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CSSM, Crop-ecological Sustainability Simulation Model: A Spatio-temporal Crop-yield Analysis Tool

Version- 5.2

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Preface

Crop-ecological sustainability simulation model, CSSM, is a computer crop-yield model developed to analyse the spatio-temporal dimensions of crop ecology and use of technology for crop-yield management. Many attempts have been made to simulate and predict crop yield by forwarding a variety of crop-growth models regarded as the physiological relationship of plant growth adopting lab-based controlled sample design, the phenological phases of plant growth with the use of various crop response functions and the climatic variability and crop-growth relationships using agro-meteorological approaches. Perhaps above all, the concern is to obtain the accurate estimation of crop-yield for better crop management and sustainable food grain production. The effort is made to fulfill the realized deficiency in the literature of crop-modelling development by developing an integrated crop yield simulation model which separates the effects of crop ecological as well as technological attributes and provides error free estimation of crop-yield because it follows deterministic approach for the calculation of ecologically based potential productivity parameters. It is simple to use and also operative on easily available statistics pertaining to weather, soil, technological attributes and crop yield from the concerned officers for a longer period of time.

The parametric calculations and the procedure of the use of present version of tool (Version – 5.2) is largely dependent on the simple computation at excel-sheet of MS- DOS based computer and the BASIC programming language to get the output files of simulated crop yield results. The spatio-temporal tool of crop-yield analysis is developed in such a manner so that the collected unformatted raw data of required attributes are to format as per the requirements of the tool by the use of Geographical Information System. The demonstration of spatio-temporal crop-yield analysis tool is made by using 29 years statistics of crop yield and its associated ecological and technological parameters to obtain simulated summer paddy yield for the Brahmaputra valley. The present tool is, in fact, unique in its nature, simple in its use and would be useful in estimating yield of various crops in a rational manner for various crop-growth systems working in different agro-ecological conditions.

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The author extends his gratitude to various Governmental as well as Non-Governmental agencies like Regional Centre, Indian Meteorological Department, Guwahati for providing monthly weather statistics of meteorological stations located in the Brahmaputra valley, the Directorate of Statistics and Economics, and the Directorate of Agriculture, Government of Assam, Guwahati for providing the statistics pertaining to summer paddy yield statistics of summer yield and use of fertilizer and other general information as required for the operation of crop yield simulation processes. The author is grateful to Professor, B.S. Mipun, Head, Department of Geography, North Eastern Hill University, Shillong who provided indispensable administrative and logistic support such as use of GIS lab in the Department. We also wish to thank the following individuals for their timely help in completing the monograph.

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In the last, but not the least, we are indebted to University Grants Commission, New Delhi for identifying our Department for its Special Assistance Programme under which the present work is completed in the form of individual project.

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Introduction

Model's Description

An accurate estimation of crop-yield in prevailing agriculture systems has brought out a great importance to predict the sustainable food grain production and the limits of the use of agricultural technology. A variety of ecologically viable plant growth and crop-yield models (Blanecy and Criddle 1950, DeWit 1958, DeWit et al. 1969; Fly, Reddy and Baker 1984, Reddy et al.1985, Gorski and Spoz-Pac 1989, Wu et al. 1994, Zhang and Dawes 1998, Kang et al. 2003, Gorski and Gorska 2003) as well as technologically input oriented production functions (Spillman 1922, 1933, Ferrell 1957, Aigner, Lovell and Schmidt 1977; Subash et al. 2004, Kiniry et al. 2004) were used to estimate crop-yield and agricultural production and to analyse the effects of ecological and technological production factors. A detail review on the development of crop simulation models implied that the plant growth was determined by emphasizing on the physiological processes and their resulting features like available carbohydrate and assimilates in the crops (DeWit et al. 1969) and later on by isolating the effects of temperature and water stress through the analysis of processes relating to respiration and transpiration of crops on the crop-growth systems (Baker et al. 1972). Generally, crop-simulation models are developed on the basis of physiological characteristics of plants and phenological development of crop response functions like CERES-Wheat (Ritchie and Otter 1985, Ritchie 1986, Mall and Singh 2000), CERES-Maize (Kinery 2004), wheat productivity function (Aggrawal, et al. 1994, Aggrawal and Kalra 1994), GOSSYM (Reddy et al. 1985), DeciBle-Wheat (Chatelin et al. 2005) and so on, in which the models considered making insights into photosynthesis of the leaf, canopy and green biomass growth of the plants. These models were fundamentally based on the physiological relationship of plant growth and were developed to use controlled experimental techniques to isolate the effects of various environmental factors on crop-growth. The yield functions using the parameters related to agro-ecological variability and the use of modern technology to create productive environment of a piece of crop-land, were not analysed in such models. Consequently, the result of such models may be far from accurately estimating crop-yield for the crop management. It is, therefore, realized that there is a need of an integrated approach towards crop-yield simulation through which the effects of ecological as well as technological production factors may be isolated for the accurate estimation and proper crop- yield management (Anbumazhi et al. 2003).

An effort here is to develop a tool for the estimation of grain-yield of a given crop and crop management in which many sub-models and relationships were assembled to capture the long-term effects of ecological and technological elements related to crop growth and grain yield predictions.

CSSM can act as 'crop-yield predictor' model where detail representation of crop ecological parameters makes it useful for assessing yield of a particular crop for specific environment. In-built model of the tool presents basic ecological dynamics and technological changes in specific crop- land systems (Fig-1). As a result, entire mechanism of CSSM is largely dependent on spatial variations of crop-ecological conditions and its temporal changes. It is realized that crop-yield varies because of variations in ecological conditions and also varies as the intensity of technological inputs differs. Similarly, it varies temporally because of ecological dynamics of a specific piece of land. CSSM is, thus, to simulate long - term feed back effects of ecological dynamics, technological enhancements and agricultural practices on crop - yield increase.

Sub-models of the present tool would have a focus on 'reproductive ecological capacity' of a piece of land where a particular crop is grown and, in accordance with the use of technological inputs like fertilizer, irrigation, machine tools, pesticides and so on, the efficiency of these input uses are assessed. Reproductive ecological capacity is parameterized in terms of potential productivity of land for a particular given crop as an indicator of maximum attainable grain yield of a particular crop, for which a crop growth sub- model is developed and used (Singh, Sharma and Dey 2005). As a result, the CSSM shows the combine effects of all ecological factors which control an environment of a piece of land for the growth and development of a particular crop. Attributes related to soil conditions and weather variability are considered as factors of potential productivity of land rather than direct influents of crop-growth. As per the output of the present tool, the crop-yield simulations are made with respect to potential productivity of land rather than a single factor of it like temperature, rainfall or soil fertility. However, the effects of such factors of land can be analysed by adopting classificatory approach of simulated yield. In order to construct the sub- model, soil characteristics were used as most-stable attributes and their spatial variations were shown to consider soil association units as operational taxonomic units (OTUs), which would work as the basis of spatial variations for crop-yield predictions. The second set of ecological attributes for the crop-growth is much more concerned with least stable attributes called weather variability which changes its magnitude and intensity hourly, daily and, consequently, seasonally as well as annually. Four interrelated and independent plant growth efficiency attributes related to weather, namely, the ratio of evapotranspiration with potential evapotranspiration (ET/PET), the soil moisture storage (ST) and the photosynthetic efficiency during the phase of vegetative growth (FE) and the thermal efficiency (TE) and one index of soil characteristics (SCI) were used to construct an index of potential productivity of land for a particular crop (PPI) as a sub-model (Fig-2).

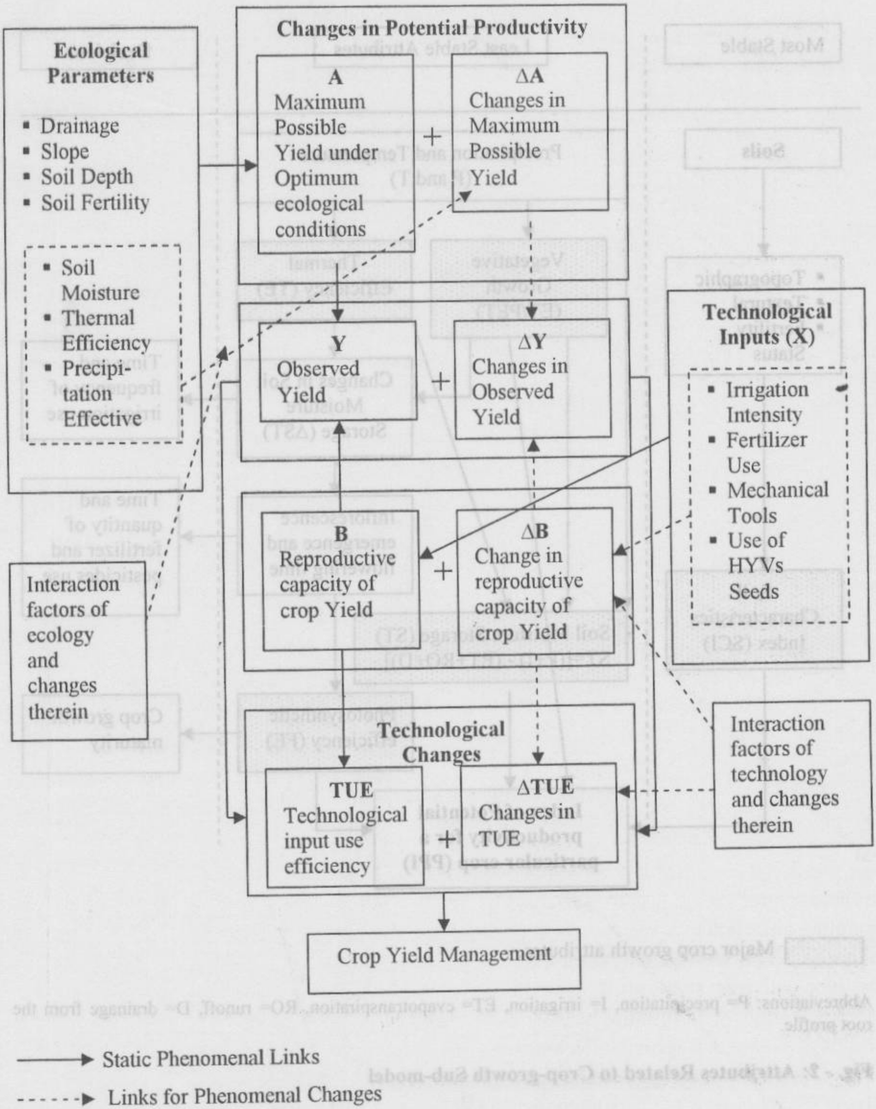
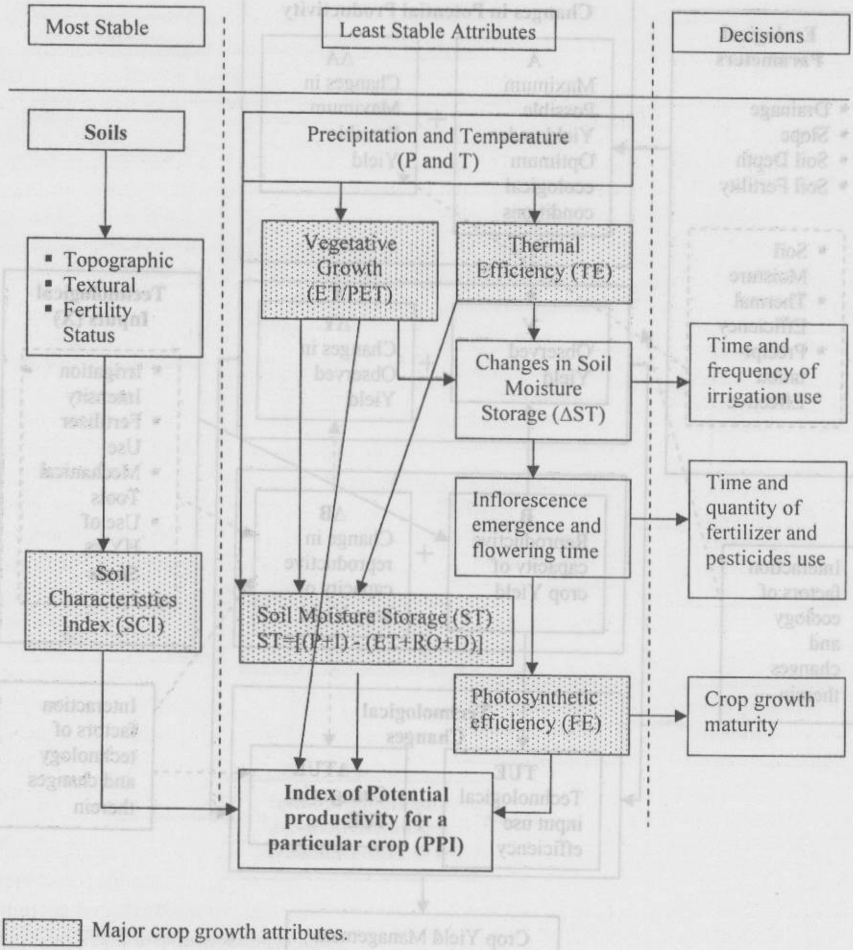


Fig. - 1: Crop-Ecologic Dynamics and Yield Changes



Abbreviations: P= precipitation, I= irrigation, ET= evapotranspiration, RO= runoff, D= drainage from the root profile.

Fig. - 2: Attributes Related to Crop-growth Sub-model

CSSM acts as 'effect isolator' to show separately the effects of ecological dynamics in terms of variation in potential productivity of land for specific crop, PPI, and reproductive capacity of crop yield, B, and, consequently, the technological input use efficiency (TUE) in its different crop-ecological scenarios (that are considered here in the form of OTUs). Model formulation may well-taken from main input data-file developed in a specific format to visualize spatio-temporal features of model's parameters and simulated yield. Main input file is used as effective and well-formatted input into the model design for long-term yield predictions and is largely dependent upon three data-feeding files which are used for the purpose of conversion of raw data into the model's input format. Finally, the formatted input data are arranged in the form of main input file which includes synthesized data of parameters pertaining to sub-models.

The CSSM includes many sub-models and equations at different levels for formatting input data, processing formatted data and creating output files in a required format, that are easy-to-use in the tool in a simple manner. CSSM presents the user a flexible way to predict the crop-yield in respect of efficient use of technological inputs. CSSM is simple in its formation and handling. Easily applicable for all type of agricultural economies, and for most crops with lesser requirements in the changes in parameters of input file and easily available required statistics of crop yield, technological inputs and weather records for longer period of time and much more flexible to use for specific crop simulation, are major characteristic features of the CSSM. Some data-conversion computer programs were also prepared to create formatted input files for its final use in the model.

The CSSM is a 'spatio-temporal based model' integrating yield parameters for different OTUs, so as to exercise it for a variety of areal domains varying from micro-areal level as ecological site, district level unit for different crop-ecological scenarios to macro-regional level such as state or even the larger part of a country for a particular crop for different period of time (Fig.-3). The larger domain of study area would have more number of OTUs and bigger set of data input files but may show better spatio-temporal results. Model's calibration is based on temporal data of annual grain yield of a particular crop and changing trends of crop-ecological attributes. The procedures of calibration the parameters and validation of the model are easy and simple to use (see detail in concerned section). The model works on the basis of annual variability in its parameters. Therefore, long-range of temporal data may provide better estimation and proper prediction of grain yield for each OTU. However, formatted input data for a shorter period of time may also be used in the model to realize the changes in technological use efficiency (TUE). Since the tool is easy to handle to analyze simulated crop-yield, it requires input statistics as raw data that can be obtained from readily available governmental/ non-governmental records of secondary sources. Crop yield and technological input statistics can be collected from government offices while monthly mean temperate and precipitation data for generation of weather based attributes of PPI may be collected from Indian Meteorological Department

(IMD), Pune. The other statistical records relating to soil characteristic features which are used as stable variables for crop-growth index, may be collected from National Bureau of Soil Survey and Land Use Planning (NBSS & LUP), Nagpur.

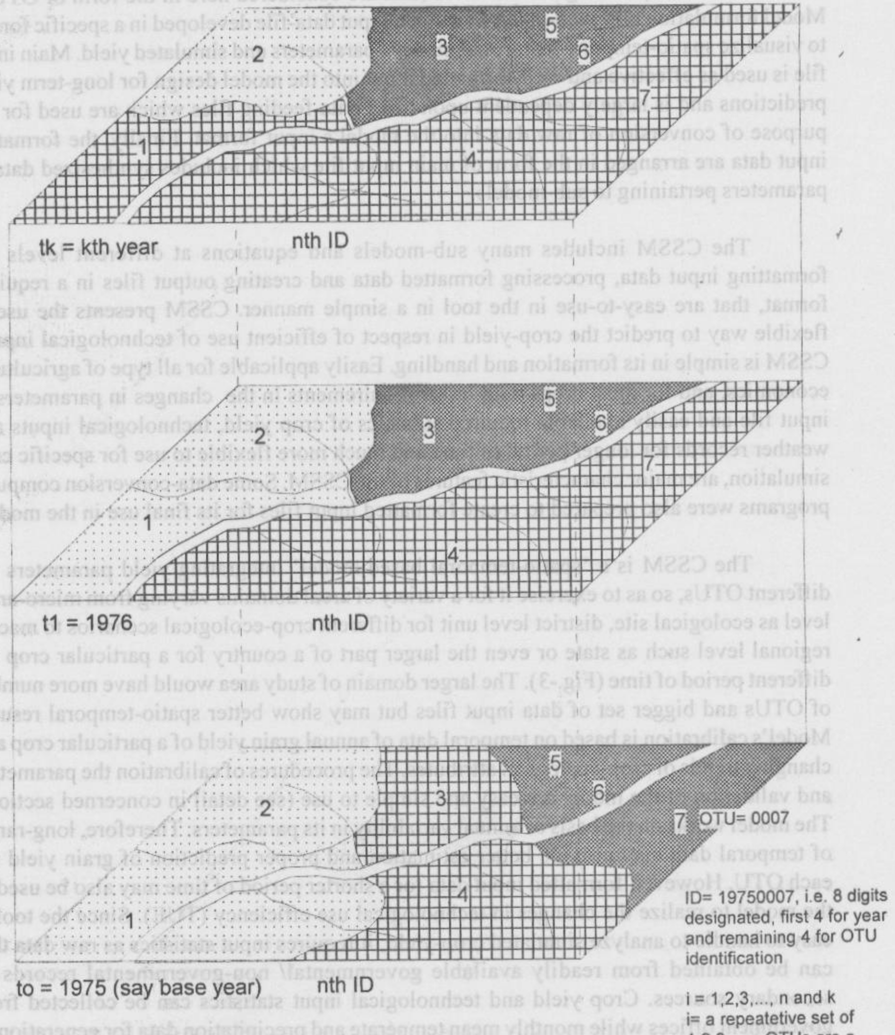


Fig. - 3: Spatio - Temporal Frame for Operation of CSSM.

A deterministic approach is adopted to calculate a frontier parameter of the model that is, A, which refers to the maximum possible grain yield of a crop and is largely dependent on the index of potential productivity of land (PPI). Since PPI varies spatially and temporally, the parameter B of the model that indicates reproductive capacity of crop-yield in the crop growth system and largely depends on A, also varies over space (for different OTUs) and time (temporal trends) in the model. In order to hold B as a constant and crop yield Y and technological input, X as variables in the model at a particular point of time, the spatial variations of reproductive capacity of crop-yield, B, and TUE that is reproductive capacity per unit of applied technological input, B/X, can be analyzed. Since A>Y at a particular time, the A/Y > 1.00 that is an indicator of TUE in the present frontier yield function because TUE= B/X= [(A-Y)/Y]. More details and well established form of the model will be described separately in the next sections. However, it is important to note here that considering A and B as constants and calculating them by using stochastic approach and applying least square principle of model parameterization, the error terms prevalent in crop-yield assessment and maximum possible yield level and their spatial pattern are tested and are shown through the use of this model. It is obvious that A is not constant; it varies spatially because of areal differentiations in potential productivity of land and also varies over time when weather conditions change (Singh, Sharma and Dey 2005). The 'processor' to process input data file to get the yield estimates is based on the following established yield function as:

$$Ye = A[1.00 + (B/X)]^{-1}, \quad \ldots \quad \ldots \quad \ldots \quad (1)$$

where Ye is estimated grain yield of a particular crop and A is maximum possible (or potential) grain yield in unit term of kg ha^{-1} as interactive function of a set of crop growth determinants forming an ecologically based land potential productivity index, PPI, with a constant, m as

$$A = m.\ PPI, \quad \ldots \quad \ldots \quad \ldots \quad (2)$$

where m is genetic crop-grain yield (kg ha^{-1}), a coefficient in the model based on cultivares and crop management which varies in different crop-ecological conditions (Mall and Singh 2000) while PPI is defined in the following manner:

$$PPI = SCI \times GI \times WUE \times FEI \times TEI \quad \ldots \quad \ldots \quad (3)$$

where SCI is soil characteristics index, GI is crop-growth index based of ET and PET, WUE refers to water use efficiency based on soil moisture storage, ST and field capacity, FC; FEI indicates photosynthetic efficiency index and TEI is thermal efficiency index. The detail elaboration of such determinants of PPI is given separately in the concerned section (see Section- III for detail).

The CSSM is used under some limitations. For instance, the model predicts effects of potential productivity on crop-yield in well- contained parametric form because of the use of many determinants in its crop-growth sub-model. However, the crop-management strategy is forwarded here to consider only one technological input rather than simultaneous technological effects of different production factors. The model does not work on economic attributes of production like the effects of input costs, transport network effects, production prices and so on. Since it is an integrated model, it may derive the effects of economic factors like crop production prices, input costs and price-elasticity on crop-yield estimation as it has been used somewhere else for analyzing the spatial structure of agricultural production function for developing economies (Singh 2002). Prediction of crop-yield and calculation of water (especially irrigation) use efficiency, fertilizer use efficiency and efficient use of pesticides and so on as we consider for decision making, are the main features of the model. It is initially used here as one factor model that can be extended further to isolate the effects of different inputs simultaneously. The multi factor form of the model is written as

$$Ye = A[1.00 + (B_1/X_1)+(B_2/X_2)+ \ldots +(B_n/X_n)]^{-1}, \quad \ldots \quad (4)$$

where B_1, B_2, ..., B_n are constants related to reproductive capacity of crop-yield corresponding to the technological production factors X_1, X_2, ..., X_n.

Internal parametric assemblages of the model is depend on the 'reciprocity law of diminishing marginal return' which controls efficiency criterion of inputs (Singh 2000) because its simplification toward linearised form follows as

$$Y^{-1} = A^{-1} + (B_1/A)(X_1)^{-1} + (B_2/A)(X_2)^{-1} + \ldots + (B_n/A)(X_n)^{-1} \quad (5)$$

It follows the principle of frontier yield function (i.e. defined as maximum possible grain yield level, A, the horizontal frontier of crop yield) in which technological efficiency of a particular production factor, X_n is linked with the reproductive capacity of crop-yield, Bn, as (B_n/X_n) (Singh, Sharma and Dey 2005) because oif its first order partial derivative as:

$$\delta Y/\delta X_n = (-)[AB_n(1+B_n/X_n)^{-2} \cdot X_n^{-2}]. \quad \ldots \quad \ldots \quad (6)$$

Thus, the basics of CSSM follow two sets of parameters based on two concerned sets of spatial data: first, the ecological information and weather statistics for assessing potential productivity in term of maximum possible crop yield and, secondly, the observed yield of a particular crop and technological input data to calibrate and validate the model for processing and creation of output files (Fig.-4)

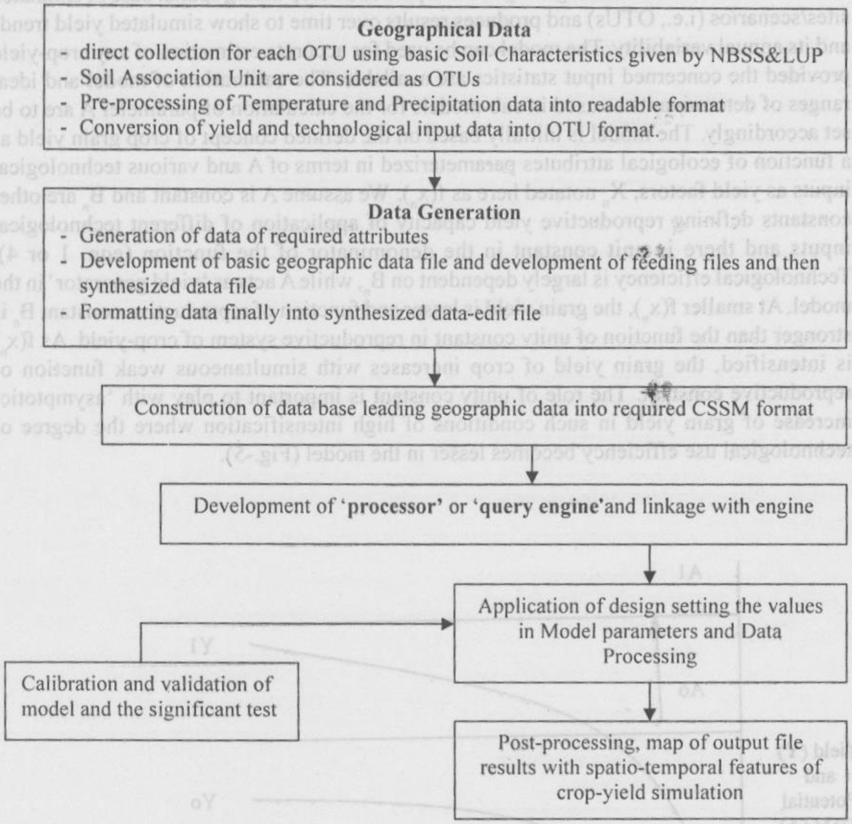


Fig. - 4: Procedure of Data Generation, Arrangement and Formatting in the Use for CSSM

The CSSM simulates grain yield of a particular crop taking spatial base of simulated sites/scenarios (i.e., OTUs) and produces results over time to show simulated yield trends and its annual variability. The model can be used for accurate estimation of any crop-yield provided the concerned input statistics are available. The calibration of model and ideal ranges of determinants as used in sub-models for the calculation of parameter A are to be set accordingly. The model is initially based on the defined concept of crop grain yield as a function of ecological attributes parameterized in terms of A and various technological inputs as yield factors, X_n notated here as $f(x_n)$. We assume A is constant and B_n are other constants defining reproductive yield capacity of application of different technological inputs and there is unit constant in the denominator of the function (eqn. 1 or 4). Technological efficiency is largely dependent on B_n, while A acts as 'yield generator' in the model. At smaller $f(x_n)$, the grain yield is lesser and function of reproductive constant B_n is stronger than the function of unity constant in reproductive system of crop-yield. As $f(x_n)$ is intensified, the grain yield of crop increases with simultaneous weak function of reproductive constant. The role of unity constant is important to play with 'asymptotic' increase of grain yield in such conditions of high intensification where the degree of technological use efficiency becomes lesser in the model (Fig.-5).

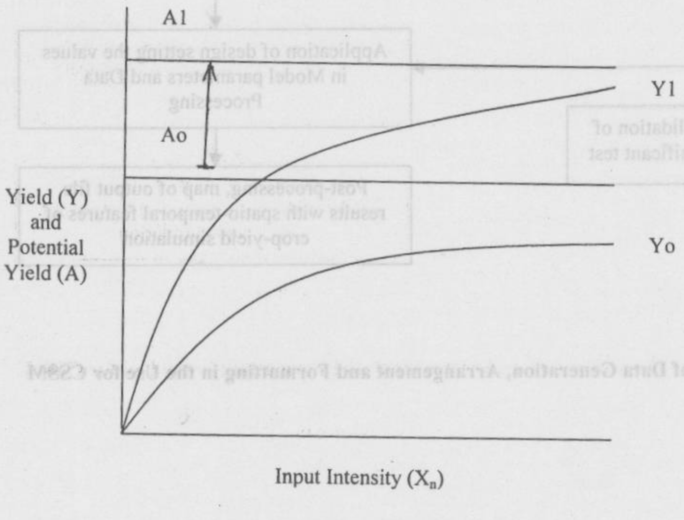


Fig. –5: Asymptotic Increase in Crop Yield

In real world situation, the parameter A is considered as variable and is assessed by using potential productivity of land, PPI for a particular crop for different scenarios or OTUs and their changing PPI over time. Since data of A, Y and X_n are now available for model's operation, its B_n values have been calculated by following the deterministic approach for simplification of yield pattern. In fact, stochastic approach was used to demonstrate validity of model while the output files were created to use the calculated values of parameter A and to consider it as variable with using temporal data of weather conditions. Simulated yield patterns were also compared to understand the nature of error term in the distribution of crop-yield. Otherwise the output of the model is mainly based on deterministic procedure of model application. As a result, its output of yield estimates are more accurate and usable for decision support system.

Testing procedures of CSSM was done in the present case to consider summer paddy yield simulation subject to fertilizer use efficiency (FUE) of the effect of prevailing in Brahmaputra valley, India, for which Government of Assam realized a need for a method of estimating and predicting summer paddy yield in the state of Assam where, in spite of favorable paddy ecological conditions, the paddy yield is not up to the mark (Singh, Sharma and Dey 2005). A number of 39 soil assimilation units which were simplified from the soil map of Assam prepared at R.F. 1/500,000 (scale 1"= 5 km) by NBSS and LUP (1999), were considered as OTUs for spatial as well as temporal variations of yield parameters like the potential productivity of land for paddy crop, PPI, the level of maximum possible paddy grain yield, A, the reproduction capacity of summer paddy yield, B, and the Fertilizer use efficiency, FUE in the Brahmaputra valley. The temporal statistics of the weather variability concerned with mean monthly temperature and precipitation and the statistics relating to annual paddy crop yield and fertilizer use were used for 29 years (1975 to 2003) to test the validity of present proposed crop yield-analysis tool.

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Section – II
Establishing an Input Data File

A preliminary investigation of area under consideration that is the state or part of it, is needed through various documents and records. The following steps to such investigation and examination of basic facts are important.

Step-1: Since attributes related to soil characteristics provide an essential base of crop-ecological systems and crop-yield simulation, a detail soil map of the area of investigation is to be examined for the areal patterns of soil attributes. We recommend a soil map prepared by National Bureau of Soil Survey and Land Use Planning (NBSS&LUP), Nagpur at R.F 1/500,000 scale for different states of the country following USDA soil taxonomy (a system of soil classification).

Step-2: Using soil association units that are called here as operational taxonomic units (OTUs) as a base of spatial pattern of crop-yield estimation and the operation of yield prediction processes, the unit-wise given data of soil characteristics in the form of soil assimilation units by NBSS&LUP are used for basic spatial information on the soils.

Step-3: Number the OTUs with their location codes to format the information, which were generated from other sources. This numbering system is used in the model for identifying quickly the OTUs in program and proper arrangement of output data accordingly. Since the tool is spatio-temporal based, OUTs repeat their numbers in each point of time. The spatio-temporal frame of years and OTUs is assigned identification numbers (IDs) for the purpose.

Step-4: Identify the locations of meteorological stations located within and/or outside in the surroundings of the area under investigation to prepare detail isohyetal and isothermic maps in general and polygon maps of station centroids for the generation of daily/weekly/monthly weather statistics as required for each ID.

Once the preliminary examination is over, the input data file can be prepared and formatted. After collecting, converting, generating or developing concerned statistics through various concerned records, personal visits/inspections and through the use of information as given in this monograph, an input data file is established (Table-1).

Table- 1: Forming an Input Data File

Row	General Information
1	**Identification of area under investigation:** *the state or part of it (description of areal extent)* ▪ Name …………………………………………… ▪ Latitudes ………………… and, longitudes …………………… ▪ Total area (sq.km)……………………………..
2	Number of OTUs ………, Average size …………..... sq.km.
3	**Climatic conditions in general:** *Temperature* - January ……… °C, July……….°C *Precipitation* - January ……… mm, July ……..mm. Mean annual temperature ………...mm. Average annual precipitation………..mm. Soil Types in general…………………………………………
4	(a) Average observed crop-yield …………..kg/ha (b) Use of fertilizer …………………..kg/ha (c) Percentage of area under irrigation ………… % (d) Area under use of HYVs: Total …………..,Percent………
5	Crop-yield and input used in the area ………………………………
6	Number of Years information used: total years (from ….. to ……..)
7	End of file

Column	Parameter's description
1	Spatio-temporal ID for each OTU for given years
2	OTU Area (in ha)
3	Duration of crop season (in number of days)
4	Surface form (weight number).
5	Parent material (weight number).
6	Soil depth class (weight number).
7	Soil temperature regime (weight number).
8	Soil reaction, pH value classes (weight number).
9	Ground water depth (weight number).
10	Surface stoniness (weight number).
11	Slope class (weight number).
12	Soil erosion (weight number).
13	Flooding Class (weight number).
14	Soil texture (weight number as per particle size class)
15	Soil Fertility Status (weight number).
16	Water holding capacity of soil (weight number).
17-28	Potential Evapotranspiration of each month from January to December (in mm) (see description and process of calculation)
29-40	Evapotranspiration of each month from January to December (in mm) (see description and process of calculation)
41-52	Soil moisture storage in each month from January to December (in mm) (see description)
53 - 64	Thermal efficiency in each month from January to December (in terms of heat index)
65	Irrigation intensity (in mm; un-irrigated -0, irrigated once-10mm, twice-20mm, …, n)
66	Machine tool intensity (Rs per hectare of Net Sown Area)
67	Use of chemical fertilizers (kg per hectare of Net Sown Area)
68	High yield varieties seeds (% area of total cultivated area)
69	Use of pesticides (kg per hectare of Net Sown Area)
70	Crop yield (kg/ha), (see description for formatted yield calculation)
Format	(I8, F8.2, I4, 13F5.2, 36I4, 12F5.2, I2, 5I5)

Arrangement of raw data and creation of input data file have a three-stage procedure to establish formatted main input data file. First, preparation of basic attribute data file, secondly the establishment of spatial conversion files which will convert raw data into its spatial arrangement as per model's requirement. Lastly, creation of data feeding files which will feed data to the main input file in its spatio-temporal basis (see Fig-7 in the proceeding part of this section). Input data of monthly weather conditions (temperature and precipitation) of various IMD stations for each year of the period of time under consideration for investigation were arranged separately for its spatial conversion by using interpolation (distance gradient) method of spatially distributed phenomena while district-wise statistics of technological inputs and crop yield were also put up for spatial conversion in the format of OTUs by using 'areal weightage' method. (see details in the next Section of the Monograph).

Description of Parameters Given in Input File

(a) Description of Row Parameters:

A brief statement describing the extent of area which is going to be investigated, is to be given as name, latitudes and longitudes, areal extent, location and its surroundings. Areal variations in general, soil and climatic conditions, average crop-yield and the use of technological production factors and the years which represent temporal dimensions of spatial data are to be given. Number of OTUs and its average size should also be included in this general description to understand basis of spatial variations of crop-yield phenomena.

(b) Parameters Associated with OTUs:

There are four main parts of input data file, which are associated with the data drawn from various data feeding files. Part-A of the main input file shows identification and general information (col 1-3), Part-B includes soil characteristic (col 4-16), Part-C accounts for monthly crop attributes pertaining to weather conditions (col 17-64) and Part-D of the file includes variables related to input and crop-yield (col 65-70), though these partitions are not shown in input data file.

Part- A: Identification and General Information (col 1-3)

1. Each OTU of the area under investigation is identified in the ID in first column by a number like 19950001, 19950002, 19950003, ..., 19959999; eight-digits designation to the identification of OTU wise-data for the each year. Out of eight-digits designation, first four digits are assigned to the concerned years and last four digits for OTUs identification which repeat for each year up to k^{th} years, while the n^{th} OTUs are assigned not more than 9999 because it may cover a much larger spatial dimension (see spatio-temporal frame, Fig-3). Any OTU may be assigned by any number. However, numbering to OTUs is to be assigned starting from any corner of the area. Based on soil characteristics, the NBSS&LUP, Nagpur has assigned the soil association numbers. If soil assimilation units given by

NBSS&LUP are considered as such, the same ID numbers are to be assigned. Otherwise any modified scheme of number assignment to OTUs may be adopted.

2. Once OTU base map of area under investigation is digitized with latitudes and longitudes, the areal extent of each OTU is calculated in hectares and is placed in second column of the input data file in four- digits designation for analysis of output produced by the model.

3. This column includes the duration of crop season in number of days in three-digits designation. If area under study is small, the crop-season duration may be considered same for all OTUs. It will vary in OUT numbers as area under investigation becomes larger.

Part-B: Soil Attributes (col 4-16):

4-6 Weight to the soil surface form (col-4), Parent material weight (col-5) and soil depth class weight (col-6) of three-digits designation each assigned as per the requirement of soil productivity to crop growth (Table-2)

7-13 Soil temperature (col-7), soil reaction (pH) (col-8), ground water depth (col-9), surface stoniness (col-10), soil surface slope (col-11), degree of erosion (col-12), soil floating (col-13) are noticeable attributes which determine the nature and extent of soil fertility for plant growth and influence directly or indirectly the crop-yield potentials. A three-digits designation for each column are given as assigned in the main input data file. A scheme of classification of such attributes given by NBSS&LUP, Nagpur for Indian soils are used to weight them (Table- 3).

14. Soil texture: A detail soil texture classification given by USDA Washington in the form of texture triangle which is followed by NBSS&LUP, Nagpur for classifying soils type by their particle size classes, was followed to assign the soil texture weight (Fig-6). Different textural classes have different amount of available water, infiltration rate and water holding capacity which guides to understand soil water retention capacity, plant nutrients infiltration and drainge conditions of soils and crop suitability and potential productivity of soils (Table-4).

15. Soil fertility status: The status of soil fertility based on macronutrients (N, P, K) in a particular OTU was analysed and accordingly the fertility weights were assigned. It is calculated by using 'weight - age mean' formula. The number to be input to the file and soil fertility status are tabled as:

For example, suppose an OTU falls under a category of low status of O/C, medium P_2O_5 and K_2O, the weighted mean of soil fertility status of that parameter OTU becomes 0.933 as [{(0.8+1.0+1.0)/3}= 0.933] (see Table-5). This value will be in three-digits designation in col-15 of the input data file.

16. Average water holding capacity of soil: A three- digits designation of mm of water per meter of soil depth of the upper horizon was calculated as per the given soil texture. Water holding capacity varies with soil texture as given in the following table. The value in weight as given in the last column of the table is the input to the data file.

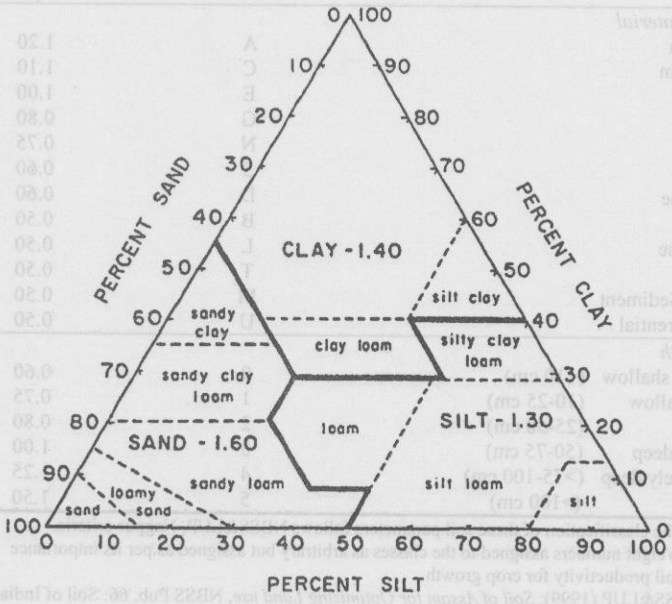

Fig.- 6: Soil Texture Triangle given by USDA, Washington

N.B. Soil bulk density (g/cm_3) for each of the major soil texture

Table- 2: Assignment of Weights for Topographic Attributes of Soil Productivity

Description		NBSS Code	Weight Number
A. Surface Form			
Dissected		D	0.90
Hummocky		H	1.10
Level		L	1.25
Gently Sloping		G	1.00
Undulating		U	0.80
Rolling		O	0.60
Steeping		S	0.50
Ridges		R	0.50
Valleys		V	0.50
Terraces		T	0.50
Plateau		P	0.40
Island		I	0.40
Marches		M	0.40
B. Parent Material			
Alluvium		A	1.20
Colluvium		C	1.10
Aeolian		E	1.00
Granite		G	0.80
Gneiss		N	0.75
Schist		S	0.60
Sandstone		D	0.60
Basalt		B	0.50
Limestone		L	0.50
Glacial		T	0.50
Marine Sediment		M	0.50
Un-differential		U	0.50
C. Soil Depth			
Extreme shallow	(<10 cm)	0	0.60
Very Shallow	(10-25 cm)	1	0.75
Shallow	(25-50 cm)	2	0.80
Slightly deep	(50-75 cm)	3	1.00
Moderately deep	(>75-100 cm)	4	1.25
Deep	(>100 cm)	5	1.50

N.B. 1. The classification of these soil parameters follows NBSS&LUP, Nagpur criteria.
2. Weight numbers assigned to the classes as arbitrary but assigned as per its importance in soil productivity for crop growth.

Source: NBSS&LUP (1999): *Soil of Assam for Optimizing Land use*, NBSS Pub. 66: Soil of India series, Nagpur.

Table- 3: Different Classes of Physical Attributes of Soil with their Weights

Names	Classes	Weight
A. Soil Temperature Regime(Temp °C)		
1. Frigid	< 8	0.50
2. Mesic	8-15	0.75
3. Thermic	15-22	1.00
4. Hyperthermic	22-28	1.15
B. Soil Reaction (pH)		
1. Strongly acidic	< 4.5	0.60
2. Moderately acidic	4.5 - 5.5	0.80
3. Slightly acidic	5.5-6.5	0.95
4. Neutral	6.5-7.5	1.15
5. Slightly Alkaline	7.5-8.5	0.85
6. Moderately Alkaline	8.5-9.5	0.80
7. Strongly Alkaline	> 9.5	0.50
C. Ground water depth (in m)		
1. Shallow	< 1.0	0.60
2. Moderately Shallow	1.0-2.0	1.00
3. Moderately Deep	2.0-5.0	1.20
4. Deep	> 5.0	0.80
D. Surface Stoniness (in percentage of area covered of total area)		
1. Slight	< 15	1.1
2. Moderate	15-40	1.0
3. Strong	> 40	0.7
E. Surface Slope (in percent)		
a Level	0 – 1.0	1.20
b Very gently sloping	1.0 – 3.0	1.10
c Gently sloping	3.0 – 8.0	1.00
d Moderately sloping	8.0 – 15.0	0.90
e Moderately sleep	15.0 – 30.0	0.80
f Steeply sloping	30.0 – 50.0	0.70
g Very steeply sloping	> 50.0	0.60
F. Degree of soil Erosion		
1. Slight	-	1.20
2. Moderate	-	1.00
3. Severe	-	0.80
4. Very severe	-	0.60
G. Degree of Flooding		
1. Slight	-	1.00
2. Moderate	-	0.90
3. Severe	-	0.80
4. Very severe	-	0.60

N.B: Name and values of classes are followed as given by NBSS&LUP (1999) and the weight of each class is assigned as per their importance and contribution to soil suitability and soil potential for crop-growth.

Table- 4: Available Water and Infiltration Rate for Different Textural Classes

Particle Size	cm of water per m of soil		Infiltration rate	Soil Productivity Weight
	Ranges	Average	(cm/ha)	
Sand (G)	3.25- 6.25	4.75	< 15.5	1.00
Loamy Sand (S)	6.25-10.50	8.50	10.0 - 12. 5	1.10
Sandy Loam (L)	10.50-14.50	12.50	5.0 - 10.0	1.10
Loamy, silt loam, silt (M)	12.50-19.00	15.80	1.0 - 5.0	1.20
Sandy Clay loam (L)	14.50-17.00	15.80	0.5 - 3.5	1.10
Clay loam, silty Clay loam (M)	17.00-21.00	19.00	0.5 – 1.0	1.00
Silty clay (T), Clay (60%) (Y)	17.00-21.00	19.00	0.1 – 0.5	0.90
Clay (60%) (C,F)	13.00-17.00	15.00	0.1 – 0.1	0.80

N.B.: 1. Soil productivity weights are assigned as per crop growth suitability in the soils. Soil weight may be altered as per the soil suitability for a particular crop. For example, summer paddy is better grown in silty clay and clay soils, higher weight may be assigned to these soils for summer paddy crop.

2. Symbols in parentheses in first column indicate NBSS&LUP classification of soils based on its particle sizes.

Source: Sys, C. : *Land Evaluation*, University of Ghent, Ghent (Belgium), c.f. NBSS&LUP (1994): *Land Resource Atlas- Nagpur District*, NBSS Publication- 22, Plate No. 12.

Table- 5: Soil Fertility Status

Fertility Status	Available Macro nutrients status			Weight
	O/C (%)	P_2O_5 (kg/ha)	K_2O (kg/ha)	
Low	< 1.50	< 20	< 118	0.80
Medium	1.50 – 2.25	20 – 50	118 – 280	1.00
High	> 2.25	> 50	> 280	1.20

Table- 6: Water Holding Capacity of Soils varying with their Texture

Soil Texture	Water holding capacity in soils (mm of water/m)		Soil Productivity
	Range	Average	Weight
Course Sand	20 – 60	40	0.60
Sand	40 – 90	65	0.80
Loamy Sand	60 – 120	90	0.90
Sandy Loam	110 – 150	130	1.00
Fine Sandy Loam	140 – 180	160	1.10
Loam and Silty Loam	170 – 230	200	1.30
Clay Loam and Silty Clay Loam	140 – 210	175	1.20
Silty Clay and Clay	130 - 180	155	1.00

Source: Isrealson and Hangon 1962, c.f. NBSS &LUP (1994).

Part -C: Attributes for Crop - growth (col 17 - 64):

17–28 The values of monthly potential evapotranspiration, PET, in mm in three-digits designation are placed in the set of 12 columns. The PET data is transferred from concerned feeding files created under the files- II A and II B.

29-40 The values of monthly actual evapotranspiration, ET, in mm in three-digits designation style are placed in the next 12 column.

41-52 The values of monthly soil moisture storage, ST, in mm in three-digits designation are placed in the next 12 column of this part. The monthly data of such three sets of attributes (that are varies in its present position) are transferred from the concerned feeding file-II where it is generated from conversion files-II A and II B through developing an algorithm (as given in the next part of the Monograph).

53-64 The values of monthly thermal efficiency, TE, in terms of heat index as it is a direct function of temperature, are given in four- digits designation. Thermal efficiency values are imported from data feeding file – II placed in this set of 12 columns in Table- 11.

Part - D: Input Factors and Crop Yield Data (Col 65–70):

65 Irrigation intensity in mm in two-digits designation as per the frequency of irrigation for a particular crop is calculated and formatted in input file (Table- 7).

Table- 7: Intensity of Irrigation

Sl.No	*Frequency of Irrigation*	*Irrigation intensity (in mm)*
1	Un-irrigated crop land	0
2	Irrigated once	10
3	Irrigated twice	20
4	Irrigated thrice	30
5	Irrigated -fourth times and more	40

66-70 The input data pertaining to technological factors of yield and the observed crop-yield data are arranged in the subsequent column of input data file as the intensity of machine tool (Rs/ha) in four-digits, use of chemical fertilizers (kg/ha) in four-digits, use of pesticide (kg/ha) in three-digits and crop-yield (kg/ha) in four-digits arranged in the last part of the file. The data of such attributes for each OTU were transferred from the data-feed file-III.

Preparation of Data Feeding Files to Format Main Input Data

There are three data feeding files which generate and format the input data for establishing finally the formatted main input file for further operation (Fig.-7).

(i) Preparing Basic Data Feeding File-I: Transformation of soil attributes data (17 col)

Calculation and arrangement of parameters pertaining to soil characteristics: Data of 14 parameters of soil attributes as given by NBSS&LUP, Nagpur at soil assimilation taxonomic unit have already been published for most of the states of India. The data feeding file of these 14 attributes must provide a set of 13 soil attributes (4-16 col) and their weight for the soil index which are arranged in 13 columns from col-4 to col-17 in the main input data file as initially prepared. Water holding capacity given in mm placed in the last column of the data feeding file-I, must be used in calculation of soil moisture availability for different soils. Since soil characteristics are considered more stable attributes over time, this data feeding file can be used for longer period of time to operate the models constants and coefficients relating to soil characteristics. Description of these parameters has already given in earlier parts with main input data file. The first three columns in this data feeding file show the general information with spatio-temporal ID Codes (Table- 8).

1. **Data Feeding File – I: Soil characteristics (16 col file)**
2. **Data Feeding File – II:**

II A: Conversion of Spatial Dimensions

Conversion File-II A: Point raw data into OTU data
Conversion of Monthly Temperature, T, and Precipitation, P, data of given meteorological stations to OTUs
Spatial converters are based on polygons and distance-gradient method.

II B: Spatial Parametric Conversion

Conversion File- II B: Raw statistics into required crop-growth factor data
Conversion of spatially formatted data of monthly T and P of given OTUs to monthly PET, ET and ST variables of crop-growth through Thornthwaite & Mather (1957) conversion tables

III: Transfer of Input and Yield Data (7 col file)

Conversion File-III: Input and Yield data conversion
Spatial conversion of input factors and Crop-yield data given at district level to OUT level
Spatial converter based on areal weight method is used

Fig. - 7: Creation of Data Feeding Files

Table- 8: Data Feeding File-I: Formatting the Soil Characteristics Weight

Spatio-temporal ID Codes	OTU Area (sq.km)	Duration of Crop Season (in no of days)	Soil Surface Form	Parent Material	Soil Depth Class	Soil Temperature Regime	Soil Reaction pH Value Weight	Ground Water Depth	Surface Stoniness	Surface Slope	Soil Erosion	Flooding	Soil Texture and Particle Size	Soil Fertility Status	Water Holding Capacity (weight)	Water Holding Capacity (in mm)
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
xxxxxxxx	xxx.xx	xxx	x.xx	x.xx	x.xx	x.xx	x.xx	x.xx	x.xx	x.xx	x.xx	x.xx	x.xx	x.xx	x.xx	xxx
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(ii) Preparing Data Feeding File - II

Establishment of data feeding file of crop growth factors as given in equation (3) is a complex process of data generation in its required spatio-temporal format because of different spatial format of given raw data and a different sets of the data of growth factors which are to be abstracted from given raw statistics of temperature, T, and precipitation, P. It involves two stages of raw data conversion: (A) the spatial conversion of monthly T and P data into required spatial format of nth OTUs and (B) the conversion of the given data of weather elements, monthly T and P, into crop-growth factors, namely PET, ET, ST and TE that are used finally to prepare crop- growth indexes for the assessment of potential productivity of land for CSSM.

(iii) Data Conversion File –II A: Conversion of Monthly T and P in its Spatial Dimension :

Many geo-computation methods and geographical analysis machines were developed to handle larger amount of geographical referenced data for solving spatial patterning problems (Openshaw, et.al 1987, Goodchild 1997, Openshaw 1998). The tools like dynamically linked spatial association visualizer were built for spatial data analysis, which were based on Thiessen (dirichlet) polygons and spatial gradient functions (Anselin 1995 and 1998, Burrough and McDonnel 1998, Alvanides, Opensaw and MacGill 2001). A simple tool, namely, spatial data converter, which is able to convert given geographical information of a few points (i.e., centroids of fixed polygons) into required many more points (i.e. dependents) located within the given polygons by creating spatial searching an attribute is used here. Spatial data converter works by following an algorithm. The whole operation of the tool is initially operated through the data of point locations in term their coordinates and values of attributes as weights. The centroid points (i, X_i, Y_i), the distances between centroid and dependents (i, j, d_{ij}) within the polygons boundaries (X_{i1}, Y_{i1}; X_{i2}, Y_{i2}; …; X_{ik}, Y_{ik}) are fixed elements of spatial structure which works to convert the information relating to spatial attributes (Anselin 1998). Spatial data converter, SDC, algouthm involves the following.

Step-1: Read in X,Y data of all ith centroid and jth dependent points for an attribute like monthly T (or monthly P) as weights only for centroids ith points, while dependent jth points are empty.

Step-2: Identify the central points among all possible nearest neighbor centroids from centroid, C1, to form the boundary of a centroid based polygon.

Step-3: Repeat Step-2 until all centroids posses their polygons. It is fixed structure to convert the spatial weights.

Step-4: Calculate distance-gradients of given attribute as spatial weight for each direction from the centroid considering j^{th} is central point between two centroids that is boundary point at which mean weight, Wm, equals $\{W_1 + W_2)/2\}$ and is fixed.

Step-5: Apply the same procedure to calculate spatial gradient weight of particle attribute like monthly T or P on one direction as $Wij = [W_1 + \{(W_1+W_2)/ 2\}] /dij$.

Step-6: Repeat step 4 to 5 until all dependent points get the data of attribute else go to step 7.

Step-7: Repeat the process Step -6 until the information of all given attributes are converted into spatially distributed dependent point structure.

Step-8: Create output file in order of a spatial sequence as given OTU identification number and point the result of monthly T and P in Data conversion file II A, as demonstrated (Table- 9, Apendix - I).

Step-9: Stop.

The output of spatially converted data of monthly T and P attributes as given in rows of column 8 and 9 in Table- 9 is finally arranged column wise format in Table- 10 to go for further operation

(iv) Data -Conversion File-II B: Spatial Parametric Conversion

Procedure of calculation of crop-growth Factors- PET, ET, ST and TE through given spatially converted monthly T and P data:

We tried to apply direct mathematical functions for calculation of monthly PET, ET and ST data for calculation of crop-growth factors data. Among many ET-computation methods like FAO 56PM formulation, Penman method, Blanecy-Criddle equation and other methods, the Blanecy and Criddle (1950) is judged ideal to establish T and ET relationship (Singandhupe and Sethi 2004). The experiences show that Blanecy-criddle equation may produce ideal results for site-specific cases rather than area/region-specific studies, though it is easy to use. A widely accepted procedure which is based on standard water balance equation (i.e., P= ET+∆ST+RO, where ∆ST = monthly change in soil moisture storage and RO= run-off) developed by Thornthwaite and Mather (1957) through the establishment of required conversion tables including the tables of moisture retained in the soils after given amount of accumulated potential water loss depending upon water holding (field) capacity of soils, was used by developing an algorithm and computer programme. The computation of monthly temperature efficiency, TE, was made to consider the heat index that is the direct function of temperature (Thornthwaite and Mather 1957). The input to run the algorithm is taken from well-formatted monthly T and P data as given in Table- 10. An algorithm on water - balance table involves the following steps:

Step-1: Read in monthly T (°C) and monthly P (in mm) data of two sets of 12 columns each (1 to 12 for T and 13 to 24 for P) for i^{th} observations up to total kn as per given ID codes in Table- 10.

Step-2: Convert monthly T_{ij} (°C) into monthly heat index (H_{ij}) using Thornthwaite's 'base-variable and power-constant' equation as $H_{ij} = (T_{ij}/5)^{1.514}$

Step-3: Add H_{ij} for the whole year to calculate Heat Index; $HI = \sum_{1}^{12} H_{ij}$.

Step-4: Find unadjusted PET (Unadj PET) corresponding to T and HI from a given Table (Thornthwaite and Mather 1957, Table-4).

Step-5: Multiply unadj PET to location specific correction factor table value to convert it into PET (Thornthwaite and Mather 1957, Table-6).

Step-6: Find P-PET to count months of water deficiency.

Step-7: Find Accumulated water loss, AccWL, accumulating deficient amount of water in each month.

Step-8: Find monthly ST from corresponding value of AccWL in given soil moisture retention table prepared for different values of water holding capacity of soils (Thornthwaite and Mather 1957, Table- 23 through 33). Water holding capacity is identified from data-feeding file -I (col-17 in Table- 8 in the present text).

Step-9: Establish monthly change in ST, ΔST, computing its monthly soil moisture deficiencies.

Step-10: Subtract ΔST from P to find ET only for the soil moisture deficient months as well as soil recharge months; otherwise consider ET = PET.

Step- 11: Calculate monthly value of GI, WUE, FEI and TEI as per terms defined in equation (3) preceding Section (for detail, see also the equations- 8 through 15 in the next Section).

Step-12: Create output file to arrange monthly values of these attributes/ parameters and print the result in data feeding file –II (Table-11, Appendix - II).

Step-13: Stop.

Preparing Data Feeding File -III

Calculation of data pertaining to technological inputs and observed crop-yield:

It is a kind of conversion of district level given data of technological inputs as well as of crop yield to OTU format to place the required data into a given spatio-temporal format of input data file from its col- 65 to 70 in Table-1. Since the areal boundary of OTU does not match with district boundary, the areal proportions of their cross-boundary units are calculated to remove the spatial compatibility problem. Such cross-boundary areal units are attributed to the weight of a particular attribute that is to be converted spatially. 'Weighted Mean' formula is used for the same. For example suppose some portions of the area of three districts fall partly with in a particular OTU, the proportionate share of the area of each cross boundary units falling within the total area of OTU is considered as 'areal relative weight' of each cross-boundary unit, W_j, for a particular attribute to be converted. Say for instance, the crop-yields of the different districts falling under a particular OTU, Y_j, the weighted mean yield of that particular OTU, Y_w becomes as $Y_w = (W_1Y_1 + W_2Y_2 + W_3Y_3 + W_iY_i + W_{n'}Y_m) = \Sigma^{n'}_{i=1} W_iY_i$ where summation of $W_1, W_2, W_3, \ldots, W_{n'}$ equals unity (Fig.- 8)

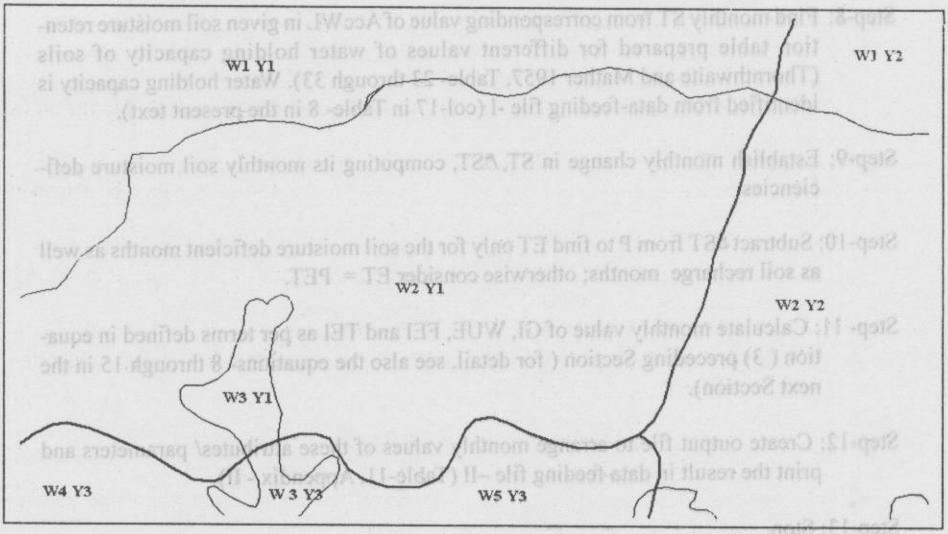

Fig.- 8: Map Showing Areal Proportions of Cross boundary areal units for Data Conversion

N.B.: W refers to OTU (shown by thin lines) and Y refers to district unit (shown by thick lines) at which the statistics of attributes (say crop yield and / or technological inputs) are to be spatially formatted.

It is obvious to say that the same procedure of assessment of crop yield is adopted by District Agriculture Office in the country to predict district level crop yield of various crops taking crop-cutting samples of crop during its harvest time from different soil belts of the district. Of course, conversion of given data of district-based crop-yield to OTU-based ones is an inverse procedure of the same method as adopted by District Agriculture Office. On account of larger amount of data to be converted from district-based to OTU-based spatial format, the spatial structure of the areal relative weights must remain constant for all cases when district-based data of the attributes (that are technological inputs or crop yield) are considered as variables and mean areal weights as constant for spatially formatted data. To develop a fixed spatial structure for conversion of data relating to a particular attribute, GIS and digitized boundary maps are advised to get the fast and accurate results of generating the areal data of cross-boundary units and their areal weights, W_j. Major steps to such conversion are given below:

Step-1: Read spatial data of area, A_i, and attribute values Y_i of each cross-boundary units falling within each OTU, that are $_{n'}$ in number; a set of $_{n'}$ rows are to be established in data conversion file-III for each spatio-temporal ID codes (Table- 12). Note that it is fixed set of $_{n'}$ cross-boundary units of each OTU which is subsequently used for the spatio- temporal conversion of data for different attributes.

Step-2: Calculate proportional shares of corresponding areal values of cross-boundary areal units falling within each OTU, $W_{n'}$; the data are to be arranged in $_{n'1, n'2, n'3, \ldots, n'n}$ sets for $_{nth}$ OTU in column- 3. The data of the column is used as constant for attributes conversion.

Step-3: Corresponding attribute values of each cross-boundary units, $Y_{n'}$ are to be placed in col- 4 in Table -10. It is the variable to be converted.

Step-4: Multiply col- 3 and 4 to get weighted attribute value of ith units of $_{n'th}$ set as $W_{n'}.Y_{n'}$ and place the value in col- 5 in the Table.

Step-5: Add the rows up to $_{n'}$ for each OTU and place it in col- 6 which are finally converted values of a particular attribute.

Step-6: Repeat the process until all IDs up to kn is over.

Step-7: Transfer converted values of all input as well as crop-yield attributes in the data feeding file-III (Table- 13, Appendix - III).

Step-8: Stop.

Table- 9: Data Conversion File – II A: Spatial Dimensions of Conversion of Monthly T and P Data into given Spatial Format to Feed Data Calculation File II A

Spatio-temporal ID Codes	Months	Central Point Coordinates of each OTUs Location (X and Y)		Distances between point of Centroid and Dependants with in Polygon	Distance Gradient Weight for T	Distance Gradient Weight for P	Multiplier to get T value (Col 5 x 6) (Round off)	Multiplier to get P value (col 5 x 7) (Round off)
1	2	3	4	5	6	7	8	9
xxxxxxxx	xx	xxx.xx.xx	xxx.xx.xx	xxx.xx	xx.xx	xxxx.xx	xxx	xxxx
19750001	1							
	.							
	12							
19750002	1							
	.							
	12							
19750003	1							
	.							
	12							
1975 n	1							
	.							
	12							
k 0001	1							
	.							
	12							
k 0002	1							
	.							
	12							
k 0003	1							
.	.							
.	12							
i	1							
	.							
kn	12							

Table-10:Spatio-temporal Arrangement of Spatially Converted Monthly P and T Data

	Mean Temperature (T in °C)					Total Precipitation (P in mm)				
Spatio-temporal ID Codes	January	February	March	…	December	January	February	March	…	December
	1	2	3	…	12	13	14	15	…	24
xxxxxxxx	xx.xx	xx.xx	xx.xx	xx.xx	xx.xx	xxxx	xxxx	xxxx	xxxx	xxxx
19750001										
19750002										
19750003										
.										
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.										
1975 n										
19760001										
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Table- 11: Data Feeding File – II: Calculation of Crop Growth Factors through the Use of Parametric Conversion of Monthly T and P

Spatio-temporal ID Codes	January	February	March	April	May	June	July	August	September	October	November	December	Annual Totals	Seasonal Totals	Seasonal Percents
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
xxxxxxxx	xxxx	xxxx	xxxx	xxxx	xxxx	xxxx	xxxx	xxxx	xxxx	xxxx	xxxx	xxxx	xxxxx	xxxxx	xx.xx
19750001															
T°C															
Heat Index															
Unadjusted PET															
PET															
P															
P – PET															
ACC WL															
ST Values															
Change ST															
ET															
GI															
WUE															
TEI															
FEI															
19750002															
T°C															
Heat Index															
Unadjusted PET															
PET															
P															
P – PET															
ACC WL															
ST Values															
Change ST															
ET															
GI															
WUE															
TEI															
FEI															
.															
.															
kn															

Table- 12: Data Conversion File- III: Conversion of District – Based Data into OTU

Spatio-temporal ID Codes	Cross Boundary District Units (Unit)	District Unit Area ($A_{n'}$)	District Unit Weight ($W_{n'}$)	Unit Attribute Value ($Y_{n'}$)	Weight Attribute Value ($W_{n'} . Y_{n'}$)	Converted Data $Y_w = \sum(W_{n'} . Y_{n'})$
	1	2	3	4	5	6
xxxxxxxx	xxx	xxx.xx	.xxxx	xxxx	xxxx.xx	xxxx.xx
19750001	1					
	2					
	3					
	.					
	.					
	n'_1					
19750002	1					
	2					
	3					
	.					
	.					
	n'_2					
19750003	1					
	2					
	3					
	.					
	.					
	n'_3					
19750004	1					
	2					
	3					
	.					
	.					
	n'_4					
19750005	1					
	2					
	3					
	.					
	.					
	n'_5					
n	n					

Table- 13: Data Feeding File- III: Transfer of Converted Input and Yield Data into Formatted Data File

Spatio-temporal ID Codes	Attributes related to Input Factors					Crop Grain Yield (kg/ha)				
	Irrigation	Machine Tools	Use of Chemical Fertilizer	Use of HYVs Seeds	Use of Pesticides	Paddy	Wheat	Maize	Gram	others
	1	2	3	...	m	m+1	m+2	m+3	...	m+ C
xxxxxxxx	xxxx	xxxx	xxxx	xxxx	xxxx	xxxx	xxxx	xxxx	xxxx	xxxx
19750001										
19750002										
19750003										
.										
.										
.										
1975 n										
19760001										
19760002										
19760003										
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19770001										
19770002										
19770003										
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19790002										
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k 0002										
k 0003										
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Arrangement of Data Feeding Files

Converted data of different required attributes, which are now formatted into a common spatio-temporal based ID code format, are available in the feeding files created as above. Generally, the data feeding file-I includes the attributes relating to Part A and B of the main input file. Likewise data feeding files -II and III obviously concern the attributes relating to Part C and D respectively. A systematic arrangement of all data feeding files is done to finalize the main input data file as given in Table- 14 which follow similar format as given in Table- 1.

Using NBSS&LUP, IMD and State Government Statistics

There are three major sources of data to prepare the input data file and to run the computer program.

(1) Data attributes pertaining to topographic and textual characteristics of soils from data file can directly and easily be obtained from NBSS&LUP, Nagpur. Using NBSS&LUP data format at state level analysis the boundaries of each OTU are delineated to consider soil assimilation units of the given NBSS&LUP map. We can minimize the degree of search of referred data on soil characteristics by using the soil statistics of theNational Bureau. Secondly, NBSS&LUP soil classification is standard because it follows widely accepted soil taxonomy given by USDA, Washington. The weight assignment of each soil attribute is given by considering its role in potential productivity of land for agricultural development in general and crop-growth in particular.

(2) A data sheet of monthly mean temperature and precipitation for many meteorological stations location in the area under investigation for a longer period of time can be obtained from Indian Meteorological Department (IMD), Pune to use it as raw data. Through the use of spatial converter tool and conversion tables as described earlier, such data are formatted into required crop growth factors and then arranged in main input data file.

(3) Spatial and temporal statistics pertaining to technological input attributes like irrigation, fertilizer use, machine tools, use of pesticides, weedicides and High Yield Variety (HYV) seeds and even the observed crop-yield which were arranged in the last part of input data file from col- 21 to col- m+4 in the Table- 14, are easily available from the published and unpublished records of Ministry of Agriculture, Government of India New Delhi or Directorate of Agriculture, Directorate of Economics and Statistics of the concerned states. District-wise data are easy to handle for the period considered for temporal trends and crop-yield predictions. The results procured in the output file can again be converted at district level for easy use of models result in connection with

Table- 14: Arrangement of Data Feeding File into Main Input Data File

	Data Feeding File-I			Data Feeding File-II				Data Feeding File-III	
Spatio-temporal ID Codes	OTU Area	Duration of Crop Season	Soil Attributes	GI	WUE	FEI	TEI	Inputs	Crop Yeld
1	2	3	4...16	17	18	19	20	21...m	m+1...m+ (
xxxxxxxx	xxxx	xxxx	xxxx	x.xxx	x.xxx	x.xxx	x.xxx	xxxx	xxxx
19750001 19750002 19750003 . . 1975 n 19760001 19760002 19760003 . . 1976 n 19770001 19770002 19770003 . . 1977 n 19780001 19780002 19780003 . . 1978 n 19790001 19790002 19790003 . . 1979 n k 0001 k 0002 k 0003 . . kn									

acceleration of decision-making process by the state government agencies and district level government departments.

(4) The spatial data of remaining attributes placed in input data file like soil fertility status, water holding capacity, monthly soil moisture availability and so on are important and have direct impact on soil productivity, crop-growth and potential productivity of green biota. Since the data pertaining to available nitrogen (N) phosphorous (P_2O_5) and potassium (K_2O) for different soils prevailing in the area under investigation are procured in the institutions relating to agricultural studies like Agriculture University, Regional Centres of Indian Council of Agricultural Researches (ICAR) and its state branches and the Soil Divisions of Directorate of Agriculture at State level, such statistics may be obtained from these offices. However, a few important tables regarding the data on water holding capacity of different soils, soil fertility status, ideal crop-growth seasons of the agricultural crops, genetic yield of different crops, etc. are also presented here in compiled form to work as ready reckoner of missing data.

-- oOo --

Section – III

Synthesis of Input Data Files and Model's Calibration

There are two main steps to use the model: one is to take before the use of the input file as per the basic requirements of the model and another concerns calibration of model's parameters to get the model output error free. The description of such steps would be given in detail to understand the synthesis of formatted input data and the procedures of sub-models of the tool.

(A) Preparing and Formatting A Synthesized Input Data File:

Values of associated attributes/factors as given in data feeding files and later transferred to the main input data file (Table- 14) are maintained in the synthesized input data file for further use. The values of crop growth determinants associated with potential productivity of land is the next step of CSSM requirement. That is why synthesization of variables is suggested because of sorting out the variables which are directly linked to the model for further operation. Synthesis of crop growth attributes is more associated to and procedurally concerned with the following aspects of the analysis of sub models in the present tool.

(a) *Determinants Associated with Potential (Ecological Possible) Crop-Yield*: Synthesization of factors to establish determinants and indexes for potential crop-yield, A, is essentially based on the requirement of equations (2) and (3) where PPI is obtained through the use of five indexes determining potential productivity of land in relation to crop-growth parameters, namely, SCI, GI, WUE, FEI and TEI (see notations of equation- 3 for detail). Besides soil characteristics index called SCI, the PET, ET, ST and TE are common crop growth factors which ultimately and finally result PPI in the process of factors synthesis. As equation (3) indicates that the parameters related to plant growth index, water use efficiency and photosynthesis efficiency are emerged as major attributes from the above three factors while thermal efficiency is direct function of air temperature and temperature threshold in crop growth environment. Reviewing critically the classical and neo-classical literate on these aspects of crop-growth, it is implied that the classical concept of thermal efficiency and precipitation effectiveness (Thornthwaite 1931) which was used by Papadakis (1952) as a plant growth index by establishing relationship between plant growth and thermal factor was important. It was implicitly based in the use of basic weather factors and later on modified by Reqiuer et al. (1970) by accounting incoming insolation, mean temperature and humidity which were used in the form of PET, ET and ST as strong factors (as they were called parameters) of plant-growth (De Witt 1958, John and Smith 1975, McCall and Bishop and Hurlley 2003, Kang et al. 2003). The requirement of sub-model's equation (3) and their procedural details are forwarded in the following manner.

(1) Weight allotted to each soil-element as given in the first part of main input data file (j = 4 to 16th columns) were added to get their composite score ΣSC_j and divided by a value, ΣSC_j*, that is the representative of ideal composite score to get composite index of soil elements for a particular areal unit, SCI_i. The ideal composite score is calculated with the consideration of soil suitability for the optimal growth of a particular crop. Identification of ideal weight of each soil element is, though it is a cumbersome task, done with the help of a soil science manual. It may provide a strong base for the calculation of soil attribute weights as well as ideal composite score for a particular crop. A set of simplified tables of the weights of soil attributes is given in the earlier sections of the monograph. The mathematical form of composite index of soil element is written as

$$SCI_i = (\Sigma SC_j / (\Sigma SC_j*). \quad ... \quad ... \quad ... \quad (7)$$

The value of the ideal composite score, ΣSC_j*, may vary spatially because of variations in climatic conditions and use of modern agriculture technology. The farmers adopt and alter their crop-duration and crop-season as per applied irrigation technology which also influences nutrient status of soils and compels the farmers to change the ideal weight value of the soils. Thus, the given scheme of the weights for the elements of soil is enough flexible.

(2) It is generally viewed that crop-growth has direct proportion to the ratio of ET/PET (Johns and Smith 1975, McCall and Bishop-Hurley 2003, Kang et al. 2003). Calculation of ratio of ET/PET was made not only to construct the crop-growth index, GI, as required for sub-model (eqn- 3), but also to understand actions of temperature, soil moisture and evaporative demands for crop-growth. The remaining four indexes for the measurement of PPI are calculated with the use their ratio as:

(a) There is no vegetative growth at sowing time of a particular crop but growth factor ET/PET remains active throughout the year. In order to measure crop-growth index, GI, the relative growth factor is considered as unity at sowing time when there is no crop-growth. The relative growth is assessed dividing monthly figures of (ET/

PET) distribution of the crop-season by a constant, that is (ET/PET)*, a growth factor at sowing time of a practical crop. Thus, the crop-growth index is written as

$$GI = {}^{1}/m\ \Sigma\{(ET/PET)/(ET/PET)^{*}\}, \quad \ldots \quad \ldots \quad (8)$$

where m is number of months of total duration of crop season. The ET and PET values for each month of different years are compiled in data feeding file (see Table-11).

(b) The mechanism of water (soil moisture) use for crop-growth, W, that is indicative of soil moisture storage, ST, per unit of field capacity under a tension of about one-third atmosphere, FC, written as

$$W = (ST/FC). \quad \ldots \quad \ldots \quad \ldots \quad (9)$$

Computation of variables of such functions is largely dependent on many established soil-water relationships and initially with the basic equations related to hydraulic conductivity of different type of soils (Jons and Smith 1975). However, a well-documented and largely accepted conversion tables of soil retention capacity given by Thornthwaite and Mather (1957) are used.

Since crop-growth is a function of water use, (ET/PET) = f(w), its (water use) optimal level, w*, may be assessed by way of the field observations. Optimal requirements vary month-wise and crop-wise. For example, paddy needs minimum requirement of 180mm soil moisture with FC of 200mm/m in the month during vegetative growth (W = .9), while wheat needs W = .75 and millets (Jawar/Bajra) W = .50 even less to grow optimally. Water deficiency for crop can also be assessed by these ideal level of water requirements. The values of W are found at given minimum requirements of moisture in the root zone soil of one-meter for given crop of specific environment conditions to feed in the above equation. Now, water use efficiency index, WUE, must be written as

$$WUE = 1/m\ \Sigma(W/W^{*}), \quad \ldots \quad \ldots \quad (10)$$

where m accounts number of months during crop-season. For example, if w* is recorded higher during May to June in one of the OTUs, it means that there is deficiency of rain water during these months. Overally, WUE must be less than unity (Fig.- 9).

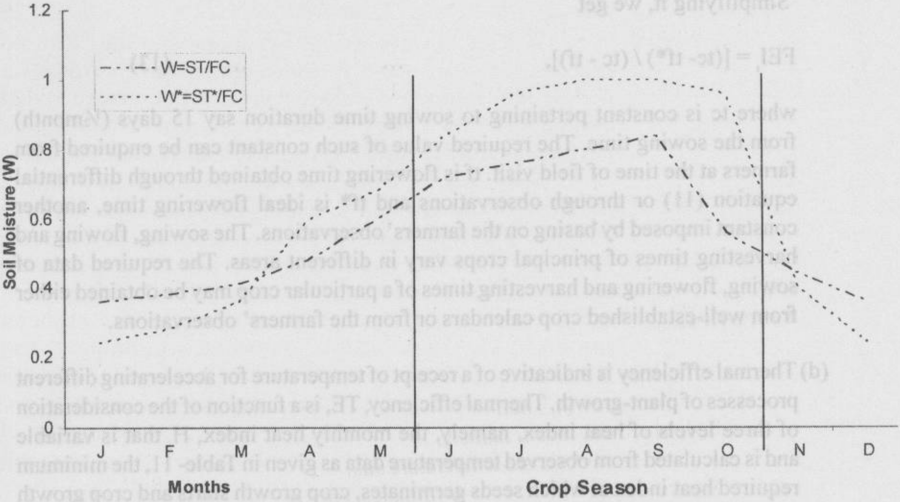

Fig.- 9: Seasonal Variation in Water Use Efficiency

(c) When the duration of photosynthetic efficiency during vegetative growth (tc-tf) {that includes the duration of initiation growth phase which starts after a few days of sowing when seedlings come out (tc-td) and fast vegetative growth phase (td-tf) at the time of inflorescence emergence and flowering of the crop growth, tf} is shorter than the degree of efficiency of radiation used in the process of photosynthesis to reproduction becomes higher nd *vice-versa* (Mc Call and Bishop-Hurley 2003). A ratio of total crop-season duration, D, with the duration of reproduction growth period (tc-tf), is a representative of the use of photosynthetic efficiency by plants. Photosynthetic efficiency index, FEI, is made to fix the ideal time duration of vegetative growth period as (tc-tf*), though it varies in different environmental conditions. The data pertaining to (tc-tf*) may be collected by field observation of farmers. While (tc-tf) is generated by differentiating ET/PET as function of time, t and setting it equal to zero as

$$d(ET/PET)/dt = 0 , \quad \ldots \quad \ldots \quad (11)$$

and then getting solution for t, the FEI for a particular observation is calculated as

$$FEI_i = [\{D/(tc\text{-}tf)\} / \{D/(tc\text{-}tf^*)\}]. \quad \ldots \quad \ldots \quad (12)$$

Simplifying it, we get

$$FEI_i = [(tc - tf^*) / (tc - tf)], \quad \ldots \quad \ldots (13)$$

where tc is constant pertaining to sowing time duration say 15 days (½month) from the sowing time. The required value of such constant can be enquired from farmers at the time of field visit. tf is flowering time obtained through differential equation (11) or through observations and tf* is ideal flowering time, another constant imposed by basing on the farmers' observations. The sowing, flowing and harvesting times of principal crops vary in different areas. The required data of sowing, flowering and harvesting times of a particular crop may be obtained either from well-established crop calendars or from the farmers' observations.

(d) Thermal efficiency is indicative of a receipt of temperature for accelerating different processes of plant-growth. Thermal efficiency, TE, is a function of the consideration of three levels of heat index, namely, the monthly heat index, H_j, that is variable and is calculated from observed temperature data as given in Table- 11, the minimum required heat index at which seeds germinates, crop growth starts and crop growth simulation takes place that is called base (or threshold) heat index, H_{jbase}, as constant, and the monthly optimal level of heat index for proper crop-growth during vegetative as well as reproductive growth phases, H_j^*, that is another variable. Thus, monthly thermal efficiency is a ratio between them as:

$$TE_i = [(H_j - H_{jbase}) / (H_j^* - H_{jbase})], \ \ldots \quad \ldots \quad (14)$$

where H_{jbase} is constant. Then temperature efficiency index, TEI, for a particular crop season and for an ith observation, may be written as

$$TEI_i = 1/m \text{ “ } [(H_j - H_{jbase}) / (H_j^* - H_{jbase})], \quad \ldots \quad (15)$$

where m is number of month during crop season. For example, several studies indicate that threshold temperature for summer paddy crop is estimated to be 10°C (H_{jbase} = 2.856) and the maximum 33°C (H_{jmax} i= 17.4096) but must not exceed 42°C (H_j= 25.0818), while the range of optimal temperature varies from 25°C in May to 30°C in June and July (vegetative growth phase) and 28°C(H_j= 13.5755) in October at the time of harvest (reproductive phase). It means that heat indexes, H_j and H_j^*, vary temporally while H_{jbase} is constant which determines temperature efficiency (Fig .- 10)

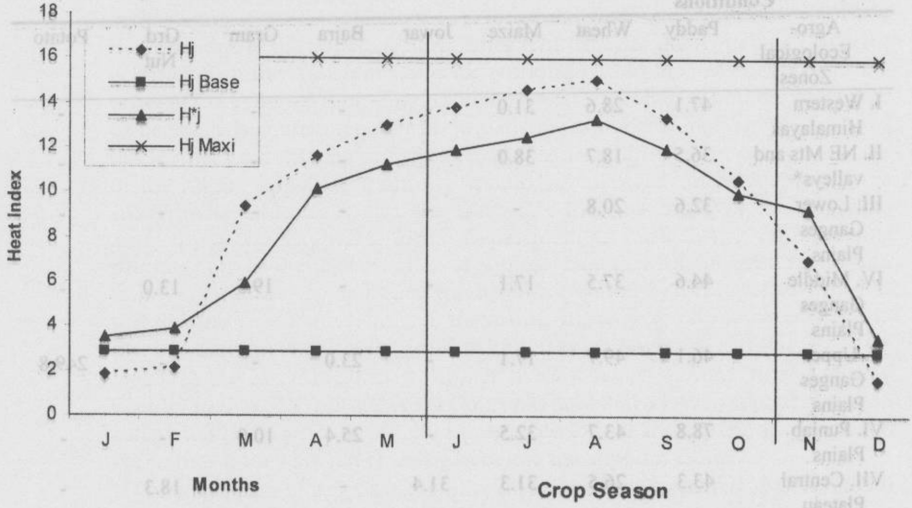

Fig.- 10: Seasonal Variation in Thermal Efficiency

(e) Data pertaining to crop genetic coefficient, m, are also required to convert potential productivity of land index PPI values into the maximum possible yield, A, as per the requirement of sub-model (eqn- 2).

Genetic coefficients are derived in many ways by many scientists considering variation in agro- ecological conditions and grain development stages of a particular crop. Indian Council of Agricultural Research (ICAR), New Delhi developed a data bank on genetic crop yield for the principal crops grown in India on the basis of their phenological development and crop management in choosing the sites of different agro-ecological conditions under the First Line Transfer Technology Projects (Prasad, et al. 1987). Such values of genetic crop yield assessed on experimental basis may be used for the genetic coefficient in the model (Table- 15).

Table- 15: Genetic Crop Yield (qu/ha) of Principal Crops in Different Agro-ecological Conditions

Agro-Ecological Zones	Paddy	Wheat	Maize	Jowar	Bajra	Gram	Grd. Nut	Potato
I. Western Himalayas	47.1	28.6	31.0	-	-	-	-	-
II. NE Mts and valleys*	36.5	18.7	38.0	-	-	-	-	-
III. Lower Ganges Plains	32.6	20.8	-	-	-	-	-	-
IV. Middle Ganges Plains	44.6	37.5	17.1	-	-	19.5	13.0	-
V. Upper Ganges Plains	46.1	49.7	17.1	-	23.0	-	-	249.8
VI. Punjab Plains	78.8	43.7	32.5	-	25.4	10.0	-	-
VII. Central Plateau	43.3	26.5	31.3	31.4	-	-	18.3	-
VIII. Central Highlands	42.2	26.6	36.3	33.3	19.5	-	18.3	-
IX. north Deccan	38.5	26.8	16.3	31.1	31.7	-	-	-
X. South Deccan	52.3	23.8	51.0	55.1	-	16.2	25.0	-
XI. East Coasts	50.6	23.6	-	16.5	26.7	-	10.9	-
XII. western Coasts	40.0	26.6	15.0	31.1	31.7	8.3	11.5	-
XIII. The Gujrat	-	39.0	21.6	-	32.3	-	-	285.4
XIV. The Thar	33.0	41.6	40.8	35.3	19.5	-	-	-
All India Average	48.3	37.1	32.6	34.0	25.2	14.1	16.7	240.7

N.B.* It includes Brahmaputra valley (Assam state only). The crop-yield statistics for different Agro-ecological zones were compiled by the author, see Singh (1994, Table 4.8).

Source: 1. First Line Transfer of Technology Projects, ICAR, New Delhi, 1987

2. National Demonstrations Project- An Overview, ICAR, New Delhi, 1985.

(b) Establishing the Synthesized Data File:

Synthesization of data file includes the crop growth parameters for calculation of the PPI values. The spatio-temporal pattern of such variables in addition to the main attributes which are more concerned with the simulated yield analysis are arranged together in this file (Table- 16). Following are major steps to create the file.

Step- 1: Transfer spatio-temporal ID, its area, duration of crop season, seasonal heat index, seasonal amount of precipitation and monthly mean of soil moisture during crop season from the last part of data feeding file-II (Table-11) and finally arrange them in the established file.

Step- 2: Calculate SCI dividing ΣSCj by ΣSCj^* of the concerned file and place the index value in col- 9 of existing established synthesized data file in four- digits designation

Step- 3: Transfer index values of crop growth from Table- 14.

Step- 4: Generate a column for a given genetic coefficient as col- 14 in four- digits designation in the existing synthesized data file.

Step- 5: Transfer formatted input and crop-yield data given in cols- 21 to m+–ℓ and the last part of the main input data file (Table- 14) to the last part of existing established synthesized data file (Table – 16).It is important to note here that, if we use one input factor model for a particular crop, only one column is to be established for technological input and one-column for crop-yield. We would exemplify the use of one-input factor form of CSSM for the analysis of fertilizer use efficiency, FUE for summer paddy crop yield in the monsoon lands of Brahmaputra valley in the next part of the discussion.

(B) Calibrating the Parameters of CSSM

In order to get the error-free output of the model, a stochastic least-square method is significant to test the validity of CSSM. Considering crop-yield and technological input factors data as given in last part of synthesized data file (col 15 to 16) and assuming that crop-yield, Y, is the function of input factors as X_n variables say Y= f(X_n), the best-fit statistics is used to calculate the coefficients of the function, that are A and B_n with the degree of error term SE, t test value for testing level of significance and coefficient of determinant R^2. Since we have now formatted temporal data of each OTU and OTUs are considered as base of spatial features of crop-yield, the best setting of the yield function (eqn.- 1) with the temporal data of OTU is done to calibrate the parameters of the model, A and Bn, into its best fit value to check the error term SE and maximize the R^2 in its temporal distribution. There will now be total number of sets equal to total number of OTUs and the number of observations must be equal to number of years, k, for each set of $_n^{th}$ OTUs. The best fit statistics is used to get A, and B_n, coefficients for each set of OTU. Note that A which is achieved by using deterministic process of PPI calculations, can not match with the values of A calculated through applying the yield function for each OUT. In order to equate both the values of maximum possible crop yield calculated by the deterministic procedure, defined as A_d and stochastic method, as A_s, the value of genetic coefficient, m, is modified since PPI is resultant of the deterministic variables pertaining to soil and weather elements in its spatio-temporal frame. The modified coefficient m of equation (2) is to be written as $m\text{-}_{modi}$ to calibrate the parameter A of the model and to integrate the effects of technological factors with the factors of crop ecology in the process of crop yield estimation. The value of $m\text{-}_{modi}$ is calculated by simplifying equation-2 for $m\text{-}_{modi}$ as

Since $A_d = A_s$, and

A_d= m. PPI as per equation-2, then

$A_s = m\text{-}_{modi}$. PPI , and

the equation for m-midi must follow the condition as

$$m\text{-}_{modi} = (A_s / PPI). \quad \ldots \quad \ldots \quad \ldots \quad (16)$$

A simple algorithm is used to calibrate the model for different OTUs (Fig.- 11). Main steps to set the model's parameters for single technological input factor are as follows:

Step- 1: Rearrange data in the set of kth observations for each OTU

Step-2: Initiate the linear form of the model (eqn - 5) with the help of X and Y_o given data in the last part of synthesized data file (Table-16) for $_n^{th}$ OTUs and kth observations.

Step-3: Calculate parameters A and B of given equation (1) and then get corresponding estimated crop-yield values in Y_e vector form.

Step-4: Calculate the Standard Error, SE of Y_e distribution, the significant test for slope gradient and degree of determinant, R^2 in the distribution and repeat the process until nth sets of OTU are over.

Step-5: Alter the value of parameter Ad with the help of achieved $m\text{-}_{modi}$ coefficient for a given equation for each OTU.

Step-6: Find $m\text{-}_{modi}$ for each observation and write values in output file to calculate the parameters of the yield function (Table- 17, Appendix –IV).

Step-7: Stop.

Note: Theoretically, Y_e and Y_o must follow linear equation $Y_e = Y_o$ where a = 0 and b=1.0. Check the best fit distribution calculating parameter of linear equation and print in output file for model's validation.

Now, one can proceed further for detail description of results from the simulated yield data given in output file produced by the tool. The first part of Table– 16 (its 9 columns) is reproduced as such because these attributes provide the bases of the interpretation of output results (Table-17).

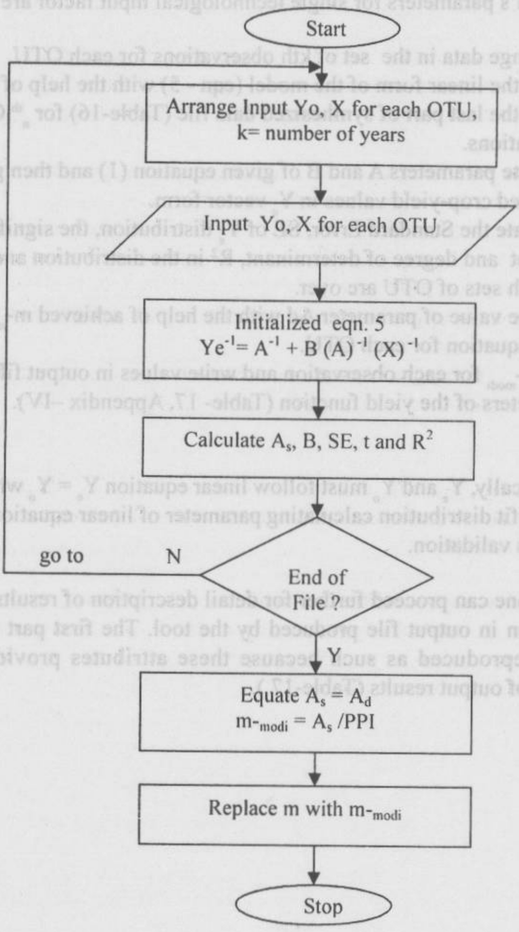

Fig. - 11: Flow Chart of Calibration Module for Parametric Setting and Model's Validation

Table- 16: Synthesized Data File

Spatio-temporal ID Codes	Area (in sq.km)	Crop Duration (days)	Seasonal					SCI	GI	WUE	TEI	FUE	Genetic Yield Coefficient (m)	Crop Yield (Y)	Input (X_n)
			Heat Index		Precipitation		Monthly Soil Moisture (ST in mm)								
			Total	%	Total	%									
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
xxxxxxxx	xxxx.xx	xxx	xxxxx	xx.xx	xxxxx	xx.xx	xxx.xx	x.xx	x.xx	x.xx	x.xx	x.xx	xxxx	xxxx	xxxx
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Table-17: Overview Output File

Spatio-temporal ID Codes	Area (in sq.km)	Crop Season (days)	Seasonal Heat Index (Total)	Seasonal Heat Index (%)	Seasonal Precipitation (Total)	Seasonal Precipitation (%)	Monthly Average Seasonal Soil Moisture	SCI	PPI	Modified Genetic Yield Coefficient (m)	Maximum Possible Yield (A)	Reproductive Capacity of Crop Yield (B)	FUE (B/X)	Yield Gaps (A – Y)	Estimated Yield (Y_e)	Observed Yield (Y_o)	Standard Error (SE)	Degree of Determinants (R^2)
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
xxxxxxx	xxxx.xx	xxx	xxx.x	xx.xx	xxxx	xx.xx	xxx	x.xx	x.xx	xxxx	xxxx	x.xxx	xx.xxx	xxxx	xxxx	xxxx	xxxx	.xxxx
19750001																		
19750002																		
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Section – IV

Demonstrating the Tool

A demonstration of spatio-temporal crop-yield analysis tool is made in the form of its many steps starting from the table of available raw data statistics to its well-formatted spatio-temporal output matrix. In order to demonstrate the procedural steps of the tool, the Brahmaputra valley situated in the North-Eastern parts of India, is considered as study area. Summer paddy is the dominant crop of the valley, while paddy yield , Y, and one technological input namely the use of chemical fertilizer, X, have been taken into account for the demonstration of tool. The valley extends between 25° 302 to 28° 092 N latitudes and 89° 422 to 95° 162 E longitudes and covers about 89,580 sq. km. area of the state of Assam with its nearly 950 km. length from East to West and 60 -100 km width at its North to South direction varying with elevations from 32m to 135m above m.s.l. (Fig.-12). The valley is formed by alluviation processes of soil deposition and is considered as 'rice-bowl' of the North-East. Alluvial plains provide stable base of the growth of paddy corp. However, a significant degree of weather variability is recorded in the valley as the monsoon lands of high humidity. Collecting statistics pertaining to (a) the soil characteristics in the form of modified 39 soil association units (i.e; OTUs) from the Report and Soil Map prepared by the Regional Centre, NBSS and LUP, Jorhat for the whole of Assam State at RF 1:500,000 (scale 1cm = 5km) (NBSS and LUP 1999), (b) the monthly mean temperature and precipitation of seven meteorological stations for the last 29 years (1975 -2003) from Regional Centre, Indian Meteorological Department, Guwahati, (c) the annual average yield of summer paddy and *kharif* season fertilizer consumption statistics for the eleven districts which fall under the valley for the same period of time from the Offices of the State Government, Guwahati, a set of three data raw tables are prepared. There are in all six steps to finally obtain the simulated crop yield and its associated parameters.

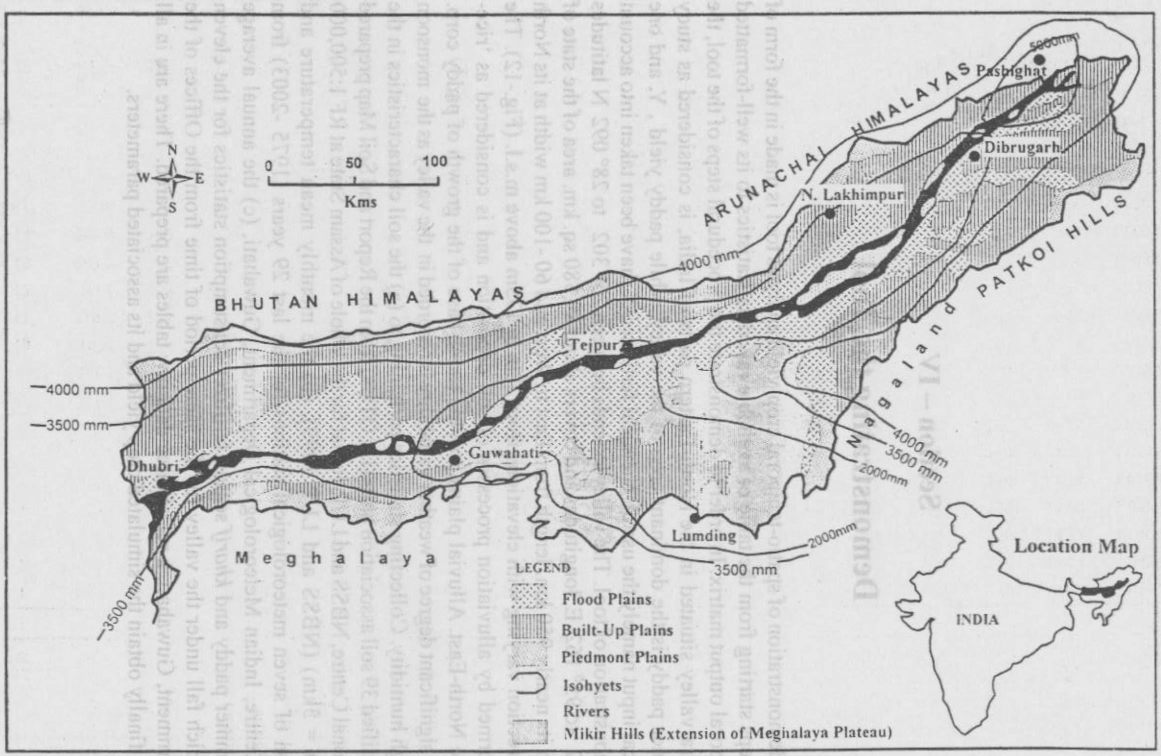

Fig. - 12: Agro-ecological Conditions in Brahmaputra Valley

Step-1: Raw Data tables for preparation of Data feeding Files.

As per discussion above and the requirements of forming an input data files, there are three raw data tables of their different dimensions.

Table-18: Soil Characteristics Index based on Assigned Weights of Soil Attributes

OTU	Area (Sq. Km)	Duration Of Crop (Days)	Surface Form	Parent Material	Soil Depth Class	Soil Temperature Class	pH Value	Ground Water Depth	Surface Stoniness	Slope Class	Erosion Class	Flooding	Particle Size Class	Soil Fertility	Water Holding capacity	Water Holding capacity (mm/m)	Total Weight	Soil Index
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
1	4707	153	0.56	1.13	1.5	1.15	1.04	0.93	1.1	1.09	0.92	1.1	1.1	1.2	1.4	250	14.16	1.0151
2	2354	153	0.6	1.2	1.5	1.15	1.03	1.12	1.1	1.12	1	1.1	1.1	1.2	1.4	250	14.54	1.0423
3	732.2	153	0.67	1.2	1.5	1.15	1.02	1.07	1.1	1.07	0.97	1.1	1.1	1.2	1.4	250	14.52	1.0409
4	1188	153	0.83	1.2	1.5	1.15	1.02	1.07	1.1	1.1	1	1.1	1.1	1.2	1.4	150	14.67	1.0516
5	3684	153	0.6	1.11	1.5	1.15	1	0.92	1.1	1.12	0.94	1.1	1.1	1.2	1.4	150	14.18	1.0165
6	1557	153	0.63	1.2	1.5	1.15	1.1	1.15	1.1	1.15	0.95	1.1	1.1	1.2	1.4	150	14.71	1.0545
7	364.5	153	0.75	1.2	1.5	1.15	1.05	1.1	1.1	1.15	1	1.1	1.1	1.2	1.4	150	14.75	1.0573
8	765.4	153	0.67	1.2	1.5	1.15	1.03	1.07	1.1	1.13	0.93	1.1	1.1	1.2	1.4	150	14.55	1.0430
9	413.5	153	0.5	1.2	1.5	1.15	1.15	1.1	1.1	1.15	1	1.1	1.1	1.2	1.3	200	14.5	1.0394
10	1974	153	0.67	1.2	1.5	1.15	0.95	1	1.1	1.07	1	1.1	1.1	1.2	1.3	200	14.17	1.0158
11	719.7	153	0.67	1.2	1.5	1.15	1.03	1.07	1.1	1.1	0.97	1.1	1.1	1.2	1.3	200	14.46	1.0366
12	1861	153	0.5	1.2	1.5	1.15	1.05	1	1.1	1.05	0.95	1.1	1.1	1.2	1.35	225	14.25	1.0215
13	203.2	153	0.5	1.2	1.5	1.15	1.15	1.2	1.1	1.15	0.85	1.1	1.1	1.2	1.35	225	14.55	1.0430
14	555.4	153	0.5	1.2	1.5	1.15	0.88	0.9	1.1	1.15	0.95	1.1	1.1	1.2	1.35	225	14.08	1.0093
15	3346	153	0.5	1.14	1.5	1.15	1.04	1.11	1.1	1.16	0.89	1.1	1.1	1.2	1.4	250	14.38	1.0308
16	1795	153	0.75	1.2	1.5	1.15	0.95	1	1.1	1.05	1	1.1	1.1	0.8	1.4	250	13.9	0.9964
17	1955	153	0.55	1.2	1.5	1.15	0.99	1	1.1	1.05	0.95	1.1	1.1	0.8	1.4	250	13.81	0.9900
18	2992	153	0.8	1.2	1.5	1.15	0.8	0.8	1.1	0.95	1	1.1	1.1	0.8	1.4	250	13.65	0.9785
19	426	153	0.7	1	1.5	1.15	0.92	0.93	1.1	1	0.97	1.1	1.1	0.8	1.4	250	13.6	0.9749
20	1084	153	0.5	1.05	1.5	1.15	0.97	0.93	1.1	1.13	1.43	1.1	1.1	0.8	1.4	250	14.13	1.0129

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
21	3178	153	0.68	1.2	1.5	1.15	0.87	0.92	1.1	1.06	0.98	1.1	1.1	0.8	1.4	250	13.82	0.9907
22	1539	153	0.5	1.2	1.5	1.15	1.08	0.88	1.1	1.2	1.48	1.1	1.1	0.8	1.4	250	14.45	1.0358
23	1838	153	0.54	1.2	1.5	1.15	0.94	0.97	1.1	1.13	0.99	1.09	1.09	0.8	1.4	250	13.88	0.9950
24	502.6	153	0.5	1.2	1.5	1.15	1.05	1	1.1	1.2	0.95	1.05	1.05	0.8	1	150	13.6	0.9749
25	3005	153	0.73	1.17	1.5	1.15	0.85	0.73	1.1	0.97	0.97	1.1	1.1	0.8	1	150	13.1	0.9391
26	1344	153	0.8	1.2	1.5	1.15	0.8	0.8	1.1	0.95	1	1.1	1.1	0.8	1	150	13.25	0.9498
27	5297	153	0.68	0.9	1.5	1.15	0.87	0.84	1.1	1.04	0.98	1.1	1.1	0.8	1	150	13	0.9319
28	2430	153	0.5	1.2	1.5	1.15	1.15	1	1.1	1.2	1	1.1	1.1	0.8	1	150	13.8	0.9892
29	624.4	153	0.8	0.6	1.5	1.15	0.95	0.8	1.1	0.9	1	1.1	1.1	0.8	1	150	12.5	0.8961
30	4784	153	0.7	1.1	1.5	1.15	0.95	0.8	0.7	0.9	1	1.1	1.1	0.8	1	150	12.7	0.9104
31	1022	153	0.65	0.68	1.5	1.15	0.8	0.8	1.1	1.05	1	1.1	1.1	0.8	1	150	12.63	0.9054
32	920.1	153	0.5	1.09	1.5	1.15	1.06	0.8	1.1	1.13	0.93	1.1	1.1	0.8	1.4	200	13.64	0.9778
33	232	153	0.6	1.2	1.5	1.15	1.03	0.8	1.1	1.1	0.93	1.1	1.1	0.8	1.4	150	13.78	0.9878
34	2167	153	0.5	0.75	1.5	1.15	0.8	0.8	0.7	1.02	1	1.1	1.1	0.8	1	150	12.12	0.8688
35	1557	153	0.5	1.2	1.5	1.15	0.8	1	1.1	1.2	0.9	1	1	0.8	1	250	13.25	0.9498
36	1078	153	0.5	1.2	1.5	1.15	1.15	1	1.1	1.2	1.48	1.1	1.1	0.8	1	150	14.28	1.0237
37	86015	153	0.5	1.2	1.5	1.15	1.15	1	1.1	1.2	0.9	1.1	1.1	0.8	1.4	250	14.1	1.0108
38	828.3	153	0.5	1.2	1.5	1.15	1.15	1	1.1	1.2	0.85	1.1	1.1	0.8	1.3	200	13.95	1.0000
39	543.2	153	0.5	1.2	1.5	1.15	0.95	1	1.1	1.2	0.8	1.1	1.1	0.8	1.35	225	13.75	0.9857

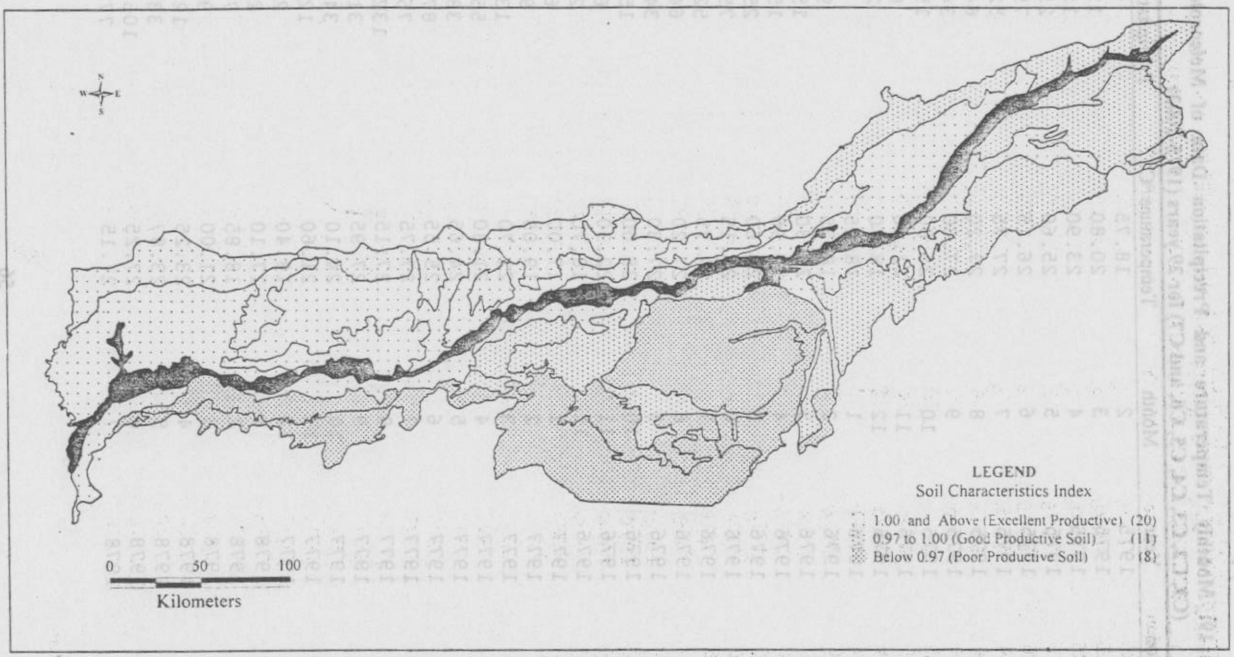

Fig. - 13: Soil Productivity for Summer Paddy in Brahmaputra Valley

Table- 19: Monthly Temperature and Precipitation Data of Meteorological Stations (C1, C2, C3, C4, C5, C6, and C7) for 29 years (1975-2003)

Station	Year	Month	Temperature °C	Precipitation (in mm)
C6	1975	2	18.75	92
C6	1975	3	20.80	150
C6	1975	4	23.90	156
C6	1975	5	25.60	259
C6	1975	6	26.15	758
C6	1975	7	27.75	529
C6	1975	8	27.20	649
C6	1975	9	27.30	342
C6	1975	10	25.00	156
C6	1975	11	22.30	67
C6	1975	12	18.70	27
C6	1976	1	18.25	0
C6	1976	2	18.75	92
C6	1976	3	20.80	150
C6	1976	4	23.90	156
C6	1976	5	25.60	259
C6	1976	6	26.15	758
C6	1976	7	27.75	529
C6	1976	8	27.20	649
C6	1976	9	27.30	342
C6	1976	10	25.00	156
C6	1976	11	22.30	67
C6	1976	12	18.70	27
C6	1977	1	17.00	66
C6	1977	2	19.05	96
C6	1977	3	22.70	139
C6	1977	4	21.80	552
C6	1977	5	24.65	387
C6	1977	6	25.55	874
C6	1977	7	27.75	757
C6	1977	8	27.15	1323
C6	1977	9	27.95	317
C6	1977	10	24.10	346
C6	1977	11	21.60	120
C6	1977	12	18.40	25
C6	1978	1	17.10	21
C6	1978	2	18.85	76
C6	1978	3	21.00	93
C6	1978	4	23.25	126
C6	1978	5	23.87	330
C6	1978	6	27.25	1058
C6	1978	7	27.15	777

Contd...

Table- 20: District - wise Crop Yield and the Use of Chemical Fertilizer for 29 years (1975-2003)

Sl.No	Years/ Districts	Yield (kg/ha)	Fertilizers Used (kg/ha)
	1975-76		
1	Dhubri/ Goalpara	970	0.001
2	Kokrajhar	970	0.001
3	Bogaigaon	970	0.001
4	Kamrup	969	0.005
5	Nogaon	1274	0.005
6	Darrang	1192	0.005
7	Jorhat	1275	0.008
8	Tinsukhia	1297	0.008
9	Dibrugarh	1200	0.007
10	N.Lakhimpur	1272	0.001
11	K. Anglong	1212	0.001
	1976-77		
1	Dhubri/ Goalpara	977	0.001
2	Kokrajhar	977	0.001
3	Bogaigaon	977	0.001
4	Kamrup	764	0.006
6	Darrang	1092	0.006
5	Nogaon	1150	0.006
7	Jorhat	1150	0.006
8	Tinsukhia	1212	0.006
9	Dibrugarh	1322	0.008
10	N.Lakhimpur	1210	0.001
11	K. Anglong	1107	0.001
	1977-78		
1	Dhubri/ Goalpara	1043	0.001
2	Kokrajhar	1043	0.001
3	Bogaigaon	1043	0.001
4	Kamrup	892	0.007
5	Nogaon	1131	0.007
6	Darrang	1092	0.007
7	Jorhat	1131	0.007
8	Tinsukhia	1260	0.007
9	Dibrugarh	1368	0.006
10	N.Lakhimpur	1288	0.001
11	K. Anglong	1361	0.001

Contd...

Step-2: Conversion of monthly T and P in its Spatial Dimension (used for Data Feeding File-II):

Table- 21: Formation of Spatial Structure with Thiessen Polygons and Spatial Gradients between Centroids and Dependent (See Figs. – 14 & 15).

Centroid	Polygon	Distance (km)	Direction	Direction Alignment	Distance from Centroid
Dhubri(C1)			C1 to A		98
	1	48.4		1	
	2	80.7		1	
	3	80.5		1	
	35	-96.0		1	
	37	12.8		1	
Guwahati(C2)			C2 to A		98
			C2 to B		50.2
			C2 to C		67.2
	4	98.3		2	
	5	65		2	
	6	46		2	
	7	54.8		3	
	8	44.9		3	
	33	-26.8		4	
	34	12.5		2	
	36	1.3		2	
Tezpur(C3)			C3 to B		50.2
			C3 to D		39
			C3 to E		58
	9	-50.3		5	
	10	40.8		5	
	11	-20.2		5	
	32	-52.6		5	
	38	-20.7		7	
Lakhimpur(C4)			C4 to D		39
			C4 to F		70
			C4 to G		80
	12	11.3		10	
	13	-6.3		8	
	14	20.6		8	
	39	-26		9	

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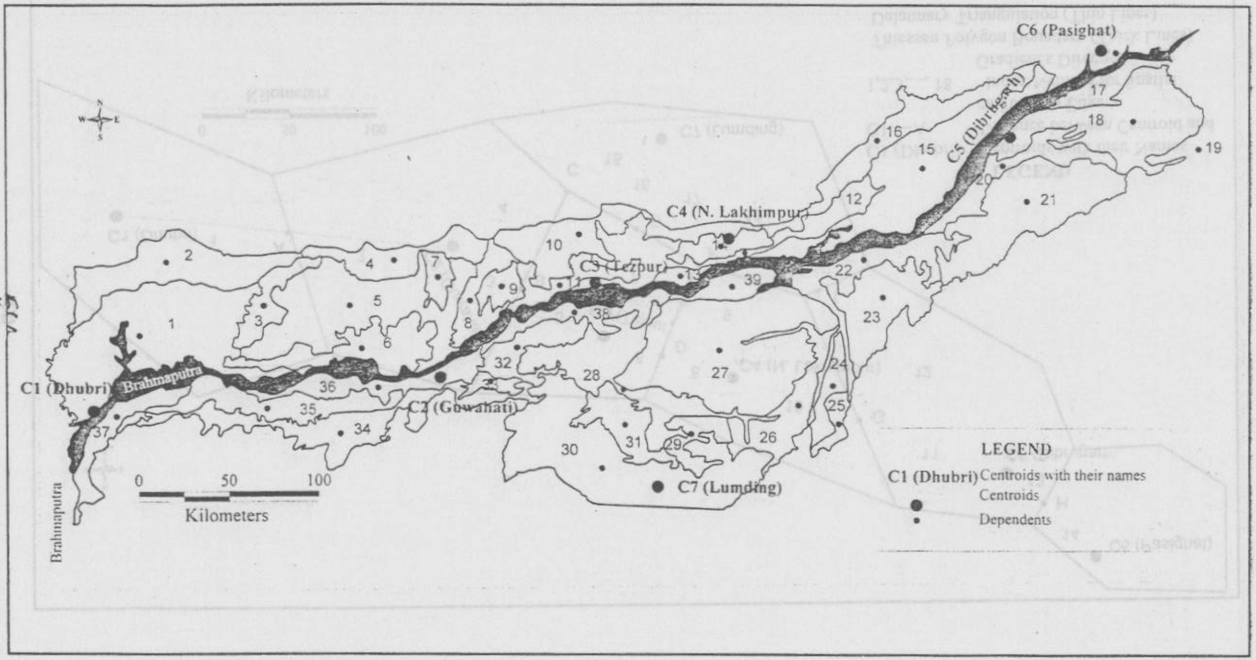

Fig. - 14: Location of Centroids and Dependent Points

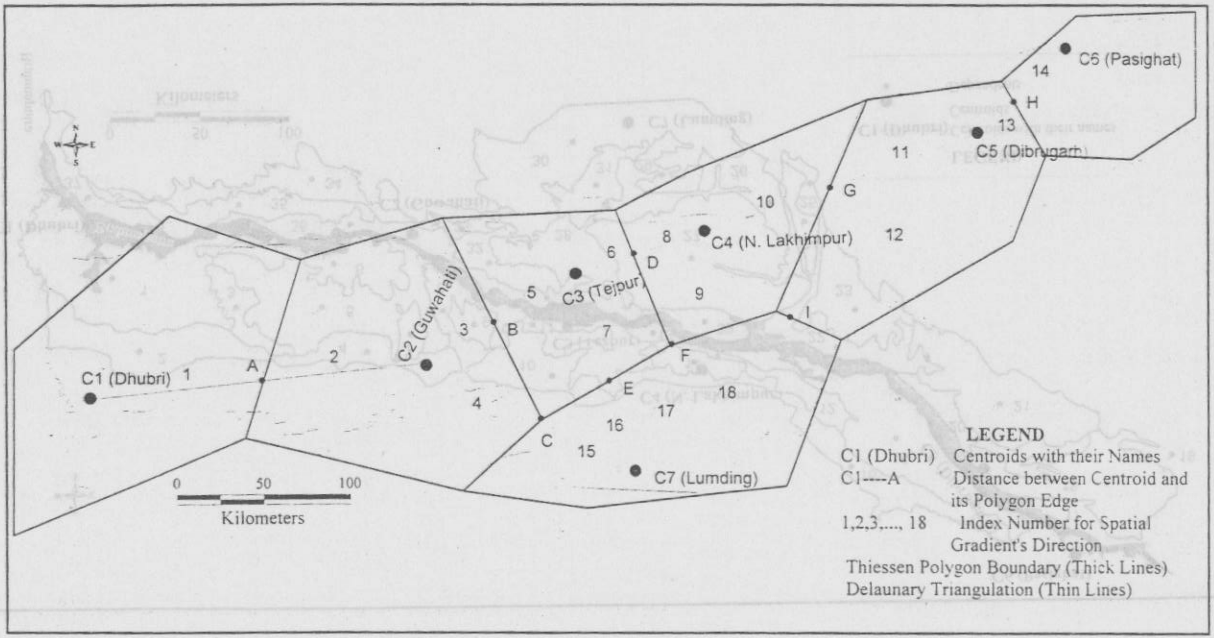

Fig. - 15: Thiessen Polygons and Index Numbers for Spatial Gradients

Table- 22: Formatted Data of Monthly Temperature (T) and Precipitation (P) after Spatial Conversion

OTU		J	F	M	A	M	J	Ju	A	S	O	N	D
1	T (°C)	16.2	18.9	24.1	27.2	26.4	28.8	27.5	28.5	27.4	26.6	21.0	16.8
	P (mm)	68.8	101.8	7.8	117.0	556.0	328.0	739.8	367.0	457.0	186.7	0.0	96.8
2	T (°C)	16.2	18.9	24.1	27.2	26.4	28.8	27.5	28.5	27.4	26.6	21.0	16.8
	P (mm)	114.0	166.4	11.1	117.0	556.0	328.0	743.1	367.0	518.3	212.6	0.0	161.4
3	T (°C)	16.2	18.9	24.1	27.2	26.4	28.8	27.5	28.5	27.4	26.6	21.0	16.8
	P (mm)	113.7	166.0	11.1	117.0	556.0	328.0	743.0	367.0	518.0	212.4	0.0	161.0
4	T (°C)	16.9	19.1	23.8	26.9	26.6	28.5	28.0	28.8	27.7	26.8	21.9	17.0
	P (mm)	143.6	197.6	23.8	52.0	235.0	281.0	401.8	173.0	375.8	169.6	0.0	196.6
5	T (°C)	16.9	19.1	23.8	26.9	26.6	28.5	28.0	28.8	27.7	26.8	21.9	17.0
	P (mm)	97.0	131.0	20.5	52.0	235.0	281.0	398.5	173.0	312.5	143.0	0.0	130.0
6	T (°C)	16.9	19.1	23.8	26.9	26.6	28.5	28.0	28.8	27.7	26.8	21.9	17.0
	P (mm)	70.4	93.0	18.6	52.0	235.0	281.0	396.6	173.0	276.4	127.8	0.0	92.0
7	T (°C)	16.9	19.1	23.8	26.9	26.6	28.5	28.0	28.8	27.7	26.8	21.9	17.0
	P (mm)	115.6	110.6	85.2	106.8	235.0	281.0	424.9	189.4	402.7	249.9	54.8	109.6
8	T (°C)	16.9	19.1	23.8	26.9	26.6	28.5	28.0	28.8	27.7	26.8	21.9	17.0
	P (mm)	95.8	90.8	72.4	96.9	235.0	281.0	418.9	186.5	364.1	221.2	44.9	89.8
9	T (°C)	20.4	20.4	24.9	24.0	25.0	31.5	37.4	30.5	28.5	27.5	24.9	19.4
	P (mm)	0.0	0.0	0.0	80.7	113.0	193.0	169.8	298.9	25.8	0.0	0.0	0.0
10	T (°C)	20.4	20.4	24.9	24.0	25.0	31.5	37.4	30.5	28.5	27.5	24.9	19.4
	P (mm)	82.6	89.6	63.0	171.8	113.0	193.0	224.5	326.2	381.1	247.3	65.8	106.6

contd...

Step- 3 : Conversion of Formatted monthly Temperature (T) and Precipitation (P) into its Parametric Conversion to find Growth Factors, GI, WUE, FEI, TEI (see Data Conversion File-II)

Table- 23: Monthly Variation in Crop Growth Factors

Months		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
20030003														
Heat Index	...	5.1	7.5	10.6	11.2	5.8	12.6	13.1	14.2	13.4	12.1	9.1	7.4	122.2364
Unadjusted PET	...	0.9	1.3	1.3	1.3	1.1	1.3	1.3	1.3	1.3	1.3	1.3	1.3	
PET	...	25	34	40	42	38	44	46	44	40	39	35	35	
P	...	230	49	137	173	103	653	363	131	175	271	81	23	
P-PET	...	206	15	97	131	64	609	317	87	136	232	45	-12	1926.22
ACC WL	...	253	49	137	173	103	653	363	131	175	271	81	23	
ST Values	...	250	250	250	250	250	250	250	250	250	250	250	250	
Change ST	...	0	0	0	0	0	0	0	0	0	0	0	0	
ET	...	25	34	40	42	38	44	46	44	40	39	35	23	
GI	...	1	1	1	1	1	1	1	1	1	1	1	1	1.00
WUE	...	1	1	1	1	1	1	1	1	1	1	1	1	1.00
TEI	...	2	3	4	4	2	4	5	5	5	4	3	3	4.59
FEI	...	1	1	1	1	1	1	1	1	1	1	1	1	1
Months		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
20030004														
Heat Index	...	5.8	7.9	9.4	11.6	13.0	13.8	14.6	15.1	14.4	12.6	10.0	7.6	135.5935
Unadjusted PET	...	0.9	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	
PET	...	25	26	31	32	35	34	35	34	31	30	27	27	
P	...	281	68	120	249	51	581	737	261	217	281	119	12	
P-PET	...	256	41	89	217	16	546	702	227	186	252	92	-15	2609.16
ACC WL	...	293	68	120	249	51	581	737	261	217	281	119	12	
ST Values	...	150	150	150	150	150	150	150	150	150	150	150	150	
Change ST	...	0	0	0	0	0	0	0	0	0	0	0	0	
ET	...	25	26	31	32	35	34	35	34	31	30	27	12	
GI	...	1	1	1	1	1	1	1	1	1	1	1	0	1.00
WUE	...	1	1	1	1	1	1	1	1	1	1	1	1	1.00
TEI	...	2	3	3	4	5	5	5	5	5	4	4	3	4.93
FEI	...	1	1	1	1	1	1	1	1	1	1	1	1	1
Months		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
20030005														
Heat Index	...	5.8	7.9	9.4	11.6	13.0	13.8	14.6	15.1	14.4	12.6	10.0	7.6	135.5935
Unadjusted PET	...	0.9	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	
PET	...	25	26	31	32	35	34	35	34	31	30	27	27	
P	...	188	58	120	249	751	571	601	251	197	248	86	12	

P-PET ...	163	31	89	217	716	536	565	217	166	218	59	-15	2963.16
ACC WL ...	200	58	120	249	751	571	601	251	197	248	86	12	
ST Values ...	150	150	150	150	150	150	150	150	150	150	150	150	
Change ST ...	0	0	0	0	0	0	0	0	0	0	0	0	
ET ...	25	26	31	32	35	34	35	34	31	30	27	12	
GI ...	1	1	1	1	1	1	1	1	1	1	1	0	1.00
WUE ...	1	1	1	1	1	1	1	1	1	1	1	1	1.00
TEI ...	2	3	3	4	5	5	5	5	5	4	4	3	4.93
FEI ...	1	1	1	1	1	1	1	1	1	1	1	1	1
Months	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
20030006													
Heat Index ...	5.8	7.9	9.4	11.6	13.0	13.8	14.6	15.1	14.4	12.6	10.0	7.6	135.5935
Unadjusted PET ...	0.9	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	
PET ...	25	26	31	32	35	34	35	34	31	30	27	27	
P ...	135	52	120	249	580	565	523	245	186	229	67	12	
P-PET ...	110	25	89	217	545	531	487	211	155	199	40	-15	2594.56
ACC WL ...	147	52	120	249	580	565	523	245	186	229	67	12	
ST Values ...	147	150	150	150	150	150	150	150	150	150	150	150	
Change ST ...	-3	3	0	0	0	0	0	0	0	0	0	0	
ET ...	25	26	31	32	35	34	35	34	31	30	27	12	
GI ...	1	1	1	1	1	1	1	1	1	1	1	0	1.00
WUE ...	1	1	1	1	1	1	1	1	1	1	1	1	1.00
TEI ...	2	3	3	4	5	5	5	5	5	4	4	3	4.93
FEI ...	1	1	1	1	1	1	1	1	1	1	1	1	1
Months	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
20030007													
Heat Index ...	5.8	7.9	9.4	11.6	13.0	13.8	14.6	15.1	14.4	12.6	10.0	7.6	135.5935
Unadjusted PET ...	0.9	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	
PET ...	25	26	31	32	35	34	35	34	31	30	27	27	
P ...	159	65	120	304	604	557	805	264	218	293	76	505	
P-PET ...	135	39	89	272	570	522	770	230	188	263	49	478	3603.76
ACC WL ...	665	65	120	304	604	557	805	264	218	293	76	505	
ST Values ...	150	150	150	150	150	150	150	150	150	150	150	150	
Change ST ...	0	0	0	0	0	0	0	0	0	0	0	0	
ET ...	25	26	31	32	35	34	35	34	31	30	27	27	
GI ...	1	1	1	1	1	1	1	1	1	1	1	1	1.00
WUE ...	1	1	1	1	1	1	1	1	1	1	1	1	1.00
TEI ...	2	3	3	4	5	5	5	5	5	4	4	3	4.93
FEI ...	1	1	1	1	1	1	1	1	1	1	1	1	1
Months	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
20030008													
Heat Index ...	5.8	7.9	9.4	11.6	13.0	13.8	14.6	15.1	14.4	12.6	10.0	7.6	135.5935
Unadjusted PET ...	0.9	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
PET ...	25	26	31	32	35	34	35	34	31	30	27	27	
P ...	132	61	120	294	525	556	720	258	207	273	66	416	
P-PET ...	107	34	89	262	490	521	685	224	177	243	39	389	3260.16
ACC WL ...	548	61	120	294	525	556	720	258	207	273	66	416	
ST Values ...	150	150	150	150	150	150	150	150	150	150	150	150	
Change ST ...	0	0	0	0	0	0	0	0	0	0	0	0	
ET ...	25	26	31	32	35	34	35	34	31	30	27	27	
GI ...	1	1	1	1	1	1	1	1	1	1	1	1	1.00
WUE ...	1	1	1	1	1	1	1	1	1	1	1	1	1.00
TEI ...	2	3	3	4	5	5	5	5	5	4	4	3	4.93
FEI ...	1	1	1	1	1	1	1	1	1	1	1	1	1
Months	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
20030009													
Heat Index ...	5.9	7.8	9.3	11.1	12.3	13.6	13.7	14.3	13.8	12.0	9.6	7.4	130.7745
Unadjusted PET ...	1.0	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	
PET ...	28	29	34	35	38	38	39	37	34	33	30	30	
P ...	0	0	90	121	0	281	0	277	243	129	0	0	
P-PET ...	-28	-29	56	85	-38	243	-39	240	209	97	-30	-30	736.7999
ACC WL ...	0	0	90	121	0	281	0	277	243	129	0	0	
ST Values ...	150	150	150	150	150	150	150	150	150	150	150	150	
Change ST ...	0	0	0	0	0	0	0	0	0	0	0	0	
ET ...	0	0	34	35	0	38	0	37	34	33	0	0	
GI ...	0	0	1	1	0	1	0	1	1	1	0	0	0.80
WUE ...	1	1	1	1	1	1	1	1	1	1	1	1	1.00
TEI ...	2	3	3	4	4	5	5	5	5	4	3	3	4.72
FEI ...	1	1	1	1	1	1	1	1	1	1	1	1	1
Months	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
20030010													
Heat Index ...	5.9	7.8	9.3	11.1	12.3	13.6	13.7	14.3	13.8	12.0	9.6	7.4	130.7745
Unadjusted PET ...	1.0	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	
PET ...	28	29	34	35	38	38	39	37	34	33	30	30	
P ...	118	45	90	212	504	290	611	332	343	312	82	369	
P-PET ...	91	16	56	176	466	252	572	295	309	279	52	339	2904
ACC WL ...	487	45	90	212	504	290	611	332	343	312	82	369	
ST Values ...	150	150	150	150	150	150	150	150	150	150	150	150	
Change ST ...	0	0	0	0	0	0	0	0	0	0	0	0	
ET ...	28	29	34	35	38	38	39	37	34	33	30	30	
GI ...	1	1	1	1	1	1	1	1	1	1	1	1	1.00
WUE ...	1	1	1	1	1	1	1	1	1	1	1	1	1.00
TEI ...	2	3	3	4	4	5	5	5	5	4	3	3	4.72
FEI ...	1	1	1	1	1	1	1	1	1	1	1	1	1

Contd...

Step -4: Conversion of Statistics Related to Crop-yield and the use of Chemical Fertilizer data into its formatted file (see Data Feeding File-III)

Table- 24: Formatted Data of Crop-yield and the use of Chemical Fertilizer

OTU	Summer Paddy Yield (kg/ha)	Chemical Fertilizer Used (kg/ha)
20000001	1405.07	0.0407
20000002	1362.28	0.0562
20000003	1119.96	0.0411
20000004	1535.92	0.0923
20000005	1406.23	0.0606
20000006	1394.40	0.0584
20000007	1567.00	0.0980
20000008	1567.00	0.0980
20000009	1567.00	0.0980
20000010	1567.00	0.0980
20000011	1567.00	0.0980
20000012	1555.33	0.0916
20000013	1567.00	0.0980
20000014	1567.00	0.0980
20000015	1418.18	0.0113
20000016	1408.46	0.0114
20000017	1475.05	0.0697
20000018	1490.74	0.0722
20000019	1465.00	0.0770
20000020	1818.00	0.0152
20000021	1883.00	0.0307
20000022	1840.86	0.0303
20000023	1887.00	0.0320
20000024	1887.00	0.0320
20000025	1887.00	0.0320
20000026	1164.06	0.0052
20000027	1247.81	0.0144
20000028	1623.92	0.0820
20000029	1438.19	0.0537
20000030	1165.64	0.0122
20000031	1559.94	0.0722
20000032	1729.00	0.0980
20000033	1655.58	0.0892
20000034	1510.52	0.0590
20000035	1252.68	0.0389
20000036	1462.64	0.0661
20000037	1429.00	0.0400
20000038	1697.66	0.0980
20000039	1855.09	0.0453

20010001	1529.18	0.0757
20010002	2086.82	0.0614
20010003	1769.55	0.0687
20010004	2208.48	0.0875
20010005	2168.31	0.0630
20010006	2160.56	0.0617
20010007	2230.00	0.0920
20010008	2230.00	0.0920
20010009	2230.00	0.0920
20010010	2230.00	0.0920
20010011	2230.00	0.0920
20010012	2191.28	0.0865
20010013	2230.00	0.0920
20010014	2230.00	0.0920
20010015	1706.53	0.0170
20010016	1703.80	0.0171
20010017	1981.37	0.0631
20010018	2003.00	0.0650
20010019	2003.00	0.0690
20010020	1990.37	0.0180
20010021	1894.03	0.0347
20010022	1841.98	0.0343
20010023	1887.00	0.0360
20010024	1887.00	0.0360
20010025	1887.00	0.0360
20010026	1181.62	0.0101
20010027	1313.40	0.0184
20010028	2120.26	0.0779
20010029	1763.68	0.0529
20010030	1240.41	0.0162
20010031	1997.03	0.0692
20010032	2322.00	0.0920
20010033	2287.27	0.0852
20010034	2124.20	0.0711
20010035	1595.50	0.0737
20010036	2196.00	0.0673
20010037	1505.00	0.0770
20010038	2304.20	0.0920
20010039	1974.85	0.0473
20020001	1929.58	0.1630
20020002	2160.26	0.0850
20020003	1857.56	0.1060
20020004	2134.38	0.0699
20020005	2191.41	0.0848
20020006	2190.78	0.0862
20020007	2140.00	0.0680
20020008	2140.00	0.0680

20020009	2140.00	0.0680
20020010	2140.00	0.0680
20020011	2140.00	0.0680
20020012	2113.09	0.0649
20020013	2140.00	0.0680
20020014	2140.00	0.0680
20020015	1778.22	0.0262
20020016	1774.29	0.0262
20020017	2081.51	0.0566
20020018	2105.00	0.0575
20020019	2105.00	0.0610
20020020	2089.98	0.0188
20020021	1975.36	0.0515
20020022	1922.10	0.0509
20020023	1967.00	0.0540
20020024	1967.00	0.0540
20020025	1967.00	0.0540
20020026	1263.47	0.0050
20020027	1389.73	0.0128
20020028	2149.04	0.0567
20020029	1811.50	0.0368
20020030	1316.19	0.0075
20020031	2032.45	0.0498
20020032	2340.00	0.0680
20020033	2308.13	0.0720
20020034	2263.65	0.1140
20020035	1859.39	0.1419
20020036	2224.36	0.0824
20020037	1924.00	0.1720
20020038	2301.31	0.0680
20020039	2042.33	0.0568
20030001	1929.58	0.1630
20030002	2160.26	0.0850
20030003	1857.56	0.1060
20030004	2134.38	0.0699
20030005	2191.41	0.0848
20030006	2190.78	0.0862
20030007	2140.00	0.0680
20030008	2140.00	0.0680
20030009	2140.00	0.0680
20030010	2140.00	0.0680
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Step- 5: Preparation of Synthesized File to Proceed Further

Table- 25: Output of Synthesized File

ID	Area	Crop Durtn (Days)	.... S e a s o n a l ...... Heat Index Tot	Heat Index (%)	Precipitation Tot	Precipitation (%)	Monthly Soil Moisture (ST in mm)	Genet Co-eff (m)	SCI	GI	WUE	TEI	FEI	PPI	A	Yield	Fertiliser
19750001	4707.00	153	131.71	50.88	3026.70	68.67	242.97	2900	1.0151	1.00	1.12	1.08	1.12	1.3763	3991	969.98	0.0011
19750002	2354.00	153	131.71	50.88	3294.90	65.83	250.00	2900	1.0423	1.00	1.12	1.08	1.12	1.4132	4098	969.14	0.0044
19750003	732.20	153	131.71	50.88	3293.20	65.84	250.00	2900	1.0409	1.00	1.12	1.08	1.12	1.4113	4093	969.77	0.0019
19750004	1188.00	153	133.36	50.80	2249.80	62.28	150.00	2900	1.0516	1.00	1.12	1.09	1.12	1.4455	4192	1156.65	0.0050
19750005	3684.00	153	133.36	50.80	1973.50	66.28	150.00	2900	1.0165	1.00	1.12	1.09	1.12	1.3972	4052	983.56	0.0050
19750006	1557.00	153	133.36	50.80	1815.80	69.10	150.00	2900	1.0545	1.00	1.12	1.09	1.12	1.4495	4203	973.70	0.0049
19750007	364.50	153	133.36	50.80	2365.50	65.44	150.00	2900	1.0573	1.00	1.12	1.09	1.12	1.4533	4215	1192.00	0.0050
19750008	765.40	153	133.36	50.80	2197.30	66.98	150.00	2900	1.0430	1.00	1.12	1.09	1.12	1.4337	4158	1192.00	0.0050
19750009	413.50	153	149.39	53.47	881.20	78.02	150.00	2900	1.0394	0.62	1.12	1.34	1.12	1.0823	3139	1192.00	0.0050
19750010	1974.00	153	149.39	53.47	2064.50	66.46	150.00	2900	1.0158	1.00	1.12	1.34	1.12	1.7130	4968	1192.00	0.0050
19750011	719.70	153	149.39	53.47	1131.00	79.79	150.00	2900	1.0366	0.94	1.12	1.34	1.12	1.6370	4747	1192.00	0.0050
19750012	1861.00	153	126.84	52.10	3264.40	70.40	237.87	2900	1.0215	1.00	1.12	1.06	1.12	1.3603	3945	1197.73	0.0047
19750013	203.20	153	126.84	52.10	2948.10	74.09	199.45	2900	1.0430	1.00	1.12	1.06	1.12	1.3890	4028	1192.00	0.0050
19750014	555.40	153	126.84	52.10	3702.80	66.11	245.39	2900	1.0093	1.00	1.12	1.06	1.12	1.3441	3898	1192.00	0.0050
19750015	3346.00	153	123.51	52.86	2925.20	64.52	249.46	2900	1.0308	1.00	1.12	1.04	1.12	1.3516	3920	1269.63	0.0012
19750016	1795.00	153	123.51	52.86	3071.40	63.18	250.00	2900	0.9964	1.00	1.12	1.04	1.12	1.3065	3789	1269.81	0.0011
19750017	1955.00	153	121.59	51.92	3035.80	77.46	214.99	2900	0.9900	1.00	1.12	1.00	1.12	1.2432	3605	1291.39	0.0075
19750018	2992.00	153	121.59	51.92	2821.10	79.05	203.59	2900	0.9785	0.95	1.12	1.00	1.12	1.1634	3374	1289.99	0.0079
19750019	426.00	153	121.59	51.92	2748.90	79.26	201.82	2900	0.9749	0.90	1.12	1.00	1.12	1.0965	3180	1297.00	0.0080
19750020	1084.00	153	123.51	52.86	2960.60	65.25	241.85	2900	1.0129	1.00	1.12	1.04	1.12	1.3281	3852	1210.94	0.0071
19750021	3178.00	153	123.51	52.86	3582.60	61.27	250.00	2900	0.9907	1.00	1.12	1.04	1.12	1.2990	3767	1270.46	0.0079
19750022	1539.00	153	123.51	52.86	1695.70	72.09	176.11	2900	1.0358	0.60	1.12	1.04	1.12	0.8149	2363	1271.28	0.0076
19750023	1838.00	153	123.51	52.86	1679.00	72.18	175.59	2900	0.9950	0.60	1.12	1.04	1.12	0.7828	2270	1275.00	0.0080
19750024	502.60	153	137.89	50.15	3778.60	54.66	150.00	2900	0.9749	1.00	1.12	1.12	1.12	1.3751	3988	1275.00	0.0080
19750025	3005.00	153	137.89	50.15	3642.50	55.09	150.00	2900	0.9391	1.00	1.12	1.12	1.12	1.3246	3841	1275.00	0.0080
19750026	1344.00	153	137.89	50.15	3270.70	56.43	150.00	2900	0.9498	1.00	1.12	1.12	1.12	1.3397	3885	1216.76	0.0015
19750027	5297.00	153	137.89	50.15	1863.40	68.58	150.00	2900	0.9319	1.00	1.12	1.12	1.12	1.3144	3812	1224.50	0.0021
19750028	2430.00	153	137.89	50.15	1766.90	69.17	150.00	2900	0.9892	1.00	1.12	1.12	1.12	1.3953	4046	1263.56	0.0043
19750029	624.40	153	137.89	50.15	1411.10	75.05	148.72	2900	0.8961	1.00	1.12	1.12	1.12	1.2639	3665	1245.10	0.0031
19750030	4784.00	153	137.89	50.15	1467.40	71.60	150.00	2900	0.9104	1.00	1.12	1.12	1.12	1.2841	3724	1218.02	0.0014
19750031	1022.00	153	137.89	50.15	1542.00	72.39	150.00	2900	0.9054	1.00	1.12	1.12	1.12	1.2771	3703	1257.63	0.0039
19750032	920.10	153	149.39	53.47	867.90	77.95	139.15	2900	0.9778	0.60	1.12	1.34	1.12	0.9640	2853	1274.00	0.0050
19750033	232.00	153	133.36	50.80	1298.30	77.23	105.77	2900	0.9878	0.93	1.12	1.09	1.12	1.2654	3670	1206.95	0.0050
19750034	2167.00	153	133.36	50.80	1537.90	75.50	129.55	2900	0.8688	1.00	1.12	1.09	1.12	1.1942	3463	1047.47	0.0042
19750035	1557.00	153	131.71	50.88	2347.20	71.33	176.42	2900	0.9498	0.96	1.12	1.08	1.12	1.2361	3585	969.96	0.0011
19750036	1078.00	153	133.36	50.80	1444.70	78.19	111.05	2900	1.0237	1.00	1.12	1.09	1.12	1.4071	4081	1030.76	0.0050
19750037	8601.50	153	131.71	50.88	2731.20	72.45	166.28	2900	1.0108	1.00	1.12	1.08	1.12	1.3705	3974	970.00	0.0010
19750038	828.30	153	149.39	53.47	1180.00	79.85	144.94	2900	1.0000	0.98	1.12	1.34	1.12	1.6495	4784	1258.14	0.0050
19750039	543.20	153	126.84	52.10	2890.40	73.75	160.90	2900	0.9857	1.00	1.12	1.06	1.12	1.3126	3807	1274.80	0.0074
19760001	4707.00	153	132.32	49.07	3088.20	83.94	229.07	2900	1.0151	1.00	1.12	1.03	1.12	1.3217	3833	972.10	0.0011
19760002	2354.00	153	132.32	49.07	3346.60	81.61	243.96	2900	1.0423	1.00	1.12	1.03	1.12	1.3571	3936	793.71	0.0053
19760003	732.20	153	132.32	49.07	3344.90	81.62	243.93	2900	1.0409	1.00	1.12	1.03	1.12	1.3553	3930	928.10	0.0021
19760004	1188.00	153	133.62	49.96	2302.40	67.66	150.00	2900	1.0516	1.00	1.12	1.07	1.12	1.4186	4114	1094.19	0.0060
19760005	3684.00	153	133.62	49.96	2036.00	69.47	149.92	2900	1.0165	1.00	1.12	1.07	1.12	1.3712	3977	789.21	0.0060
19760006	1557.00	153	133.62	49.96	1884.00	70.74	146.43	2900	1.0545	1.00	1.12	1.07	1.12	1.4225	4125	773.94	0.0059
19760007	364.50	153	133.62	49.96	2474.90	66.45	150.00	2900	1.0573	1.00	1.12	1.07	1.12	1.4263	4136	1150.00	0.0060

19760008	765.40	153	133.62	49.96	2301.80	67.45	149.60	2900	1.0430	1.00	1.12	1.07	1.12	1.4070	4080	1150.00	0.0060
19760009	413.50	153	131.74	49.66	678.50	81.46	149.60	2900	1.0394	0.60	1.12	1.04	1.12	0.8200	2378	1150.00	0.0060
19760010	1974.00	153	131.74	49.66	1901.90	68.58	149.60	2900	1.0158	1.00	1.12	1.04	1.12	1.3357	3874	1150.00	0.0060
19760011	719.70	153	131.74	49.66	928.20	81.48	149.60	2900	1.0366	0.60	1.12	1.04	1.12	0.8227	2386	1150.00	0.0060
19760012	1861.00	153	124.28	51.39	2900.70	75.99	233.46	2900	1.0215	1.00	1.12	1.01	1.12	1.3022	3776	1154.29	0.0056
19760013	203.20	153	124.28	51.39	2531.10	80.27	201.02	2900	1.0430	1.00	1.12	1.01	1.12	1.3296	3856	1150.00	0.0060
19760014	555.40	153	124.28	51.39	3449.20	70.45	244.89	2900	1.0093	1.00	1.12	1.01	1.12	1.2867	3731	1150.00	0.0060
19760015	3346.00	153	122.43	52.00	3033.90	64.32	243.75	2900	1.0308	1.00	1.12	1.01	1.12	1.3085	3795	1208.85	0.0012
19760016	1795.00	153	122.43	52.00	3217.20	63.18	247.72	2900	0.9964	1.00	1.12	1.01	1.12	1.2649	3668	1208.36	0.0011
19760017	1955.00	153	125.86	50.16	3003.20	77.63	210.44	2900	0.9900	1.00	1.12	1.00	1.12	1.2432	3605	1216.27	0.0057
19760018	2992.00	153	125.86	50.16	2765.60	78.84	198.62	2900	0.9785	0.97	1.12	1.00	1.12	1.1927	3459	1219.95	0.0061
19760019	426.00	153	125.86	50.16	2689.80	78.68	198.27	2900	0.9749	0.93	1.12	1.00	1.12	1.1328	3285	1212.00	0.0060
19760020	1084.00	153	122.43	52.00	2924.10	66.87	234.47	2900	1.0129	1.00	1.12	1.01	1.12	1.2858	3729	1300.13	0.0077
19760021	3178.00	153	122.43	52.00	3528.60	64.70	239.68	2900	0.9907	1.00	1.12	1.01	1.12	1.2576	3647	1160.42	0.0061
19760022	1539.00	153	122.43	52.00	1810.90	75.19	195.00	2900	1.0358	0.60	1.12	1.01	1.12	0.7889	2288	1147.46	0.0057
19760023	1838.00	153	122.43	52.00	1785.50	75.56	194.13	2900	0.9950	0.60	1.12	1.01	1.12	0.7579	2198	1150.00	0.0060
19760024	502.60	153	139.80	47.60	4971.60	75.56	150.00	2900	0.9749	0.85	1.12	1.07	1.12	1.1156	3235	1150.00	0.0060
19760025	3005.00	153	139.80	47.60	4752.50	75.22	150.00	2900	0.9391	0.85	1.12	1.07	1.12	1.0732	3112	1150.00	0.0060
19760026	1344.00	153	139.80	47.60	4154.20	74.12	150.00	2900	0.9498	0.85	1.12	1.07	1.12	1.0816	3137	1110.25	0.0014
19760027	5297.00	153	139.80	47.60	2590.00	75.74	136.95	2900	0.9319	0.85	1.12	1.07	1.12	1.0590	3071	1110.66	0.0020
19760028	2430.00	153	139.80	47.60	2163.40	69.17	147.15	2900	0.9892	0.84	1.12	1.07	1.12	1.1178	3242	1094.53	0.0052
19760029	624.40	153	139.80	47.60	1452.50	62.95	135.76	2900	0.8961	0.84	1.12	1.07	1.12	1.0071	2920	1098.99	0.0037
19760030	4784.00	153	139.80	47.60	1432.80	57.86	146.28	2900	0.9104	0.84	1.12	1.07	1.12	1.0229	2966	1105.54	0.0015
19760031	1022.00	153	139.80	47.60	1659.00	63.66	144.08	2900	0.9054	0.84	1.12	1.07	1.12	1.0185	2954	1096.51	0.0046
19760032	920.10	153	131.74	49.66	874.80	81.46	130.38	2900	0.9778	0.60	1.12	1.04	1.12	0.7714	2237	1092.00	0.0060
19760033	232.00	153	133.62	49.96	1304.50	71.87	121.17	2900	0.9878	0.60	1.12	1.07	1.12	0.7995	2319	1019.90	0.0060
19760034	2167.00	153	133.62	49.96	1616.10	73.56	133.90	2900	0.8688	0.95	1.12	1.07	1.12	1.1165	3238	889.95	0.0050
19760035	1557.00	153	132.32	49.07	2485.80	88.08	176.82	2900	0.9498	0.67	1.12	1.03	1.12	0.8314	2411	969.02	0.0012
19760036	1078.00	153	133.62	49.96	1526.40	74.72	125.03	2900	1.0237	0.93	1.12	1.07	1.12	1.2876	3734	830.42	0.0060
19760037	8601.50	153	132.32	49.07	2803.50	87.00	161.93	2900	1.0108	1.00	1.12	1.03	1.12	1.3161	3817	977.00	0.0010
19760038	828.30	153	131.74	49.66	992.30	77.24	140.03	2900	1.0000	0.60	1.12	1.04	1.12	0.7890	2288	1103.22	0.0060
19760039	543.20	153	124.28	51.39	2418.40	76.90	170.32	2900	0.9857	0.89	1.12	1.01	1.12	1.1192	3246	1138.29	0.0060
19770001	4707.00	153	170.27	38.24	4517.80	66.73	246.92	2900	1.0151	1.00	1.12	1.04	1.12	1.3266	3847	1039.53	0.0011
19770002	2354.00	153	170.27	38.24	5105.80	63.09	250.00	2900	1.0423	1.00	1.12	1.04	1.12	1.3621	3950	913.06	0.0062
19770003	732.20	153	170.27	38.24	5102.10	63.12	250.00	2900	1.0409	1.00	1.12	1.04	1.12	1.3603	3945	1008.33	0.0024
19770004	1188.00	153	127.13	51.91	4217.00	55.54	150.00	2900	1.0516	1.00	1.12	1.06	1.12	1.3980	4054	1060.16	0.0070
19770005	3684.00	153	127.13	51.91	3611.00	58.96	150.00	2900	1.0165	1.00	1.12	1.06	1.12	1.3513	3919	905.06	0.0070
19770006	1557.00	153	127.13	51.91	3265.20	61.48	150.00	2900	1.0545	1.00	1.12	1.06	1.12	1.4018	4065	898.36	0.0069
19770007	364.50	153	127.13	51.91	4110.30	56.61	150.00	2900	1.0573	1.00	1.12	1.06	1.12	1.4055	4076	1092.00	0.0070
19770008	765.40	153	127.13	51.91	3806.50	58.21	150.00	2900	1.0430	1.00	1.12	1.06	1.12	1.3865	4021	1092.00	0.0070
19770009	413.50	153	135.30	50.49	1698.10	74.40	150.00	2900	1.0394	0.66	1.12	1.10	1.12	0.9563	2773	1092.00	0.0070
19770010	1974.00	153	135.30	50.49	3780.50	60.02	150.00	2900	1.0158	1.00	1.12	1.10	1.12	1.4111	4092	1092.00	0.0070
19770011	719.70	153	135.30	50.49	2152.80	73.66	150.00	2900	1.0366	0.94	1.12	1.10	1.12	1.3573	3936	1092.00	0.0070
19770012	1861.00	153	122.07	52.40	3626.10	63.22	240.44	2900	1.0215	1.00	1.12	1.02	1.12	1.3049	3784	1106.03	0.0066
19770013	203.20	153	122.07	52.40	3109.00	67.19	199.80	2900	1.0430	1.00	1.12	1.02	1.12	1.3324	3864	1092.00	0.0070
19770014	555.40	153	122.07	52.40	4386.60	58.72	250.00	2900	1.0093	1.00	1.12	1.02	1.12	1.2894	3739	1092.00	0.0070
19770015	3346.00	153	119.59	52.53	4103.10	60.66	250.00	2900	1.0308	1.00	1.12	0.99	1.12	1.2864	3731	1282.20	0.0013
19770016	1795.00	153	119.59	52.53	4362.90	59.15	250.00	2900	0.9964	1.00	1.12	0.99	1.12	1.2435	3606	1282.64	0.0012
19770017	1955.00	153	123.14	50.78	3670.80	67.45	214.71	2900	0.9900	1.00	1.12	0.99	1.12	1.2279	3561	1266.25	0.0065
19770018	2992.00	153	123.14	50.78	3289.10	68.96	201.37	2900	0.9785	1.00	1.12	0.99	1.12	1.2137	3520	1267.81	0.0069
19770019	426.00	153	123.14	50.78	3140.20	69.44	197.78	2900	0.9749	1.00	1.12	0.99	1.12	1.2050	3494	1260.00	0.0070
19770020	1084.00	153	119.59	52.53	4124.60	62.17	245.45	2900	1.0129	1.00	1.12	0.99	1.12	1.2641	3666	1339.11	0.0061
19770021	3178.00	153	119.59	52.53	5183.50	58.16	250.00	2900	0.9907	1.00	1.12	0.99	1.12	1.2364	3586	1145.36	0.0069
19770022	1539.00	153	119.59	52.53	1873.70	80.65	170.63	2900	1.0358	0.60	1.12	0.99	1.12	0.7756	2249	1144.57	0.0066
19770023	1838.00	153	119.59	52.53	1820.50	81.79	168.04	2900	0.9950	0.60	1.12	0.99	1.12	0.7451	2161	1131.00	0.0070

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Step- 6: Final Output File

Table- 26: Final Output Table

ID	A	B	Yo	Ye	Yo-Ye)	m	PPI	Ao	m-modi	A-Yo	FUE	B.modi
19750015	1439	0.000243	1270	1197	72	2900	1.3516	3920	1065	169.67	0.1336375	0.0001604
19760015	1439	0.000243	1209	1197	12	2900	1.3085	3795	1100	230.45	0.1906359	0.0002288
19770015	1439	0.000243	1282	1213	69	2900	1.2864	3731	1119	157.10	0.1225240	0.0001593
19780015	1439	0.000243	1176	1197	-21	2900	1.3751	3988	1047	263.31	0.2239051	0.0002687
19790015	1439	0.000243	1130	1302	-172	2900	1.3554	3931	1062	309.51	0.2739537	0.0006301
19800015	1439	0.000243	1401	1302	99	2900	1.3663	3962	1053	38.52	0.0274991	0.0000632
19810015	1439	0.000243	1116	1302	-186	2900	1.3808	4004	1042	323.14	0.2895106	0.0006659
19820015	1439	0.000243	1389	1341	48	2900	1.3123	3806	1097	50.22	0.0361536	0.0001193
19830015	1439	0.000243	1241	1302	-61	2900	1.3456	3902	1070	198.49	0.1599682	0.0003679
19840015	1439	0.000243	1331	1227	105	2900	1.3406	3888	1074	107.97	0.0810995	0.0001135
19850015	1439	0.000243	1385	1302	83	2900	1.3402	3887	1074	54.50	0.0393559	0.0000905
19860015	1439	0.000243	1221	1302	-81	2900	1.3194	3826	1091	218.57	0.1790488	0.0004118
19870015	1439	0.000243	1297	1411	-115	2900	1.3290	3854	1083	142.61	0.1099802	0.0013528
19880015	1439	0.000243	1217	1411	-195	2900	1.3635	3954	1056	222.61	0.1829638	0.0022505
19890015	1439	0.000243	1223	1413	-191	2900	1.3496	3914	1066	216.55	0.1771009	0.0023377
19900015	1439	0.000243	1460	1422	38	2900	1.3431	3895	1072	-20.34	-.0139348	-.0002801
19910015	1439	0.000243	1401	1401	0	2900	1.3496	3914	1066	38.25	0.0273010	0.0002402
19920015	1439	0.000243	1253	1377	-124	2900	1.3812	4005	1042	186.10	0.1485000	0.0008019
19930015	1439	0.000243	1638	1377	261	2900	1.3304	3858	1082	-198.63	-.1212688	-.0006549
19940015	1439	0.000243	1271	1369	-98	2900	1.4059	4077	1024	168.61	0.1326919	0.0006237
19950015	1439	0.000243	1359	1374	-15	2900	1.3534	3925	1063	80.63	0.0593449	0.0003027
19960015	1439	0.000243	1300	1357	-57	2900	1.3825	4009	1041	139.17	0.1070433	0.0004282
19970015	1439	0.000243	1345	1394	-49	2900	1.3793	4000	1044	94.32	0.0701276	0.0005260
19980015	1439	0.000243	1398	1403	-5	2900	1.3434	3896	1071	41.02	0.0293361	0.0002758
19990015	1439	0.000243	1409	1394	15	2900	1.4126	4097	1019	30.69	0.0217876	0.0001612
20000015	1439	0.000243	1418	1409	9	2900	1.3747	3986	1047	21.12	0.0148924	0.0001683
20010015	1439	0.000243	1707	1419	287	2900	1.2191	3535	1181	-267.23	-.1565925	-.0026621
20020015	1439	0.000243	1778	1426	352	2900	1.4256	4134	1010	-338.92	-.1905950	-.0049936
20030015	1439	0.000243	1778	1426	352	2900	1.2470	3616	1154	-338.92	-.1905950	-.0049936
dof = 27	SE =	153.19	t =	0.00223	rsq = 0.481434							
.												
.												
.												
19750027	1412	0.000223	1225	1277	-52	2900	1.3144	3812	1075	187.97	0.1535090	0.0003224
19760027	1412	0.000223	1111	1271	-160	2900	1.0590	3071	1334	301.81	0.2717409	0.0005435
19770027	1412	0.000223	1315	1282	33	2900	1.2635	3664	1118	97.42	0.0740822	0.0001630

19780027	1412	0.000223	1373	1257	116	2900	1.3166	3818	1073	39.59	0.0288385	0.0000519
19790027	1412	0.000223	1208	1301	-93	2900	1.2800	3712	1103	204.44	0.1692357	0.0004400
19800027	1412	0.000223	1698	1301	397	2900	1.2025	3487	1175	-285.67	-.1682242	-.0004374
19810027	1412	0.000223	1179	1301	-122	2900	1.3611	3947	1038	233.43	0.1979846	0.0005148
19820027	1412	0.000223	1468	1308	160	2900	1.3365	3876	1057	-55.78	-.0379896	-.0001064
19830027	1412	0.000223	1391	1341	50	2900	1.2222	3545	1156	21.18	0.0152245	0.0000639
19840027	1412	0.000223	1249	1330	-81	2900	1.3100	3799	1078	163.87	0.1312445	0.0004725
19850027	1412	0.000223	1372	1330	42	2900	1.3218	3833	1069	40.54	0.0295509	0.0001064
19860027	1412	0.000223	1145	1323	-178	2900	1.3217	3833	1069	267.55	0.2336860	0.0007712
19870027	1412	0.000223	1370	1368	1	2900	1.3365	3876	1057	42.84	0.0312798	0.0002158
19880027	1412	0.000223	1226	1356	-130	2900	1.2222	3545	1156	186.29	0.1519285	0.0008204
19890027	1412	0.000223	1207	1340	-133	2900	1.3100	3799	1078	205.76	0.1705147	0.0006991
19900027	1412	0.000223	1526	1386	141	2900	0.9835	2852	1436	-113.98	-.0746688	-.0008662
19910027	1412	0.000223	1345	1388	-42	2900	1.0175	2951	1388	66.98	0.0497825	0.0006173
19920027	1412	0.000223	1383	1366	17	2900	0.9835	2852	1436	29.02	0.0209779	0.0001385
19930027	1412	0.000223	1519	1325	194	2900	0.9835	2852	1436	-106.92	-.0703692	-.0002393
19940027	1412	0.000223	1726	1380	346	2900	1.0175	2951	1388	-313.58	-.1816739	-.0017441
19950027	1412	0.000223	1550	1369	180	2900	1.0175	2951	1388	-137.07	-.0884574	-.0006280
19960027	1412	0.000223	1477	1383	95	2900	1.0175	2951	1388	-64.85	-.0438958	-.0004521
19970027	1412	0.000223	1505	1391	114	2900	1.0175	2951	1388	-92.16	-.0612497	-.0008820
19980027	1412	0.000223	1288	1394	-106	2900	1.0175	2951	1388	124.41	0.0965885	0.0016420
19990027	1412	0.000223	1247	1391	-144	2900	1.3464	3905	1049	165.46	0.1326868	0.0019240
20000027	1412	0.000223	1248	1391	-143	2900	1.3365	3876	1057	164.66	0.1319606	0.0019002
20010027	1412	0.000223	1313	1396	-82	2900	1.2222	3545	1156	99.07	0.0754315	0.0013879
20020027	1412	0.000223	1390	1388	1	2900	1.3100	3799	1078	22.74	0.0163642	0.0002095
20030027	1412	0.000223	1390	1388	1	2900	1.3218	3833	1069	22.74	0.0163642	0.0002095

dof = 27 SE = 151.48 t = 0.00202 rsq = 0.460227

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References

Aggrawal, P.K. and N. Kalra 1994. Analysing the limitations set by climatic factors, genotype. Water -II: climatically potential yields and management strategies. *Field Crops Research.* 38, 93-103.

Aggrawal, P.K. et al. 1994. Analyzing the limitation set by climatic factors, genotype, water and nitrogen availability on productivity of wheat: I- the model description, parameterization and validation. *Field Crops Research.* 38, 73-91.

Aigner, D.J.; C.A.K. Lovell, and P. Schmidt. 1977. Formulation and estimation of stochastic frontier production function. *Journal of Econometrics.* 6, 21-37.

Alvanides, S.; S. Openshaw and J. MacGill 2001. Zone design as a spatial analysis tool, in Nicholas, J.T and P.M. Atkinson (eds): *Modelling Scale in Geographical Information Science.* John Wiley & Sons Ltd. Chichester (England). 141-157.

Anbumozhi, V. *et al.* 2003. The role of crop simulation models in agricultural research and development – a review. *Agricultural Engineering Journal.* 12 (1&2), 1-18.

Anselin, L. 1995. Local indicators of spatial association- LISA. *Geographical Analysis.* 27, 93-115.

Anselin, L. 1998. Exploratory spatial data analysis in a geocomputational environment, in Longley, P.A. et al. (eds): *Geocomputational- A Primer.* John Wiley & Sons Ltd. Chichester (England). 77-94.

Baker, D.N. et al. 1972. Simulation of growth in cotton: I- gross photosynthesis, respiration and growth, *Crop Science.* 12, 431-435.

Blanecy, H.F. and W.D. Criddle 1950. *Determining Water Requirement in Irrigated Areas from Climatical and Irrigation Data.* US Department of SCS. TP- 96.

Burrough, P.A. and R.A. McDonnel 1998. *Principles of Geographical Information Systems.* Oxford University Press. UK. pp. 64-67 and 114-117.

Chatelin,M.H., et al. 2005. DeciBle, a software package for wheat crop management and simulation. *Agricultural Systems.* 83(1), 77-99.

DeWit, C.T. 1958. *Transpiration of crop Yield,* Veerse Landbouwk Ondrez, 64.6 Institute of Biological and Chemical Research on Field Crops and Berbage, Wegeningen, The Netherlands.

DeWit, C.T. et al. 1969. The simulation of photosynthesis systems:I- models and Methods. *Proceedings.* IPB/PP Technical Meeting. Pudoc. wageningen.

Ferrell, M.J. 1957. The measurement of productive efficiency. *Journal of the Royal Statistical Society-A.* 120 (Part-3), 253-281.

Fye, R.E. et al. 1984. The validation of GOSSYM: Part-I. Arizona conditions. *Agricultural Systems.* 14, 85-105.

Goodchild, M.F. 1997. Towards a geography of geographic information in a digital world, *Computers, Environment and Urban Systems,* 21, 377-91.

Gorski, T and W. Spoz-Pac. 1989. A method for forecasting sugar beet yields in Poland. *Zeszyty Problemowe Postepow Nauk Rolniczych.* 369, 31-43.

Gorski, T. and K. Gorska. 2003. The effects of scale on crop yield variability. *Agricultural Systems.* 78, 425-434.

Johns, G.G. and R.C.G. Smith. 1975. Accuracy of soil water budgets based on a range of soil water availability on actual water use. *Australian Journal of Agricultural Research.* 26, 871-883.

Kang, S.Z. *et al.* 2002. Effects of limited irrigation on yield and water use efficiency of winter wheat in the Loess plateau of China. *Agricultural Water Management.* 55, 203-216.

Kang, S.Z., *et al.* 2003. Simulation of winter wheat yield and water use efficiency in the Loess plateau of China using WAVES. *Agricultural Systems.* 78, 355-367.

Kiniry, James R., et al., 2004. Maize yield potential: critical processes and simulation modeling in a high yielding environment. *Agricultural Systems.* 82(1), 45-56.

Mall,R.K. and K.K.Singh. 2000. Climatic variability and wheat yield progress in Punjab using CERES-wheat and WTGROWS models. *Vayu Mandal.* 30(3-4), 35-40.

McCall, D.G. and G.J. Bishop-Hurley. 2003. A pasture growth model for use in a whole farm dairy production model. *Agricultural Systems.* 76(3), 1183-1205.

NBSS & LUP. 1999. *Soils of Assam for Optimizing Land Use.* NBSS Publ-66. Soils of India Series. Nagpur.

Openshaw, S. 1998. Building automated geographical analysis and explanation machines, in Longley, P.A. et al. (eds): *Geocomputation- A Primer.* John Willey & Sons Ltd., Chichester (England). 95-115.

Openshaw, S. et.al. 1987. A mark-I geographical analysis machine for the automated analysis of point datasets. *International Journal of Geographical Information Systems.*1, 335-58.

Papadakis, J. 1952. *Agricultural Geography of the World* (edited Vol.). Buenos Aires.

Prasad, C. *et al.* 1987. *First-line Transfer of Technology Projects.* Publication and Information Division. Indian Council of Agriculture Research. New Delhi.

Reddy, V.R. et al. 1985. Validation of GOSSYM: Part-II. Mississippi conditions, *Agricultural Systems.* 17, 133-154.

Riquier, J.; Bramao, D.L. and Cornet, J.P. 1970. *A New System of Soil Appraisal in Terms of Actual and Potential Productivity.* Monograph No-AGL: TESR/70/6. FAO. Rome.

Ritchie, J.T. 1986. CERES- wheat: a general documentation, USDA-ARS Grassland, Soil and Water Resources Laboratory. Temple. Texas.

Ritchie, J.T. and Otter, S. 1985. Description and performance of CERES-wheat: a user – oriented wheat yield model. in USDA– *ARS Wheat Yield Project.* ARS- 38, National Technical Information Service. Springfield. VA: 159 – 175.

Singandhupe, R.B. and Sethi, R.R. 2004. Computation of evapotranspiration by different methods – a case study, *Indian Journal of Soil Conservation.* 32(1), 5-9.

Singh, S. 2002. Optimising the spatial structure of agricultural production function. *Geographical Analysis.* 34(3), 229-244.

Singh, S., B. Sharma and P.P. Dey 2005. A crop-ecological sustainability simulator (CSS) for fertilizer use efficiency and summer paddy yield management on monsoon lands of Brahmaputra valley, India. Paper submitted for presentation in International Conference on Simulation and Modeling. AIT. Bangkok.

Singh, S. 2000. Modeling, structure and functions of agricultural yield potential. *Transactions of the Institute of Indian Geographers.* 22, 1-15.

Spillman, W.J. 1922. Application of the law of diminishing returns to some fertilizer and seed data. *Journal of Fertilizer Economics.* 5, 36-52.

Spillman, W.J. 1933. Exponential yield function, c.f. Alber, R., Adams, J.S. and Gould, P. 1971. *Spatial Organisation.* Prentice-Hall Inc. Engelwood Cliffs. New Jersey. p.143.

Subash, S.; G.D. Bino-Paul and A. Ramanathan. 2004. Technical efficiency in rice production – an application of stochastic frontier analysis. *Indian Journal of Regional Science.* XXXVI (1), 118-126.

Thornthwaite, C.W. (1931): The climates of N. America, *Geographical Review,* XXI (4): 633-655.

Thornthwaite, C.W. 1931. Climates of North America. *Geographical Review.* 21(4), 633-55.

Thornthwaite, C.W. and J.R. Mather. 1957. *Instructions and Tables for Computing Potential Evapotranspiration and Water Balance,* Publications in Climatology Vol X(3), Drexel Institute of Technology, Centerton, New Jersey.

Wu, H.E. *et al.* 1994. An integrated rate methodology for multi-factor growth rate modeling. *Ecological Model.* 73, 97-116.

Zhang, L. and W. Dawes. 1998. *WAVES – An Integrated Energy and Water Balance Model,* CSIRO Land and Water, Technical Report No. 31/98, Canbera ACT 2601, Australia.

--oOo--

Appendixes

Appendix - I

Conversion of Monthly Temperature (T) and Precipitation (P) in its Required Spatial Dimension

```
'      ***** GENDAT.BAS ****
' Generates data from CSSMDA.2 (obtained from the excel file)
' for the 7 different stations and the corresponding polygon
elements
'
      DIM dist$(18), wt(18, 24), a$(18), t$, tm(7, 12), rf(7,
12), tp$(7)
      DIM gradtm(12), gradrf(12), Otm(12), Orf(12), d(24),
b$(39), yr(29)
      FOR i = 75 TO 99
        yr(i - 74) = i
      NEXT
      FOR i = 2000 TO 2003
      j = i - 1974
      yr(j) = i
      NEXT
'     INPUT "Enter the input filename :"; finp$
'     INPUT "Enter the year :"; yr
      FOR y = 1 TO 29
      PRINT TIME$; ".....Processing data for the year.....";
yr(y)
      OPEN "cssmda.2" FOR INPUT AS #1
' Create a temporary file based on year only
      OPEN "cssmda.tmp" FOR OUTPUT AS #2
1       IF EOF(1) THEN 2
      INPUT #1, a$
      IF VAL(MID$(a$, 15, 4)) = yr(y) THEN PRINT #2, a$
      GOTO 1
2       CLOSE #1, #2
'
'  Read temperature and precipitation for 12 months for each
station
'
      OPEN "cssmda.tmp" FOR INPUT AS #1
3       IF EOF(1) THEN 4
      INPUT #1, a$
      i = VAL(MID$(a$, 2, 1))
      j = VAL(MID$(a$, 23, 2))
      tm(i, j) = VAL(MID$(a$, 30, 5))
      rf(i, j) = VAL(RIGHT$(a$, 5))
      GOTO 3
4       CLOSE #1
```

```
'
' Create the output file with the above data
'
      OPEN "dref" FOR INPUT AS #1
      finp$ = "D" + LTRIM$(STR$(yr(y)))
      D1$ = finp$ + ".1"
      D2$ = finp$ + ".2"
      D3$ = finp$ + ".3"
      D4$ = finp$ + ".4"
      D5$ = finp$ + ".5"
'        D6$ = finp$ + ".o"
      D6$ = "Dall.O"
      OPEN finp$ FOR OUTPUT AS #2
      INPUT #1, a$
      PRINT #2, a$
      INPUT #1, a$
      PRINT #2, SPACE$(75) + a$
'Dhubri(C1) Data Creation
      INPUT #1, a$
      PRINT #2, a$ + SPACE$(14);
      i = 1
      FOR j = 1 TO 12
            PRINT #2, USING ("##.## "); tm(i, j);
      NEXT j
      PRINT #2, SPACE$(4);
      srf = 0
      FOR j = 1 TO 12
      PRINT #2, USING ("####.# "); rf(i, j);
      srf = srf + rf(i, j)
      NEXT j
      PRINT #2, srf
      FOR i = 1 TO 3
            INPUT #1, a$
            PRINT #2, SPACE$(15) + a$
      NEXT
      FOR i = 1 TO 2
            INPUT #1, a$
            PRINT #2, SPACE$(14) + a$
      NEXT
'Guwahati(C2) Data Creation
      INPUT #1, a$
      PRINT #2, a$ + SPACE$(14);
      i = 2
      FOR j = 1 TO 12
            PRINT #2, USING ("##.## "); tm(i, j);
      NEXT j
      PRINT #2, SPACE$(4);
```

```
      srf = 0
      FOR j = 1 TO 12
      PRINT #2, USING ("####.# "); rf(i, j);
      srf = srf + rf(i, j)
      NEXT j
      PRINT #2, srf
      FOR i = 1 TO 2
            INPUT #1, a$
            PRINT #2, SPACE$(35) + a$
      NEXT
      FOR i = 1 TO 5
            INPUT #1, a$
            PRINT #2, SPACE$(15) + a$
      NEXT
      FOR i = 1 TO 3
            INPUT #1, a$
            PRINT #2, SPACE$(14) + a$
      NEXT
'Tezpur(C3) Data Creation
      INPUT #1, a$
      PRINT #2, a$ + SPACE$(12);
      i = 3
      FOR j = 1 TO 12
            PRINT #2, USING ("##.## "); tm(i, j);
      NEXT j
      PRINT #2, SPACE$(4);
      srf = 0
      FOR j = 1 TO 12
      PRINT #2, USING ("####.# "); rf(i, j);
      srf = srf + rf(i, j)
      NEXT j
      PRINT #2, srf
      FOR i = 1 TO 2
            INPUT #1, a$
            PRINT #2, SPACE$(35) + a$
      NEXT
      INPUT #1, a$
      PRINT #2, SPACE$(15) + a$
      FOR i = 1 TO 4
            INPUT #1, a$
            PRINT #2, SPACE$(14) + a$
      NEXT
'Lakhimpur(C4) Data Creation
      INPUT #1, a$
      PRINT #2, a$ + SPACE$(14);
      i = 4
      FOR j = 1 TO 12
```

```
            PRINT #2, USING ("##.## "); tm(i, j);
      NEXT j
      PRINT #2, SPACE$(4);
      srf = 0
      FOR j = 1 TO 12
      PRINT #2, USING ("####.# "); rf(i, j);
      srf = srf + rf(i, j)
      NEXT j
      PRINT #2, srf
      FOR i = 1 TO 2
            INPUT #1, a$
            PRINT #2, SPACE$(35) + a$
      NEXT
      FOR i = 1 TO 4
            INPUT #1, a$
            PRINT #2, SPACE$(14) + a$
      NEXT
'Dibrugarh(C5) Data Creation
      INPUT #1, a$
      PRINT #2, a$ + SPACE$(14);
      i = 5
      FOR j = 1 TO 12
            PRINT #2, USING ("##.## "); tm(i, j);
      NEXT j
      PRINT #2, SPACE$(4);
      srf = 0
      FOR j = 1 TO 12
    PRINT #2, USING ("####.# "); rf(i, j);
      srf = srf + rf(i, j)
      NEXT j
      PRINT #2, srf
      FOR i = 1 TO 2
            INPUT #1, a$
            PRINT #2, SPACE$(35) + a$
      NEXT
      FOR i = 1 TO 6
            INPUT #1, a$
            PRINT #2, SPACE$(14) + a$
      NEXT
'Pashighat(C6) Data Creation
      INPUT #1, a$
      PRINT #2, a$ + SPACE$(14);
      i = 6
      FOR j = 1 TO 12
            PRINT #2, USING ("##.## "); tm(i, j);
      NEXT j
      PRINT #2, SPACE$(4);
```

```
        srf = 0
        FOR j = 1 TO 12
        PRINT #2, USING ("####.# "); rf(i, j);
        srf = srf + rf(i, j)
        NEXT j
        PRINT #2, srf
        FOR i = 1 TO 3
              INPUT #1, a$
              PRINT #2, SPACE$(14) + a$
        NEXT
  'Lumding(C7) Data Creation
        INPUT #1, a$
        PRINT #2, a$ + SPACE$(12);
        i = 7
        FOR j = 1 TO 12
              PRINT #2, USING ("##.## "); tm(i, j);
        NEXT j
        PRINT #2, SPACE$(4);
        srf = 0
        FOR j = 1 TO 12
        PRINT #2, USING ("####.# "); rf(i, j);
        srf = srf + rf(i, j)
        NEXT j
        PRINT #2, srf
        FOR i = 1 TO 3
              INPUT #1, a$
              PRINT #2, SPACE$(35) + a$
        NEXT
        FOR i = 1 TO 8
              INPUT #1, a$
              PRINT #2, SPACE$(14) + a$
        NEXT
        CLOSE #1, #2

  '
  ' End of data creation (based on year input) module.
  '
  '
  ' 1.BAS
  ' Pick up the following from the input file :
  ' Direction information,
  ' Distance from centroid,
  ' and rainfall (if available)
  ' Store them to output file
  '
        OPEN finp$ FOR INPUT AS #1
        OPEN D1$ FOR OUTPUT AS #2
```

```
      INPUT #1, a$
5   IF EOF(1) THEN 6
      INPUT #1, a$
' Records with temperature and precipitation data
    IF MID$(a$, 36, 1) = "C" AND LEN(a$) > 200 THEN PRINT #2,
MID$(a$, 36, 7), MID$(a$, 58, 5), MID$(a$, 74, 167)
' Records without temperature and precipitation data
      IF MID$(a$, 1, 1) = "C" AND LEN(a$) < 63 THEN PRINT #2,
MID$(a$, 1, 7), MID$(a$, 23, 5)
      GOTO 5
6   CLOSE #1, #2

'
'********* 2.BAS ************
'
'The progam sorts the input data in order of the 7th charcter
'
'
      OPEN D1$ FOR INPUT AS #1
      FOR i = 1 TO 18
            INPUT #1, a$(i)
      NEXT
      CLOSE #1
      FOR i = 1 TO 17
            FOR j = i + 1 TO 18
                  IF MID$(a$(i), 7, 1) > MID$(a$(j), 7, 1) THEN
                     t$ = a$(i)
                     a$(i) = a$(j)
                     a$(j) = t$
                  END IF
      NEXT j, i

'
'Fill up the missing Temperature and Precipitation data
'
      FOR i = 1 TO 18
            IF VAL(MID$(a$(i), 29, 5)) > 0 THEN
                  k = VAL(MID$(a$(i), 2, 1))
                  tp$(k) = MID$(a$(i), 30, 165)
            END IF
      NEXT

      FOR i = 1 TO 18
            IF VAL(MID$(a$(i), 29, 5)) = 0 THEN
                  k = VAL(MID$(a$(i), 2, 1))
                  l = LEN(RTRIM$(a$(i)))
                  IF l = 17 THEN
```

```
      a$(i) = a$(i) + SPACE$(12)
                  ELSE
      a$(i) = a$(i) + SPACE$(10)
                  END IF
                  a$(i) = a$(i) + tp$(k)
            END IF
      NEXT
'
'Arranging the data in order of 2nd element within the pair of
records
'
      FOR i = 1 TO 17 STEP 2
            IF MID$(a$(i), 2, 1) > MID$(a$(i + 1), 2, 1) THEN
                  t$ = a$(i)
                  a$(i) = a$(i + 1)
                  a$(i + 1) = t$
            END IF
      NEXT i
'
' Creation of output file Dyy.2
'
      OPEN D2$ FOR OUTPUT AS #1
      FOR i = 1 TO 18
            PRINT #1, a$(i)
      NEXT
      CLOSE #1

'*********** 3.BAS **************
' Calculation of Gradient is done as follows :-
'
' Divide the sum of 3rd column values of two adjacent records by
' the sum of the 2nd column values to get the Gradient.
'
      OPEN D2$ FOR INPUT AS #1
      OPEN D3$ FOR OUTPUT AS #2
7       IF EOF(1) THEN 8
            INPUT #1, a$
            INPUT #1, b$
            l = 29
            m = 105
      FOR i = 1 TO 12 STEP 2
                  tm(1, i) = VAL(MID$(a$, l, 5))
                  rf(1, i) = VAL(MID$(a$, m, 5))
                  l = l + 6
                  m = m + 6
            NEXT
```

```
            FOR i = 1 TO 12
                  tm(2, i) = VAL(MID$(b$, l, 5))
                  rf(2, i) = VAL(MID$(b$, m, 5))
                  l = l + 6
                  m = m + 6
            NEXT
            SUM.OF.2ND.COL.VALUE = VAL(MID$(a$, 16, 4)) +
VAL(MID$(b$, 16, 4))
            FOR i = 1 TO 12
                  gradtm(i) = (tm(1, i) + tm(2, i)) /
SUM.OF.2ND.COL.VALUE
                  gradrf(i) = (rf(1, i) + rf(2, i)) /
SUM.OF.2ND.COL.VALUE
            NEXT
            PRINT #2, a$ + SPACE$(5);
            FOR i = 1 TO 12
          PRINT #2, USING ("##.## "); gradtm(i);
            NEXT
            FOR i = 1 TO 12
          PRINT #2, USING ("####.# "); gradrf(i);
            NEXT
            PRINT #2,
            PRINT #2, b$ + SPACE$(5);
            FOR i = 1 TO 12
                  PRINT #2, USING ("##.## "); gradtm(i);
            NEXT
            FOR i = 1 TO 12
          PRINT #2, USING ("####.# "); gradrf(i);
            NEXT
            PRINT #2,
            GOTO 7
8       CLOSE #1, #2
'
'*********** 4.BAS **************
'
'Next progam sorts the above data on 2nd character
'
      OPEN D3$ FOR INPUT AS #1
      FOR i = 1 TO 18
           INPUT #1, a$(i)
      NEXT
      CLOSE #1
      FOR i = 1 TO 17
      FOR j = i + 1 TO 18
          IF MID$(a$(i), 2, 1) > MID$(a$(j), 2, 1) THEN
            t$ = a$(i)
```

```
            a$(i) = a$(j)
            a$(j) = t$
        END IF
    NEXT j, i
'
'Rearranging the data in order of 2nd element within the pair of
records
'
'FOR i = 1 TO 17 STEP 2
'    IF MID$(a$(i), 2, 1) > MID$(a$(i + 1), 2, 1) THEN
'       t$ = a$(i)
'       a$(i) = a$(i + 1)
'       a$(i + 1) = t$
'    END IF
'NEXT i
'
'Creation of output file Dyy.4
'
     OPEN D4$ FOR OUTPUT AS #1
     FOR i = 1 TO 18
         PRINT #1, a$(i)
     NEXT
     CLOSE #1

'
' ********** 5.BAS *********
'
' Read direction and gradients data from input file
'
     OPEN D4$ FOR INPUT AS #1
     FOR i = 1 TO 18
          INPUT #1, a$
          dist$(i) = LEFT$(a$, 7)
          k = 201
          FOR j = 1 TO 12
               wt(i, j) = VAL(MID$(a$, k, 5))
               k = k + 6
          NEXT
          k = 275
          FOR j = 13 TO 24
               wt(i, j) = VAL(MID$(a$, k, 5))
               k = k + 6
          NEXT
     NEXT
     CLOSE #1
```

```
'
      OPEN finp$ FOR INPUT AS #1
      OPEN D5$ FOR OUTPUT AS #2
      INPUT #1, a$
      INPUT #1, a$
      PRINT #2, SPACE$(75) + a$
9       IF EOF(1) THEN 10
      INPUT #1, a$
      IF MID$(a$, 36, 1) = "C" AND LEN(a$) > 220 THEN
            PRINT #2, a$
            k = 75
            FOR i = 1 TO 12
                  Otm(i) = VAL(MID$(a$, k, 5))
                  k = k + 6
            NEXT
            k = 152
            FOR i = 1 TO 12
                  Orf(i) = VAL(MID$(a$, k, 5))
                  k = k + 7
            NEXT
      END IF
      IF MID$(a$, 1, 1) = "C" AND LEN(a$) < 63 THEN PRINT #2,
SPACE$(35) + a$
      IF MID$(a$, 1, 1) <> "C" AND MID$(a$, 36, 1) <> "C" THEN
'
' Pick up the D.align value to be used as index
'
            j = VAL(MID$(a$, 32, 3))
'
' For each polygon element, rainfall = distance x weight
'
            FOR i = 1 TO 12
                  d(i) = Otm(i) + VAL(MID$(a$, 6, 6)) * wt(j, i)
                  IF d(i) < 0 THEN d(i) = 0
            NEXT
            Trf = 0
            FOR i = 13 TO 24
                  d(i) = Orf(i - 12) + VAL(MID$(a$, 6, 6)) * wt(j,
i)
                  IF d(i) < 0 THEN d(i) = 0
                  Trf = Trf + d(i)
            NEXT
            IF VAL(LEFT$(a$, 2)) > 9 THEN
                  PRINT #2, SPACE$(15) + a$ + SPACE$(24);
            ELSE
                  PRINT #2, SPACE$(16) + a$ + SPACE$(24);
            END IF
```

```
'           FOR i = 1 TO 12
                    PRINT #2, USING ("###.# "); d(i);
                PRINT #2, USING ("###.# "); Otm(i);
            NEXT
'           PRINT #2, SPACE$(5);
            FOR i = 13 TO 24
                PRINT #2, USING ("####.# "); d(i);
            NEXT
            PRINT #2, Trf
      END IF
      GOTO 9
10      CLOSE #1, #2
'
'**** 6.BAS *****
'
      OPEN D5$ FOR INPUT AS #1
      INPUT #1, a$
      INPUT #1, a$
      i = 1
11      IF EOF(1) THEN 12
      INPUT #1, a$
      IF VAL(LEFT$(a$, 2)) >= 1 THEN
            b$(i) = a$
            i = i + 1
      END IF
      GOTO 11
12      CLOSE #1
'
'Sort the data according to 1st column ie according to polygon
elements
'
      FOR i = 1 TO 38
      FOR j = i + 1 TO 39
            IF VAL(LEFT$(b$(i), 2)) > VAL(LEFT$(b$(j), 2)) THEN
                  t$ = b$(i)
                  b$(i) = b$(j)
                  b$(j) = t$
            END IF
      NEXT j, i
'
' Append sorted data into the final output file DALL.O
'
'       open D6$ for output as #1
      OPEN D6$ FOR APPEND AS #1
    IF yr(y) < 100 THEN
       PRINT #1, yr(y) + 1900
```

```
ELSE
   PRINT #1, yr(y)
END IF
  FOR i = 1 TO 9
        PRINT #1, SPACE$(1) + b$(i)
  NEXT
  FOR i = 10 TO 39
        PRINT #1, b$(i)
  NEXT
  CLOSE #1
'
' Delete all the temporary files
'
'   KILL finp$
'   KILL D1$
'   KILL D2$
'   KILL D3$
'   KILL D4$
'   KILL D5$
 NEXT y
 END
```

(The Program was prepared in the Computer Centre, North Eastern Hill University Shillong)

Appendix – II

Calculation of Monthly Heat Index, ET, PET, ST and their Associated Crop-growth Indexes, as Summary file generation

```
    CLS
    DIM hi(47), t(136), uadjpet(136, 47), TEMP(12), CORRFACT(2,
12), upet(12)
    DIM rf(12), accwl(12), ST(12), DST(12), PET(12), P.PET(12),
ET(12)
    DIM T150(80, 11), T200(106, 11), T250(141, 11), GI(12),
WUE(12), hidx(12)
    DIM area39(39), sci(39)
    GOSUB 100
    GOSUB 200
    GOSUB 300
    GOSUB 400
    GOSUB 500
    GOSUB 600
    GOSUB 700
    OPEN "DALL.O" FOR INPUT AS #1
    OPEN "summary.o" FOR OUTPUT AS #2
    OPEN "AREARAT.O" FOR INPUT AS #3
    PRINT #2, "                              ...... S  e  a  s  o  n
a  l ......"
    PRINT #2, "                                 H e a t
Precipitation    Monthly"
    PRINT #2, "                      Crop     I n d e x
Soil     Genet"
    PRINT #2, "                      Durtn   Tot    (%)    Tot
(%)    Moisture   Co-eff"
    PRINT #2, "ID          Area     (Days)
(ST in mm)    (m)      SCI       GI     WUE    TEI    FEI   PPI     A
Yield   Fertiliser"
    FOR years = 1 TO 29
     INPUT #1, a$
     b$ = LEFT$(a$, 5)
     PRINT TIME$; " Processing data for the year " + LEFT$(a$, 5)
     FOR ii = 1 TO 39
        INPUT #1, a$
        INPUT #3, C$
        IF ii < 10 THEN PRINT #2, b$ + "000" + LTRIM$(STR$(ii));
        IF ii > 9 THEN PRINT #2, b$ + "00" + LTRIM$(STR$(ii));
        PRINT #2, USING (" ####.##   153   "); area39(ii);
```

```
        IF ii < 10 THEN
           k = 58
           l = 135
        ELSE
           k = 59
           l = 136
        END IF
        hi.jan.dec = 0
        hi.jun.oct = 0
        FOR j = 1 TO 12
            TEMP(j) = VAL(MID$(a$, k, 5))
            rf(j) = VAL(MID$(a$, l, 6))
            hidx(j) = (TEMP(j) / 5) ^ (1.514)
            hi.jan.dec = hi.jan.dec + hidx(j)
            IF j >= 6 AND j <= 10 THEN hi.jun.oct = hi.jun.oct +
hidx(j)
            k = k + 6
            l = l + 7
        NEXT j
'       PRINT #2, hi.jan.dec, hi.jun.oct,
hi.jun.oct*100/hi.jan.dec
        PRINT #2, USING ("###.## ###.## "); hi.jan.dec;
hi.jun.oct * 100 / hi.jan.dec;
' Unadjusted PET Calculation ...
        FOR k = 1 TO 12
            IF (TEMP(k) <> 0) THEN
               IF TEMP(k) >= 34 THEN
                  i = 136
               ELSE
                  i = 1
                  WHILE (TEMP(k) > t(i))
                        i = i + 1
                  WEND
               END IF
               IF (hi >= 140) THEN
                  j = 47
               ELSE
                  j = 1
                  WHILE (hidx(k) > hi(j))
                        j = j + 1
                  WEND
              END IF
            END IF
            upet(k) = uadjpet(i, j)
       NEXT
'      PRINT #2,
```

```
'  PET Calculation .......
      FOR i = 1 TO 12
         IF (ii >= 1 AND ii <= 14) OR (ii >= 22 AND ii <= 39)
THEN
            PET(i) = upet(i) * CORRFACT(1, i)
            P.PET(i) = rf(i) - PET(i)
         ELSE
            PET(i) = upet(i) * CORRFACT(2, i)
            P.PET(i) = rf(i) - PET(i)
         END IF
      NEXT
' Total Precipitation Calculation ......
      Trf12 = 0
      Trf5 = 0
      FOR i = 1 TO 12
          Trf12 = Trf12 + rf(i)
          IF i >= 6 AND i <= 10 THEN Trf5 = Trf5 + rf(i)
      NEXT
'     PRINT #2, Trf12,Trf5,Trf5*100/Trf12
      PRINT #2, USING ("####.## ###.##    "); Trf12; Trf5 * 100
/ Trf12;
      FOR i = 1 TO 12: accwl(i) = rf(i): NEXT i
      i = 7
      x = 0
      WHILE (rf(i) >= 0 AND i < 12)
            i = i + 1
      WEND
      IF i = 12 THEN
         accwl(1) = rf(1) + rf(12)
         x = 1
      END IF
      IF (i < 12) THEN
         FOR k = i + 1 TO 12
             IF accwl(k - 1) < 0 THEN accwl(k) = accwl(k - 1) +
rf(k)
         NEXT
      END IF
      IF (accwl(12) < 0 AND x = 0) THEN
         accwl(1) = rf(1) + accwl(12)
      END IF
      FOR k = 2 TO 6
          IF accwl(k - 1) < 0 THEN
             accwl(k) = accwl(k - 1) + rf(k)
          END IF
      NEXT
'
' ST Values calculation
```

```
    FOR i = 1 TO 12
        IF accwl(i) < 0 THEN ST(i) = accwl(i)
    NEXT
    IF (ii >= 4 AND ii <= 8) OR (ii >= 24 AND ii <= 31) OR (ii
>= 33 AND ii <= 34) OR ii = 36 THEN
        FOR i = 1 TO 12
            IF accwl(i) < 0 THEN
               x = INT(ABS(accwl(i)))
               k = INT(x / 10) * 10
               m = x - k + 1
               l = 1
               WHILE (k < T150(l, 1) AND l < 80)
                     l = l + 1
               WEND
               ST(i) = T150(l + 1, m)
            ELSE
               IF i > 1 THEN ST(i) = ST(i - 1) + accwl(i)
               IF i = 1 THEN ST(i) = accwl(i)
               IF ST(i) > 150 THEN ST(i) = 150
            END IF
            WUE(i) = ST(i) / 150
        NEXT
    END IF
    IF (ii >= 1 AND ii <= 3) OR (ii >= 12 AND ii <= 23) OR ii
= 35 THEN
        FOR i = 1 TO 12
            IF accwl(i) < 0 THEN
               x = INT(ABS(accwl(i)))
               k = INT(x / 10) * 10
               m = x - k + 1
               l = 1
               ST(i) = T250(l + 1, m)
            ELSE
               IF i > 1 THEN ST(i) = ST(i - 1) + accwl(i)
               IF i = 1 THEN ST(i) = accwl(i)
               IF ST(i) > 250 THEN ST(i) = 250
            END IF
            WUE(i) = ST(i) / 250
        NEXT
    END IF
    IF (ii = 32 OR ii = 37 OR ii = 38 OR ii = 39) THEN
        FOR i = 1 TO 12
            IF accwl(i) < 0 THEN
               x = ABS(accwl(i))
               k = INT(x / 10) * 10
               m = x - k + 1
```

```
                l = 1
                WHILE (k < T200(l, 1) AND l < 106)
                    l = l + 1
                WEND
                ST(i) = T200(l + 1, m)
            ELSE
                IF i > 1 THEN ST(i) = ST(i - 1) + accwl(i)
                IF i = 1 THEN ST(i) = accwl(i)
                IF ST(i) > 200 THEN ST(i) = 200
            END IF
            WUE(i) = ST(i) / 200
        NEXT
    END IF
    TST12 = 0
    TST5 = 0
    FOR i = 1 TO 12
        TST12 = TST12 + ST(i)
        IF i >= 6 AND i <= 10 THEN TST5 = TST5 + ST(i)
    NEXT
'   PRINT #2, TST12/12,TST5/5
    PRINT #2, USING ("###.##       "); TST12 / 12;
'
' Delta ST Values calculation
' difference of ST  (Jan-Feb, Feb-Mar...... Dec-Jan)
'
    DST(1) = ST(1) - ST(12)
    FOR i = 2 TO 12
        DST(i) = ST(i) - ST(i - 1)
    NEXT
'
' Evapotranspiration(ET) calculation
'
    FOR i = 1 TO 12
        IF rf(i) >= PET(i) THEN ET(i) = PET(i)
        IF rf(i) < PET(i) THEN ET(i) = rf(i) - DST(i)
    NEXT
' Genetic Co-efficient (m) ..............
'
   m=2900
   PRINT #2, using("#### ");m;
' Soil Characteristics Index
'
    PRINT #2, USING ("  #.####"); sci(ii);
'
' Growth Factor(GI) Calculation ..........
    FOR i = 1 TO 12
' ******* Correction added for PET(i)=0 situation ******
```

```
        IF PET(i) > 0 THEN GI(i) = ET(i) / PET(i)
    NEXT
    SGI = 0
    FOR i = 6 TO 10
        SGI = SGI + GI(i)
    NEXT
    PRINT #2, USING (" ###.## "); SGI / 5;
'
' Water Use Efficiency(WUE) Calculation ...
'
    SWUE = 0
    FOR i = 6 TO 10
        SWUE = SWUE + WUE(i) / .89
    NEXT
    PRINT #2, USING ("###.## "); SWUE / 5;
' Temperature Efficiency Index (TEI) Calculation
    STEI5 = 0
    FOR i = 6 TO 10
        STEI5 = STEI5 + (hidx(i) - 2.856) / 9.79
    NEXT
    PRINT #2, USING ("##.## "); STEI5 / 5;
'
' Photosynthetic Efficiency Index (FEI) Calculation
'
    FEI = 1.12
    PRINT #2, USING ("#.##  "); FEI;
    PPI = sci(ii)*(SGI/5)*(SWUE/5)*(STEI5/5)*FEI
    PRINT #2, using (" #.#### ");PPI;
    A = m*PPI
    PRINT #2, using ("####  "); A;
    PRINT #2, RIGHT$(C$, 16)

  NEXT ii
 NEXT years
 CLOSE #1, #2, #3
 END


100 OPEN "uadjpet.txt" FOR INPUT AS #1
 INPUT #1, a$
 INPUT #1, a$
 INPUT #1, a$
 x$ = ""
 k = 1
 FOR i = 7 TO LEN(a$)
     IF MID$(a$, i, 1) <> " " THEN
        x$ = x$ + MID$(a$, i, 1)
```

```
        ELSE
           hi(k) = VAL(x$)
           k = k + 1
           x$ = ""
        END IF
    NEXT
    hi(k) = VAL(x$)
    FOR i = 1 TO 136
        INPUT #1, a$
        t(i) = VAL(LEFT$(a$, 5))
        k = 8
        FOR j = 1 TO 47
            uadjpet(i, j) = VAL(MID$(a$, k, 3))
            k = k + 4
        NEXT
    NEXT
    CLOSE #1
    RETURN

'      Read correction factor from CORRFACT
200   OPEN "CORRFACT" FOR INPUT AS #1
      FOR i = 1 TO 2
          INPUT #1, a$
          k = 8
          FOR j = 1 TO 12
              CORRFACT(i, j) = VAL(MID$(a$, k, 5))
              k = k + 8
          NEXT
      NEXT
      CLOSE #1
      RETURN

300 OPEN "150.tab" FOR INPUT AS #1
    INPUT #1, a$
    FOR i = 1 TO 80
        INPUT #1, a$
        k = 1
        FOR j = 1 TO 11
            T150(i, j) = VAL(MID$(a$, k, 4))
            k = k + 4
        NEXT j
    NEXT i
    CLOSE #1
    RETURN

400 OPEN "200.tab" FOR INPUT AS #1
    INPUT #1, a$
```

```
    FOR i = 1 TO 106
        INPUT #1, a$
        k = 1
        FOR j = 1 TO 11
            T200(i, j) = VAL(MID$(a$, k, 4))
            k = k + 4
        NEXT j
    NEXT i
    CLOSE #1
    RETURN

500 OPEN "250.tab" FOR INPUT AS #1
    INPUT #1, a$
    FOR i = 1 TO 141
        INPUT #1, a$
        k = 1
        FOR j = 1 TO 11
            T250(i, j) = VAL(MID$(a$, k, 4))
            k = k + 4
        NEXT j
    NEXT i
    CLOSE #1
    RETURN
'
'   read the area of 39 locations
'
600 OPEN "area39.txt" FOR INPUT AS #1
    FOR i = 1 TO 39
        INPUT #1, a$
        area39(i) = VAL(MID$(a$, 8, 8))
    NEXT
    CLOSE #1
    RETURN
700 OPEN "SCI.TXT" FOR INPUT AS #1
    INPUT #1, a$
    FOR i = 1 TO 39
        INPUT #1, a$
        sci(i) = VAL(MID$(a$, 3,9))
    NEXT
    CLOSE #1
    RETURN
```

(The Program was prepared in the Computer Centre, North Eastern Hill University Shillong)

Appendix - III

Conversion of Technological Inputs and Crop Yield from District based Data to OTU

```
    DIM Y(29, 11),Z(29,11)
    GOSUB 100
    FOR yr = 1975 TO 2003
        OPEN "yld_conv.txt" FOR INPUT AS #1
        OPEN "arearat.o" FOR APPEND AS #2
        s = 0
        INPUT #1, a$
'       PRINT #2, a$
1       IF EOF(1) THEN 2
        INPUT #1, a$
        IF MID$(a$, 3, 6) = "      " THEN
            area = VAL(MID$(a$, 9, 6))
            IF s > 0 THEN PRINT #2, USING ("####.##  ##.####");
s,t
            s = 0
            t=0
            IF VAL(MID$(a$, 1, 2)) < 10 THEN PRINT #2, STR$(yr) +
"000" + MID$(a$, 1, 2),
            IF VAL(MID$(a$, 1, 2)) > 9 THEN PRINT #2, STR$(yr) +
"00" + MID$(a$, 1, 2),
        ELSE
            IF VAL(MID$(a$, 1, 2)) < 10 THEN
                x = VAL(MID$(a$, 1, 1))
            ELSE
                x = VAL(MID$(a$, 1, 2))
            END IF
            a = VAL(MID$(a$, 3, 10))
            b = a / area
            s = s + b * Y(yr - 1974, x)
            t = t + b * Z(yr - 1974, x)
'           PRINT #2, USING ("    ##  ####.#   #.####"); x; a; b
        END IF
        GOTO 1
2       PRINT #2, USING ("####.##  ##.####"); s,t
        CLOSE #1, #2
        NEXT
    END
```

```
100  OPEN "YIELD.TXT" FOR INPUT AS #1
     INPUT #1, a$
     FOR i = 1 TO 29
        INPUT #1, a$
        FOR j = 1 TO 11
            INPUT #1, a$
            Y(i, j) = VAL(MID$(a$, 22, 6))
            Z(i,j)=   VAL(MID$(a$, 30, 7))
        NEXT j
     NEXT i
     CLOSE #1
     RETURN
```

(The Program was prepared in the Computer Centre, North Eastern Hill University Shillong)

Appendix - IV

The program takes 29 years data for 39 OTUs Calculates Yield Difference (Yo-Ye), Max. Possible Yield(A), Yield Gap (A-Yo), Reproductive Yield (B), Fertiliser Yield Efficiency (FUE), Potential Productivity Index (PPI) and Modified Genetic Yield (m-modi) (areasum1.o in an input file which is processed to generate output file calyld1.o.)

```
    DIM id$(29), x(29), Y(29), Yeinv(29), xinv(29), yinv(29),
Ye(29)
    DIM sxinv(29), syinv(29), sxy(29), sxsq(29), A(29), b(29),
b.by.A(29)
    DIM s.Ye.y.sq(29), Ainv(29), m(29), PPI(29), A0(29)
    CLS
    OPEN "areasum1.o" FOR INPUT AS #1
    OPEN "calyld1.o" FOR OUTPUT AS #2
    N = 29
    FOR ii = 1 TO 39
    sxinv = 0
    syinv = 0
    sy = 0
    sxy = 0
    sxsq = 0
    s.Ye.y.sq = 0

    FOR i = 1 TO N
        INPUT #1, A$
        id$(i) = MID$(A$, 1, 9)
        Y(i) = VAL(MID$(A$, 15, 8))
        x(i) = VAL(MID$(A$, 29, 7))
        m(i) = VAL(MID$(A$, 43, 5))
        PPI(i) = VAL(MID$(A$, 57, 8))
        A0(i) = VAL(MID$(A$, 71, 5))
        xinv(i) = 1 / x(i)
        yinv(i) = 1 / Y(i)
        'PRINT id$(i), y(i), x(i)
    NEXT
    FOR i = 1 TO 29
        sy = sy + Y(i)
        sxinv = sxinv + xinv(i)
        syinv = syinv + yinv(i)
    NEXT
    FOR i = 1 TO 29
        sxy = sxy + (xinv(i) - sxinv / 29) * (yinv(i) - syinv /
29)
```

```
        sxsq = sxsq + (xinv(i) - sxinv / 29) * (xinv(i) - sxinv
/ 29)
    NEXT
    b.by.A = sxy / sxsq
    Ainv = syinv / 29 - b.by.A * sxinv / 29
    A = 1 / Ainv
    b = A * b.by.A
    s.yinv.Yeinv.sq = 0
    s.Ye.ymean.sq = 0
    s.Y.ymean.sq = 0
    FOR i = 1 TO 29
        Ye(i) = A / (1 + b / x(i))
        Yeinv(i) = (1 + b / x(i)) / A
        s.Ye.y.sq = s.Ye.y.sq + (Ye(i) - Y(i)) ^ 2
        s.yinv.Yeinv.sq = s.yinv.Yeinv.sq + (yinv(i) - Yeinv(i))
^ 2

        s.Ye.ymean.sq = s.Ye.ymean.sq + (Ye(i) - sy / 27) ^ 2
        s.Y.ymean.sq = s.Y.ymean.sq + (Y(i) - sy / 27) ^ 2
    NEXT
    SE = SQR(s.Ye.y.sq / 27)
    SEinv = SQR(s.yinv.Yeinv.sq / 27)
    t = b.by.A / SEinv
    rsq = s.Ye.ymean.sq / s.Y.ymean.sq
    PRINT #2, "ID            A      B       Yo    Ye   (Yo-Ye)  m
PPI     A0   m-modi      A-Yo      FUE       B.modi"
    FOR i = 1 TO 29
        PRINT #2, id$(i); USING (" #####  #.###### ####  ####
####   ####   #.####   ####   ####   #####.##  #.#######
#.#######"); A; b; Y(i); Ye(i); Y(i) - Ye(i); m(i); PPI(i);
A0(i); A / PPI(i); A - Y(i); (A - Y(i)) / Y(i); ((A - Y(i)) *
x(i)) / Y(i)
    NEXT i
    PRINT #2, USING ("dof = ##  SE = ####.##  t = ##.#####  rsq
= #.######"); N - 2; SE; t; rsq
    NEXT ii
    CLOSE #1, #2
    END
```

(The Program was prepared in the Computer Centre, North Eastern Hill University Shillong)

About the Author

Surendra Singh did his Ph.D in Agricultural Geography in 1979 and is currently working as Professor in the Department of Geography at North-Eastern Hill University, Shilong-793022 (India). He contributed many research articles on agricultural sustainability which published in different Journals of National as well as International repute. He visited many research Institutions under collaborative work including Institute of Geography and Spatial Organization, Polish Academy of Sciences, Warsawa, Institute of Cultivation, Pulawy (Poland) to deliver a series of lectures and also has been Visiting Professor to teach a course on Agricultural Development (January - April 2004) at the Asian Institute of Technology, Bangkok. His major interests are in sustainable agricultural development especially the development of tools for prediction of crop yield. He is at present the coordinator of the Indo- Polish (DST-KBN) Collaborative Research Programme and also coordinator of Special Assistance Programme (SAP) at Department of Geography in the University, sponsored by University Grants Commission, New Delhi.

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