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# Agro-climatical zoning using temporal satellite data and GIS

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**An Agro-climatic zone is a region with a characteristic inter-relationship between agronomy/farming systems and climate. In this study a modest attempt has been made to divide the study area into homogenous climatic zones.The study was conducted in Pathanamthitta district which is a part Western Ghat ecosystem and is situated between 76$^0$ 29' to 77$^0$ 01' E longitude and 9$^0$ 06' N to 9$^0$ 30' N latitude. Terra MODIS data products i.e., Terra/MODIS Surface Reflectance and Terra/MODIS Land Surface Temperature were used for the study other than ancillary data.Agro-climatic zones were based on criteria of agro-climatic parameters viz. Temperature, Rainfall, Potential Evapotranspiration, Thermal index and Moisture index. Regression analysis to assess the relationship between elevation and temperature indicates strong negative trend and the coefficients were found significant. The data clearly reveals that with increase in elevation there is corresponding decrease in temperature.**

**Key words :** Agro-climatical, Zoning, Kerala gis.

## INTRODUCTION

As a result sustainable agricultural development planning is increasingly being based on agro-ecological zones. In this process agro climate zoning has become very popular (Krishnan, A 1988). Agro-climatic zone is a region with a characteristic inter-relationship between agronomy/farming systems and climate.

Agro-climatic zones were based on criteria of agro-climatic parameters viz. Temperature, Rainfall, Potential Evapotranspiration, Thermal index and Moisture index. The agro-climatic regime map is prepared by GIS aided integration of thermal regimes, rainfall zone, moisture index zone and biomass regimes map layers.

The overall objective of the present effort was to demonstrate the usefulness of Remote Sensing and Geographical Information System technology for delineating agro climatic zones based on thermal index and moisture index and to assess elevation based spatial variation in climate over Pathanamthitta district of Kerala.

## GENERAL DESCRIPTION OF STUDY AREA

### Geographical Setting :

The study area for Agro-climatical zoning is Pathanamthitta district which is a part Western Ghat ecosystem. The study area is situated between 76$^0$ 29' to 77$^0$ 01' E longitude and 9$^0$ 06' N to 9$^0$ 30' N latitude. The total area of the district is 2642 sq. km., of this 1390.73 sq.km., comes under forest. The study area extends to nearly 124498 Ha.

## DATA USED

### Satellite Data:

Terra MODIS data products were used for the study and the details are given in the table1.

### Meteorological data:

Minimum temperature, maximum temperature, rainfall, relative humidity, wind speed and sunshine hours of six met station within and surrounding the study area were collected and used for the study purpose.

**Table1 :** Data used for the study

| Data | Period | Spatial Resolution |
|---|---|---|
| Terra/MODIS Surface Reflectance | January to December ( 8 daily composite) | 250m |
| Terra/MODIS Land Surface Temperature | January to December (8 daily composite) | 1000m |

**Table 2 :** Terra MODIS surface reflectance data set

| EDG Data Set Name | Granule Shortname |
|---|---|
| MODIS/Terra Surface Reflectance 8-Day L3 Global 250m SIN Grid | MOD09Q1 |

| SDS | Units | Data Type-bit | Fill Value | Valid Range | Multiply by Scale Factor |
|---|---|---|---|---|---|
| Surface Reflectance for band 1 (620-670 nm) | reflectance | 16-bit signed integer | -28672 | -100 - 16000 | 0.0001 |
| Surface Reflectance for band 2 (841-876 nm) | reflectance | 16-bit signed integer | -28672 | -100 - 16000 | 0.0001 |
| *Surface reflectance 250m quality control flags | Bit field | 16-bit unsigned integer | 65535 | 0-4294966531 | |

Source: http://edcimswww.cr.usgs.gov

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**Table 3 :** Terra/MODIS Land Surface Temperature data set

| EDG Data Set Name | | | | | Granule Short name | |
|---|---|---|---|---|---|---|
| MODIS/Terra Land Surface Temperature/Emissivity 8-Day L3 Global 1km SIN Grid | | | | | MOD11A2 | |
| SDS | Units | Data Type-bit | Fill Value | Valid Range | Multiply by Scale Factor | Add Additional Offset |
| Daily daytime 1km grid Land-surface Temperature | Kelvin | 16-bit unsigned integer | 0 | 7500 - 65535 | 0.0200 | na |
| *Quality control for daytime LST and emissivity | na | 8-bit unsigned integer | 0 | 0 - 255 | na | na |
| Time of daytime Land-surface Temperature observation | Hrs | 8-bit unsigned integer | 0 | 0 - 240 | 0.1000 | na |
| View zenith angle of daytime Land-surface Temperature | Degree | 8-bit unsigned integer | 255 | 0 - 130 | 1.0000 | -65.0000 |
| Daily nighttime 1km grid Land-surface Temperature | Kelvin | 16-bit unsigned integer | 0 | 7500 - 65535 | 0.0200 | na |
| Quality control for nighttime LST and emissivity | na | 8-bit unsigned integer | 0 | 0 - 255 | na | na |
| Time of nighttime Land-surface Temperature observation | Hrs | 8-bit unsigned integer | 0 | 1 - 240 | 0.1000 | na |
| View zenith angle of nighttime Land-surface Temperature | Degree | 8-bit unsigned integer | 255 | 0 - 130 | 1.0000 | -65.0000 |
| Band 31 emissivity | na | 8-bit unsigned integer | 0 | 1 - 255 | 0.0020 | 0.4900 |
| Band 32 emissivity | na | 8-bit unsigned integer | 0 | 1 - 255 | 0.0020 | 0.4900 |
| Clear-sky Days | na | 8-bit unsigned integer | 0 | 0 - 255 | na | na |
| Clear-sky Nights | na | 8-bit unsigned integer | 0 | 0 - 255 | na | na |

## MATERIALS AND METHODS

The various procedures adopted in the present investigation consists of following important steps.

**Creation of Agro-climatic parameters database:**

a. Annual temperature
b. Annual rainfall
c. Potential evapotranspiration (PET)
d. Moisture Index (MI)
e. Thermal Regimes
f. Vegetation Biomass variability

**a. Annual Temperature**

Annual mean temperature is obtained from meteorological data and Land surface temperature is derived from Terra MODIS data product MOD11A2.

**c. Potential Evapotranspiration (PET)**

Mean monthly temperature was adopted for computing monthly potential evapotranspiration. The method was the mean monthly temperature, the latitude of the place and month of the year to compute the PET. It is calculated as:

$$\mathbf{PET = 1.6\ (10\ T_{ijk}/I_{jk})^{a_{jk}}}$$

Where,

$$I_{jk} = \sum_{i=Jan}^{Dec} (T_{ijk}/5)^{1.514}$$

T = Mean air temperature (°C)

i = Month of a year (i = Jan, Feb, ……Dec)

j = Pixel value of i th row

k = Pixel value of j th column

a = An empirical exponent computed by the following expression:

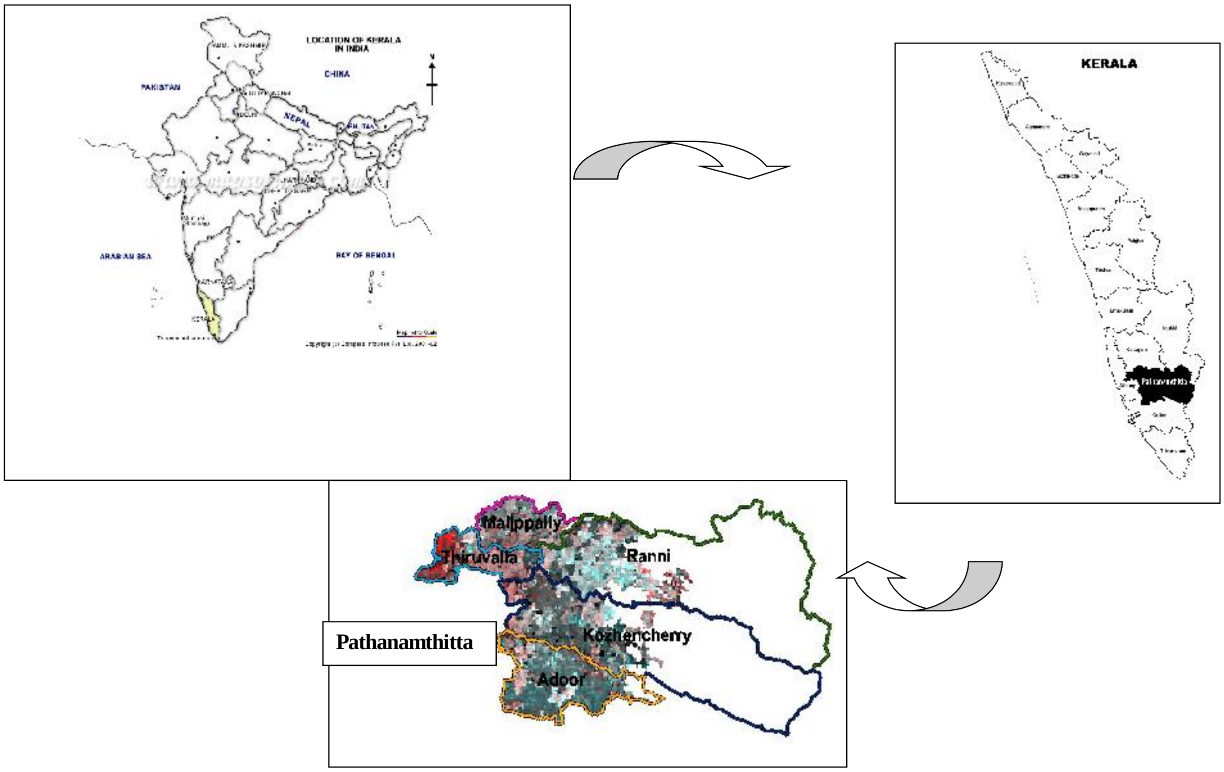
$$a_{jk} = 67.5*10^{-8}(I_{jk})^3 - 7.71*10^{-5}*(I_{jk})^2 + 0.01792(I_{jk}) + 0.4923$$

For adjusted PET, the formula is modified as under:

PET = (K x e x 10) mm per month.

Where K value for meteorological stations of the study area is obtained from reference table (Michael, 1978). It is correction factor of the place.

**Fig. 1 :** Location Map of Study Area




**d. Moisture Index (MI)**

The revised moisture index of Thornwaite and Mather (1955) method based on precipitation and potential evapotranspiration was used.

$$MI = \frac{P - PET}{PET} \times 100$$

Where,

| | | |
|---|---|---|
| M | = | Moisture Index |
| P | = | Precipitation (mm) |
| PET | = | Potential Evapotranspiration (mm) |

The moisture index with positive and negative values indicates moist or dry climate and seasonal variation of effective moisture. The assessment of moisture index (MI) which stands for a balance between moisture availability and extent of dryness and thermal efficiency indicative of radiation energy received and summer concentration, represents the percentage of solar radiation in summer. This information is vital to congenial biotic environment and has been used to classify the agro-climatic types.

To arrive at homogeneous zones, the limits of moisture index of the various agro-climatic types was scaled as:

**Moisture index classifications:**

| **Climatic type** | **Moisture Index** | **Classification** |
|---|---|---|
| Semi arid | - 66.7 to – 33.3 | D |
| Dry sub humid | - 33.3 to 0 | C1 |
| Moist sub humid | 0 to 20 | C2 |
| Humid | 20 to 100 | B1, B2, B3 AND B4 |
| Per humid | > 100 | A |

**e. Thermal regimes**

Temperature regime is important properties which controls the soil formation as well as plant growth. The thermal index was calculated as :

$$Ti = \frac{T_{max} + T_{min}}{2}$$

Climate on the basis of thermal index (Ti)

| **Climate group** | **Thermal Index** |
|---|---|
| Warm Temperate | 10 to 15 °C |
| Sub - Equatorial | 15 to 20 °C |
| Equatorial | > 20 °C |

**f. Vegetation Biomass variability**

Using NDVI to estimate standing green biomass proved to be a reliable source of biomass data. A existing functional relationship between monthly cutting of green dry matter (DM) and the advanced Terra MODIS normalized difference vegetation index (NDVI) was used to derive the Max NDVI in a year is in order to retrieved biomass and the equation is:

$DM=(1.615*NDVI_{max})^{1.318}$ ; $R^2=0.90$

Biomass (Kg/ha) = $1000*[(1.615*(NDVI_{max})^{1.318}]$

Where : NDVImax= Maximum monthly NDVI in year

$NDVI=(\rho2 - \rho1)/(\rho2 + \rho1)$

$\rho1$, $\rho2$ are reflectances in Terra MODIS Band 1 and Band 2, respectively ]

The biomass value :

Biomass

| Class | Value (Kg/Ha) |
|---|---|
| 1. | <1200 |
| 2. | 1200-1300 |
| 3. | 1300-1400 |
| 4. | >1400 |

**Creation of Physiographic-soil and Terrain Slope data base**

The soil resource inventory was compiled from reports of Department of Soil Survey, Kerala and terrain slope map of study area was created using Digital Elevation Model (DEM) generated from the Survey of India toposheets

**Agro-climatic zones (ACZ)**

Agro-climatic zones is a region with a characteristic inter-relationship between agronomy/farming systems and climate.

Agro-climatic zones were based on criteria of agro-climatic parameters viz. Temperature, Rainfall, Potential Evapotranspiration, Thermal index and Moisture index. The agro-climatic regime map was prepared by GIS aided integration of thermal regimes, rainfall zone, moisture index zone and biomass regimes map layers.

**Agro- edaphic zones (AEdZ)**

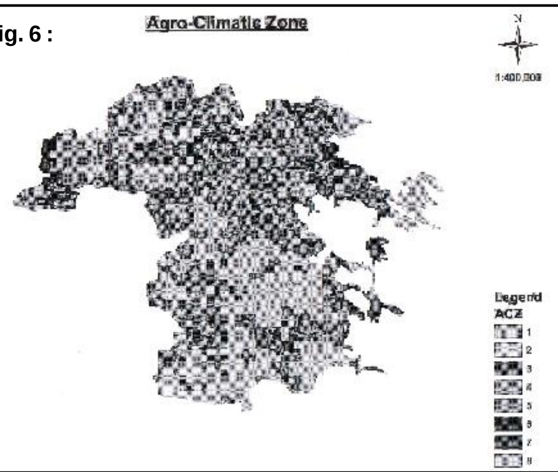
Agro-edhapic zones depicting soil and terrain potentiality for agriculture was generated by combining soil characteristics (physiography soil texture, and soil depth), and slope.

## RESULTS AND DISCUSSION

**Delineation of Agro Climatic Zones**

The essential elements in demarcating of Agro-climatic zones are thermal regime and moisture regime. Thermal regimes indicate to the amount of heat available for plant growth and development during the growing period. Moisture regimes are the vital to classify the agro-climatic zones.

**Fig. 6 :**



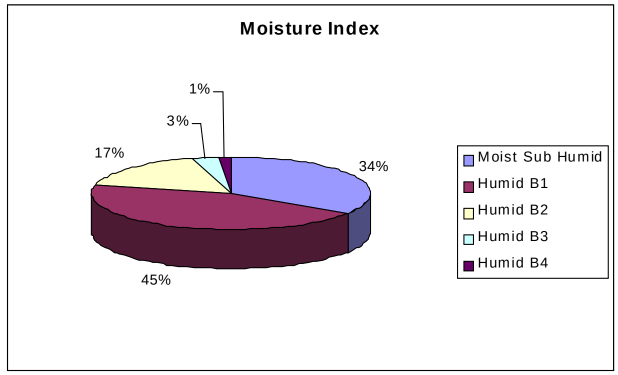

**Moisture Regimes**

Moisture regimes were derived from the PET maps generated from the surface temperature maps. The study area is predominantly humid with moisture index varying from 0 to 100. Maximum area is found in the Humid B1 region followed by moist subhumid as illustrated in the Table: 4 and Fig: 2.

**Table: 4** Moisture Index variability

| Thermal Index | Area (Ha) | Percentage |
|---|---|---|
| Moist Sub Humid | 48513 | 34% |
| Humid B1 | 63625 | 45% |
| Humid B2 | 23612 | 17% |
| Humid B3 | 4637 | 3% |
| Humid B4 | 1803 | 1% |

**Fig. 2 :**




**Bioclimate Regimes**

Analysis indicates that entire study area comes in the equatorial region. The equatorial regimes indicates that the region is suitable for all field crops and two crops of rice can be grown in a year.

However, the study area could be categorized into five classes based on the observed variations in the bioclimate regimes as indicated in the Table: 5 and Fig: 3.

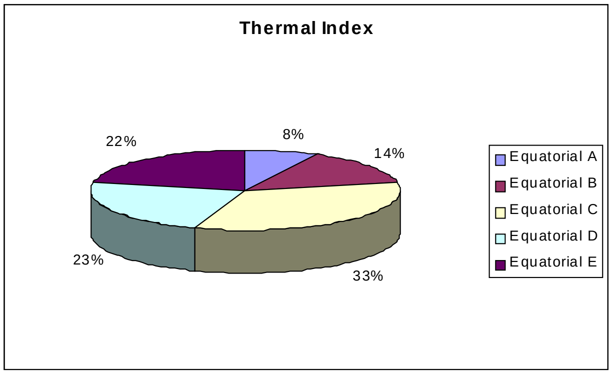
**Table 5 :** Thermal Index variability

| Thermal Index | Area (Ha) | Percentage |
|---|---|---|
| Equatorial A | 11162 | 8% |
| Equatorial B | 20092 | 14% |
| Equatorial C | 47397 | 33% |
| Equatorial D | 32113 | 23% |
| Equatorial E | 31426 | 22% |

**Table 6 :** Agro-Climatic Zones

| Ag-Cl- Zone | Description | Area(Ha) | Percentage |
|---|---|---|---|
| 1 | Moist sub Humid – Low biomass | 24756 | 20% |
| 2 | Moist sub Humid – High biomass | 14612 | 12% |
| 3 | Humid(B1)-Low biomass | 30618 | 25% |
| 4 | Humid(B1)- High biomass | 27403 | 22% |
| 5 | Humid(B2) -Low biomass | 8628 | 7% |
| 6 | Humid(B2) - High biomass | 11676 | 9% |
| 7 | Humid(B3) -High biomass | 2306 | 2% |
| 8 | Humid(B4) - High biomass | 4409 | 4% |

**Fig. 3 :**



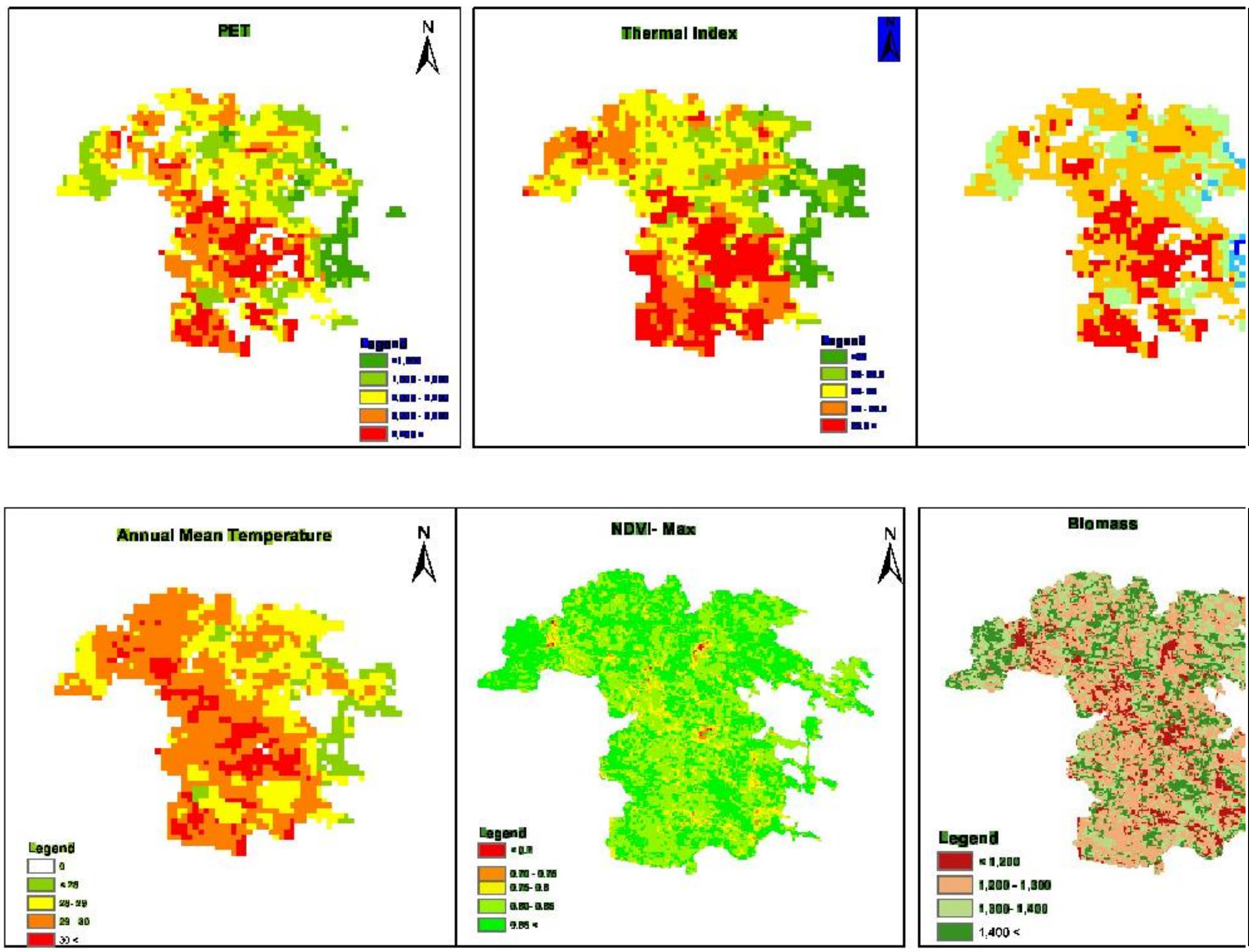

The agro-climatic database generated as shown in fig 4 was superimposed and reclassified to delineate eight Agro-Climatic Zones (ACZ I to VIII). Area extent and the percentage of each zone is given in the Table: 6 and Fig:6. The spatial extent of the different Agro-Climatic Zones are illustrated in the fig: 5

It can be inferred that quarter (25%) of the district comes under Humid (B1)- Low biomass followed by Humid(B2)-High biomass(22%) , Moist sub Humid-Low biomass(20%).

### Climate – Elevation relationship

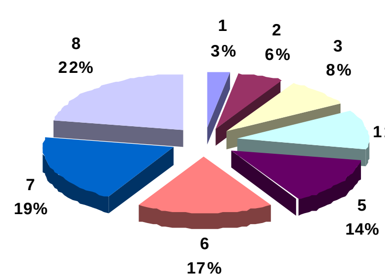
The primary criterion that distinguishes mountains from other land surface is its significant positive relief and the complexity and heterogeneity of climate and land use distribution associated with mountains are all outcome of this primary factor relief. That is, temperature falls and rainfall increases with increasing elevation.

**Fig. 4 :** Agro-Climatic Data Base




Regression analysis to assess the relationship between elevation and temperature indicates strong negative trend and the coefficients were found significant. Temperature data for March, September and Annual mean temperature were used for the analysis and the observations are illustrated in fig:7,8&9 and table:7 . The data clearly reveals that with increase in elevation there is corresponding decrease in temperature.

**Fig. 5 :** Agro-Climatic Zone




## CONCLUSION

Remote Sensing and Geographical Information System technology can be used for delineating agro climatic zones based on thermal index and moisture index. Total district was divided into eight agroclimatic zones of which quarter i.e., (25%) comes under Humid (B1)- Low biomass followed by Humid(B2)-High biomass(22%) , Moist sub Humid-Low biomass(20%). Study also clearly reveals that with increase in elevation there is corresponding decrease in temperature over Pathanamthitta district.

**Table 7 :** Relation between Temperature & Elevation in March and October

| Sl. No. | Month | Mean Temperature ($^oC$) |
|---|---|---|
| 1. | March | Y=30.95-0.00764 x DEM<br>R2=0.64 |
| 2. | October | Y = 29.15-0.00487 x DEM<br>R2=0.53 |
| 3 | Mean | Y= 29.64531-0.00557 x DEM<br>R2=0.58 |

**Fig. 7 :**

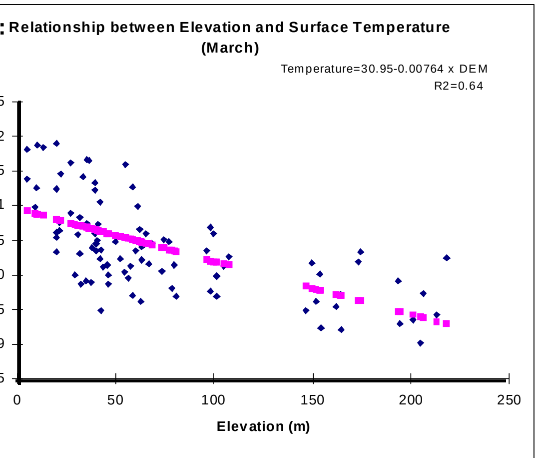



**Fig. 8 :**

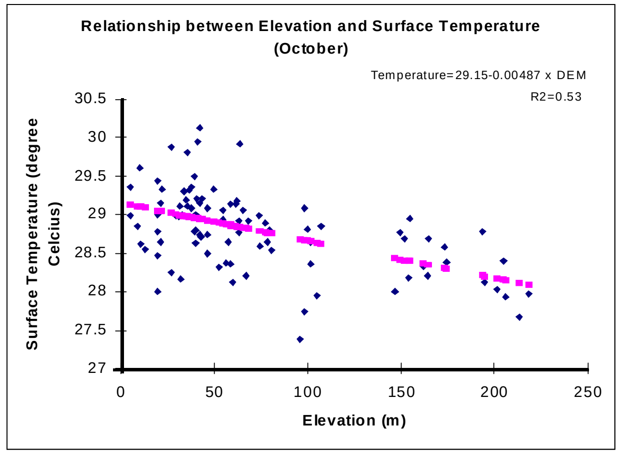
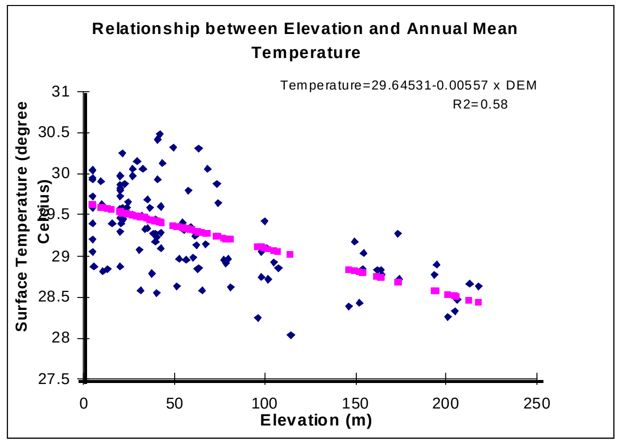



**Fig. 9 :**




## REFERENCE

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