CHAPTER 1
INTRODUCTION

1.1 Background:
The tea industry in India is about 170 years old. It has been occupying an important place and playing a very vital role in the national economy. Wild tea plants were discovered in upper Brahmaputra Valley of Assam by Robert Bruce in 1823 (Ukers, W. H., 1935) and after 15 years the first Indian tea from Assam was sent to the United Kingdom for public sale. After that, it extended to other parts of the country. However, due to certain specific soil and climatic requirement its cultivation is confined only to the certain parts of the country like Assam, West Bengal, Tamilnadu and Kerala. In Assam, tea production system is characterized by two sectors of opposite structure existing next to each other plantation management versus smallholder production. Both sectors can be distinguished by their typical production system. The plantation sector (big garden) was implemented during the colonial times and is characterized by production units larger than 20 hectares and socially structured in a hierarchic order. Crops are cultivated in monoculture, production is labour intensive with high investment rates for artificial fertilizer, pesticides, High Yielding Varieties (HYV), equipment infrastructure and factories where processing take place. The concept of small tea plantation started in Assam in 1978 (Borgohani, J. K., 2008). But it gained momentum during the mid 90’s due to the prevailing high price at that time. Presently around 70,000 small tea growers are operating in Assam (Asomya Protidin, 12 May 2010). Small tea grower has been defined by the Tea Board of India as a person who has tea plantation area up to 10.12 ha. The small tea gardens of Assam have a countable contribution to the total tea production. More than 9,00,000 people are involved in the small tea growing business in Assam. Almost 2,50,000 hectares of land is covered with such plantations. They contribute to 30 percent of the total tea production in Assam, which is 14
percent of the total tea production of India (Asomya Protidin, 12 May, 2010). In Assam though there were 515 numbers of small tea gardens established in 1991 and 1992 (Baruah, K. S., 2008), these were increased to more than 38,779 in 2008 (Phukan, D., 2008) and in 2010 it reached up to 70,000. For good production of tea plant, the soil should be deep, well drained and thoroughly aired, nutritious with a low pH (4.5-5.5). Extended drought periods, water logging conditions and temperatures below 12°C and above 30°C are not favourable for the growth of tea plant. It is imperative to say that the quality aspect of tea is a relative term. Tea quality generally hovers around maintaining bush hygiene and sticking to judicious use of agro-inputs.

Mr. Digen Saikia was the first small tea grower in Sonitpur district, Assam (Borgohani, J. K., 2008). The small holder sector is very heterogeneous, partly representing the traditional way of agricultural production. The small tea growers have less knowledge about treating the bushes and the land. They use various agrochemicals without proper scientific testing of the soil, hence the soil as well as water quality inside and outside area of the gardens are degraded day by day. Tea production has a great impact on the environment. Tea is grown in monoculture, which reduces biodiversity. In the absence of other plants to maintain the ecological balance, intensive use of pesticides and fertilizers is needed to protect the plants against pest infestation and to enhance productivity. These agrochemicals come to the soil and then leach to the drinking water sources. Due to mining of nutrients from soil, the fertility status of many tea lands have declined resulting in low yield. The soil is also degraded due to the sloping nature and heavy rainfall in most tea lands in the area where soil erosion is common.

The most suitable soil properties for tea are as follows (Sharmah, G. C., 2008).
i. Soil should be deep, at least 60 cm and better if it is more than 1 meter deep.

ii. Soil should be rich in nutrients, with a well balance of different nutrients.

iii. Soil should be moderately acidic, i.e pH (4.5 to 5.5).

iv. Water should enter to the soil easily during rain.

v. Soil should have the capacity to store a lot of water, and slowly release it to plant roots during dry weather.

vi. Soil should be well drained as the underground water is at least in the 80 cm. below the surface of the soil.

vii. Soil should be soft enough to work easily, and to penetrate plant roots,

viii. Soil should be healthy, organic matter breaks down rapidly, and plants do not get root-rot diseases or nematodes.

Soil and water quality contributes to our health and environment. Soil is a limited natural resource on which agrarian activities (agriculture, livestock and forestry) are carried out. It is interconnected with other natural resources, which are also essential for human life, such as the air, water, fauna and flora. Soil acts as the most important intermediate and regulating factor for most agricultural processes and, by extension, the environmental effects of agriculture. The long term development of global socio-economic systems require the sustainable use of natural resources. This paradigm is fundamental in the well established concept of sustainable development defined in the report of Bruntland, G. H., (1987), which states that sustainable development is development that “meets the need of the present without compromising the ability of future generations to meet their own needs”. The sustainable use of soil resources depends on three factors: soil characteristics, related environmental (climate, hydrology etc.) conditions and land use. These factors interact on system based principles, where the change in one factor causes alternation in the others. Therefore
the sustainable use of soil resources is a dynamic category. It is highly important to assess our soil resources from this standpoint and consider soil as the prime object of sustainable use in relation to land management under given (changing) natural conditions. From whence it can be said that if the soil is well managed, the effects of agriculture on the environment will be acceptable and conversely, if it is badly managed, agriculture and other resources like water, fauna, flora and atmosphere needed by human will deteriorate.

Soil resources are critical to the environment, as well as to food and fiber production. Soil provides minerals and water to plants. Soil absorbs rainwater and releases it later, preventing floods and drought. Soil cleans the water as it percolates. Soil is the habitat for many organisms, the major part of known and unknown biodiversity is in the soil, in the form of invertebrates (earthworms, woodlice, millipedes, centipedes, snails, slugs, mites, springtails, enchytraeids, nematodes, protists), bacteria, archaea, fungi and algae, and most organisms living above ground have part of them (plants) or spend part of their life cycle (insects) below ground. Above ground and below ground biodiversities are tightly interconnected, (Ponge, et. al., 2003), (De Deyn, et. al., 2005) making soil protection of paramount importance for any restoration or conservation plan. Soils have three basic quality issues productivity, environment and health of humans and animals. Ever increasing population of the world has raised the agrochemical pressure of soil to get more production from the soil. So the quality of the soil is degraded day by day which affects the production of agriculture as well as human health. In this chapter, a short review of existing literature on soil quality, and water quality, broad objectives of our research problem along with its significance are discussed. Bhuyan, B., (2006) studied the soil and water quality in tea gardens of Lakhimpur district, Assam, India.
The growth of literature and database on soil and water, its quality and pollution and environmental health hazard survey have been really tremendous during the last several years. An exhausting literature survey is thus a near impossible task and, therefore, only a sample of the published literature, having relevance directly and indirectly to our research work is given here.

We never know the worth of water till the well is dry (Thomas Fuller, 1732)

Water is essential for life, it is a medium in which all living process occurs. Access to safe drinking water is essential to health, a basic human right and a component of effective policy for health protection. Most recently, the U.N General Assembly declared the period from 2005 to 2015 as the International Decade for Action, “Water for life’. The water we use every day for cleaning, drinking or washing is termed potable when it is safe for human consumption. The history of human civilization reveals that water supply and civilization are synonymous. Water for human consumption should be free from germs and toxic matters besides containing essential minerals. However, a clear and colourless water sample without a taste or odour does not guarantee of purity and safety for drinking. Chemical contamination of drinking water, either naturally or by anthropogenic sources, is a matter of serious concern as the toxic chemicals do not show acute health effects unless they enter into the body in appreciable amounts, but they behave as cumulative poisons showing the adverse health effects after a long period of exposure (Plant, J. A., et. al., 2005). High rates of mortality and morbidity due to water-borne diseases are well known in India. Access to safe drinking water remains an urgent necessity, as 30% of urban and 90% of rural households still depend completely on untreated surface or groundwater (Kumar, R. et. al., 2005). Serious degradation of water quality in urban India has often been attributed to indiscriminate disposal of sewage and industrial effluents and
agricultural runoff into surface water bodies. The fresh water supply in the earth for
drinking is very limited. On the other hand, explosive population growth has exerted
tremendous pressure on the water bodies. The factors such as massive
industrialization, rapid urbanization and wide spread applications of various
chemicals, pesticides, insecticides, herbicides in the agricultural fields have added
considerable number of pollutants to the water resources (Pionke, H. B., et. al., 1990).
The population in rural India is mainly dependent on the groundwater as a source of
drinking water (Srikanth, R., 2009). As a quality concern the groundwater is often
found to be contaminated with fluoride, arsenic, iron and salts. In recent years,
fluorosis has emerged as major public health issue in rural India. While access to
drinking water in India has increased over the past decades, the tremendous adverse
impact of unsafe water on health continues (WHO/UNICEF., 2004). Water related
diseases are rare in developed countries because of the availability of efficient
provisions for adequate water supply and waste water disposal system. But in
developing and underdeveloped countries contamination of drinking water by
domestic and industrial wastes as well as human and animal excreta is a common
feature (Crocker, K. J., 2000). Diseases related to contamination of drinking water
constitute a major burden on human health. It is estimated that about 21% of
communicable diseases in India is water related (Brandon, C., et. al., 1995). The
dehvelopment characteristics of an area also influence the rate of presence of
concentrations of various chemical substances on the water bodies
(http://whqlibdoc.who.int).

The use of various structurally complex synthetic compounds in the field of
industry and agriculture has added many potentially toxic chemicals in the aquatic
environment (Randhawa, G. K., et. al., 2009). The major toxic contaminants of water
are As, F, Pb, Hg, Cd, Cu, Ni, Zn, NO₃⁻, NO₂⁻, Se, Ag, Ba, Be, CN⁻, pesticides, poly
nuclear aromatic hydrocarbons, phenols etc. There are other chemical constituents,
which are non toxic, but affect the aesthetic and organoleptic quality of water. These
include Al, Cl⁻, Cu, hydrogen sulphide, Fe, Mn, DO (dissolved oxygen), Zn, SO₄²⁻
etc. (Oates, L. et. al., 2009). The need to monitor drinking water quality has been
universally recognized and is a necessary safeguard against a large number of health
hazards.

While the shift in usage from surface water to ground water has undoubtedly
controlled microbiological problems in rural India (Shah, T., 2005.) the same has
however, led to newer problems of fluorosis and arsenicosis (Rao, S. M., 2004;
Chakraborty, A. K., et, al., 1987). Excess iron is an endemic water quality problem in
many parts of eastern India (Smedley, P. L., 1991). In 2002, 17 states were affected
by severe fluorosis and now the problem exists in 20 states, indicating that endemic
fluorosis has emerged as one of the most alarming public health problems of the
country (Teotia, S. P. S., et. al., 1984). About 62 million people are suffering from
various levels of fluorosis, of which 6 million are children below the age of 14 years
they suffer from dental, skeletal and non-skeletal fluorosis (Susheela, A. K., et. al.,
(RGNDWM), a nodal agency responsible for setting up systems of monitoring rural
drinking water in India, indicated in its report during 1993 (based on 1% random
sampling) that 2,17,211 inhabitants had water-quality problems in rural India.

1.2. Review of Literature

1.2.1. The Concept of Soil Quality

"As knowledge increases, and as the earth becomes more crowded, geo-chemical
information is becoming an increasingly significant factor in decisions affecting the
management of the overall environment, ultimately this information affects human survival." (Darnley, A. G., 1995). Soil may be defined as the weathered superficial layer of the earth's crust that is typically made up of either decomposed or partly decomposed parent rock material with associated organic matter in various stages of decomposition. Soil is a natural body consisting of layers (soil horizons) of mineral constituents of variable thicknesses, which differ from the parent materials in their morphological, physical, chemical, and mineralogical characteristics (Birkeland, et al., 1999). It is composed of particles of broken rock that have been altered by chemical and environmental processes that include weathering and erosion. Soil differs from its parent rock due to interactions between the lithosphere, hydrosphere, atmosphere, and the biosphere (Chesworth, 2008). It is a mixture of mineral and organic constituents that are in solid, gaseous and aqueous states (Voroney, R. P., 2006.). Soil particles pack loosely, forming a soil structure filled with pore spaces. These pores contain soil solution (liquid) and air (gas) (Taylor, S. A., et. al., 1972). A good soil can be compared with a new sponge where water can enter easily, and remains stored inside for later use. The ease with which water enters the soil, and is stored in the soil, is determined by two properties, texture and structure. Adding organic matter will improve the water entry and water storage of any soil. Capacity of soil lies in functioning within ecosystem boundaries to sustain biological productivity, maintain environmental quality and promote plant and animal health. In the context of agriculture, it may refer to its ability to sustain productivity. A healthy soil would ensure proper retention and release of water and nutrients, promote and sustain root growth, maintain soil biotic habitat, respond to management and resist degradation.
Figure 1.1: Bad and good soil structure

Most soils have a density between 1 & 2 g/cm³ (www.pedosphere.com/textbook.cfm). Soil is also known as earth, it is the substance from which our planet takes its name. In engineering, soil is referred to as regolith, or loose rock material. Soil is the natural medium where the roots of most plants grow. From soil the plant absorbs water and solutes necessary for its continued well-being. If soil is fertile, it contains in a readily available form of all the chemical elements essential for plant growth. Soil is a complex system which includes mineral (inorganic) matters, organic matters, water, air and organisms (Weier, T. E., et. al., 1973). The chemical composition of soil is determined by the nature of the starting materials from which the soil was formed and by the processes that it has undergone over time. Soil in the field is not a monolithic mass of unchanging composition. Rather, it is characterized by large spatial variability in both the horizontal and vertical dimensions. The chemical nature of soil is determined by the combination of minerals and organic matters that make up the soil (Vanloon, W. et. al., 2005). Soil health has been broadly defined as the capacity of a living soil function, which has a natural or managed ecosystem boundaries, to sustain plant and animal productivity, maintain or enhance water and air quality, and promotes plant and animal health (Doran, J. W., et. al., 1996), (Doran, J. W., et. al.,
Soil filters and purifies water and affects its chemistry. Rain water and pooled water from ponds, lakes and rivers percolates through the soil horizons and the upper rock strata, and thus become ground water. Pests (viruses) and pollutants such as persistent organic pollutants, oils (hydrocarbons), heavy metals (lead, zinc, cadmium), and excess nutrients (nitrate, sulphates, phosphates) are filtered out by soil (Kohne John Maximilian, et. al., 2009) and soil organisms metabolize them or immobilize them in their biomass and necromass (Diplock, E. E., et. al., 2009), thereby incorporating them into stable humus (Moeckel Claudia., et. al. 2008). The physical integrity of soil is also a prerequisite for avoiding landslides in rugged landscapes (Rezaei, Khalil., et. al., 2009). Soil is classified into categories in order to understand relationships between different soil and to determine the usefulness of a soil for a particular use. One of the first classification systems was developed by the Russian scientist Dokuchaev around 1880. It was modified a number of times by American and European researchers and developed into the system commonly used until 1960s. It was based on the idea that soils have a particular morphology based on the materials and factors that form them. In 1960 a different classification system began to emerge, that focused on soil morphology instead of parental materials and soil forming factors. Since then, it has undergone further modifications. The World Reference Base for Soil Resources (WRB) (IUSS Working Group WRB 2007) aims to establish an international reference base for soil classification. In the U.S (United States) system, there are 10 orders of soil classifications.

Soil is broadly divided taxonomically as vertisols, alfisols etc. They are also texturally divided as sandy, loamy, clayey and their mixed textures. Though, they have some common characters, they differ vastly from place to place in their nutrient content, pH, limiting factors like sodium, etc. Even in a small farm, the same type of
soil varies a lot in its fertility and productivity depending upon factors like depth, slope, cropping history, irrigation, rainfall, drainage conditions etc. The fertilizer application therefore should be based on close study of all such factors for every plot of the farm. Soil testing in this context provides immense information. In many parts of the country, the ground water is saline, alkaline and also contains toxic levels of fluorine, arsenic, iron etc. But unknowingly farmers are using this water for irrigation without taking remedial measures and damage their soils.

1.2.2. Soil Functions

Soil, a non-renewable natural resources, has several functions in the biosphere and for human. It is a reactor, transformer and integrator of material and energy from other natural resources, a medium for biomass production, storage of water, nutrients and heat, natural filter and detoxication and buffering systems, an important gene-reservoir, and a medium of past and present human activities (Blum, W. H. E., 2005, Nortcliff. S., 2002, Varallyay, G. Y., 1997). Soil functions are general or specific capabilities of soil for various agricultural, environmental, landscape and urban applications. In the soil protection strategy (E. C., 2006), the main functions are identified as,

- Biomass production
- Storing, filtering and transforming nutrients and water
- Hosting the bio-diversity pool
- Acting as a platform for most human activities
- Providing raw materials
- Acting as a carbon pool
- Storing geological and archaeological heritage
These functions are performed on different levels and are determined by inherent soil characteristic (e.g. texture, organic matter content, pH, cation exchange capacity, porosity etc.) and external environmental (climatic, terrain, hydrological, biological) and anthropogenic (soil-use and management) factors. With the evolvement of the paradigm of sustainable development, recent applications of land evaluation tend to include a combination of different aspects and performance characteristics of soil use (Gall, Z., et. al., 2003, Vrscaj, R., 2006). These approaches attempt to provide a comprehensive answer to current needs of the society and represent the art of scientific knowledge, which are supported by modern soil databases.

1.2.3 Soil Degradation

Soil degradation can take a number of forms, including nutrient depletion, soil erosion, salinization, agrochemical pollution, vegetative degradation from overgrazing and the cutting of forests for farmland (Scherr, S. J., 2001; Lhoste, P., 1993). Nobel Prize winner Dr. Alexis Carrel says that the earth is ailing almost beyond repair. All the life will be either healthy or unhealthy, according to the fertility of the soil. It has been established (Vazhenin, I. G., 1987) that under anthropogenic enrichment the maximum content of pollutant is observed in the surface layers of soil, 0-5 cm i.e., in the plough depth of soil in agricultural fields. Directly, or indirectly, all food comes from soil. Today soils are tired, overworked, depleted, sick, poisoned by synthetic chemicals. Hence the quality of food has suffered. Malnutrition begins with the soil, human health depends on wholesome food, and this can only come from fertile and productive soils. Minerals in the soil control the metabolism of cells in plant, animal, and human. Diseases are created chiefly by destroying the harmony reigning among mineral substances present in infinitesimal amounts in air, water, food, but most importantly in soil. If soil is deficient in trace elements, food and water
Land degradation is a human induced or natural process which impairs the capacity of land to function. Heavy metal pollution of soil enhances plant uptake causing accumulation in plant tissues and eventual phytotoxicity and change of plant community (Ernst, W. H. O., 1996; Zayed, A., et. al., 1998; Gimmler, H., et. al., 2002). In general, an increase of metal concentration influences soil microbial properties (e.g. respiration rate, enzyme activity), which appear very useful as indicators of soil pollutions (Brookes, P. C., 1995; Szili-Kovacs, et. al., 1999). Short- term and long- term effects of pollution differ depending on metal and soil characters (Kadar, I., 1995). In the after effect of heavy metal pollutions, the role of pollutant bounding or leaching increases, which determine their bio-availability and toxicity. In addition, some heavy metals enter in soil directly, together with mineral (phosphorous) fertility (for example Cd), metal containing pesticides (Zn, Cu, Sn, Hg, etc.) and also sewage sludge, which are used as non-traditional fertilizer. River water contaminated by industrial sewage can enrich soils with heavy metals anthropogenically when used for irrigation. Soils are the critical component in land degradation when it involves acidification, contamination, desertification, erosion, or salination. The soil acidification degrades land and lowers the crop productivity and increases soil vulnerability to contamination and erosion. Acidification occurs when the basic elements are removed from the soil profile by normal rainfall or the harvesting of forest or agricultural crops. Soil acidification is accelerated by the use of acid-forming nitrogenous fertilizers and by the effects of acid precipitation. Soil contamination is either soil or liquid hazardous substances mixed with the naturally occurring soils. Usually, contaminants in the soil are physically or chemically attached to soil particles, or, if they are not attached, they tend to get trapped in the small spaces between soil particles. Naturally, some soils are dry when hard, very
sticky when wet, poorly drained, gravelly and stony or have very low nutrient contents or toxic amounts of aluminium or salt. Acid sulphate soils are the nastiest soils in the world. They generate sulphuric acid, where 10 cubic meters of sulphidic soil may generate 1.5 tones of sulphuric acid and release a cocktail of aluminium, heavy metals and arsenic. The acid corrodes steel and concrete, pollutes streams and estuaries, killing fish and causing disease. The effects of aluminium, heavy metal and arsenic on the food chain are certainly harmful.

1.2.4. Soil Degradation Threats

Soil is essentially a non-renewable resource with possible high rate of degradation and extremely slow rate of regeneration processes. Degradation deteriorates soil quality by partially or entirely damaging one or more of its functions (Blum, W. H. E., 1988). Degradation processes occurring in Europe are widely studied (Batjes, N. H., et. al., 1993; Kirkby, M. J., et. al., 2004). Risk of soil degradation depends on soil and terrain properties which make the soil inherently receptive of degradation. Van C. L., et. el., 2004, provides substantial knowledge towards identifying and describing hazards to soil. The main threats to soil functioning abilities are identified as follows,

i. Decline in organic matter

ii. Soil erosion

iii. Salinisation

iv. Landslide and Floods

v. Contamination

vi. Sealing

Protection of soil quality under intensive land use and fast economic development is a major challenge for sustainable resource used in the developing world (Doran, J. W.,
et. al., 1996). The basic assessment of soil health and soil quality is necessary to evaluate the degradation status and changing trends following different land use and smallholder management interventions (Lal, R., et. al., 1995). In Asia, adverse effects on soil health and soil quality arise from nutrient imbalance in soil, excessive fertilization, soil pollution and soil loss processes (Zhang, W. L., et. al., 1996, Hedlund, A., et. al., 2003). In Africa, three quarters of farm land is severely degraded (Eswaran, H., et. al., 1997; Stocking, M. A., 2003). As a result, Africa cannot produce enough food to keep pace with her needs, and per capita food production is declining (Lal, R., 1998) largely due to loss of soil health and soil quality.

1.2.5. The Concept of Soil Sustainability

The concept of soil quality emerged in the literature in the early 1990's (Doran, J. W., et. al., 1997; Wienhold, B. J., et. al., 2004), and the first official application of the term was approved by the Soil Science Society of America Ad Hoc Committee on Soil Quality (S-581) and discussed by Karlen, D. L., et. al., 1997. Soil quality was defined as “the capacity of a reference soil to function, within natural or managed ecosystem boundaries, to sustain plant and animal productivity, maintain or enhance water and air quality, and support human health and habitation”. Subsequently the two terms ‘soil health’ and ‘soil sustainability’ are used interchangeably (Karlen, D. L., et. al., 2001) although it is important to distinguish that, soil quality is related to soil function (Karlen, D. L., et. al., 2003) whereas soil health presents the soil as a finite non renewable and dynamic living resource (Doran, J. W., et. al., 2000). Sustainable soil use refers to “the use of soil as a natural resource on a way that does not exert any negative effects that are irreparable under rational conditions either on the soil itself or any other systems of the environment (Toth, G., 2004). The sustainability of soil use can be achieved by the practical methods of management and
can only be guaranteed if the material and energy flow associated with soil processes are controlled and positively influenced. This means the management and maintenance of certain level of soil characteristics, which eventually embrace soil quality as well. Long term influence of human impact (by land use change; amelioration/restoration measures; degradation effects) on the ecological conditions of soil as well as the seasonal soil use operations (drainage, cultivation, irrigation, nutrient management etc.) modify material and energy flows, resulting in the transformation of the pedogenic processes at smaller or greater extent. When these processes are traceable, controllable, soil use and soil quality remains sustainable in the long run. The society needs simple measurements to compare the options for utilizing soil functions and measuring the risk of that particular utilization to soil degradation processes. Soil quality assessment can serve as a basis of this comparison and should be one of the main criteria for planning and practising sustainable soil use. Although, not the sole basis of decision making, soil quality can have an important input to various policy development considerations. The most important questions of soil use related decision making (Varallyay, G. Y., 2002) can be answered on the bases of soil quality assessment.

1.2.6. Soil Fertility

Soil fertility is a scientific discipline that integrates the basic principles of soil biology, chemistry, and physics to develop the practices needed to manage nutrients in a profitable, environmentally sound manner. Historically, the study of soil fertility has focused on managing soil nutrient status to create optimal conditions for plant growth. Fertile, productive soils are vital components of stable societies to ensure that the plants needed for food, fiber, animal feed and forage, medicines, industrial products and for an aesthetically pleasing environment can be grown. Two other
fundamental principles underlay the study of soil fertility, first is the recognition that optimum nutrient status alone will not ensure soil productivity. Other factors, such as soil moisture and temperature, soil physical condition, soil acidity and salinity, and stresses (disease, insects, and weeds) can reduce the productivity of even the most fertile soils. Second is the realization that modern soil fertility practices must stress environmental protection as well as agricultural productivity. For soil fertility purposes, availability of the 13 essential mineral elements (N, P, K, Ca, Mg, S, B, Cl, Cu, Fe, Mn, Mo, Zn) for plant growth in soils need to be assessed. For environmental purposes essential plant nutrients that may be transported to other ecosystems and the fate of essential and non essential elements that may impact human or ecosystem health. Non essential elements of greatest concern are Al, As, Ba, Cd, Cr, Pb, Hg, Ni, and Se. Potentially toxic essential elements are Cu, Mn, Mo, and Zn.

1.2.7. Soil Fertility Evaluation: Purpose, General Principles and Practices

The fundamental purpose of soil fertility evaluation has always been to quantify the ability of soils to supply the nutrients required for optimum plant growth. Knowing this, the nutrient management practices need to achieve economically optimum plant performance. For better management of soil the following factors should be noticed.

(i) To identify the factors that reduce soil productivity (e.g. acidity, salinity, elemental phytotoxicity).

(2) To determine if the intended use of the soil may negatively impact environmental quality.

Basically, soil fertility is evaluated by observations and tests which are used to predict the response of plants, environment, and nutrient management. Soil fertility evaluation involves an impressive array of field and laboratory diagnostic techniques and a series of increasingly sophisticated empirical and theoretical models that
quantitatively relate these indicators of soil fertility to plant response. Diagnostic techniques include chemical and biological soil tests, visual observations of plant growth for nutrient deficiency or toxicity symptoms and chemical analysis of plant tissues are important for better crop production and observe fertility status of soil. New approaches include remote sensing techniques and geographic information systems (GIS) that facilitate landscape-scale, site-specific assessments of soil fertility. Computerized expert systems enable these indicators of soil fertility to be related to quantitative or qualitative assessments of plant performance (yield, composition, quality, colour, health) and thus, to rapidly adjust soil management practices for the most efficient use of nutrients.

1.2.8. Soil Fertility Evaluation: For Agricultural & Non Agricultural Systems

The study of soil fertility evolved within ecosystem is devoted primarily to the production of agricultural crops. The importance of soil fertility to world agriculture continues, today as a spiraling world population and a diminishing arable land base, create unprecedented pressure on scientists and practicing agriculturalists to produce more food/beverage per unit area of land than ever before. Higher crop yields mean greater depletion of soil nutrient which eventually must be balanced by increased nutrient inputs from outside to maintain fertile soils. Soil fertility evaluation will play an important role in the future of global agriculture production i.e. to maximize production from existing soils. Other land uses also require a thorough, in-depth evaluation of soil fertility for maximum economic and environmental efficiency. Examples are horticultural systems, disturbed lands needing reclamation, and soil conservation and remediation practices.

1.2.9. Soil Fertility Evaluation: Environmental Issues

Environmental quality is inextricably linked with soil fertility. Soils must be managed
to optimize plant productivity, and to avoid or minimize pollution in water, atmosphere, and the food chain. Some essential plant nutrients contribute to environmental problems. Nitrogen may cause human and animal health problems if \( \text{NO}_3\text{-N} \) leaches to ground water which is used for drinking water supplies. Ammonia-N volatilized from fertilizers and animal manures cause soil acidification. Nitrogen oxides (e.g. \( \text{NO}_3 \)) produced by denitrification have been implicated in ozone depletion and global warming. Eutrification of surface waters is caused by entry of P and N in runoff, erosion and aerial deposition. Soil salinity problems arise where salts accumulate, particularly in arid regions. Recycling of wastes or byproducts as sources can also, directly or indirectly, affect environmental quality. Under developed countries often use wastes and wastewater as fertilizers and for irrigation owing to the lack of resources, equipment and infrastructure. Land application for biosolids (and animal manures) is usually based on the amount of N needed for optimum yield. However, the unfavourable N and P ratio in most organic wastes, relative to that in crops, means that P accumulates above required levels in waste amended soils. This creates an environmental dilemma because organic wastes are used at beneficial N rates causes the buildup of P which can impact surface waters by losses in runoff and erosion. Soil fertility evaluation is more complex today because of the need to balance productivity and environmental protection for a wider and more diverse range of land uses.

1.3. The Concept of Water Quality

Water is the most precious natural resource and is extremely essential for survival of all living organisms. It is the medium in which all living processes occur (CIA-The world fact book, 2008). Water covers almost 71% of the earth's surface it is found mostly in oceans, seas and other large water bodies, with 1.6% of water below ground
in aquifers and 0.001% in the air as vapour, clouds (formed of solid and liquid water particles suspended in air), and precipitation (Lomborg, B., 2001). The quality of water is vital concern for mankind since it is directly linked with human welfare. Most of the Indian people depend on ground water so it is very essential for ground water protection and management (Patil, P. R., et. al., 2001). The health and happiness of the human race are closely tied up with the quality of the water used for consumption where the per capita consumption of water is an index of quality of life of the people as well as their economic and social condition. There is a clear correlation between access to safe drinking water and GDP per capita (Kulshreshtha, S. N., 1998). However, entrance of safe drinking water has improved steadily and significantly over the last decades in almost every part of the world. According to the report, about 70% of the freshwater is used in agriculture (Baroni, L., et. al., 2007). Over the year, water is being used without much prejudice as a result we have now come to a stage where we cannot afford to waste even a little bit of water without judicious use. It is being estimated that, by the year 2025, more than half of the world population will be facing water-based vulnerability (Kulshreshtha, S. N., 1998).

Anthropogenic activities like mining, ultimate disposal of treated and untreated waste effluents containing toxic metals as well as metal chelates (Amman, A. A., et. al., 2002) from industries, e.g. tannery, steel plants, battery industries, thermal power plants etc. and also the indiscriminate use of heavy metal containing fertilizers and pesticides in agriculture resulted in deterioration of water quality rendering serious environmental problems posing threat to human beings (Lantzy, R. J., et. al., 1979; Nriagu, J. O., 1979; Ross, S. M., 1994) and sustaining aquatic biodiversity (Ghosh, S., et. al., 1997; Das, R. K., et. al., 1997). Though some of the metals like Cu, Fe, Mn, Ni and Zn are essential as micronutrients for life processes in
plants and microorganisms, while many other metals like Cd, Cr and Pb are not known to the physiological activity, but they are proved detrimental beyond a certain limit (Marschner, H., 1995; Bruins, M. R, et. al., 2000) which is very much narrow for some elements like Cd (0.01 ppm), Pb (0.10 ppm) and Cu (0.050 ppm) (BIS 1991). The deadly diseases like edema of eyelids, tumor, congestion of nasal mucous membranes and pharynx, stuffiness of the head and gastrointestinal, muscular, reproductive, neurological and genetic malfunctions caused by some of these heavy metals have been documented (Johnson, F. M., 1998; Abbasi, S. A., 1998). Therefore, monitoring these metals is very important for safety assessment of the environment and human health in particular (Kar, D., et. al., 2008).

1.3.1. Water Resources in India

India is going to face a turbulent of water in future. The country has a highly seasonal pattern of rainfall, with 50% of precipitation falling in just 15 days and over 90% of river flows occurring in just four months. The Indian mainland is drained by 15 major (drainage basin area >20,000 km²), 45 medium (2,000 to 20,000 km²) and over 120 minor (<2,000 km²) rivers, besides numerous ephemeral streams in the western arid region (Sharmah, R. B., et. al., 2006). For large-scale analysis of water resources, the country is often separated into some 19 major drainage regions (Amarasinghe, U., et. al., 2005). The Indus and Ganga-Brahmaputra-Meghna systems cover respectively some 10% and 35% of the entire country, and are characterized by extensive flood in plains and deltas. There is considerable spatial variation in mean annual precipitation, which ranges from about 100 mm in western Rajasthan to more than 2500 mm in north-eastern areas with a world maximum of 11,000 mm near Cherrapunji in Meghalaya. This coupled with a variety of geological and topographical conditions within a given basin results in a large spatial variability of flow regimes ranging from
regimes partially fed by snowmelt in the rivers originating from the Himalayan mountains, to regimes of alluvial plains rivers, which receive considerable base flow from groundwater in the autumn (Bandyopadhaya, J., 1995). These rivers play a major role in the economy of India through sustaining agriculture, industry, and energy generation and by providing ecological services. The average annual precipitation in India in volumetric terms is 4,000 Billion Cubic Meter (BCM). The average annual surface flow from this is 1,869 BCM, the rest being evaporated or infiltrated. Due to topographical and other constraints, it is estimated that only 690 BCM can be effectively utilized. By trans-basin diversions, it is estimated that a further 25 mha potential can become available through surface and 10 mha through groundwater sources. The share of per-capita withdrawals by the domestic and industrial sectors is some of the lowest in the developing world.

However, with increasing urbanization and per-capita demand, the water demands in domestic, industrial and other sectors are expected to increase and become highly competitive with the irrigation sector. Several factors influence India’s future water supply and demand. These include spatial variation and future growth of the population, urbanization and growing income levels and changes in food habits (higher consumption of animal-based products), growth in crop yields, cropping intensity and groundwater use potential of rain fed agriculture and future growth in industrial and environmental water demand. National Commission on Integrated Water Resources Development (NCIWRD) of India has estimated the country’s potentially utilizable water resources at 1022 km$^3$ (690 km$^3$ from surface water and 432 km$^3$ from groundwater). According to NCIWRD the total water use in the country was estimated at the level of 611 km$^3$ in 2000 and projected to 793 km$^3$ in year 2025 and 1104 km$^3$ during 2050. These water demand projections are based on
the population projections at the level of 1.581 billion by 2050. With competing and evolving demands, and declining per capita availability of renewable water, India is faced with turbulent times ahead if these demands, including the needs of the poor, are to be met or even maintained.

1.3.2. Drinking Water Quality in National Context

Ensuring the supply of safe drinking water in India is a constitutional mandate with the Article 47 conferring the duty of providing clean drinking water and improving public health standards to the state. In recent years High Courts around the country have been recognizing the right to safe drinking water as a fundamental right (Srikanth, R., 2009). The National Water Policy (2002) of India also emphasizes through a generic statement that both surface and ground water should be regularly monitored for quality. A phased programme is undertaken for improvements in water quality (National Water Policy of India, Govt of India, 2002). India occupies only 3.29 million km² geographical areas (http://www.nih.ernet.in/water.htm), which forms 2.4% of the world's land area, it supports over 15% of the world's population. The population of India as on 1st March, 2001 stood at 102,70,15,247 (131,00,00,000 in 2011) persons. Thus India supports 1/6th of world population, 1/50th of world's land and 1/25th of world's water resources. India has a livestock population of about 500 million, which is about 20% of world's total livestock population (Sharmah, H. P., 2010). With rapid growth of population, livestock population and improving living standards the pressure on our water resources is increasing and per capita availability of water resources is reducing day by day. Over exploitation of ground water is leading to low flows in rivers, declining of the ground water resources and salt water intrusion in aquifers of the coastal areas. The quality of surface and ground water resources is also deteriorating because of increasing pollution loads from point and
non point sources. Several factors influence India's future water supply and demand. These factors need to be carefully assessed in future water supply and demand projection. India, with more than one billion population is projected to become the most populated country in the coming decades. Since the First Five-Year Plan in 1951, investments made in water and sanitation have been estimated at Rs. 1105 million. Yet, it has been estimated that around 37.7 billion. Indians are affected by water-borne diseases annually, 1.5 million children are estimated to die of diarrhoea alone and 73 million working days are lost due to water-borne diseases each year (Divakar, H. et. al., 2003). The resulting economic burden is estimated at US$ 600 million a year (Murthy, M. N. et. al., 1999). Clearly, the health benefits in terms of reduction in water-borne diseases have not been commensurate with the investments made (Hughues, G. et. al., 2001). Planned expenditure for the water supply sector reforms under the various five-year plans has also for the 54th round of the National Sample Survey showed that 50% of rural households were served by a tube well/hand pump, 26% by a well, and 19% by tap (Central Statistical Organization, 1999) . In most parts of the country, however, the water supplied through groundwater is beset with problems of quality. The over dependency on groundwater has led to 66 million people in 22 states at risk due to excessive fluoride and around 10 million at risk due to arsenic in six states (Central Ground Water Board of India, Technical report, 2002). According to central pollution control board (CPCB) around 1,95,813 habitations are affected by poor water quality due to chemical parameters (CPCB, 1999).

1.3.3. Ground Water Quality and Major Ground Water Contaminants

Groundwater accounts for more than 80% of the rural domestic water supply in India (World Bank, 1998). In India high arsenic (As) contents have been reported from West Bengal, from the districts of Nadia, Murshidabad, Malda, Bardhaman, North
and South Parganas (Chakraborty, D. M. K., et. al., 2004). India’s Tenth Five-Year Plan lists excess fluoride concentration as one of the major hurdles to the sustainable supply of safe water for domestic use (Planning Commission, 2002). Twenty Indian states have excess fluorides in the groundwater (Susheela, A. K., 2001). Nearly 6 million children below the age of 14 suffer from dental, skeletal and non-skeletal fluorosis (Teotia, S. P. S., et. al., 1984). Bacteriological contamination, especially faecal coliform, is the most widespread groundwater pollution problem in India (CPCB, 1999). The presence of faecal coliforms and related pathogens accounts for a number of water-borne diseases like diarrhoea, gastroenteritis, jaundice, hepatitis, cholera, typhoid, polio, etc. (Marra, D. D., et. al., 1999). Sanitary risks of locating a drinking water source (hand pump) close to household toilets and accumulation of animal excreta near a drinking water source are the major risks in typical rural settings (Water Aid, 2008). Iron, hardness and salinity impart an unpalatable taste to water, making it unfit for drinking. Many coastal districts in India suffer from excess salinity in ground-water (Central Pollution Control Board, 2003). Iron is found in parts of Madhya Pradesh, Uttar Pradesh, Coastal Orissa, Andhra Pradesh and Tamil Nadu (Handa, B. K., 1984).

1.3.4. Ground Water Quality Monitoring

Monitoring of groundwater quality is a prime concern for ensuring safe drinking water which generates reliable and accurate information about water quality, because most of the Indian people depend upon the ground water. The contamination of natural water is being increased every day as the organic and inorganic pollution load is going to be increased day by day. Drinking water quality is considered as a very serious issue all over the world and more attention has been given to the problem in the developing countries (WHO, 2004). However, water quality parameters by means
of physical, chemical and bacteriological examination are used as a tool for the evaluation of water quality pollution and also to provide guidelines for the provision of safe drinking water to the citizens. Decrease in pollution or improvement in water quality used for human consumption depends upon reliable analytical measurements (Lepom, P., et al., 2009). The World Health Organization (WHO) has introduced a set of guideline values for drinking water quality (WHO, 2004) to ensure the physical, chemical and biological composition of water within the limits, so as not to cause undesirable effect to human being over a long time of consumption. So monitoring of drinking water quality is of utmost importance for public health.

1.4. Objectives

The following are the objectives taken for consideration in this present study.

❖ To study the physico-chemical characteristics of soil in and around the selected small tea gardens of Gohpur and Biswanath Chariali Sub-Divisions of Sonitpur district, Assam, India by estimating the available nutrients present which basically determine fertility.

❖ Formation of basic recommendation, the use of lime and fertilizers by soil testing which will reduce the production cost and improve the quality of soil.

❖ To investigate the physico-chemical characteristics of ground water quality in and around the tea gardens of Gohpur and Biswanath Chariali Sub-Divisions, Sonitpur district, Assam, India.

❖ To identify the possible sources of parameters, which are found at the concentration levels of pollution.

❖ To determine the statistical correlations among various parameters.

❖ To arrive at some conclusions regarding the soil and water quality in the area.
1.5. Significance of the Study

Managing soil health is a formidable challenge to ensure productivity, profitability and national food security. The United Nations Millennium Development Task Force on hunger made Soil Health Enhancement as one of the five recommendations for increasing agricultural productivity and fighting hunger in India. Modern agriculture practices such as pumping of ground water for irrigation and indiscriminate use of fertilizers containing toxic substances contribute to environmental degradation as well as deteriorating soil fertility status. Such anthropogenic activities invariably result in the depletion of water bodies, deterioration of soil quality, contamination of drinking water and various health hazards. Hence there is need to study in a comprehensive manner about the soil and water quality issues. Present major targets in the assessment of soil and water quality in the small tea garden areas to strengthen the database on soil and water quality as well as to educate and raise awareness so that concerted strategies could be adopted, at the planning level, to keep the contamination of soil at the minimum level, which will help reduction in the production cost of tea, improvement of its environment, and promotion of sustainable development. Types and amount of chemical substances in agricultural field increasing rapidly, as a result soil and water pollution becomes conspicuous. Soil testing is the only way to accurately determine the fertility status of the particular field which will detect the problems before they become serious. Similarly pure drinking water is a human right by testing of water parameters will help this area in near future for potable water. In the present study scientific data are presented for fertility management of tea gardens soil and water and assess the environmental impact which will help the good environment as well as economic benefit of small tea growers by using low fertilizer and high yield.