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Determination of agricultural infrastructural suitability in aspirational districts: A case study of Bundelkhand

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ABSTRACT

Agricultural infrastructure has the potential to transform subsistence farming into commercial and dynamic farming system. Adequate markets, roads, irrigation, extension services, credit facilities, storage etc. facilitate lowering of farming costs and increase in farm income. The study, carried out during 2017–20 at ICAR-NIAP, presents methodology for measuring adequacy status of rural infrastructure and its categorisation into five classes using a case study of Bundelkhand region.The results show that there is ample scope for agricultural productivity enhancement in Bundelkhand by focussing on agricultural markets, credit institutions, roads, agricultural extension and storage infrastructure.The proposed methodology can be replicated for other regions, states and districts.

Keywords: Agricultural infrastructure, Agricultural market, Crop suitability, Farm credit, Krishi Vigyan Kendras

Agricultural productivity depends on rural infrastructure, well-functioned domestic markets, appropriate institutions and access to appropriate technologies (Llanto 2012). Expansion of infrastructure accelerates agricultural and economic growth rate. One per cent increase in the stock of infrastructure is associated with a one per cent increase in GDP across all countries (Patel 2014). Improvement in market access increases agricultural productivity by facilitating specialisation and exchange transactions in rural areas (Kamara 2004, Chamberlin and Jayne 2013). Deficit transportation-infrastructure leads towards narrowing cropping choices, lowers agricultural productivity and technological adoption in developing countries (Narayanamoorthy *et al.* 2015). Access to irrigation is one of the key factor contributing to agricultural productivity. The extension personnel and communication technologies help the farmers in better understanding of various supportive policies and schemes (Casella and Schilling 2017, Singh and Kour 2014). Credit access via formal financial institutions generates positive and significant effect on agricultural production (Barslund and Tarp 2008, Sajesh and Suresh 2016, Pandey *et al.* 2018). Considering the multi-dimensions of agricultural infrastructure, the present study explores vulnerable Bundelkhand region of India to estimate the infrastructural adequacy for agriculture based on these parameters and categorises districts into various classes ranging from highly suitable to not suitable. The paper contributes by (i) proposing the methodology for determination of agricultural infrastructural adequacy for any region in the country; (ii) analysis of the infrastructural adequacy in aspirational districts using Bundelkhand region; (iii) policy recommendations for enhancement of agricultural income in Bundelkhand region. The study will be useful for researchers and the policy makers to prioritise and identify the areas requiring government investment to promote and support agriculture, thereby supporting the national development goals.

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MATERIALS AND METHODS

The study, carried out during the year 2017–2020 at ICAR-NIAP, presents methodology for measuring adequacy status of rural infrastructure and its categorisation into five classes using a case study of Bundelkhand region. The Bundelkhand Region of central India is a semi-arid plateau that comprises seven districts of Uttar Pradesh (UP), viz. Jhansi, Jalaun, Lalitpur, Mahoba, Hamirpur, Banda and Chitrakoot and six districts of Madhya Pradesh (MP), 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.

Five dimensions namely road density, market concentration, extension system, credit and storage infrastructure are explored to determine the agricultural infrastructural adequacy index based on authentic data sources (Census of India 2011, GoI 2019, ICAR 2019, Indiastat 2019). The basic idea of agricultural infrastructural adequacy revolves around matching the availability with the requirements and classifies adequacy into four classes namely S1, S2, S3 and N and is adapted from crop suitability classes (Jain *et al.* 2020). Further, it requires converting qualitative data into suitable quantitative score. For example, if a facility like road, credit institution, communication or an extension institution is within a village, it is given a full score of 10. On the other hand, if it is available in the range of 0-5 km, 5-10 km or > 10 km then assigned scores are 3, 5 and 0 respectively.The scores were estimated at district level and state level using area-weighted village level scores. We developed adequacy criteria by dividing the state level estimated scores into S1, S2, S3 and N using mean and standard deviations across the country for all the states data (Table 1). The results are applicable to any region across the country due to extensive coverage of data for the estimations. The availability score of different parameters are estimated as proposed below.

Estimation of market adequacy score: The market adequacy score is expressed by radial distance catered by a market in kilometres. Market concentration (number of markets per 1000 ha of NSA) was modified to radial distance (R) using equation (1). R is inversely related to market availability as lower radial distance means more adequate market infrastructure (Table 1). Radial distance catered by one market in kilometres is as follows:

$$R = \sqrt{\frac{\text{Net sown area (in '000 ha)}}{100 \times \prod \times \text{no. of markets}}} \quad (1)$$

Estimation of irrigation infrastructure score: Area under irrigation per ha of net sown area (I) was used as a proxy for availability of irrigation infrastructure. Data (Table 1) showed that districts having more than 82% of net sown area under irrigation are under S1 category while the ones, which are less than 17%, are under N category.

Estimation of road density score: The qualitative road data at village level (Census of India 2011) was converted to quantitative values using scores in the range 0-10 and assigning weights to each type of road to get a consolidated road density score (Eq 2). Estimation of weights of different category of roads was obtained using pair-wise comparison matrix approach (Satty and Vergas 2012) the resulting weights for national highways (NH), state highways (SH), district roads (DR), other district roads (ODR), pukka road (PR), kuccha road (KR) and water bound macadam (WBM) are 0.3, 0.3, 0.2, 0.1, 0.1, 0 and 0 respectively. Estimation of road density score and corresponding adequacy criteria (self-explanatory) are presented in Eq (2) and Table 1 respectively.

$$\text{Road density score} = £\,\frac{a_i}{A} \times V_i \quad (2)$$

where a_i = area of i^{th} village; A= $\sum a_i$, "i.e sum of areas of all villages in a district"; $V_i = \sum w_i \times$Road Score, "i.e. road score of a village"; w_i refers to assigned weight to a category of road.

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

KVK score: KVK score (K) is estimated using the ratio of filled posts to total number of approved posts in a KVK (Eq 3). In case of more than one KVK in a district, the number of post was merged for the district.

$$\text{KVK score (K)} = \frac{\text{Filled posts}}{\text{Total approved posts}} \quad (3)$$

Communication score: Communication score was estimated using Eq (4-5)

$$C_V = \sum_{i=1}^{4} W_i M_i \quad (4)$$

where, C_v is communication score of a village 'v' out of 10; W_i is the weight assigned to i^{th} communication (0.35 to landline or mobile, 0.1 for PCO and 0.2 for internet based on Delphi method); M_i = Communication score for i^{th} mode will be 3, 5 or 10 (refer paragraph 1 of methodology);

$$C_d = \sum_{i=1}^{n} \frac{a_i}{A} \times C_{V_i} \quad (5)$$

where, C_d: district communication score; a_i: Geographical area of the village; A: Area of the district; C_{Vi}: Communication score of the village I; n: Number of villages in the district.

Extension suitability score (E_d) of a district (or a state) is finally estimated using the Eq 6, allotting 0.6 weight to communication and 0.4 weight to KVK (based on experts' opinion).

$$E_d = 0.6^* C_d + 0.4^* K_d \quad (6)$$

In Eq 6 above K_d refers to the KVK score of a district which is fraction of filled posts to the approved posts, then

Table 1 Criteria used for assigning suitability classes to markets, irrigation, road, extension and credit adequacy

Suitability class	Market adequacy (R - radial distance in km)	Irrigation score (I)	Road score (S)	Extension score (E)	Credit score (L)
S1	<6.45	>8.20	>5.48	>8.30	>5.73
S2	6.45-10.88	4.90-8.20	4.53-5.48	6.51-8.30	4.00-5.73
S3	10.88-15.10	1.70-4.90	3.58-4.53	4.72-6.51	2.28-4.00
N	>15.10	<1.70	<3.58	<4.72	<2.28

Source: Based on empirical analysis by authors multiplied by 10.

Credit suitability score: For credit facilities in the village four institutional setups, viz. commercial bank, cooperative bank, agricultural credit societies and self-help groups, were given equal weightage. Credit score was estimated using Equations (7-8)

$$L_v = \sum_{i1}^{4} 0.25 L_i \quad (7)$$

where, L_v = Credit suitability score of the village; L_i = Institutional setup score for availing credit (value 3, 5 or 10- as explained in paragraph 1 of methodology);

$$L_d = \sum_{i=1}^{n} \frac{a_i}{A} \times L_{v_i} \quad (8)$$

where, L_d = district credit suitability score; L_v = village credit suitability score; A = Geographical area of the village.

Estimation of storage suitability score: Data on state-wise requirement and availability of cold-storage structures was used to estimate the storage gap (NCCD 2015).The deficit state (requirement>availability) with percent gap up to 25% were categorized as marginally deficit, 25 to 50 as moderately deficit, 50 to 75 as deficit and more than 75% gap were considered as highly deficit states. Other areas (requirement<availability) are considered as surplus.

Estimation of composite infrastructural suitability: Composite infrastructural suitability of a place, referred as 'O_i', (state/district) was estimated using the worst criteria principle (Rezaei 2015). Thus Oi is minimum of the estimated suitability classes for market, irrigation, road, extension, credit and storage.

RESULTS AND DISCUSSION

The district wise suitability scores for market, roads, irrigation, extension and credit and corresponding distribution as per suitability class are presented in Table 2 and Fig 1.

Markets: In MP-Bundelkhand all districts are marginally adequate. In case of UP-Bundelkhand, Jhansi, Jalaun, Hamirpur and Mahoba districts are under S2 while districts like Banda, Chitrakoot and Lalitpur are under S3. Overall, the UP-Bundelkhand as well as MP-Bundelkhand are under S3 in terms of radial distance covered by a market and needs improvement (Table 2).

Irrigation: With respect to irrigation infrastructure, Bundelkhand region is under S2 with 55 per cent net irrigated area. The irrigation status of the region depicts that out of 13 districts, one district namely Lalitpur of UP Bundlekhand region is suitable (S1), six districts (Sagar, Tikamgarh, Jalun, Jhansi, Datia and Banda) are under S2 and remaining six (Hamirpur, Chirakoot, Mahoba of UP Bundelkhand and Chhatpur, Panna and Datia of MP Bundlekhand) are under S3 (Table 2). Districts of both UP-Bundelkhand and MP-Bundelkhand show that area under irrigation is much lower. In spite of some districts of Bundelkhand are under S2, inadequate, suboptimal and untimely water quantity along with lower operating capacity are affecting irrigation in the region (Purushotham and Panni 2016, Samra 2008). Thus, there is a need to conserve groundwater, promote rainwater-harvesting infrastructures, enhance operating capacity and improve water use efficiency in the region.

Table 2 Scores based on market radial distance, irrigation, road density, communication, KVK, extension and credit for districts under Bundelkhand region

District	Radial distance catered by a market (in km)	Irrigation score out of 10	Road density score out of 10	Communication score out of 10	KVK score out of 10	Extension score out of 10	Credit suitability score out of 10
Chhatarpur	12.0	4.40	4.05	4.50	4.30	4.46	3.76
Damoh	13.0	3.90	3.45	4.50	6.10	5.12	3.79
Datia	12.8	7.70	3.71	4.10	0.00	2.46	3.30
Panna	14.6	3.20	3.66	4.50	4.50	4.54	2.74
Sagar	12.6	6.30	3.99	4.80	7.60	5.92	3.28
Tikamgarh	12.1	7.60	3.62	4.20	5.70	4.76	3.78
MP Bundelkhand	12.9	5.47	3.75	4.51	5.64	4.96	3.48
Banda	12.7	5.00	5.32	5.10	8.10	6.30	4.22
Chitrakoot	11.7	3.60	4.78	5.00	9.10	6.64	3.44
Hamirpur	10.2	4.20	3.03	3.70	9.60	6.05	3.78
Jalaun	10.1	6.00	4.27	4.30	8.90	6.15	4.03
Jhansi	10.0	6.10	4.41	4.00	10.00	6.41	3.84
Lalitpur	13.9	8.30	5.06	4.50	10.00	6.72	3.74
Mahoba	10.4	4.10	4.95	3.90	10.00	6.34	3.93
UP Bundelkhand	11.3	5.52	4.55	4.38	9.64	6.48	3.87
Bundelkhand	12.1	5.49	4.15	4.45	7.89	5.82	3.66

Source: Estimated by authors based on developed methodology

Road: Problem of poor condition of the roads in Bundelkhand region has been raised in many studies (NITI 2016). Road density score among districts in Bundelkhand varies from 3.03 to 5.32 with an average score of 4.15 (Table 2) and ranges from N to S2 category. Damoh (3.45) and Hamirpur (3.03) are under N. More than 50% districts are under S3, thus indicating ample scope to improve agricultural income by road infrastructure development. The quality of road is comparatively poor in MP-Bundelkhand due to half completed work, damaged road shoulders and heavy encroachments (NITI 2016).

Extension: Farmers need information regarding technologies, post-harvest management facilities like storage and handling, marketing and processing (Babu *et al.* 2013). Improvement in extension system for reducing knowledge gaps has potential for further yield enhancement. Three districts in MP-Bundelkhand, i.e. Chhatarpur, Datia and Panna are under N category while the other three are S3. Five districts namely Chitrakoot and Lalitpur of UP-Bundelkhand are S3 and 2 districts are S2. Inadequate technology delivery system coupled with acute shortage of staff are the major backdrops for the region (Table 2).

Credit: Based on our estimates, the relative rank of Bundelkhand region with respect to access to credit comes at number 15 among the considered 22 states. Large variations are observed in credit availability score (2.7 to 4.2) across Bundelkhand (Table 2). Eleven districts are under S3 while 2 are under S2.Therefore, there is a need for development of rural financial infrastructure in Bundelkhand region.

Cold storage: Uttar Pradesh show surplus availability of cold storage structures up to the range of 2874 '000 MT, while Madhya Pradesh has huge gaps in the cold storage capacity. Closer inspection of cold storage availability and their capability in districts of Bundelkhand indicates inadequateness (Indiastat 2019). Thus, there is wide inequality in cold storage facilities between Bundelkhand districts and non-Bundelkhand districts of the parent states. 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: Five districts (Chhatarpur, Damoh, Datia, Panna and Hamirpur) are in N others are in S3, indicating lack of agricultural infrastructure. These results call for the attention of the policy makers towards the need to intensify the development of agricultural infrastructure in the region. The results are in conformity with the literature mentioning lack of economic infrastructure is a common feature of Bundelkhand region (Purushottam and Panni 2016, NITI 2016).

UP-Bundelkhand and MP- Bundelkhand districts are under S3 and N category. Further, the study concluded that overall none of the districts is under S2. Further deeper analysis revealed that Datia requires improvement in communication status and strengthening of extension system. The district is poor in literacy rate; therefore, face-to-face interactions and demonstrations would be much more effective rather than distance learning techniques. The 50% of the districts requires attention from the Government in two dimensions. Among these districts, Jalaun, Damoh and Hamirpur requires improvement in road and extension; Banda and Lalitpur in markets and extension; Panna in irrigation and extension. The 25% are inadequate in three dimensions. Among these, Chattarpur and Mahoba require improvement in irrigation status, credit access as well extension system while Chirakoot needs significant improvement in irrigation, market and credit access. The Bundelkhand region is having red and black soils characterised by undulated and rugged topography and hence the runoff potential is very high which needs to be harvested. Though number of programmes and schemes are operating for harvesting the rainwater in the region, entrepreneurship in rainwater harvesting may be promoted and irrigation water markets need to be institutionalised. Tikamgarh and Sagar are under moderate category of irrigation availability but inadequate in all other four parameters. Besides agroforestry, models including pastoral components should be promoted in the region due to their lesser water requirement and relatively higher returns.

Policy Implications: The study proposed the methodology for quantification of agricultural infrastructure and its categorisation into four categories namely S1, S2, S3 and N. Five dimensions mainly markets, roads, irrigation, extension and credit facilities were considered in the methodology. Besides, the analysis is demonstrated using case study of Bundelkhand districts. The proposed categorisation (Table 1) will motivate agricultural and policy researchers to extend the analysis for other regions in the country to determine the status and growth of agricultural infrastructure and identify priority areas for public investment in agricultural infrastructure.

The analysis in the paper reflects that provision of agricultural infrastructure is poor and hampering agricultural output growth. Public investments on rural roads, irrigation, credit, communication, and agricultural markets in Bundelkhand will create enabling environment necessary to stimulate agricultural growth and facilitate farm income enhancement. Besides, there is need for developing regional crop plan based on available resources (Jain *et al.* 2018) The study (i) developed methodological framework for quantification of agricultural infrastructure, (ii) estimated of adequacy level of infrastructure in districts of Bundelkhand, and (iii) suggested interventions at district level to boost the agricultural productivity and farm income.

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