IJCRT.ORG ISSN : 2320-2882

INTERNATIONAL JOURNAL OF CREATIVE RESEARCH THOUGHTS (IJCRT)

An International Open Access, Peer-reviewed, Refereed Journal

Applications Of Remote Sensing And GIS In Sericulture

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Abstract: Sericulture is one of the important sectors for rural population to generate income. There is tremendous scope for improving the production and quality of silk through expansion of sericulture in new areas. The geospatial tools comprising of Remote Sensing (RS), Geographical Information System (GIS) and web technology have the potential of integrating, analyzing and disseminating the satellite derived and other required information for further expansion of sericulture in the country. During the last decade, remote sensing techniques are applied to explore silkworm host plants cultivation practices such as crop acreage estimation, site suitability for mulberry cultivation and identification of pest infestation. Hyperspectral radiometry has been useful for detection of damage caused by sucking pest of mulberry. Spectral reflectance of red band and green bands are more sensitive to pink mealy bug, spiraling whitefly and thrips respectively. A geoportal titled 'Sericulture Information Linkages and Knowledge System' (SILKS) was open source GIS software system to provide spatial information on potential areas for silkworm host plant cultivation which was hosted in the public domain, http://silks.csb.gov.in. Hence, this review helps to know about remote sensing techniques and GIS in detecting mulberry pests and diseases, and also would be useful to strengthen the sericultural activities in our country.

***Index Terms* -** Mulberry pests, SILKS, Hyperspectral radiometry.

Introduction

Sericulture is an eco-friendly, agro-based labour intensive rural cottage industry. India continues to be second largest producer of silk in the World. An annual silk production of more than 35261 metric tonnes was generated in 2018-19. Out of this mulberry contributed more than 80% of the country's silk production. The present global scenario clearly indicates better opportunities for the Silk Industry. But, sericulture production is still limited to a few pockets in our country. Central Silk Board (CSB) is taking proper steps to improve production in the country, through identification of additional potential areas with the technical support from North Eastern Space Applications Centre (NESAC). There is considerable scope for improving the production and quality of silk through identification of additional potential areas and employing improved methods of information collection, processing and dissemination. Identifying the additional potential sites for mulberry production is generally classified as spatial information directly derived from various sources of information that influence plant growth and yield. These include climate, soil information, Wastelands, Groundwater prospects and Slope. These area specific parameters vary both in terms of intensity and quality. This information could be utilized to determine suitability classes for mulberry plantation.

Geographic Information System (GIS) and Remote Sensing (RS) have been effectively used to generate, integrate and analyses the multiple data sources in order to identify the suitable sites for mulberry plants (CSB, 1994). GIS has been used extensively for spatial analysis. It also provides greater reliability with lesser time and cost compared to manual operation (Bera *et al*, 2002). Today, remote sensing is potentially a practical management tool for site-specific crop management for sustainable sericulture (Casady and Palm, 2002). Keeping in view the importance of remote sensing and GIS technology, the relevant literature on application of remote sensing and GIS in sericulture is reviewed and reported in the present manuscript.

II. Principles of Remote Sensing

Different objects reflect or emit different amounts of energy in different bands of the electromagnetic spectrum. The amount of energy reflected or emitted depends on the properties of both the material and the incident energy (angle of incidence, intensity and wavelength). Detection and discrimination of objects or surface features is done through the uniqueness of the reflected or emitted electromagnetic radiation from the object. A device to detect this reflected or emitted electro-magnetic radiation from an object is called a ―sensor (e.g., cameras and scanners). A vehicle used to carry the sensor is called a ―platform (e.g., aircrafts and satellites).

Main stages in remote sensing are the following.

A. Emission of electromagnetic radiation
  1. The Sun or an EMR source located on the platform
B. Transmission of energy from the source to the object
  2. Absorption and scattering of the EMR while transmission
C. Interaction of EMR with the object and subsequent reflection and emission
D. Transmission of energy from the object to the sensor
E. Recording of energy by the sensor (Photographic or non-photographic sensors)
F. Transmission of the recorded information to the ground station
G. Processing of the data into digital or hard copy image
H. Analysis of data

III. Geospatial techniques in Sericulture

Central Silk Board (CSB) and Indian Space Research Organisation (ISRO) in collaboration with the concerned State Sericulture/Textiles Departments used the technology of RS and GIS for mulberry acreage estimation, garden condition assessment and for finding suitable areas for introducing sericulture in the non-traditional states (Nageswara Rao *et al*., 1991; CSB, 1994). ISRO and CSB had carried out a project, called SPAARS (Survey of Potential and Actual Area under Sericulture with Remote Sensing), for mapping of potential and actual areas under Sericulture at 1: 250000 scale. Because of the coarse mapping scale the derived information could not meet the requirement for district and block/taluka level planning. Hence a project titled 'Applications of Remote Sensing and GIS in Sericulture Development' was taken up for implementation during 2008-09 to 2013-14 period with an objective to identify the additional potential areas for development of silkworm food plants for 108 priority districts in 24 states at 1: 50000 scale in three phases;

Phase I: 41 districts covering all 8 states in North Eastern Region (NER) including Sikkim.

Phase II: 45 districts covering 11 other non-traditional states viz., Bihar, Chhattisgarh, Himachal Pradesh, Jharkhand, Kerala, Madhya Pradesh, Maharashtra, Orissa, Punjab, Uttarakhand, and Uttar Pradesh.

Phase III: 22 districts in 5 traditional states viz. Andhra Pradesh, Jammu and Kashmir, Karnataka, Tamil Nadu and West Bengal.

It was also envisaged to develop a geoportal for integrating the potential area maps along with other required information for expansion of sericulture at district level. Quick development of web technologies has transformed geo informatics from a science for specialists into an application tool for wide range of users. Geoportals were developed to find and access geospatial information and associated geographic services (display, editing, analysis, etc.) via the internet. Geoportals are important for effective use of GIS and a key element of Spatial Data Infrastructure (SDI).

Considering there is no other geoportal available in the country on sericulture, a geoportal titled Sericulture Information Linkages and Knowledge System (SILKS) was planned to develop integrating all the project outputs for 108 districts along with required district level information for expansion of sericulture and to host it under the domain name http://silks.csb.gov.in.

IV. Identification of Potential Areas for Mulberry

The methodology for identification of potential areas for sericulture development involves evaluation of land, water resources and climatic requirements for growing silkworm food plants as well as rearing of silk worms (Sys 1985, Sys *et al*., 1993). It needs interpretation and integration of soils, climatic parameters, vegetation and other aspects of land, like wastelands and slope using GIS. As there is limited scope of expansion of plantations area under silkworm food plants, emphasis was given in identifying cultivable wastelands using satellite data using standard classification approach (NRSC, 2006). Out of 23 wastelands categories at 1:50000 scale as per National Wasteland Classification System (NRSC, 2011), 7 categories were considered for further evaluation of suitability for silkworm food plants. IRS Resoursesat-1 and Resources at 2 LISS III satellite data during the period of 2008-2009 were acquired for delineating the cultivable wasteland areas.

4.1. Evaluation of Site Suitability Based on Landscape and Soil Characteristics

Six parameters of soil viz., drainage, ground water, texture, depth and pH and two topographic and landscape parameters viz., slope and erosion were considered for suitability evaluation. Soil characteristics were obtained from the soil map prepared under two projects at national level viz., National Natural Resources Data Base (NRDB) of Department of Space and project on soil mapping by National Bureau Soil Survey and Land Use Planning (NBS&SLUP) and Soil and Land Use Survey of India (SLUSI). Slope map was derived from SRTM DEM (Shuttle Radar Topographic Mission- Digital Elevation Model). Information on ground water availability was obtained from ground water prospect map prepared under Rajiv Gandhi National Drinking Water Mission. Soil erosion map of the study area was generated using Universal Soil Loss Equation (USLE) in GIS environment. Different thematic layers were generated in GIS environment for each of the land characteristics and compared with the requirements of silkworm food plants. Criteria of limitation ranging from 1 (suggesting no or slight limitation) to 4 (suggesting very severe limitation) were assigned to generate the suitability map as per the following FAO Sericulture Manual Standards (1990) (Table 1).

Table 1: Criteria of limitation rating for evaluation of soil site suitability for Mulberry

Soil-site characteristics		Degree of limitation and suitability class			
	Unit	0-1 None to slight	2 Moderate	3 severe	4 Very severe
		S1 Highly suitable	S2 Moderately suitable	S3 Marginally suitable	N Not suitable
Topography and landscape					
Slope	(%)	0-3 Level to very gentle	3-5 Gentle	5-10 Moderate	>10 Steep
Erosion		E1	E2	E3	E4
Soil characteristics					
Drainage	Class	Well	Well	Well	Excessive
Ground water	Availability	Good	Fair	Fair to moderate	Poor
	Quality EC Micro mohs\cm	Very good <2000	Fair to good 2000-3000	Moderate 3000-4000	Poor>4000
Texture	Class	Clay loam–gravely loam	Fine loamy	Coarse loamy	Sandy fragmental
Depth	Cm	Deep	Mod shallow To mod deep	Shallow	Very shallow
pH		6.5 -7.5	5.5-6.5 7.5-8.5	4.5-5.5 8.5-9.5	>4.5 >9.5

4.2. Evaluation of Site Suitability Based on Climatic Parameters for Silkworm Food Plants

Suitability of climate for the food plants were described in terms of:

(i) Temperature
(ii) Rainfall (water supply) and
(iii) Minimal length of growing period.

The weather data, collected from the class-I observatories of IMD and the Automatic Weather Stations (AWS) established by ISRO have been analysed for rainfall, maximum and minimum temperature, Potential Evapotranspiration (PET) and length of growing period (LGP) for the silkworm food plants.

4.2.1. Spatial Distribution of Temperature and Rainfall

The point observations on temperature and rainfall need to be translated into spatial domain and this was done by analyzing long term monthly and annual average of mean temperatures of all the stations with corresponding elevation data (Patel, 2000).The empirical relation thus developed is used in GIS environment for depicting spatial variation of annual mean temperature or mean temperature for the growing season of silkworm food plants. For interpolation of rainfall data from point locations to represent the spatial coverage kriging method was adopted as kriging method assumed to yield more accurate predictions than linear regression (Goovaerts, 1999).

4.2.2. Spatial Distribution of Length of Growing Period (LGP)

Length of Growing Period (LGP) or moisture availability period for crop growth is the period (in days) when precipitation exceeds 50 percent of the PET (Potential Evapotranspiration). Shorter LGP (less than 120 days for mulberry and 90-120 days for castor, as examples) are not suitable for cultivation of silkworm food plants. Monthly potential evapotranspiration (mm) were computed by Thornth waite method (1948). The calculated LGP is presented in spatial domain with interpolation using geo statistical analyst tools. Based on climatic characteristics, limiting levels viz., highly suitable, moderately suitable, marginally suitable and unsuitable have been decided by matching the requirements of silkworms food plants (Table 2) and assigned suitability class (limitation). The climatic limitation map was superimposed on the soil constraints map to finally derive site suitability map.

Table 2: Evaluation of climatic site suitability for Mulberry

Climate characteristics	Suitability class			
	Highly suitable	Moderately suitable	Marginally suitable	Not suitable
Mean temperature in growing season	20-30	31-37	31-37	<15, >37
Total rainfall	500-750	751-2000	2001-3400	<500, >3400
LGP(days)	>200	-	-	-

4.3. Evaluation of Suitability for Silkworm Rearing

Silkworms are delicate and very sensitive to environmental conditions. Among the various environmental factors, the most important are atmospheric temperature and humidity prevailing at the time of rearing. The combined effect of both temperature and humidity largely determines the satisfactory growth of the silkworms. The optimum temperature and humidity for normal growth in mulberry silkworm is between 23-28^{0}C and 70-85% respectively. Spatial layers on the temperature suitability for silkworm were generated as it was done in case of silkworm food plants.

V. Integrated Evaluation of Soil and Climatic Suitability for Silkworm Food Plants and Sericulture Development

The maps generated indicating limitations for climate, landscape and soil characteristics have been spatially overlaid in GIS environment to produce a resultant polygon layer. Each polygon has 8 values (soil characteristics) of degree of limitation. Based on the number and the intensity of limitations, suitability classes have been decided and graded as highly suitable (S1), moderately suitable (S2), marginally suitable (S3) and not suitable (N) as given in Table 3. Figure 1.

Table 3: Criteria for determination of land suitability classes

Land classes	Criteria
S1:highly suitable	Land units with no or only 4 slight limitations
S2: moderately suitable	Land units with no or only 4 slight limitations and no more than 3 moderate limitations
S3: marginally suitable	Land units with more than moderate limitations and no more severe limitations
N: Not suitable	Land units with very severe limitation

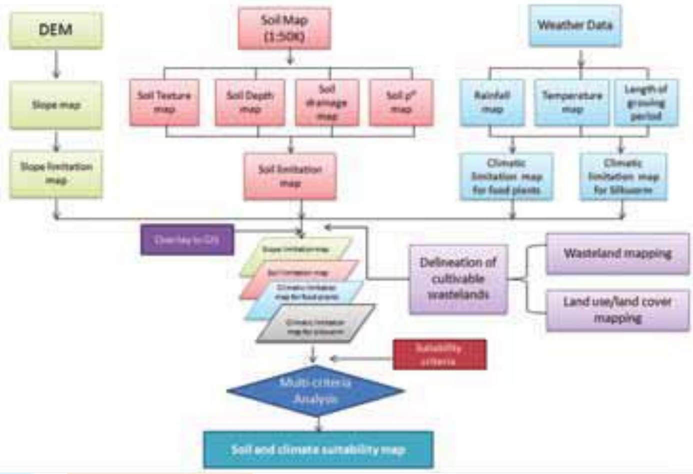

Fig.1: Flow chart of methodology for soil and climate suitability for sericulture development

VI. Development of SILKS Geoportal

A geoportal titled Sericulture Information Linkages and Knowledge System (SILKS) has been developed as a single window decision support system to provide all the sericulture related information for all the selected 108 districts. SILKS spatial modules has inbuilt web GIS tools for displaying and querying of spatial data. The portal has been developed using open source software packages. The UMN Map Server (developed by the University of Minnesota, and often referred as UMN Map Server) is used as a GIS engine, PostgreSQL/PostGIS as an object oriented relational database management system (ORDBMS) and Geo Server for creating OGC (Open Geospatial Consortium) web services. An open source web application tool built on top of Map Script using the PHP programming language has been used for development of interactive user interface. SILKS allows effective dissemination, sharing and management of spatial information, which can be used as an effective decision making tool for sericulture planning and development. The non-spatial modules were created using web tools such as HTML (Hypertext Mark up Language), CSS (Cascading Style Sheets), java scripts etc. The basic architecture of SILKS is shown in Figure 2.

First, the user makes a request having Map server parameters. The Apache HTTP web server upon receiving the parameters invokes the Map server engine. The Map file inside the Map server defines the basic and query template and tells how the maps will appear on the browsers. The Map server can connect to both local Postgre SQL data as well as external OGC data services from remote servers. The re-projection of the incoming data can be done on-the fly as per the projection defined in the "projection object". The Map server then processes the data as per the parameters and returns images in the desired map output format defined in the Map file.

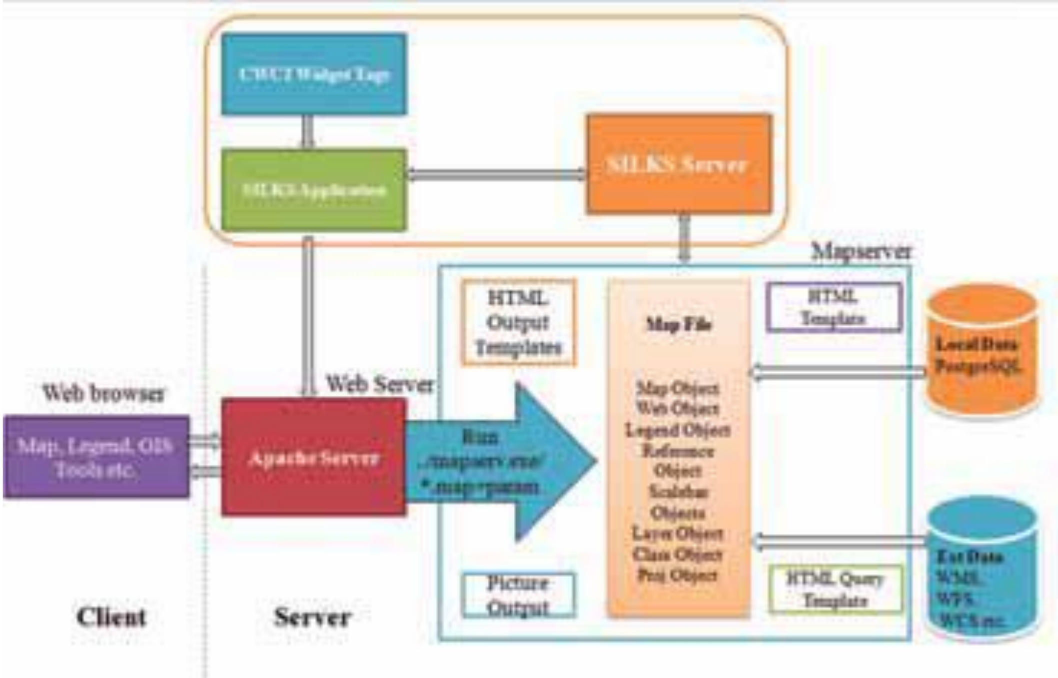

Fig. 2: SILKS Application architecture

VII. Additional Area Suitable for Mulberry Host Plants in NE States

Out of total 108 districts, 41 districts were selected from 8 NE states including Sikkim covering a total geographical area of 9, 35,195 sq km (Table 4). Among the NE states, Nagaland is found to have maximum suitable areas (21.9% of total geographical area) that can be brought under Mulberry Sericulture. This is followed by Meghalaya state (15.8%). Due to limitation of physiographic conditions and climate, Arunachal Pradesh is having very limited areas (17242 Ha in selected 7 districts) that can be brought under sericulture activities.

Table 4: Suitable for Mulberry host plants in NE states

States	No of selected districts	TGA	Highly suitable	Moderately suitable	Marginally suitable	Total	% of TGA
Arunachal pradesh	7	36981	13	1908	15321	17242	0.47
Assam	9	32713	1169	76893	232377	310439	9.49
Manipur	9	22327	-	-	67675	67675	3.03
Megahalya	2	5051	13928	32381	33425	79733	15.79
Mizoram	6	18278	85598	73495	17567	176660	9.67
Nagaland	5	10910	-	-	239306	239306	21.93
Sikkim	1	750	-	827	5095	5922	7.90
Tripura	2	4423	219	17388	14745	32352	7.31

VIII. Additional Area Suitable for Mulberry Host Plants in Other Selected States

Among non-traditional sericulture states, Bihar has been found to have the highest percentage of areas suitable for mulberry sericulture, which is about 11% of total geographical areas in the selected 3 districts, followed by Madhya Pradesh (10.2%) and Himachal Pradesh (9.7%). Among traditional sericulture states, Karnataka is found to have as high as 11.6% of total geographical areas in the selected districts are suitable for mulberry sericulture. The state of Punjab has been found to be least suitable for mulberry sericulture with only 521 ha of areas delineated as marginally suitable in the selected two districts. Other two states which have been found to be less suitable for Mulberry sericulture are uttarakhand (0.05%) and chattisgarh (0.6%) but uttarakhand has about 595 ha of area under highly suitable categories in the selected 5 districts. For non-mulberry sericulture, Bihar and West Bengal have significant proportion of suitable areas for Ericulture. West Bengal and uttarakhand have significant suitable areas for Muga. For tropical Tasar, Orissa has the highest percent of suitable areas (25% of TGA) in the selected 4 districts followed by Jharkhand (21.2% of TGA) in the selected districts (Table 5).

Table 5: Suitable for Mulberry host plants in other than NE states

States	No of selected districts	TGA	Highly suitable	Moderately suitable	Marginally suitable	Total	% of TGA
Andhra Pradesh	4	37518	2366	10339	6641	19346	0.52
Bihar	3	8934	-	59916	41458	101374	11.35
Chhattisgarh	2	22060	-	3162	9994	13156	0.60
Himachal Pradesh	4	15607	13755	96073	42254	152082	9.74
Jammu and Kashmir	2	2108	2551	6154	11299	20003	9.49
Jharkhand	3	8742	-	7651	11531	19182	2.19
Karnataka	4	33878	-	11877	379932	391809	11.56
Kerala	2	9411	9914	21970	14803	46686	4.96
Madhya Pradesh	6	35132	1136	77208	279563	357907	10.19
Maharashtra	7	72520	-	6441	76401	82843	1.14
Orissa	4	25986	238	7976	88217	96431	3.71
Punjab	2	4568	-	-	521	521	0.11
Uttara Pradesh	6	23886	584	8135	16382	25101	1.05
WestBengal	9	50438	38038	54272	24571	116882	2.32

IX. Information Dissemination through SILKS Geoportal

The SILKS geoportal developed as a part of the project has been put in the public domain under the domain name http://silks.csb.gov.in (Figure 4). SILKS is a single window, ICT-based information and advisory services system for the farmers, sericulture extension workers, administrators and planners working in the field of sericulture development. It provides computerized information storage, value addition, and supply sericulture knowledge to the users and planning and advisory services in formats and language appropriate for the local sericulturists. The portal is now made available in 12 languages viz., English, Hindi, Telugu, Kanada, Assamese, Bengali, Mizo, Manipuri, Khasi, Garo, Ao Naga and Sumi Naga. It has 13 major non-spatial modules and 4 spatial modules, which are grouped into three categories, namely Planning Services, Other Services and Natural Resources Management.

The available modules under Planning Services are Silkworm Food Plants Production Technologies, Techniques of Rearing Silkworm, Diseases and Pest Management of Silkworm Food Plants, Improved Varieties of Silkworm Food Plants, Species of Silkworm, Processing of Cocoons, Infrastructure and Equipments and Allied Sectors and Occupations. Other Service has modules like Micro Credit and Self Help Group, Seri Marketing, Seed Distribution Centres, Weaving Reeling Centres and Schemes & Grants for Farmers. Farmers Services module consists of Weather and Weather Advisory, Disease and Pest Forewarning and Support Services. Within a short span of about one year, the portal has been able to make significant impact particularly in North Eastern region and a number of sericulture expansion activities have been initiated based on the outcome of the study. Regular updation of information content in the portal requires continuous support from all the stakeholders based on the feedback from the users particularly the sericulture farmers.

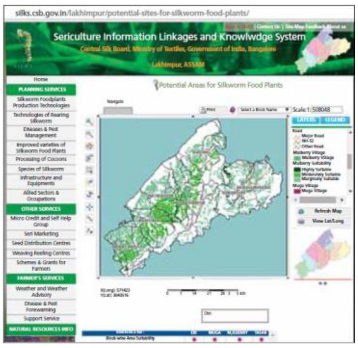

Fig. 4: SILKS webportal

X. Hyperspectral radiometry for assessment of damage caused by mulberry sucking pests

In this experiment, V1 variety having different crop duration and susceptibility to insect pests were chosen. The damages caused by three sucking pests namely pink mealy bug (*Maconellicoccus hirsutus*), thrips (*Pseudodentrothrips mori*), Spiralling whitefly (*Aleurodicus dispersus*) were studied. In these experiments, the per cent damage was recorded in healthy and infested plots at 15 days interval during active damage stage. Spectral reflectance in various bands was also recorded using hyperspectral radiometer.

Based on the studies it was found that, spectral reflectance curve of mulberry plants damaged by pests namely pink mealy bug, thrips and spiralling whitefly were different from that of healthy plants. The per cent sensitivity of red reflectance to pink mealy bug damage was the highest, in comparison to other bands in all four observations. Among the spectral indices, Normalized difference vegetation index was found to be more sensitive to pink mealy bug damage followed by Green red vegetation index. With respect to spiralling whitefly damage, red band was more sensitive than other bands. The Spiralling whitefly sensitivity curve showed single peak in visible region of the electromagnetic spectrum. Among the vegetative indices GRVI was found sensitive to spiralling whitefly damage. Green band was more sensitive to damage caused by thrips than other bands. Among the vegetation indices, RVI was found sensitive to thrips damage based on sensitivity analysis. Thus, using hyperspectral radiometry identification and assessment of damage caused by various sucking pests is possible, in addition to discrimination of various pests damages through analysis of spectral bands and indices.

XI. Advantages of remote sensing and GIS

• Remote-sensing technology provides many advantages over the traditional methods in agricultural resources survey. The advantages include

(a) Capability of synoptic view
(b) Potential for fast survey
(c) Capability of repetitive coverage to detect the changes
(d) Low cost involvement
(e) Higher accuracy

XII. Disadvantages of remote sensing

• Expensive to build and operate
• Measurement uncertainty can be large
• Data interpretation can be difficult

XIII. Conclusion

Identification of land suitability for mulberry food plants using spatial information model developed by GIS has been regarded as highly effective. This provides the required information compared with conventional operation. Similar approach can be extended to all the areas in the state, to identify potential sites for sericulture. It is evident that in the integrated approach, the technology could be transferred and resources could be utilised for identification of additional potential areas.

For over all development of sericulture industry a holistic approach has to be adopted and needed encouragement be provided to all the segments of sericulture industry under a cooperative initiative. State sericulture department/cooperation in coordination with CSB has to introduce various measures to ensure sustainable growth of the industry. In formulating developmental programmes it is essential to learn from the setbacks witnessed in 1990's, and climate change related ill effects.

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