Developing Food Insecurity Index and Vulnerability Information System (FIVIMS) For a Tribal District - A Case Study of Alirajpur District, Madhya Pradesh, India

Technical report for 2025 ISPRS Scientific Initiatives

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Abstract

Food insecurity is a pressing issue among tribal communities in Madhya Pradesh, a state known for its diverse tribal (indigenous) population in India. Approximately 32% of tribal households experience severe food insecurity in the state. The present study proposes a statistics, GIS and Artificial Intelligence (AI) integrated methodology to identify food insecure villages by assessing food security of a tribal district. For the purpose of the study, a tribal district namely Alirajpur with 541 *abadi* (inhabited) villages was selected as case study area. To assess village wise food security three main parameters namely Food Availability, Food Access and Food Absorption were identified from literature review. To calculate village wise index for each of the above parameter, relevant sub-parameters were further identified from the literature. Up-to-date data were collected for each sub-parameter and geospatial maps were prepared to show spatial distribution of each sub-parameter. Further normalization of the data was done by using max-min technique and indices for Food Availability, Food Access and Food Absorption were calculated for 541 villages in the district. Using index values of Food Availability, Access and Absorption, Food Insecurity Index was calculated for each of 541 villages. Combination of AI models such as Random Forest Regression model and XGBoost regression model was run on indices and Food Availability Index was found to be the most dominating factor for food security. Since Cultivated Area and Irrigation extent have major influence on Food Availability Index, food security can be achieved by improving these two parameters.

Study area

Alirajpur District is located in Madhya Pradesh at Central India (Figure 1.A). As per Census 2011, the district has the highest (89%) concentration of tribal population in India. The district an approximate area of 3,182 square kilometers and has population of 729,000.

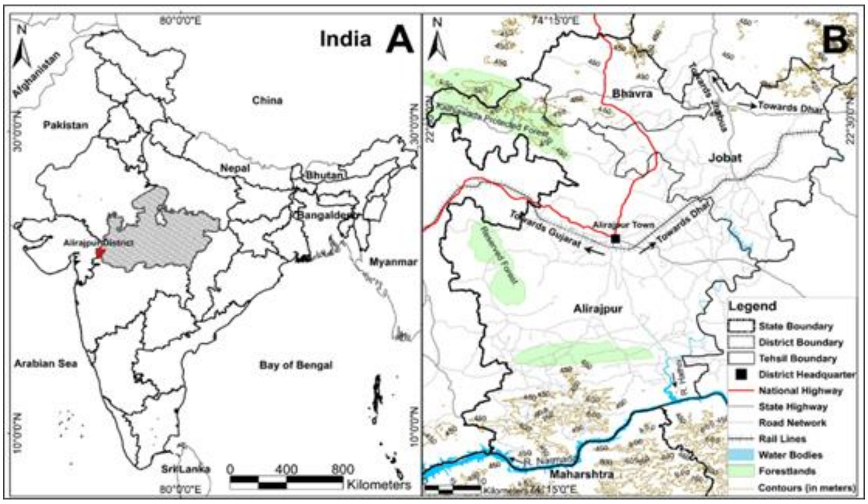

Fig 1. A. Location of Alirajpur District in India, B. Tehsils in Alirajpur District

Framework of the study

The Food Insecurity Index and Vulnerability Information System (FIVIMS) framework was adopted to assess the food insecurity in a multidimensional manner. From literature review (FAO 2002, 2008) three parameters of food insecurity have been identified such as Food Availability, Food Access and Food Absorption (table 1). These three parameters were further measured through sub-parameters. The list of sub parameters under the three parameters of Food Insecurity and their implications are provided in the table 1.

Table 1. Parameters and sub parameters of Food Insecurity Index

Indicators	Measurable Parameters	Importance
Food Availability	The Gross Primary Production (GPP) in cubic kg/m2	Represents total photosynthetic carbon fixation measured in cubic kg/sqm, high biomass indicates higher chances of food availability
	Cultivated area in ha	indicate the extent of agricultural land use and production capacity
	Irrigation Extent in ha	captured resilience against rainfall variability and ensured stability in food production
	Rural connectivity in km	facilitating transport of agricultural produce, access to inputs, and market participation of rural producers
Food Access	Agricultural labourers	higher shares reflecting greater vulnerability
	Cultivators	represents livelihood engagement and earning capacity.
	Proportion of Tribals and other marginalized groups (ST & SC)	serving as indicators of structural marginalization in food access
	Rural female literacy	critical factor influencing nutritional awareness and household decision-making
Food Absorption	Access to safe drinking water	reflecting reduced disease risk and improved nutrient absorption
	Access to Primary health services	healthcare accessibility for addressing malnutrition and disease
	Availability of Toilet facility	sanitation's role in reducing open defecation and improving nutrient retention
	Availability of Mid-day Meal services	children regularly receiving meals to enhance dietary intake

Data collection and methodology

For the purpose of GIS analysis shape files of the 541 villages were downloaded from geoportal namely 'India Water Resources Information System' (https://indiawris.gov.in/wris/#/geoSpatialData) maintained by government of India. The said data is collated and published in 2011. The details of the data of four parameters of food availability are given in Table 2.

Table 2. Summary table for data sources

Indicators	Parameters	Data source	Time period	Spatial Resolution
Food Availability	GPP	MOD17A2H - GPP, MOD17A3H - NPP	2024	500 meter
	Cultivated area	Land Record Department, Alirajpur District	2024	NA
	Irrigation extent			
	Rural connectivity	Open Street Map (OSM)	2024	NA
Food Access	Agricultural labourers	District Census Handbook, 2011	2024	NA
	Cultivators	Jal Jeevan Mission (JJM) Reports (2024)	2024	NA
	Proportion of Tribals and other marginalized groups (ST & SC)	District Census Handbook, 2011		
	Rural female literacy			
Food Absorption	Access to safe drinking water	Jal Jeevan Mission (JJM) Reports by 2024	2024	NA
	Access to Primary health services	OSM		
	Availability of Toilet facility (Rural)	Swachh Bharat Mission (Grameen) 2.0		
	Availability of Mid-day Meal services	PM POSHAN report		

Village level GPP was derived from the MODIS MODI7A3HGF Version 6.1 annual product (500m resolution) using Google Earth Engine (GEE) and ArcGIS. The methodology of acquiring GPP is shown in Figure 2.

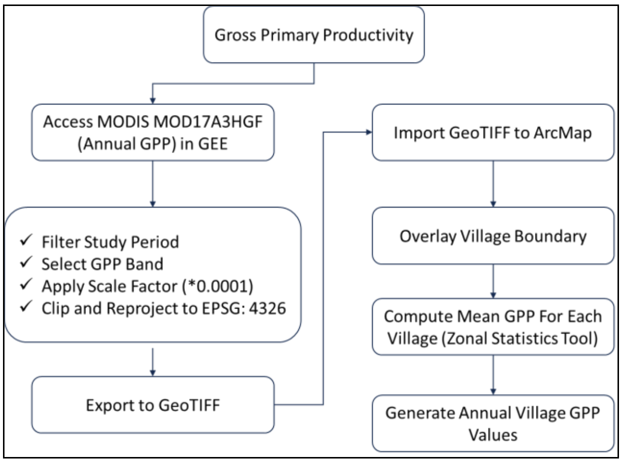

Figure 2. Methodology flow chart for GPP

Rural connectivity and access to primary health services was mapped using OpenStreetMap road networks, where Euclidean distance from village centroid to the nearest all-weather road was calculated in GIS software. Data on Agricultural labourers, ST & SC population, Rural female literacy were acquired from the 2011 district census handbook and projected to 2024 using the Arithmetic Increase projection technique using the formula (1).

$$Pt = P0 + (P0 \cdot r \cdot t)/100 \qquad \text{........................(1)}$$

Where,
P_t= projected population,P_0 = base year population,r = growth rate in % (referred from district census handbook)t = number of years in the projection period

Data on access to safe drinking water, availability of toilet facility (Rural) and availability of mid-day meal services were gathered from designated government mission portals. To standardise parameters with varying units, the Min–Max normalization technique was used using formula 2:

$$X = \frac{\mathrm{X} - \mathrm{Xmin}}{\mathrm{Xmax} - \mathrm{Xmin}} \qquad \text{.........2}$$

Where X= value under any parameter for a particular village
X min = minimum value under that parameter
X max = maximum value under that parameter

The normalized value for each parameter ranges between 0 and 1, where higher values indicate better performance (e.g., higher irrigation extent), while parameters inversely related to the outcome (e.g. distance to nearest road), were normalized inversely. After normalization, weightage was assigned based on the number of parameters included within each vertical of Food Insecurity. For example, since Food Availability has 4 parameters, the weightage was assigned for each parameter for (1/4)=0.25. The normalised values were multiplied by their weights and summed to create indices for Food Availability. Food Access and Food Absorption. Finally, the Food Insecurity Index was computed by applying an equal weightage of 1/3 to each of the three aforementioned verticals and summing them.

Analysis and discussion

A. Food Availability

Fig.3 (A-D) shows spatial distribution of sub-parameters of food availability. Three classes were made with raw data value using equal interval method for each sub- parameter where lower value represents low class and higher value represents high class for all parameters except Road Distance where low distance from nearest road represents good connectivity.

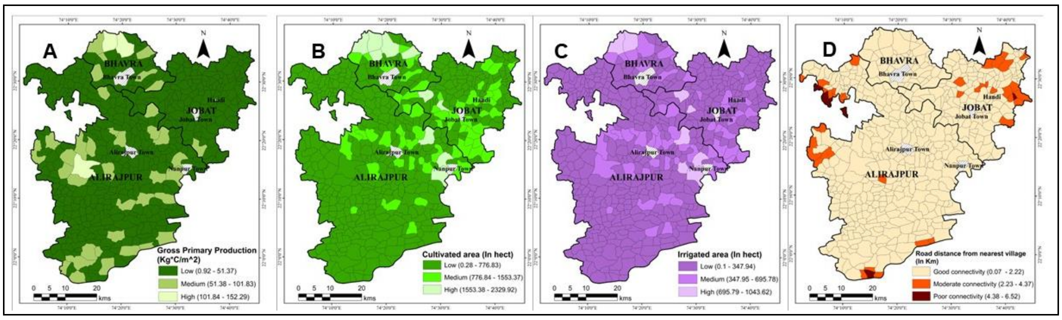

Fig.3. A. GPP, B. Cultivated Area, C. Irrigated Area, D. Road Distance

Figure 3 shows more than 80% villages falls under the lowest category of all parameters. A Food Availability Index was calculated using normalized values of each parameter (fig.4A).

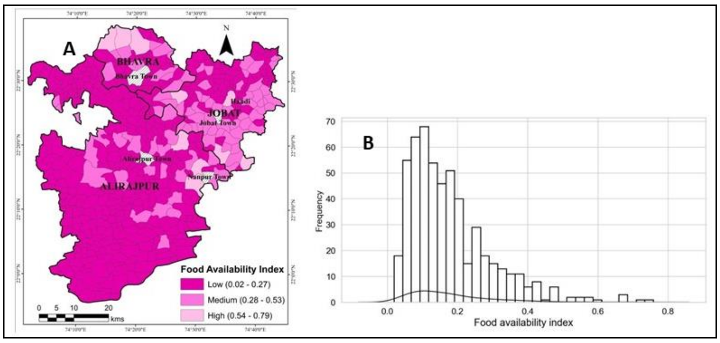

Fig. 4. A. Spatial distribution of villages in different categories of Food Availability Index, B. Graphical representation of frequency distribution.

A. Food Access

Fig. 5 (A – E) shows spatial distribution of five sub- parameters of food access.

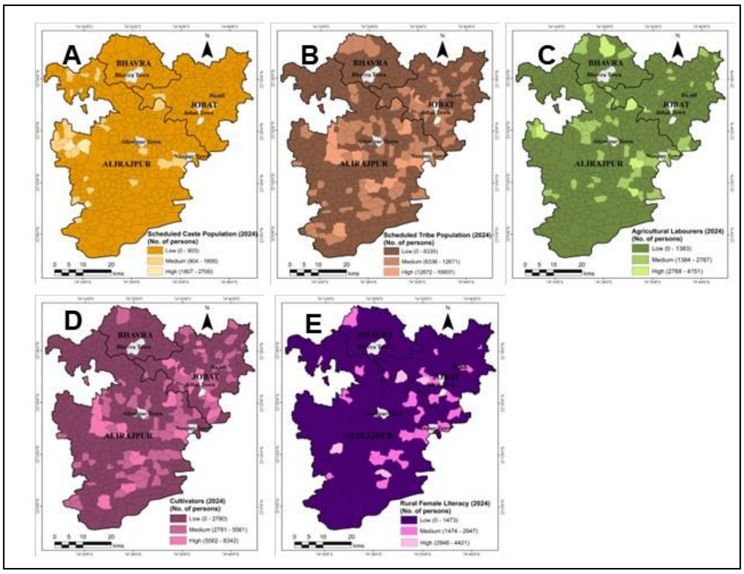

Fig.5 A. SC population, B. ST population, C. Agricultural labourers, D. Number of Cultivators, E. Rural Female Literacy.

89.65% of total villages in the district falls within the lowest category of Agricultural labourers i.e.0-1383 (Fig.5C) which indicates high ownership of the agricultural land. According the census of India, 'cultivators' are those people who owns agricultural land. Fig.5D shows concentration of cultivators is high in villages as 18.67% of total villages having cultivators between 2781 - 8342 which is upto 60% of village population. Situation regarding rural female literacy is concerning as 95.01% of the villages falls within lowest range of rural female literacy i.e. (0-1473 literate persons) (fig.5 E). This contributes to the low rural female literacy (35 %) in the district, while the state average is 59.24% (Census of India, 2011). A Food Absorption Index was calculated using normalized values of each parameter (Refer section 3. Data collection and Methodology).

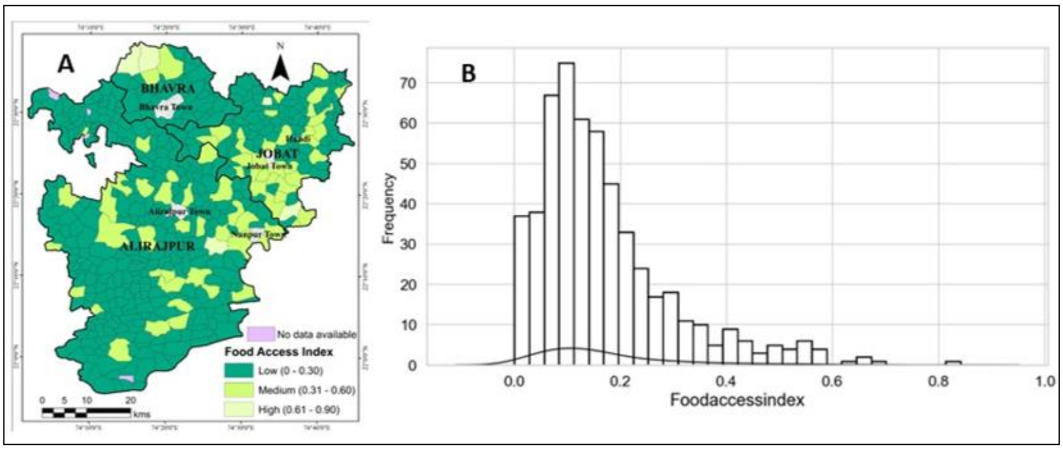

Figure 6. A. Choropleth map showing spatial distribution of villages in different categories of Food Access Index, B. Graphical representation of frequency distribution.

A higher proportion of the number of villages with low index values indicates a critical state of food absorption in the district (fig.6A).

Food Absorption

Fig. 7 (A-D) shows spatial distribution of four important sub-parameters of food absorption. The number of meals served in the entire district ranges between (0-705) (fig.7B). The number of households having tap water services range between (0-1965) (fig.7C) while the number of households having toilet services range between (0-1854) (fig.7D). In case of distance from public healthcare services, the least distance range is (0-6.00) km representing good connectivity while (6.01-12.00) km represents moderate connectivity and (12.01-18.00) (fig.7A).

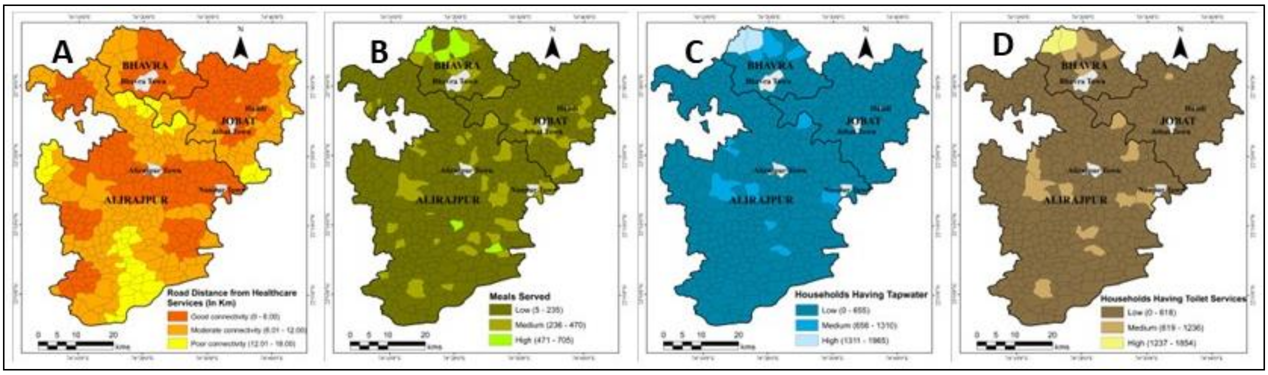

Figure. 7. A. Access to public healthcare, B. No. of Mid-day meals served , C. Households having tap water, D. Households having toilet

Fig.7 C and D show that 97.60% and 96.86% of total villages falls within lowest range of Households having tap water and toilets respectively. It reflects the poor coverage of water supply and sanitation network in the district. Food Absorption Index was calculated using normalized values of each parameter (fig.8).

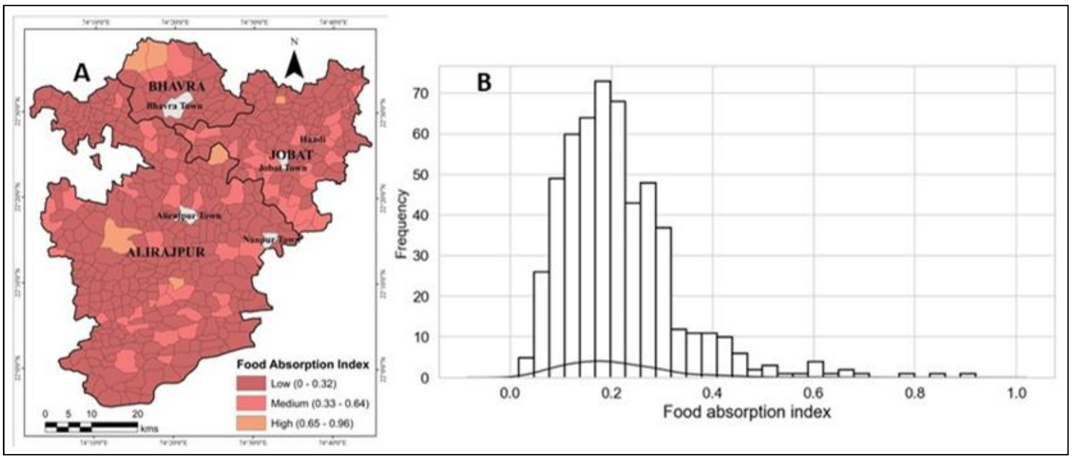

Figure 8. A. Choropleth map showing spatial distribution of villages in different categories of Food Absorption Index, B. Graphical representation of frequency distribution

According to fig.8A, 88.54% of the villages fall within the low category i.e. between 0-0.32. fig.8B shows the mean value is 0.21 which is the highest among three indices.

Food Insecurity Index

Using indices values for Food Availability, Access and Absorption, Food Insecurity Index was calculated for each of 541 villages of Alirajpur district (fig.9).

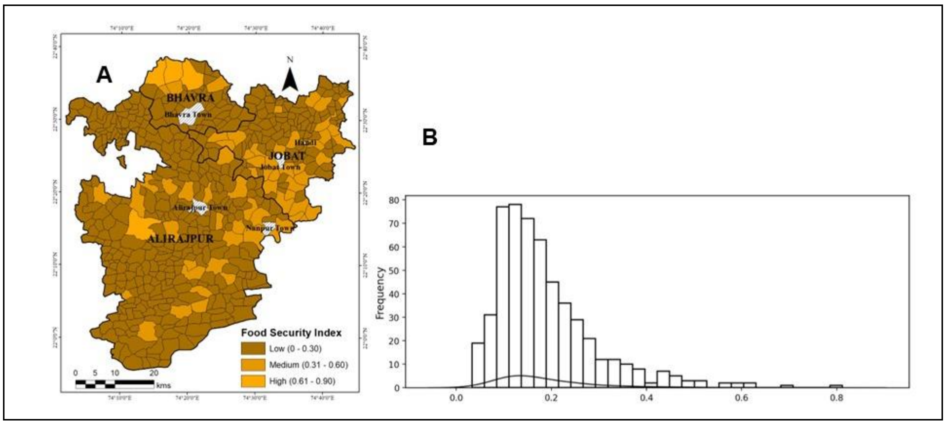

Figure 9. A. Village wise Food Insecurity Index of Alirajpur District, B. Graphical representation of frequency distribution

Fig.9 shows that 87.80% villages of the district fallowing with the low category of index value reflecting high food insecurity in those villages.

Identifying dominant predictor for Food Security through Artificial Intelligence Technique

Since equal weightage was applied to the contributing variables to calculate Food Security Index (FSI), linear regression method cannot be used to identify dominant parameter for Food Security. Regression was calculated on indices values of Food Availability, Access and Absorption using Random Forest Regression model and XGBoost regression model as these models are capable of handling geo-spatial data. Both models were used as the non-linear baseline model to develop predictors for Food Security Index (FSI), using an 80/20 train-test split for 541 villages. The output values of each model were normalized and averaged. The Random Forest and XGBoost models demonstrated strong predictive performance with high R^2 value (>0.86), and a very low MAE/RMSE (<0.026/0.045) indicating that collectively, the three parameters explain most of the variation in FSI when examined together.

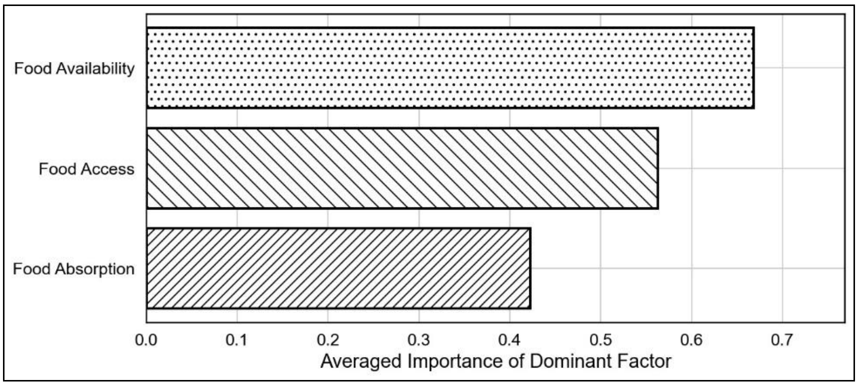

Figure 10. Identification of dominant predictor for Food Security Index

According to fig 10, the most influencing parameter of FSI is Food Availability with average dominance value of 0.66 followed by Food Access (0.56) and Food Absorption (0.42). Since Food Availability is the most dominant factor, by improving parameters of food availability, food security can be ensured. Within food availability, most dominating sub-parameter is cultivated area followed by irrigation extent (fig#). It implies the fact that cultivable area with irrigation opportunity can increase the food security in the tribal district of Alirajpur, Madhya Pradesh.

FIVIMS dashboard

The dashboard was designed as a simple map-based interface with separate panels for the map, filters, legends, and analytics. The idea was to help users to understand village-level food availability and access without reading raw data (fig.11).The Dashboard was hosted in 'Vercel' as a static site and open sourced JavaScript 'Leaflet' was used to create interactive maps. The URL for the dashboard is https://fivims-dashboard.vercel.app.

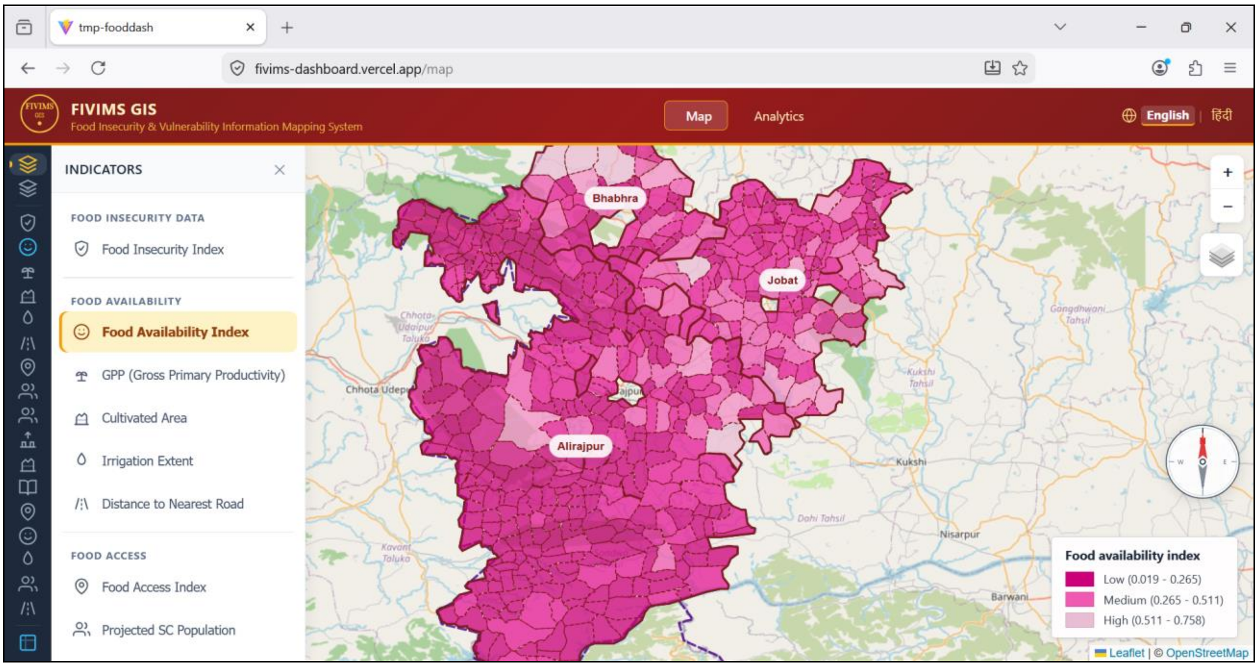

Figure 11. FIVIM dashboard

Capacity Building Workshop

A workshop on ‘Food Insecurity Index and Vulnerability Information System (FIVIMS) for Tribal District’ was conducted on 17th March 2026 at Collectorate Office, Alirajpur, Madhya Pradesh, India. The main objective of the programme was to built the capacity of stakeholders, local officials to use the data related to food security by demonstrating the website. Total 20 participants including representatives from local administration, scientists from local agricultural research centre and a research fellow have attended the workshop (fig.12).

Figure 12. FIVIM workshop