban Systems, 26, pp.553 575.
9. US Geological Survey, 2010. <http://glovis.usgs.gov/.> Retrieved April 6, 2010
10. GoP. 1998. <http://www.statpak.gov.pk/> depts/pco/index.html. Retrieved 01 June 2010.
11. Mapper, Global. 2010. Global mapper llc. <www.globalmapper.com.>
12. ESRI. 2010. Arcview. www.esri.com/ software/arcview/index.html.
13. ITT 2010. ITT Visual Information Solutions. Envi 4.7. <www.ittvis.com/ProductServices/ENVI.aspx.>
14. Hill, J., Sturm, B., 1991,Radiometric correction of multi-temporal Thematic Mapper data for use in agricultural land-cover classification and vegetation monitoring. International Journal of Remote Sensing, 12(7), pp.1471-1491.
15. Franklin, S.E., Giles, P.T., 1995, Radiometric processing of aerial and satellite remote-sensing imagery. Computers & Geosciences, 21(3), pp. 413--423
16. Paola, J. D., Schowengerdt, R.A., 1995, A detailed comparison of back propagation neural network and maximum-likelihood classifiers for urban land-use classification. Geoscience and Remote Sensing, 33(4), pp.981-996
17. IUCN and SDPI. 2006. Environmental fiscal reform in Abbottabad, mining and quarrying. IUCN-Pakistan.

ESSENTIALITY OF MANAGING INDIGENOUS KNOWLEDGE IN PAKISTAN

Mohammad Saeed Lodhi and Peter Mikulecký***

ABSTRACT

Indigenous knowledge refers to the large body of knowledge and skills that has been developed outside the formal educational system. It is embedded in culture and is unique to a given location. Although many authors in the past wrote extensively about the importance of indigenous knowledge, but until now proper management of this kind of knowledge is limited. Management of indigenous knowledge is essential for food security and health of millions of people in the developing world. Indigenous knowledge can be managed by its integration with scientific knowledge to achieve developmental goals.

Keywords: *Indigenous knowledge, Development, Technical innovation, Environment, Communities, Management*

1. INTRODUCTION

This article is about the significance of indigenous knowledge and its management in Pakistan s context. In Pakistan, about 66% people are living in rural areas and literacy rate is approximately 55%, which is even less for rural areas. Moreover, 25% people are living below the poverty line. Due to a varied climate, Pakistan is quite rich in medicinal herbs, which are scattered over large part of the country. Many indigenous communities living in different parts of the country indicate the importance of managing indigenous knowledge. Intelligent and sustainable use of land, water and soil without causing damage to the resilience and functioning of the surrounding ecosystem, is what is required by indigenous communities, which is of course possible with appropriate management at local and national levels. According to the World Development Report WDR (1999) knowledge and not capital, is the key to sustainable social and economic development. Building on local knowledge, the basic component of any country s knowledge system is the first step to mobilize such capital. Exchange within a community where providers and recipients speak the same language and share its underlying cultural concepts is much more easily accomplished than transferring tacit knowledge across cultures. Indigenous Knowledge and appropriate techno blending is essential in a sense that how people use their own locally generated knowledge to change, improve their livelihood and provide opportunities for designing development projects. If serious consideration is given to Indigenous Knowledge management, it has the capability to provide practical tools for poverty alleviation, sustainable development and empowerment in general. The exchange of indigenous knowledge is the ideal outcome of a successful transfer and it could be useful to provide the foundation for indigenous innovations and experimentations. It is crucial for Pakistan to improve scientific as well as traditional or indigenous knowledge at the local level for monitoring and managing complex ecosystems, such as watersheds, forests, and seas, and for helping to predict and manage the impact of climate change and the loss of biodiversity and also try to learn through best practices of utilizing indigenous knowledge in different parts of the world.

2. LITERATURE REVIEW

2.1 Indigenous Knowledge

Indigenous or local knowledge refers to a complete body of knowledge, know-how and practices maintained and developed by people, generally in rural areas, who have extended histories of interaction with the natural environment. Indigenous Knowledge is unlike the international knowledge system, which is generated by universities, research institutions and private firms. According to Flavier et al., (1995) Indigenous Knowledge is the information base for a society, which facilitates communication and decision making; it is dynamic and is continuously influenced by internal creativity and experimentation as well as by contact with external systems. While Warren (1991) defines indigenous knowledge as local knowledge that is unique to a given culture or society, the basis for local-level decision making in agriculture, healthcare, food preparation, education, natural resource management and a host of other activities in rural communities. Msuya (2007) stated that local or traditional knowledge is unique to every culture or society. The knowledge influences planning as well as decision-making in local areas. Indigenous knowledge is culture-specific, and represents people s lifestyles and it may be related to a common practice seen in communities that are indigenous to a specific area. Indigenous knowledge is usually shared among local communities and transferred from one generation to the next, through oral traditions and story-telling. Also local people often have a good understanding of how and why resources and the environment have changed over time. It is unique to a given location or

* COMSATS Institute of Information Technologies Abbottabad Pakistan. Email: saeedlodhi@ciit.net.pk
** University of Hradec Králové Czech Republic. Email: peter.mikulecky@uhk.cz

society and provides basis for decision-making of communities regarding food security, human and animal health, education and natural resource management.

2.2. Indigenous Knowledge Methodology

When discussing the indigenous methodology, one of the well-known Native American scholars, Elisabeth Cook-Lynn (Crow Creek Sioux) argues that, While it is important that scholars become theoretically informed, Indians should define their own perspectives on Indian history and culture instead of relying solely on the thoughts and dictates of anthropology and history theorists (Mihesuah, 1998).

Indigenous ways of thinking, understanding and approaching knowledge have long been dismissed by the academic world because they have been considered as not belonging to any existing theory (Cook-Lynn, 1997) or, often, they have been reduced to some nativist or even illogical and contradictory discourse (Smith, 1999). The quest for indigenous methodologies has often been interpreted by the academic world as a political gesture on part of indigenous people in their struggle for self-determination. Nevertheless, it must be acknowledged that indigenous methodologies already form part of the body of knowledge about indigenous peoples, and that they have a theoretical value.

Indigenous Knowledge is a practical concept, which can be used to facilitate communication among people coming from different backgrounds such as researchers, development practitioners and beneficiaries. Indigenous Knowledge is a key element of the social capital of the poor; their main asset to invest in the struggle for survival, to produce food, to provide shelter or to achieve control of their own lives. Indigenous knowledge contains several important characteristics which distinguish it from other types of knowledge. These include originating from within the community, maintaining a non-formal means of dissemination, collective ownership, development over several generations and subject to adaptation, and embedded in a community s way of life as a means of survival. This kind of knowledge is generally passed by word of mouth through generations and is not often recorded in writing, but to achieve the desired results for development, it should be recorded and the latest available technologies could prove useful in this endeavour. Indigenous knowledge is dynamic in nature, and changes its character as the needs of people change. It also gains vitality from being deeply entrenched in people s lives, consequently it has the potential of being translated into commercial benefits by providing leads for development of useful practices and processes for the benefits of the mankind.

2.3 Significance of Indigenous Knowledge

The focus on the role of knowledge in development processes is the result of understanding about the relationship between economic growth and the application of knowledge. Indigenous knowledge is an integral part of the development process of local communities (Davies and Ebbe, 1995). Indigenous knowledge is an important resource in the development process and sharing it within and across communities can help in enhancing cross-cultural understanding and promoting the cultural dimension of development. Indigenous knowledge is an important part of the lives of the poor while it is also an integral part of the local ecosystem. It is also evident that knowledge for development should not only be confined to scientific and technical knowledge but also encompass community-based knowledge systems and development practices that underpin the day-to-day survival and innovations at local levels. Indigenous knowledge holders and innovators encourage economic self-sufficiency for indigenous peoples, and also provide incentives for the conservation and sustainable uses of environment (Mwantimwa, 2008). Indigenous knowledge is important for both the local and global communities as it is based on exchange within a community and expresses human creativity, both individual and collective. Nakashima (2000) supports that indigenous knowledge provides the basis for local-level decision-making about many fundamental aspects of day-to-day life, e.g.` hunting, fishing, gathering, agriculture and animal husbandry, food production, water, health; and adaptation to environmental or social change. Indigenous knowledge provides the basis for problem-solving strategies for local communities, especially the poor. Local and traditional knowledge is the knowledge held by individuals that comes from their own observations, experiences, beliefs or perceptions rather than from scientific research. Low economic cost is involved in acquiring indigenous knowledge but it can contribute largely to overall economy. Allen (2001) found that the use of indigenous knowledge and local innovation is cost-effective, sustainable and locally manageable, since deployment and mobilization is not expensive. Similarly, UNESCO (1999) and Hamel (2004) argued that indigenous knowledge is capable of increasing production and real the economic growth rate without

further damaging the environment by better knowing, harvesting and using knowledge as a vital and competitive development resource. Knowledge is indispensable for understanding and promoting technical, economic and social change in society. Elisabetsky (1990) reported that annual world market value for medicines derived from medicinal plants by indigenous people is US $ 43 billion. Gorjestani (2005), states that building an indigenous knowledge can be particularly effective in helping to reach the poor since indigenous knowledge often is the only asset they control and certainly one with which they are very familiar with. It is also a key element of a social capital of the poor and constitutes their major asset in the effort to gain control of their own lives. Significance of indigenous knowledge for Pakistan is greater due to its large area with high mountains and varied climate. According to Pie and Mandhar (1987), at least 70% of medicinal plants and animal species in the Himalayan ranges Pakistan of consist of wild species and for healthcare 70-80% population depends on the traditional medicines.

2.4. Transformation of Indigenous Knowledge

The integration of indigenous knowledge into the development process is essentially a process of exchange of information. Indigenous knowledge is local and tacit in nature which is rooted in a particular community and situated within broader cultural traditions; it is a set of experiences generated by people living in those communities. Therefore, separating the technical from the non-technical and the rational from the irrational could be problematic, so its transformation needs careful attention. The process of exchange of indigenous knowledge within and among developing countries, and many developing and industrial countries involves essentially six steps according to the World Bank (1998):

2.4.1 Recognition and Identification

Some indigenous knowledge may be embedded in a mix of technologies or in cultural values, rendering them unrecognizable at first glance to the external observer (technical and social analyses may be required to identify such indigenous knowledge).

2.4.2 Validation

This involves an assessment of significance and relevance (to solving problems) of indigenous knowledge, reliability (i.e., not being an accidental occurrence), functionality (how well does it work?), effectiveness and transferability.

2.4.3 Recording and Documentation

Recommendation and documentation is a major challenge because of the tacit nature of indigenous knowledge (it is typically exchanged through personal communication from master to apprentice, from parent to child, etc.). In some cases, modern tools could be used, while in other circumstances it may be appropriate to rely more on traditional methods (e.g., taped narration, drawings).

2.4.4 Storage in Retrievable Repositories

Storage of indigenous knowledge is not limited to text documents or electronic formats, it could include tapes, films, storytelling, gene banks, etc.

2.4.5 Transfer

This step goes beyond merely conveying the knowledge to the recipient; it also includes the testing of knowledge in a new environment. Pilot studies are the most appropriate approach in this step.

2.4.6 Dissemination

The dissemination to a wider community adds the development dimension to the exchange of knowledge and could promote a wider and deeper ripple impact of the knowledge transfer. Indigenous knowledge could prove to be useful for the poor in areas like: agriculture, animal husbandry and ethnic veterinary medicine, use and management of natural resources, primary health care (PHC), preventive medicine and psycho-social care, saving and lending, community development, and poverty alleviation. Indigenous knowledge could be a missing link between neglect and empowerment, as well as between losing and surviving (World Bank,1999).

2.5 Indigenous Knowledge System

Unlike other knowledge systems, the Indigenous Knowledge System (IKS) is a policy framework to stimulate and strengthen the contribution of indigenous knowledge to social and economic development. Local knowledge systems often combine specific and general aspect of knowledge with great ease as everybody has local, everyday knowledge about the environment. The degree of local or indigenous knowledge also depends on the nature

of the community. Indigenous knowledge systems are geared to dealing with diversity in both natural environment and social organization, and continue to evolve over time. They differ from scientific knowledge in their capacity to deal with local problems and in the degree to which they are accessible to the members of a social group charged with resource management and production. Indigenous knowledge has benefited from the flow of information, resources, skills and perspectives over a period of time. Traditional knowledge is different than formal scientific knowledge. The latter is an explicit or codified knowledge that is transmittable in formal, systematic language (Table-1). On the other hand, traditional knowledge is a tacit knowledge of the local or indigenous people, which is personal, content-specific, and therefore hard to formalize and communicate. Local or indigenous people acquire knowledge by actively creating and organizing their own experiences.

Indigenous knowledge systems are typically human centeric, very diverse, applies technology of local origin with strong cross-linkages and is developed after years of experience and experimentation, trial and error and incremental refinement. For example, knowledge about the characteristics of a particular plant and its properties as a healing substance, the technology of its use, is what gives medicinal plants their social and economic value. Management of knowledge is important, since to have knowledge is not sufficient but connecting knowledge with its application empirically or conceptually or even philosophically to desirable social ends is essential. Indigenous knowledge systems generally provide a way of connecting, knowing, feeling and doing. It is necessary to integrate indigenous knowledge systems to other knowledge systems for achieving more benefits. Rahman (2000), supports that in order to properly understand and incorporate traditional knowledge systems for sustainable socio-economic development and poverty alleviation, the scientific community perhaps need to unlearn the old view of knowledge and should grasp the importance of local or indigenous people s view.

Table-1: Distinctions of Traditional and Scientific Knowledge Systems (Rahman, 2000)

Traditional knowledge	Scientific knowledge
Tacit knowledge (Subjective)	Explicit knowledge (Objective)
Knowledge of experience (body)	Knowledge of rationality (mind)
Simultaneous knowledge (hare and now)	Sequential knowledge (there and then)
Analog knowledge (practice)	Digital knowledge (theory)

An indigenous knowledge system consists of a wide range of knowledge that has largely remained hidden from the mainstream of education, innovation, industry and commerce. Indigenous knowledge holders, as custodians thereof, have enormous potential for innovation and commercialization of indigenous knowledge. In such knowledge systems, generation of knowledge starts with "stories" as the base units of knowledge; proceeds to "knowledge," an integration of the values and processes described in the stories; and culminates in "wisdom," an experiential distillation of knowledge (Smylie, 2003). The existing knowledge about critical spheres, such as health, agriculture and water management could be captured using a variety of existing means. These may be recorded using a variety of existing media such as paper, images, audio and video. Existing practices recorded using low-tech ICT without adding large, expensive infrastructure and is retained in the local language using local techniques for capturing it, indeed low-tech approach should be a starting point.

3. BEST PRACTICES BY THE APPLICATION OF INDIGENOUS KNOWLEDGE

During natural disasters in rural areas, survival mostly depends on indigenous knowledge, because the informal means by which indigenous knowledge is disseminated provides a successful model for other knowledge on disaster risk reduction management. Velasquez (2008), highlighted that the locals of Chitral (Pakistan) have learned to interpret early signs of potentially destructive flash floods. Such signs may be the color, smell and behavior of mountain streams as well as meteorological forecast skills. In 2005, 106 houses were destroyed in Brep village due to a Glacial Lake Outburst Flood (GLOF). However, not a single life was lost since the interpretation of the stream behavior acted as an early warning and the village was

evacuated in time. Dekens (2007) states that based on this experience and the local knowledge of a flood 100 years ago, in 2006 the community twice warned an engineering company to relocate their camp since it was on the flood. The company did not heed to the local knowledge, and a foreign engineer lost his life to a flash flood on July 14th 2006, which also destroyed millions of rupees worth of equipment.

Another example of the best practices of indigenous knowledge which is related to development process is given as a Karez system in Xinjiang area of the China. Turpan is one the district of Xinjiang, which is very dry in all seasons and very hot during spring, summer and autumn. High temperature and strong solar radiation result in high annual evaporation. So local people developed a traditional irrigation water system (TIWS) for irrigation which is called Karez, this is TIWS which is able to make use of underground water efficiently. According to Velasquez (2008) Karez is composed of four primary components: vertical wells, underground canals, a surface canal and small reservoirs. As a result of Karez system, Turpan, a basin located in the arid area of Northwestern China, is well-known for its wide variety of agricultural products. In the Turpan area of Xinjiang, Karez is still being used to supply water resources for irrigation and domestic use. At present, modern technology has been integrated into the traditional Karez system to further reinforce the successful traditional practice.

The Karez system is a proven and effective indigenous drought reduction technology that is still in use.

This system based on traditional knowledge has several advantages that are given as follows:

3.1 Support by Earth s Gravity

Since Karez takes advantage of topography to divert deep subsurface flow through an underground canal to land surface for gravity irrigation, the cost for water-lifting equipment and its maintenance are almost negligible.

3.2 Stable Outflow

The major water sources of the Karez system are melting snow and underground water. The underground canal can minimize high evaporation so the impact of climate change is small. In addition, problems with sand blast can be avoided in the underground canal. All this makes the Karez system able to provide stable water resources, though total water volume may not be very large. As observed, there has been a very stable population for thousands of years in Karez areas, regardless of environment changes.

3.3 High Water Quality

Melting water from glaciers enters the system and the soil provides a very good filter to remove pollutants. Unlike water channels on land, the underground canal minimizes water pollution and at the same time is rich in minerals. The water quality is suitable for drinking and domestic use.

3.4 Construction with Simple Tools

Most Karez systems are built with simple tools and do not require complex equipment.

Indigenous communities in Pakistan also have traditional Karez system in Baluchistan which can be improved and reinforced with modern technology and management. Knowledge about flood preparedness is transmitted orally through learning by doing, daily observation of their local surroundings, storytelling, and the internalization of certain practices over generations. The dissemination of this knowledge occurs at two levels: among community members (i.e., early warning of upcoming floods) and between generations (i.e., transmitting knowledge and lessons learnt from previous flood events).

4. MEASURES TO MANAGE INDIGENOUS KNOWLEDGE

Indigenous knowledge needs to be addressed and integrated into educational programs or learning environments (Mwantimwa, 2008). Students connect well to what they are taught and can become a major knowledge source for their community s sustainable development. The Ministry of Science and Technology will need to support the department of education and labour to provide indigenous knowledge holders with means to obtain specific education and training.

It is worthwhile to prepare national policies in support of indigenous practices, to ensure that valuable indigenous knowledge is identified, recovered and documented, shared and applied for improving the living conditions of the society. The department of education should take steps to include indigenous knowledge into curricula and relevant accreditation frameworks. This could create awareness among students about indigenous knowledge and enable

them to understand the impact indigenous knowledge systems on their daily lives.

It is essential to create a knowledge sharing culture among communities and encourage those who could initiate innovation. Although indigenous knowledge is an important component of global knowledge but before adopting indigenous knowledge, integrating it into development programs, or even disseminating it, practices need to be scrutinized for their appropriateness just as any other technology because without proper verification it may be harmful in some cases. It is presumed that the awareness, pilot applications and mainstreaming are necessary steps required for the successful integration of indigenous knowledge into the development process in Pakistan. Higher education institutions need to play a role in harnessing and disseminating indigenous knowledge for sustainable development by providing a knowledge base, and transmitting new skills, libraries that can be used for collecting, preserving and dissemination of the indigenous knowledge. Incorporating indigenous knowledge into an educational environment can help students feel ownership of the knowledge they bring to learning environments. In this way scientific and indigenous knowledge can be integrated for the development process.

5. SIGNIFICANCE OF ICTS FOR MANAGING INDIGENOUS KNOWLEDGE

Technology should be introduced where necessary, but in minimalistic ways, so as to add value to the traditional systems and make them more resilient to new threats, such as those posed by climate change. Undoubtedly information and communication technologies can play major roles in improving the availability of indigenous knowledge systems and enhancing its blending with the modern scientific and technical knowledge, information and communication technologies. This could generate wealth and jobs, build bridges between governments and citizens, build relations among organizations and communities, and improve the delivery of essential services to poor people. Therefore, the application of ICTs is essential to stimulate the flow of indigenous knowledge and incorporation of modern scientific and technological understandings to traditional knowledge. It can enable indigenous communities to protect their unique cultures and knowledge through digitization. Further possible uses of ICTs for indigenous knowledge are as follows:

- Capture, store and disseminate indigenous knowledge so that traditional knowledge is preserved for the future generation;
- Promote cost-effective dissemination of indigenous knowledge;
- Create easily accessible indigenous knowledge information systems;
- Promote integration of indigenous knowledge into formal and non-formal training and education;
- Provide a platform for advocating improving benefits from indigenous knowledge systems to the poor.

Environmentally friendly technologies together with indigenous knowledge can be used for both conservation and sustainable use of the natural resources, as well as reducing poverty. Indigenous knowledge and technical innovation are important parts of the lives of the poor and main assets to invest in the struggle for survival, to produce food, to provide shelter and help to shape local visions and perceptions of environment and society. Indigenous knowledge and techno blending practices to the local setting can help to improve agriculture production and sustainability of development assistance. Technologies should be used to collect, preserve and exchange indigenous knowledge in Pakistan, particularly in rural areas.

6. CONCLUSIONS AND RECOMMENDATIONS

Indigenous knowledge is not exclusive to the developing world, nor is it always related to ancient traditions but it is found to be somewhat conflicting with knowledge systems generated by universities, research institutions and private firms across the world. It is not sensible to overlook the importance of indigenous knowledge, especially in the developing countries as it forms important the basis for local-level decision-making in agriculture, healthcare, food preparation, education, natural resource management, and a host of other activities in rural communities. Effective exchange, adaptation and use of indigenous knowledge and technical innovation could lead to poverty alleviation in rural communities. According to IFAD (2007), the availability and application of local knowledge resources and appropriate provision for facilitating and sharing innovations improves productivity and generates livelihood choices with or without value addition. Indigenous knowledge is linked to so many different aspects of daily life and is thus so firmly embedded within local communities. Further research and development of indigenous knowledge will have a

broad impact on the livelihoods of rural peoples. Indigenous knowledge have potential to contribute development strategies in several ways, such as by helping identify cost-effective and sustainable mechanisms for poverty alleviation that are locally manageable and locally meaningful by better understanding of the complexities of sustainable development in ecological and social diversity. The valuable leads/clues provided by traditional knowledge help save time, money and investment of modern biotech and other industries into any research and product development. Partnership for indigenous knowledge and technological innovation will be fruitful when the developing countries like Pakistan share as well as use indigenous knowledge. Pakistan needs to pay special attention to identifying, collecting, documenting, characterizing, recognizing and sharing indigenous knowledge at national level. There is also a need to strengthen local authorities at district level, including administrators, teachers, and nurses, extension workers to support communities in managing and sharing their indigenous knowledge and acquiring knowledge from outside world. The following steps could be prolific to manage indigenous knowledge in Pakistan:

- Identifying and testing instruments for capturing and dissemination of indigenous knowledge;
- Integration of different knowledge systems, indigenous and modern
- Raising awareness of the importance of indigenous knowledge among native communities and general public;
- Protecting the intellectual property rights related to indigenous knowledge;
- Promoting inter-cultural exchange of experiences in education for sustainable development.

It is crucial to develop a framework for incorporating indigenous knowledge system into development programmes of governmental and non-governmental organization (NGOs) and into the curricula at various levels, which can bridge the existing gaps between modern and indigenous knowledge systems.

REFERENCES

- Allen and Davina, 2001. Dependency Theory (online), Available at: http://www.xrefer.com
- Cook-Lynn, E., 1997. Who Stole Native American Studies Wicazo Sa Review, 12:1, pp. 9 28.
- Davies, S., and Ebbe, K., 1995. Traditional knowledge and sustainable development; proceedings of a conference, held at the World Bank in September 1993, World Bank, Environmentally sustainable development proceedings Series No. 4, Washington D.C.
- Dekens, J., 2007. Local Knowledge on Disaster Preparedness in Chitral District, Pakistan ICIMOD, Kathmandu, Nepal 2007 www.proventionconsortium.org/themes/default/pdfs/.../Pakistan3_GN.pdf
- Elisabetsky, 1990. Plants used as analgesics by Amazonian Capbocols, *International Journal of Crude Drug Research,* 28,pp. 309-320.
- Flavier, J.M., et al., 1995. The Regional Program for the Promotion of Indigenous Knowledge in Asia. In Warren D.M, L.J., Slikkerveer, D. and Brokensha, L. (Eds)
- Gorjestani, N., 2005. Indigenous Knowledge for Development, Opportunities and Challenges. Available at: <www.higher.edu.et/index.php/he-documents/.../110-assaye-and-ziyn 5>
- Hamel, L. J., 2005. Knowledge Policies for Sustainable Development in Africa: A Strategic Framework for Good Governance. ECA /SDD, Addis Ababa.
- IFAD, 2007. Promotion of Local Knowledge and Innovations in Asia and the Pacific Region.
- Mihesuah, D. A., 1998. Natives and Academics: Researching and Writing about American Indians. Lincoln: University of Nebraska Press.
- Msuya, J., 2007. Challenges and Opportunities in the Protection and Preservation of Indigenous Knowledge in Africa. *International Review of Information Ethics*, 7, pp.1-8
- Mwantimwa, K., 2008. The Relationship of Indigenous Knowledge and Technological Innovation to Poverty Alleviation in Tanzania.
- Nakashima, D.J., 2000. What relationship between scientific and traditional systems of knowledge? pp. 432-444 In: Ana Maria Cetto (ed.), Science for the Twenty-First Century: A new commitment , Paris, UNESCO
- Pie S. J., and Manandhar., 1987. Sources of some local medicines in the Himalayan Ecosystems
- Rahman, A., 2000. United Nations Conference on Trade and Development Expert Meeting on Systems and National Experiences for Protecting Traditional Knowledge, Innovations and Practices, r0.unctad.org/trade_env/docs/rahman.
- Smith, L.T., 1999. Decolonizing Methodologies: Research and Indigenous Peoples. London: Zed Books.
- Smylie, J., et al., 2003. Knowledge translation and indigenous knowledge Circumpolar Health 2003 jch.fi/issues/63suppl2/ICCH12_Smylie.

International Journal of Circumpolar Health, 63.

- UNESCO, 1999. Indigenous and Local Knowledge Systems and Sustainable Development; www.unescoorg/shs/most
- Velasquez, J., 2008. Indigenous Knowledge for Disaster Risk Reduction. www.unisdr.org/…Indigenous Knowledge./ Indigenous_Knowledge-DRR.pdf
- Warren, D. M., 1991. Using Indigenous Knowledge in Agricultural Development; Discussion Paper 127, Washington: World Bank Research Center (IDRC). 958-201-1-DD-Topic 1991
- World Bank, 1998. Indigenous Knowledge for Development a Framework for Action. Available at: www.worldbank.org/afr/ik/ikrept.pdf
- World Bank, 1999. World Development Report 1998/1999: Knowledge for Development. World Bank Development Report 1999 Knowledge for Development Oxford University Press, London

ROLE OF GREEN STRUCTURE AND ECOLOGICAL SERVICES: A CASE STUDY OF BAHAWALPUR CITY, PAKISTAN

Adila Shafqat and Sana Arshad**

ABSTRACT

Cities can make broader contribution to achieve the goals of sustainable development as they are considered major consumers of resources and ecological services. Ecological services provide a range of benefits at local, regional and global levels. Terrestrial ecosystem has different components in urban environment that provides ecological services to its inhabitants. Cities not only benefit from the internal urban ecosystem but also depend upon other ecosystems beyond the city limit. Green structure is an important component in terms of making city more sustainable and habitable. Green structure in urban environment means green infrastructure that is planned and supports sustainable urban development. From planning perspective, spatial structure of green space provides a basis for sustainable urban development. In sustainable perspective, green structure is more than the sum of green spaces. It is considered as spatial network of open spaces, public and private gardens and parks, sports fields, allotment gardens, woodlands and recreational grounds. Therefore, it is considered as a significant part of built-up environment and major source of ecological services. To structure urban areas for sustainable development, it is necessary to develop a proportion between grey and green cities. Keeping in view, research has been conducted to investigate spatial network of green structure in planned areas of Bahawalpur City of Pakistan. This study analyzes the ecological services generated from the investigated green structures, and helped develop an approach of inter-relation between green environment and urban society. Moreover, strategies for better land-use planning in green and sustainable perspective have been proposed.

Keywords: *Green Structures, Ecological Services, Sustainable cities, Greening.*

1. INTRODUCTION

World urban population is growing and expanding massively. Developing countries face many problems regarding urban population expansion, such as excessive use of energy and water, overproduction of waste, air pollution, that has severe societal consequences. As Davis (1991) shows that public amenities are radically shrinking, parks are becoming derelict, libraries and playgrounds are closing and streets are becoming more desolate and dangerous. Many social and environmental problems are arising in cities. One of these problems is the destruction and reduction of green structures in the cities. Growth of urban centers and use of urban land only for residential and commercial purposes has reduced the natural and greenery structures within the city. Closely built buildings and roads with minimum spaces of greenery characterize compact urban areas. It encompasses a high density of built forms and artificial structures. The destruction of vegetation and inadequate plantable spaces degrade the environment quality (Jim, 2000), quality of life and human health (Jackson, 2003). The long history of urban development has generated a diversity of forms and functions due to organic growth or conceived plans. The phenomenal city expansion and intensification in recent decades have somewhat diluted the greening tradition. While some cities manage to retain or even extend their green spaces, others experience degradation and destruction (Jim, 2004). Compact cities tend to encounter more inherent restrictions to greening, and many cities in developing countries have inherited the old compact form. In the course of environmental transition, cities could attempt to keep as many as possible of the environmental-sustainability ingredients, including green spaces (Marcotullio, 2001). So there is a dire need to develop and preserve green structures in the cities so that ecological and sustainable development can be realized. The green city is an ideal appeal as it has spatial, temporal and cultural diversity (Hestmark, 2000). Humanity is increasingly urban, but continues to depend on nature for its survival. Cities are dependent on the ecosystems beyond the city limits, and also benefit from internal urban ecosystems (Bolund and Hunhammar, 1999). It is human nature to make psychological attachment with natural object such as amenity vegetation (Kaplan, 1984; Ulrich, 1986).

Greening is practiced to different extent in cities, often subject to societal attitudes and political climate (Mumford, 1961; Attorre, et al., 2000). The brown agenda is essential for making a city work for a healthy and livable environment and for creating the human and economic opportunities, which have driven cities throughout their history (UN-Habitat, 2009). All cities consume land and resources, such as energy, water and materials, which they use for buildings and transport. In the process of making a city functional,

* Department of Geography, the Islamia University of Bahawalpur, Pakistan. Email: adila.shafqat@iub.edu.pk; sanaiub111@gmail.com

these resources are turned into wastes. It is now possible to quantify this impact in one parameter called ecological footprint. The brown functions of a city generally consume its green resources and degrade its processes, unless interventions related to urban planning and environmental management are made. The green natural systems of a city have real limits and capacity issues associated with their use. The challenge for urban planning is to find ways that cities can integrate these two agendas: to respect the natural environment and to improve the human environment.

The use of photosynthetic processes in cities reduces their ecological impact by replacing fossil-fuels and can bring substantial ecological benefits through emphasis on natural systems. There has been a positive trend in planning the direction of an expanded notion of urban infrastructure, that includes the idea of 'green infrastructure'. Green infrastructure refers to the many green and ecological features and systems, from wetlands to urban forests that provide a host of benefits to cities and urban residents.

There is no accepted definition of a 'sustainable city', and as it happened with the concept of sustainable development, many interpretations exist as to which characteristics a city should be considered sustainable, and many criteria and indicators have been developed to assess them (Chiesura, 2004). The idea of livable and ecological cities has blossomed in sustainable cities. The concept of sustainable cities includes a number of fundamental objectives, such as:

- minimization of the use of non-renewable resources;
- achievement of the sustainable use of renewable resources; and
- staying within the absorptive capacity of local and global waste absorption limits.

Action to attain these objectives provides the link between the natural and the built environment, or between the green and brown agendas. Urban planning is one of the few occupations with a specific remit that encompasses the three pillars of sustainable urbanization – economic, environmental and social – and should, therefore, be at the centre of attempts to define new approaches that integrate solutions seamlessly. As Redclift (1993) states:

> "It soon becomes clear that we cannot achieve more ecological sustainable development without ensuring that it is also socially sustainable. We need to recognize, in fact, that our definition of what is ecological sustainable answers to human purpose and needs, as well as ecological parameters. By the same token, we cannot achieve more socially sustainable development in a way that effectively excludes ecological factors from consideration."

So when keeping in view sustainable cities, all its needs of social, economic, ecological and cultural development must be taken in context (Jenks & Jones, 2010). There are many planning aspects which should be covered in sustainable cities. But greening a city is really very important because it not only fulfills the city's aesthetic needs but also has consideration for a resource base, wildlife habitation, free air filtration and many ecological services to the residents. As Mayur (1990) believes:

> "A green city is a living city by definition. It is an existing city where the full potentials of all intricately interconnected forces of nature are realized. A green city is complete in its survival capacity."

So it must be made sure that urban residents are not divorced by nature and green both as a resource provider and as source of personal well-being. Leff (1990) argues that:

> "Greening the city implies the articulation of urban function in an overall sustainable development process. It implies new function for the city and its reintegration into the overall productive process through a more balanced spatial distribution."

Sustainable urban development must consider social, economic and environmental problems, and take into account how air pollution, poverty, HIV, crime rate, lowering of water table and other problems are linked to each other. By understanding this mechanism it becomes clear that sustainable urban development must be linked with sustainable community development. As many problems of urban growth can be solved with the help of technology and machines, but the problems of community suffocation, peace of mind and aesthetic reduction can only be sorted out with the help of changing the patterns and planning of city development and management.

There is a growing realization that urban green structures are valuable resources for creating

sustainable cities. A city with high quality of green spaces optimizes good planning, a healthy environment for its residents, vegetation and wildlife population (Adams, 1987; Johnston, 1990). These sites can fulfill the increasing needs of many people who harbor the ecocentric form of environmental value and prefer informal and wild sites that provide solitude and respite from city life (Thompson, 2002). 'How green is the city' and 'how green it must be', need a complete set of assessment tools and sustainability indicators (Devuyst, et al., 2001).

2. TYPES AND FUNCTIONS OF GREEN STRUCTURES

Every city has its own distinctive type of green structures that result from the interaction of certain natural and human processes. Multiple functions and benefits of urban vegetation are widely known (Mole, 1992; Petit, 1995). Based on their origin three green structure, layers can be identified (Werquin, et al., 2005):

i. The pre-urban layer of natural landscape that were already there before the city came into existence. It includes rivers, forest, wetlands, arable land and pastures;
ii. Urban layer or the amenity green structures. This layer includes public parks, playing fields and cemeteries. Gardens in residential areas, institutional grounds and commercial parks are also included in this layer.
iii. Infrastructures, such as roads, railway lines and canals can include important linear green spaces.

According to the functions, green structures can be categorized as given in Table-1 (Dunnett et al., 2002):

3. MATERIALS AND METHODS

This research study mainly concentrates on Bahawalpur city of Pakistan, where a survey was conducted in March 2011. The study area, Satellite Town, is located on the eastern side of the city. 'Satellite Town' or 'Satellite city' is a concept of urban planning near any metropolis, these are smaller municipalities near urban city having all commercial, residential, educational and other facilities.

According to the Physical Housing and Town Planning Department of Bahawalpur, the Satellite Town is a planned area built at some distance from the core city to accommodate the increasing population. It was built in 1978 and was extended in 1985 to Bahawalpur.

This planned residential area provides all the facilities for good standard of living. The distribution of built-up area also contains reasonable proportion of open spaces for health and recreation purposes as shown in Figure-1. According to the Planning Department, each block contains an open space in the center for all the block residents. There are a total of 18 open spaces in the planning of Satellite Town. This planned area also contains a large neighborhood park in the center of the town, named as "Madir-e-Millat Park" or "Central Park". According to the National Reference Manual on Planning and Infrastructure Standards, the Government of Punjab and the local Government have proposed some standards for the planned

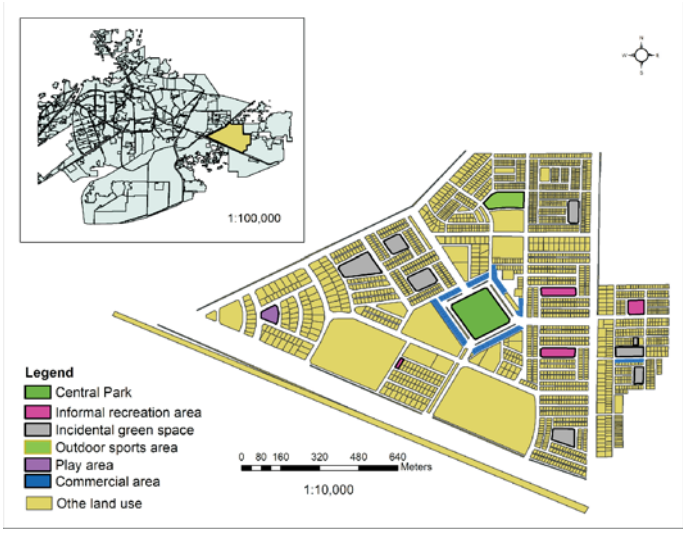

Figure-1: Classification of green spaces in Satellite Town, Bahawalpur

Table-1: Definition of Types of Urban Green Structures

AMENITY GREEN SPACE All land which is designed primarily for amenity, both visual amenity and enjoyment for access and recreation. It consists mainly of publicly owned land but also includes private land, such as domestic gardens, which can contribute greatly to the green fabric of towns and cities. Sub–types of amenity green space are:	**Parks and Gardens:** Areas of green space specifically designed for public access and enjoyment and combining a variety of landscape and horticultural elements (sometimes including semi-natural habitats) and facilities for the public (including buildings) and in some cases incorporating sports facilities and/or play areas. At the smaller scale may include community gardens.
	Informal Recreation Areas: Areas of green space available for public access and enjoyment but with only low key provision of facilities. Usually consist mainly of grass areas for informal recreation, but may also have trees, a play area, paths and sometimes toilets and parking area.
	Outdoor Sports Areas: Green space designed to accommodate sports; including sports pitches, playing fields, golf courses, and other outdoor activities. Often occur within parks, but may also be separate, especially in the case of golf courses.
	Play Areas: Green space designed specifically for children's play, with various levels of provision of equipment and facilities. May occur separately but also often incorporated within parks, informal recreation areas and outdoor sports facilities.
	Incidental Green Space: Areas of green space that, although publicly owned and managed, and accessible for public enjoyment, have no clear recreation function and little significant value as habitat. Their function is usually as a green 'landscape backdrop' but their landscape value can sometimes be minimal because of poor design. They include the 'left over' green spaces within housing and other forms of development.
	Domestic Gardens: Green space within the cartilage of individual dwellings, which is generally not publicly accessible, but which often makes a significant contribution to the green fabric of urban environments.
FUNCTIONAL GREEN SPACE Green space which has a primary function other than amenity or recreation, although some of these areas may also be publicly accessible and available for people's enjoyment. The primary functions include farming, horticulture, burial grounds and educational and other institutional use. Access to these green spaces may go hand in hand with the primary function (for example cemeteries, churchyards and allotments) or be by public right of way, or by agreement, for example where school grounds are made available for public use.	**Farmland:** Green space under agricultural management. Includes farms which also have a recreation and education function such as City Farms.
	Allotments: Green Space available for members of the public who occupy them to cultivate vegetable or fruit crops for their own use.
	Burial Grounds: Land used as burial grounds, including cemeteries and churchyards.
	School Grounds: Green space in the grounds of schools including sports pitches, other outdoor sports facilities, play areas, gardens, nature areas, school farms and growing areas and incidental green space.

continue...

...continued

	Other Institutional Grounds : Green space in the grounds of institutions such as universities and colleges, hospitals and nursing homes, and associated with commercial and industrial premises, including gardens, sports pitches, other outdoor sports facilities, play areas, semi-natural habitats and incidental green space.
SEMI-NATURAL GREEN SPACE Green space that is made up of semi natural habitat. These habitats may be encapsulated areas of the countryside that existed before the urban area expanded. Alternatively they may have been formed by the natural processes of colonization and succession on abandoned or disturbed ground or by deliberate creation of new habitats through initiatives such as urban forestry and reclamation of derelict land. All these habitats make a vital contribution to the urban landscape but may or may not be accessible for public enjoyment. In some cases where there is access it may be unofficial, but still extremely important to local people.	**Wetland:** Green space dominated by wet habitats, including water bodies, running water and fen, marsh, bog and wet flush vegetation.
	Woodland: All forms of urban woodland including deciduous woodland (both ancient semi-natural and woodlands of more recent origin) and mixed and coniferous woodland (including plantations and shelterbelts). Includes newly planted woodland.
	Moor and Heath: Areas of moorland and heathland vegetation consisting mainly of ericaceous species, and including moorland grass, shrub moor, shrub heath and bracken. Likely to include some Commons within urban areas.
	Grassland: Grassland which is not agriculturally improved and not formally part of an amenity green space, including calcareous grassland, acidic upland grassland and unimproved meadows. Could include established vegetation on reclaimed derelict land which is not part of a formal recreation green space.
	Disturbed Ground: Land which has been disturbed by previous development or land use but is now abandoned, waste or derelict and is becoming re-colonized by processes of colonization and natural succession.
LINEAR GREEN SPACE Green space that occurs in association with linear features, especially transport routes such as roads, railways and canals, but also rivers and streams. It is a matter for debate whether this category should be considered separately, since these spaces might also be defined as either semi natural habitat, or functional green spaces whose primary function is transport, or incidental green space with a visual amenity function. These spaces are, however, distinguished by their linear character and are often an important part of strategic green space designations such as green links and green corridors and for this reason we suggest that they should be considered separately.	**River and Canal Banks:** Green space occurring along the margins of canals or rivers and forming part of the river or canal corridor.
	Transport Corridors: The often substantial areas of green space associated with transport Includes: the variety of habitats, associated with railways, which are often inaccessible but when they fall into disuse can become an important part of an open space network; green space associated with roads, and especially the large areas of grassland, scrub, trees and woodland found along major roads and motorways; and green space along cycle ways and walking routes.
	Other Linear Features: Cliffs and other natural areas of linear green space.

residential areas, in which open spaces and parks should cover 5 to 10 % of the total built-up area. The green space area of satellite town covers 7 % of the total area.

To conduct the study in the Satellite Town, urban green spaces were classified into three categories: (i) Amenity Green Spaces; (ii) Functional Green Spaces; (iii) Semi Natural Green Spaces; and (iv) Linear Natural Green Spaces. Data was collected by researchers through field survey method in two steps: 1st step was to identify the green structures by surveying the area. All green structures were visited and located on the map and coded in their respective category of the questionnaire.

In the 2nd step, a questionnaire and a checklist was prepared, the cultural, environmental and social functions were observed, counted and listed in the table of functions for all types of green structures.

4. RESULTS AND DISCUSSION

Satellite Town is one of the main residential sectors of the city. It has a large commercial area in its center, around which residential pattern grows in blocks designated as A, B, C and onward. Due to the continuous expansion of area and population green spaces are changing their functions within the research study. Figure-2 shows the distribution of green structures in the planned area of Satellite Town.

There is a central green space in the middle of the town and each block of the residential area has its own central green space to fulfill the needs of the environment and community as well. By following the classification given by Dunnett, et al. (2002), these green spaces are divided according to their functions (Figure-3). The green spaces situated in different residential blocks can be categorized differently. The central green space of the town performs duties of central park, around which a busy commercial area comprising of shops, plazas, medical clinics, school, colleges, and salons is present. So it may be said that it is one of the busiest parks in the town giving different services to the community. Other partly and non-functional green spaces are identified, which shows that conservation and preservation of these grounds were not taken into account by the authorities. Due to the ignorance of the residents and authorities, some green spaces are now abandoned, wasted or derelict, and are becoming re-colonized. The detail of every green structure identified and classified is as follows:

- Central green space of Satellite Town is classified as park and garden area. Park and garden area of Satellite Town is provided with all type of recreational facilities. The visitors perform several activities. It is the central park of the Town that reduced inflow of the visitors on the other green spaces.
- In some blocks of the Town three informal recreation areas are present. These green spaces provide outdoor recreational facilities. These green spaces are provided with basic recreational facilities like grassy plots, boundary walls,

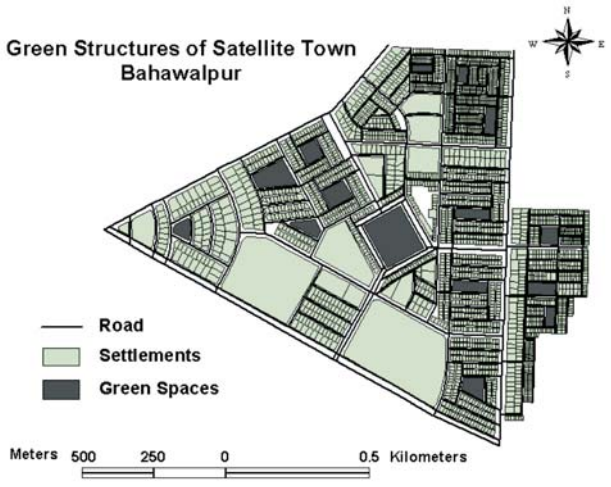

Figure-2: Identification of Green Spaces in Satellite town Bahawalpur

Table-2: Landuse by Area in Satellite Town Bahawalpur

Land use plot	Area in ha
Residential	54 ha
Commercial	1.26ha
Green spaces	8.58ha

benches, and lighting facilities. Visitors have undertaken various activities like walking, enjoying the environment, and social meeting.

- One open space of the Town is classified as outdoor sports area. This open space serves as sports area. Although it is not equipped completely but partly enable various sports activities like basketball, cricket, and football.
- There are seven incidental green spaces present in the other remaining blocks of Satellite Town. These green spaces are not in good condition for any activity. People perform very few cultural and sports activities.

These green spaces perform different functions for the residents and the environment. The number and quality of functions a green space provides to its community not only assures its ecological services but also enhances its social standing in terms of its benefits. There are a number of functions which these green spaces can perform for community. The checklist in Table-3 prepared on the basis of observations classifies qualitative parameters of green spaces.

Green spaces in the cities facilitate sustainable urban planning. Planned urban areas in the city are provided with a range of amenity green structures that are termed as functional green spaces. The provision of ecological services by these spaces increases the sustainability of the planned areas. Figure-3 shows the distribution of functional green structures through qualitative analysis.

The interview conducted from the local administration department of Satellite Town showed that the green spaces being continuously supervised by authorities are more functional. As the Figure-3 represents, most qualitative green spaces in terms of functions is Central Park of Satellite Town. Interviews conducted with park visitors also verify that most functional and green space present in the study area is Central park. Table-4 presents visitors' response towards the use of green spaces in the study area. The highest visiting frequency by the users on daily basis of Central park is 65 % and then 61 % for the users who also prefer their home garden along with Central Park. However, 100 % use of the Park is by children for playing sports daily. Table-5 presents the cross tabulation result of most liked green space and time spent there. The result shows a significant relationship between them as 72 % users who like Central Park for recreation spend upto one hour for their activities and remaining 27 % spend upto two hours. Similarly, as sports and play area of the Park is mostly preferred by children, therefore 100 % users spend two hours for games. Table-3 also

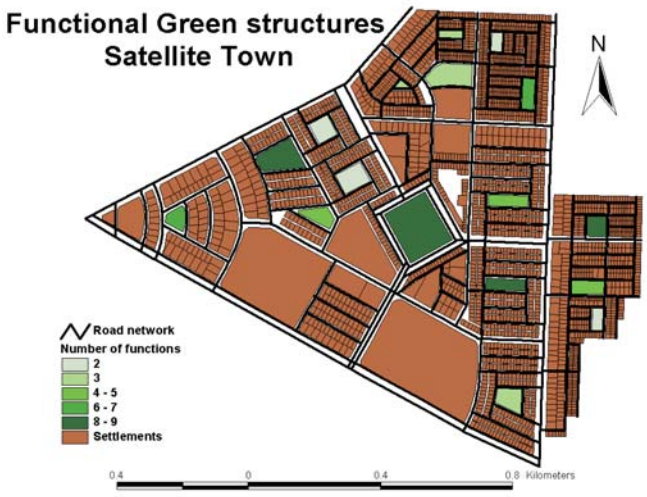

Figure-3: Functional green structures in Satellite Bahawalpur

Table-3: Checklist for Services Analysis of Green Spaces in Satellite Town

Active and passive Recreation	Central Park	Informal recreation area	Play areas	Outdoor sports	Incidental green space
Morning walk	√	√	√	√	×
Playground activities	√	√	√	√	√
Community gathering	√	√	×	√	√
Festivals (marriages etc)	×	×	√		√
Health Benefits					
Exercise	√	√	√	×	×
Psychological relaxation	√	√		×	×
Educational Benefits	×	×	×	×	×
School grounds	×	×	×	×	×
College grounds	×	×	×	×	×
Environmental benefits					
No of trees or plants					
Nill					
2-5			√		√
6-10		√		√	
<10	√				
Fauna (Present)	√	√	√	√	
Fauna (Absent)					√

Table-4: User s Perception on Different Aspects of Visit to Green Spaces (%)

Type of green space	Visiting time			Visit frequency			Easily accessible		quality		Gender	
	Morning	Evening	Night	daily	Once a week	Twice a week	Yes	No	good	Not good	Male	Female
Central Park	20	45	35	65	10	25	90	10	60	40	76	24
Informal recreation area	37	50	12	50	13	37	87	12	62	38	75	25
Home garden and central park	28	66	4.8	61	10	28	95	5	52	48	95	5
Play and sports area	0	100	0	100	0	0	100	0	50	50	100	0

depicts that all green spaces are used mostly by males rather than females, and also that informal recreation

Table-5: Results of Cross Tabulation between visit to Green Space and Time Spent

Most liked green space Vs time spend in hours	Upto one hour	Upto 2 hours
Play and sports area	0 %	100 %
Central park	72 %	27 %
Home garden	87 %	12 %
Informal recreation area	47 %	52 %

area is mostly used for group activities and by various users, therefore time spent there is mostly upto two hours.

The presence of greenery in an area ensures the cleansing and cooling of local environment. By performing different functions, it gives a relaxing effect on local and surrounding community. Keeping in view the services and function of green areas, planners and urban developers must take into account the importance of greenery in sustainable urban planning and design.

5. CONCLUSIONS

Green is not only a color; it is a state of mind. Greening a city can bring it closer to its sustainable development goals. Environmental and societal impact of compactness in cities can be reduced by insertion and allocation of green structures in the planning. These green spaces not only help to sooth the atmosphere and combat pollution but also perform a number of ecological services for the surrounding community. Preservation and restoration of these amenity parks by the authorities is very essential. The planner could guard such “gap sites” against conversion to preserve the high degree of naturalness and wildlife habitation, and to enhance their essential contribution to urban environmental and scenic qualities (Parsons, 2002). The allocation of green structures in the area of Satellite Town, Bahawalpur, is very well planned. All the green spaces perform many functions for the community. But proper management and restoration of play grounds and amenity parks can enhance the services and positive impacts of these spaces on overall city environment.

REFERENCES

- Adams, L. W., Leedy, D.L. (Eds.), 1987. Integrating Man and Nature in the Metropolitan Environment, Columbia MD: National Institute for Urban Wildlife.
- Attorre, F., et al., 2000. Landscape changes of Rome through tree-lined roads. *Landscape and Urban Planning,* 49 , pp. 115–128.
- Bolund, P. & Hunhammar, S., 1999. Ecosystem services in urban areas. *Ecological economics,* 29, pp. 293-301.
- Chiesura, A., 2004. The Role of urban parks for the sustainable city. *Landscape and Urban Planning,* 68, pp. 129-138.
- Davis, M., 1991. City of Quartz: Excavating the Future in Los Angeles. London: Verso.
- Devuyst, D., Hens, L. and Lannoy, W. D., 2001. How green is the city? Sustainability assessment and the management of urban environments, New York, Columbia University Press.
- Dunnett, N., Swanwick, C. and Woolley, H., 2002. Improving urban parks, play areas and green spaces, Department for transport, local government and the regions.
- Hestmark, G., 2000. Temptations of the tree. *Nature,* 408.
- Jackson, L. E., 2003. The relationship of urban design to human health and condition. *Landscape and Urban Planning*, 64, pp. 191-200.
- Jenks, M., and Jones, C., (Eds.), 2010. Future City: Dimensions of the Sustainable City, Springer Netherlands.
- Jim, C. Y., 2000. The urban forest programme in the heavily built-up milieu of Hong Kong. *Cities,* 17, pp. 271–283.
- Jim, C. Y., 2004. Green-space preservation and allocation for sustainable greening of compact cities. *Cities,* 21, pp. 311-320.
- Johnston, J., 1990. Nature areas for city people. Ecology Handbook London: London Ecology Unit.
- Kaplan, R., 1984. Impact of urban nature: a theoretical analysis. *Urban Ecology* 8, pp. 189–197.
- Leff, E., 1990. The global context of the greening of cities In: Gordon, D. (ed.) Green Cities ecological sound approaches in urban space. Black Rose Books.
- Marcotullio, P. J., 2001. Asian urban sustainability in the era of globalization. *Habitat International,* 25.

- Mayur, 1990. Vision and joy of green cities. In: Gordon, D. (ed.) Green Cities: Ecologically Sound Approaches to Urban Space. Black Rose Books.
- Mole, G., and Young, S., 1992. Growing Greener Cities: A Tree Planting Handbook, Los Angeles, CA., Living Planet Press.
- Mumford, L. 1961. The City in History: Its Origins, its Transformations, and its Prospects, London., Secker and Warburg, .
- Parsons, R., and Daniel, T,C., 2002. Good looking, in defense of scenic landscape aesthetics. *Landscape and Urban Planning,* 60, pp. 43–56.
- Petit, J., Bassert, D.L. and Kollin, C., 1995. Building Greener Neighborhoods: Trees as Part of the Plan.
- Redclift, M., 1993. Sustainable Development: Needs, Values, Rights. *Environmental Values,* 2, pp. 3-20.
- Thompson, C. W., 2002. Urban open space in the 21st century. *Landscape and Urban Planning,* 59, pp. 59–72.
- Ulrich, R. S., 1986. Human response to vegetation and landscapes. *Landscape and Urban Planning,* 13, pp. 29-44.
- UN-Habitat, 2009. Planning sustainable cities : Global report on Human Settlements 2009, London; Sterling, VA, Earthscan.
- Werquin, A.C., et al., (Eds.), 2005. Green Structure and Urban Planning - Final Report. Belgium.

FOOD SECURITY AND ECOLOGICAL FOOTPRINT OF CHITTAGONG HILL TRACTS IN BANGLADESH

B. K. Bala, M. A. Hossain** and S. Majumder****

ABSTRACT

This paper presents food security and ecological footprint of the Chittagong Hill Tracts (CHT) in Bangladesh. To estimate food security and ecological footprint, primary and secondary data were collected and a multistage sampling was designed for selecting the farm households from the three districts of the Hill Tracts of Chittagong. A quantitative method for computation of food security was used. To estimate the environmental sustainability at upazila (sub-district) levels, a method of computation of ecological footprint developed by Wackernagel was used. Multiple logistic regression models were fitted to data on food security of the farmers in CHT to identify the factors affecting food security at household levels in CHT. Overall status of food security at upazila levels was found to be good for all the upazilas except Rangamati sadar and the best was found in Alikadam. Environmental status in the Hill Tracts of Chittagong was poor for all the upazilas. Household food security was found to be significantly ($p<0.05$) affected by farm size, education, professions, crops cultivated (jhum and tobacco), distance from market and transition from jhum to horticulture. This study supports transition from jhum to horticulture crops for increased food security and banning tobacco cultivation to avoid deforestation in CHT.

Keywords: *Food security, Ecological footprint, Shifting agriculture, Logit model, Hill Tracts of Chittagong.*

1. INTRODUCTION

Chittagong Hill Tracts (CHT) are the only extensive hilly area in Bangladesh, located in the south eastern of the country. The area of the Chittagong Hill Tracts is about 13,184 sq. km., of which 92% is highland, 2% medium highland, 1% medium lowland and 5% homestead and water bodies. The total population of CHT is 13,31,996, out of which about 51% are tribal people.

Agriculture is the main source of livelihood for this population. Non-farm income opportunities are very limited and, in some areas, non existent. The tribal population here is the most disadvantaged group in Bangladesh. Shifting agriculture is still the cultivation system in this region, with little impact of different plans and programs to promote the agricultural land use patterns. As a result, the tribal populations are suffering from food insecurity and shifting agriculture has led to indiscriminate destruction of forest for food resulting ecological degradation.

Promoting sustainable development in uplands of Chittagong Hill Tracts poses important challenges. These upland areas are remote, and are mostly inhabited by many ethnic minorities. The majority of the ethnic minorities are Chakma (48%) and Marma (28%). The incidence of poverty is very high. To meet the livelihood needs, upland farmers often use unsustainable land use practices. Uplands are essentially caught in a vicious cycle of poverty, food insecurity and environmental degradations. Land use practices in uplands not only degrade the resource-base but also negatively impact on the livelihoods and resource bases downstream. Wider environmental impacts also occur in the form of reduced biodiversity, reduced ability of the ecosystem to regulate the stream flow and reduced carbon sequestration.

Food security is a social sustainability indicator, and most commonly used indicators in the assessment of food security conditions are food production, income, total expenditure, food expenditure, share of expenditure of food, calorie consumption and nutritional status etc. (Riely et al., 1999). Accounting tools for quantifying food security are essential for assessment of food security status and also for policy planning for sustainable development. Several studies have been reported on food security in terms of per capita food availability in Bangladesh (Begum, 2002), pattern of household food consumption and causes of food insecurity (RDRS, 2005); and access and utilization of food and the issues of food and nutritional security (Mishra and Hossain, 2005). These studies give descriptive statistics of the food security. Bala and Hossain (2010) reported a quantitative method of computation of food security. Several studies have been reported to identify the determinants of food security at household level using logistic models (Babatunde et al., 2007; Haile et al., 2005; Faridi and Wadood, 2010 and Sikwela, 2008). But no study has been conducted to identify the determinants of household food security in CHT.

Ecological footprint is an ecological stability indicator and it is a synthetic indicator used to estimate a population s impact on the environment; it quantifies total terrestrial and aquatic area necessary to supply all resources utilized and to absorb all emissions produced in a sustainable way. Apart from analyzing

* Universiti Putra Malaysia. Email: bkbalabau@yahoo.com ** Bangladesh Agricultural Research Institute, Bangladesh.
*** Bangladesh Agricultural University, Bangladesh

the present situation, ecological footprint provides framework of sustainability planning in the public and private scales. Several studies have been reported on the applications of ecological footprint during past decade to address environmental sustainability (Wackernagel et al., 1999; Monfreda et al, 2004; Zhao et al., 2005; Medved, 2006; Chen and Chen, 2006; Bagliani et al., 2008; Niccolucci et al., 2008; Bala and Hossain, 2010). The ecological footprint has been jointly used combining emergy analysis to evaluate ecological footprint for regional level (Zhao et al., 2005) and national level (Chen and Chen, 2006) as well as to assess ecological footprint and biocapacity (Monfreda et al., 2004; Medved, 2006; Bagliani et al., 2008).

The purpose of this paper is to estimate the present status of food security and environmental degradation of the Chittagong Hill Tracts of Bangladesh at upazila (sub-district) levels and develop logit models to identify the factors affecting food security at household levels.

2. MATERIALS AND METHODS

2.1 Sample Survey and Data Analysis

A multi-stage sampling was designed for selecting the farm households from the Hill Tracts of Chittagong consisting of Bandarban, Rangamati and Khagrachhari districts. The sampling framework consisted of primary sampling units of the district, secondary sampling unit of upazila, pre-ultimate sampling units of the village and ultimate sampling of individual households. The ultimate sampling units from each of the villages were selected by stratified random sampling method with proportional allocation, where farm categories were considered as the strata. Multi-stage sampling procedure designed in this study was used to select a total of 1,779 households. In addition, a Focus Group Discussion was held with the Sub-Assistant Agricultural Officers of 10 Blocks of Khagrachhari Sadar Upazila on jhum cultivation, on 16 April 2009, in the Khagrachhari Upazila Agricultural Extension Office. Data on population, crop, tobacco, livestock and forestry were collected to estimate the present status of food security at upazila levels in Bangladesh from upazila office of Government Department of Statistics, Agriculture, Fishery and Livestock. Information collected using multi stage stratified sampling was used to develop logit models to identify the factors affecting household food security.

2.2 Computation of Food Security

The US Department of Agriculture (USDA) evaluated food security based on the gap between projected domestic food consumption and a consumption requirement (USDA, 2007). All food aid commodities were converted into grain equivalent based on their calorie content. Based on the USDA concept, the food security is defined as:

Food Security = (Food available from different sources and also equivalent food from different sources - Food requirement) / Food requirement Eq. (1)

The total food intake proposed is 2,345 kcal/cap, which midway between the values suggested by WHO (2,310 kcal) and FAO (2,400 kcal). The proposed 2345 kcal is equivalent to 1.357 kg of rice based on price. All food aid commodities were converted into grain equivalent based on economic returns (price) to compute the food security. Based on this concept the food security is computed as (Bala and Hossain, 2010):

Food Security = ((Food available from crops including equivalent food from income of tobacco + Food available from aquaculture and equivalent food from income of aquaculture + Food available from livestock and equivalent food from income of livestock + Food available from forestry and equivalent food from income of forestry) Total food requirement) / Total food requirement Eq. (2)

Positive food security means surplus food and negative food security means shortage in food supply to lead healthy life.

2.3 Computation of Ecological Footprint and Biological Capacity

Ecological footprint represents the human demands, taking into account the production and supply of resources (energy, food and materials) and assimilation of the wastes (in all forms) generated by the analyzed system. Ecological footprint of a given population is the total area of productive land and water required to produce all the resources (energy, food and materials consumed), and to absorb the waste generated by that population of a region or nation using prevailing technology and resource management practices. The ecological footprint calculation is based on average consumption data converted into the usage of productive lands. The bioproductive land is divided into 6 categories

according to the classification of the World Conservation Union: (1) cropland; (2) grazing land; (3) forest; (4) fishing ground; (5) build-up land; and (6) energy land.

Total ecological footprint is the sum of the ecological footprints of all categories of land areas which provide for mutually exclusive demands on the bio-sphere. Each of these categories represents an area in hectares, which is then multiplied by its equivalence factor to obtain the footprint in global hectares. One global hectare is equal to 1 hectare with productivity equal to the average of all the productive hectare of the world. Thus, one hectare of highly productive land is equal to more global hectares than one hectare of less productive land. The ecological footprint can be expressed as (Monfreda et al., 2004):

Footprint (gha) = Area (ha) × Equivalence Factor (gha/ha) Eq. (3)

where Equivalence Factor = the world average productivity of a given bioproductive area / the world average potential productivity of all bioproductive areas.

Equivalence factor represents the world average productivity of a given bioproductive area relative to the world average potential productivity of all productive areas and it is the quantity of global hectares contained within an average hectare of cropland, build-up land, forest, pasture or fishery.

An important part of the ecological footprint analysis of a region or zone is represented by the calculation of its Biological Capacity (Biocapacity). This takes into account the surfaces of ecologically productive land located within the area under study. Biological capacity represents the ecologically productive area that is locally available and it indicates the local ecosystems potential capacity to provide natural resources and services. Biological capacity is the total annual biological production capacity of a given biologically productive area. Biological capacity can be expressed as (Monfreda et al., 2004):

Biocapacity (gha) = Area (ha) × Equivalence Factor (gha/ha) × Yield factor Eq. (4)

where Yield factor = Local yield/ global yield

Total biocapacity is the sum of all bioproductive areas expressed in global hectares by multiplying their area by the appropriate equivalence factor and the yield factor specific to that country/locality. Biological capacity can be compared with the ecological footprint, which provides an estimation of the ecological resources required by the local population. The ecological status is expressed as the difference between biocapacity and ecological footprint. A negative ecological status (BC < EF) indicates that the rate of consumption of natural resources is greater than the rate of production (regeneration) by local ecosystems (Rees, 1996). Thus, an ecological deficit (BC < EF) or surplus (BC > EF) provides an estimate of a local territory s level of environmental sustainability or unsustainability. This also indicates how close is the specific area to sustainable development.

2.4 Logit Model for Household Food Security

Logit model is a form of regression which is used when the dependent variable is categorical and independent variables could be of any type. It can be used to predict a dependent variable on the basis of continuous and/or categorical independent variable: to determine the effect size of the independent variables on the dependent; to rank the relative importance of independent variables; to assess interaction effects; and to understand the impact of covariate control variables.

Let Yi denote the food security at household level, where Yi =1 if ith household is food secured and Yi = 0 if not. Also let the k independent variables $X1_i$, $X2_i$, , Xk_i which are either categorical ones coded as dummy variables, such as farm category, profession, training status, etc. or continuous, such as road distance, years of schooling, etc. are measured for each of the n households. In the linear logistic regression model, the dependence of the probability of success on independent variables is assumed to be (Gujrati and Sangeetha, 2007):

$$P_i = \frac{\exp(\sum_{j=0}^{k} \beta_j X_{ij})}{1+\exp(\sum_{j=0}^{k} \beta_j X_{ij})} \quad \text{Eq. (5)}$$

$$1-P_i = \frac{1}{1+\exp(\sum_{j=0}^{k} \beta_j X_{ij})} \quad \text{Eq. (6)}$$

where $X_{0j} \equiv 1$, β_0= intercept and (j=1,2,...,k) are the unknown coefficients.

Equations (5) and (6) look complicated; however, the logarithm of the ratio of P_i and (1-P_i) which is called the logit to Pi turns out to be a simple linear function fo the X_{ij} that is:

$$\lambda_i = \log it(P_i) = \log_e \frac{P_i}{1-P_i} = \sum_{j=0}^{k} \beta_j X_{ij} = \beta_0 + \sum_{j=1}^{k} \beta_j X_{ij} \quad \text{Eq. (7)}$$

λ_i is also called the logistic transform of P_i and the equation (7) is known as a linear logistic regression model.

The parameters of the logit model are estimated based on the maximum likelihood method suggested by Cox (1970). This model calculates the changes in the log odds of the dependent, and not the changes in the dependent itself as OLS regressions would.

3. RESULTS AND DISCUSSIONS

3.1 Food Security and Ecological Footprint at Upazila Level

Figure-1 shows the food security status in nine upazilas of Bandarban Sadar, Alikadam, Ruma, Rangamati Sadar, Barkal, Kaptai, Khagrachhari Sadar, Mahalchhari and Dighinala. Bandarban Sadar (+37.10%), Alikadam (+141.03%), Ruma (+89.67%), Barkal (+6.52%), Kaptai (+8.71%), Khagrachhari Sadar (+5.04%), Mahalchhari (+51.19%) and Dighinala (+36.73%) have positive food security status, and, only Rangamati Sadar (-24.43%) has negative food security status. This implies that Bandarban Sadar, Alikadam, Ruma, Barkal, Kaptai, Khagrachhari Sadar, Mahalchhari and Dighinala are food surplus and Rangamati Sadar are food deficit upazilas.

Figure-2 shows the contributions of crop and horticulture to food security in the nine upazilas of Bandarban Sadar, Alikadam, Ruma, Rangamati Sadar, Barkal, Kaptai, Khagrachhari Sadar, Mahalchhari and Dighinala. Mahalchhari (77%) has the largest contribution to food security from crop followed by Dighinala (64%) and Khagrachhari Sadar (59%) and these upazilas are crop dominated while Bandarban Sadar (18%) has the largest contribution to food security from horticulture followed by Kaptai (16%) and Khagrachhari Sadar (16%).

Figure-3 shows the ecological footprint in the nine upazilas of Bandarban Sadar, Alikadam, Ruma,

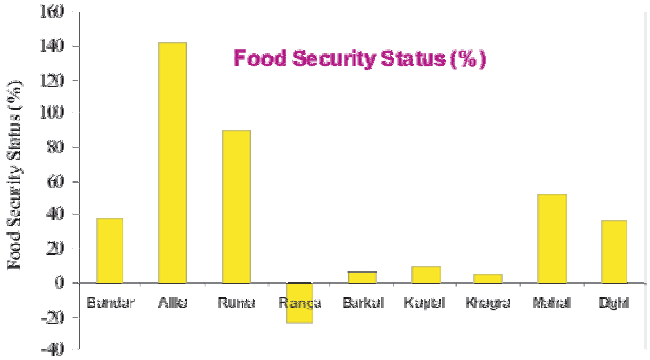

Figure-1: Food Security Status of Different Upazilas

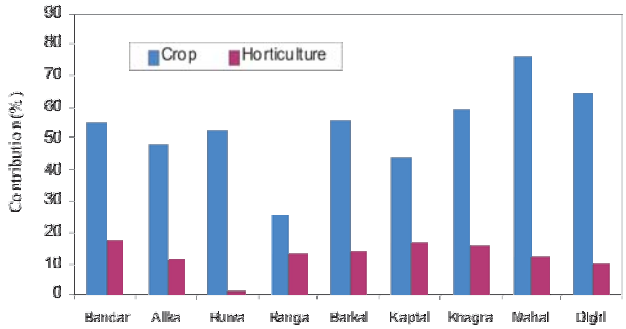

Figure-2: Contributions of Crop and Horticulture to Food Security of Different Upazilas

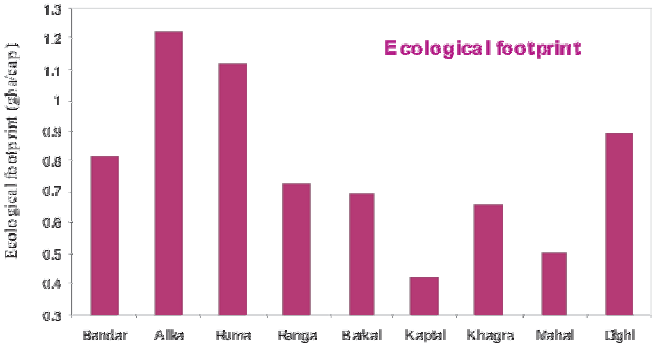

Figure-3: Ecological Footprint of Different Upazilas

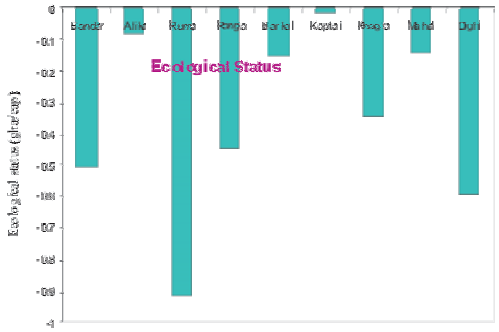

Figure-4: Ecological Status of Different Upazilas

Rangamati Sadar, Barkal, Kaptai, Khagrachhari Sadar, Mahalchhari and Dighinala. The largest ecological footprint is at Alikadam (1.223 gha/cap) followed by Ruma (1.119 gha/cap) and the lowest ecological footprint is at Kaptai (0.426 gha/cap). This implies that Alikadam and Ruma have suffered serious environmental degradation and Kaptai is the least suffered upazila.

Figure-4 shows the ecological status in the nine upazilas of Bandarban Sadar, Alikadam, Ruma, Rangamati Sadar, Barkal, Kaptai, Khagrachhari Sadar, Mahalchhari and Dighinala. The ecologial status of all the upazilas is negative which implies that these upazilas are facing environmental degradation. The ecological status of all the upazilas is deficit because a large amount of wood are used in the kiln for tobacco processing in addition to a large amount of leaves and trees are burnt out for the cultivation of Jhum. Bala and Hossain (2010) assessed the ecological status in the nine upazilas of the coastal zone of Bangladesh, and found that only two upazilas are ecologically surplus and the rest of the five upazilas are ecologically deficit. Wackernagel et al. (1999) also reported that the ecological status for Bangladesh as a whole is -0.20 gha/cap. The average ecological status (-0.2) of Bangladeesh is marginally deficit, but the ecological status (-0.914) of Ruma is 4.5 times of the national average of Bangladesh and needs policy level commitment and programs to arrest the growth and reduce environment degradation.

3.2 Food Security at Household Levels

The results of multiple logit regression models fitted to the data on household food security of the farmers in CHT are shown in Table-1. The logit analysis shows that food security of large farmers is significantly ($p<0.05$) higher than that of other farmers. Large farmers are 1.41 times more likely to be food secured than that of other farmers. Food security appears to be significantly ($p<0.05$) lower among the non-tribal farmers than the tribal ones. The odds ratio shows that there is a 34 per cent decrease in the risk of food insecurity among the tribal farmers as compared to that of non-tribal ones.

A significantly ($p<0.05$) lower food security is found among the farmers whose professions are only agriculture than the farmers having professions like

Table-1: Results of multiple logistic regression model fitted to the data on food security of the farmers in CHT

Variable	Category	Estimated Coefficient ($\hat{\beta}$)	SE ($\hat{\beta}$)	Wald's P	Odds Ratio
Farm category	Large Other (ref.)	0.340* -	0.157	0.030	1.41
Inhabitant	Non-tribal Tribal (ref.)	-0.411* -	0.193	0.033	0.66
Years of Schooling		0.019	0.012	0.128	1.02
Profession	Agriculture Non-agriculture (ref.)	-0.247* -	0.109	0.023	0.78
Road Distance		-0.046	0.031	0.139	0.96
Family Size		-0.043	0.023	0.062	0.96
Jhum Cultivation	Yes No (ref.)	-0.448*** -	0.113	0.000	0.64
Training Status	Yes No (ref.)	0.136	0.136	0.316	1.15
Micro- Credit	Formal Informal Both No (ref.)	0.099 0.126 0.672 -	0.119 0.201 0.412	0.403 0.532 0.103	1.10 1.13 1.96
Extension Service	Yes No (ref.)	0.086 -	0.139	0.535	1.09
NGO Service	Yes No (ref.)	-0.007 -	0.163	0.967	0.99
Rice Cultivation	Yes No (ref.)	0.008 -	0.109	0.939	1.01
Commercial Fruits	Yes No (ref.)	-0.132 -	0.106	0.210	0.876
Livestock	Yes No (ref.)	-0.057 -	0.126	0.651	0.944
Tobacco Cultivation	Yes No (ref.)	2.510*** -	0.325	0.000	12.30
-2 Log Likelihood = 2302.744		Model Chi-Square Value = 161.275 (p<0.001)			

* and *** indicate significance at p<0.05 and p<0.001

service, business, labour, service+agriculture and business+agriculture and labour+agriculture. The odds ratio Table-1 implies that there is 22 percent decrease in the risk of food insecurity among the farmers having foresaid professions than that of the farmers whose professions are only agriculture.

Food security is significantly (p<0.001) lower among the jhum cultivators than those of the farmers who do not practice shifting cultivation. The risk of food insecurity decreases by 36 percent if the farmers involve themselves with other agricultural activities like rice cultivation, forestry and horticulture instead of shifting cultivation. The farmers who produce tobacco are highly significantly (p<0.001) food secured than the others. The odds ratio Table 1 indicates that tobacco cultivators are about 12 times more likely to be food secure than that of tobacco non-cultivators.

The results of multiple logistic regression models fitted to the data on transition from *Jhum* to horticulture are shown in Table-2. The transition from *jhum* to horticulture of the large farmers is significantly (p<0.01) higher than those of other farmers. Large farmers are 31.48 times more likely to transit from *jhum* to horticulture than that of other farmers. Education exerts a significantly (p<0.05) positive association with the transition from *jhum* to horticulture. A significantly higher transition is observed among the farmers of better educational qualification than that without any such qualification. The impact of market distance on the transmission from *jhum* to horticulture appears significant (p<0.05) and its negative sign in Table-2 indicates that better transition occurs for lower market distance.

Table-2: Results of multiple logistic regression model fitted to the data on transmission from jhum to horticulture

Variable	Category	Estimated Coefficient $(\hat{\beta})$	SE $(\hat{\beta})$	Wald's P	Odds Ratio
Farm category	Large Other (ref.)	3.449**	1.010	0.001	31.48
Years of Schooling		0.060*	0.027	0.028	1.06
Market Distance		-0.028*	0.012	0.015	0.97
Extension Service	Yes No (ref.)	0.289	0.188	0.125	1.34
Family Labour		0.056	0.078	0.476	1.057
-2 Log Likelihood = 719.805		Model Chi-Square Value = 64.001 (p<0.001)			

Note: * and ** indicate significance at p<0.05 and p<0.01

4. POLICY IMPLICATIONS

Agricultural systems of the Hill Tracts of Chittagong are still traditional with marginal yield i.e. jhum cultivation resulting in soil erosion and an expanding coverage of tobacco cultivation along banks of the hilly rivers which results in rapid depletion of the nearby reserve forests for kilning the tobacco. These traditional agriculture and expanding coverage of tobacco cultivation are threats to the environment and even this rapid expansion of tobacco cultivation may cause the total destruction of the reserve forests of the Hill Tracts of Chittagong within a short period of time. The findings of this study analysis suggest the following policy implications:

Fruit trees with other horticultural crops control soil erosion and landslides. Tobacco cultivation should be banned deforestation and extension service. Infrastructural development for access to market and development of marketing channels for agro products need promotion of environmentally sustainable and economically viable agricultural systems.

5. CONCLUSIONS

Food security and environmental degradation in terms of ecological footprint of nine upazilas of three districts of the Hill Tracts of Chittagong are estimated.

The overall status of food security at upazila level is good for all the upazilas (5.04% to 141.03%) except Rangamati Sadar (-24.43) and the best is the Alikadam upazila (141.03%).

The environmental status in the CHT region is poor for all the upazilas. The environmental status in the CHT region has degraded mainly due to jhum and tobacco cultivation.

Household food security is found to be significantly (p<0.05) affected by farm size, education, professions, crops cultivated (jhum and tobacco), distance from market and transition from jhum to horticulture. Finally, gradual transition from jhum to horticulture crops for increased food security and banning tobacco cultivation to avoid deforestation in CHT are logical choices for sustainable development.

ACKNOWLEDGEMENTS

The financial support of FAO is gratefully acknowledged for this study under National Food Policy Capacity Strengthening Programme (CF-6). Constructive criticisms, comments and suggestions made throughout the study period by the TAT members Ms. Marie Jo A. Cotijo and Prof. Dr. Sheikh Abdus Sabur for this research are also sincerely acknowledged.

REFERENCES

- Babatunde, R.O., Omotesho, O.A., and Sholotan, O.S., 2007. Factors influencing food security status of rural farming households in North Central Nigeria. Agricultural Journals, 2(3), pp. 351-357.
- Bagliani, M., Galli, A., Niccolucci, V., and Marchettini, N., 2008. Ecological footprint analysis applied to a sub-national area: The case of the Province of Siena Italy). Environmental Management, 86(2), pp.354-364.

- Bala, B.K., and Hossain, M.A., 2010. Food security and ecological foot print of the coastal zone of Bangladesh. Environment, Development and Sustainability, 12, pp.531-545.
- Begum, S., 2002.Proceedings of the APO seminar on role of rural women in food security in Asia and the Pacific held in Thailand from 21-25 August 2000 Asian Productivity Organization Tokyo, Japan.
- Chen, B., and Chen, G.Q., 2006. Ecological footprint accounting based on energy- A case study of the Chinese society. Ecological Modeling, 198, pp. 101-114.
- Cox, D.R. 1970. Analysis of Binary Data. Methuen & Co., London.
- Faridi, R., and Wadood, S.N., 2010. An econometric assessment of household food security in Bangladesh. The Bangladesh Development Studies, 33(3).
- Gujrati, D.N., and Sangeetha. 2007. Basic Econometrics. Tata McGraw, New delhi, India.
- Haile, H.K., Alemu, Z.G., and Kudhlande, G.2005. Causes of household food insecurity in Koredegaga Peasant Association, Oromiya Zone, Ethiopia. Working paper. Department of Agricultural Economics. University of the Free State.
- Medved, S., 2006. Present and future ecological footprint of Slovenia- The influence of energy demand scenarios. Ecological Modeling, 192, pp. 25-36.
- Mishra, U., and Hossain, S.A.K.,2005. Current food security and challenges: Achieving 2015 MDG hunger milepost. Food security in Bangladesh. Paper presented in the national workshop. October 19-20,2005, Dhaka Bangladesh. pp 01-06
- Monfreda, C., Wackernagel, M., and Deumling, D.,2004. Establishing national natural capital accounts based on detailed ecological footprint and biological capacity assessment. Land Use Policy, 21, pp. 231-246.
- Niccolicci, V., et al., 2008. Ecological footprint analysis applied to the production of two Italian wines. Agriculture, Ecosystems and Environment, 128, pp. 162-166.
- RDRS. 2005. A report of survey on food security and hunger in Bangladesh. ISBN 984-32-2562-7.
- Rees, W.E. 1996. Revisiting carrying capacity: area-based indicators of sustainability. Population and Environment, 17, pp.195-215.
- Riely, F., et al., 1999. Food security indicators and framework for use in the monitoring and evaluation of food aid programs. Food and Nutrition Technical Assistance Washington DC.
- Sikwela, M.M., 2008. Determinants of household food security in the semi-arid areas of Zimbabwe: a case study of irrigation and non-irrigation farmers in Lupane and Hwange districts. MS thesis, University of Fort Hare, South Africa.
- USDA. 2007.Food Security Assessment. USDA economic research Service. Appendix- Food Security Model: Definition and Methodology.GFA-19. Washington DC.
- Wackernagel, M., et al., 1999. National natural capital accounting with the ecological footprint concept. Ecological Economics, 29, pp. 375-390.
- Wackernagel, M., and Rees, W.E., 1996. Our ecological footprint: Reducing human impact on the earth New society Gabrioala BC Canada. ISBN 1-55092-251-3.
- Zhao, S., Li, Z.Z., and Li, L., 2005. A modified method of ecological footprint calculation and its application. Ecological Modeling, 185, pp. 65-75.

PHYSICO-CHEMICAL AND MICROBIOLOGICAL ANALYSIS OF DRINKING WATER QUALITY AND EPIDEMIOLOGICAL STUDY OF DISTRICT NEELUM, AZAD JAMMU AND KASHMIR

Sadiqullah Khan, Naeem Ali** and Syed Shahid Ali****

ABSTRACT

Quality of water is vital for sustaining healthy life and associated activities. More than a billion people in the developing world including Pakistan lack safe drinking water [1]. Whereas, nearly three billion people live without access to adequate sanitation systems necessary for reducing exposure to water-related diseases. In Pakistan, the calamity of the October 2005 earthquake tore apart a large area of Azad Jammu & Kashmir (AJK), including District Neelum. In this situation, not only water sources but water distribution systems were also badly damaged. In this regard, a comprehensive study was designed to investigate the condition of freshwater at sources (springs) and reservoirs, and their management and the diseases caused by the use of these source water.

Keywords: *Water Supply, AJK, Water contamination, Chemical and Microbial Contamination, Water-borne Diseases*

1. INTRODUCTION

All living things need water for their survival and the continuation of their lives. Throughout the world, water is present in huge amounts; nearly 70% of Earth s surface is covered with water. 97.5% of the total water is in oceans, which are salty and not fit for drinking. The 2.5 % of the remaining water is fresh water. Less than 1% of the total fresh water is useable. If proper methods are used to get fresh water and carefully applied, the existing resources of water are enough for the whole population of the world. Clean drinking water is important for prevention of diseases, and regulating body temperature [2].

Drinking or potable water has acceptable quality in terms of its physical, chemical and bacteriological parameters so that it can be used without short or long term harmful effects [3,4]. Humans have insufficient access to drinking water throughout the world and consume contaminated sources of water, which have objectionable levels of dissolved chemicals and a huge amount of pathogens. These can lead to widespread, acute and persistent diseases and is a major cause of death. Mostly, the disease-causing organisms are transmitted through drinking water from fecal source, because organic wastes serve as food for bacteria [5-8].

A huge amount of polluted water is returned to natural sources of water from the surrounding area and makes them hazardous as it carries pathogenic organisms and toxic chemicals [8]. Over large parts of the world, the most common contamination of raw water sources is due to anthropogenic activities, which are usually of two categories: chemical/physical and microbiological. Chemicals/physical contaminants are heavy metals, trace organic compound, total suspended solids, while *Coliform* bacteria, *E.Coli* and some other species of bacteria and viruses are microbiological parameters of contamination. Some of the disturbances that happen in study area in Neelum Valley are anthropogenic and natural. Anthropogenic disturbances are water extraction for irrigation, washing activities, toilet use, waste and littering, sewage inflow, picnic, animals, deforestation, etc., while natural disturbances are droughts, floods, snow melting, erosion, landslides and earthquake, etc [9].

The 21st century will open with one of the most essential unmet conditions of human development: universal access to basic water services. More than a billion people in the developing world are deficient in safe drinking-water, a necessity being taken for granted by the populations of developed countries. Nearly three billion people live without access to adequate sanitation systems necessary to diminish exposure to water-related diseases. The failure of the states, local organizations and international aid community to ensure these essential human requirements has led to substantial, unnecessary yet preventable human suffering. An estimated 14-30 thousand people, mostly young children and the elderly, die every day from water-related infections [10-11]. In the developing world, about 400 children below age of 5 years die per hour from water-borne diarrheal diseases [6]. Unsafe and hazardous water, poor sanitation and unhygienic conditions cause approximately 3.1% of annual deaths (1.7 million) and 3.7% (54.2 million) of the annual health encumber worldwide [5, 12].

Microbial pathogenic parameters are usually of greatest concern because of their immediate health risks. Disease-causing organisms are known as enteric pathogens because these microbes are commonly of fecal derivation and transmit through drinking water [13]. Since the pioneering epidemiology in the 1850 s, whereby the English physician John

* International Islamic University, Islamabad. Email: sadiq@iiu.edu.pk ** Department of Environmental Science, International Islamic University, Islamabad. *** Quaid-i-Azam University, Islamabad.

Snow recognized that cholera was waterborne, it is confirmed that water can cause the diseases in human beings [14], it has been observed that diarrhoea and other diseases in humans are caused by various pathogens which are transmitted through the use of potable water [5, 13,15]. In the faeces of all warm-blooded animals and some reptiles, common fecal indicator bacterium, *Escherichia coli* (E. coli), is responsible for cholera (*Vibrio cholerae*) and typhoid fevers (*Salmonella typhi and S. paratyphi*). These bacterial species are considered necessary to be isolated from drinking water by treatment, traditionally filtration and chlorination [1,16].

Dissolved minerals, gases, and organic constituents may create aesthetically disgusting color, taste and odors. Some chemicals may be noxious, and some of the dissolved organic ingredients have been shown to be carcinogenic. Turbidity in surface water is mostly caused due to the erosion of colloidal materials, such as clay, silt, rock fragments and metal oxide from soil [17]. Taste and odor problem is caused by turbidity, and it is not only unsightly but also hinders the distillation abilities of disinfectants [18]. Measurement of electric conductivity (EC) and its relation to cations and anions, and the total solid concentration has been widely used for pollution detection and monitoring the quality of agricultural and surface waters and in chemical oceanography for salinity determination [19]. The pH is of major importance in determining the corrosiveness of water. pH usually has no direct impact on water consumers. Irritation to the eyes, skin, and mucous membranes is due to exposure to extreme pH values. It may have an indirect effect on health because pH can affect the degree of deterioration of metals as well as disinfection efficiency [20].

It has been reported that atleast 52 nations are expected to face a severe deficiency of potable water, including half the world's population till 2025. In the next 25 years, water scarcity will be a major problem for about 3 billion people. Currently, the major issue of South Asia includes: non-availability or inadequate access to potable drinking water, outbreak of water-borne diseases, arsenic contamination of drinking water, seasonal limitation of availability of natural resource, depletion of fresh water aquifers and organic pollution [2].

The study area was badly affected by the 2005 earthquake and was cut off from the outside world. Due to this calamity most of water sources and supply schemes were also damaged badly. In 1998, the population of Neelum valley was 0.126 Million that has increased to 0.159 Million till 2006 [21]. In AJK, there is no municipality-supplied drinking water. For a long time, streams have been the main sources of drinking water for the locals. An unplanned disposal of a large volume of solid wastes, i.e., household, municipal, and industrial, contaminate the sources of water by pouring high concentrations of trace elements and other pollutants [6].

Access to protected and safe drinking water is indicated by the number of people using appropriate hygienic sources. These improved drinking water sources have household links, public standpipe, borehole condition, protected dug well, protected spring, and rain water collection. This assessment expected to indicate the impact of intense anthropogenic use of water quality in a densely populated mountainous area in the Neelum district region. The importance of such investigations is documented through the fact that a huge population is utilizing drinking water from unprotected springs. Water for house-holds is therefore often heavily contaminated and causes chronic and severe infections, especially in summertime. Although, throughout the Neelum Valley there are numerous springs, due to non-availability of well-structured water supply schemes, lack of sewage treatment or controlled sewage discharge, these water resources are being polluted. Such resources could be utilized for water supply to the surrounding settlement, if organized in cooperation with the local population.

This study was conducted to estimate the overall quality (physico-chemical) of different water sources in order to understand the pollution load; and to investigate the water quality with reference to physico-chemical and micro biological parameters in order to find out, the quality of water at source; to investigate the impact of water quality on human health and the types of water-related infections in local people during the past one year. The sites were selected with regard to anthropogenic use, and proximity to the settlements. Furthermore, the variability of springs in the district Neelum was investigated and suggestions for further water management were made.

For this study, 64 Water Supply Schemes (WSS) were surveyed in five union councils (UCs) of district Neelum and were found in bad physical conditions. Eleven (11) WSS have developed spring boxes, while only one was developed, maintained and fenced. On the other hand, 7 schemes were found to be protected from flood diversion channels and only 12 schemes

had no stagnant water around the sources. However, water sources had evidence of microbiological contaminants from adjacent areas due to human and animal activities which were causing severe health problems. For the purpose of physico-chemical and microbial analyses, a total of 64 water samples were collected from five union councils (UCs) and analyzed in triplicate for different physico-chemical and microbiological characteristics. Results revealed that only three water samples out of 64 were found to have turbidity levels higher than permissible limits prescribed by World Health Organization. However, all the water samples showed presence of microbial contamination in the form of either total coliform, while presence of E. coli was confirmed from 52 out of 64 water samples. A questionnaire survey about water-borne diseases among five union councils and capital city of district Neelum was conducted.

According to the results, people irrespective of their age were affected by water borne diseases and infections, such as diarrhoea and dysentery (22.7%), cholera (12.2%), typhoid (4%), skin infection (9.2%), eye infection (9.2%), hepatitis (2.3%), intestinal worms (7.82%), gastrointestinal infection (7%), kidney infection (3.67%) and hemorrhagic fever (14.33%). Considering the overall results of this study, it can be concluded that water supply schemes of the district Neelum were not responsible for any significant physico-chemical contamination in water from sources. However, the presence of microbial contamination in water sources is the evidence of diseases and infection that were commonly ailing the inhabitants of district Neelum.

2. MATERIALS AND METHODS

2.1 Study Area

District Neelum is located in Azad Jammu & Kashmir (AJK), Pakistan. Neelum valley is about 200 km long bow-shaped deeply forested area. At remote areas in district Neelum, visits were made to different sites for the collection of water samples and information associated to the study area (Table-1). Meetings and interviews were conducted with local people to understand the background of the problem stated in the earlier parts of the paper.

2.2 Materials

Water Samples and Sampling: The water sampling in the field was started as per the planned programme. Sampling task was completed in five days, from 16th July to 20th July 2009. A total of 192 water samples were collected from 64 water supply schemes of five UCs. Generally, the water supply schemes in AJK, including Neelum valley have chiefly originated from natural springs and lakes. Two types of water samples were collected from each scheme separately, one for physico-chemical and the other for bacteriological analysis.

2.3 Methods

2.3.1 Physico-chemical Analysis

On-site analysis for physico-chemical parameters, i.e. pH, turbidity and electric conductivity and total dissolved solids, were conducted.

pH: The pH of water samples was determined in the field by using pH Meter (Oakton EcoTest Pocket). The meter was selected for testing samples due to its main features: +/- 0.1 per cent accuracy across full pH range; automatic temperature compensation; auto-buffer recognition and auto-calibration functions. Before measuring pH of water samples, the instrument was calibrated with distilled water.

Turbidity: Turbidity was measured using Waterproof Portable Turbidity Meter EUTECH TN 100, which was calibrated with standard turbidity suspensions, i.e. 0.02, 20 and 100 NTU (Nephelometric Turbidity Units). The sample was taken in specific crystal bottles that were inserted in the turbidity meter placed on plain surface. The reading was noted three times and average was taken.

Electric Conductivity (EC): Electric conductivity of the water sample was analyzed with the help of Hanna

Table-1: Sampling of Water Supply Schemes (WSS) from Union Councils of Distt. Neelum

S. No	Union council (UC)	Number of WSS
1	Bharian	36
2	Doodhnayal	06
3	Kail	01
4	Shah Kot	20
5	Sharda	01

EC Meter - HI-98304 Dist4, ITALY .

Total Dissolved Solid (TDS): The TDS in water samples was determined with the help of a TDS meter.

2.3.2 Microbial Analysis

Bacteriological analysis was also carried out in the field by using field testing kits, Delagua and MERCK, Germany. For analysis of bacteriological samples, standard protocol was adopted in the field.

Total Coliform: Microbiological analysis was also carried out in the field. To analyse total *Coliform* in water samples, the special Merck Kits were used. After taking samples, the Merck kit was placed at 37°C in incubator for 24 hours. After the required time the samples were analyzed.

Escherichia Coli: The Oxfam-DelAgua Water Testing Kit was used for analysis of *E.Coli*. After the collection of samples and applying standard procedures, the samples were placed at 44°C for 24 hours for quantitative analysis. On next day, the *E.Coli* colonies were counted and the total number was recorded.

2.4 Questionnaire Survey

Epidemiological health status of the local population was determined using the questionnaire survey. Questionnaire survey was completed with the help of a research team led by a Research Supervisor. The questionnaire survey was completed according to plan, from 16th July 2009 to 20th July 2009. From each of the five union councils and capital of District Neelum (Autmuqam), 20 families were interviewed about their health conditions during past one year.

The questionnaire included questions related to family information, age and sex composition of each family, water supply source, domestic water treatment (boiling or filteration), type of the water-borne diseases experienced (diarrhea and dysentery, cholera, typhoid, skin infection, eyes infection, hepatitis, intestinal worms, GIT infection, kidney infection) faced by the family during the past one year, number of days the patient suffered from illness, reason of disease, (poor/improper food, water-borne or other causes), number/frequency occurrence of disease during past one year, magnitude of the disease, and hospitalization.

2.5 Hospital Record

For the confirmation of water-borne diseases in the study area, the past two year, i.e., from July 2007 to July 2009, hospital records were obtained from Tehsil Headquarter Hospital, Autmuqam District Neelum. This data included total record of the patient consultations during that specific time period.

3. RESULTS AND DISCUSSION

3.1 Physico-chemical Analysis

On-site analysis for physico-chemical characteristics of water samples, i.e., pH, turbidity and EC and TDS, were conducted (Table-2).

pH: The prescribed limit of pH in fresh water by WHO is 6.5-8.5. The average pH value in all water samples of different schemes was 8.05. The analyzed samples of drinking water were within permissible limit for pH. The range of pH value in the analyzed water sample was 7.3 to 8.8, however most of the 60 samples were falling in the range of limits prescribed by WHO. Only 04 samples exceeded the WHO limit (Table-2).

Turbidity: The prescribed limit of turbidity of fresh water is 5 nephelometer turbidity units (NTU) in WHO and 5-25 in Pakistan Standards & Quality Control Authority (PSQCA) standards. In all the water samples collected, the minimum turbidity value was 0.08 and the maximum value was 9.3, and their average value was 1.45 NTU. The results showed that turbidity of 03 samples were higher than WHO standards.

Electric Conductivity (EC): There is no guideline value of electric conductivity in fresh water in WHO standards, but the water having E.C above than 500 $\mu s/cm^3$ is not considered good quality water. Average electrical conductivity of all the water samples of 64

Table-2: The Results of Physico-chemical Analyses

Parameters	Total No WSS	Value varies From-To	Average Conc	No. of WS Exceeding WHO STD
Turbidity	64	0.08-9.3 NTU	1.45 NTU	03
pH	64	7.3-8.8	8.05	04
EC	64	30-507 $\mu s/cm^3$	158.38 $\mu s/cm^3$	00
TDS	64	26.95-304.2 mg/l	87.341000 mg/l	00

Table-3: The Results of Microbiological Analysis

Microbial Parameters	Total No WSS	WSS within WHO STD	WSS Exceed WHO STD
Total Coliform	64	00	64
E.coli	64	12	52

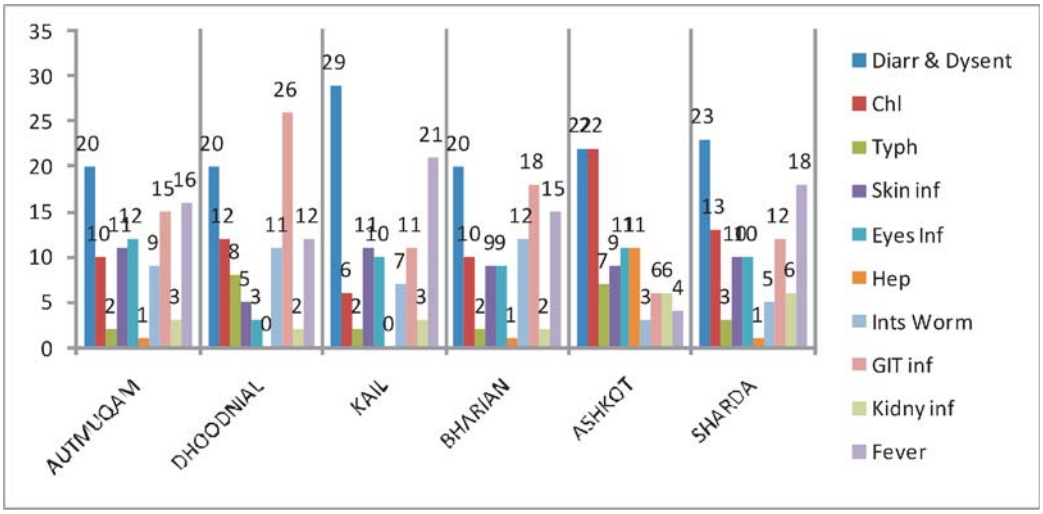

Figure-1: Percentages of each Type of Disease / Union Council Distribution

water supply schemes was 158.38, though it varied between 30µs/cm^3 to 507µs/cm^3. All 64 water samples in the five union councils were falling in the range.

Total Dissolved Solids (TDS): The prescribed limit for TDS in fresh water according to WHO standards is 1000 mg/l. Average TDS concentration in water samples was 87.34; however, TDS concentration in all water samples, varied from 26.95 to 304.2 mg/l. Most of the 57 samples were falling below the range of 150 mg/l. None of water samples exceeded the WHO limit (Table-2).

3.2 Microbial Analysis

Bacteriological analysis for total *coliforms* and *E. coli,* was also carried out in the field by using field testing kits provided by the local NGO. *Coliforms* are relatively easy to identify, and are usually present in larger numbers than more dangerous pathogens. *E. coli* as being the member of *coliform* bacteria is always taken as indicator of fecal pollution in water. The results of the present study positively indicated the presence of total *Coliform* in all water samples of the WSS, while the fecal *coliform* in the form of *E. Coli* was present in 52 out of 64 water samples of the water supply schemes (Table-3).

3.3 Population Survey for Disease Prevalence

Diseases caused by water are the most crucial concern when determining the quality of water. The enteric pathogens found in water include a broad variety of viruses, bacteria and protozoan parasites [12]. These pathogens cause severe and chronic health risks. In the study area, diarrhoea and dysentery was commonly found. As indicated in Figure-1 showing the percentages of the specific water-borne diseases, diarrhoea and dysentery were present in high ratios of the population than other diseases in each union council. Diarrhoea and dysentery were found prevalent among 20% population of population in Autmuqam, Bharian & Doodhnayal, 29% in Kail, 22% in Ashkot and 23% in Sharda, out of the recorded diseases. Figures of 12% in Doodhnayal, 22% in Ashkot and 13% in Sharda, cholera was observed. Typhoid was in the 8% population of Doodhnayal and 7% of Ashkot.

In the study area, a number of people were observed suffering from skin infections. Skin infection was found more common in Autmuqam and Kail (11%), and Sharda (10%). Whereas, eye infections were found in Autmuqam (12%), Kail and Sharda (10%), and Ashkot (11%). Hepatitis was observed in Ashkot (11%). Intestinal worms were found in Dhoodhnayal (11%), Bharian (12%). Gastro-Intestinal Tract (GIT) infections

were common in Doodhnayal (26%), Bharian (18%), and Ashkot. Kidney infections were also observed and investigated in Ashkot and Sharda (6%). On the other hand, Hemorrhagic Fever was found in Autmuqam (16%), Kail (21%), Bharian (15%), and in Sharda (18%).

3.4 Hospital Record for Comparison and Verification of Water-borne Diseases in District Neelum

Figure-2 points out that the residents of district Neelum were infected and suffered from acute Diarrhoea (9.79%), Acute Jaundice Syndrome (0.02%), Bloody Diarrhoea (0.8%), Injuries (0.09%), Lower Respiratory Track Infection (10.15%), Malaria (0.06%), Measles (0%), Cholera (0%), Scabies (5.11%), Unexplained Fever (1.08%), Upper Respiratory Track Infection (25.05%) and Others (47.86%). Other problems, i.e., body aches, headache, depression or other psychiatric problems, head lice, joint pain etc, are included in other diseases.

4. CONCLUSIONS AND RECOMENDATIONS

Bacteriological contamination was evident in all water sources with few exceptions. Therefore, water-borne diseases were common and had infected a huge number of people in study area. However, no significant variation in physico-chemical quality parameters was observed. In the light of this study, it is recommended to adapt disinfection measures, such as boiling, chlorination, and use of direct sun light at domestic level. Water resources should be protected from mixing with human and animal wastes. Furthermore, to avoid house-hold waste contamination, separate laundry points for washing clothes should be constructed to reduce contamination due to soap and detergents. Quantitative and qualitative monitoring of water in the supply schemes with reference to bacteria and awareness about the water-borne diseases should be initiated as soon as possible.

REFERENCES

1. WHO, 2006. Guideline for Drinking Water Quality (Electronic Source). Edition 3rd: Vol.1, pp 121,125, 145, 184-187, 390.
2. Kahlown, M. A., Tahir, M. A., and Rasheed, H. 2008. Fifth Water Quality Monitoring Report 2005-06. Pakistan Council of Research in Water Resources (PCRWR).,133-2007, 3-38.
3. Gadgil, A.,1998. Drinking Water in Developing Countries. *Annual review of energy and the environment*, 23, pp. 253-286.
4. Prasai, T., Lekhak, B., Joshi, D. R, and Baral, M. P., 2007. Microbiological analysis of drinking water of Kathmandu valley: Kathmandu, Nepal, Nepal Academy of Science and Technology. 5(5), pp. 112-113.
5. Ashbolt, N. J., 2004. Microbial contamination of drinking water and disease outcomes in developing regions: Sydney, University of New South Wales, 198, pp. 229-238.
6. Javaid, S., Sarwar, G. S., Jabbar, A. C., and Haleem, M. K. 2008. Assessment of Trace Metal Contamination of Drinking Water in the Pearl Valley, Azad Jammu and Kashmir: Uxbridge, UK: Institute for the Environment, Brunel University, 36(2), pp. 216-219.
7. WHO. 2003. Quantifying selected major risks to health. The World Health Report.2002. World Health Organization, Geneva.
8. White, D. M., Garland, D. S., Narr, J., and Woolard, C. R., 2003. Natural organic matter and DBP formation potential in Alaskan water supplies: University of Alaska Fairbanks USA, *Water and Environmental Research Center*., 37, pp. 939-947.
9. Habermann, B., and Reisenberger,M., 2000. Water Quality Assessment in Mallam Jaba Valley N.W.F.P, Dep. of Hydrobiology, Fisheries and Aquaculture, University of Agricultural Sciences, Vienna, 1.2-4, (4-36 pp)
10. Gleick, P. H., 1999. The human right to water. *Water Policy* ,1 (5), pp. 487-503
11. Kindhauser, M. K., 2003. Communicable Diseases 2002. Global defense against the infectious disease threat: Geneva, Switzerland: World Health Organization, pp. 241
12. Clasen, T. F., and Bastable, A., 2003. Faecal contamination of drinking water during collection and household storage: the need to extend protection to the point of use, *Journal of Water and Health*, 01(3), pp. 109-115.
13. Hunter, P. R., Waite, M., and Ronchi, E., 2002. Drinking Water and Infectious Disease: Establishing the Links: London: IWA Publishing, (54-79 pp).
14. Paneth, N., Viten-Johansen, P., Brody, H., and Rip, M., 1998. A rivalry of foulness: official and unofficial investigations of the London cholera epidemic of 1854; Michigan State University, USA, East Lansing, Department of Epidemiolgoy. *American Journal of public Health*., 88(10), pp. 1545 1553.
15. Bryan, J. P., et al., 2002. Epidemic of hepatitis in a

military unit in Abbottabad, Pakistan, Department of Preventive Medicine and Biometrics, Uniformed Services University of the Health Sciences, Bethesda, Maryland, *The American Journal of Tropical Medicine and Hygiene*, 67(6), pp. 662-668.
16. Enriquez, C., Nwachuku, N., and Gerba, C. P., 2001. Direct exposure to animal enteric pathogens. *Review of Environmental Health*, 16, pp. 117-131.
17. Greenberg, A. E., Clesceri, L. S., Eaton, A. D., 1998. Standard Methods for the Examination of Water and Waste Water: 20th Edition. Washington DC: American Public Health Association, 2.8- 4 (134 pp).
18. Peavy, H., Rowe, D., and Tchobanoglous, G., 1985. Environmental Engineering. McGraw-Hill Inc London, (15-45 pp).
19. Ahmad, I., 2004. Palas Conservation and Development Project
20. WHO, 2004. pH in Drinking water, Background document for development of WHO Guidelines for Drinking water Quality WHO/SDE/WHO/03.04/12
21. Atiq-ur-Rehman, A. U. R., and Anis, H., 2008. Impact of hydropower Projects on Economic Growth of AJK
22. WOK Grabow, 1996. Water born diseases: Update on water quality assessment and control, Water SA, 221996, pp. 193-202

INSTRUCTIONS FOR AUTHORS

Typescripts:
Papers should be typewritten on A4 paper (210x297 mm), with double spacing and 3 cm margins. Each section should begin on a new page and may include: title page, 150 words abstract/summary, keywords, text, illustrations, tables, references/bibliography and acknowledgement.

Title Page:
The title page should contain: (i) the title of the article; (ii) names and initials of each author with their highest academic qualifications; (iii) Name and affiliation of all the authors; (iv) the department or institution to which the work should be attributed (if necessary); and (v) name and address of the author responsible for correspondence.

Abstracts:
The second page of the manuscript should carry an abstract of not more than 150 words, which may contain a gist of the review, study or investigation, main findings, and the principle conclusions.

Tables and Illustrations:
The tables and illustrations should be provided separately from the text and: (i) numbered according to the order in which they are mentioned in the text; (ii) carefully revised for facts and figures and any discrepancies removed; (iii) have short explanatory captions; and iv) mention the source (if necessary) at the bottom.

Abbreviations:
Authors should limit the use of abbreviations. Terms that are mentioned frequently may be abbreviated but only if this practice does not hinder the readers' comprehension. Abbreviations should be used consistently through out the text, but must be clearly defined right at the start of the text.

References and Bibliography:
In order to standardize the referencing and citation style, the authors are requested to preferably use the alphabetical/name-date system in a particular style known as the Harvard style. In this style of referencing/citation, the author's surname and the year of publication are cited in the text (e.g. Bond, 2004) and a reference list (of these citations) is included at the end of the article/paper, in alphabetical order by author-name with date. Such a reference list also includes important details, for instance the title and publisher.

A bibliography may be provided to list relevant scholarly content that has been used in the preparation of the article/paper but not necessarily cited in the text. The bibliography should also be in the Harvard style.

Queries/Comments and Submission of Articles/Papers:

The contributions, queries and comments may be sent to the Managing Editor – Science Vision on the following address:

COMSATS Secretariat
4th Floor, COMSATS Building
Shahrah-e-Jamhuriat, G-5/2, Islamabad- 44000, Pakistan.
Tel: (+92-51) 9214515-7, Fax: (+92-51) 9216539
Email: comsats@comsats.org; info@sciencevision.org.pk

SCIENCE VISION

CONTENTS PAGE

COMSATS SECRETARIAT

4th Floor, Shahrah-e-Jamhuriat, Sector G-5/2, Islamabad, Pakistan.
Tel: (+92-51) 9214515-7 Fax: (+92-51) 9216539
Email: comsats@comsats.org, Website: www.comsats.org
Email: info@sciencevision.org.pk, Website: www.sciencevision.org.pk