A Simple Model to Predict Tea Production of Dibrugarh District Based on Major Weather Parameters (A Review)

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Abstract— *The present work is proposed to see the effect of a few major weather parameters, mainly average temperature, amount of rainfall received, number of rainy day, open pan evaporation, average sunshine hour, and average humidity on tea production and to develop a simple model for predicting production of tea based on those parameters. This software-based statistical analysis can ensure establishment of a solid model to forecast the effect of successive weather conditions in Upper Assam on the expected crop yield with higher measure of accuracy, thus aiding the tea gardens to a great extent.*

Keywords - *Tea, Weather Parameters.*

I. Introduction

Tea plant (Camelia Sinesis) is a perennial evergreen woody plant used as a source of non-alcoholic beverage worldwide. Tea plant has recently attracted considerable attention because of the health benefits and medicinal properties of tea. This plant typically grows in more than 45 countries worldwide, spreading within the latitudinal range of 45°N to 34°S, particularly in subtropical region **(Barua, 2008; Karak and Bhagat, 2010).**

According to FAO report, globally 3.94 million ha land is covered under tea cultivation **(FAO, 2007).** India is the second largest tea cultivated country and total tea-planted area in India is 0.58 million ha which accounts for 14.72% share of total tea-cultivated land in the world. Assam, a state in India extending from 89°42′ E to 96°E longitude and 24°8′N to 28°2′N latitude, is blessed with favourable soils and climatic conditions for tea cultivation. This is also reflected by the state's major share of tea-cultivated land covering an area of 0.32 million ha in India. Assam alone produces more than 50% of the tea produced in India i.e. 487.5 million kg per year, which accounts for about 14% of the world's total tea output **(Tea statistics of India, 2009).** The tea industry has a very prominent place in the Indian economy and the net foreign exchange earned in India from tea is around 281 million USD per annum. However, over the past century, India has experienced some noticeable abiotic stresses for tea cultivation of which climatic change typically challenges tea cultivation. This abiotic stresses affect the amount of functional components in tea leaves, leading to changes in tea color, taste, and aroma as well as tea green leaf production. The temperature extremes in tea producing regions negatively affect the quality and yield of tea leaves and restrict the spatial distribution and cultivation of tea plant. Progressive climate change, which refers to long-term changes in the baseline climate (i.e. changes in absolute temperatures and shifts in rainfall regimes) over time spans of several decades, presents the overarching major challenge to tea production in North Eastern state of India like Assam in terms of both policy and science.

Today's tea cultivation systems are adapted to current climate conditions, yet there is very dearth of information about how well they will stand up to progressive climate change, particularly as they come under increasing pressure from other global drivers and entirely novel climates are encountered in many places **(Vermeulen et al., 2012)**. Many broad-scale analyses identify regions of Upper Assam and tea crop that will be sensitive to progressive climate change **(Dutta et al., 2011)**, but there is sparse scientific knowledge as to how current tea cultivation systems can adapt, and which current tea cultivation practices will enable adaptation.

In general, a rise in temperature may bring an adverse effect on the availability of water for tea plant. The impact of climate change on potential evapotranspiration (ET_0) in tea crop therefore becomes important for water management and agricultural sustainability (**Chattaraj et al., 2014**). The warmer climate may increase the ET_0 of tea plant leading to greater demand for irrigation water. Climatic factors other than temperature, like radiation, humidity, wind speed and rainfall also influence the ET_O. Consequently, any variation in these factors will also modify the crop evapotranspiration (ETc). These changes are however, difficult to project especially on regional (**Chattopadhyay and Hulme, 1997**) or local scales. Furthermore, there is no information in connection with different climatic parameters to predict tea production in Upper Assam. Therefore, the proposed insightful objective is to generate a predictive model for tea production at major tea growing region of upper Assam through statistical package.

The Model to be developed will require crop data from different tea estates of Dibrugarh district for over a decade to see the effect of varying weather parameters such as amount of rainfall and its distribution, morning and afternoon relative humidity, maximum and minimum temperature, sunshine hour and open pan evaporation on crop yield. Data of annual tea production for last 12 years i.e. for the period from 2004 to 2015 along with available met data will be collected from 47 tea estates of Dibrugarh district individually. Centrally recorded Meet Data of the aforementioned weather parameters for those twelve years (2004-2015) will be collected from Tea Research Association (TRA), Dikom, TRA, Dikom, Dibrugarh, is a branch of the premier R&D institute- Tocklai tea Research Institute (TTRI),Jorhat, Assam. The parameters of the previous 10 years will be analysed using Hierarchical Cluster Analysis and the parameters having minimum effect on the crop yield shall be filtered out using Variable Reduction Technique of Principal Component Analysis. A multivariate regression equation shall be developed using multiple linear regression and the same shall be modelled graphically using SPSS Software Version-13. The prediction model thus developed shall give us a predicted measure of the crop production. The same shall be compared with the original crop data to analyse the efficiency (accuracy) of the developed model.

II. LITERATURE REVIEW

In recent years, there has been growing interest in curbing the rapid rise of greenhouse gases in the atmosphere in order to control future climate change. Many observers are concerned that changes in climate will in turn lead to significant damages to both market and nonmarket sectors. In an effort to understand the entire picture of the effects of climate change, it is necessary to examine all sectors affected by climate change. One such area examined is the social effect of climate change focusing on several potentially affected sectors, among which are forestry and ecosystems, coastal zones, agriculture, fisheries water resources, and energy developments (**Reilly and Thomas 1993**). **Toman, Firor, and Darmstadter** suggest that while "the potential impacts of climate change are broad, some aspects of human society are more sensitive than others"(1996, 11). Further suggesting that systems that are highly managed like agriculture may be less sensitive than systems that are managed less. Although several sectors have been studied, none have received more attention than agriculture. In the United States, the initial studies suggested large negative agricultural effects in terms of crop yield reduction, loss of fertile soils, and increased cost of production (**Smith andTirpak 1989**). More recent analyses, that have incorporated more up to date climate forecast and adaptation, however, consistently find that American agriculture will be resilient to climate change (**Crosson 1993, Kaiser et al. 1993, and Mendelsohn, Nordhaus, and Shaw 1994**). The agricultural sectors of other developed countries in temperate climates are expected to react similarly. However, it is not clear what effect of climate change will have on agriculture in the rest of the world because, agricultural systems are different in developing countries, these agriculture systems may be less adaptable, and tropical and subtropical ecosystems may respond differently to climate change. There has been considerable debate whether or not the steadily increasing levels of carbon dioxide observed in the atmosphere will lead to climate change (**Nierenberg 1995**). Most atmospheric scientists concur that greenhouse gases will affect climate by raising temperature and changing water cycles. The debate, at this point, is focused upon the magnitude of this change. The consensus of atmospheric scientists is presented in the **Intergovernmental Panel on Climate Change (IPCC) report (1990)** which predicts that world temperatures will increase by 1.5-4.5 degree C by 2060 (from the doubling of greenhouse gases since 1880). The best guess of this group is a 2.5 degree C increase. An updated assessment, provided in the second IPCC report (**Brack and Grubb 1996**) suggests an increase in global mean surface air temperature of about 2 degree C by the year 2100 with a range of uncertainty of 1.0-3.5 degree C. These higher world temperatures will increase the hydrological cycle activity leading to general increase in precipitation and evapotranspiration. What scientists have not been able to predict thus far is how this worldwide change will manifest itself across the planet. There are no consensus predictions of temperature and precipitation changes at the regional or local level, although there are many individual models with detailed predictions (**Barron 1995**). The climate change in any one area as a result of global change could be quite different from the global average. In addition, policy implications for climate change must be viewed separately from other types of environmental pollution as the effect of global warming is an irreversible phenomenon (**Mathews 1991**). Impact studies should focus on measuring climate response functions for specific areas rather than focusing on limited climate scenarios because, the actual climate change that any area is likely to experience is not known at this time. For example, agricultural studies could be more effective if they measure how farm outputs and net revenues are affected by a range of temperature and precipitation changes rather than a limited set of climate change scenarios. Agricultural studies must also consider the direct effect of carbon dioxide since it is clear that CO_2 has a positive influence on crop yields (**Kimball 1983**) and water efficiency

(**Woodward 1993**). The magnitude of and circumstances in which this carbon fertilization effect takes place is debated (**Bazzaz and Fajer 1992; Van de Geijn et al. 1993; Kimball et al. 1993; and Mooney and Koch1994**), but the importance of including this effect is unequivocal. Although, a great deal has been learned about the link between energy systems, emissions, ambient greenhouse gas concentrations, and climate change, relatively little analysis has been focused on what will happen if climate changes. Global warming may affect agriculture by directly altering yields, changing water availability, or affecting soils. Most empirical work undertaken has focused on the United States. This is especially true for economic analyses of the impact of climate change on agriculture. Existing studies include: **USEPA (Adams et al. 1989, 1990,1993; Rosenzweig and Parry 1993); USDA (Kaiser and Drennan 1993; Kaiser et al. 1993; Mendelsohn, Nordhaus, and Shaw 1994; Shaw et al. 1995); and DOE (Crosson 1993**). The earlier studies in this group consistently predicted that there would be large negative impacts from climate change in the form of reduced quantities and qualities of yield of grain crops (See also **Scimmelpfennig et al. 1996**). In contrast, the more recent studies consistently predict that US agricultural systems will readily adapt to climate change, by introducing new technologies, new crop varieties, and cultivation practices, so that there will be minimal changes in yields and net profits. These results likely to extend to other Organization for Economic Cooperation and Development (OECD) countries suggesting that agriculture in developed countries is not sensitive to climate change. Less is known, however, about what effect climate change will have on the agricultural systems of developing countries. **Kaiser and Crosson** (1995) suggest that to be successful, the international context in which agriculture operates must be taken into account. Several studies have addressed the impact of climate change on the food supply and risk of hunger in developing countries, especially Africa (**Parry 1992; Downing and Parry 1993; Rosenzweig and Parry 1993; and Parry and Rosenzweig 1994**), and Egypt (**Strzepek et al. 1994**). A recent study by Rosenzweig and Iglesias 1994 has addressed responses of grain crops (maize, wheat, soybean, and rice) to climate change in various countries, including India and Brazil. Adaptation in these studies has been treated mainly by changing values of parameters on an ad-hoc basis. These studies suggest that if high amounts of adaptation are assumed, developing countries could adapt to climate change. The only problem would be isolated areas of subsistence farmers who could remain vulnerable to severe local climate effects. Although levels of adaptation are explored in these developing country studies, these studies do not model what adaptations are likely to occur. No attempt has been made to quantify how farmers have actually adapted to climates in developing countries. Without solid adaptation estimates, the existing literature has probably overestimated the impacts of climate change in developing countries. Further, like the early United States studies, the studies listed above included only grains, which capture only roughly half of the agricultural land in many developing countries (in particular 59% and 31% of the arable land in India and Brazil in 1993, respectively (**FAO 1994**)). A comprehensive empirical analysis of the impacts of climate change on other important crops in developing countries has yet to be accomplished. In addition to these empirical studies that have attempted to predict the effect of climate scenarios on yields, there have been a handful of studies which have focused on the relevance of international trade. **Reilly et al. (1994), and Kane, Reilly, and Tobey (1991)** assume yield reduction in different parts of the world and then predict what would happen to world agricultural prices. These studies, if combined with solid estimates of impacts in each region, could eventually forecast what would happen to world agricultural prices. However, at the time these studies were completed, impacts in different regions were unknown, thus limiting the power of these international studies. Coupled with new estimates of yield changes, however, an updated version of the Reilly models could address concerns about price impacts that cannot be properly handled at the regional level. One way climate change may impact agriculture is by reducing the available supply of water for irrigation. Through either reduction in precipitation or increase in evapotranspiration, available water for irrigation may be reduced. This may be especially important in developing countries, because, agriculture utilizes as much as 80% of water resources (**WRI 1992; Xie et al.1993**). Water availability is a key factor in agricultural productivity, especially with developing countries located in arid and semi-arid regions. Further, developing countries may not be able to afford extensive manipulations of water systems, so, they may face limited options to adapt to water shortages (**Frederiksen 1992**). For example, a recent study by **Fulglestvedt et al. (1994**) provides a tally of country case studies on climate change, includes few studies on impact estimates, and even fewer studies on policy reaction in developing countries

Measuring Climate Change Models

Agricultural impact studies must draw a link between climate change and farming because of the direct relationship between climate and agricultural production processes. The traditional approach has been to turn to a General Circulation Model (GCM) for a forecast of the gases. Each GCM model produces a climate change associated with a doubling of greenhouse specific forecast which can then be used to predict yield and farm revenue changes. These climate models have limitations in their approach to address the specific effects of climate change in crop production. Firstly, there is tremendous variation across different locations. Although, the analyst can proceed by choosing specific forecasts, it is impossible to capture the range of impacts from a limited set of model runs. Secondly, the climate with a doubling of greenhouse gases represent one distant moment in time mates associated (around 2060). So, the climate is likely to go on changing gradually and impact studies should be developed based on response functions under specific scenarios. As climate scenarios change, these response functions can be used to predict what will happen at each location and time period. In contrast, the climate scenario approach becomes outdated, the moment one moves away from the specific changes being analyzed.

There are two main approaches for measuring climate impacts on agriculture in the literature: an agronomic production function approach and a Ricardian model. The agronomic production function approach begins with a crop simulation model and predicts changes in yield in response to climate. The yield changes are then either extrapolated to an aggregate effect as with **Rosenzweig and Parry (1993)**, or they are introduced into an economic model as in **Adams et al. (1989, 1990, 1993) or Crosson (1993)**. The economic models in turn estimate aggregate damages to the agricultural sector. An alternative approach is to empirically estimate the direct impact of climate on agricultural net revenues, using the Ricardian model (**Mendelsohn et al.1994; and Shaw et al. 1995**). Both approaches have strengths and weaknesses and tend to complement each other. The agronomic production function approach has the strength of being tied closely to carefully controlled experiments where specific climate or CO_2 levels are varied holding all the Ricardian estimates. This eliminates one of the potential problems with other variables constant method, that climate variables may be correlated with other omitted variables resulting in biased estimates. In order to handle the agronomic production function approach properly, farmer adaptations should be included in the modelling. Simulations should be run with a variety of different farm methods such as varying planting times, crop varieties, harvests dates, and tilling and irrigation methods. The researcher would then be able to determine which activity would maximize profit and practice, this is too expensive, and studies using this methodology either do not incorporate adaptation at all, or at best explore a limited number of alternative farming methods. One of the limitations of the agronomic production function approach therefore is that, it fails to properly overestimate negative impacts.

Another distinction that is often made between models is whether or not they include price effects. The Ricardian model explicitly assumes away price changes. In contrast, some of the economic models using the agronomic production function approach have emphasized price markets changes as part of their results (**Adams et al. 1989, 1990, 1993**). However, predictions of global yields are generally quite poor in quality because there are no sufficient measurements of both climate and yields at all sites. Attempts such as **Rosenzweig and Parry (1994)**, **Darwin et al. (1994)**, are to measure global prices. However, each of these studies suffers from inaccurate measurements of climate-induced supply changes (**Reilly et al. 1994**) especially in developing countries. For example**, Darwin (1994) and Darwin et al. (1994**) use a global model that includes 8 world regions (US, Canada, European Community, Japan, China and several other east Asia Countries, some Southeast Asia countries, Australia and New Zealand. These studies use a Computerized General Equilibrium (CGE) model that aggregates information on land and climatic resource changes (based on a Geographic Information System (GIS)) and changes in climate that are predicted by GCMs. Although comprehensive, the CGE model requires detailed knowledge of land and agricultural uses which cannot be accurately measured. Further, the authors have no way of reliably predicting how these large land areas would actually react to climate change. By providing sound measurements of impacts in developing countries, our results should complement these global models and help them generate more reliable global estimates. The agronomic production function approach begins with the basic relationship between climate and crop production. Through agronomic experiments, agronomists have calibrated models which predict the yield of specific crops depending on weather patterns. These simulation models have historically been used to predict changes in yields for specific crops (**Adams et al. 1989 or Rosenzweig and Parry 1993**). The outcome from these simulations is then fed through an economic model of farmer behaviour which in turn leads to a partial equilibrium model of the farm sector. This agronomic production function approach is attractive in its close collaboration with agronomic science. It can also be carefully linked with hydrologic conditions. Finally, the production function approach is the only current method capable of including carbon dioxide fertilization (provided appropriate agronomic models). **Innes and Kane** provide a discussion on agricultural impacts of global warming. They have generated a list of variables which they feel need to be included in the complex modelling to predict the potential effects of greenhouse gas accumulation on agricultural production and pricing.

Effects of greenhouse gases on climate itself, including ambient temperature, precipitation, ENSO cycles, and climatic events such as cyclones and hurricanes may result in a complicated mosaic of changes in climatic conditions with a wide geographical variance and strong localized effects driven primarily by precipitation patterns. Physical responses of agricultural systems to greenhouse gases and climate change includes the so-called CO_2 - fertilization effect and potential changes in pest problems from warmer and more humid conditions. Behavioural responses to climate change for given technologies and institutions may include not only farmer shifts in cropping patterns, planting dates, tillage practices, irrigation techniques, and other management approaches, but also in regional adaptation, for example, water delivery systems. Technological change, which may include both exogenous improvements in agricultural productivity and changes in technology induced by climatic changes effects the international agricultural markets. Innes and Kane indicate that no analysis, thus far, has successfully incorporated all of these variables.

III. Methods and Methodology

The Model to be developed will require crop data from different tea estates of Dibrugarh district for over a decade to see the effect of varying weather parameters such as amount of rainfall and its distribution, morning and afternoon relative humidity, maximum and minimum temperatures, sunshine hour and open pan evaporation on crop yield.

Data of annual tea production for last 12 years i.e. for the period from 2004 to 2015 along with available met data will be collected from 47 tea estates namely Tamulbari T.E., Dikom T.E., Bagrodia T.E., Durgapur T.E., Mancotta T.E., South Borbam T.E., Nahortoli T.E., Lengrai T.E., Lepetkata T.E., Mahabir T.E., Romai T. E., Mokalbari T.E., Phukonbari T.E., Beheating T.E., Jalannagar T.E., Singlijan T.E., Kamakhyabari T.E., Radheshyam T. E., Muttuck T.E., Jalannagar SouthT.E., Rungliting T. E., Narayan T.E., Madarkhat T. E., Bokel T.E., Ethelwold T.E., Basmatia T.E., Mannabarie T.E., Chowdung T.E., Ida T.E., Baughpara T.E., Belbari T.E., Goneshbari T. E., Maud T.E., Sessa T.E., Mohunbaree T.E., Ghograjan T.E., Mulchandbag T.E., Jamirah T.E., Alimur T.E., New Parbatipur T. E., Helenbari T. E., Hattiali T.E., Chubwa T.E., Sealkottee T.E., Dirial T.E. and Kharjan T.E. of Dibrugarh district individually.

Centrally recorded Met data of the aforementioned weather parameters for those twelve years (2004 – 2015) will be collected from Tea Research Association (TRA), Dikom. TRA, Dikom, Dibrugarh, a Branch of the premier R&D institute-Tocklai Tea Research Institute (TTRI), Jorhat, Assam which is carrying out research works in the field of tea science in Upper Assam. TRA has been meticulously recording data of various meteorological parameters effecting tea productivity for decades and at the same time is coming on helping and guiding the tea estates (members of TRA) of the region of Upper Assam in all aspects of tea growing and good management.

The parameters for the previous 10 years will be analyzed using Hierarchical Cluster Analysis and the parameters having minimum effect on the crop yield shall be filtered out using Variable Reduction Technique of Principal Component Analysis.

A multivariate regression equation shall be developed using multiple linear regression and the same shall be modeled graphically using SPSS Software.

The prediction model thus developed shall give us a predicted measure of the crop production. The same shall be compared with the original crop data to analyze the efficiency (accuracy) of the developed model.

IV. Conclusion and Future Scope

The efficiency and utility of the prediction model developed will be determined based on percentage accuracy of predicted annual crop production on comparing with the actual annual crop production of the estates under consideration. On having wide difference of predictive figure with the actual crop production figure, fine tuning of the model with respect to the weather parameters used for may be necessary which will be possible after running the fully developed model using collected data for crop and the weather variables.

The prediction made by the developed Model may or may not come very close to the actual crop production of the estates but scope will always remain to make improvement of such model with finer adjustment of the parameters used for. Since, advance weather forecasting is made possible with the use of Satellite; such information can be used in such model to make crop prediction in advance and also to take precautionary measures to minimize such crop loss. If necessary, modified model can be developed based on the outcome and feed-back received from such model.

The developed multivariate regression equation can be used to forecast the effect of major weathers parameters on the crop yield of the following years. Establishment of a solid model to forecast the effect of successive weather conditions in Upper Assam on the expected crop yield with higher measure of accuracy shall act as a boon, immensely aiding the tea gardens of the region and the prediction methodology might as well be applied for other agricultural crops covering other agriculture-based regions in the world.

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