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Detecting Aphid Concentration in Wheat Leaf Using Remote Sensing and GIS

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Wheat lies among the most prominent cereal crop of Pakistan which has a significant role in the stability of Pakistan's economy. Certain biotic and a biotic factors including agro-climatic conditions, rainfall, lack of irrigation infrastructure and conventional agricultural methods are raising the risk of aphid attacks. The current study utilized satellite imagery for obtaining thermal datasets of complete wheat growth. Results revealed that rainfall is a significant parameter for the determination of aphid growth on wheat plant. A region receiving 0-10 mm rainfall, supported the growth of aphid. Moreover, the aphid survival was highly supported at a moderate temperature ranging between 20-25 °C with relative humidity ranging from 70-75 %. The study also revealed the production of weed in wheat crop acted as a moistrizing agent which consequently provided favorable conditions to the aphid population for growth. Inapropriate usage of fertilizers increased the nitrogen content in soil which turned to be favourable for the aphid attack. Thus, the study concludes that agro-climatic conditions must be considered before the aplication of pesticides.

Key Words: Aphid; Conventional Agricultural method; Moistourizing agent; Agro-climatic condition.

Author's Contribution
All authors contributed equally.

CONFLICT OF INTEREST:
The authors declare that the publication of this article has no conflict of interest.

Project details. Nil

Introduction

Wheat (Triticum aestivum L.) is a prominent crop in Pakistan[1], with the largest area under cultivation and plays a crucial part in the country's economic stability [2]. Traditional methods of agriculture, lack of irrigation infrastructure, barani regions, soil fertility, and the insect pest attacks are the major factors responsible for a decline in wheat production which ultimately effects the regional economy in comparison to other neighboring countries. Besides, cultural, physical, mechanical, biological, chemical aspects, host plant resistance is also considerable parameter which may not be ignored while evaluating the overall production. Aphid has been observed one of the most threatening and a yield degrading factor among others. Aphids reduce yields either directly (35-40%) by sucking the plant's sap or indirectly (20-80%) by transferring viral and fungal infections [3].

Abiotic factors are also responsible for an increase in Aphid population [4]–[6]. The population of aphids increases throughout the spring season[7] (February-March), and biocontrol agents such as coccinellids grow as a natural check on this pest [8]. A combination of naturally occurring population controlling variables keeps aphid populations below the economic harm threshold. However, if aphids are present in great numbers, they can be extremely harmful, necessitating the application of insecticides to control them [9]. The wheat crop is commonly plagued with aphids during the growth stages, when both adults and nymphs wreak havoc on the plants by sucking cell sap and reducing the plant's vitality [10][11]. The infested leaves become paler, wilt, and seem silky[12]. Toxins are found in the saliva of several species, and a dense infestation can destroy new shoots[13]. Aphid infestations are commonly accompanied by honeydew excretion and sooty molds, both of which affect the rate of photosynthesis in plants[14]. The wheat crop's low yield is primarily due to its vulnerability to aphid infestation [15]. Aphids are regarded as a major pest of wheat crops[16]. Under ideal conditions, they can quickly multiply on leaves, stems, and inflorescence[17]. The infestation produces severe leaf and inflorescence deformation, as well as a considerable reduction in yield due to direct feeding. Abiotic factors such as conventional methods of farming, poor yielding cultivars, and a lack of sufficient irrigation facilities in most places are all contributing to the drop in wheat crop output.

The population of Aphid is highly dependent upon agro-climatic conditions [18] and a rapid shift has been observed in the whole weather system e.g., the rainy season have been shifted and we receive rainfall at inappropriate times/ places. Our farmer religiously follow the crop calendar where the dates/ time of every event is fixed therefore, the application of pesticides and insecticides at unsuitable times cause a lost to local economy which is ultimately contributing in regional financial affairs. Therefore, it is a need of the hour to create an awareness among individuals to adopt the latest technologies/ farming practices for sustainable/ economic agriculture.

The main objective of this research is to delineate the vulnerable zones to Aphid incorporating regional environmental parameters including temperature, humidity and rainfall. It also aim to take remedial measures in time/ space to ensure the wheat growth and development in a protective environment.

Material and Methods

In the current section, the material and methodology adopted in this research is described in details. The data used in this research include thermal datasets based on satellite imagery for the complete growth period of wheat crop. Moreover, the humidity data was recorded through hygrometer and rainfall data, which was collected from Pakistan Metrological Department (PMD). The step-by-step methodology adopted in this research is as below

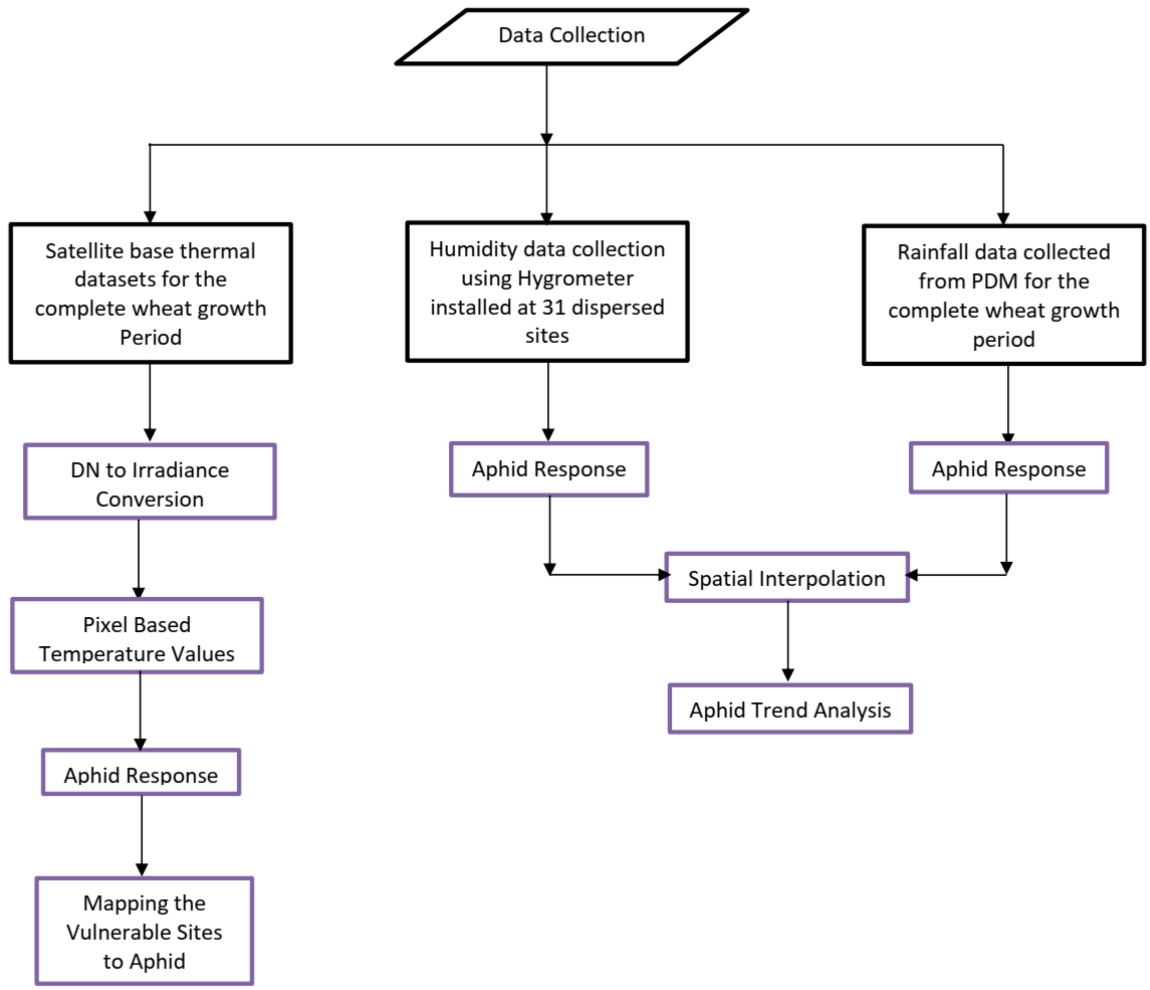

Figure 1. Flow of methodology

Aphid is an insect of wheat crop which is considered as the largest limiting factor to crop productivity[19]. In this research, various kinds of datasets including rainfall, temperature and humidity were utilized to determine the spatial distribution of aphid dynamics in the wheat crop. Aphid is very sensitive to humidity and its population get many folds as the humidity gets double[20]. To check the trend of humidity, we installed hygrometers at 31x dispersed spatial locations in the study site. The data was collected against each growth stage of wheat crop therefore about 160 values (for each location) of humidity were recorded during the complete growth/development period. These values were averaged and the interpolation technique IDW was applied on 31 locations to map the trend of humidity as shown in Figure 2 as below,

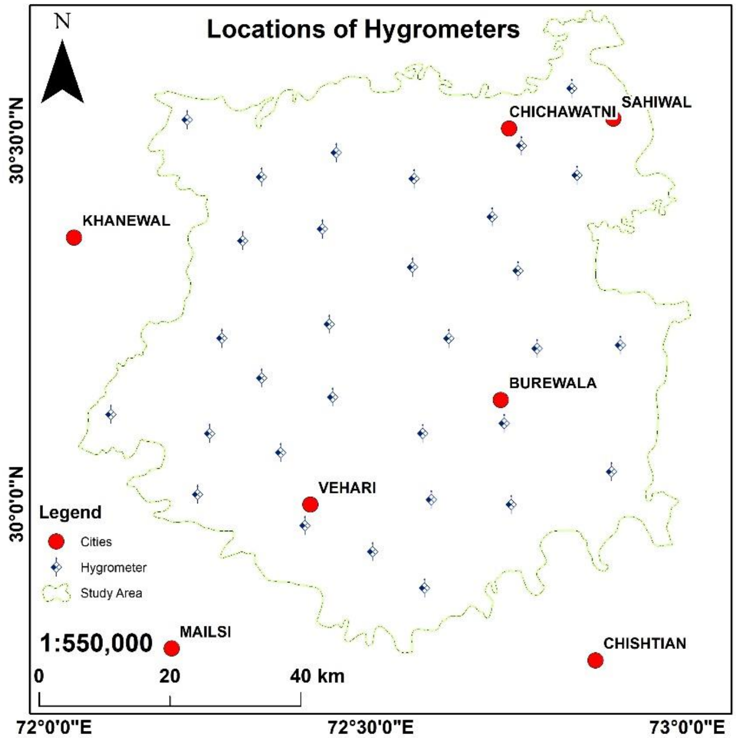

Figure 2. Spatial distribution of Hygrometers installed in the study site

Pakistan Meteorological Department (PMD) is continuously collecting the rainfall data in mm. Rainfall spells received during the complete study span in the investigations site is shown in Table 1.

Table 1. Rainfall Spells during Aphid life cycle.

Sr No	Month	Rainfall Spells
1.		04-05 Feb 2020
2.	February	12-14 Feb 2020
3.		20-21 Feb 2020
4.		28-29 Feb 2020
5.		05-08 Mar 2020
6.	March	12-14 Mar 2020
7.		21-24 Mar 2020
8.		26-27 Mar 2020
9.		01-10 April 2020
10.	April	11-20 April 2020
11.		21-30 April 2020

PMD generated rainfall maps which were scanned, geo-referenced and digitized to extract actionable information regarding spatial distribution of rain.

Landsat 8 datasets are comprised of two thermal bands including Band 10 and Band 11[21] which provide very precise and reliable information regarding spatial distribution of temperature[22]. We downloaded these thermal bands for the complete wheat growth period and computed pixel-based temperature values. The information regarding downloaded datasets is as below,

Table 2. Rainfall Spells during Aphid life cycle.

Sr No	Growth Stage of Wheat Crop	Date of imagery
3.	Heading	06 Feb 2020
4.	Milky Dough	09 Mar 2020
5.	Maturity	10 April 2020

Thermal bands are comprised of array of brightness values which are converted to irradiance [23]using the equations as below,

*Irradiance B10= 0.0003342 * B10 + 0.1 (1)*

*Irradiance B11=0.0003342 * B11 + 0.1 (2)*

The irradiance is further converted to temperature values using the equations[24] as below,

$T\ B10 = \{K_2 / Ln\ (\mathcal{E}\ K_1\ / Irradiance\ B10 + 1)\} - 272.15$ (3)

$T\ B11 = \{K_2 / Ln\ (\mathcal{E}\ K_1\ / Irradiance\ B11 + 1)\} - 272.15$ (4)

In equations (3) and (4), K1 and K2 are the constants for thermal bands and their values are mentioned in the metadata of Landsat 8 [25] which are;

K1 for B10 = 774.89; K1 for B11 = 480.89; K2 for B10 = 1321.08; K2 for B11 = 1201.14

Value of emissivity (Ɛ) used in the equations (3) and (4) is 0.95. Final temperature against each pixel is computed by taking an average of both datasets T B10 and T B11.

T = (T B10 + T B11) / 2

Pixel based temperature values are computed using "Raster Calculator", an elegant tool embedded in Arc GIS 10.1.

Result and discussions.

Temperature based vulnerable zones for Aphid.

Spatial distribution of temperature was computed using thermal datasets enlisted in Table 2. The stages of wheat crop affected by Aphid has been incorporated and categorized into less, moderate and not favorable zones. The basic reason for computing the pixel-based temperature values only for the month of Feb, March and April is that Aphid emerges in the month of Feb and the complete life cycle ends up to April. Spatial distribution of temperature across the study site is mapped in Figure 2.

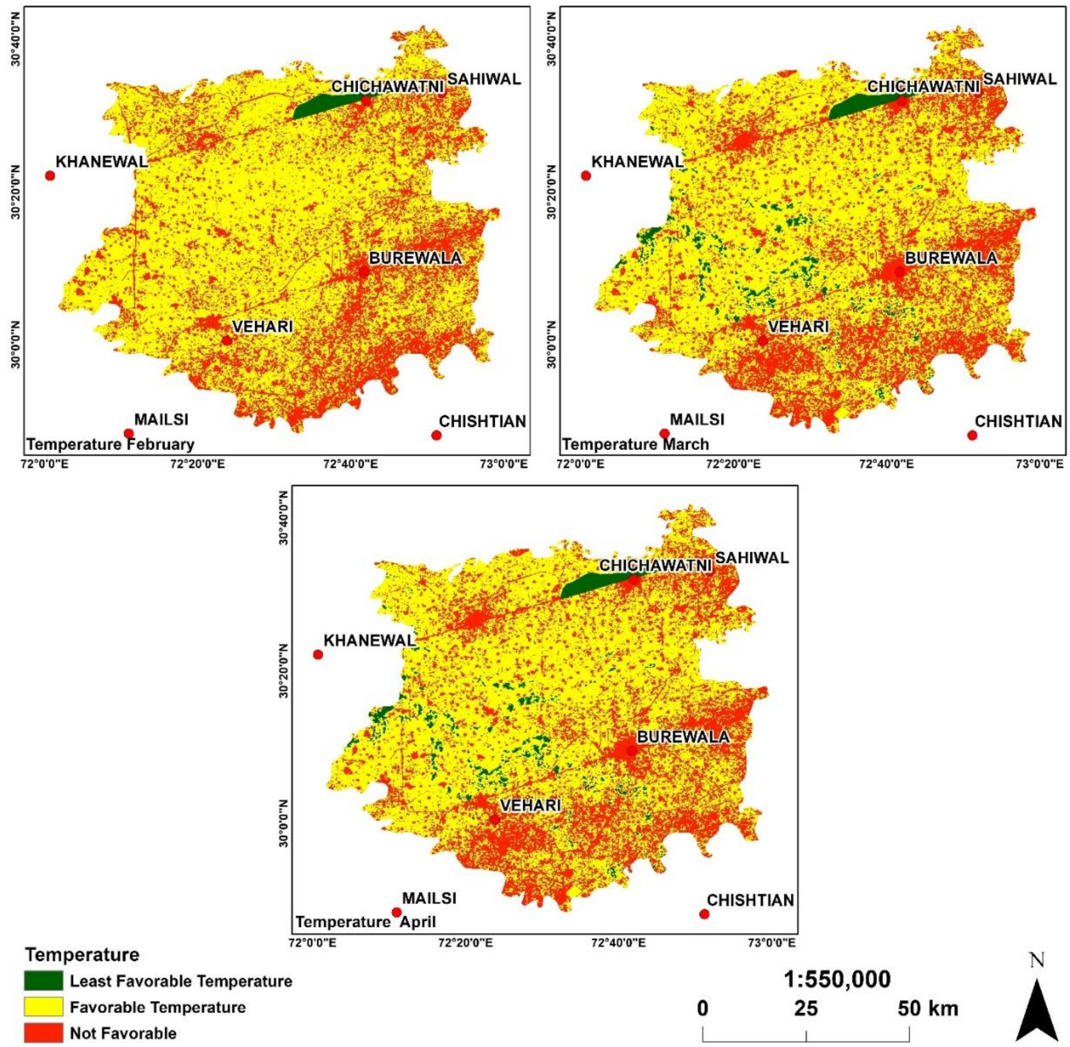

Figure 3. Spatial distribution of vulnerable zones for Aphid during months Feb, March and April.

The results are given Table

Table 3. Areas in km^2 regarding vulnerable zones to Aphid.

Sr No	Date of Satellite Imagery	Favorable area km^2	Moderately area km^2	Not Favorbale area km^2
1.	06 Feb 2020	73	3987	1638
2.	09 Mar 2020	129	4123	1704
3.	10 April 2020	153	4568	1283

Rainfall based vulnerable zones for Aphid.

Rainfall acts as a promoting factor for growth in population of Aphid. It has been observed that just after 01 x day of rainfall, the insects come out of their holes and the population increases many folds. We could get 11 x spells of rainfall during Feb-April. The intensity of rainfall was geotagged and interpolated. The results of interpolation are mapped in Figure 3-5.

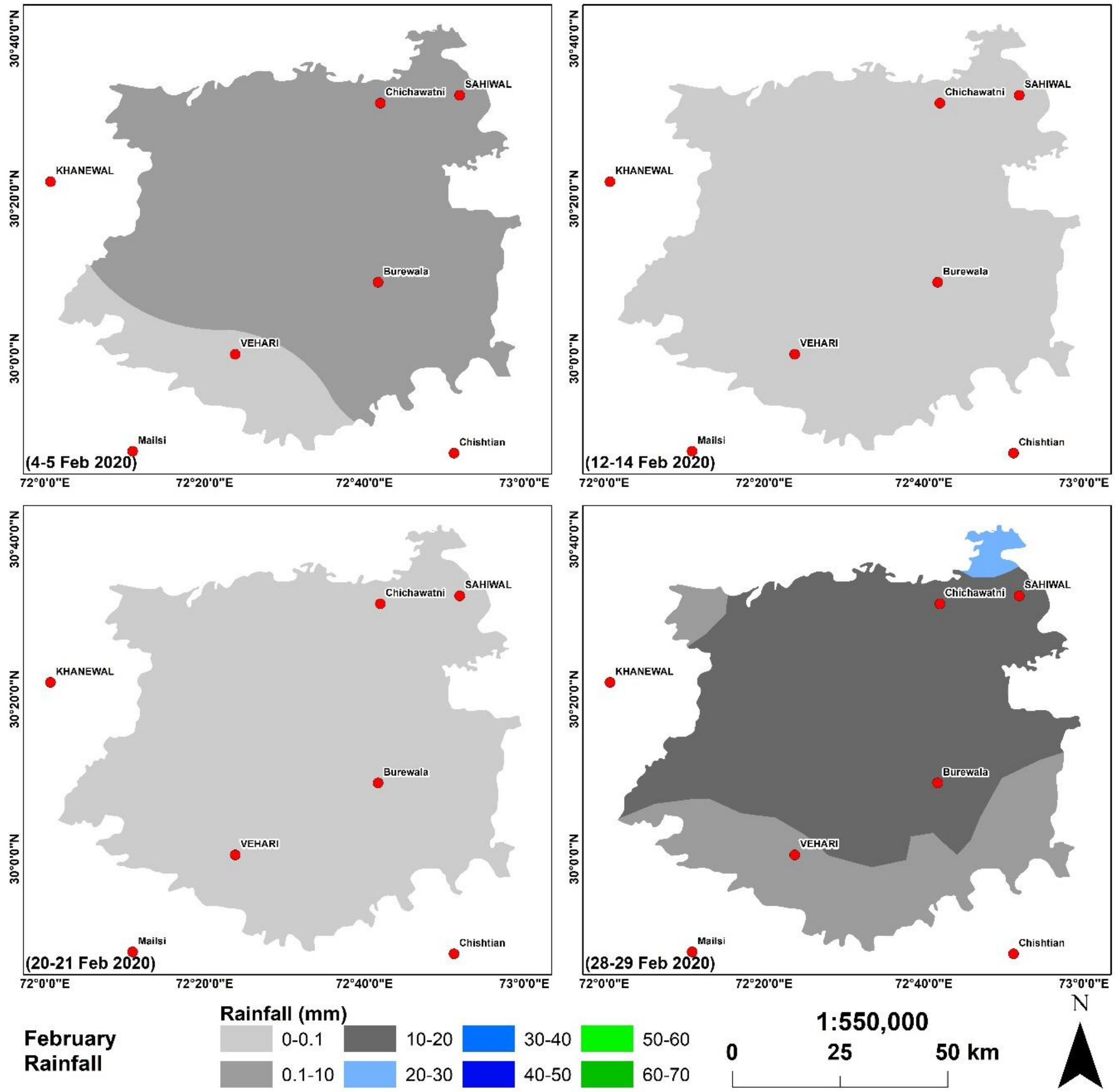

Figure 4. Spatial distribution of rainfall intensity during the month of Feb 2020.

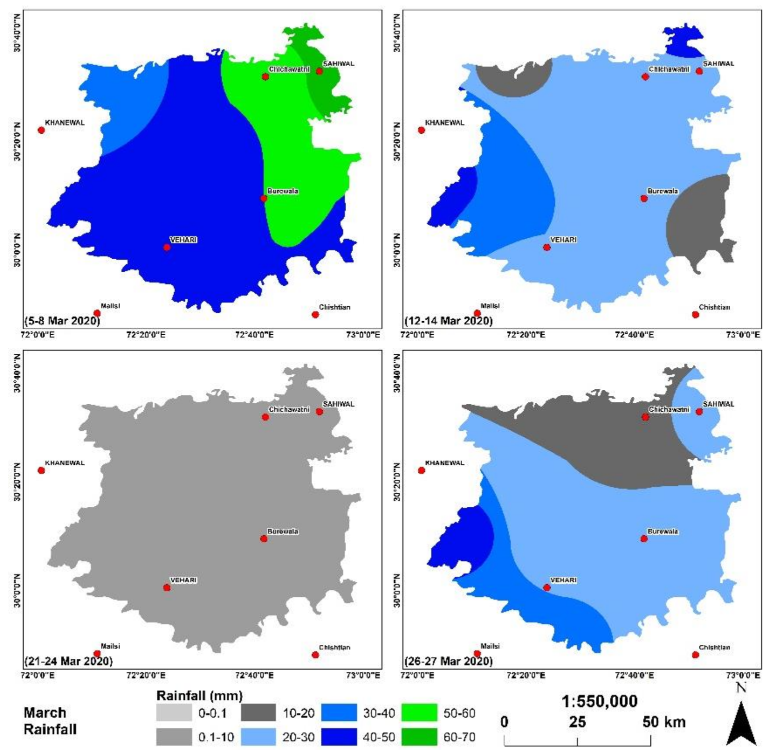

Figure 5. Spatial distribution of rainfall intensity during the month of March 2020.

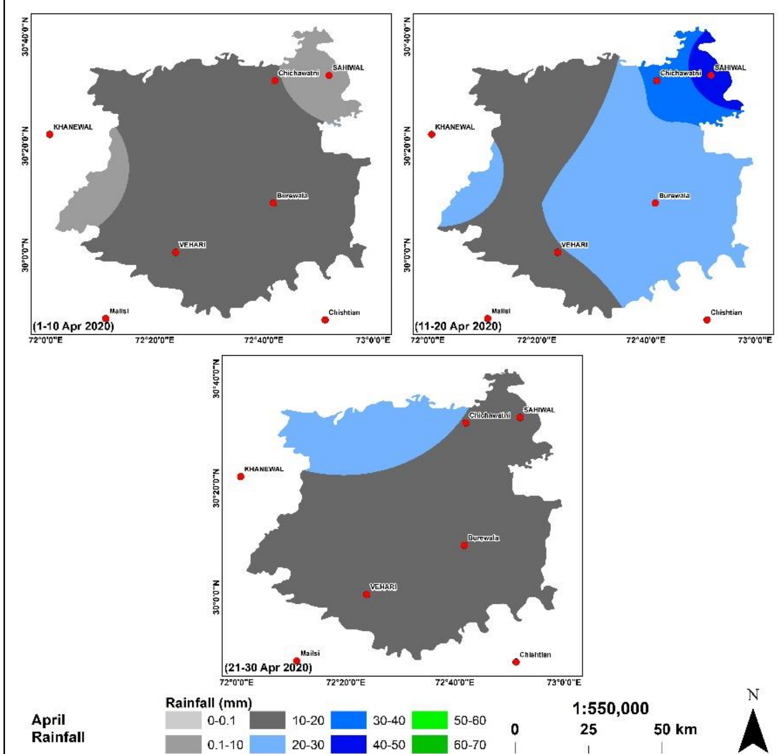

Figure 6. Spatial distribution of rainfall intensity during the month of April 2020.

Figure is showing the spatial distribution of rainfall across the study site during the month of Feb 2020. Most of rainfall received in the fourth spell from 28-29 Feb 2020 in the northeast with rainfall intensity 20-30 mm. The effect of rainfall in other spells did not effect the Aphid growth however, in the forth spell, the dark grey and light blue areas are showing instable zone for Aphid to stay on the plant and they fall on the ground. Spell 2 and 3 are showing the rainfall intensity less than 10 mm that did not effect the the Aphid existance therefore, its population increased exponetially untill the fouth spell hit the area. It takes about 1 week for Aphid to reinstate into its previous condition of the wheat plant which was observed before the first spell of march that receieved heavy rainfall in specific regions highlighted with green and blue colors which were observed the death regions for Aphid however, the blue regions receieved 40-50 mm which was so intense that created danger for Aphid survival. During march 2020, the study site receieved more intense rainfall as comparted to the previous month. The intensity of rainfall was not homogenous but it was diversed therefore the behaviour of Aphid was not similar throughout the study site.

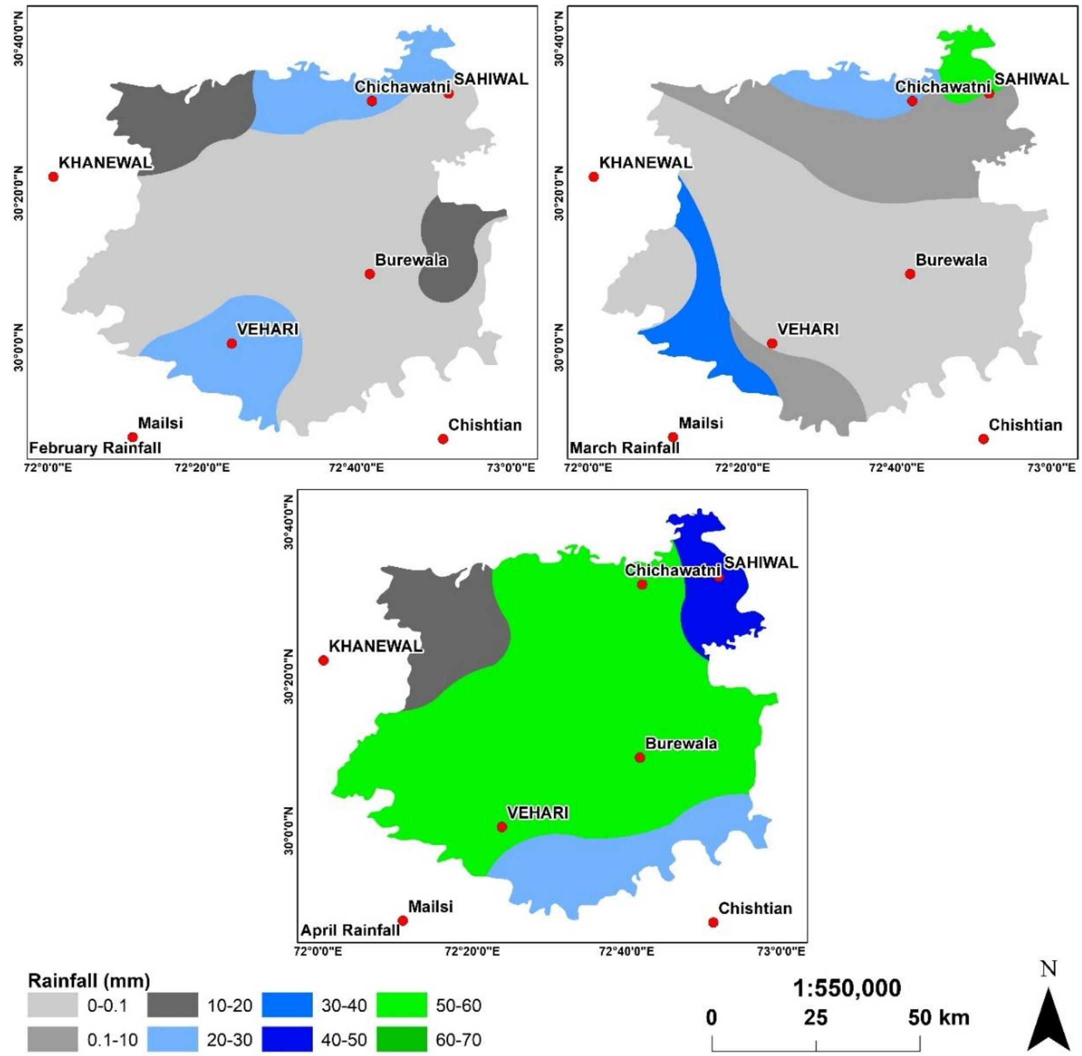

Figure 7. Integarted map of rainfall.

Rainfall is an important factor to determine the population of Aphid. Aphid grow in the regions receiving rainfall within a range of 0-10 mm and if the rainfall is greater than 10mm, aphid destablizes and can not stay on the wheat stem/ leaf. Thefore, healthy rainfall is considered favorable to escape form aphid however, cloudy conditions for long times result to boost aphid population.

Humidity based vulnerable zones for Aphid.

Humidity plays a vital role toward the population of Aphid. As humidity increases, the population increases exponentially. The spatial distribution of humidity as recorded by 31 well distributed sites is mapped in Figure 8. Humidity maps were generated of each month from Feb- April to evaluate the existence/vulnerable zones for Aphid existence.

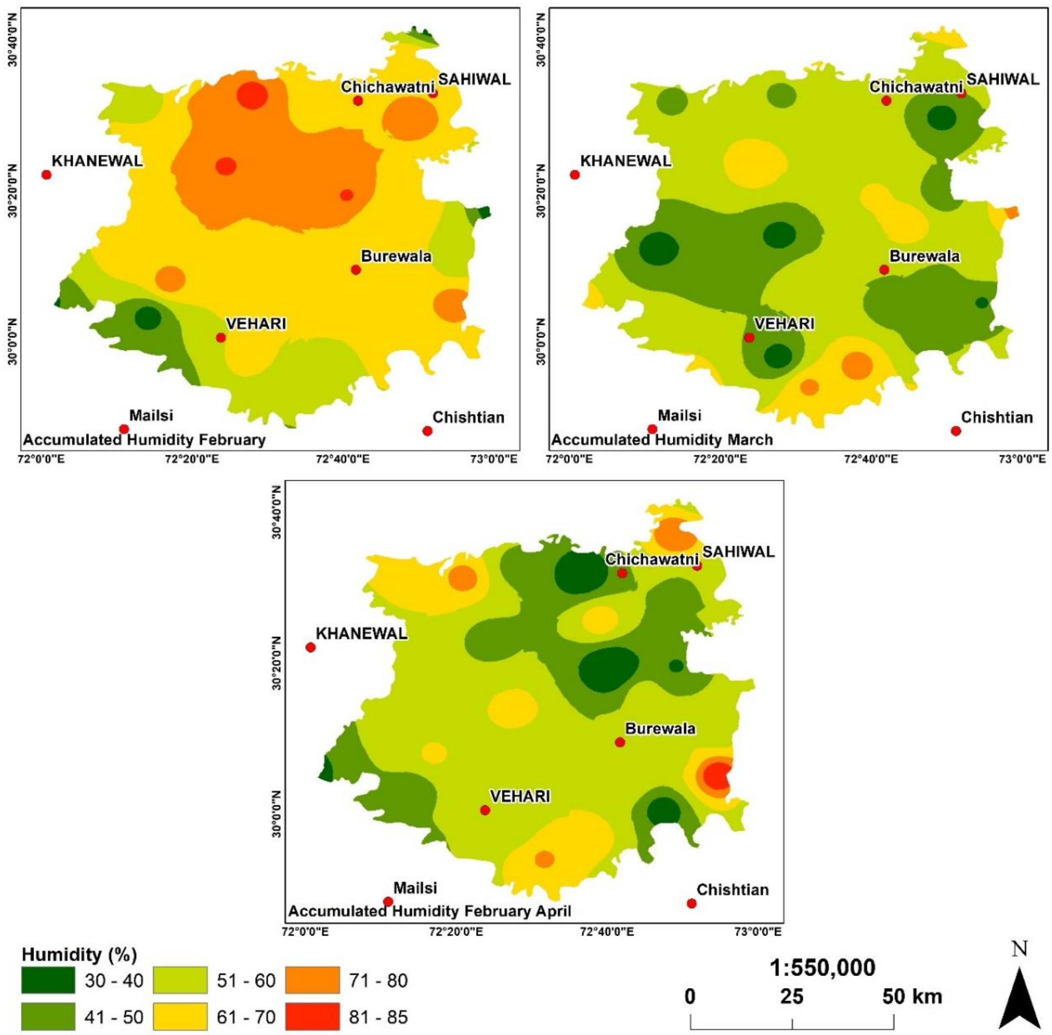

Figure 8. Humidity maps were generated of each month from Feb- April.

Discussions.

The results determine that moderate temperature of 20-25 °C with relative humidity ranging from 70-75 % is highly suitable for aphid to survive therefore, these climatic conditions may be treated to apply pesticides on emergency grounds. It has been observed that weed act as moisturizing agent and provide favoroable conditions for aphid to have proper growth therefore weeds must be abolished to remove safe houses for aphid.

Sowing time of wheat crop play a significant role against attacks/damages by aphid. It is recommended that wheat sowing practices must be completed before 25 Nov which results in hard dough that provides a shield against aphid attacks. The inapropriate applications of fertilizers invite aphid to attack the wheat crop, e.g., the excessive use of nitrogen in comparison to phosphorus results in high population of aphid. Number of irrigations also effects the aphid population. If there exist sufficient moisture content in wheat field. There are healthy chances of aphid to damage the wheat crop.

Adoption of sowing strategy is also important to control the aphid population. In case of uneven distribution of wheat seeds, the wind is unable to pass through the wheat plants which provide favourable zone to aphid for growth and development. Moreover, 30kg/acre is recommended at sowing time that results in sparse plantation however, 50kg/acre results in dense wheat crop which is favourable for aphid to survive for long times.

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