

## Climatic Suitability of the Distribution of the Rice Cultivation Zone in Haryana, India

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Received 20 January 2017; Accepted 23 February 2017 ; Published online 14 March 2017

**Abstract** Suitability analysis in agriculture is a prerequisite for optimum utilization of the available land resources. The present study was to find out suitable zones for rice cultivation based on climatic and physical factors of production using GIS approach. The study was carried out for Haryana state (27°39' N to 30°55' N latitudes and 74°27' E to 77°36' E longitudes) in India. Biophysical variables like climate, soil and topography were considered for suitability analysis. Suitable zones were identified on the basis of suitability of weather at different phenological stages. In the present analysis, 31.1% area of state was found suitable for rice pro-

duction out of which 28.2% was highly suitable where weather conditions and physiographic factor were found highly suitable. 18.61% area of central parts of Haryana fell under moderately suitable areas where rice could be cultivated with supplementary irrigation only. The research also confirms the capability of GIS in taking better decision for optimal use of land resources.

**Keywords** Geographical information systems, GIS, Suitability, Overlay analysis, Rice.

### Introduction

India may become the largest exporter of rice next year amid higher demand anticipated from African and Middle East countries and competitive prices as reported in newspaper (The Economic Times Oct 8, 2014). This implies demands for higher production as well as larger production area in future. The term rice is life is most appropriate for India as this crop plays vital role in countrys food security and is the backbone of livelihood for millions of rural households. Rice is one of the principal crops cultivated as well as consumed in India. About 13% of the total land area is planted with rice in India. In

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2009-2010 annual rice consumption was estimated to 74.7 kg per person in rural areas and 56.64 kg per person in urban areas and only rice shared about 50% of total cereal consumption [1]. The rice production has increased from 223 thousand tonnes to 3630 thousand tonnes (more than sixteen-fold) during the period 1966-67 to 2009-10 [2]. Sangwan [3] observed that changes in the cropping pattern of Haryana state resulted from increase in irrigation facilities to a large extent. Owing to the diversity of soil, agro-climatic conditions, availability of canal irrigation and infrastructure services like road and markets across the region, there exists lot of potentiality to cultivate varied types of crops. Spatial information on agricultural practices is very much crucial for agricultural planning. There has been a growing consensus about the need of local level (at least district level) agricultural planning. In Haryana, it would be of importance to know the level of crop suitability on regional dimensions to formulate district specific agricultural policies.

The suitability is a function of crop requirements and land characteristics and it is a measure of how well the qualities of land unit match the requirements of a particular form of land use [4]. Geographic Information System (GIS) have emerged as a powerful tool in the management and analysis of the large amount of spatio-temporal data and information and further, land use decisions. In recent years FAO has been developing GIS linkage with its agro-ecological zoning and similar models, applying these to tackle issues of land at regional levels [5]. GIS technology is very useful for automated logical integration of bio-climate, terrain and soil resource information, which are required for land use planning in a region.

Therefore, the present study was planned to analyze rice suitability ones using GIS. As per Planning Commission of India, the state comes under the VI agro-climatic region i.e. Trans-Gangetic plain region [6]. It lies within the geographical coordinates from 27°39'N to 30°55' N latitudes and 74°27' E to 77°36' E longitudes. Total geographical area is 44,212 sq km (1.37% of countrys geographical area) and 85% of it is available for agricultural use. Rest of 15% is covered under non agricultural uses such as built up,

barren land or forests . Major agricultural crops of the area are wheat, rice, cotton, oil seeds, guar, bajra and sugarcane. Out of 21 districts in the state, districts of Bhiwani, Faridabad, Fatehabad, Gurgaon, Mahendragarh, Mewat, Palwal and Rewari are water stressed, mostly arid land because of the high water table depth and less irrigation water supply [7].

## Materials and Methods

This study was undertaken at Department of agricultural Meteorology, CCS HAU Hisar to delineate suitable zones in Haryana for rice cultivation. Climate variable were analyzed in spatial domain along with other physical variable such as soil and slope to find out suitable region for cultivation of rice crop. District level data of monthly temperature (maximum and minimum ) and relative humidity was collected from agro climatic Atlas of Haryana. Total 19 points were generated at different locations corresponding to different districts in the state. Interpolation and zoning was carried out for each month in Arc GIS 10.1 after selection of specific suitable limits of suitability for growth stage of rice in respective month.

Information on slope (topography) of land was acquired from Shuttle Radar Topographic Mission (STRM), NASA, USA available for all on USGS site. SRTM is radar data that represents terrain elevation as imagery of 90 m spatial resolution. Suitable soil classes were identified from soil map of Haryana available in Resource Atlas of Haryana [8]. The flow-chart shown in Figure 1 describes the procedure and steps followed for this research. Criteria for determination of suitability zones are presented in Table 1.

## Results and Discussion

### Topography

Rice is a crop which is required to be drowned upto some centimeters in water. Therefore, flat surface are more suitable for its cultivation. Although Haryana has flat topography, yet in some pockets, the slope conditions are not supportive of rice crop. To access the slope in the state, height information

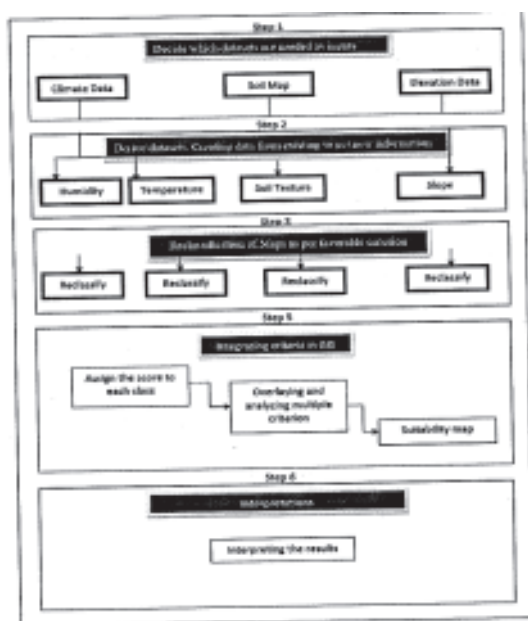


Fig. 1. Flow chart of methodology.

was interpreted from SRTM 90 m data. From this, percentage slope information was generated in GIS and the different suitable zones were identified for rice crop.

a) *Highly suitable topography* : Land surface falling in 0-2% slope classes was put in highly suitable category for rice crop which covered all parts of Haryana except for some parts in north and southern Haryana where hills of Shiwalik or Aravali range change the topography.

b) *Suitable topography* : Land area having 2-5% slope along the hills in north-east part of Haryana (parts of Panchkula and Yamunanagar districts) fall in this zone.

c) *Moderate suitable topography* : Land area within 5—8% slope included in this zone which was present in north part of panchkula district.

d) *Unsuitable topography* : Land area having more than 8% slope was delineated as unsuitable for rice crop.

#### Soil texture

Clayey soil has been observed as best soil for rice crop. The other type of soils having high portions of clay contents with good moisture availability are also considered suitable for rice. Following suitability zones were identified on the basis of soil texture in the state.

a) *Highly suitable* : Soil texture classes such as clay, clay loam were categorized as highly suitable for rice crop. North -east and east part of Haryana (districts of Panchkula, Ambala, Yamunanagar, Karnal, Painpat and Sonipat) fell under this zone.

b) *Suitable soil texture zone* : Loamy clay, loam, fine silt were classified in this zone. These soils found in all part of Haryana except for western parts of Sirsa, Fatehabad, Hisar, Bhiwani and Mahendragarh, Rewari and Gurgaon districts.

Table 1. Suitability criteria for rice crop in Haryana.

Suitability classes	Slope	Soil texture	Relative humidity	May temp (°C)	Jun temp (°C)	Jul-Aug temp (°C)	Sep-Oct temp (°C)
Highly suitable	<2 %	Clay, Clay loam	—	—	—	—	—
Suitable	2–5%	Loamy clay, Loamy fine silt	60–80%	18–40	12–35	16–35	12–30
Moderately suitable	5–8%	—	—	—	—	—	—
Unsuitable	> 8%	Sandy, Sandy loam, Loamy sand	<60%	>40	>35	>35	>30

c) *Unsuitable soil texture zone* : Sandy, sandy loam, loamy sand soils which had poor capacity to hold the moisture were put in unsuitable zone for rice cultivation. This zone comprised of Mahendragarh, Rewari, Gurgaon, Sirsa and western parts of Hisar and Bhiwani districts.

#### Relative humidity (RH)

Moist humid weather during vegetative growth and dry-sunny weather during ripening is most desirable. A relative humidity of 60-80 % is observed to be optimum in different researches. Higher value of relative humidity was desired for all the vegetative phases of rice crop from May to October. Therefore, following zones were delineated :

a) *Suitable* : North and south-east part of Haryana along with some part of Rohtak and Jhajjar districts were best suitable (RH 60-80%) for rice crop. This zone covered in eastern agroclimatic zone of Haryana.

b) *Unsuitable* : This zone RH (<60%) found in west and south-west part of Haryana including some part of Jind and Gurgaon districts.

#### Temperature

The average temperature required throughout the life period of the rice crop ranges from 21 to 37°C. Temperature greatly influences not only the growth duration, but also the growth pattern of rice crops [9]. Rice plant has four major growth stages and every stage has an optimum temperature range for its proper development. Duration of the critical temperature, have a great impact on physiological status of the plant. High temperatures are a constraint to rice production and cause yield reduction. When temperatures exceed the optimum limit for biological process, crops often respond negatively with a steep decline in net growth and yield. In Haryana, rice cropping process starts from May and lasts up to October. Following optimum temperature limits (maximum and minimum) were selected for different growth stages to demarcate suitable temperature zones in the state by GIS.

#### May (for germination period)

High temperatures are associated with May in the state with limited or no rainfall. Conditions were found more severe in western parts as compared to eastern parts. Area falling under temperature ranges of 18°C to 40°C was included in suitable zone. The north part of Haryana i.e. districts of Panchkula, Ambala, Yamunanagar, Karnal, Kurukshetra, Kaithal and some part of Fatehabad, Hisar, Panipat and Sonipat were found suitable for germination of rice i.e. rice nursery. Other regions where more than 40°C temperature prevails were categorized as un-suitable zone for rice cultivation as thermal conditions were not suitable in May month for germination of the crop. The south and western part of Haryana fell under this zone.

#### June (seed emergence period)

The month of June is seed emergence period for rice. The suitable temperature zone for this growth stage of rice ranges from 12°C to 35°C. North part of Haryana i.e. districts of Panchkula, Ambala, Yamunanagar, Karnal, Kurukshetra, kaithal including and parts of Jhajjar and Bhiwani districts were found suitable for this growth stage, whereas, southern and western parts of Haryana were classified as un-suitable because of more than 35°C temperature in June.

#### July-August (i.e. rooting and growth period)

The suitable temperature zone for rooting as well as further growth of rice was from 16°C to 35°C. Area having optimum temperatures i.e. suitable for this growth stage was found in the northern districts of Haryana along with some part of Fatehabad, Hisar and Sonipat districts. The southern and western parts of state were un-suitable for this stage of rice crop as temperature was beyond the optimum limits.

#### September-October (growth and ripening period)

For growth of rice as well as ripening or harvesting period, suitable temperature was from 12°C to 30°C as reported in researches. North part of Haryana i.e.

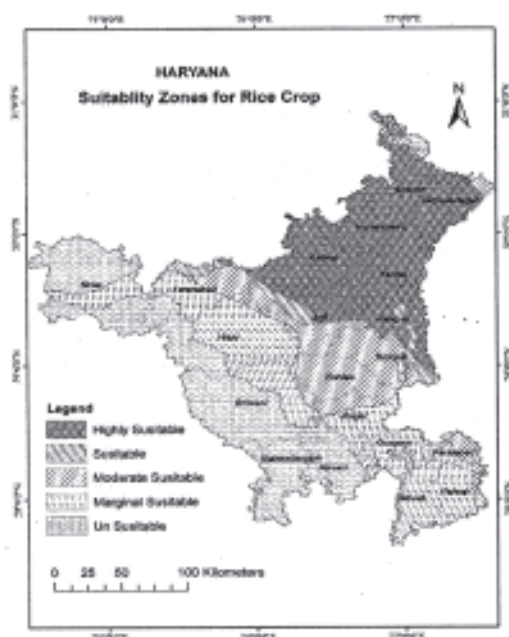


Fig. 2. Suitability zone for rice crop.

districts of Panchkula, Ambala, Yamunanagar, Karnal, Kurukshetra, Kaithal and some part of Jind district fell under this (suitable) zone. Rest of the entire state was deemed as un-suitable zone for rice growing as maximum temperature exceeds 30°C in these months.

Final zoning by union of all geo-meteorological parameters

All the GIS layers for different weather parameters were brought together to make a composite layer to find the different types of suitable zones in the state for rice crop. Analytical process in GIS carried out by union operator in which features from two or more map layers were combined to form a single composite layer. Finally, the polygons were grouped into different zones on the basis of numbers of aggregate suitable parameters and different suitability

zones were identified (Fig. 2).

Viz :

a) *Highly suitable zone* : Areas under suitable category in all of parameters were demarcated as highly suitable area. It denotes highly suitable geo-meteorological zone that meet climate, soil and topography suitability criteria for rice crop cultivation. This zone was found dominated in north east Haryana and extended up to central parts of state. Districts of Panchkula, Ambala, Yamunanagar, Kurukshetra, Kaithal, Karnal, Jind and Panipat were found in this zone. This total area covered under highly suitable zone for rice was 28.2% of total geographical area of the state.

b) *Suitable zone* : A narrow belt covering parts of Jind, Faridabad, Sonipat, Panipat and Panchkula district fell in this zone. This zone was differed from highly suitable zone because of at least one of the criteria was not suitable for rice crop cultivation. The total area covered under suitable zone was just 2.9% of geographical area of state.

c) *Moderate suitable zone* : Central parts of state which are also the transition zone of both of agro-climatic zones (i. e. eastern and western) of state were covered in this zone. This zone comprised of the polygons (area) which did not meet at least two parameters of suitability criteria. The districts Rohtak, Sonipat and part of Jind, Fatehabad, Hisar, Jhajjar, Faridabad, Palwal, Yamunranagar and Panchkula districts fell under this zone. The total area covered under this zone was 15.7% of geographical area of state.

d) *Marginally suitable zone* : Area having at least one criterion suitable for rice crop were put in this zone. Districts of Fatehabad, Hisar, Gurgooan, Palwal, Mewat and parts of Faridabad, Sonipat and Sirsa districts of Haryana fell under this zone. This zone extended over arid (west) and semi arid area (east) in the state. Although, rainfall low but due to better irrigation facility rice was grown in some parts of this zone. In Sirsa, rice is cultivated in ghaggar river belt.

The total area covered under marginal suitable zone was 24.5% of geographical area of state.

e) *Un-suitable zones* : This was unsuitable zone for rice crop which was in vicinity of extreme western dry area of the state. All the parameters under analysis were found unfavorable for rice crop in this zone. Districts of Mahendragarh, Rewari and Sirsa along with major part of Bhiwani and parts of Gurgaon, Faridabad and Mewat districts fall under this zone. The total area covered under un-suitable zone for rice was found to be 28.7% of geographical area.

### Conclusion

Haryana state is one of major contributors in central pool of agriculture produce. Flat topography, fertile soil and facility of irrigation had resulted in intensive area under rice cultivation. GIS has now become a useful tool for suitability analysis in spatial sciences. In Haryana, more than 70% geographical area had found suitable for rice cultivation in Haryana under different suitability classes. Area under highly suitable and suitable zones was 28.2% and 2.9% respectively of total geographical area of the state.

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