LAND SUITABILITY MODELING FOR ARHAR PULSE THROUGH ANALYTIC HIERARCHY PROCESS USING REMOTE SENSING AND GIS: A CASE STUDY OF SEONATH BASIN

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ABSTRACT: Agriculture is the primary needs of the any developing country where more than 70 % people directly depend on agriculture for its livelihood. In this regards, Seonath Basin is not exception because it is an important agriculture dominated area which spread over the fertile plain of Seonath River and its tributaries. The study area is located in between $20^0$10' N to $22^0$33'N and $80^0$25'E to 81^0 58'E covering an area of 21035.27 km^2 with 317 metre average height above mean sea level. The present study is based on secondary data which is collected from Satellite Image (Landsat ETM+), ASTER GDEM, Toposheet, Chhattisgarh Atlas, etc. Now-a-days, Arhar Pulse is the most important Kharif Crop and daily uses demandable Pulse in the area. This pulse mostly followed by rainfall, soil fertility, slope and irrigation facilities but other attributes also has been taken into consideration for its suitable growth. The spatial distribution of suitable land for Arhar Pulse has been delineated by Land Suitability Modeling (LSM) through Multi-Criteria Decision Making (MCDM) approach in Analytic Hierarchy Process (AHP) of Saaty followed by FAO's Land Evaluation Framework (LEF) based on existing land use, soil, relief, slope, irrigation, climate etc. on Remote Sensing and GIS Platforms. Seonath Basin sharing the area of 13.83% High Suitability (S1), 34.27% Moderate Suitability (S2),14.42 %Marginal Suitability (S3), 19.26% Marginal Unsuitability (N1), and 18.22% Unsuitable (N2) for the growth of Arhar Pulse.

Therefore, finally concluded that high suitability (S1) area fulfill the requirements of all suitable factors for suitable growth and production of Arhar Pulse but other suitability area (S2, S3, N1 &N2) suffering from the lack of one or more factors for the growth and production of Arhar Pulse. Thus, the use of geo-spatial technology and mathematical calculation helps accurately to delineate the suitable land and provides real time information to take right decisions for future planning of Arhar Pulse.

INTRODUCTION:

Agriculture is the primary and oldest activity of man, the pillar of any developing country and its civilization where most of the people directly depends on agriculture. In this regards, Seonath Basin is not exception because it is an important agriculture area where most of the people directly or indirectly depends on agriculture mostly on Crops. Crop means those agricultural practices which directly related to land as tiling the land for production of food stuff (Das, 2000). Pulse as an annual leguminous crop yielding from one to twelve seeds within the pod and harvested for dried seeds (FAO). Arhar Pulse is an important demandable leguminous Kharif Crop in the area where most of the people daily used it as a vegetable. Now-a-days most of the people in the area concentrate for the cultivation of Arhar Pulse because the cost of cultivation of Arhar Pulse is very cheap (Rs. 4760/acre) and net income (Rs. 6067/acre) is very high due to high national market price (Rs. 92-100/kg.) than other pulses (Banerjee et al., 2010). But Arhar Pulse share 2.96% of the total cropped in the area which is very limited in the area for the economic development of cultivators (Field data, 2009).

Keeping in mind about the aforesaid facts, the geospatial technology (Remote Sensing and GIS) and mathematical modeling (Analytic Hierarchy Process) are used for the solutions of current scarcity of land and searching of the available suitable land for the cultivation of Arhar Pulse in the area. Remote Sensing is a modern technology used for real time data collection from the earth's surface where Geographic Information System (GIS) generates informations based on geospatial data and making decisions for the solutions of current arising problems based on such mathematical calculations and modelings. In this regards, Remote Sensing and GIS and Analytical Hierarchy Process (AHP) of Saaty are used for searching of suitable land for the cultivation of Arhar Pulse through Land Suitability Modeling (LSM) based on several physical, cultural and socio-economic criteria on ERDAS Imagine and ARC GIS platforms.

STUDY AREA:

Seonath Basin is a central part of Chhattisgarh state, (India) extends in between $21^0$10'N to $22^0$33'N and $80^0$25' E to 81^0 58' E covering an area of 21035.27 km^2 and 317 metre average height above mean sea level. The area encircles by Durg, Rajnandgaon and Kawardha districts. Seonath Basin is old geological formation of Peninsular India and Seonath is the main River while Kharun, Dotu are its main tributaries (Tiwari, 2004). The study area is rich in black fertile soil and having Monsoon type of AW climate (W. Koppen). The maximum temperature in May 34.35^0C and minimum in October 25.20^0C with average annual rainfall 140 cm in the area. Population of the area is 4678212 (Census 2001) and its density 220 person per square kilometer. The Iron and Steel is the main industry of the region with well connected by rail and road transportations system.

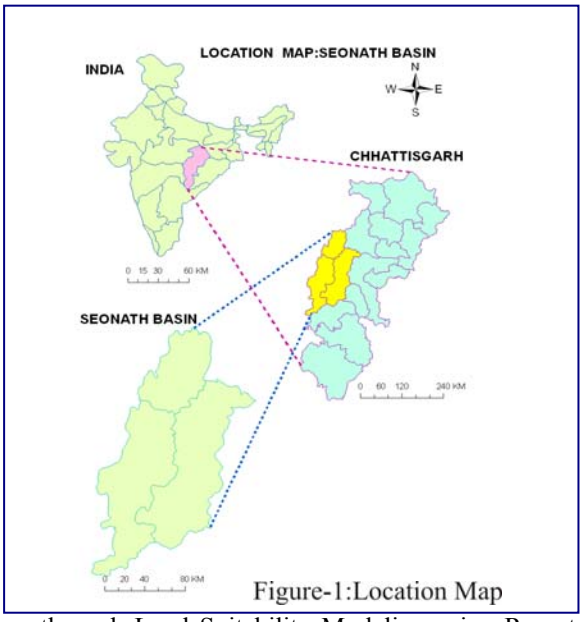

Figure-1:Location Map

OBJECTIVES:

The present study is based on some basic objectives which are outlined below with following heads, e.g.:

i. To find out the limitations and suitable conditions for the cultivation of Arhar Pulse in Seonath Basin.
ii. To find out the Suitable land and its spatial distribution for the cultivation of Arhar Pulse in the area through Land Suitability Modeling using Remote Sensing and GIS for future planning.

METHODOLOGY:

The present study is based on secondary data as Satellite Imagery; Landsat ETM+ (Spatial Resolution 30 metre, 2003) and ASTER GDEM (Spatial Resolution 30 metre and Vertical Accuracy 20 metre) collected from open sources of NASA. Others data like soil map, climatic information collected from Chhattisgarh Atlas prepared by NATMO, 2004. The Land Use and Land Cover map is prepared on 1:50,000 scale from Landsat ETM+ using Supervised Classification techniques with 90% thematic accuracy in ERDAS IMAGINE environment. The Relief Map and Slope Map are prepared from ASTER GDEM with 20 metre vertical accuracy on 1: 50,000 scale in ARC GIS engine. The other vector layer maps like, Soil Map, Rainfall distribution Map are prepared from Chhattisgarh Atlas through heads up digitization in ARC GIS engine on 1:100000 scale showing in **Figure 3 & 4.**

Land Suitability is the fitness of a given type of land for a defined uses (FAO, 1976). Land Suitability Modeling (LAM) is a technique to find out the suitability of land for specific purpose as use for Arhar Pulse based on several criteria. This technique helps to determine the land capability and to evaluate land characterization for land use planning. Land Suitability Modeling is done using geospatial technology which is based on such mathematical calculations and decision rules. Such mathematical calculations and decision rules are designed by Thomas Saaty's Analytic Hierarchy Process (1970s) showing in following **Figure 2.** Analytical Hierarchy Process (AHP) is a mathematical decision making techniques that allows consideration of both qualitative and quantitative aspects of decisions between making goal and to choosing alternatives (Saaty, 2008).

Analytical Hierarchy Process is gone through following steps:

a) Goal determination (Land Suitability Modeling for Arhar Pulse),

b) Making judgment on Criteria based on their suitability and limitations followed by Saaty's 9 rating point scale **(Table 1&2)** through Pair-wise Comparison Matrix (PCM) and determined No. of Comparison using following formula (n=7):

$$\textbf{No. of Comparison} = n(n-1)/2 \quad \ldots\ldots (1)$$
$$=21$$

c) Calculate Eigen Value using following formula for n x n order of matrix (n=7)

$$|A - \lambda I| = 0 \quad \ldots\ldots (2)$$

Table 1
Suitability and Limitations of Criteria Classes and their Rating

Layers Name (Main-Criteria)	Degree of Limitations and Suitability of Criteria Classes (Sub-Criteria) and their Rating				
	None	Slight	Moderate	Severe	Very Severe
	S1	S2	S3	N1	N2
	3	2	1	-1	0
Annual Rainfall (mm)	Medium (1300-1400)	High (1400-1500)	Low (below 1300)	-	-
Rainfall from Oct-Dec.(mm)	High (75-100)	Low (50-75)	-	-	-
Soil	Deep black	Medium black	Shallow black & Red loamy	Red sandy	Laterite
Slope (in degree)	Moderate	Gentle	-	Steep	Very gentle
Relief (in metre)	300-350	350-450	255-300	450-650 & 650-750	240-255 & 750-1000
Irrigation	Irrigated crop land	Non-irrigated crop land	-	-	-
LU/LC	Cropped Land	Agricultural Plantation	-	-	Fallow land, Open/Scrubs, High Land with Forest, Water bodies, Built Up, Waste land

Source: Calculated by Author

Table 2

Fundamental Rating Scale of Thomas L. Saaty for Pair-wise Comparison Matrix

Intensity of Importance	Definition	Explanations
1	Equal Importance	Two activities contribute equally to the objective
2	Weak /light	
3	Moderate importance	Experience and judgment slightly favour one activity over another
4	Moderate Plus	
5	Strong Importance	Experience and judgment strongly favour one activity over another
6	Strong Plus	
7	Very strong or demonstrated importance	An activity is favoured very strongly over another, its dominance demonstrated in practice
8	Very, very strong	
9	Extreme Importance	The evidence favouring one activity over another is of the highest possible order of affirmation.

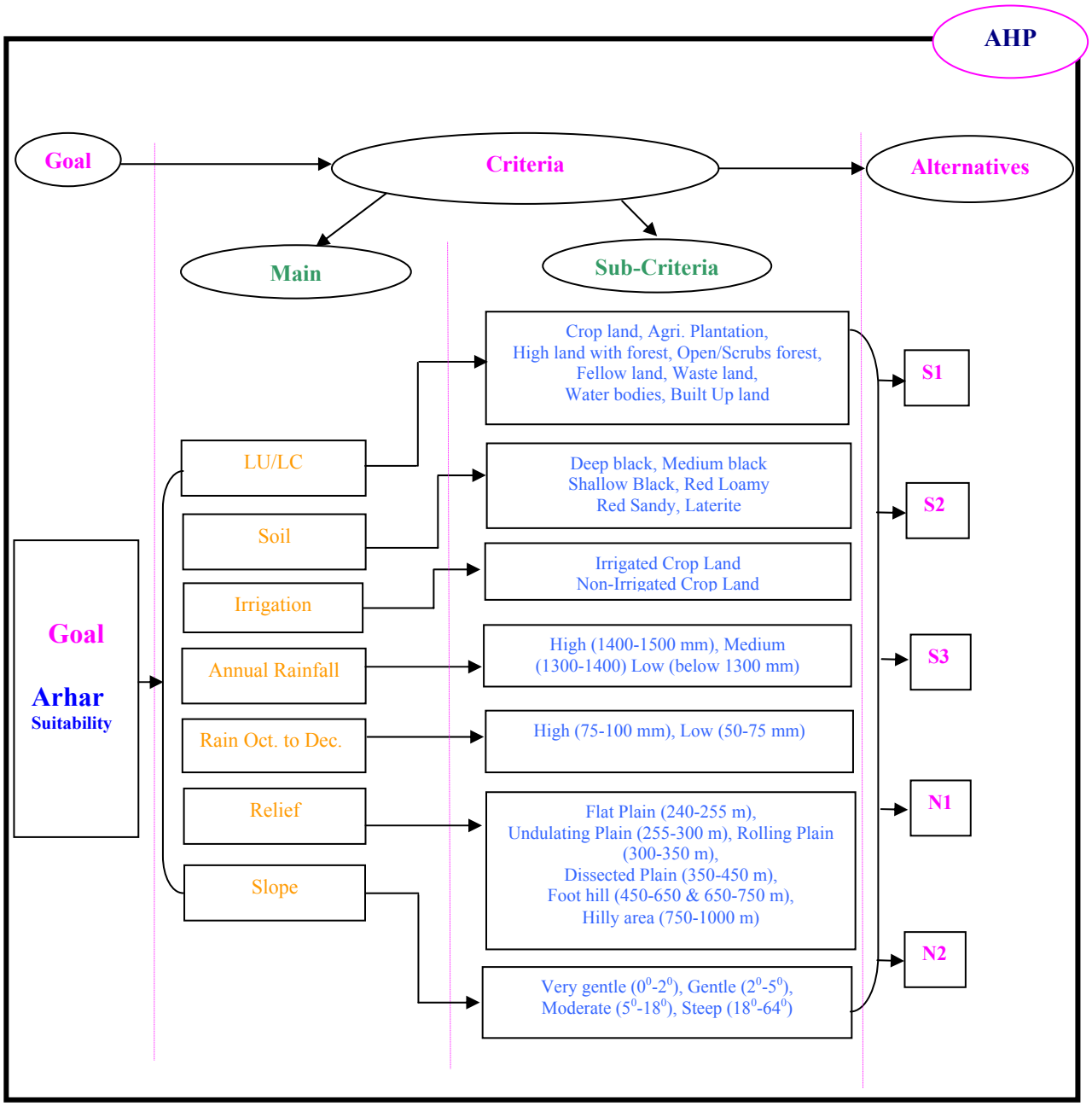

Figure-2: Methodological Flowchart of Analytic Hierarchy Process (AHP)

d) Then calculate Eigen Vector using following formula for n x n order of matrix (n=7)

$$\mathbf{(A-\lambda I)X=0} \quad \ldots\ldots (3)$$

e) Then calculate Normalized Eigen Vector to determine **Weight (Wi, ∑ Wi= 1.00)** for each criteria **(Table 3)** using following formula:

$$\mathbf{X_i / \sum_{i=1}^{n} Xi} \quad \ldots\ldots (4)$$

Where, n= order of matrix, A=square matrix/PCM, λ= Eigen value, X= Eigen vector, I= Identity Matrix.

f) Determination of the Consistency of judgment using formula:

$$\mathbf{Consistency\ Ratio\ (CR) = CI/\ RI} \quad \ldots\ldots (5)$$

CR =0.06 which is acceptable (Acceptable CR =<0.10). Where, Consistency Index (CI) = λmax-n/n-1 =**0.082,** Randomized Index (RI) =**1.32** for n x n order of matrix=7(constant), λmax =**7.49 (**λmax = ∑λ/n)

Table 3

Judgment, Rating and Criteria Weight Using AHP for LSM of Arhar Pulse

Arhar Pulse	Annual Rainfall	Rain Oct.-Dec.	Soil	Slope	Relief	Irrigation	LULC	Weight(W_i)
Annual Rainfall	1	2	3	4	6	8	9	0.34
Rain Oct.-Dec.	1/2	1	3	4	6	8	9	0.28
Soil	1/3	1/3	1	3	4	5	7	0.16
Slope	1/4	1/4	1/3	1	2	4	5	0.10
Relief	1/6	1/6	1/4	1/2	1	3	4	0.06
Irrigation	1/8	1/8	1/5	1/4	1/3	1	4	0.04
LULC	1/9	1/9	1/7	1/5	1/4	1/4	1	0.02
$\sum W_i$								1.00

Source: Calculated by Author.

f) To select the best alternatives, final score is calculated on ARC GIS engine using following formula:

$$\textbf{Final Score (FS)} = \sum W_i a_j \quad i, j = 1, 2...N; \quad \ldots\ldots (6)$$

Where, W_i = weight, a_j = Criteria matrix

Then the final score is classified into five suitability classes where higher score represents high suitability class and lower value represents unsuitable. The degree of suitability is followed by FAO's Land Evaluation Guide, as **S1**= High Suitability, **S2**= Moderate Suitability, **S3**= Marginal Suitability, **N1**= Marginal Unsuitability and **N2**= Unsuitable (Prakash, 2003) and it is find out that the Seonath Basin sharing the area of 13.83% High Suitability (S1), 34.27% Moderate Suitability (S2), 14.42 % Marginal Suitability (S3), 19.26% Marginal Unsuitability (N1), and 18.22% Unsuitable (N2) for the growth of Arhar Pulse showing in **Figure-5**.

CONCLUSION:

Seonath Basin is an agriculture dominated area and an important part of **'Rice Bowl of India'** where more than 70 % people directly depends on agriculture which is their primary needs where Arhar Pulse is their daily uses vegetable and an important source of profitable income investing an small input. The study reveals that the degree of suitability increases indicates the degree of suitable factors increases and degree of limitations decreases and hence the spatial distribution of land suitability varied in the area which sharing 13.83% High Suitability (S1), 34.27% Moderate Suitability (S2), 14.42 % Marginal Suitability (S3), and 19.26% Marginal Unsuitability (N1), and 18.22% Unsuitable due to the spatial variation of the suitable factors and limitations for the growth and production of Arhar Pulse in the area. Therefore it is concluded that if the study is implemented practically in the study area then the area of Arhar Pulse increase from 2.96% (Field data, 2009) to 13.83% (H1) which can be provided better economic benefits to the farmer than the other pulses. Thus, the use of geo-spatial technology and mathematical calculation helps accurately to delineate the suitable land and provides real time information to take right decisions for future planning of Arhar Pulse.

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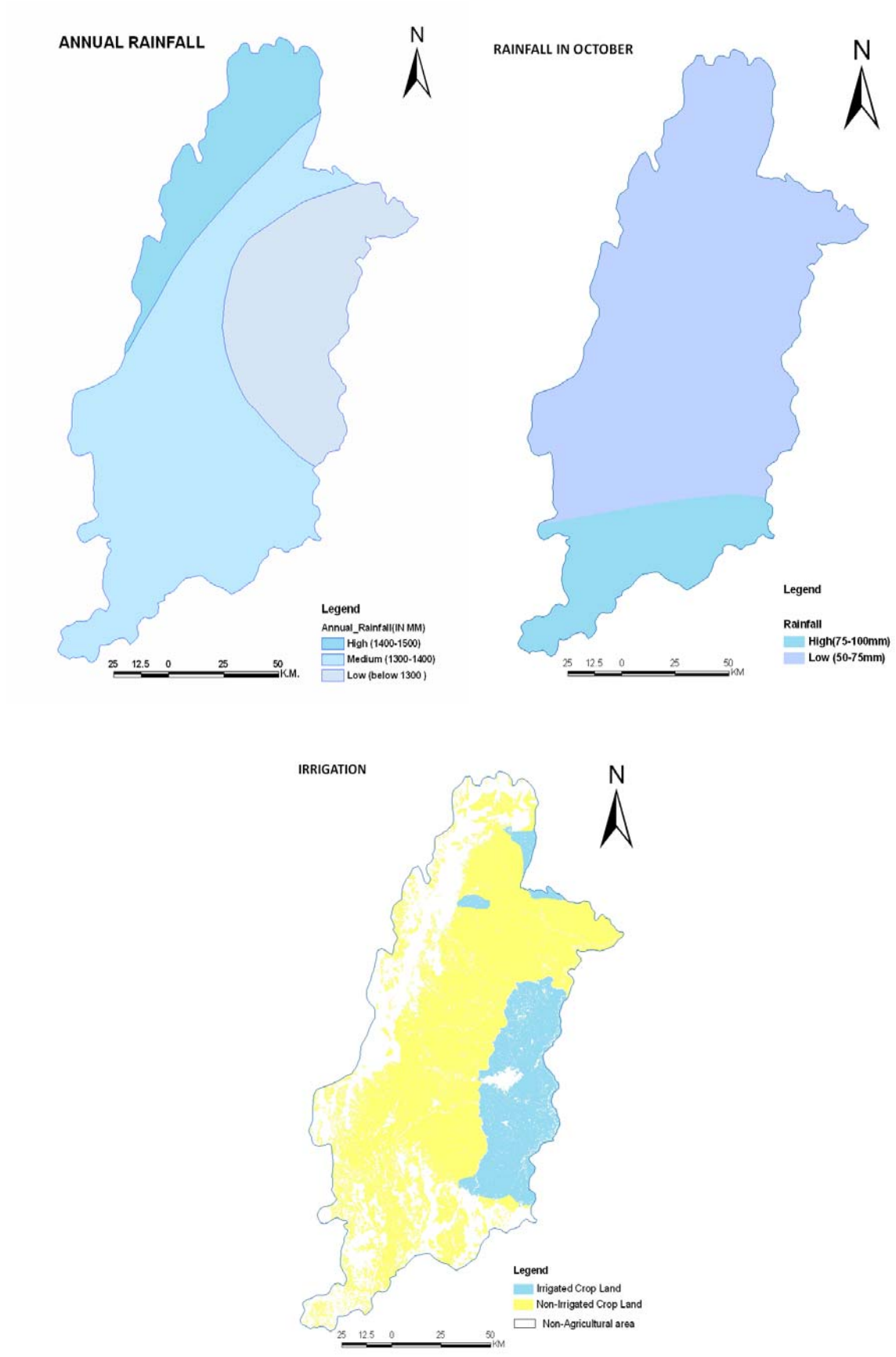

Figure-3:Criteria Classes

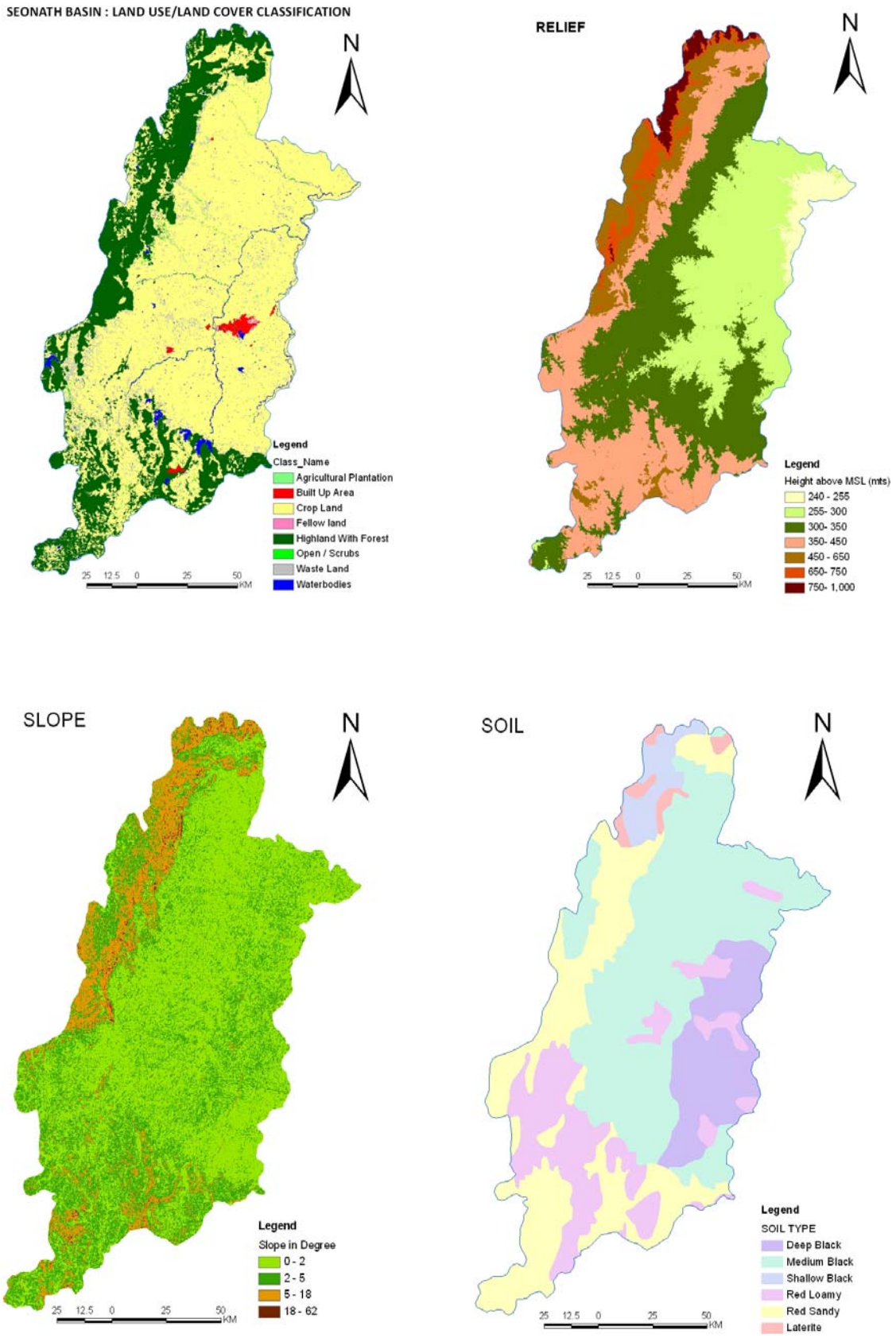

Figure-4: Criteria Classes

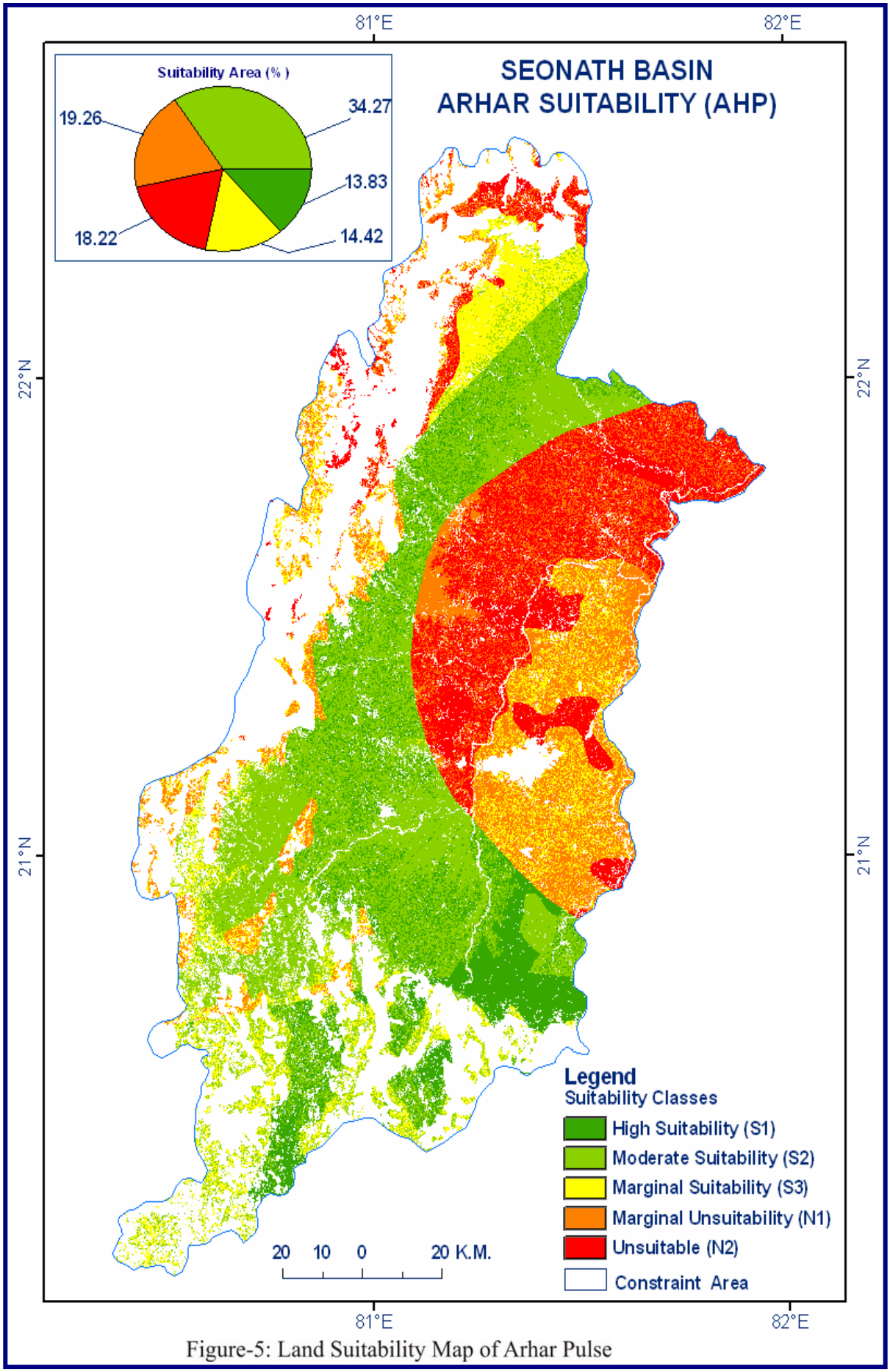

Figure-5: Land Suitability Map of Arhar Pulse