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RESEARCH ARTICLE

Identifying key determinants of pulse crop productivity in Jammu region using principal component analysis

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Abstract

This study examines the factors influencing agricultural productivity, with a specific focus on pulse cultivation, in the purposively selected districts of Kathua, Doda, Kishtwar and Udhampur in the Jammu region. Primary data were collected from 240 farmers using a multistage random sampling technique. To identify the underlying determinants of productivity, Principal Component Analysis (PCA) was employed. The PCA results extracted four principal components in each district, collectively accounting for 71 % to 81 % of the total variance in the dataset. The analysis identified that land characteristics, income diversification and farmer education were the most significant contributors to agricultural performance. Land fragmentation and ownership emerged as critical factors in Doda and Kishtwar, whereas income sources and educational qualifications of farmers were more influential in Kathua and Udhampur. These findings highlight the importance of region-specific policy interventions, particularly those aimed at improving land management, promoting income diversification and enhancing farmer education, to effectively boost pulse productivity and overall agricultural sustainability in the region.

Keywords: analysis; determinants; principal component; productivity; pulse

Introduction

Indias' economy heavily relies on agriculture, which employs approximately 49 % of the workforce. Providing affordable food and nutrition to over 1.25 billion people remains a major concern and top priority for the government (1). The governments' support for rice and wheat through the Minimum Support Price (MSP) and Public Distribution System (PDS) has encouraged farmers to focus on these crops or cash crops like cotton and sugarcane. Pulses, primarily grown in rainfed areas, are often relegated to secondary importance. These regions support over 40 % of the population and two-thirds of the countrys' livestock (2).

In 2021-22, India produced 27.30 Mt of pulses, nearing self-sufficiency. Over the past six year period from 2015-16 to 2021-22, pulse production increased at a Compound Annual Growth Rate (CGAR) of 5 %, with individual crops showing varying growth rates : Tur (9 %), Gram (11 %), Mung (12 %), Urd (6 %) and Lentil (4 %). This production supports the livelihoods of over 5 crore farmers and their families. India is a major player in the global pulse market, accounting for 36 % of global area and 26 % of global production (3).

Globally, pulses are cultivated on approximately 94.14 Mha, yielding 89.74 Mt with an average productivity of 953 kg/ha. India leads the world in pulse cultivation, with over 35 Mha under pulses, contributing 37 % of the global area and 29 % of total production. In 2021-22, Indias' pulse productivity reached 932 kg/ha, marking a notable improvement over the past five years (4).

India also plays a dominant role in global pulse trade, meeting 39 % of the worlds' demand and accounting for nearly 15 % of total imports and exports. As the largest producer, Indias' share of global production stands at 28 %. Between 2017 -18 and 2021-22, pulse imports fluctuated between 23.16 and 56.08 lakh t, with the highest import recorded in 2017-18 (56.08 lakh t) (5). A declining trend in imports has been observed, contributing to foreign exchange savings. During the same period, pulse exports remained relatively stable, with a 34 % increase reported in the most recent year compared to the previous one.

Pulses, a traditional component of Indian diets, serves as the primary protein source (20-25 %) for 43 % of vegetarians (2), complementing staples cereals such as rice and wheat. They are essential for food and nutrition security, especially for low-income populations reliant on plant-based protein. Pulses offer multiple benefits, including health and nutrition, poverty and hunger reduction and enhanced ecosystem resilience (6). Pulses are recognized for their ability to improve soil fertility. Pulses have deep roots, fix nitrogen, shed leaves and help mobilize insoluble soil nutrients, particularly phosphorus. The integration of legumes, particularly pulses, into cereal-based cropping systems is essential for maintaining long-term agricultural

productivity. These crops offer dual benefits: they serve as a valuable source of nutrition for humans and livestock and enhance soil health by improving its physical, chemical and biological properties. (7).

In the Union Territory (UT) of Jammu and Kashmir, 18893 ha are under pulse cultivation, with 12955 ha in the Jammu region and 5938 ha in the Kashmir. The main pulses found in J&K are Black gram, French gram, Green gram, Horse gram, Rajma, red lentil, etc (8). While the Green Revolution (1961 - 2015) led to dramatic increases in the production of maize, wheat, rice and soya, the yield of pulses improved by only59 %. Globally, per capita pulse consumption is about 7 kg/ year. India's total pulse consumption is projected to reach 39 Mt by 2050, necessitating an annual growth rate of 2.2 % to bridge the supply-demand gap (9).

Most farmers in J&K practice low-input agriculture, which inadvertently protects the soil and environment from the adverse effects of synthetic chemical inputs (10). J&K has a great deal of promise for organic farming because chemical fertilizers are not readily available there. Many high altitude areas of Jammu; especially Kishtwar, Udhampur, Doda and Kathua; already practise semi-organic farming by default. Due to the region's temperate climate, a variety of crops are cultivated with minimal or no use of chemical pesticides and fertilisers. However, certification is required to formally classify the produce as organic (11). So, the marketable surplus of the produce from these areas can be sold as an organic or semi-organic crop. Farmers may take advantage of the expanding market for organic products to preserve soil quality and increase biodiversity. To make farming sustainable, many farmers in J&K are already cultivating pulses, spices, basmati rice, walnuts and other crops organically (12).

Materials and Methods

The selection of methodologies was guided by the research problem and the specific research questions formulated. The following sections present a detailed description of the methods employed across various domains.

Research design

The Jammu division comprises ten districts. The current study was conducted in four districts of the temperate Jammu region:: Doda, Kishtwar, Udhampur and Kathua. These districts were purposively selected based on the maximum area under pulse cultivation (Table 1).

Table 1. District-wise area sown under pulse crop in the temperate regions of Jammu 2016-17

Sl. No.	District	Pulses Area (in ha)
1	Doda	1488
2	Kishtwar	1170
3	Kathua	2403
4	Udhampur	1576

Locale of the study

The study was concentrated in Doda, Kishtwar, Udhampur and Kathua districts within the Jammu division. These districts were purposefully selected due to their relatively large area dedicated to pulse crop cultivation area. According to 2018 data from the Department of Statistics and Economics, these districts reported the highest acreage under pulse in the temperate zone of Jammu, thereby making them suitable for examining the contribution of pulse farming to rural livelihoods.

To determine the sample size, a multi-stage random sampling method was applied. In the first stage, one sub-division was randomly selected from each of the four chosen districts. In the second stage, six pulse-growing villages were randomly selected from each chosen sub-division using simple random sampling. In the final stage, ten farmers involved in pulse cultivation were randomly selected from each village, resulting in a total sample size of 240 respondents (4 districts × 6 villages' × 10 farmers). This structured sampling strategy ensured robust representation of the study area and enabled a meaningful analysis of the factors affecting pulse production and income dependency. Comparable sampling approaches have been employed in previous regional studies.

Profile of the study area

Jammu, situated between 32°50′ and 33°30′ North latitude and 74°24′ and 75°18′ East longitude, lies approximately 600 km from New Delhi. Jammu and Kashmir, covering an area of 101387 km^2 (2.42 Mha) excluding the areas under Pakistani and Chinese control, represents 3.08 % of Indias' geographical area. Of this, 30.38 % (0.742 Mha) constitutes the net sown area, with 51.90 % (0.378 Mha) under double cropping and 41.70 % (0.309 Mha) irrigated. Forests occupy 27.24 % (0.658 Mha), while 12.13 % (0.293 Mha) is utilised for non-agricultural uses. Fallow land accounts for 3.02 % (0.073 Mha), barren and uncultivable land for 11.96 % (0.289 Mha) and the remaining 14.94 % (0.361 Mha) includes cultivable waste, permanent pastures and other grazing areas (13). This study focuses on four specific districts within this region.

Kathua district

The district is situated 32°17′ to 32°55′ North Latitude and 75°70′ to 76°16′ East longitude, covering an area of 2502 Km^2. The district has a population of 6.16 Lakhs, comprises 5 Assembly Constituencies and is administratively divided into 11 Tehsils and 19 blocks, encompassing approximately 512 villages (14). Dogri is the traditional language of Kathua whereas pahari languages are prevalent in the mountainous region of the east. The sex ratio is 890 females for every 1000 males.

Udhampur District

Udhampur district lies on the southern side of the State and constitutes 4 tehsils. The district constitutes 331 villages. Udhampur ranks 10th among all district in terms of population, with a total of 554985 people, representing 4.43 % of the total population of the State. The rural area spans of 2593.28 km^2, while 43.72 km^2 (15). The sex ratio in Udhampur is 870 females per 1000 males, which is lower than the States' ratio of 889.

Doda District

Doda district lies in the outer Himalayan range, approximately 175 km from Jammu and Kashmir. It comprises 4 tehsils, with

Doda being the largest. The district constitutes 406 villages with an area of 8892.25 km^2. In contrast, its urban sector comprises an area of 19.75 km^2 with a population of 409936 comprising 3.27 % of the total population of the State (16). The sex ratio is 919 females per 1000 males.

Kishtwar District

The district derives its name from its district headquarters, the town of Kishtwar. It is comprised of 4 tehsils. The rural part of the district constitutes 157 villages including two uninhabited villages, encompassing an area of 1643.65 km^2 while the urban sector is spread over an area of 0.63 km^2 and is made up of only 1 town namely, Kishtwar with a population of 230696, comprising 1.84 % of the total population of the State (17). The sex ratio is 920 females per 1000 males.

Selection of respondents

A list of temperate sub-divisions along with the areas under pulse crops was prepared for each selected district. One sub-division from each district was then selected randomly, resulting in a total of four sub-divisions, one from each district. Subsequently, lists of villages cultivating pulses were prepared for each selected sub-division. From these, six villages per sub-division were randomly selected using a simple random sampling technique, yielding a total of 24 villages across the four sub-divisions. For each of the selected villages, a list of pulse-growing farmers was prepared. From each list, ten farmers were randomly chosen to serve as respondents for the study. In this way, a total of 240 farmers engaged in pulse crop production were selected as the final sample size for the study, as presented in Table 2.

Variables and their measurement

Two types of variables were studied for the study, independent and dependent variables, as shown in Table 3.1 and 3.2.

Operational definitions

Operational definitions are broadly classified into two types: measured and experimental. Measured operations focused on the mechanism used to quantify a variable, while experimental operations highlight the researchers' control over the variables.

Age

Age was recorded based on the respondents' completed years at the time of the study. Respondents were classified according to their ages using the mean and standard deviation (18). The categories of age groups are:

- Young: 22-35 years
- Middle: 36-59 years
- Old: Above 59 years

Education

This variable denotes the number of years of formal education completed by the respondents at the time of the interview. Based on their responses, individuals were classified into the following categories: illiterate, below primary, primary, middle, matriculate, 10+2, graduate and above.

Family size

It refers to the total number of members in a household. Three categories of respondents are made based on the Singh cube root method of categorization (19).

Table 2. Sampling plan of pulse crop growers in the selected districts

SN	District	Sub-division	Villages covered	Number of respondents from each village	Number of respondents from selected villages
1	Doda	Pranoo	Bigota Masari Shekpura Bathoh Tantla Thilroo	10	60
2	Kishtwar	Mughal Maidan	Bhata Moolchatar Seeri Sigdi Markhar Bankari Dahayan	10	60
3	Kathua	Machedi	Machedi Badnota Nangala Dull Bijohi Najot Kindli	10	60
4	Udhampur	Pancheri	Kultyar Upper Meer Lower Meer Gailote Sadhota Suman	10	60
Total number of respondents from selected villages					240

Table 3.1. Dependent variable

Variable	Code	Measurement
Pulse crop income to household income	Y1	Percentage (%)

- Category 1: 2-4 members
- Category 2: 5-7 members
- Category 3: Above 7 members

Family type

A joint family is defined as one where two or more generations cohabitate and share resources. A nuclear family consists of members of the same generation living independently and managing separate property.

Operational land holding

It is calculated as the number of land owned (in ha) by the pulse crop growers including leased in and excluding leased out.

Operational Land Holding =

Area owned + Area leased in - Area leased out (20)

Extension contacts

This variable measures the respondent's contact with agricultural extension personnel. It is measured by awarding 1 score for extension contact and 0 for no extension contact.

Occupation

The main source of livelihood is considered as the occupation of the respondents. The respondents are categorized into six categories based on their frequency in each of the six occupations. The seven categories are:

- Category 1: Only agriculture
- Category 2: Agriculture + Government service
- Category 3: Agriculture + Retired from government service
- Category 4: Agriculture + Business
- Category 5: Agriculture + Labour
- Category 6: Agriculture + Private job
- Category 7: Agriculture + Shop

Social participation

This refers to the respondent's involvement in formal or informal organisations, either as a member or office bearer. Participation was scored as 1 for involvement and 0 for non-involvement.

Livestock possession

It is considered as the actual number of animals or livestock possessed by the respondents at the time of inquiry. It is measured in terms of the number of based animals or livestock possessed by the respondents.

On-farm income

In this study, farm income includes income from crops and livestock. In calculating agricultural crop income, all incomes generated from farming are accounted for. The quantity of crop yields is obtained from individual households through face-to-face interviews and the reported price of each product by each household is used in the calculation. The reported prices for each seasonal product are the same as those of their local markets. Agricultural income is calculated by multiplying crop yields by respective product prices. The common livestock found in the study area are cows, buffalo, oxen, sheep and poultry. The annual income from livestock, milk yield and sale of animals are calculated.

Table 3.2. Independent variables

Variables	Codes	Measurements
Age	X1	Chronological age of the respondent.
Education	X2	Number of years of formal schooling
Family size	X3	Number of members in the family
Family type	X4	Joint/nuclear
Experience in collection	X5	Number in Years
Operational land holdings	X6	Area in ha
Irrigated/unirrigated	X7	1 for irrigated and 0 for unirrigated
Extension contacts	X8	1 for contact and 0 for no contact
Occupation	X9	1 for farming and 0 for off-farm activities
Source of information	X10	1 for yes and 0 for no
Social participation	X11	1 for yes and 0 for no
Livestock possessions	X12	In numbers
On-farm income	X13	In rupees
Off-farm income	X14	In rupees
Income from pulse crop	X15	In rupees

Off-farm income

Off-farm income includes the total income generated from wage labour, business, private job, private shops and permanent employment such as a pension, government staff, etc.

Experience in pulse crop cultivation

It is measured in terms of the number of years a farmer practiced pulse crop cultivation.

Distance from various organizations

Distance from the pulse market

It is the total distance from home to the pulse market (in km).

Distance from agriculture office

It is the total distance from home to the agriculture office (in km).

Distance from forest office

It is the total distance from home to the forest office (in km).

Distance from main road

It is the total distance from home to the main road (in km).

Information utilization pattern

This refers to different sources utilized by the farmers in obtaining information regarding different aspects of pulse crop production and other than pulse crop production technology and is measured in terms of the percentage of cultivators reporting the different sources.

Constraints

It is measured as the limitations faced by the pulse crop growers in the production recommendations of pulse crop cultivation in terms of the percentage of farmers reporting the different sources.

Suggestions

Respondents were asked to provide their valuable suggestions to avoid the challenges faced by them during the cultivation, storage, processing and marketing of pulse crops. These suggestions were summarized based on the number and percentage of respondents offering each recommendation.

Construction of research tool

An interview schedule was constructed to facilitate data collection while keeping the objectives of the study in mind. It consisted of three parts:

- Part 1: Socio-personal profile of pulse crop growers
- Part 2: Regarding pulse crop cultivation practices
- Part 3: Constraints and suggestions

Pre-testing of the research instrument

Before the collection of actual data, the research instrument was pre-tested on 20 non-sampled farmers of the Udhampur district. The pre-testing of the research instrument was done with the objectives of finding out the weaknesses and ambiguity in any part of the schedule, removing the difficulties that are likely to come up during the actual data collection, to see how it worked for clarity and understanding by the respondents and to see how much time is taken to interview a respondent. These 20 respondents are not included in the final sample of 240 respondents. Based on the information obtained, required interventions are made in the research schedule to make it easy to record the data and to remove any ambiguity, if available. This helped a great deal in getting the correct response from the pulse crop growers under investigation.

Data collection

A semi-structured interview schedule was used to conduct personal interviews with the chosen respondents. Interviews were conducted at respondents' homes, community centers and workplaces to capture their immediate responses. The Department of Agriculture of Jammu and Kashmir provided the secondary data used in this study.

Statistical analysis of data

The collected data were classified, quantified and tabulated. Basic statistical tools such as percentages, arithmetic mean and standard deviation were applied to summarize the data. A multistage random sampling technique was employed to collect data through in-person interviews. A detailed explanation of the statistical formulae and computational steps used are provided in the supplementary material.

Kaiser-Meyer-Olkin (KMO) and Bartlett's test of sphericity

The KMO Test measures sampling adequacy. KMO > 0.6 is generally considered acceptable. Bartlett's Test of sphericity tests evaluates whether the correlation matrix significantly differs from an identity matrix (i.e., whether variables are correlated enough for PCA). A p-value < 0.05 indicates suitability.

Before running the PCA, we checked whether the dataset met the necessary conditions for this type of analysis. The KMO measure of sampling adequacy returned values of 0.684 for Doda, 0.702 for Kishtwar, 0.673 for Kathua and 0.691 for Udhampur, all of which are above the acceptable threshold of 0.6, indicating adequate sampling. Additionally, Bartlett's Test of Sphericity was found to be highly significant ($p < 0.001$) across all districts, confirming that the variables were sufficiently correlated to justify the use of PCA.

Principal Component Analysis

Principal Component Analysis (PCA) is a statistical technique well-suited for reducing the dimensionality of large and complex datasets while preserving most of the original variability (21). In agricultural research, particularly in analyzing pulse crop productivity, datasets often include numerous interrelated variables such as climatic, soil, input-related and socio-economic factors. In this study, PCA was chosen due to its advantages over other methods. PCA transforms the original set of variables into a new set of uncorrelated variables known as principal components.

These new components are linear combinations of the original variables (22). This not only simplifies data analysis and visualization but also eliminates multicollinearity, a common issue in models like multiple regression, thereby enhancing the robustness of further statistical analyses (23). The orthogonality of the PCs ensures that each provides unique, non-redundant information (22) and projecting high-dimensional data into fewer dimensions helps uncover hidden patterns and groupings (24). These capabilities make PCA an effective tool for identifying the key determinants of pulse crop productivity in regions like Jammu and Kashmir, where multiple influencing factors must be analyzed in an integrated and interpretable manner.

The objective is to find out only a few components, which account for most of the variation in the original set of data. The principal component (Pi) is determined as follows:

$$Pi = a1jZ1 + a2jZ2 + a3j\ Z3 + \ldots\ldots + anjZn \qquad (25)$$

Where,

Pi = 1 to n, are the newly formed uncorrelated components,

aij = i = 1 to n and j = 1 to n, the Z coefficients are factor loadings,

Zi = 1 to n, are observed variables as standardized by dividing (X-X) by its standard deviation (σx).

Each principal component contributes to the total variance of the original variables in decreasing order. Typically, the first principal component accounts for the largest portion of the total variance, followed by the second, which captures the next highest share of the remaining variance and so on. The total variance of all principal components combined is equal to the total variance of the original dataset. The sum of the squares of the factor loadings for a given component ($a21j + a22j + a23j + \ldots\ldots + a2nj$) represents the amount of variance that component explains. This value is also referred to as the Eigenvalue (λ).

$$Pi = \lambda/n \times 100 \text{ (n = number of variables)} \qquad (26)$$

Results and Discussion

Determinants of factors influencing pulse productivity

The "Total Variance Explained" shows how the variance was divided among the fourteen possible factors (Table 4, 5, 6 and 7). It was observed that only the first four components have eigenvalues greater than one in all the four districts. Collectively, these components accounted for 70.946 % of the variance in Doda, 79.721 % in Kishtwar, 78.980 % in Kathua and 80.550 % in

Udhampur, indicating that these principal components captured the majority of variability in the original dataset.

The components matrix depicted the contribution of each variable to the main component, representing their correlation with the components (Table 8). Each variable showed a loading across the fourteen components; however, only those with significant correlations (≥ 0.50) were retained for interpretation. For Doda district, the significant loadings were: area (0.918), unirrigated land (0.816) and maximum fragmentation (0.793) in PC1; total income (0.870), on-farm income (0.819) and off-farm income (0.515) in PC2; minimum fragmentation (0.694) and maximum fragmentation (0.384) in PC3; and irrigated land (0.524) and off-farm income (0.445) in PC4 (Table 8). These findings demonstrated that land holdings and irrigation facilities significantly influence changes in the cropping system (26). However, the results contrast with those who found that irrigation water had a negative effect on gram production (27).

The scree plot showed that the eigenvalues start to form a straight line after the first principal component. Therefore, the remaining principal components account for a very small proportion of the variability (Fig 1). In Fig 2, Bi plot showed that horizontal axis represents PC1 and vertical axis represents PC2. Length of arrows represents the amount of the contribution by a particular variable. Longer the length of arrow higher was the contribution of that particular variable. The circumference of the circle in this biplot is known as correlation circle. If the arrows are closer to the circumference of the circle they were having high correlation. Density of the color also represented the amount of contribution. With respect to PC1, age had highest amount of contribution and with respect to PC2 total income, on-farm income, area, unirrigated variable and maximum fragmentation had highest amount of contribution.

In Kishtwar district, PCA revealed distinct underlying data structures (Table 5). PC1 was primarily characterised by land-related variables, with significant loadings for land holding (0.920), maximum fragmentation (0.871) and unirrigated land (0.830). PC2 was defined by income sources and livestock rearing, with strong loadings for total income (0.824), on-farm income (0.730) and animal rearing (0.598). PC3 reflected a combination of income and fragmentation influences, indicated by on-farm income (0.473), total income (0.384) and minimum fragmentation (0.414), highlighting interconnections between land structure and economic outcomes. PC4 captured the relevance of off-farm income and pulse income, with loadings of 0.679 and 0.529 respectively (Table 8).

As per Fig 3, the scree plot indicated that while the first PC explained a substantial portion of the variability, subsequent components made diminishing contributions. As per Fig 4, the biplot focusing on the first two PCs visually depicted the variable contributions. PC1 is heavily influenced by land area and fragmentation, while PC2 is primarily driven by age and farming experience.

The PCA of data from Kathua district (Table 6) identified four principal components with eigenvalues greater than 1, with PC1 alone explaining 42.544 per cent of the total variance. As shown in Table 8, PC1 was dominated by land use and income (unirrigated land: 0.943, fragmentation: 0.866, total income: 0.831), PC2 by farmer qualifications and off-farm income (qualification: 0.785, off-farm income: 0.724), PC3 by livestock rearing and demographics (animal rearing: 0.655, experience: 0.505, age: 0.486) and PC4 by irrigated land (0.729).

The scree plot (Fig 5) showed the dominance of PC1 and the biplot (Fig 6) highlighted the influence of land-related variables on PC1 and qualification on PC2.

Similarly, PCA conducted for Udhampur district (Table 7) retained four components, with PC1 explaining 41.991 per cent of the variance. Table 8 revealed that PC1 captured land characteristics (unirrigated land: 0.947, area: 0.893, fragmentation: 0.865), PC2 represented income and qualification (off-farm income: 0.811, qualification: 0.653), PC3 reflected livestock rearing and demographics (animal rearing: 0.731, experience: 0.593, age: 0.543) and PC4 focused on pulse income (0.766). The results support that land fragmentation strongly determine crop diversification in Ethiopia (28).

The scree plot (Fig 7) and biplot (Fig 8) confirmed the importance of land and income-related variables in shaping the agricultural structure.

Table 4. Total variance explained of pulse crop cultivation in Doda district

Total variance explained						
PC	Initial eigenvalues			Extraction sums of squared loadings		
	Total	% of variance	Cumulative %	Total	% of variance	Cumulative %
1	4.513	32.238	32.238	4.513	32.238	32.238
2	2.063	14.736	46.974	2.063	14.736	46.974
3	1.977	14.118	61.092	1.977	14.118	61.092
4	1.380	9.854	70.946	1.380	9.854	70.946
5	0.952	6.797	77.743			
6	0.901	6.436	84.179			
7	0.729	5.208	89.387			
8	0.590	4.212	93.599			
9	0.343	2.453	96.051			
10	0.294	2.097	98.148			
11	0.178	1.271	99.419			
12	0.069	0.493	99.912			
13	0.012	0.088	100.000			
14	- 3.766E- 16	- 2.690E- 15	100.000			

Extraction Method: Principal Component Analysis.

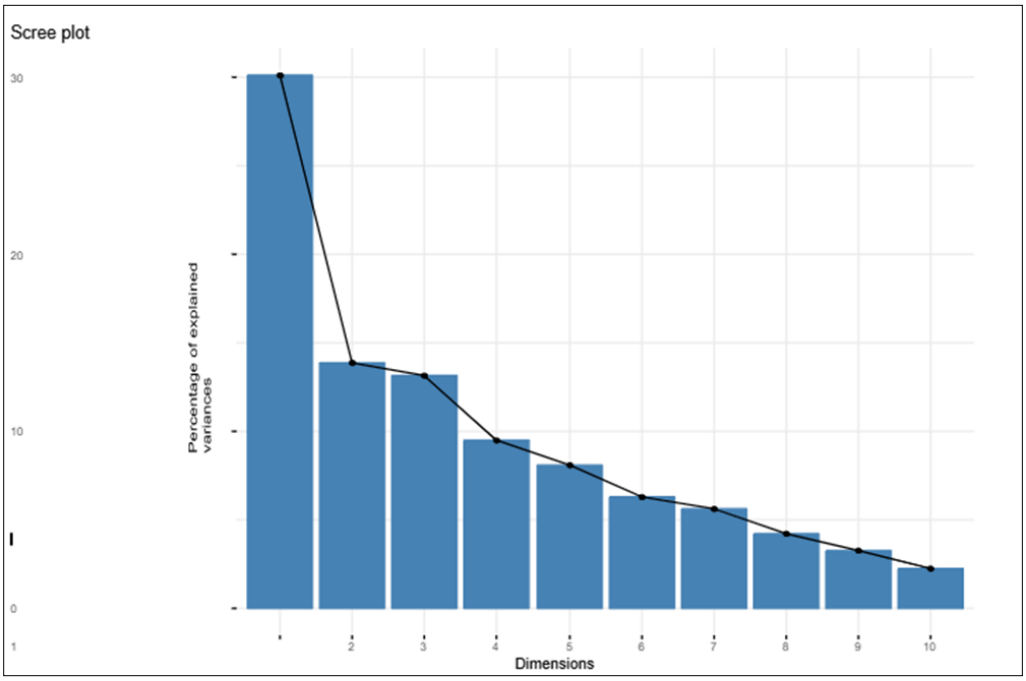

Fig. 1. Scree plot of Doda district.

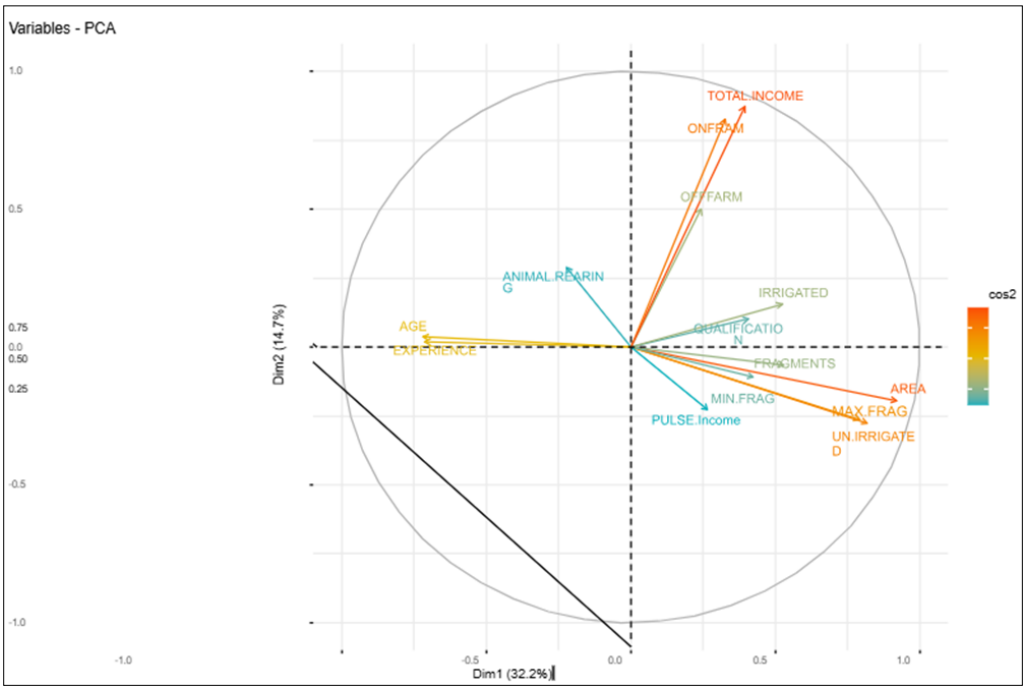

Fig. 2. Bi plot of Doda district.

Table 5. Total variance explained of pulse crop cultivation in Kishtwar district

Total variance explained						
PC	**Initial eigenvalues**			**Extraction sums of squared loadings**		
	Total	**% of variance**	**Cumulative %**	**Total**	**% of variance**	**Cumulative %**
1	4.836	34.541	34.541	4.836	34.541	34.541
2	2.560	18.287	52.828	2.560	18.287	52.828
3	1.457	10.405	63.233	1.457	10.405	63.233
4	1.288	9.203	72.436	1.288	9.203	72.436
5	1.020	7.286	79.721	1.020	7.286	79.721
6	0.760	5.429	85.151			
7	0.681	4.864	90.015			
8	0.588	4.199	94.214			
9	0.300	2.141	96.356			
10	0.269	1.920	98.276			
11	0.128	0.911	99.187			
12	0.099	0.708	99.895			
13	0.015	0.105	100.000			
14	2.833E-16	2.023E-15	100.000			

Extraction Method: Principal Component Analysis.

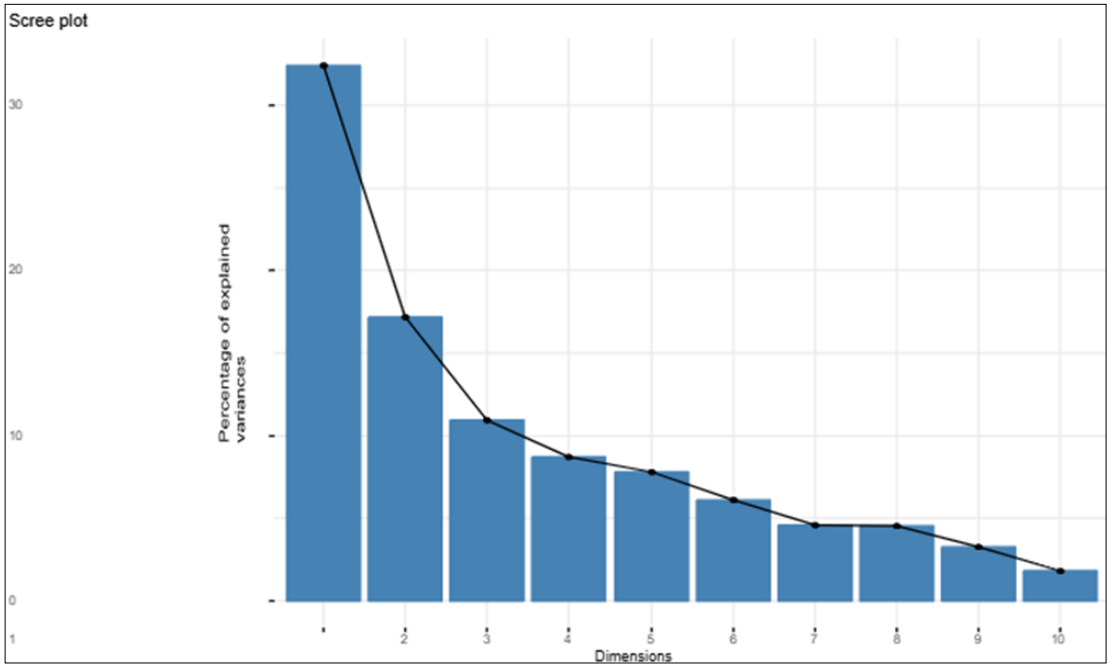

Fig. 3. Scree plot of Kishtwar district.

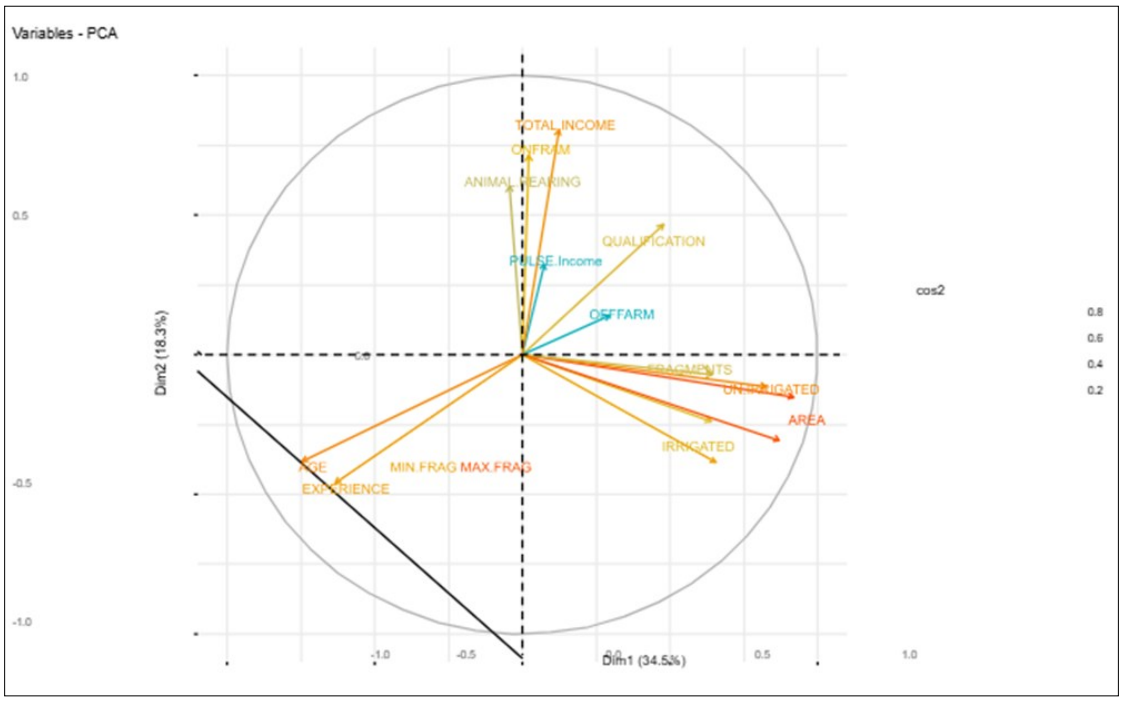

Fig. 4. Bi plot of Kishtwar district.

Table 6. Total variance explained of pulse crop cultivation in Kathua district

Total variance explained						
PC	**Initial eigenvalues**			**Extraction sums of squared loadings**		
	Total	**% of variance**	**Cumulative %**	**Total**	**% of variance**	**Cumulative %**
1	5.956	42.544	42.544	5.956	42.544	42.544
2	2.425	17.322	59.866	2.425	17.322	59.866
3	1.474	10.530	70.396	1.474	10.530	70.396
4	1.202	8.584	78.980	1.202	8.584	78.980
5	0.761	5.436	84.416			
6	0.615	4.396	88.812			
7	0.526	3.754	92.566			
8	0.397	2.834	95.399			
9	0.351	2.506	97.905			
10	0.179	1.278	99.183			
11	0.067	0.478	99.661			
12	0.048	0.339	100.000			
13	3.551E-16	2.537E-15	100.000			
14	2.699E-17	1.928E-16	100.000			

Extraction Method: Principal Component Analysis.

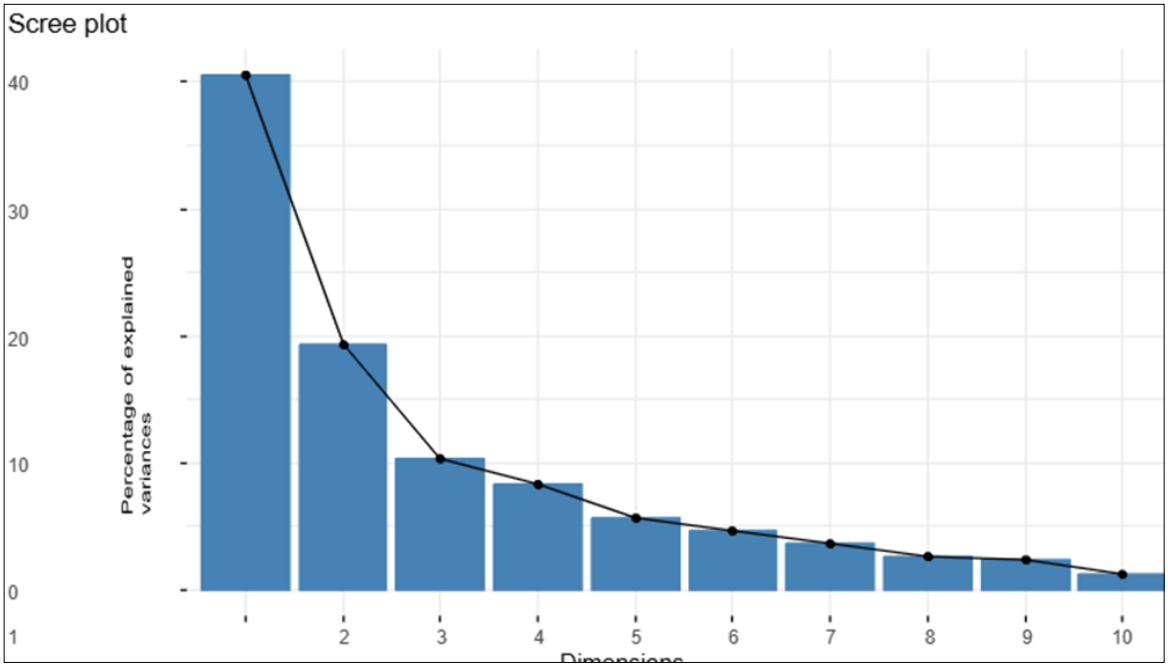

Fig. 5. Scree plot of Kathua district.

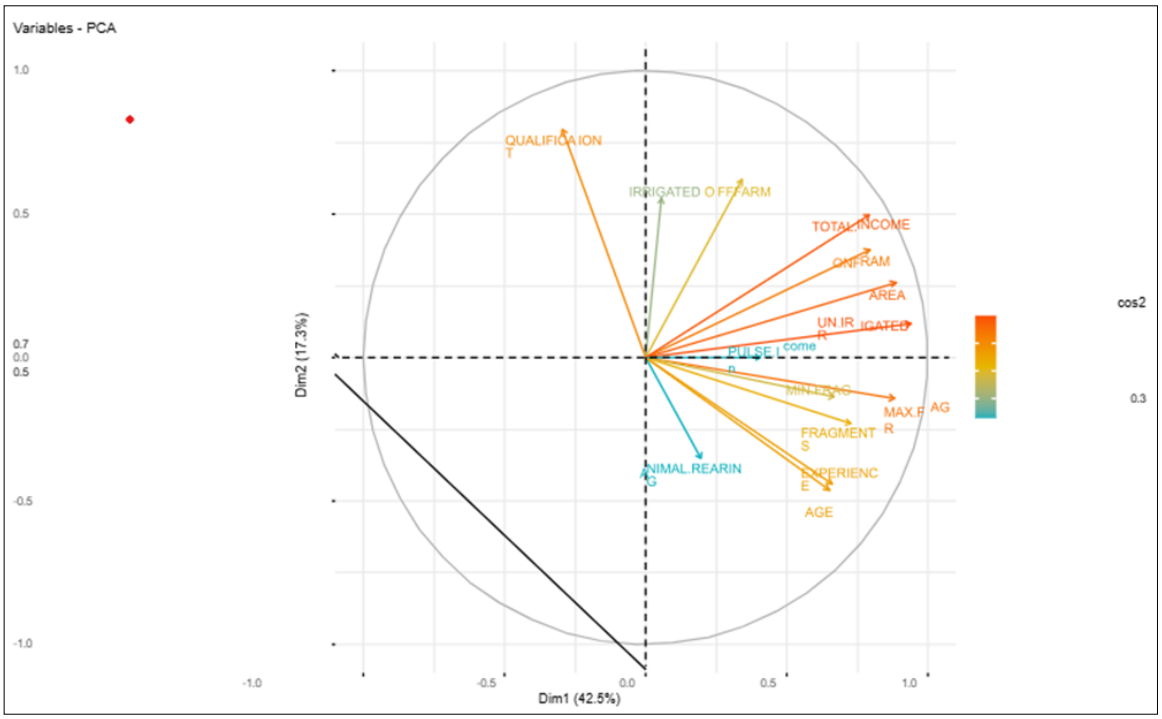

Fig. 6. Bi plot of Kathua district.

Table 7. Total variance explained of pulse crop cultivation in Udhampur district

Total variance explained						
PC	**Initial eigenvalues**			**Extraction sums of squared loadings**		
	Total	**% of variance**	**Cumulative %**	**Total**	**% of variance**	**Cumulative %**
1	5.879	41.991	41.991	5.879	41.991	41.991
2	2.535	18.106	60.097	2.535	18.106	60.097
3	1.662	11.869	71.966	1.662	11.869	71.966
4	1.202	8.584	80.550	1.202	8.584	80.550
5	0.838	5.983	86.533			
6	0.632	4.514	91.047			
7	0.486	3.472	94.519			
8	0.339	2.424	96.943			
9	0.257	1.834	98.777			
10	0.104	0.744	99.521			
11	0.040	0.287	99.808			
12	0.027	0.192	100.000			
13	1.904E-15	1.360E-14	100.000			
14	-5.849E-16	-4.178E-15	100.000			

Extraction Method: Principal Component Analysis.

Table 8. Component Matrix of pulse crop cultivation in Doda, Kathua, Kishtwar and Udhampur districts

Variable	Age	Qualification	Animal rearing	Area	Irrigated land	Unirrigated land	Fragmentation	Max-fragmentation	Min-fragmentation	Farming experience	On-farm income	Off-farm income	Pulse income	Total income
Doda														
C1	-0.724	0.404	-0.22	0.918	0.522	0.816	0.53	0.793	0.429	-0.717	0.324	0.241	0.269	0.391
C2	0.06	0.117	0.261	-0.172	0.176	-0.251	-0.063	-0.258	-0.124	0.044	0.819	0.515	-0.232	0.87
C3	0.327	-0.682	-0.324	0.13	-0.378	0.298	-0.422	0.384	0.694	0.351	0.224	0.095	-0.119	0.218
C4	0.274	-0.027	-0.666	0.07	0.524	-0.057	0.182	-0.152	-0.037	0.249	-0.25	0.445	0.147	-0.069
C5	0.187	0.308	0.23	0.228	-0.239	0.355	-0.018	0.218	-0.265	0.232	0.038	-0.206	-0.238	-0.054
Kathua														
C1	0.639	-0.245	0.188	0.896	0.08	0.943	0.707	0.866	0.647	0.647	0.812	0.41	0.41	0.831
C2	-0.425	0.785	-0.28	0.163	0.485	0.032	-0.327	-0.248	-0.253	-0.419	0.28	0.724	-0.037	0.456
C3	0.486	-0.138	0.655	-0.004	0.085	-0.029	-0.414	-0.339	-0.445	0.505	-0.051	0.199	-0.115	0.009
C4	-0.146	-0.033	0.253	0.33	0.729	0.141	-0.009	0.011	0.099	-0.095	0.11	-0.276	-0.541	-0.14
Kishtwar														
C1	-0.747	0.493	-0.049	0.92	0.636	0.83	0.642	0.871	0.648	-0.627	0.01	0.292	0.066	0.109
C2	-0.381	0.43	0.598	-0.142	-0.223	-0.112	-0.064	-0.293	-0.358	-0.466	0.73	0.147	0.333	0.824
C3	0.264	-0.6	-0.135	0.055	0.232	-0.005	0.157	0.136	0.414	0.225	0.473	0.06	-0.059	0.444
C4	0.136	-0.19	0.164	0.185	-0.258	0.29	-0.347	0.019	-0.009	0.036	-0.369	0.679	0.529	-0.005
C5	0.267	0.087	-0.184	0.137	-0.193	0.253	0.038	0.01	-0.188	0.315	0.287	0.463	-0.471	0.26
Udhampur														
C1	0.687	-0.401	0.191	0.893	0.029	0.947	0.699	0.865	0.761	0.656	0.822	0.377	-0.065	0.704
C2	-0.32	0.653	0.043	0.233	0.504	0.103	-0.411	-0.322	-0.365	-0.279	0.242	0.811	0.284	0.601
C3	0.543	-0.263	0.731	-0.138	-0.119	-0.113	-0.382	-0.291	-0.389	0.593	-0.045	0.06	0.13	0.036
C4	0.04	-0.03	-0.297	-0.229	-0.618	-0.066	0.03	0.035	0.033	-0.004	0.059	0.044	0.766	0.301

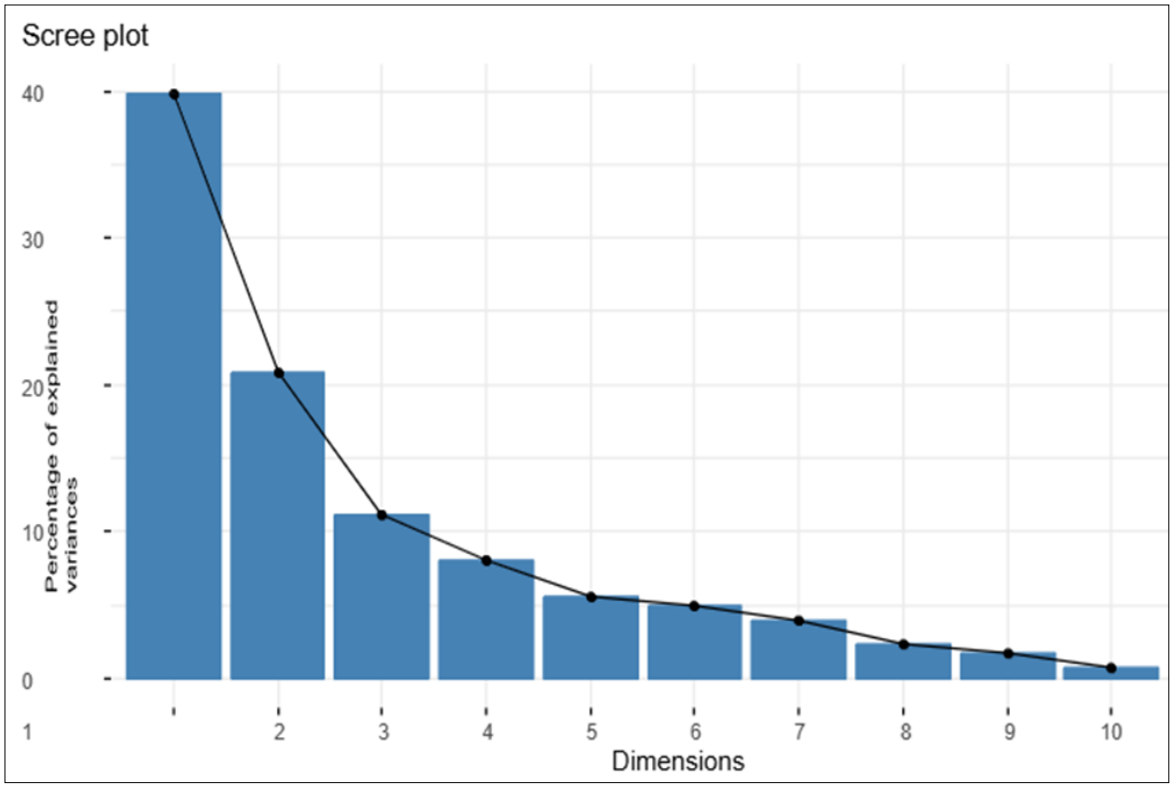

Fig. 7. Scree plot of Udhampur district.

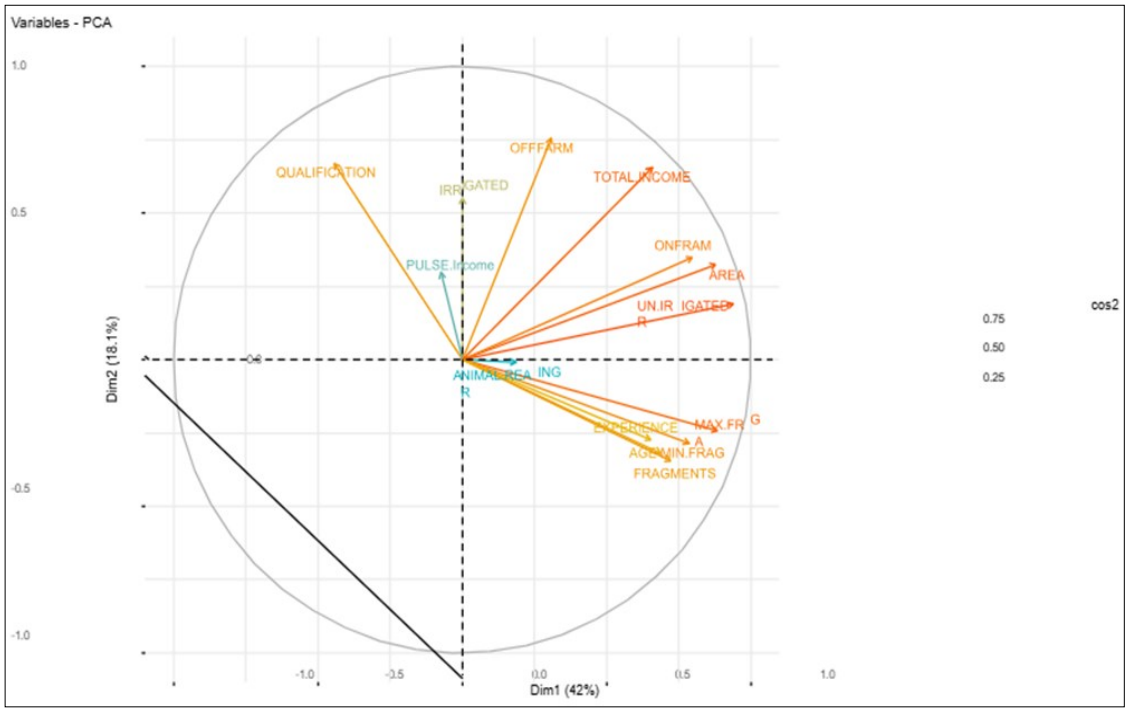

Fig. 8. Bi plot of Udhampur district.

Conclusion

Pulses are a crucial component of Indias' food and nutrition security, providing the primary source of protein for nearly half of the vegetarian population. In J&K, pulses are grown semi-organically across diverse terrains, contributing to sustainable agriculture and supporting farmer livelihoods. The results revealed the land-related factors (unirrigated land, area and fragmentation) consistently dominated the first component, while income (on-farm and off-farm) and demographic factors (age, experience and education) shaped the remaining components. These findings highlight the multidimensional influences on pulse productivity. Land development policies should prioritize irrigation expansion and consolidation of fragmented holdings. Income diversification through livestock and off-farm employment must be supported. Skill-building and education programs tailored for young and semi-skilled farmers would further enhance productivity. Promoting organic pulse farming in the naturally low-input regions of J&K could open new market opportunities and enhance sustainability. Therefore, a holistic, region-specific strategy integrating land use reform, income diversification, organic practices and skill development is essential to boost pulse production and ensure rural resilience in the region.

Supplementary Material

Percentage

Simple comparisons were made on the basis of percentage.

Sampling technique

In the current study, a multistage random sampling strategy is implemented to collect data through in-person interviews.

Arithmetic Mean

The arithmetic mean is determined by dividing the aggregate of all observed values by the total number of observations.

$X = \Sigma fX / n$

Where,

X = Arithmetic mean

$\Sigma X = X_1 + X_2 + X_3 + \ldots + X_n$

f = Frequency in each class

n = Total number of observations

Standard deviation

It is denoted by σ, quantifies the dispersion of a dataset relative to its mean and is calculated as the square root of the variance.

$$\sigma = \sqrt{\left\{\left\{\sum_{i=1}^{n}\left(x_i - \{\underline{x}\}\right)^2\right\}/\{n - 1\}\right\}}$$

Where,

σ = Represents the standard deviation, a measure of data dispersion relative to the mean.

∑(Sigma) = Summation symbol, indicating the sum of all terms in the series.

x_i= Represents each individual observation or data point in the dataset.

$\bar{x}$ = Denotes the arithmetic mean of the data (average value).

n = Represents the total number of observations in the dataset.

n - 1 = Denotes the degrees of freedom, used in the denominator for sample standard deviation to adjust for bias.

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Authors' contributions

GS conceptualized the topic, designed of methodology required for the data collection and reviewed the manuscript. PRB wrote the original draft, manuscript, reviewed and edited the manuscript. SO also wrote the original draft, wrote the manuscript, reviewed and edited the manuscript. LKS modified the design of the methodology required for the data collection and formal analysis of the data. All authors read and approved the final manuscript.

Compliance with ethical standards

Conflict of interest: Authors do not have any conflict of interest to declare.

Ethical issues: None

Declaration: The authors confirm that they obtained prior informed consent from all the participants before collecting data for the current research study.

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