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Multi-Criterion Approach for State and District Level Agricultural Infrastructural Adequacy

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Abstract

Agricultural infrastructure is essential to transform subsistence agriculture to commercial and dynamic farming system by lowering farming costs and increasing the farm income. This study developed a methodology for quantifying the status of both physical and institutional infrastructures for agriculture in India. The study identified the relative state-level agricultural infrastructural adequacy status in the country based on secondary datasets and also validated the methodology at district level using a case study of Bundelkhand region. Finally, the composite infrastructural category is identified for both state level in the country and district level in Bundelkhand Region.

Key words: Multi-criterion approach; Infrastructural adequacy; Pair wise comparison.

1. Introduction

Inadequate rural infrastructure has been considered as a major reason for low agricultural productivity. Agricultural productivity depends on rural infrastructure, well-functioned domestic markets, appropriate institutions and access to appropriate technologies (Andersen and Shimokowa, 2006). Improved roads lead to rise in rural small non-farm business (Fan and Zhang, 2004). One per cent increase in the stock of infrastructure is associated with one per cent increase in GDP across all countries (Patel, 2010). An efficient marketing system leads to enhanced farm income (Kamara, 2004). Connectivity to rural roads may result in change in cropping pattern. One per cent increase in irrigated area has bought about 0.32 per cent increase in productivity of all inputs (Casella and Schilling, 2017). Scientific and holistic development of storage structures promotes horticulture commodities and also controls the food inflation. The relation between agricultural productivity and two important infrastructures on the basis of state level estimates from 21 major states is shown in Figure 1. Pearson correlation coefficient for both market density and road density was observed significantly positive with values 0.52 and 0.56 at 1% and 5% respectively.

Agricultural infrastructure has potential to transform subsistence agriculture to commercial and dynamic farming system as adequate markets, roads, irrigation, extension services, credit facilities, storage *etc*., facilitates lowering farming costs and increase in farm income. The extension personnel and communication technologies help the farmers in better understanding of various supportive policies and schemes. Credit has positive and significant effect on agricultural production. Thus, financial institutions help in increasing production investments, which in turns enhances farmers' return. It is easier to classify a district or state into adequate or inadequate category on the basis of a single parameter, but classifying a region into these categories is difficult with multiple parameters. Considering the importance of agricultural infrastructure, allocation to the Agriculture Infrastructure Fund (AIF) increased to

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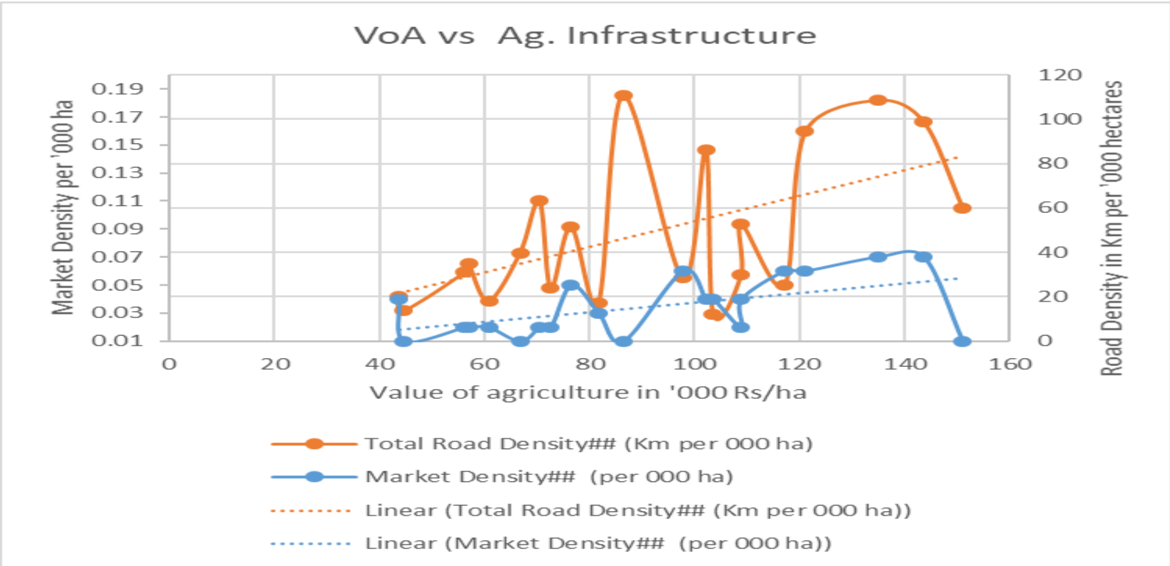
Rs. 500 crores in 2022-23 from Rs. 200 crores in RE for 2021-22. However, identifying the suitable regions having inadequate infrastructure for further infrastructural development is a challenge.

In this study, we propose a methodology for multi-criteria based agricultural infrastructural classes. The methodology is useful for any region, state level as well as at district level. Land suitability classes proposed by FAO (2017) motivated authors to identify the agricultural infrastructure adequacy classes. However, there are differences between land evaluation methodology and the one required for adequacy level estimation of infrastructure as (i) Crop wise adequacy level not needed and (ii) Standard requirement for different classes not available.



Source: Prepared by authors based on data regarding SGDP-agriculture from MOSPI, number of markets from AGMARKETNET, road density from Ministry of road, transport and highways, GoI

Figure 1: Relation between agricultural productivity and infrastructure

2. Data and Methodology

This section presents the data sources used for the development of infrastructural classes and the methodology used for classifying the infrastructural status of each dimension as well as for composite infrastructure.

2.1. Data

The data availability regarding various dimensions of agricultural infrastructure from the authentic government websites is presented in Table 1.

2.2. Weight determination using the Analytical Hierarchical Process

The Analytical Hierarchical Process (AHP) method is considered among the best available approaches to deal with relative importance of one criterion over another for determining the parameter weights, as per the AHP preference scale (Table 2). A scale of 9 indicates that one factor is more important than the other, while 1 means equal importance. The reciprocals of 1 to 9 (1/1 and 1/9) show that one is less important than the other (Saaty and

Vargas, 2001). In the pairwise comparison matrix (PWCM), the importance of parameters is decided by the experts as given in Table 2.

Table 1: Dimensions and data sources

Dimension	Website for data source
Markets	https://agmarknet.gov.in
Irrigation	https://eands.dacnet.nic.in/
Road density	https://censusindia.gov.in
KVK	https://kvk.icar.gov.in/
Credit	https://censusindia.gov.in
Communication	https://censusindia.gov.in
Storage	http://www.nccd.gov.in

Table 2: Preference scale between two parameters in AHP

Relative importance	Definition	Description
1	Equally important	Two factors contributing uniformly to the predefined goal.
3	Moderately important	Experience and judgment are negligibly in favor of one as compared to the another.
5	Strongly important	Experience and judgement strongly in favor of one in comparison to the other.
7	Very strong important	Experience and judgments very strongly favour one over the another. Its necessity is revealed in practice.
9	Extremely important	The sign favoring one as compared to the other parameter is of the maximum possible validity.
2,4,6,8	Intermediate	When compromise is needed
Reciprocals	Less importance	
← 1/9 1/7 1/5 1/3 1 3 5 7 9 →		
Less Importance more		

Source: (Saaty and Vargas, 2001).

After getting the importance from the experts, the weights for each parameter can be determined using the Satty method (Satty and Vargas, 2001). In the AHP method, while executing the pairwise comparisons of criteria, a certain level of variation may follow. To tackle this problem, Consistency Ratio is used for preventing bias through criteria weighting. As a solution, eigenvectors and the largest eigenvalue of the respective matrix were computed, and the consistency index (*CI*) was examined using the following equation:

$$CI = (\lambda_{max} - n)/(n-1) \tag{1}$$

Here, λ_{max} represents the maximum eigenvalue of the pairwise comparison matrix and n is the number of criteria in each Pair Wise Comparison Method (PWCM). At last, the uniformity of the PWCM is examined using the random consistency index (*RI*) value as shown in Table 3. Consistency Ratio (*CR*) was computed by using the method given below:

$$CR = CI/RI \tag{2}$$

To be valid, its consistency ratio should be ≤ 0.10. If the acquired value is larger than 0.10, it is essential to develop the pairwise comparison matrix again. Random Index value for varying "*n*" is shown in Table 3 (Chang, 2007; Shaloo *et al*. 2022).

Table 3: Random index (*RI*) value for varying "*n*" in the AHP

n	1	2	3	4	5	6	7	8	9	10
RI	0	0	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.49

** The RI value for 8 criteria is 1.32*
Source: Shaloo et al. 2022

2.3. Infrastructure adequacy classes

In this study, the FAO land suitability evaluation methodology (FAO, 2017; Elsheikh *et al*., 2013) which classifies the crop suitability classes into five major (*S*1, *S*2, *S*3, *N*1 & *N*2) classes was adapted for measuring the socio-economic adequacy (Table 4). However, we have combined the two not suitable classes i.e., *N*1 and *N*2 into *N*.

Table 4: Land suitability classes

Class ID	Class	Class description
*S*1	Highly Suitable	Land having no significant limitations to sustained application of a given use, or only minor limitations that will not significantly reduce productivity or benefits and will not raise inputs above an acceptable level.
*S*2	Moderately Suitable	Land having limitations which in aggregate are moderately severe for sustained application of a given use; the limitations will reduce productivity or benefits and increase required inputs to the extent that the overall advantage to be gained from the use, although still attractive, will be appreciably inferior to that expected on Class *S*1 land.
*S*3	Marginally Suitable	Land having limitations which in aggregate are severe for sustained application of a given use and will so reduce productivity or benefits, or increase required inputs, that this expenditure will be only marginally justified.
*N*1	Currently Not Suitable	Land having limitations which may be surmountable in time but which cannot be corrected with existing knowledge at currently acceptable cost; the limitations are so severe as to preclude successful sustained use of the land in the given manner.
*N*2	Permanently Not Suitable	Land having limitations, which appear so severe as to preclude any possibilities of successful sustained use of the land in the given manner.

Source: FAO, 2017

There are two basic differences between land evaluation methodology and the one required for adequacy level estimation of infrastructure. Firstly, infrastructure is mostly common for all crops; hence, there is no need for estimation at crop level. Secondly, for land evaluation framework, standard requirement of a crop is known based on agronomic practices and field level research done for the crops. On the other hand, to the best of our knowledge, there is no standard infrastructural requirement available in the known literature which can be used to match the present availability status of infrastructure with the required level. In the presented methodology, the authors attempt to quantify the existing status of the agricultural infrastructure in the study states. After quantification in all the states, four infrastructural classes have been identified along with the respective range for each class. The identified ranges are applicable to any region, state or district in India, as it is based on village level data from 21 major states in the country.

Rest of this section presents the quantification models and the criteria identified for adequacy classes of each infrastructural parameter. For estimating the market suitability, data related to number of markets was transformed into a variable called radial distance. To estimate road, communication, extension and credit suitability a corresponding score was estimated as explained in following sub-headings.

2.4. Market concentration

The market concentration is expressed by radial distance catered by a market in kilometres. Market concentration (number of markets per 1000 hectares of NSA) was modified to radial distance (R) using equation (3). R is inversely related to market availability as lower radial distance means ease of market availability.

Radial distance catered by one market in kilometres is as follows:

$$R = \sqrt{\frac{Net\ sown\ area\ (in'000ha)}{100 * \Pi *\ no.of\ markets}} \tag{3}$$

Further, the radial distance of each state level was obtained to ascertain the range of values for each market based suitability class and the obtained range for each suitability class is specified in Table 5.

2.5. Irrigation infrastructure score

Area under irrigation per ha of net sown area was used as a proxy for availability of irrigation infrastructure in the state. Criteria for irrigation infrastructure suitability across states was determined as presented in the Table 7. The identified criteria depict that the states having irrigation availability to more than 82 per cent of Net sown area are under $S1$ category while the ones, which are less than 17 per cent, are under N category.

2.6. Road density score

Criteria for road suitability class was developed using the village level data in the country and presented in Table 5. Data on seven types of roads namely national highways (NH), state highways (SH), district roads (DR), other district roads (ODR), pucca road (PR), kuchcha road (KR) and water bound macadam (WBM) from village amenities dataset was used for estimating the road density score. The qualitative road data was converted to quantitative values using scores in the range 0-10 (Table 5).

Table 5: Scoring criteria based on availability or the distance of a facility (road, communication or credit)

Distance	Score
Available	10
Available within 5 km range	5
Available within 5 to 10 km range	3
Available at more than 10 km	0

Source: Authors based on expert opinion

Further, relative importance of each type of roads is estimated using pairwise comparison method developed by Satty and Vargas, 2001 as mentioned above in Section 2.1. The weights as estimated for each category of roads are given in Table 6.

Table 6: Estimation of weights of different category of roads using pair-wise comparison matrix

Road types	NH	SH	DR	ODR	PR	KR	WBM	Weights in fraction (w)
NH	1	1	3	4	5	8	9	0.3
SH	1	1	2	3	4	8	9	0.3
DR	1/3	½	1	2	3	6	7	0.2
ODR	1/4	1/3	1/2	1	2	5	7	0.1
PR	1/5	¼	1/3	1/2	1	5	7	0.1
KR	1/8	1/8	1/6	1/5	1/5	1	3	0.0
WBM	1/9	1/9	1/7	1/7	1/7	1/3	1	0.0

Note: National Highways (NH), State Highways (SH), District Roads (DR), other district roads (ODR), Pucca Road (PR), Kuchcha Road (KR) and Water Bound Macadam (WBM)

Source: Authors based on expert opinion

Now, using obtained quantitative individual scores as well as weights associated to each road variable, road score of villages (S_{v_i}) were estimated and aggregated using area based weightage of each village in the state to obtain road density score of a higher region *e.g*. district or a state (Equation 5).

$$S_V = \sum_{j=1}^{7} W_j R_j \tag{4}$$

where,

S_v = Road suitability score of a village

R_j = score for j^{th} type of road in the village (Table 3)

W_j is the weight assigned to the j^{th} type of road (Table 4)

$$Road\ Density\ Score\ (S_s) = \sum_{i=1}^{n} \frac{a_i}{A} * S_{v_i} \tag{5}$$

where,

a_i = area of i^{th} village
$A = \sum a_i$ "*i.e.*, sum of areas of all villages in the higher region *i.e.*, state or district."

2.7. Extension suitability score

Extension suitability score is an aggregate score of KVK score and communication score.

2.7.1. KVK score

The sufficiency of extension personnel in a state is estimated using number of subject matter specialist including heads and other staff working in the KVK of the state. Thus, vacant posts denote the lack of extension personnel in the state. KVK score (Ks) is estimated using the ratio of filled posts to total number of posts in a KVK (Equation 6)

$$KVK\ Score\ (Ks) = \frac{Number\ of\ \ Posts\ Filled}{Total\ Approved\ Posts} \tag{6}$$

2.7.2. Communication score

The score is estimated using data on village amenities as extracted from census of India, 2011. Availability status of Landline, PCO, Mobile and Internet were taken as the main communication infrastructure. The qualitative data on communication score was first converted to quantitative data as presented in Table 5 for the road data.

Then, an aggregate communication score was estimated by giving weights to each mode based on their importance (based on expert's opinion). The mathematical equation (7) is shown under.

$$C_V = \sum_{j=1}^{4} W_j M_j \tag{7}$$

where,

C_v is communication score of the village 'v' out of 10,

W_j is the weight assigned to the j^{th} mode of communication (0.35 for landline and mobile each, 0.1 for PCO and 0.2 for internet),

M_j = j^{th} mode of communication *i.e.*, Landline (j=1), PCO (j=2), Mobile (j=3) and Internet (j = 4)

An aggregate communication score of a state (C_s) is then obtained by combining weighted village communication score (C_V) of all the villages in the state (Equation 8)

$$C_s = \sum_{i=1}^{n} \frac{a_i}{A} * C_{v_i} \tag{8}$$

where,

C_s: State communication score
C_{v_i}: Communication score of i^{th} village
n: Number of village in the state

(Notations 'a_i' and 'A' are similar to equation 5)

Extension suitability score (*Es*) of a state is finally estimated using the Equation 9, allotting 0.6 weight to communication and 0.4 weight to KVK (based on expert opinion)

$$Es = 0.6 * C_s + 0.4 * K_s \tag{9}$$

2.8. Credit suitability score

For assigning score to credit facilities, equal weightage were given to four institutional setups commercial bank, cooperative bank, agricultural credit societies and self-help groups. In first stage, credit suitability of a village was estimated using Equation 10

$$L_v = \sum_{j=1}^{4} 0.25 L_j \tag{10}$$

where,

L_v = credit suitability score of the village

L_j = score of j^{th} institutional setup for availing credit

The credit suitability of the state (L_s) was estimated by using area weightage of each village (Equation 11)

$$L_s = \sum_{i=1}^{n} \frac{a_i}{A} * L_{v_i} \tag{11}$$

where,

L_s = state/ region credit suitability score

L_{v_i}= credit suitability score of i^{th} village

(Notations 'a_i' and 'A' are similar to equation 5)

Table 7: Criteria used for assigning suitability classes to road, extension and credit adequacy

Category	mean plus standard deviation (S1)	Mean to mean plus standard deviation (S2)	Mean minus standard deviation to mean (S3)	< Mean minus standard deviation (N)
Irrigation score (I)	> 8.2	8.2 - 4.9	4.9 - 1.7	1.7
Road score (S)	> 5.48	4.53 - 5.48	3.58 - 4.53	3.58
Extension score (E)	> 8.3	8.30 - 6.51	6.51 - 4.72	4.72
Credit score (L)	> 5.73	5.73 - 4.00	4.00 - 2.28	2.28
Radial distance (R)	< 6.45	6.45 - 10.88	10.88 - 15.10	15.10

Source: Estimated by the authors

2.9. Estimation of storage suitability score

Data on state-wise requirement and availability of cold-storage structures was collected from All India Cold-chain Infrastructure Capacity (*Assessment of Status & Gap*) by NCCD (2015) to estimate the storage gap in '000 MT. The gap in the study was assessed solely on current consumption patterns of the urban population in the country.

Surplus and deficit states based on the per cent gap between requirement and availability of the storage capacity with respect to availability were identified. Surplus indicates higher availability and deficit represents higher requirement. Further, distribution of deficit states with respect to severity of gap was obtained. Per cent gap with respect to availability up to 25 per cent were categorized as marginally deficit, 25 to 50 as moderately deficit, 50 to 75 as deficit and more than 75 percent gap were considered as highly deficit states.

2.10. Estimation of composite infrastructural suitability

Composite infrastructural suitability of a state (O_i) was estimated using the worst criteria principle (Rezaei, 2015) as presented using equation 12.

$$O_i = min\ (R_i, I_i, S_i, E_i, L_i, W_i) \tag{12}$$

Where, R_i, I_i, S_i, E_i, L_i and W_i refer to the estimated suitability classes for market, irrigation, road, extension, credit and storage for i^{th}state.

3. Results and Discussion

The methodology as expressed in Section 2 was used to calculate the infrastructural adequacy at state level and district level for Bundelkhand region. The level of adequacy is presented in section 3.1 and 3.2 respectively.

3.1. State level

Spatial variation in selected agricultural infrastructure based suitability classes amongst various states are illustrated through Table 8 - 9. Based on the criteria score of different classes as shown in Table 5, the states are categorised into *S*1 (highly suitable), *S*2 (moderately suitable), *S*3 (marginally suitable), and *N* (not suitable) in Figures 2-7.

Table 8: Market Radial distance (in Kms), road density, communication, KVK, extension and credit (scores out of 10) for major states, India

S. No.	States	Radial Distance	Irrigation	Road Density	Comm-unication	KVK	Extension	Credit Suitability
1.	Andhra Pradesh	9.89	4.50	4.56	7.60	8.60	8.00	4.98
2.	Arunachal Pradesh	6.77	1.00	2.81	2.30	9.10	5.02	1.29
3.	Assam	18.92	0.60	5.53	5.10	9.80	6.98	3.58
4.	Bihar	17.22	6.40	4.99	4.60	7.60	5.80	3.87
5.	Chhattis-garh	8.87	3.00	3.79	4.20	8.30	5.84	3.75
6.	Gujarat	10.37	4.20	4.94	9.10	7.40	8.42	5.32
7.	Haryana	9.10	8.80	6.17	8.10	7.30	7.78	6.23
8.	Himachal Pradesh	6.50	2.00	2.84	3.40	8.30	5.36	1.77
9.	J&K	8.23	4.00	4.18	5.10	7.70	6.14	2.19

10.	Jharkhand	12.65	3.50	3.80	3.50	6.40	4.66	2.44
11.	Karnataka	12.52	2.70	4.13	7.60	8.60	8.00	5.14
12.	Kerala	7.60	2.90	6.13	9.40	9.60	9.48	8.93
13.	Madhya Pradesh	12.07	4.50	4.04	4.80	6.50	5.48	3.51
14.	Maharash -tra	12.92	8.00	4.76	7.70	8.60	8.06	5.51
15.	Odisha	11.48	2.20	3.93	5.70	7.00	6.22	3.19
16.	Punjab	7.30	9.80	5.41	8.00	8.40	8.16	4.84
17.	Rajasthan	18.89	3.10	4.49	8.10	7.40	7.82	3.72
18.	Tamil Nadu	8.49	5.70	5.70	7.00	8.60	7.64	5.04
19.	Uttar Pradesh	2.96	8.40	4.38	5.20	8.30	6.44	4.16
20.	Uttara-khand	45.94	4.00	5.06	5.70	6.20	5.90	2.96
21.	West Bengal	14.77	5.20	3.51	6.30	8.40	7.14	4.17

Source: Estimated by authors

Table 8 depicts that four states are agriculturally not suitable as per marketing status including Uttarakhand, Assam, Rajasthan and Bihar. Uttarakhand has the highest radial distance of about 46 Km, indicating lack of agricultural markets in the state. Uttar Pradesh having least radial distance of about 3 Km and Himachal Pradesh with radial distance of 6.5 Km are better off than other states and are the only two states which are under highly suitable category. Though, the radial distance catered by markets in agriculturally developed states like Punjab and Haryana is relatively higher (7.3-9.1 Km respectively), yet presence of adequate road infrastructure compensates this to some extent.

Road adequacy infrastructure status helps the policy makers in prioritizing the needs of the states. The value of score is lowest *i.e.,* about 2.8 for Arunachal Pradesh and Himachal Pradesh, followed by West Bengal, Chhattisgarh, Jharkhand and Odisha, indicating lack of road infrastructure in these states and demand immediate focus from policy makers in order to facilitate agricultural development in the region.

Irrigation score of the states (Table 9) shows that even though water is a major constraint, the states like Punjab, Haryana, Uttar Pradesh, and Maharashtra have more than 80 per cent of the net sown area under irrigation, with Punjab having highest, 98 per cent of the net sown area under irrigation, indicating adequate infrastructure availability in these states. On the other hand, most of the north-eastern states like Arunachal Pradesh and Assam have less than 10 per cent area under irrigation, which can be due to either lack of irrigation facility or no requirement of irrigation in these states.

Table 9: Percent of villages having access to irrigation across irrigation categories

Category→ State↓	Irrigation categories				
	< 20%	**20-40%**	**40-60%**	**60-80%**	**> 80%**
Andhra Pradesh	31	15	12	10	27
Arunachal Pradesh	11	0	0	0	0
Assam	74	2	2	1	2
Bihar	9	11	16	24	39
Chhattisgarh	60	10	6	5	13
Gujarat	31	15	17	16	18
Haryana	4	3	4	6	83
Himachal Pradesh	64	7	5	3	8
Jammu & Kashmir	40	9	10	11	28
Jharkhand	68	11	6	3	7
Karnataka	43	23	12	7	8
Kerala	44	13	12	10	20
Madhya Pradesh	29	21	19	15	14
Maharashtra	6	5	7	13	66
Odisha	60	4	4	5	10
Punjab	1	1	1	2	94
Rajasthan	35	17	16	13	17
Tamil Nadu	12	12	13	15	43
Uttar Pradesh	3	2	5	11	77
Uttarakhand	69	8	4	3	11
West Bengal	23	15	12	15	34

The extension score indicates that Kerala and Gujarat with the highest extension score of 9.48 and 8.42 are the highly suitable states. On the other hand, Jharkhand, Mizoram and Meghalaya are agriculturally not suitable as per extension suitability score. The major producing states like Punjab, Maharashtra, Haryana and West Bengal with an extension score varying between 8.30 - 6.51 are moderately suitable states. While with score lying between 4.00 - 2.28, Uttar Pradesh and Madhya Pradesh are found marginally suitable. Thus, there is need of strengthening of extension services in the states.

Based on credit suitability score, Kerala is the most suitable state in the country with the score of 8.93. It has the highest credit suitability as cent per cent of the villages in Kerala have SHG, 78 per cent have commercial bank, 92 per cent cooperative bank and 63 per cent of the villages have agricultural credit societies (Census, 2011). Himachal Pradesh and Arunachal Pradesh are found not suitable, indicating dearth of banking infrastructures in these states. Bihar, Chhattisgarh, Rajasthan, Madhya Pradesh, Odisha, Uttarakhand and Jharkhand are marginally suitable states with credit suitability score in the range 1.29 -3.87.

Cold storage: It has been found that there is an overall requirement-gap of 10101 (‘000 MT) in the country for fruits, vegetables, dairy and meat products. The requirement-availability gap is highest in Bihar (3876 ‘000MT) and West Bengal (3586 ‘000MT) followed by states like Maharashtra (2527 ‘000MT), Madhya Pradesh (1905 ‘000MT), Jammu Kashmir (843 ‘000MT), Gujarat (520 ‘000MT) and Karnataka (500 ‘000MT). This indicates the huge scope of agricultural development through cold storage infrastructural development. States like Uttar Pradesh show surplus availability of cold storage structures up to the range of 2874 ‘000 MT. This reveals the scope for increasing production of high value crops like fruits and vegetables besides development of dairy and livestock thereby enhancing the farmer’s income. States like Punjab and Andhra Pradesh also display sufficient cold storage facilities for the perishables. State level data on cold storage indicates Uttar Pradesh with surplus while Madhya Pradesh having huge gaps in the cold storage capacity.

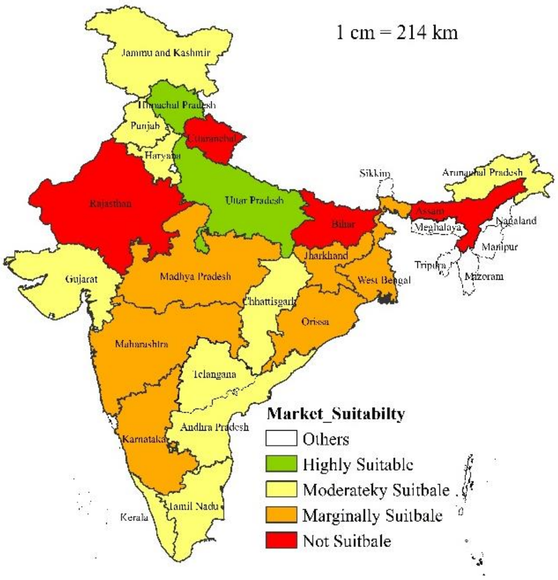


Figure 2: Market infrastructure

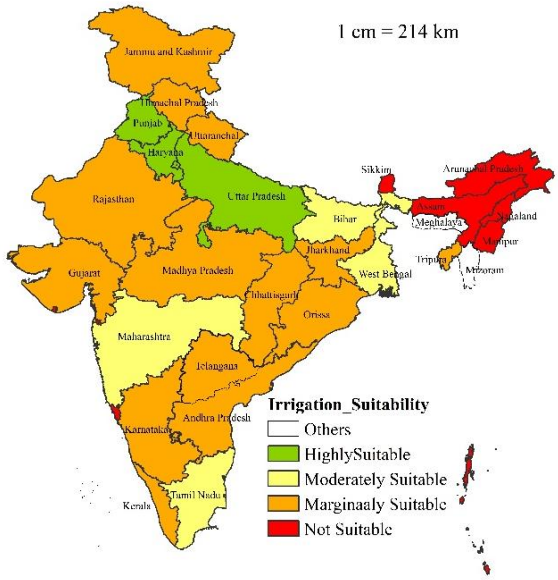


Figure 3: Irrigation infrastructure

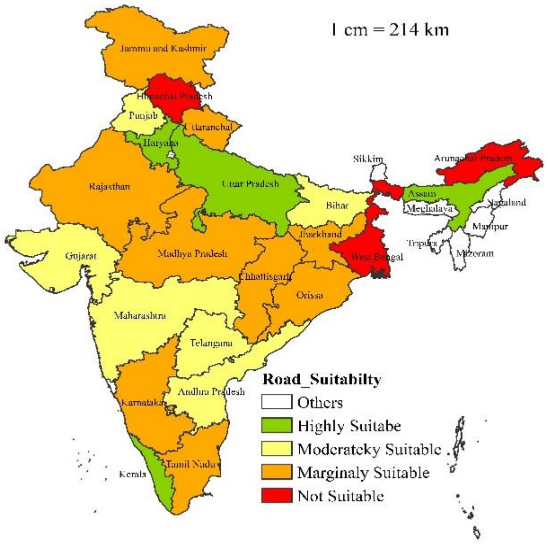


Figure 4: Road infrastructure

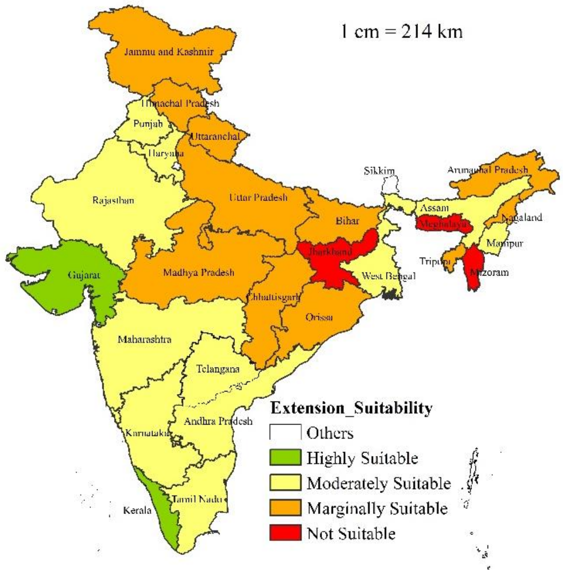
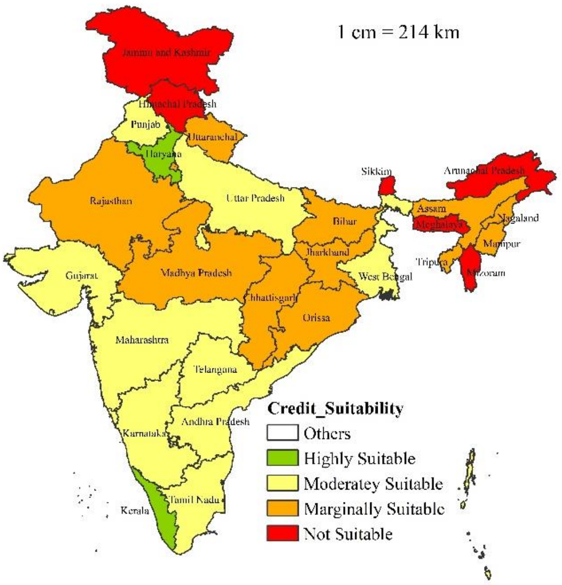


Figure 5: Agricultural Extension



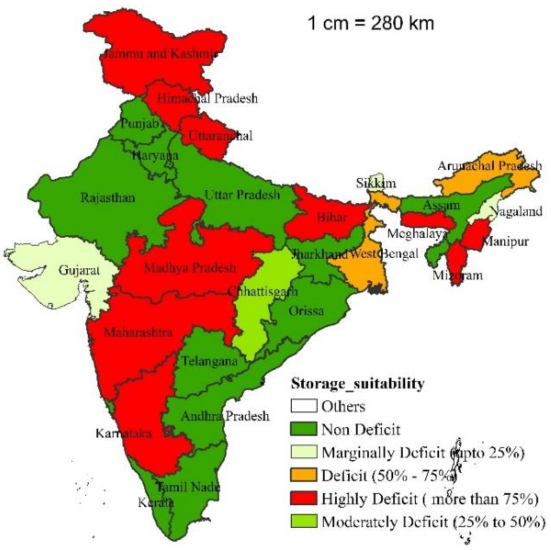


Figure 6: Agricultural credit **Figure 7: Gaps in cold storage**

Source: Authors

3.2. Composite infrastructural suitability of India

Based on suitability of each individual infrastructure facility, the state level composite infrastructural suitability status of the states was identified using the worst criteria principle (Table 10, Figure 8). The results show that none of the states is observed as having adequate infrastructure. Haryana, Punjab, Gujarat, Andhra Pradesh and Kerala are moderately suitable in terms of infrastructural adequacy (%). Other states are having marginal or not suitable infrastructure adequacy (%) indicating the dire need to improve the status of the one or more aspects of agricultural infrastructure (Figure 8).

Table 10: Distribution of the states as per suitability classes as per agricultural infrastructure adequacy

Suitability Class	**Name of the states falling in this category**	**Percent to selected states (*n*=21)**
*S*1	None	0.00
*S*2	Haryana and Punjab	9.52
*S*3	Andhra Pradesh, Chhattisgarh, Gujarat, Kerala, Orissa, Tamil Nadu and Uttar Pradesh	33.34
N	Arunachal Pradesh, Assam, Bihar, Himachal Pradesh, Jammu and Kashmir, Jharkhand, Karnataka, Madhya Pradesh, Maharashtra, Rajasthan, Uttaranchal and West Bengal	57.14

Source: Authors

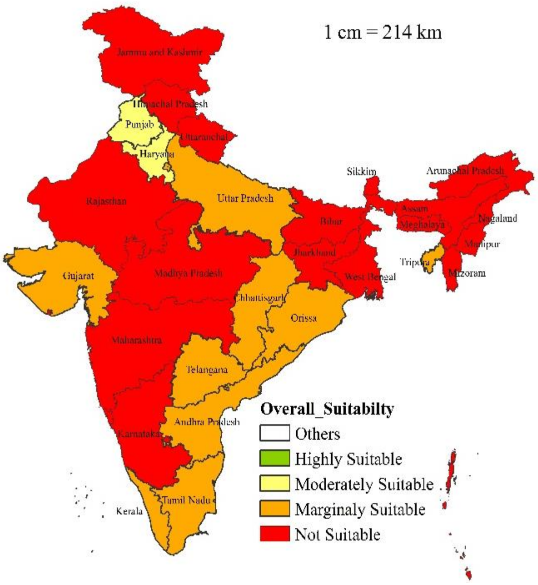


Figure 8: State level infrastructural adequacy for agriculture in India

Source: Authors

3.3. District level case study

We validated the proposed methodology at district level for Bundelkhand region. The Bundelkhand Region of central India is a semi-arid plateau that comprises seven districts of Uttar Pradesh (U.P.) *viz.,* Jhansi, Jalaun, Lalitpur, Mahoba, Hamirpur, Banda and Chitrakoot and six districts of Madhya Pradesh (M.P.) *viz.*, Datia, Tikamgarh, Chhatarpur, Panna, Damoh and Sagar. Agriculture in Bundelkhand is rainfed, diverse, complex, under-invested, risky and vulnerable. The yields obtained by the Bundelkhand farmers are usually lower than the state average for majority of the crops. District level assessment of infrastructural adequacy can help to determine level and kind of development needed in each district.

The district wise suitability score for market, roads, irrigation, extension and credit is estimated as per the criteria (Table 5) and infrastructural suitability class is shown in Figures 9-13.

Bundelkhand region is drastically deprived of the infrastructural facilities for agricultural commodities' market access in comparison to agriculturally developed states of India. The UP-Bundelkhand as well as MP-Bundelkhand are under marginally suitable category in terms of market infrastructure (Figure 9).

With reference to irrigation, out of 13 district, one districts namely Lalitpur of UP Bundlekhand region is suitable (S1), six districts *viz.*, Sagar, Tikamgarh, Jalun, Jhansi, Datia and Banda are moderately suitable and six districts of which three districts *viz.*, Hamirpur, Chirakoot, Mahoba are of UP Bundlekhand and remaining three districts *viz.*, Chhatarpur, Panna and Datia of MP Bundlekhand are marginally suitable (Figure 10). The results confirm the report of NITI Aayog indicating lowest irrigated area with respect to gross cropped area in Damoh and Chitrakkot district of Bundlekhand region (NITI, 2016).

Road density score among districts in Bundelkhand varies from 3.03 to 5.32 with an average score of 4.15. Thus, districts of Bundelkhand were categorised as moderately to not suitable classes in terms of road density score implying lack of road infrastructure facilities in the region (Figure 11). Thus, there is ample scope to improve agricultural income by road infrastructure development in the region.

Regarding Extension infrastructure in Bundelkhand MP region, 3 districts out of 6, namely Chhatarpur, Datia and Panna with extension score of 4.46, 2.46 and 4.54 are under ‘not suitable’ category. While the other three are marginally suitable. In Bundlekhand UP, 2 out of 7 district namely Chitrakoot and Lalitpur are moderately suitable and the remaining 5 district are marginally suitable (Figure 12). Inadequate technology delivery system coupled with acute shortage of staff were the major backdrops for the region. Therefore, focus on improving the extension services in the region is essentially required.

The credit suitability score across the districts of Bundelkhand region shows that overall two district of Bundelkhand UP *viz.*, Banda and Jalaun are moderately suitable. While the remaining 11 districts are marginally suitable (Figure 13). There is a strong need for development of rural financial infrastructure in Bundelkhand region.

Closer inspection of cold storage availability and their capability in districts of Bundelkhand indicates lack of cold storage facility (Indiastat.com). The scenario demands for the inclusion of storage facilities in the development plan for the region besides other infrastructural facilities.

Composite infrastructural suitability of Bundlekhand region show that Five out of 13 districts of the are in ‘not suitable’ category while remaining districts are ‘marginally suitable’, indicating lack of agricultural infrastructural adequacy (Figure 14). These results call for the attention of the policy makers towards the need to intensify the development of agricultural infrastructure in the region.

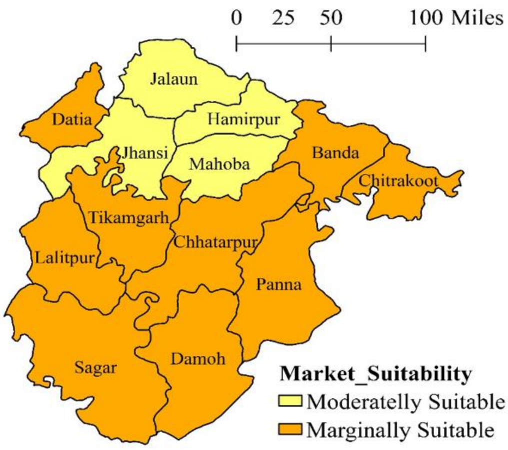


Figure 9: Market infrastructure

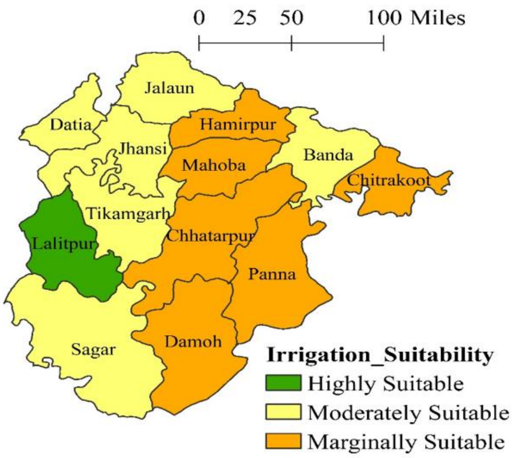


Figure 10: Irrigation infrastructure

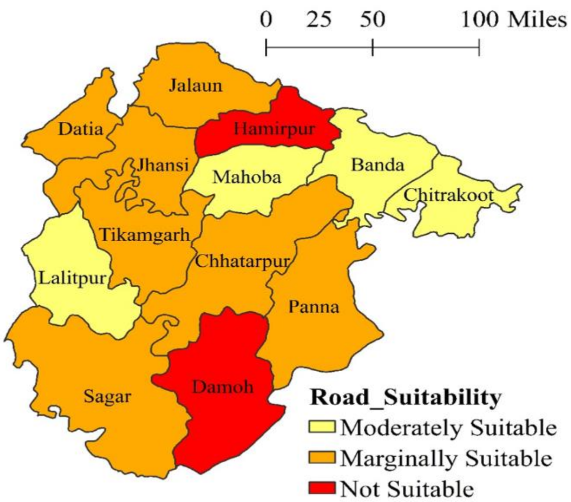


Figure 11: Roads

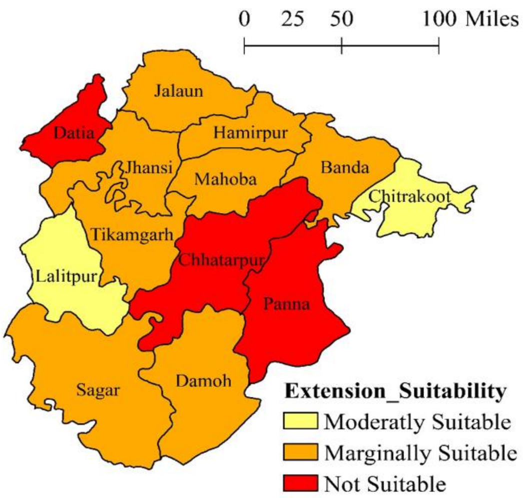


Figure 12: Extension

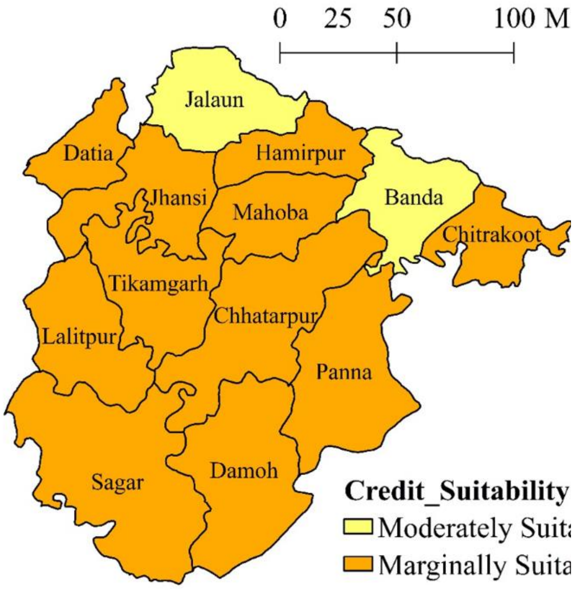


Figure 13: Credit

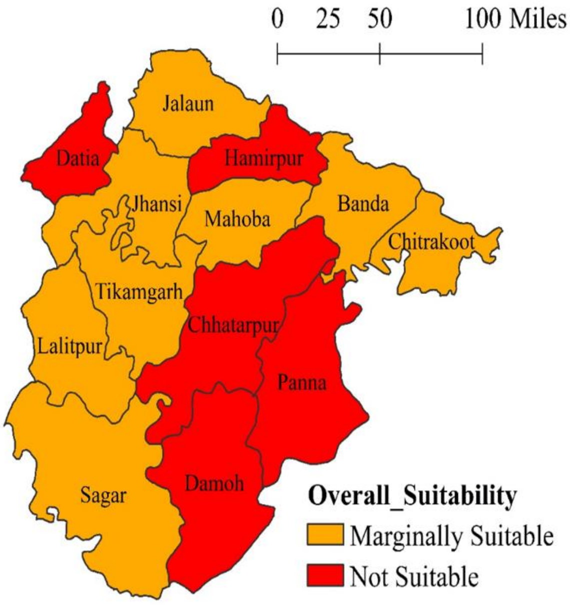


Figure 14: Composite suitability

Source: Authors

4. Conclusions and Policy Implications

The present study developed the methodology for determining agricultural infrastructural suitability status and validated the same for the country at both state levels as well as district level using a case study of districts from Bundelkhand region. The study contributes mainly by (i) developing methodological framework for quantification of agricultural infrastructure and (ii) estimation of adequacy level of agricultural infrastructure at state level and district level

The strong point of the proposed methodology is its simplicity and availability of data in public domain. The identified criteria for four infrastructural suitability classes are same for state level as well as district level. The methodology was implemented using omnipresent Excel spreadsheet. However, there is a scope for improvement in the methodology by developing the separate criteria for different agro-ecoregions.

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