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Impact of Climate Change on Sustainable Sericultural Development in India

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Abstract **– Climate change may recognize as a major threat to the survival of species and integrity of ecosystems worldwide. The rise in global atmospheric temperature are mainly depends on increase in concentration of green house gases (GHG) like carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (NO_2). Rising of these GHG emissions are associated with burning of fossil fuel, rapid industrialization, deforestation, agricultural activities, luxury/ modernization of life style (home appliances), space explosion, grazing, wetland destruction and landuse change etc. The exact effect of climate change on soil health and sericulture industry is based on prediction and not yet proven, but several explanations have been proposed in this regard. Based on prediction of several researchers from various Indian institutions, the temperature may rise from 0.5 to 4.0^o in the various part of the country in next few decades from the accumulation of anthropogenic greenhouse gases in the atmosphere, which may change practices and economy of sericulture drastically in temperate region and marginal or beneficial effect in tropical region in India. The sericulture practiced in tropical environmental regions such as Karnataka, Tamil Nadu, Andhra Pradesh, West Bengal, Uttar Pradesh, Madhya Pradesh, Chhattisgarh, Bihar, Jharkhand and Assam will be severely affected, however, small to marginal loss can be noticed in Jammu Kashmir and Sub-Himalayan region of North-Eastern India.**

Keywords **– Climate Change, Sericulture, Mulberry, Silkworm, Soil Health.**

I. INTRODUCTION

Climate change may recognize as a major threat to the survival of species and integrity of ecosystems worldwide [1]. It is recognized globally as the most impending and pressing critical issue affecting mankind survival in the 21st century. Statistically, Climate change is a significant variation in either the mean state of the climate or in its variability, persisting for an extended period (typically decades or longer), which, may be due to natural internal processes or external forcing, or to persistent anthropogenic changes in the composition of the atmosphere or in land use.

The United State Framework Convention on Climate Change (UNFCCC) stated that the climate change 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. The UNFCCC thus makes a distinction between climate change attributable to human activities altering the atmospheric composition, and climate variability attributable to natural causes.

The rise in atmospheric temperature is not new and it was started from pre-industrialization era. Some scientists reported that the fossilized remains of leaves of trees about 55 million years ago and they reached a conclusion that planet was undergoing a period of warming [2]. They also believed rise in global temperatures was due to tripling of CO_2 levels during the Paleocene age. The rise in global atmospheric temperature are mainly depends on increase in concentration of green house gases (GHG) like carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (NO_2). Rising of these GHG emissions are associated with burning of fossil fuel, rapid industrialization, deforestation, agricultural activities, luxury/ modernization of life style (home appliances), space explosion, grazing, wetland destruction and land use change etc.

On the basis of the increase of greenhouse gases, climatic models predict a 1.4^oC to 5.8^oC average increase in global warming from 1990 to 2100, probably leading to a more rapid increase in temperature at the surface of terrestrial zones and more extreme local variations [3]. The Intergovernmental Panel on Climate Change [4] suggested that if temperatures rise by about 2.0^o C over the next 100 years, negative effects of global warming would begin to extend to most regions of the world; it is believed likely that approximately 20-30 percent of plant and animal species will be at an increased risk of extinction. The IPCC also predicted that, based on a range of scenarios, by the end of the 21st century, climate change may result:

- A probable temperature rise between 1.8^oC and 4.0^o C, with a possible temperature rise between 1.1^o C and 6.4^o C.
- A sea level rise most likely to be 28 - 43cm.
- Arctic summer sea ice may disappear in second half of century.
- An increase in heatwaves being very likely.
- A likely increase in tropical storm intensity.

Global Scenario of Climate Change

According to IPCC (2007), industrialization and households directly contributes more than two third (69.1%) of global GHG emissions in 2004 whereas agriculture and allied sector including deforestation contributes 30.9% which is approximately one third of total global GHG emissions. Sector wise annual GHG emissions are given in fig. 1. Out of total global GHG emissions, CO^2 contributes 72% emissions which is almost two third of total GHG emissions, however, contribution of CH_4 and N_2O emissions are 18% and 9% respectively (http/en.wikipedia.org). It has been also estimated that the agriculture and its allied sector contributes almost one third of total CO_2 emissions, half of total CH_4 and two third of total N_2O emissions. However, agriculture is one of the few sectors that can contribute to both mitigation and to sequestration of carbon emissions in agricultural soils. Thus, in addition to reducing its own emissions, carbon sequestration in agricultural soils can play an important role in off-setting emissions from other sectors.

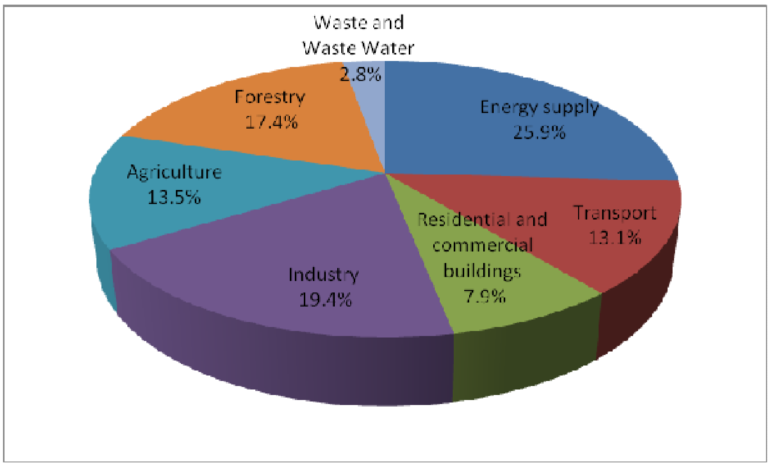

Fig. 1. Schematic diagram of Sector wise global annual emissions of GHG. Source: (IPCC 2007)

National Scenario of Climate Change

In India, GHG emissions from Energy, Industry, Agriculture, and Waste sectors constituted 58%, 22%, 17% and 3% of the net CO_2 eq emissions respectively [5]. The Indian government's report to the UN framework convention on climate change reported that the threats perceived by the experts are the rise in sea levels in the next few decades which may inundate many areas on the western coast from Gujarat through Konkan to southern Kerala and damage to the river mouths on the eastern coast. It has been also reported that the some parts of the coastal areas may altogether disappear. The summer monsoon, which provides 75 per cent of India's rainfall and on which agriculture is crucially dependent, will become unpredictable. It will lead to floods in some areas and drought in other places [6].

A World Bank study had also found that the drought-prone areas in Andhra Pradesh and Maharashtra and the flood-prone districts in Orissa are even now near climate tolerance limits. The report foresees a 4.0^o rise in maximum temperatures in some areas of Kutch and Rajasthan in the next 10 years [6].

It has also been reported that, the average temperature in India has risen by about 0.5^o C from the accumulation of anthropogenic greenhouse gases in the atmosphere during the past century or so. The effect of recent emissions will be manifested over several decades and given current trends, the temperature rise will likely exceed 2.0^o C. [7].

Based on prediction of several researchers from various Indian institutions, the temperature may rise from 0.5 to 4.0^o in the various part of the country in next few decades from the accumulation of anthropogenic greenhouse gases in the atmosphere, which may change practices and economy of Indian agriculture or sericulture drastically.

History of Sericulture

Sericulture or silk production in the world has a long and colourful history which is mostly unknown to most of the people. According to Pliny, the Roman historian, wrote in his natural history in 70 BC, silk was obtained by removing the down from the leaves with the help of water, whereas the Chinese legend gives the title "Goddess of Silk" to lady "Hsi-Ling-Shih", wife of the mythical yellow emperor, who was said to have ruled China in about 3000 BC. Another example is a group of ribbons, threads and woven fragments, dated about 3000 BC, and found at Qianshanyang in Zhejiang province. The recent archaeological findings are a small ivory cup carved with a silkworm design, spinning tools, silk thread and fabric fragments from sites along the lower Yangzi River and thought to be between 6000 and 7000 years old which reveals the origins of sericulture to be even earlier (*Encyclopedia*).

History of sericulture is date back in India and it is known as *Patt* in Eastern India, *Pattu* in Southern India, and *Resham* in Hindi and Urdu. As per thearchaeological discoveries in Harappa and Chanu-daro, the local or native wild silk threads were more popular during the time of Indus Valley Civilization [8]. According the article in nature journal by Philip Ball in 2009, the silk objects from the Indus valley civilization in Eastern Pakistan are believed to date from between 2450 BC and 2000 BC, making them similarly ancient.

Sericulture Institutional Setup in India

The Central Silk Board is a statutory body under the administrative control of the Ministry of Textiles, Govt. of India. It is one of the earliest commodity board constituted in April 1949 under an Act of the Parliament (Act No. LXI of 1948). The Central Silk Board is entrusted with the overall responsibility of developing silk industry covering the full gamut of sericultural activities in the country. At present Central Silk Board is working with a wonderful institutional setup with research and development wings in the various part of the country. The institutional setup of Central Silk Board is given in Table 1.

Table 1. Institutional Setup of Central Silk Board

Sl. No.	Name of Institutes/ Research Units	No. of Institutes/ Research Units
1.	Central Sericultural Research and Training Institute	03
2.	Central Tasar Research and Training Institute	01
3.	Central Muga & Eri Research and Training Institute	01
4.	Silk Technological Research Institute	01
5.	Silk Mark Organization of India	01
6.	Regional Sericultural Research Stations	10
7.	Regional Tasar Research Stations	08
8.	Regional Muga Research Station	01
9.	Regional Eri Research Stations	02
10.	Research Extension Centre	58
11.	Sub-Units	19
12.	Zonal Silkworm Seed Organisation	02
13.	Silkworm Seed Production Centre	21
14.	Sericulture Service Centre	33

(Source: Central Silk Board, Bangalore official website.)

Besides that, the Basic Seed Multiplication and Training Centre (BSMTC), Basic Tasar Silkworm Seed Organization (BTSSO), Central Sericultural Germplasm Resource Centre (CSGRC), Raw sliks Material Banks, Regional Offices, Seed Coccon Procurement Centre, Seribiotech Laboratory, Textiles Testing Laboratory, National Silkworm Seed Organisation and Seri Kisan Call Centre etc. playing the role towards research and development in the various part of the country. Apart from Central Silk Board, Sate Governments and various central and state universities also have a separate departments providing master degree in sericulture with full fledged research and development units to promote the sericulture industry.

Present Scenario of Sericulture in India

The major chunk of population of our country depends primarily on agriculture and agro based industries like sericulture for their livelihood. Historically, India has played an important role in silk production and trade. Presently, India occupies second largest position next to China, with 17.54% share in global raw silk production in 2011 provides employment to about 7.25 million persons, most of whom are land less labours, small and marginal farmers.

Out of 17.54% Indian share in global raw silk production, Mulberry (79.1%) assumes the major contribution followed by Tasar (6.9%), Eri (13.5%) and Muga (0.6%) respectively (CSB, Bangalore, 2012). Total mulberry acreage in India was 1.85 lakh during 2007-08 followed by 1.83 lakh ha. in 2011-12. Traditionally, sericulture practiced in tropical environmental regions such as Karnataka, Tamil Nadu, Andhra Pradesh, West Bengal and Jammu and Kashmir in temperate region. Besides that, sericulture also practiced in a limited context in Uttar Pradesh, Madhya Pradesh, Chhattisgarh, Bihar, Jharkhand and Assam and entire North-Eastern India. The production of world raw silk is given in Table 2.

Table 2. World Raw Silk Production (MT):

Country	**2007**	**2008**	**2009**	**2010**	**2011**	**(%) share in 2011**
China	108420	98620	104000	115000	104000	79.10
India	18320	18370	19690	20410	23060	17.54
Japan	105	95	90	53	44	0.03
Brazil	1220	1177	811	770	558	0.42
Korea Republic	150	135	135	135	135	0.10
Uzbekistan	950	865	750	2448	2448	1.86
Thailand	760	1100	665	655	655	0.50
Vietnam	750	680	550	550	550	0.42
Others	500	350	304	30	29	0.02
Total	**131175**	**121392**	**126995**	**140051**	**131479**	**100.0**

(Source: Central Silk Board, Bangalore website update October, 2012)

Effect of Climate Change on Soil Health

Soil is a soul of infinite life and also a bank of both essential and beneficial nutrients which nourish the life. Soil health is defined as the continued capacity of soil to function as a vital living system, by recognizing that it contains biological elements that are key to ecosystem function within land-use boundaries [9, 10]. These functions are able to sustain biological productivity of soil, maintain the quality of surrounding air and water environments, as well as promote plant, animal, and human health [11]. However, soil quality has been 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 to support human health and habitation.

Soil health indicators is a composite set of measurable physical properties (soil texture, structure, porosity, aggregate stability, infiltration, bulk density, soil and rooting depths, soil water etc.), chemical properties (pH; electrical conductivity, rate of exchangeable cations/anions, acidification, calcification, alkalization, leachable salts, adsorption, cation exchange capacity and plant available nutrients) and biological properties (soil organic matter, respiration, soil biota biomass e.g. earthworms, ants and nematodes etc., microbial biomass e.g. PGPR and VAM etc., N and P mineralization capacity and also enzyme activity). These health indicators relate to functional soil processes and can be used to evaluate soil health status, as affected by management practices and climate change drivers.

While defining soil health in relation to climate change, it is necessary to consider the impacts of a range of predicted global change drivers such as rising atmospheric GHGs especially carbon dioxide (CO_2) levels, elevated temperature, precipitation (rainfall) and atmospheric nitrogen (N) deposition, on soil chemical, physical and biological functions [12]. The soil health indicators are given in Fig. 2.

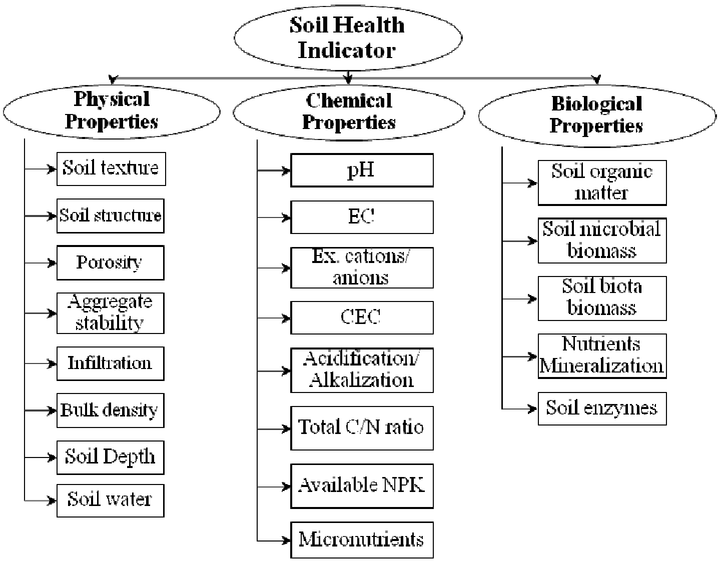

Fig. 2. Schematic diagram of soil health indicators.

Effect of Climate Change on Physical Properties of Soils

Soil physical properties such as soil texture, structure, porosity, aggregate stability, infiltration, bulk density, soil & rooting depths, soil water etc. considered as a useful soil health indicators which involved in maintaining important ecosystem functions in soil including organic carbon accumulation, infiltration capacity, movement and storage of water, and root and microbial community activity; it can also be used to measure soil resistance to erosion and management changes [13, 14]. Because of its association with the storage of soil organic carbon and water, its measurement can be useful to guide climate adaptation strategies, especially in areas that are likely to experience high and intense rainfall and consequently increased erosion events.

Porosity and pore size distribution provide a direct, quantitative estimate of the ability of a soil to store root-zone water and air necessary for plant growth [15]. Pore characteristics are strongly linked to soil physical quality; bulk density and macro porosity are functions of pore volume, while soil porosity and water release characteristics directly influence a range of soil physical indices including soil aeration capacity, plant available water capacity and relative field capacity [16]. Growth and development of plants and soil enzyme activities are closely related to soil porosity and pore size distributions [17].

Climate change scenarios such as high CO_2 concentration, increase in temperature, variable and extreme rainfall events may alter the root development and soil biological activities, soil porosity, pore size distribution and consequently soil functions are likely to be affected in unexpected directions. This aspect needs an attention of researchers in future studies on the relationship of soil health and climate change. Moreover, pore size distribution and aeration status, besides other factors, are the key factors in governing methane (CH_4) fluxes, both CH_4 emission and uptake [18], and nitrous oxide (N_2O) emissions from soil.

The availability of water to the plant and soil is governed by a range of soil properties including porosity, field capacity, lower limit of plant available water etc. [19]. Bulk density is in general negatively correlated with soil organic matter (SOM) or SOC content [20], loss of organic C from increased decomposition due to elevated temperatures [21] may lead to increase in bulk density and hence making soil more prone to compaction via land management activities and climate change stresses, for example, from variable and high intensity rainfall and drought events [22].

Effect of Climate Change on Chemical Properties of Soils

Soil chemical properties such as pH; electrical conductivity, exchangeable bases, acidification, calcification, alkalization, leachable salts, adsorption, and plant available nutrients etc. are considered as a useful soil health indicators. Soil pH, a function of parent material, time of weathering, vegetation and climate, is considered as one of the dominant chemical indicators of soil health, identifying trends in change for a range of soil biological and chemical functions including acidification, salinization, crop performance, nutrient availability and cycling and biological activity [23]. Climate change will affect organic matter status, C and nutrient cycling, plant available water and hence plant productivity, which in turn will affect soil pH [24].

Soil electrical conductivity can be used as a chemical indicator to classify the saline, alkali and sodic soils along with pH and also to inform soil biological quality in response to crop management practices [25]. Using elevation gradient as a surrogate for increasing temperatures and decreasing precipitation under climate change scenarios, Smith *et al.* [26] found that EC decreased and pH increased in a semi-arid environment. The cation exchange capacity (CEC) is considered important soil health indicator to determine the retention of major nutrient cations Ca, Mg, Na and K, and immobilization of potentially toxic cations Al and Mn. The high and intense rainfall under climate change may lead leaching of base cations in lower layers, which may promote soil acidity and thus transporting alkalinity from soil to waterways. This phenomenon will be depends on the increasing rate of decomposition of organic matter and its loss due to elevated temperatures [23].

Similarly, the available nutrients N, P, K, S and micronutrients are directly co-related with the climate change. Measurement of extractable nutrients may provide indication of a soil's capacity to support plant growth; conversely, it may identify critical or threshold values for environmental hazard assessment [25]. Nutrient cycling, especially N, is intimately linked with soil organic C cycling [22], and hence drivers of climate change such as elevated temperatures, variable precipitation and atmospheric N deposition are likely to impact on N cycling and also on phosphorus and sulphur.

Effect of Climate Change on Biological Properties of Soils

The activity and population of soil microorganisms are dependent on environmental factors such as temperature, moisture, vegetation structure and nutrient availability, all of which are probably to be affected by climate change [4]. The production and consumption processes of CO_2, CH_4 and N_2O GHGs are mainly due to soil microbes. These GHGs can play various roles in the metabolism of microorganisms.

World soils are projected to hold two times more carbon than atmosphere, making them one of the principal sinks for atmospheric CO_2 and organic carbon [27]. The quantity of carbon stored in the soil is directly based on the equilibrium among the carbon inputs from plants and carbon outputs from the processes of decay and heterotrophic respiration [23] and indirectly by microbial function as plant symbionts or pathogens and by modifying nutrient availability in the soil system [28]. Minute variations in degradation rates could not only influence CO_2 emissions in the atmosphere, but also result larger changes to the quantity of carbon stored in the soil [23].

Natural and human-induced CH_4 emissions are due to microbial methanogenesis. It is the process, where, methanogens reduce carbon into methane in anaerobic, carbon-rich natural ecosystems such as wetlands, oceans, etc. and on other hand these natural sources are exceeded by emissions from human activities such as rice cultivation, landfill etc. The entire methane produced by methanogenesis is not entering in to the atmosphere though, by the oxidizing action of methanotrophic bacteria, methane is converted into CO_2 in the presence of oxygen. While methanogens in the soil produce methane sooner than can be used by methanotrophs in soil layers, methane escapes into the atmosphere [27].

Likewise CO_2 and CH_4 emissions, world N_2O emissions have mainly microbial in origin. Natural and manmade sources are conquered by emissions from soils, chiefly as a result of microbial nitrification and denitrification [4]. Soil microorganisms arbitrate the nitrogen cycle, making nitrogen available for living organisms. In the course of nitrification, microbes liberate NO and N_2O, serious greenhouse gases, into the atmosphere as intermediates. The majority of the N_2O produced by nitrification is due to the activity of autotrophic ammonia (NH_3) - oxidizing bacteria [29]. In the other hand, denitrification is a long process in which every action is mediated by a definite group of microorganisms and the production of N_2O is characteristically the result of partial denitrification.

Mulberry – a Silkworm Host Plant

Mulberry (*Morus spp*) is economically and traditionally very important plant of deciduous type for the development of sericulture industry. Mulberry has characteristic long idioblast cells in the upper epidermis of leaves. Inflorescence is a catkin / spike with unisexual flowers, hence, it is a cross pollinated crop. Mulberry plants belongs to the family Moraceae and are successfully grown under varied climate ranging from warm temperate and subtropical regions of Asia, Africa, Europe and United State of America with the majority of the species native to east and south Asia.

Mulberry species successfully grown across the world are *Morus atropurpurea*, *Morus bombycis*, *Morus cathayana*, *Morus indica*, *Morus japonica*, *Morus kagayamae*, *Morus laevigata*, *Morus latifolia*, *Morus liboensis*, *Morus macroura*, *Morus mongolica*, *Morus multicaulis*, *Morus notabilis*, *Morus rotundiloba*, *Morus serrata*, *Morus tillaefolia*, *Morus trilobata and Morus wittiorum* etc.

The mulberry species like *Morus alba*, *Morus indica*, *Morus bombycis*, *Morus sinensis* and *Morus multicaulis* *etc.* are very important successfully grown in India. The mulberry leaves are basic food material for silkworm *Bombyx mori* L. and nutritious leaves are the most important growth regulating factors for above silk worm. Silkworm being a monophagous insect, it derives almost all the nutrients essential for its growth from the mulberry leaf itself. Bulk of the silk produced in the world by the mulberry silk worm is directly derived from protein of mulberry leaves; hence, silkworm should be feed with good quality of mulberry leaves in abundant quantity for the successful cocoon production.

Effect of Climate Change on Physiological Growth of Mulberry

The physiological growth and development of any plants are dependent on environmental condition like rainfall, moisture, temperature and fertility status of soils. Another significant environmental variable is evapotranspiration. Collectively, these two processes influence the life cycle of plants in terms of photosynthesis. It is predicted that, global warming affects the cultivation area of various crops including mulberry. In cereals and seed crops, water stress conditions may lead to lower yields in various crops whereas warmer temperatures will shorten the length of growing season and reduce yields.

As mulberry is a C_3 plants and its physiology is totally different from C_4 plants. The C_3 plants are relatively inefficient in using CO_2 and have their photosynthetic apparatus in the outer mesophyll cells. To compensate for this inefficiency stomata must remain open longer exposing them to potentially increased evapotranspiration and respiration rates. As a result these plants grow better in cooler moist environments with elevated CO_2 concentrations. The enzymes of C_4 plants located in the mesophyll are more efficient in fixing CO_2 which decreases the time stomata must remain open and decreases the evapotranspiration and respiration rates compared to C_3 plants. In C_3 plants, CO_2 is reacted with ribulose biphosphate (RuBP) by the enzyme ribulose biphosphate carboxylase/oxygenase (RuBisCO), which is an inefficient enzyme with low substrate specificity (i.e. sometimes fixes O_2 instead of CO_2). It preferentially fixes $^{12}CO_2$ over $^{13}CO_2$, resulting in isotope fractionation during carboxylation [30].

Long *et al.* [31] and Polley [32] reported the effect of rising CO_2 on plants yield through photosynthesis and stomatal conductance whereas the growing evidence suggesting that C_3 crops, may respond positively to increased atmospheric CO_2 in the absence of other stressful conditions [33], but the beneficial direct impact of elevated CO_2 can be offset by other effects of climate change, such as elevated temperatures, higher tropospheric ozone concentrations and altered patterns of precipitation.

IPCC [34] also reported the direct and indirect effect of climate change as: (1) direct effects from changes in temperature, precipitation, or carbon dioxide concentrations, and (2) indirect effects through changes in soil moisture and the distribution and frequency of infestation by pests and diseases.

Effect of Climate Change on Mulberry Disease and Pest

The potential impact of global climate change plant-pest populations depends on the combined effects of climate e.g. temperature, precipitation, humidity etc. and other components like soil moisture, atmospheric CO_2 and tropospheric ozone (O_3). Changes in sericultural productivity can be the result of direct effects of these factors at the plant level, or indirect effects at the system level, for instance, through shifts in insect pest occurrence. An increase in temperature may changes in geographical distribution, increased over wintering, changes in population growth rates, increases in the number of generations, extension of the development season, changes in crop-pest synchrony of phenology, changes in interspecific interactions and increased risk of invasion by migrant pests [35, 36].

In recent years, many pests and diseases have been reported to be the major limiting factors affecting production and productivity of mulberry leaves due to intensive cultivation practices and indiscriminate use of nitrogenous fertilizers and pesticides. There is also a change in the insect pest scenario in mulberry due to changes in climate and agro ecosystem. These pest are Bihar hairy caterpillar **(***Diacrisia oblique*), Pink mealybug (*Maconellicoccus hirsutus*,), Thrips (*Pseudodendrothrips mori*) , Leaf webber (*Diaphania pulverulentalis*), Mites **(**Bud mites) *and* diseases are Root-knot disease **(***Meloidogyne incognita),* Powdery mildew **(***Phyllactinia corylea*), Leaf rust **(***Peridiospora mori*) and Leaf spot (*Cercospora moricola*) etc.

It has been reported that, the pink mealy bug, *Maconellicoccus hirsutus* has got 346 host plants and in mulberry it causes leaf yield loss of 4500 kgs/ ha/year thus depriving the farmer a brushing of about 450 dfls/ha/year leading decline in cocoon production of 150 kg/ ha/year [37]. The leaf webber, *Diaphania pulverulentalis* has been noticed as a serious pest in Karnataka since 1995 which has also spread to Tamil Nadu and Andhra Pradesh on local, M5, MR2, S36 and V1 varieties. The infestation of *D. pulverulentalis* is higher during October to February in Krishnagiri area [38, 39] and October to December in Salem area [40]. Similarly, Rajadurai *et al.* [41](2000) reported that the pest caused the leaf yield loss of 12.8% with average incidence of 21.77%.

In global scenario, a major effect of climate change in the temperate zone could be a change in winter survival of insect pests. It may disturb the synchrony between temperature and photoperiod; because insect and host plant species show individualistic responses to temperature, CO_2 and photoperiod. Many mathematical models that have been useful for forecasting plant disease epidemics are based on increases in pathogen growth and infection within specified temperature ranges. Coakley *et al.* [42] stated, plants are more susceptible to rust diseases with increased temperature. Fungi that cause plant disease grow best in moderate temperature ranges. Temperate climate zones that include seasons with cold average temperatures are likely to experience longer periods of temperatures suitable for pathogen growth and reproduction if climates warm. He also stated that, more frequent and extreme precipitation, higher CO_2 concentration, denser canopies with higher humidity that favour pathogens.

Effect of climate change on pathogen of several crops has also been reported by several workers, for example, elevated CO_2 may modify pathogen aggressiveness and/or host susceptibility and affect the initial establishment of the pathogen, especially fungi, on the host [43, 44], increased fecundity and growth of some fungal pathogens under elevated CO_2 [45, 46] and greater plant canopy size, especially in combination with humidity and increased host abundance, can increase pathogen load [47, 48].

Effect of Climate Change Chawki and Late Age Rearing

The mulberry silkworm (*Bombyx mori* L.) is very delicate and highly sensitive to global warming and also unable to survive extreme fluctuation in temperature, rainfall and humidity. As mulberry silkworm is domesticated since long times, the adoptability of these silkworms in unfavourable climatic conditions are quite different from the wild silkworm and other insects. As silkworms are cold-blooded animals, temperature will have a direct effect on various physiological activities. Among the abiotic factors, temperature plays a major role on growth and productivity of silkworms [49, 50]. The optimum temperature for production of quality of cocoons is ranges from 22-27^0 C and the quality of cocoons will be inferior above this temperature range [51, 52]. In general, the early instar larvae are resistant to high temperature which also helps in improving survival rate and cocoon characters. High temperature during silkworm rearing particularly in late instars accelerates larval growth and shortens the larval period. On the other hand, at low temperature, the growth will be slow and larval period will prolong [53]. It has also been reported by several researchers that the optimum temperature for normal growth of silkworms is ranges from 22^o C to 27^o C and the desirable temperature for maximum productivity ranges from 23^o C to 27^o C. Temperature below 20^o C and above 30^o C directly affects the physiology of silkworms especially in early instars resulting they become unhealthy and susceptible to various diseases.

During silkworm rearing, high temperature adversely affects nearly all biological processes including the rates of biochemical and physiological reactions [54] and the silkworms were more sensitive in fourth and fifth stages [55, 56]. Thiagarajan *et al.* [57] and Ramesh *et al.*[58] reported that the phenotypic expression is greatly influenced by environmental factors such as temperature, relative humidity, light, and nutrition.

Effect of Climate Change on Post Cocoon Technology

The quality, quantity and efficiency of a cocoon play very important role in the economical growth of sericulture industry. The significant variations in shape and size of hybrid cocoon results the variation in filament size and the quality of the reeled threads [59]. The thread breakage, hindrance due to slugs, poor reelability, poor cooking, decreased raw silk recovery, variation in raw silk denier, and poor neatness also results in irregular and non-uniform cocoon [60].

Akahane and K. Subouchi [61] recommended that the water content of the cocoon layer should be below 20% in order to obtain good-quality cocoons with better reelability. Gowda and Reddy [62] studied the effect of temperature on cocoon and reeling parameters of new bivoltine hybrids during spinning period, however, Rahmathulla *et al.* [63] evaluated the influence of various nutritional and environmental stress factors on silk fiber characters of bivoltine silkworm.

Due to lack of proper investigation in this field, very limited information is available on the combined effect of different temperature and humidity on various cocoon characters and reeling parameters at different stages during rearing and spinning of silkworm larvae which in turn will provide valuable information to the technology developers who are engaged in the improvement of quality and quantity of silk acceptable to the level of international standard [64]. The scientists and researchers involved in the spinning sector of sericulture industry need to pay much attention on the combined effect of climate change on quality, quantity and efficiency of a cocoon for betterment of reelers and sericulture industry.

Effect of Climate Change on Economy of Sericulture Industry

Sericulture is an agro based industry. The vulnerability of raw silk production to climate change depends not only on the physiological response of the affected silkworm host plants, but also on silkworm rearing and post cocoon technology as well as with changes in the frequency of droughts or floods. Several researchers working either in the field of agriculture or sericulture predicted the significant effect of climate change production and productivity of several crops silkworms host plants, silkworm rearing and post cocoon technology which directly affects the Indian economy.

In agriculture, the climate variability is expected to lead to crop loss of 10 to 40 per cent and hundreds of billions of rupees in loss of revenue from agriculture with a 2^o C rise in average global temperature. The losses are likely to be higher, if one takes into account other effects, including damage to land and livelihoods due to sea level rise and coastal erosion, morbidity and mortality with increased incidence of disease, forced displacement and property loss from flooding and landslides [7]. The loss in net revenue at the farm level is also estimated to range between 9% and 25% for a temperature rise of 2-3.5^o C, however, no estimated data available for net revenue loss of sericulture industry. Kumar and Parikh [65] shows that the economic impacts would be significant even after accounting for farm-level adaptation. Sanghi *et al.* [66] calculated that the 2^o C rise in mean temperature and a 7% increase in mean precipitation would reduce net revenues by 12.3% for the country as a whole.

It is predicted that the global warming will lead to reduction in mulberry leaf yield and raw silk production, silk content, breakage in silk thread during reeling or spinning, water stress, draught, risk of soil acidification and salinization, decomposition of organic matter, N fixation and mineralization of N, P and S, soil erosion, runoff, longer growing season insect pests, shorter growing period of silkworms, high probability of viral, bacterial and fungal infection and crop-weed competition etc.

It is also predicted that the sericulture practiced in tropical environmental regions such as Karnataka, Tamil Nadu, Andhra Pradesh, West Bengal, Uttar Pradesh, Madhya Pradesh, Chhattisgarh, Bihar, Jharkhand and Assam will be severely affected due to rise of 2^{o} C or more mean annual temperature, however, small to marginal loss can be noticed in Jammu Kashmir and Sub-Himalayan region of North-Eastern India. The net revenue loss in sericulture may vary between 10-20% in temperate region as reported by the researchers in agriculture. The net loss may be less or even revenue gain may be achieved from tropical region like Jammu & Kashmir and Sub-Himalayan region of Eastern and North-eastern India.

II. CONCLUSION

It can be concluded that the exact effect of climate change on soil health and sericulture industry is based on prediction and not yet proven, but several explanations have been proposed in this regard. Based on prediction of several researchers from various Indian institutions, the temperature may rise from 0.5 to 4.0^{o} in the various part of the country in next few decades from the accumulation of anthropogenic greenhouse gases in the atmosphere, which may change practices and economy of sericulture drastically in temperate region and marginal or beneficial effect in tropical region in India.

The rise of annual mean temperature, irregular rainfall, humidity, unpredictable monsoon, accumulation of anthropogenic greenhouse gases in the atmosphere and lack of management practices will lead to reduction in mulberry leaf yield and raw silk production, silk content, breakage in silk thread during reeling or spinning, water stress, draught, risk of soil acidification and salinization, decomposition of organic matter, N fixation and mineralization of N, P and S, soil erosion, runoff, longer growing season insect pests, shorter growing period of silkworms, high probability of bacterial and fungal infection, less stomatal opening of mulberry leaves and crop-weed competition etc.

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