Desert Locust Schistocerca gregaria in Rajasthan, India and Establishing an Early Warning System for Locust Control in India

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Desert Locust *Schistocerca gregaria* in Rajasthan, India and Establishing an Early Warning System for Locust Control in India

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Desert Locust is considered to be the most serious pests that cause a devastated damage to the crops and the other agricultural products during their invasions. The Desert Locust is a major threat for food security, livelihoods, environment and economic development in a region. The recent Locust Outbreak caused major damage to standing crops and vegetables in the Central and Western states of India, including Rajasthan, Punjab, Haryana, and Madhya Pradesh, with Rajasthan being the most affected. India had experienced such massive locust invasion after two decades. Establishing an Early Warning System for Locust Control in India is essential to reduce the impact by providing timely and relevant information in a systematic way contributing to increasing in resilience of the country. The distribution of Desert Locusts in Rajasthan, India has been presented from June 2019 to August 2020, along with the key Environmental Factors of Temperature, Rainfall, Soil Moisture and Prevalence of Vegetation significantly affecting Locust Activity. All the datasets used were obtained from Secondary sources. These datasets were obtained from Open Government Data (OGD) Platform. The Maps created in the study show the Distribution of Desert Locusts in Rajasthan, India; along with this the Choropleth map show Average- Temperature, Rainfall, Soil Moisture and Normalized Difference Vegetation Index (NDVI), all at District level. The Early Warning System for Desert Locust Control in India is a key integration of four key elements of: Risk Knowledge, Monitoring and Warning Service, Dissemination and Communication and Response Capability, and four-four sub elements of each key element. Establishing an Early Warning System for Locust Control in India is of paramount importance.

The Desert Locust *Schistocerca gregaria* is one of about a dozen species of short horned grasshoppers. The Desert Locust is considered to be one of the most dangerous migratory pests in the world. Desert Locusts have the ability to change their behavior, physiology, color and shape in response to change in locust numbers [1]. As the locusts Swarm, they voraciously feed on nearly all green vegetation (leaves, flowers, bark, stems, fruit and seeds) that comes their way, including key staple crops such as Maize, Wheat, Mustard, Guar, and Moong, In turn thereby significantly affecting the livelihoods of small holder farmers and pastoralists. Locusts can cause 80-100% crop losses across affected areas [2].

In general, the desert locust breeds extensively; during quiet periods in semi -arid and arid deserts extending from West Africa through the Middle East to Southwest Asia, area consisting of about 30 countries; during plagues the pest may spread to larger areas. During plagues, the desert locust has the potential to damage the livelihood of a tenth of the world's population [1]. In India, the states of North -Central -Western India, especially Rajasthan, Gujarat, Punjab, Madhya Pradesh, Haryana and Uttar Pradesh are particularly susceptible to desert locust attacks. Until the 1960s, locust outbreaks frequently occurred, except for a few surges in 1978 and 1993, post these years outbreaks were less frequent and occurred, on average, once in a decade. India has had many plagues, uprising and incursions in the past [3]. In India, there were approximately 12 locust plagues until 1962. In 2019 locusts invaded Rajasthan after a gap of about 26 years. Until February 2020, swarms had damaged crops across 6 70,000 hectares in 12 districts with an estimated loss of about Rs. 1,000 crores (10,000 million). Using conventional methods to calculate economic losses from desert locust episodes is difficult. The cash value of crops, social value of subsistence farming, adverse effects on pasturage, rangeland, and livestock; costs of food aid and aid for displaced human populations are challenging to assess [4].

Studies have shown that Desert Locust have the ability to change its behavior, ecology, and physiology in response to change in climatic conditions. The impacts of 'climate crises' are directly linked to desert locusts. With increase in temperature, unusual events of rainfall and shifting wind patterns – the maturation rate of locusts have become more rapid leading to more frequent outbreaks and new invasive areas [5]. The desert locust is the most widely distributed among all species. The invasion area contains a great variety of climatic conditions, soil types and vegetation. Rainfall is the most important requirement for the Desert Locust breeding, because it orients the necessary environmental conditions for the breeding, development and multiplication. Rainfall determines whether there is sufficient growth of vegetation to provide adequate food supply for the insect. Rainfall is also found to be influencing the timing of certain developmental milestones in the egg indirectly through soil moisture [6]. Previous studies on behavior of desert locust have suggested that wind along with temperature and vegetation has a definite role in its migration [7]. All the different phases in the life cycle of a locust require certain ideal conditions for it to develop. Bioclimatic (Temperature and Rainfall) and Edaphic (Soil Moisture and Sand Content) along with Wind patterns and prevalence of Vegetation are the most critical variables for Desert Locust breeding locations. Meteorological data are important for both assessing the current locust situation and forecasting its development. Rainfall data can be used to identify which areas may become suitable for breeding or where green vegetation and locusts may be present. Temperature data can be used for estimating the development rate of eggs and hoppers, as well as indicating whether it is warm enough for adults to take off and fly. Soil Moisture is a very good indicator of reproduction potential over an area, since female desert locusts are known to prefer warmer and more open sites for initiating probing and digging activity for oviposition. The amount of water availability in soil acts as a catalyst for other factors. In comparison to rainfall, Soil Moisture allows to focus on areas where reproduction might happen. Vegetation provides the main resource and structural element, especially in the habitat of Phytophagous insects. Movement of Locusts can be directed by the abiotic environment, such as orientation relative to a wind current, but can also be highly affected by biotic factors like resource distribution [1][6][7][8].

All countries affected by desert locust generally adopt a preventive control strategy for the management of desert locust in order to reduce the frequency, duration and intensity of plagues. Te current management strategy of the locust swarm is aerial spraying with chemical pesticides, which has a high cost on humans, livestock, and the environment in addition to its economic burden at the national level biodiversity [9].

The number and severity of disasters is rising as the climate undergoes changes, and as the world's population continues to increase. A global early warning and preventive control system against desert locust has been in place for more than half a century. To find insect infestations, these teams rely on their own knowledge as well as on information from nomads. This knowledge is combined with up-to-date satellite imagery indicating rainfall and green vegetation, allowing the teams to identify potential breeding sites and growing locust infestations. In the past decade, a new challenge is facing the locust early warning system. Political unrest and instability, national border disputes and sensitivities, kidnappings, mines, and conflict have led to insecurity in many parts of the Locust recession area [10]. Locust outbreaks can develop suddenly and unexpectedly in remote inaccessible areas or in the absence of regular surveys and incomplete data. Recent developments in satellite techniques to monitor rainfall and vegetation have made it easier to detect potential areas of significant Locust activity that may require survey and control [8]. In this context of a changing climate, increased climate variability and the vulnerability of the socio-economic activities to these factors, it is crucial for our Government to put in place a Self-Developed Early Warning System for Locust Control in India. India has an impressive array of achievements in the development of space technology for various applications. The remote sensing applications using Indian Remote Sensing Satellite- IRS have proliferated into almost every facet of national development. Prevention of biological invasions is much less expensive than post entry control [11]. Therefore, to reduce the environmental degradation, ecological destruction, habitat loss and the socio-economic losses caused by uncontrolled desert locust invasions, it is extremely essential to have knowledge of Potential grounds of locust activity. Based on this knowledge, timely and meaningful warning information will be generated and disseminated for response (conservation, planning and forecasting) and decision making. Development and Implementation of a sound Early Warning System for Locust Control in India is need of the hour.

Results

Distribution of Desert Locust Occurrence Sites.

In total, 1484 Desert Locust Occurrence Sites were recorded to be used with respect to the Study Area (Rajasthan, India) over the temporal scale from 1st June 2019 to 31st August 2020. The districts along the International Border Boundary of India-Pakistan face the Desert Locust invasions at first in the whole country. These districts include: Barmer, Jaisalmer, Bikaner and Sri Ganganagar. The Desert Locust Presence sites decrease gradually from West to East, being completely absent in the extreme Eastern and Sothern districts of, Eastern: Bharatpur, Dholpur, Karauli, Baran, Jhalawar and Bundi; Sothern: Banswara and Dungarpur. No Locust activity were observed in Rajsamand district. Figure 1 showing the Desert Locust Occurrence Sites.

Environmental Factors.

Among Environmental Factors, Choropleth maps were prepared for: Average General Temperature, Average Rainfall for the year 2019 and 2020, Average Soil Moisture for the year 2019 and 2020, and Average Normalized Difference Vegetation Index for the year 2019 and 2020.

(A) Average Temperature (in Degree Celsius - ^{o}C)

Figure 2 shows the General Average Temperature.

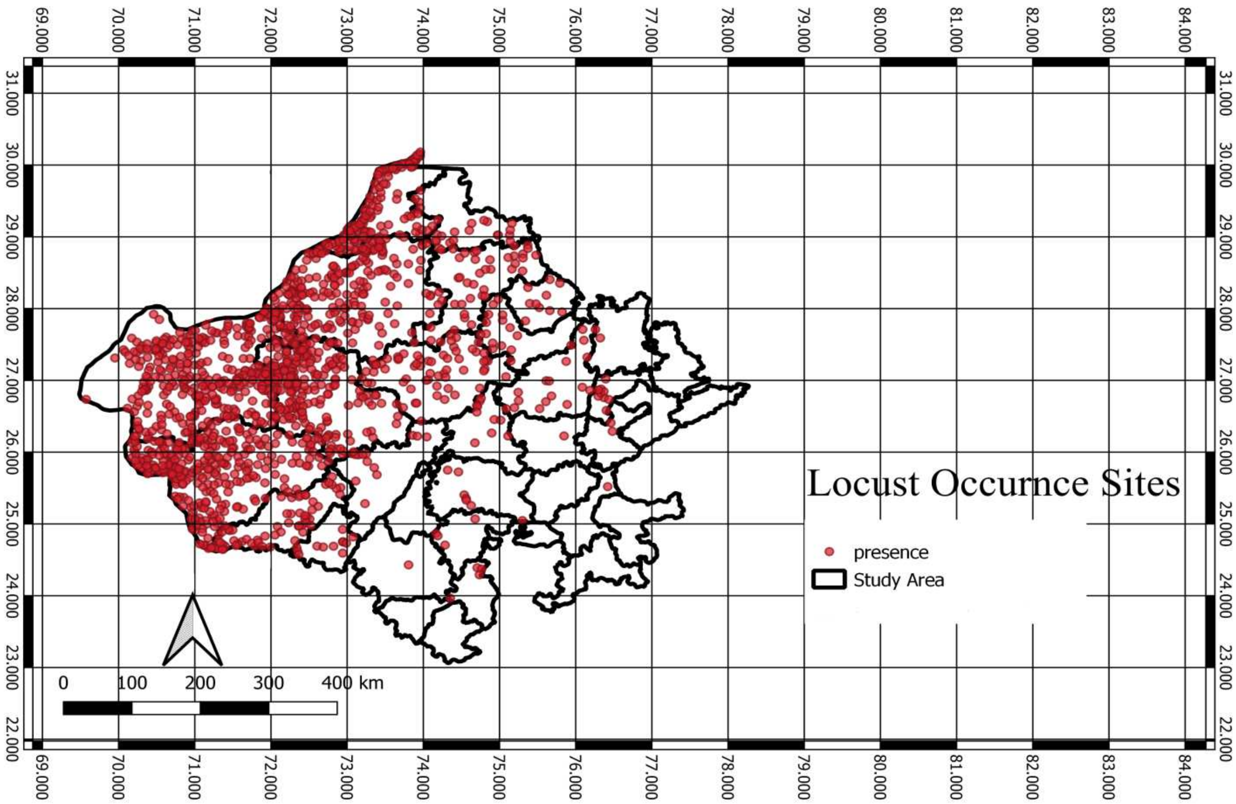

Figure 1. Desert Locust Occurrence Sites digitized using QGIS 3.16.2. Desert Locust Presence sites are shown using red circles on a District level Administrative map of Study Area.

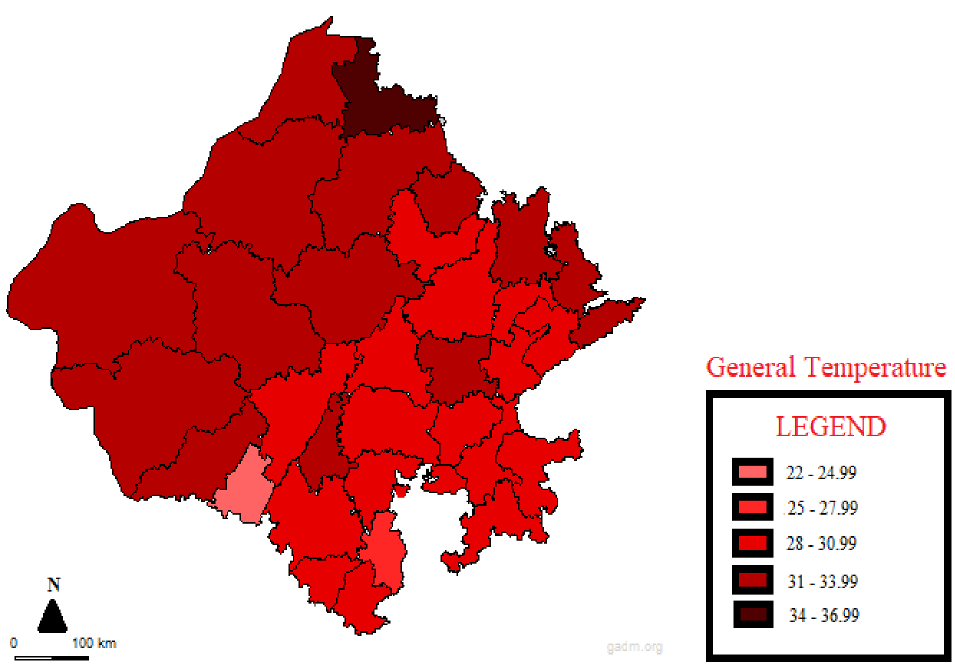

Figure 2. General Average Temperature Choropleth Map. Unit: ^{o}C

(B) Average Rainfall (in mm) for 2019 & 2020

Figure 3 shows the Average Rainfall Choropleth Map (in mm) for 2019.

Figure 4 shows the Average Rainfall Choropleth Map (in mm) for 2020

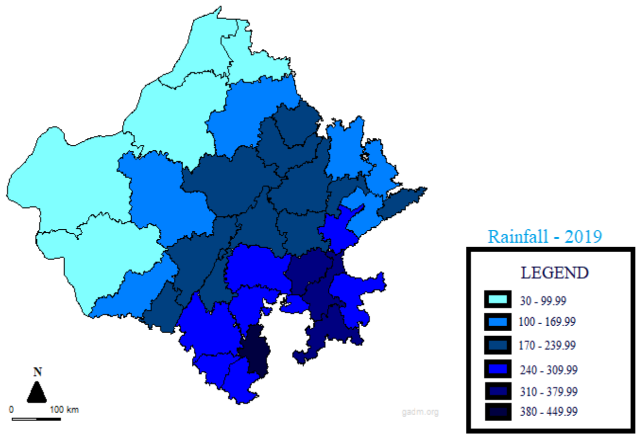

Figure 3

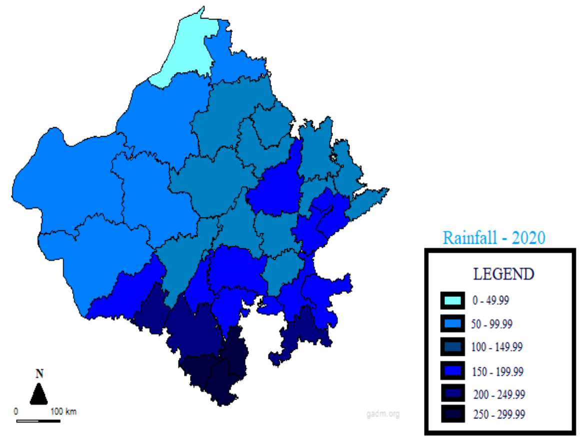

Figure 4

(C) Average Soil Moisture (in inches of water per foot) for 2019 and 2020

Figure 5 shows the Average Soil Moisture Choropleth Map (in inches of water per foot) for 2019.

Figure 6 shows the Average Soil Moisture Choropleth Map (in inches of water per foot) for 2020.

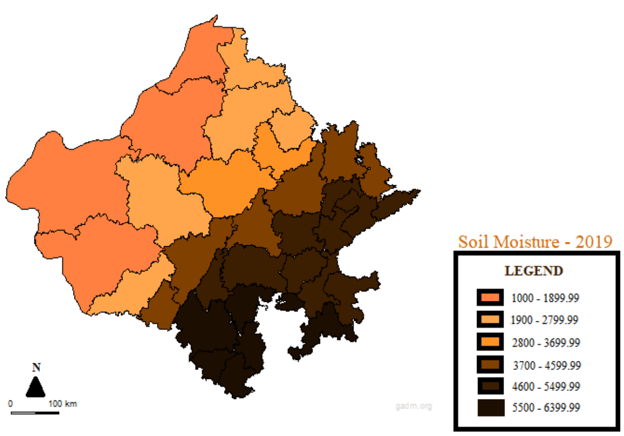

Figure 5

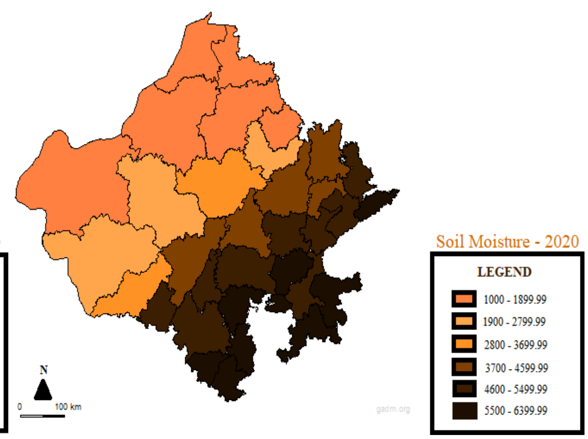

Figure 6

(D) Average Normalized Difference Vegetation Index (NDVI) for 2019 & 2020

Figure 7 shows Average Normalized Difference Vegetation Index (NDVI) Choropleth Map for 2019.

Figure 8 shows Average Normalized Difference Vegetation Index (NDVI) Choropleth Map for 2020.

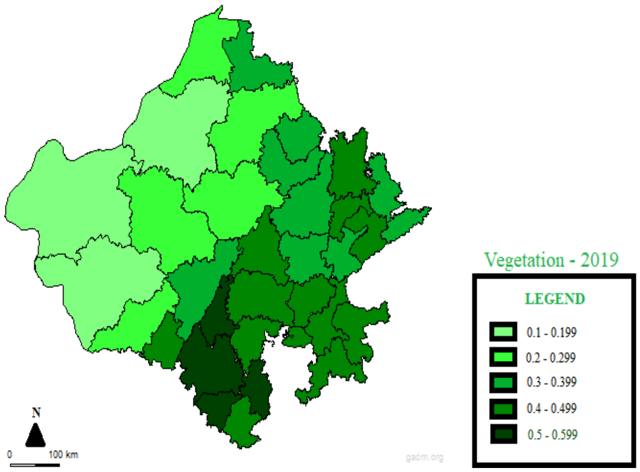

Figure 7

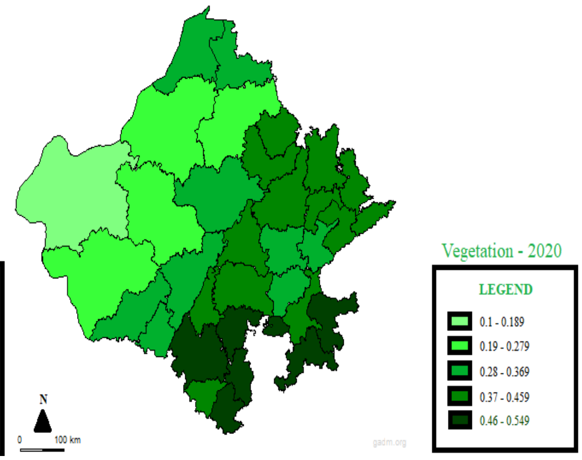

Figure 8

Visualizing Desert Locust Suitability Sites

Overall, the result maps of Distribution of Desert Locust Occurrence Sites along with Environmental Factors maps when visualized simultaneously indicate that: there is a high probability for Desert Locust Habitat Suitability and subsequent breeding in the Western districts of the State and most districts of Central Rajasthan. These regions include the districts of: Jaisalmer, Bikaner, Sri Ganganagar, Barmer and Jodhpur being the most susceptible extreme Western districts, with Jalore, Nagaur and Churu being relatively lesser susceptible Central districts of the State. There is a moderate probability of Desert Locust Activity in the districts of: Sirohi, Pali, Sikar, Hanumangarh, Jhunjhunu, Jaipur, Dausa and Ajmer. Among these districts of moderate probability, the districts of Sirohi, Sikar, Jhunjhunu and Hanumangarh are highly susceptible. Remaining districts come under areas of low probability, with no or very few Desert Locusts invasions recorded. Figure 9 shows districts of high, moderate and low probability of Desert Locust Habitat Susceptibility.

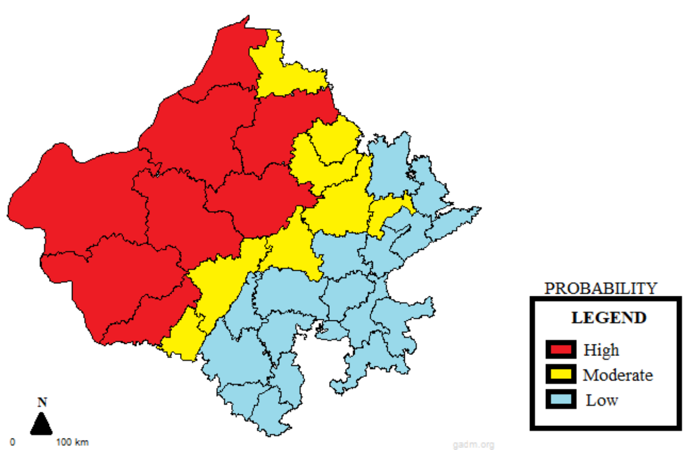

Figure 9

Early Warning System for Locust Control in India

The Early Warning System for Locust Control in India is an integration of four key elements, with four sub elements in every key element. The model is in abidance with United Nation's Development Program (UNDP) Guide to Approaches for building functional Early Warning Systems. Figure 10 is the diagram showing the four key elements of Early Warning System for Locust Control in India.

Figure 10

Risk Knowledge: - Risk arises from a combination of hazards and vulnerabilities at a particular location, in our case – India. The element of Risk Knowledge contains sub elements of: 1 Institutional Arrangement- The sub element of Institutional Arrangement takes into account factors like Regulatory Framework, Mandate, Roles and Responsibilities and Concept of Operation. Institutions like Locust Warning Organization (LWO) need to be strengthened. Step-by-Step approach shall be adopted, functioning on the basis of the roles and responsibilities assigned to each institution. Regulatory frameworks, mandates, roles and responsibilities and concept of operations shall be revised and refined regulatory. 2. Hazard Risk Assessment- A hazard is a potential for harm. The hazard agent, condition and activity shall be identified and assessed. Risk assessment is a systematic process for describing and quantifying the risks associated with hazardous substances, processes, actions or events. This sub element takes into account factors like Criteria's and Uncertainty Assessment. Characterizing the probability, frequency and severity shall be evaluated. Different models (e.g., Machine learning/Artificial Intelligence) and approaches (e.g., Ecological Niche Approach) can be used to identify and evaluate the risks. The hazard risk assessment provides the factual basis for further activities. 3. Community Vulnerability Assessment- A Community Vulnerability Assessment is a process whereby the community comes together to discuss specific areas of concern and identify possible solutions. Communities based on vulnerability (high to low) shall be identified. Community Vulnerability Assessment shall be carried out at farm and village levels. The process shall involve several detailed community meetings, field trips and interviews conducted by experts from Locust Warning Organization (LWO) with Community leader (Sarpanch) and other prominent personalities (Patwari, religious heads). 4. Information Collection, Storing and Sharing- Poor Collection and Management of data results to poor early warning system. The qualitative and quantitative data collected and generated through various modes shall be stored and shared in most fruitful manner. The designs shall be evident meeting the needs of everyone. The data shall be designed in such a manner that it provides the opportunity of revision. Data and Information Collection, Storing and Sharing shall be done through various sources of Open Government Data (OGD) Platform.

Monitoring and Warning Service: - This is the infrastructure that delivers forecasts and warnings. Systems with monitoring and predicting capabilities shall provide timely estimates of the potential risk faced by overall communities, economies and environment. Warning services lie at the core of the system. This contains of sub elements of: 1. Continuous Monitoring and Detection- Continuous monitoring of the Desert Locust upsurge parameters and precursors like favorable Environmental Factors is essential to generate evident, accurate and timely warnings. This sub element talks about Hardware, Software, Operation System and Data Analysis Software that work on continuous basis to detect any significant activity. The sub elements need to be technologically advanced and updated regularly. This will lead to improvements in many facets of the system; providing increased lead-time lengths and locally actionable service. 2. Impact based forecasting and warning- Impact-based forecasting and warning enables anticipatory actions and revolutionizes responses to Desert Locust upsurges. These forecasts and warnings provide critical information to help mitigate impacts and losses. Issuing of forecasts and warnings are generated by assessment of Hazards, Vulnerable Communities and Impacts and Risks associated with it. With Impact-based forecasting, respective institutions assess the impacts of forecasted phenomenon's related to Desert Locust and consider their warnings based on the level and severity of those impacts at those particular locations and communities. Analyzing events of past can help identify the correlations between the magnitude of previous Desert Locust plagues and their relative impacts. Climate crisis has altered the levels of impact of Desert Locust upsurges. With increase in temperature, unusual events of rainfall and shifting wind patterns the maturation rate of Locusts have become more rapid leading to more frequent outbreaks and new invasive areas. Consideration of potential future events and their impacts that may occur shall be incorporated within the functioning of Impact-based forecasting and warning. 3. Warning and other Infrastructure- Resilient Infrastructure helps in improving the utility of Monitoring and Warning service. It includes the drafts of Advisories and Statements that are carried out at Institutional levels. These processes shall function efficiently, involving the respective institutions at State and Central levels of government. 4. Time Responsive Service- Monitoring and Warning service is not useful, unless the information reaches public in evident and timely manner. The Monitoring and Warning Service should be time responsive; it should be quick in issuing forecasts and warnings and should do so time to time. To be effective warnings must be provided timely, with enough lead-time for response. Timeliness is often in conflict with the desire to have reliable predictions, which become more accurate with the input of more information. In such case, the service shall give regular updates, updating every time with the input of new data or information.

Dissemination and Communication: - An effective Early Warning System needs an effective communication system. The communication infrastructure must be reliable and robust incorporating appropriate and effective interactions among the main actors. The distribution of understandable warnings and preparedness information to the vulnerable communities (farmers) underpins the dissemination and communication process. This includes the sub elements of: 1. <u>Dissemination and Notification Methods</u>- This is totally based on the type of population present and their mode of acquiring information. Many tools are generally available for warning dissemination and notifications, the tools shall be used in the most efficient way possible. The use of Newspapers, Radio, Televisions, Warning Notices sent to Panchayats and Televisions can be used as a medium of spreading information related to Desert Locust invasions. The information shall be disseminated rapidly trying to cover each and every stakeholder. Dissemination of warnings and forecast shall follow a cascade process, starting from National level and then significantly moving downward in the scale to State, reaching Regional and Community levels. The Warnings shall be disseminated along scale of initial and final alerts. Additional location wise information related to economic mitigation can also be shared beforehand alongside (e.g., right choice of crops to sow for optimum farming, reducing the economic risk of crop damage by Desert Locust). 2. <u>Risk Communication Mode</u>- The choice of Risk Communication mode shall be made by assessing the population and its subsequent types, if possible, notifications shall be issued at all the encompassing levels. Government Notified, Public Notified and Local Community Notified modes can be selected suitably. These notifications shall be time effective and should cover most of the population depending on the functioning area. 3. <u>Community Connection and Response</u>- A successful Early Warning System shall be people and community centered. Ensuring a two-way communication network, Public Awareness regarding threats and knowing about Appropriate Response Techniques. Community connected Early Warning System helps to reduce losses by allowing people to better protect their assets (crops) on community level. This relatively helps in community empowerment. This sub element makes sure that the system addresses the needs of all members of the community, along with special needs of the most vulnerable groups. Awareness and knowledge of appropriate response techniques play a key role in response. These responsibilities can be undertaken by the suitable institutions. 4. <u>Compensation Strategy</u>- Assessment of potential damage done by Desert Locust invasion shall be accounted and addressed. Suitably, funds shall be allocated to the inflicted groups present (if any). These funds shall be compensated on the basis of the considerations (preliminary and postliminary). Effectively helping victims after an upsurge often requires government action beforehand, by putting victim compensation arrangements in place.

Response Capability: - Is the last component of the Early Warning System. This is the centralized knowledge, plans, and inputs needed for timely and appropriate actions by authorities and those at risk. The response element includes the mobilization of the necessary emergency services and first responders in the upsurge area. There is need for both discipline (structure, doctrine, process) and agility (creativity, improvisation, adaptability) in responding to the Desert Locust upsurge. Combining that with the need to build a high functioning teams of Locust Warning Organization (LWO) to quickly coordinate and manage efforts as the upsurge grows beyond the initial areas of Desert Locust activity. This key element includes the sub elements of: 1. <u>Control Strategies and Types</u>- The preventive control strategy for the management of Desert Locusts shall be based on the severity of Desert Locust Activity in the vulnerable areas. The control strategies shall be sustainable in nature not having adverse effects on livestock and environment. 2. <u>Application of Evidence based Solutions</u>- Attempts to apply previously developed models of solution have weaknesses. New innovative solutions hall be adopted for Locust Control. Studies and Researches on Locust behavior and control strategies should be promoted, effective solutions shall be applied for response across Desert Locust infected area on trial and actual phases. Quality Control solutions shall be adopted to be used in Control Operations. 3. Institutional Partnerships and Collaborations- Implementation of Effective Desert Locust Response plans require coordination across many institutions, organizations and agencies at national to local levels for the system to work effectively. It is important to tackle the hazard with the collaboration of Science, Technology, Community, Government (State and Central level), Private Sectors and other relevant stakeholders. 4. Capacity Development- Capacity is the ability of institutions to perform functions effectively and in sustainable manner. Institutional capacity, which is the ability of institutions to effectively perform response functions in a long-term sustainable manner, sets up a baseline for smooth functioning of Early Warning System for Locust Control in India. Institutional capacities need to be developed to respond to the hazards, capacities also need to be developed by assessing future trends.

Discussion

Tremendous stride has been made by India in various fields such as space technology and communication, this has opened up several frontiers which were inaccessible in recent past. In this scenario, development and establishment of Early Warning System for Locust Control in India comes into effect. Establishing an Early Warning System for Locust Control in India is of paramount importance. The system is mainly designed to aid the farmers, as they are the most vulnerable community in an area facing Desert Locust invasion. The system is meant to provide timely and meaningful information about any significant Desert Locust Activity in India. Based on the information provided, timely warnings will be generated and disseminated for response and decision making at different levels. Technology alone will not prevent Locust plagues, but when integrated with field station and locust preventive program aided with sufficient resources can contribute to improving early warning as a means of reducing the frequency of locust plagues. The study will assist policy makers and the officers of Locust Warning Organization (LWO) in prioritizing resource allocations and taking effective management actions by having a framework to adhere by. The recent Locust Attack (2020) emerged as an agrarian disaster for the nation. The maps generated in the present study could possibly guide officials to undertake focused and cost-effective monitoring methods.

Methodology

All datasets used were obtained from secondary sources; no survey for ground scouting was conducted. The study, therefore, aligns with the concept promoted by the Open Science Movement, that is encouraging the reuse of data for further discovery and advisory. The secondary datasets were all obtained from Open Government Data Platform.

Desert Locust Occurrence Sites.

The information related to Desert Locust occurrence sites was sought through Google and Web of Science. The keywords used for the search comprised the following: Desert Locust occurrence sites in India from 2019 to 2020 and known Desert Locust occurrence sites in India. The focus was given to obtain the data with respect to study area (Rajasthan, India) and temporal scale i.e., from 01st-June-2019 to 31st-August-2020 (15 months). Government of India – Locust Warning Organization, produces and issues the Desert Locust Situation Bulletin at fortnightly intervals (15 days – 2 weeks). The bulletin provides regional summary of the Locust situation along with Weather events and Ecology of potential significance of Locust development. With respect to our temporal scale Desert Locust Situation Bulletins were selected from Volume 71, Number 11 (Period – 01-15 June, 2019) to same Volume, Number 16 (Period – 16-31 August, 2020). The bulletin includes maps showing Desert Locust – Presence sites and Absence sites along with the Control Operations area (if taken). Individual Locust situation maps were clipped from each locust bulletin lying within the temporal scale, the maps were then added in QGIS 3.16.2 – QGIS Geographic Information System and the use of Raster Georeferencer tool was done using the Coordinate Reference System – ESRI:104199 GCS – WGS 1984. A total of 1484 presence sites were recorded with respect to time scale and the study area. These sites were noted along with their Place Name, Month-Year, Longitude(X) and Latitude(Y) in using Microsoft Corporation, Microsoft Excel. The Excel sheet containing the Locust Presence sites was then saved as in .csv (comma separated value) format which allowed the data to be saved in a table structured format. The converted file was then added as a layer under Add Delimited Text Layer in QGIS 3.16.2, the layer was overlaid on a Shapefile containing the district–wise administrative division of the study area (Rajasthan, India). Hence, giving the final output of the Desert Locust Presence Records Map with respect to the Temporal Scale (01st June 2019 to 31st August 2020) and the Study Area (Rajasthan, India).

Bioclimatic and Edaphic Factors

Among the many variables; Temperature (General), Rainfall (2019, 2020), Soil Moisture (2019, 2020) and Normalized Difference Vegetation Index (NDVI) Indices (2019, 2020) data was sourced from different Open Government Data Platforms to prepare District wise Choropleth Maps. Please Note for the above factors, an average of three months (June, July, August) for each factor was calculated and mapped. These three months correspond to the Desert Locust invasion activities in Rajasthan, India. Rationally, the environmental factors used are of identical Month-Year timeline with the Desert Locust Occurrence records, except for the factor of Temperature.

Temperature- A general temperature data was sourced from different platforms; mainly the data was extracted from: Government of India – Climatological Summaries of State Series – No. 16. The data was then cross-referred with Dainik Bhaskar – E-paper. The newspaper publishes daily Maximum, Minimum and Average Temperature on the upper right-hand corner of their newspaper. Historical Archives of the newspaper were studied using the newspaper's subscription available easily on the internet. Daily district wise temperature records were analysed and cross-referred from the previous data. A single map showing General Temperature was prepared for the Temperature factor.

Rainfall- Data for the factor of Rainfall was extracted from: Government of Rajasthan – Water Resources Department produced Monsoon Report 2019 and Monsoon Report 2020. District wise averages of the three months (June, July, August) were sourced to calculate the total average for 2019 and 2020. Two maps were prepared for the Rainfall factor.

Soil Moisture- The data for the factor of Soil Moisture was calculated from: Government of India – Ministry of Agriculture & Farmers Welfare – Department of Agriculture, Cooperation & Farmers Welfare – Mahalnobis National Crop Forecast System; under Projects – National Agricultural Drought Assessment and Monitoring System (NADAMS). Data on the administrative level of district using soil moisture model is provided on the portal. Two maps were prepared for the indicator of Soil Moisture.

Prevalence of Vegetation- The data for the factor of Prevalence of Vegetation was taken from the same source as that of the factor of Soil Moisture. Data on the administrative level of district is provided in Normalized Difference Vegetation Index (NDVI) format.

Data Assumptions

The study assumed that all the Desert Locust Occurrence Site(s) Records were obtained from a larger area, within the country with reference to the temporal scale and the study area. The Desert Locust Occurrence Sites follow Standard Operating Procedures (SOP) for Desert Locust Ground Survey defined by Food and Agriculture Organization (FAO) of United Nations (UN). Similarly, the sources used in the collection of Bioclimatic and Edaphic factors notify in the Disclaimer section: The Respective Department is not responsible for any errors and omissions; and the contents published within the report have been checked and authenticity assured within the limitations of human errors.

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