Application of Geographic Information System and Multivariate Techniques for the Delineation of Farm Typologies

Abstract

The farming systems in developing countries could be assumed to as heterogeneous due to a variety of factors in the biophysical (e.g., climate, soil fertility, slope, etc.) and socio-economic (e.g., preferences, prices, production goals, etc.) context. The delineation of farm typologies with respect to such smallholding farmers is important to decentralizing the agricultural decision-making process in relation to adoption of the technologies. The study applies geographic information system (land use-land cover and change detection study of the identified villages) for the collection of farm data in addition to the biophysical and socio-economic parameters to delineate farm typologies. The identified typologies were further validated by the farmers to identify the best agricultural technologies suiting their context.

Keywords Farm typologies, Geographic Information System, smallholding, Biophysical, Socio-economic

Significance Statement

The farmers in developing countries mostly comprise of smallholders with are heterogenous in biophysical and socio-economic conditions. The current research shows that the development of farm typology applying geographic information system and multivariate statistics and the farmers' subsequent validation could lead to better targeting of extension interventions.

The development of typology is an essential step towards a more realistic evaluation of the constraints and opportunities faced by the farmers resulting in proper deployment of technological solutions [1–3]. Also, it leads to the identification of factors towards the adoption/ rejection of technologies. The current study makes a novel attempt to utilize Geographic information system (GIS) data of the farm fields to further delineate the typologies in addition to biophysical features of the land and socioeconomic status of the farmers.

The study was conducted in agro-climatic Zone IV of Jharkhand. The agro-climatic zone of Jharkhand comprising of three zones (Zone-IV, V, and VI). Zone IV (Central and northeastern plateau) was purposively selected for the study. With the help of GIS and panel data, various agro-climatic situations in Zone IV were identified. From the selected agro-climatic situations, one representative bigger land parcels (village) were selected based on random sampling. Total enumeration of all the plots under the village and their operators (cultivators) were performed for the collection of primary data. Thus, both purposive, as well as simple random sampling techniques, were followed for the conveyance of research work. The three villages selected for the study were Borma village in Godda district, Raksi village in Sahibganj district, and Asanbani village in Dumka district of Jharkhand (Fig. 1). A total of 394 respondents from the three villages were selected through the complete enumeration technique. A complete enumeration-based survey with the developed interview schedule was conducted in the three villages to provide comprehensive statistical coverage over space and time. The study was conducted during January – June 2019 and covered all the farming households of the identified villages. The socio-personal, economic and biophysical variables related to the farming household and the operational farming land were captured in detail along with the geographic coordinates of the individual farmland.

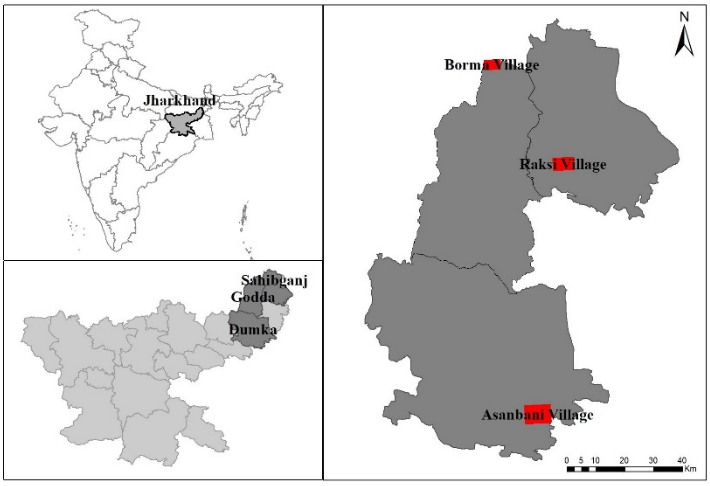

Fig. 1 The three villages selected from different districts in Agro-climatic zone IV of Jharkhand state in India

With the help of GIS and panel data, the Land Use Land Cover (LULC) study of three villages having distinct biophysical and geological features was performed to understand the changing use of the natural and human-made resources at the disposal of the farmers and government which could be made use for efficient selection, planning, and implementation of policy initiatives in agriculture for the optimum utilization and sustainable management. The multi-temporal land use/ land cover mapping and change detection analysis was carried out to categorize five distinct classes, which are fallow land, agriculture, forest, buildup area and water body. The data for the study collected from the LISS III Ortho satellite data [4] and Landsat [5]. The ground-truthing of the remote-sensing data was also conducted for better interpretation and analysis.

Further, the identification of typologies involved two multivariate statistical techniques, namely the principal component analysis (PCA) and the cluster analysis (CA). A total of 21 different variables related to socio-economic and biophysical features of the farms were used for the analysis using PCA. In PCA, the six principal components with eigenvalues greater than one were retained for further analysis. These six PCs explained 73.07 % of the total variability in the dataset. The first component explained 30.21 % variance in the dataset and is correlated with the income obtained from crops, crop diversification index, system cost of cultivation, gross system return, and system net return. Thus, the component represents income from crops and high resource farmers with more significant income generation. The second component explained 15.92 % variance and is correlated with educational index, total hired and family labour employed on the land, income from cattle, and crop diversification. In this way, this component explains the income from cattle, intensification of labour on the land and educational attainment. The third principal component explains 9.74 % variance and is correlated with the age of the farmer, the number of years devoted to farming and income from pension schemes of the government. The fourth component explains 6.29 % variance and is correlated with total area owned by the farmer and income from other sources (off source income). The fifth component explains 5.55 % variance and is correlated with household size and years for which the farmer is educated. The last component explains 5.33 % variance and is correlated with income from animals and small ruminants. In this way, the six principal components could be named as 'income from crop and net income from the system' (PC1), 'crop diversification and intensification of labour' (PC2), 'experience in farming and income from pension' (PC3), 'off-source income and total operational farm area' (PC4), 'education and household size' (PC5), and 'income from livestock' (PC6). The first six factors (Fig. 2) obtained from the Principal Component Analysis were used for further analysis using Euclidean Distance as distance measure and Ward's technique as agglomerative clustering to form four clusters which were found to be representative of the farm households in the three villages.

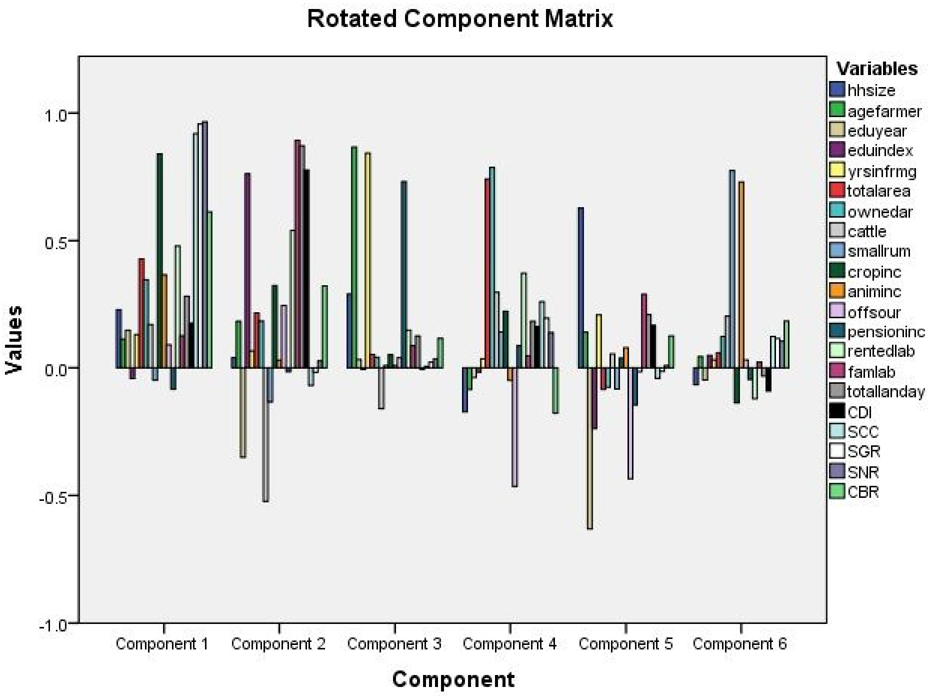

Fig. 2 Tabular representation of the rotated component matrix explaining the components

Further, the four clusters (Fig. 3) were employed with k-means clustering method to produce final clusters centres. The final cluster centers provide an interpretation of the typical features of the particular cluster. The first cluster (Cluster 1) is characterized by the diversification of crops and intensification of labour. A total of 88 farm households from the Borma village is representative of this cluster. The income from livestock characterizes cluster 2. A total of 38 farm households are identified in such cluster with 19 farm household in Borma village, 10 in Raksi and 9 in Asanbani village. Cluster 3 represents farms with higher income from cropping system along with off-source income. A total of 67 farm households are identified in this cluster with 11 farm households in Borma village, 53 in Raksi and 3 in Asanbani village. The last cluster (Cluster 4) represents the senior farmers with education and farming experience along with a sustained income through pension. This is the largest cluster with a total of 201 farm households distributed in Raksi (161 households) and Asanbani (40 households) village. In all of the identified clusters, there is the contribution of several other factors in varying proportions like income from crop and income from livestock. The authenticity of the cluster analysis was examined by conducting a one-way analysis of variance for each of the principal components (equality of group mean scores). It was concluded by observing the p-value nearing to .00 (p=0.000 for all the factors) that the components are significant in differentiating various clusters.

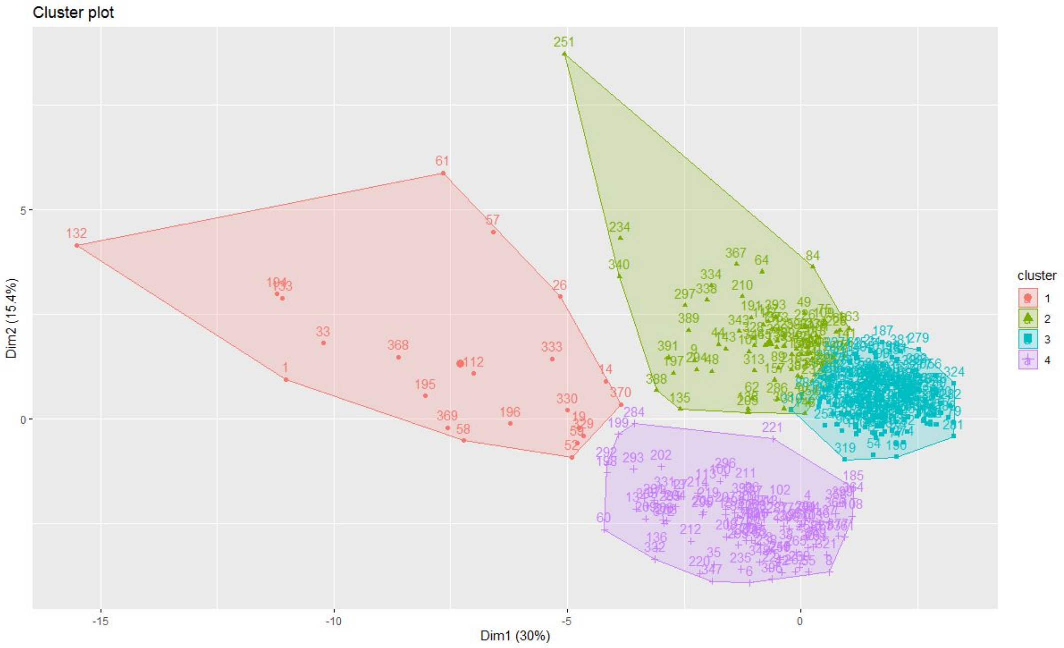

Fig. 3 Cluster plot denoting the identified clusters and farm households

The validation of the four clusters developed from our typology-based study and fitting of the agricultural technologies with the clusters was undertaken through qualitative methods. The qualitative tool utilized for this study was the focused group discussions (FGD) and participatory workshops [6]. The FGDs were organized with eight key-informants in each of the three villages for the validation of the clusters developed in our study with the farmers own criterion while the participatory workshops were organized with the same key-informants from each of the villages to understand the fitting of the agricultural technologies to each of the identified clusters by the key-information themselves. This type of comprehensive classification of the farms taking the GIS data of the farm, economic returns from the farm and non-economic factors into consideration pave a way for a more effective generalization of the farming typologies which could find better application in targeting the technological intervention in farming among the smallholders.

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