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Implications of Meteorological Forecasting for Accelerating the Success Rate in Sericulture: New Avenues in Seri-industry: A Review

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ABSTRACT

Weather and climatological studies offers great scope for strengthening the agricultural production science temperature, humidity, photoperiod and rainfall are the key factors deciding the ultimate fate of any crop including sericulture. Mulberry cultivation and silkworm rearing the two most important aspects of sericulture and both depends on environmental factors for successful harvest of cocoon crop, the ultimate product of silk industry. Various agencies like weather forecasting and meteorological department keeps an eye on the upcoming weather events for providing necessary advisory services to the farmers for making precautionary measures in order to avoid the risk of crop failure and wastage of resources. Timely information about rainfall pattern helps the farmers to decide the time of field operations and post harvest activities. In sericulture, role of environmental conditions for both mulberry and silkworm is of utmost importance and contributes 37.8% for successful cocoon crop. Cocoon crop productivity declines considerably due to slight fluctuations in temperature and humidity. Scientific knowledge therefore helps to cope up with such adervisities. Meteorological forecasting thus opens new avenues in the field of sericulture for pre planning and successful execution of silkworm crop. Therefore, an attempt has been made to present an elaborative context of meteorological studies for accelerating success rate of sericulture crop productivity at commercial level.

Key words: Crop, Environment, Forecasting, Meteorological, Productivity, Sericulture.

Science and technological advancements has changed the scenario in almost every sphere of life. Every single aspect of life ranging from morning toothbrush to last meal at night and even afterwards is totally technology based. Today everything happens according to the preplanned programmes in order to avoid any type of risks. Similar to other fields, agriculture is also now being operated with well planned management strategies. Weather forecasting is one such blessing for the field of agriculture which has completely changed the trends of traditional crop cultivation. Weather forecasting is thus defined as the advance predictions related to various parameters of the environment including minimum-maximum temperature range in degree calicoes (°C), relative humidity (RH) in percentage (%), rate of precipitation or rainfall in millimeter (mm) or even the chance of natural calamities like thunder storm, tsunami or volcano eruption and risks to the planet earth *etc.* Weather forecasting is based on information generated by computer based satellites or radars which then coded to generate data and preparation of models that helps to make predictions related to upcoming climatic events in advance. This information on upcoming climatological aspects could be utilized for making advance decisions for avoiding uncertainties and could also be applied in agriculture for deciding the right time for seed sowing, crop cultivation, harvest and in post harvest activities (Iseh and Woma, 2013). Science and technology encompasses the generation of information and data based on the methodological study of physical, chemical and natural aspects of nature with the help of research and experiments in order to achieve the realistic goal. In India the Meteorological Department is situated at Pune and was established in 1975 with prime objective to provide advance information about weather for development of agriculture sector. The key elements covered under weather forecast include; clouds over the sky, precipitation, temperature, relative humidity and wind intensity and direction (WMO, 2001). Weather forecast is generally classified into six types namely now casting (NC) weather forecast, very short range, short, medium, extendedand long range weather forecast depending upto the time period of forecast *i.e.* hours to days. Now casting (NC) weather forecast provides description of weather for 0 to 6 hours, very short forecasts provides description of weather upto 12 hours, short range upto 12 to 72 hours,

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medium for a period of 3 to 10 days, extended range for 10 to 30 days and long range forecasts are generally issued thrice in a year and their validity remains for 10 to 30 days (Didal *et al.,* 2017). The scientific era in which we are living is all about the consequences of science and technological developments which have made our lives very comfortable and easy.

Contribution of environmental factors for success of Sericulture

Sericulture is one of the most diversified fields of agriculture sector involving interrelated chain of number of activities ranging from cultivation of host plant called as Moriculture, rearing of domesticated silkworm larvae called as silkworm rearing and industrial aspects also termed as Post cocoon or industrial sector of seri-industry. Mulberry cultivation and silkworm rearing are the two most sensitive sectors as far as environmental factors are involved. For successful harvest of good quality cocoons environmental factors play the most significant role as it alone accounts for 37% of the total factors involved (Miyashita, 1986 and Bharath *et al.,* 2017). Silk farming is one of the most significant linkage of the agriculture providing numerous opportunities to the farmers for generation of their livelihood demanding low inputs and yielding high profits in return (Taufique and Areful, 2018; Chanotra *et al.,* 2019a and Taufique and Hoque, 2021). Hence sericulture could offer substitutes to poor farmers for strengthening their economy (Datta, 2000; Kumar *et al.,* 2001; Rao *et al.,* 2006; Lakshmi and Chandrashekaraiah, 2007 and Begum *et al.,* 2008).

No doubt weather and climatic conditions play significant role in growth and development of all types of crop plants. Indeed, plants necessarily require sufficient amount of moisture, temperature (Temp.), photoperiod and air current to survive in a particular climatic zone.Thus, the advance information on various aspects of weather such as rainfall, precipitation, wind and light intensity *etc.* helps the farmers to plan the cultivation practices in an efficient manner so as to maximize the yield and economy benefit for the farmers. Generally, the progressive farmers now days take the help of weather forecast for many day to day activities for ensuring the success rate of their crop (Fig 1) but the four major areas of agriculture as suggested by Didal *et al.* (2017) and Mike Elite, (2018) that are chiefly operated as per weather updates includes:

1. Irrigation schedules.
2. Fertilizer application schedules.
3. Disease and pest control practices.
4. Workability for regular field operations.

Irrigation schedules

The intensity of precipitation in any area decides the type of vegetation type for the particular region. Thus the importance of water supply or moisture for growth, survival and very existence of plants is huge. The agro-climatic zones can be roughly classified as irrigated and rainfed areas depending on the type of irrigation used there. The rainfed areas totally relay on the natural rainfall for the plants grown under such conditions whereas, in irrigated areas, the artificial means of water supply could also be utilized. The irrigation supply could be met out by means of small scale irrigation (SSI) or the large scale irrigation (LSI) depending upon the availability of basin or river inputs for the agricultural crops. As the water supply can be regulated as per the requirement, the irrigated crops always show betterresults in terms of yield and quality when compared to rainfed crops. On the other hand, the rainfed agriculture proves to be a sustainable trend in varied climatological conditions and is cost effective too (Tilahun *et al.,* 2011). The consequences related to rainfed agriculture attracted the attention of researchers to a great extent with its impact on total grain production and livelihood security in India (Rao, 2004). In India, 56% of the total agriculture area practice rainfed agriculture and 40% of the country's total food grain production comes from the rainfed agriculture including cereals (85%), pulses (83%), oilseeds (70%) and cotton (65%) and accounts for livelihood generation of almost 60% of the total population (Venkateswarlu and Parsad, 2012). Suresh *et al.,* 2014; analysed the production trends of rainfed and irrigated agriculture and observed that the rate of increase in cost of cultivation for rainfed crops was found to be minimum as compared to the irrigated crops. Thus presented the scope of sustainable agriculture by adoption of improved rainfed system with proper management strategies. Unexpected and untimely changes in climate behaviour particularly the rainfall and precipitation pattern exerted huge pressure on agriculture production. Thus demanding implications of technologies for calculating the exact amount of irrigation requirement or making cropping decisions in synchronization to the rainfall pattern for minimizing the losses due to climate fluctuations (Selvakumar and Sivakumar, 2021).

In India almost 80% of the mulberry gardens are cultivated and managed under irrigated conditions mainly in Southern parts of the country like Karnataka and Tamil Nadu *etc.* describing the significance of irrigation in mulberry cultivation (Anonymous, 2013). Soil determines the productivity status of the crop type grown in it as it sustains biological productivity, maintains ecological balance and promotes uptake of nutrients by the plant (Thakur *et al.,* 2022). On an average mulberry require 1.5-2.0" acres of water per irrigation at an interval of 6-12 days depending upon the availability of moisture content in the soil, type of soil and season prevailing in a particular area. It is also advisable to provide irrigation a frequency of 8 times (8 numbers) to 65-70 days old plant to attain the maximum yield (Rajaram and Qadri, 2014). Therefore, it can be estimated that mulberry requires about 75" acres of irrigation supply which is equivalent to 1875 mm of rainfall annually at a frequency of 36 mm per week *i.e.* 5-6 mm per day (Lal, 2001; Gupta and Despande, 2004). The measurement of requirement of irrigation or rainfall for a particular area under mulberry cultivation thus could be calculated by the knowledge and information gathered from the forecast system.

The computation of data thus obtained by the experimental research could be utilized to predict the annual or average rainfall which could further be utilized for calculating the amount and frequency of irrigation required by the mulberry plant under the specific agro-climatic conditions.

Fertilizer application schedules

Agriculture production being chiefly dependent on the agro-climatic conditions depicts the significance of optimum requirement of various meteorological parameters for success of any crop. Approximately 45% of the world's total population relies on agriculture for sustaining their livelihood and about 26% of working sector is also associated to the agricultural aspects (WMO, 2001). In addition to major micronutrients (NPK), micronutrients like zinc also play important role for enhancing crop yield (Ariraman *et al.,* 2022). With the rampant increase in the world population the demand of agriculture production has also been increased automatically. For meeting the target of required demand, fertilizers application proved to be the most convinent option for enhancing the overall production. But care must be taken to apply the correct dose of fertilizers at appropriate time for ensuring the optimum results. The calculation of correct time for fertilizer application is equally important as the choice of fertilizer will be, which otherwise may yield zero profit to the farmers (Anna and Rogna, 2020). For example; if an area will be shown to face excessive drought or rainfall in the upcoming days, with the help of meteorological forecast there will be the chances for the farmers to reschedule the time if fertilizer application and dosage as well. This immediate response to foreseen weather could viewed as an alternative to avoid the wastage of fertilizer input and manpower. Moreover, the farmer could also increase he dose of fertilizer to counterbalance the expected outputs (Anna and Rogna, 2020). They also described the importance of nitrogen based (N) fertilizers as most significant during drought conditions as compared to normal conditions. The study suggested that the choice of fertilizer input should also be made in relation to the agro-climatic conditions. The information about which could be obtained with the help of meteorological forecasting. The time, frequency and schedule of fertilizer application specifically the nitrogenous fertilizers are chiefly influenced by the geographical area and agro-climatic conditions prevailing there. For study of such instances, various techniques have been developed in the field of meteorological studies such as, Spatio-temporal data which describes the annual requirement of N-based fertilizers in any geographical region and Spatial-dynamic panel and data mode (SDPD), which gives the information based on individual-specific and time-specific fixed effects to calculate the potential unit-specific requirements of N-fertilizers (Lu and Tian, 2017).

Mulberry (*Morus* spp.) comprises the only sole food material of Lepidopetarian caterpillar *Bombyx mori* L. Being the only potential host plant for silkworm *Bombyx mori* L., mulberry is commercially cultivated across the country over 2.8 lakh hectares of area (Chanotra *et al.,* 2019b). In advanced sericulture states like Karnataka, Tamil Naidu, West Bengal, Andhra Pradesh and Jammu and Kashmir, 3-4 matrictonnes (MT) of leaf per acre could be harvested under recommended package of practices. More importantly mulberry can regain its full foliage in a shorter period of time under irrigated conditions where the plant makes use of naturally available nutrientsfrom the soil. Dandin*et al.,* 2003; reported that for production of 3-4 MT/acre of mulberry leaf, the plant utilizes 28 kg of nitrogen (N), 11 kg of phosphorous (P) and 11 kg of potassium (K). This implies that the requirement of N.P.K fertilizer for such soil would be 140:70:70 kg/acre under irrigated conditions. In addition to N.P.K fertilizers, combination of biofertilizers in the form of vermicompost + Azospirillum @ 4 kg + 4.0 kg per plant could be used as an alternative for obtaining good quality mulberry leaf (Pavankumar *et al.,* 2020). From the study of Devi and Sakthivel, 2018; it can be assumed that for calculation of appropriate dosage and schedule of N.P.K fertilizer in mulberry garden, it is important to know the annual rainfall, precipitation and soil health status for realizing the optimum quality and quantity of mulberry leaf. The data required on various aspects to generate information could be obtained with the help of climatological forecasting only.

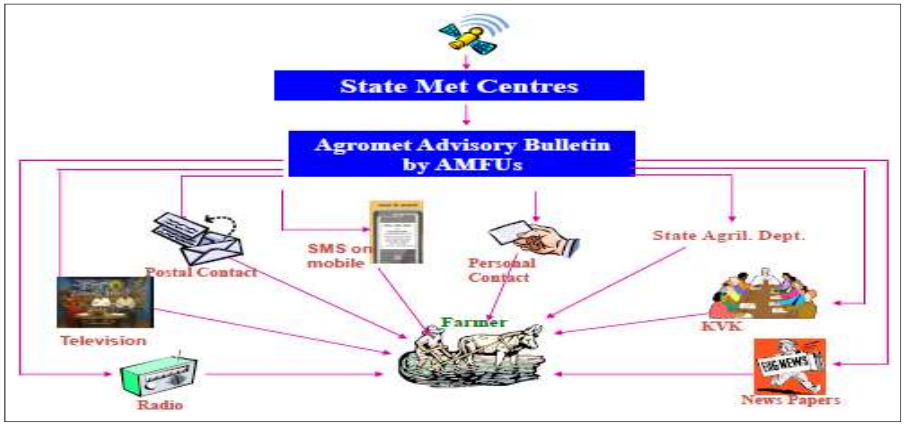


Fig 1: Scheme of functioning of weather forecasting system (Didal *et al.,* 2017).

Disease and pest control practices

With changing scenario of agriculture, the disease and pest incidences are also changed. Pest resurgence and resistance in pathogens for specific pesticides are most common phenomenon encountered in present disease and pest management strategies. Effective, accurate and in time monitoring, identification and management strategies of different categories of pest and disease causing pests and disease causing agents would be of significant importance in improving agricultural production trends. This could also be viewed as an efficient prospective for ensuring sustainable world food security.

Conventional methods of disease and pest monitoring involve the detailed survey of the area, crop grown and symptoms of attack. This could only help to categorize the type of pest but couldn't provide the insight information about the severity of attack and the regional situation over the area. Therefore, Remote Sensing Technologies (RTS) have completely replaced the old traditional methods of pest monitoring and survey. Remote Sensing is a technology applied to generate data on the spectrum of pest attack, its severity and level of infestation in advance thus offers sufficient time for making decisions regarding the precautionary measures (Dong *et al.,* 2019). Latest techniques of pest monitoring also includes Spectral indices construction and extraction of data based on sensitive bands, vegetation indices and time series changing characteristics for a particular area (Kumar *et al.,* 2001; Rao *et al.,* 2006 and Lakshmi and Chandrashekaraiah, 2007). For validation of pest monitoring and forecasting techniques, researches have also been done on pest forecast model construction which resulted in the improved efficiency of crop pest and disease monitoring and prediction strategies. Such type of work has been described by Shelestov *et al.* (2013) who successfully constructed agricultural monitoring and forecasting information system with the application of Remote sensing technology. Making use of digital satellites for automated data generation for retrieving information about crop type and related diseases and pest incidents (Begum *et al.,* 2008). Dong *et al.* (2019), utilized WebGIS based system for advance prediction of disease and pest monitoring in wheat crop in China.

Mulberry being a fast growing, deep rooted perennial plant is susceptible to various pests and disease causing pathogenic agents like fungal, bacterial, viral, mycoplasma and nematode agents (Rohela *et al.,* 2020). Different disease cause significant deterioration in leaf quality and quantity as well. Approximately, 10-20% of yield loss in mulberry is reported due to the incidence of different diseases. Silkworm when fed with infected mulberry leaves yield cocoons of relatively poor quality and it accounts for overall crop loss of about 15-20% (Shaista *et al.*, 2020). Therefore, application of pest monitoring and forecasting model became the need of the hour and research has also been made to observe the efficiency of forecasting model for disease and pest control management in mulberry.

Maji *et al.* (2012) presented the utility of forecasting model for prediction and control of bacterial leaf spot (BLS) in mulberry under potential sericultural district (Birhum) of West Bengal. The results obtained by Maji *et al.* (2012) showed that BLS causing bacteria *Xanthomonas campestris PV mori* was reported to be most prevalent during the month of May to November. The correlation studies revealed that BLS disease is reported to show considerable positive correlation with maximum and minimum temperature ranges, minimum relative humidity, rainfall pattern and period of precipitation. The sprouting pattern and time was also reported to be effected significantly depending on the environmental conditions prevailing in particular area. The adversities during sprouting period finally cause loss to the foliage quality (Pandey, 2013).

In order to present a clear picture of forecasting model they studied relationship between meteorological parameters with incidence of BLS severity. The meteorological parameters studied included mean of maximum and minimum temp., mean of maximum and minimum RH, rainfall and number of rainy days. The equation thus formulated by Maji *et al.* (2012) is denoted as:

$$Y= a+b_1x_1+b_2x_2+\ldots\ldots\ldots\ldots b_6x_6$$

Where,

Y = Predicted severity of disease on mulberry leaf.

a = Intercept.

b_1 to b_6 = Partial regression cofficient for x_1 to x_6 meteorological factors.

For the above equation, cofficient of determination (R^2) and Partial regression coefficient (b) values were performed at 5 level of significance (Snedecor and Cochrant; 1967). The results obtained from the above equation depicted that BLS showed significant positive correlation with average minimum and maximum values of the meteorological parameters. Therefore, the prediction equation thus formulated could be used in forecasting the disease severity in mulberry cultivation.

Similar to other insect silkworm is also susceptible to attack of diseases and pests and rearing if conducted under faulty environmental conditions may yield poor cocoon crop and even to entire crop loss due to increased pathogen load leading to disease outbreak (Shiva and Shamitha, 2013). Fluctuation in temperature and RH ranges during the rearing period also promotes the pathogen load in raring house leading to outbreak of diseases. Weather could be viewed as key driver for depicting the pathogen load and incidence of various insect diseases as slight alteration in optimum weather conditions can cause serious disturbances in management practices (Chakraborty, 2005). Moreover, the impact of weather could be positive or negative depending upon the intensity of pathogen load, season and their multiplication rate (Das *et al.,* 2011). Therefore, there is utmost need for creation of models and database that could be utilized for pre-warning the farmers about the chances of pathogen attack and disease outbreak in order to minimize the losses (Singh *et al.,* 2018).

Workability for regular field operations

Field workability refers to the number of days available for performing the field operations such as ploughing, sowing, intercultural activities and harvesting and post-harvest operations. Accurate information pertaining to the upcoming weather instances provides an opportunity for the farmers to plan the field operations well in time. Thus weather forecasting and monitoring revolutionize conventional agriculture practices into 'Precision Agriculture' which emphasizes the approach of accuracy and control for increasing the success rate in crop cultivation. Short range weather forecast provides enough time to plan various field activities to be taken out prior to onset of unavoidable circumstances. Short range weather forewarning enables the farmers to take operations like soil preparations, choice of crop to be grown, irrigation and fertilizer application schedule, harvesting time and post harvest activities (Didel *et al.,* 2017). Mulberry cultivation and rearing schedule should also be planned in advance for maximum output results and forewarning related to rainfall, temp. and RH helps the farmers to conduct all the operations well in time.

Silkworm is a peciulothermic insect and is highly sensitive to biotic and abiotic environmental factors prevailing in a particular area (Udea *et al.,* 1975 and Benchamin and Jolly, 1986). Slight fluctuation in optimum ranges of temperature effect the genotypic expression of the worm which in turn affect the expression of various metric traits such as cocoon weight, shell weight, cocoon shell ratio and reliability *etc.* (Rahtmullah, 2012). Therefore, for achieving good quality cocoon crop the environmental conditions needs to be maintained as per the requirement which can be achieved by weather forecasting to a great extent. The optimum range of temperature required for normal growth of silkworm larvae is 20°C to 28°C but it thrives best under a temperature range of 23°C to 28°C executing full of its potential.Similar to temperature, relative humidity also affects the physiology of silkworm to a great extent. The combined effect of temperature and RH provides satisfactory results for determing the success of cocoon crop. Hence, both temperature and humidity would be considered as key factors for determining the success rate of silkworm rearing (Biram *et al.,* 2009; Sarkar *et al.,* 2009 and Hussain *et al.,* 2011). RH in the range of 80 to 90% with temperature of 26°C to 28°C yields better results in qualitative and quantative cocoon characters (Rahtmullah, 2012). Embryonic development in silkworm is also influenced by the fluctuations in the environmental factors. Maximum ovulation and fecundity in silkworm was observed at temperature of 25±0.17°C and slight change in this range may adversely affect the embryonic development of the zygote resulting in decreased ovulation, poor fecundity and more number of dead eggs (Mathur *et al.,* 1988 and Hussain *et al.,* 2011). Failure in maintaince of optimum conditions of temperature and humidity while silkworm rearing also pose serious impact on racial characters of different breeds with respect to cocoon shape and size (Hirashi, 1912; Katsuki and Nagasawa, 1917; Gamo and Ichiba, 1971; Gamo *et al.,* 1985; Nakada, 1989; Nakada, 1994; Singh *et al.*, 1998 and Mathur *et al.*, 2000). More interestingly, spinning of cocoon would be equally dependent on temperature and humidity along with sufficient air current in the range of 22-25°C, 60-70% RH and 50 cm/second respectively for revealing high quality silk fiber (Ramachandra *et al.,* 2001 and Manisankar *et al.,* 2008). Thus forewarning about the weather conditions would open new avenues in sericulture for realizing maximum profits.

Agromet advisory services (AAS) is one of the preliminary approaches in the field of sericulture working on the concept of disease and pest forewarning in Andhra Pradesh, operated by Central Sericulture Research and Traning Institute, Mysore, India, which describes the agro-meteorological advisory for taking the necessary precautions for ensuring successful silkworm rearing and cocoon production (Anonymous, 2014). Recently AAS operated by meteorology department of Pune on pilot basis has started weather forewarning initially for Andhra Pradesh and will be extended to its adjoining sericulturally potential districts. The farmers can avail this opportunity by registrating themselves with the digital portal and the advisory services would be delivered to them in the form of short message service (SMS) on the registered mobile numbers (Anonymous, 2020). Another important advancement in meteorological science for strengthening the silk industry is Sericulture Information Linkages and Knowledge System (SILKS). SILKS is a computer based single window providing information and advisory specifically for sericulture farmers (Fig 2) and is available in public domain on web portal of CSB *viz.*, http://silks.csb.gov.in. SILKS gather information by network of Automatic Weather Stations (AWS) all across the country connected to the research and development (RandD) laboratories of CSB (Fig 3). Advisory of pest and disease outbreak chances can also provide the farmer to plan the suitable dates for brushing for achieving synchronized growth of the larvae (Singh *et al.,* 2016).

Singh *et al.* (2018) conducted an experiment for generating information on extent of damage caused by infestation of predators in commercial rearing of tasar silkworm (*Antheraea mylitta*) at Pilot Project Centre (PPC), Kathikund area of Jharkhand, India. For the execution of the study, daily weather data was collected along with the information on predator invasion. Using the data, interaction was made between the correlations of predator with respect to the change in daily weather conditions. The results revealed maximum infestation of the predators during the 31st Standard Meteorological Week (SMW). Thus an advisory could be formulated for tasar rearers to pay most attention during 31st SMW for expecting maximum yield.

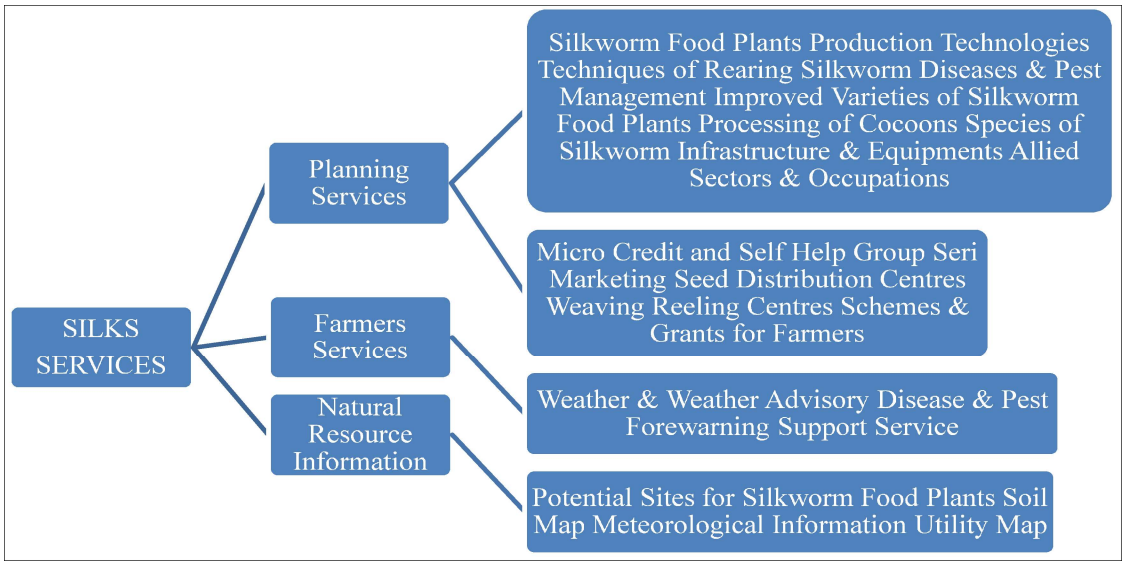


Fig 2: Generalized scheme of SILKS in the field of sericulture.

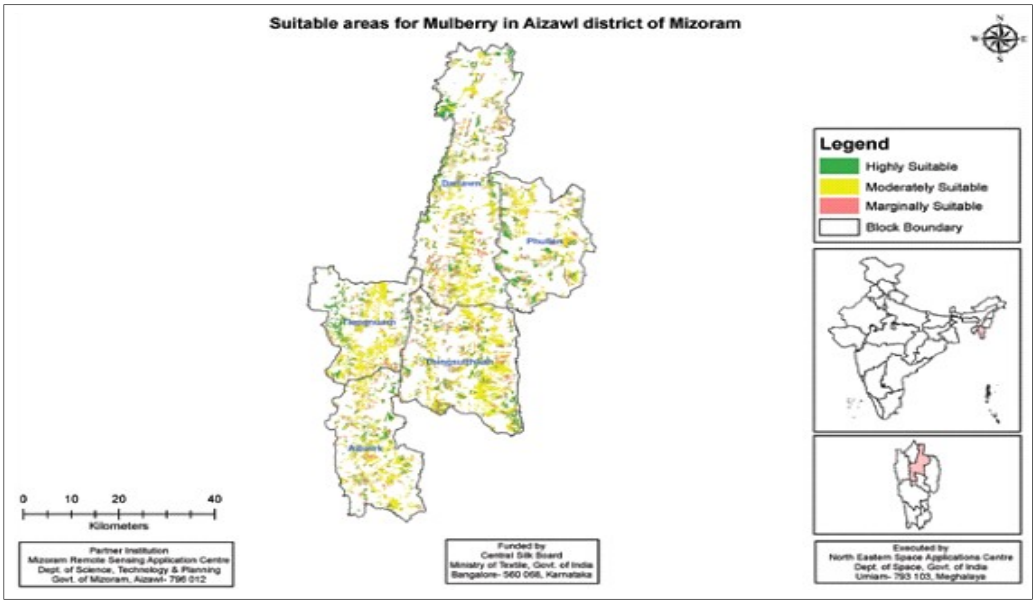


Fig 3: Potential area map for mulberry in Aizwal district, Mizoram identified with the help of geographic information system (GIS) technology.

Objectives of Climatological forecasting in Seri-industry

- To analyse and collect data on climatological factors prevailing in a particular area for formulation of data base so as to generate predictions for upcoming weather events.
- To provide advance advisory services to the farmers for making strong decisions related to choice of crop to be grown in a specific area in a particular season.
- To schedule the field operations in synchronization with the weather conditions.
- To develop simple, efficient and suitable crop weather models based on geographical and meteorological data.
- Prediction of chances of pest and disease outbreak in a specific area and season along with the extent of its severity.
- Forewarning and advisory services for the farmers related to trends of environmental fluctuations for ensuring minimum risks to silk farming industry and thus minimizing the risks of wastage of available resources.

CONCLUSION

Weather plays vital role in deciding the success or failure of any crop. Similarly, the success rate of sericulture in the form of production of quality mulberry leaf and cocoon of internationally acceptable grade is chiefly dependent on

biotic and abiotic factors of the environment. Weather monitoring and forewarning provides accurate advisory about the weather in advance which helps the farmers for planning precautionary measures for reducing the risks of crop failure and wastage of inputs.

Conflict of interest

All authors declared that there is no conflict of interest.

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