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Research Paper

Sustainable agriculture: exploring resource use efficiency across different farm size

Gali Krishna Chaithanya[1*], Omar Fayaz Khan[2] and Bhagya Laxmi Sahu[3]

[1]*Division of Agricultural Economics; Faculty of Horticulture,* [2]*Division of Extension Education, Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir, Shalimar, Srinagar-190 025 Jammu and Kashmir (India); College of Agriculture, OUAT, Bhubaneswar*
[*]e-mail: *krishnachaithanya7680@gmail.com*

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ABSTRACT

The present study was conducted on resource use efficiency on different sizes of farms. The study was carried out in the district Anantnag of Jammu and Kashmir during the year 2023-24. In the Study area, six key crops-Rice, Maize, Apple, Walnut, Garlic and Chili were chosen randomly for evaluating resource use efficiency, as they represent a significant portion of regions agricultural output, providing valuable insights in optimizing inputs and enhancing productivity in diverse cropping systems. Accordingly, the data were elicited from 150 farmers from 3 blocks and 2 villages. From each village 25 respondents were selected. Efficiency of the input use has been worked out with the help of Cobb Douglas production function. The resource use efficiency analysis of apple indicated that the variable inputs such as manure and labour were under utilization. In walnut, the inputs manure and fertilizer were overused and labour was underutilized. In garlic, labour and fertilizer inputs were overused and seed, manure, fertilizers, and labour used in the cultivation of rice were found to be underutilized. In maize, all of the resources were overused except manure and in chilli, the variables seeds, fertilizers, and pesticides were found to be greater than 1, indicating that there is scope to increase the level of these inputs in the production of chilli crops.

Key words: Agriculture, cobb-douglas production, efficiency, input use.

Kashmir's crops are extremely important due to their distinct quality, cultural significance, and economic value. Kashmir known for its fertile soil and favourable climatic conditions, the region produces premium crops such as apples, walnuts, almonds, and paddy etc., Fruits such as apples from Kashmir dominate the Indian fruit market, while walnuts are sought after for their taste and health benefits. These crops not only support the livelihood of thousands of farmers, but also play an important role in preserving the agrarian heritage and boosting the region's economy. The region's agricultural and economic identity is anchored on Kashmir's crops, which make a substantial contribution to both local livelihoods and national markets. Kashmiri apples and walnuts are highly valued for their exceptional quality, meeting both local and foreign demand. Rice, a main crop in the area, is produced through paddy cultivation, which is essential to the local diet. These crops establish Kashmir as an important agricultural club by supporting local communities and gaining international recognition for their outstanding quality.

Crops grown in Kashmir, such as maize, apples, walnuts, garlic, and chilies, are essential to the region's food security and agricultural economy. Another main grain that supports rural livelihoods and livestock rearing is maize. Kashmir is famous for its apples, which rule the Indian fruit markets and provide a substantial contribution to exports with a wide variety and international recognition. Due to their exceptional flavour and nutritional content, walnuts are in great demand both domestically and abroad. While Kashmiri chillies are treasured for their vivid colour and mild heat, which enhances culinary appeal, garlic is valued for its flavour and medicinal qualities. Together, these crops support livelihoods, increase exports, and showcase the unique agricultural heritage of the area. Agriculture is a critical sector that supports global food security, livelihoods, and economic development. However, the growing pressures of population growth, climate change and resource scarcity have heightened the need for efficient use of resources in farming systems. Resource use efficiency, which refers to the optimal utilization of inputs such as land, water, labour, and capital to maximize outputs, has emerged as a key metric for sustainable agricultural practices. Farm size is an important determinant of resource use efficiency, as it influences production methods, access to technology, and economies of scale. Smallholder farms often rely on traditional practices and limited resources, whereas larger farms are better positioned to adopt advanced technologies and benefit from mechanization. However, the efficiency of resource use varies widely across different farm sizes and depends on contextual factors such as access to markets, credit and extension services. The study aims to explore the relationship between farm size and resource use efficiency. By investigating how farms of different sizes manage resources and identifying the drivers of efficiency, the study seeks to offer insights into strategies for enhancing agricultural productivity and sustainability. The findings will contribute to policy formulation and the development of targeted interventions that support efficient resource use in diverse farming contexts.

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MATERIALS AND METHODS

The study was conducted in the district of Anantnag in Jammu and Kashmir (UT) which was purposely selected, as there are few studies of this kind conducted in Jammu and Kashmir. The district Anantnag comprises 17 community development blocks out of which 3 blocks namely Bijbehara, Dachnipora and Pahalgam were selected. Further 2 villages from each selected block were selected randomly making a total 6 selected villages. From each village, 25 Farmers were selected by Probability Proportional to Size (PPS) method. Keeping in view the certain objectives, a structured and comprehensive survey schedule was developed in consultation with experts/scientists from Agricultural Economics from the Faculty of Horticulture, SKUAST-K Shalimar.

To evaluate resource use efficiency on different sizes of farms in the study area: The land use pattern, cropping pattern, input use pattern and productivities of the crops were examined to analyse the extent of natural and human resources use in the study area. The resource use efficiency in crop production was estimated with the help of Cobb-Douglas production function.
The Cobb-Douglas production function is described as below:

Where,

Y = Output (Quintals/Ha.)
a = Intercept
X_1 = Labour (Man-days)
X_2= Manure(quintal)
X_3= Seed (Kg or grams or quintals)
X_4 = Pesticide Use (Rs)
X_5 = Fertilizer use (Kg or quintal)
$b_1, b_2, b_3, b_4, b_5, b_6$ & b_n area regression coefficients.

For estimation of the above-mentioned model, it is converted into linear form by taking log on both sides. The double log linear form of the model may be written as:

$$\text{Log } Y = a+b_1\log X_1+b_2\log X_2+b_3\log X_3+b_4\log 1\ X_4+b_5\log X_5+ b_6\log X_6$$

As stated below, the marginal productivities of several inputs were calculated in order to determine their efficiency:

And then was compared with the following conclusions:

If, there is under use of the i^{th} input in the production process,
If, there is over use of the i^{th} input in the production process and
If, there is optimal use of the i^{th} input in the production process.
The optimal level of the input use can be calculated by following equation:
Or,

The marginal value products (MVP) and their corresponding marginal factor costs were estimated using the regression coefficients of the relevant independent variables (MFC). The following equation was used to calculate the resource efficiency using the MVP to MFC ratio. (Rahman and Lawal 2003).

$$r = MVP/MFC$$

here, r = Efficiency ratio (ratio of the MVP of an input and unit price of the input)
MVP = Marginal value product of a variable input.
MFC = Marginal factor cost (price per unit input)

The marginal productivity of a resource depicts the increase to gross returns in value terms caused by an increasing one unit of that resource, when other inputs are held constant. The marginal physical product (MPP) was multiplied by the product price per unit to produce the MVP. The resources (Xi) and gross return (Y) are evaluated using their geometric mean to obtain the most accurate and practical estimation of MVP (Dhawan and Bansal 1977). The MVPs, which are determined by multiplying the production coefficient of the available resources by the ratio of the gross return's geometric mean (GM) to the GM of the available resources, that is,

$$\ln Y = \ln a + bi \ln Xi$$

Therefore,

$$dY/dXi = bi\ [Y/Xi]$$

or,

$$MVP\ (Xi) = bi\ [Y(GM)/\ Xi\ (GM)]$$

here,

$Y(GM)$ = Geometric mean value of gross return.
$Xi\ (GM)$ = Geometric mean value of the ith variable input.

According to the conventional neo-classical test of economic efficiency, a production input is being used efficiently if the ratio of the MVP of an input and the unit price of the input equals unity. Thus,

If $r < 1$, it means the resource in question was over utilized hence decreasing the quantity used of that resource increases profit.
If $r > 1$, it shows that the resource was being under-utilized and increasing the quantity of use will raise profit level.
If $r = 1$ it means resource was being efficiently utilized.

The relative percentage change in MVP of each resource required so as to obtain optimal resource allocation that is,

$r = 1$ or MVP = MFC, was estimated using the following equation:

$$D = (1 - MFC/MVP) \times 100 = (1 - r - 1) \times 100$$

here, D = Absolute value of percentage change in MVP of each resource (Mijindadi 1980).

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RESULTS AND DISCUSSION

Estimation of resource use efficiency in garlic using Cobb-Douglas production function: The resource use efficiency analysis revealed that labour and fertilizer inputs were overused in the production of garlic and that their quantity needed to be reduced for the optimum allocation (Table 1). Additionally, it was discovered that seed and use of manure was being underutilized; as a result, its quantity must be increased by at least 27.11 and 96.68 per cent respectively for optimal distribution. This could be a result of farmers in the research area receiving insufficient extension services and training opportunities. Therefore, it would be highly advised to provide the farmers with relevant technical information, as well as opportunities for interaction and exposure, in order to get the best price for their resources, so enhancing their produce and profit from garlic. For fertilizers and labour utilized for the production of garlic, the MVP (Marginal Value Product) to MFC (Marginal Factor Cost) ratio was less than one. This showed that the resources were not being utilized for maximum economic gain. To ensure optimal utilization, the marginal value products of all the resources need to be adjusted. Participation in social organizations may promote knowledge and experience and increase negotiating power of farmers when buying inputs and selling their produce. Since there was little evidence of participation in social groups and training sessions, the extension services were poor in the study area. In comparison to the overall area of land owned by households, the land allotted for the cultivation of garlic was quite little. It is a result of the topography's complexity and farmers' lack of knowledge and skills. This result is consistent with earlier research (Ahmed *et al.,* 2011), which found that seed is being used excessively. On the other hand, organic manure and labour were underutilized.

Table 1: Estimation of resource use efficiency in garlic using Cobb-Douglas production function

Inputs	Coefficient	MPP	MVP	MFC	r	D	Remark
Seed(qtl)	0.31	4.57	8231.22	6000.00	1.37	27.11	Underutilized
Manure(qtl)	0.09	4.18	7529.37	250.00	30.12	96.68	Underutilized
Fertilizer(qtl)	0.06	1.00	1794.99	3000.00	0.60	-67.13	Overutilized
Labour	0.36	0.10	188.32	500.00	0.38	-165.50	Overutilized

Estimation of resource use efficiency in chilli using Cobb-Douglas production function: From Table 2, The M.V.P to M.F.C ratio for the variables seeds, fertilizers, and pesticides were found to be greater than 1, indicating that there is scope to increase the level of these inputs in the production of chilli crops, while the variables manure and labour were found to be less than optimal, indicating overuse of these inputs. According to Table 2 modification of the MVPs for optimal resource use, a reduction in manure and labour of more than 104 per cent and 467 per cent, respectively, was necessary for optimal resource allocation.

Table 2: Estimation of resource use efficiency in chilli using Cobb-Douglas production function

Inputs	Coefficient	MPP	MVP	MFC	r	D	Remark
Seed(kgs)	0.65	2.23	8909.53	60	148.49	99.33	Underutilized
Manure(qtl)	-0.06	-1.38	-5535.12	250	-22.14	104.52	Overutilized
Fertilizer(qtl)	0.15	1.18	4728.66	3000	1.58	36.56	Underutilized
Pesticide(Rs)	0.15	0.00	4.84	1	4.84	79.34	Underutilized
Labour	-0.21	-0.03	-136.19	500	-0.27	467.13	Overutilized

The amount of seed, insecticide, and fertilizers needed to produce chilies at their best levels was underutilized, requiring an increase of nearly 99 per cent, 79 per cent, and 36 per cent, respectively. Training programmes for chilli producers should be conducted by agriculture extension agencies so

that inputs can be used more effectively to lower costs and increase profits per unit of area and per unit of input use. Jagtap *et al., (*2014) reported similar findings.

Estimation of resource use efficiency in maize using Cobb-Douglas production function: When evaluating resource use efficiency, we consider four factors: labour, fertilizer, manure, and seed. The estimated MVP of several resources for maize is listed in Table 3. With the exception of manure, all of the resources were overused because their efficiency ratios were less than 1. In other words, the sample farmers overused their inputs. Manure was underutilized, therefore for optimal distribution, its quantity needs to grow by at least 98 per cent. Seed, fertilizer, and labour were overused; to produce maize at their best levels, they needed to be decreased by 101 per cent, 112 per cent and 152 per cent, respectively. The farmers used more seed because they didn't want to face the extra burden of sowing it again and to reduce the chance of germination. The labor used for maize seed production in large scale because maintaining a farm in a smaller area is easier, farmers have been seen to take better care of their small farms. This result is consistent with earlier research (Gani and Omonona, 2009) which found that the ratio of MVP to MFC shows resulting ratios to be greater than unity for seeds, labour, fertilizer and farmland indicating that such inputs were underutilized.

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Table 3: Estimation of resource use efficiency in maize using Cobb-Douglas production function

Inputs	Coefficient	MPP	MVP	MFC	r	D	Remark
Seed(kgs)	-1.35	-1.12	-2010.30	25	-80.41	101.24	Overutilized
Manure(qtl)	3.26	11.85	21334.18	250	85.34	98.83	Underutilized
Fertilizer(qtl)	-0.54	-13.65	-24564.77	3000	-8.19	112.21	Overutilized
Labour	1.06	0.11	197.92	500	0.40	-152.62	Overutilized

Estimation of resource use efficiency in walnut using Cobb-Douglas production function: The resource use efficiency analysis revealed that the inputs Manure and fertilizer were overused in the production of walnut, their quantity needed to be reduced for the optimum allocation (Table 4). Use of labour was underutilized; as a result, its quantity must be increased by at least 72.85 per cent for optimal distribution. The MVP (Marginal Value Product) to MFC (Marginal Factor Cost) ratio was less than one in manure and fertilizer. This showed that the resources were not being utilized for maximum economic gain. The manure and fertilizer required approximately 4 per cent and 156 per cent reduction, respectively of these inputs for optimal walnut production. The land allotted for the cultivation of walnut was very little when compared to the total area of land possessed by households because of its dense canopy. Laborers were underutilized because of demanding huge money which was their right as they climb such giant trees at the cost of their lives.

Table 4: Estimation of resource use efficiency in walnut using Cobb-Douglas production function

Inputs	Coefficient	MPP	MVP	MFC	r	D	Remark
Manure (qtl)	0.05	0.01	239.56	250	0.96	-4.36	Overutilized
Fertilizer(qtl)	-0.11	-0.30	-5300.96	3000	-1.77	156.59	Overutilized
Labour	0.49	0.11	1841.82	500	3.68	72.85	Underutilized

Estimation of resource use efficiency in rice using Cobb-Douglas production function: Using the MVP/MFC ratio, the allocative efficiency of the input variables was computed. In profit maximization and efficient resource use, one must use more and more inputs as long as the value of additional output is more than the resources producing it. Table 5 illustrates the MVP-MFC ratio for the variables utilized in the Rice production. The MVP and MFC ratios of the seed, manure, fertilizers, and labour used in the cultivation of rice were found to be 2.68, 1.15, 1.28, and 1.32, respectively and are, thus, underutilized. Contrastingly, it was found that the allocative efficiency

for pesticide use was less than one, indicating that rice growers were using them excessively. The underutilization of the labours in the research area may be because most people prefer non-agricultural activities because they provide greater prospects and involve lesser risk than agriculture. The ratio of MVP and MFC of pesticides used in the rice production was found to be 0.21 and are, thus, underutilized. The farmer needs to reduce the pesticide use by 385 per cent for optimal rice production. Our results corroborate with the findings of Lone *et al.,* (2012). The farmers would need to increase the seed, manure, fertilizer and labour inputs by 62 per cent,13 per cent, 21 per cent and 24 per cent to ensure that the resource is adjusted to unity.

Table 5: Estimation of resource use efficiency in Rice using Cobb-Douglas production function

Inputs	Coefficient	MPP	MVP	MFC	r	D	Remark
Seed(kgs)	0.10	0.05	161.05	60	2.68	62.75	Underutilized
Manure(qtl)	0.19	0.10	288.08	250	1.15	13.22	Underutilized
Fertilizer(qtl)	0.37	1.28	3838.94	3000	1.28	21.85	Underutilized
Pesticide (Rs)	0.02	0.00	0.21	1	0.21	-385.38	Overutilized
Labour	1.02	0.22	661.51	500	1.32	24.42	Underutilized

Estimation of resource use efficiency in apple using Cobb-Douglas production function: From Table 6, The M.V.P to M.F.C ratio for the variables manure and labour were found to be greater than 1, indicating that these variables are underutilization and there is a scope to increase the level of these inputs in the production of apple by 99 per cent and 87 per cent to get the optimal production. The variables fertilizer, insecticide and fungicide were found to be less than optimal, indicating overuse of these inputs. According to Table 6, modification of the MVPs for optimal resource use, a reduction in fertilizer, insecticide and fungicide of more than 122 per cent, 105 per cent and 312 per cent, respectively, was necessary for optimal resource allocation. The over utilization of the Insecticides and pesticides by the farmers was to reduce loss due to pest attacks and diseases, the fruit growers use almost every type of pesticides. This finding is in line with earlier research (Ali *et al.,* 2019).

Table 6: Estimation of resource use efficiency in apple using Cobb-Douglas production function

Inputs	Coefficient	MPP	MVP	MFC	r	D	Remark
Manure (qtl)	0.08	6.33	25308.47	250	101.23	99.01	Underutilized
Fertilizer(qtl)	-0.13	-3.39	-13553.61	3000	-4.52	122.13	Overutilized
Insecticides (Rs)	-0.14	0.00	-17.29	1	-17.29	105.79	Overutilized
Fungicides (Rs)	0.01	0.00	0.24	1	0.24	-312.22	Overutilized
Labour	0.37	1.00	3992.43	500	7.98	87.48	Underutilized

CONCLUSION

The study showed the natural and human resource use pattern in agriculture using different crops grown in the region and resource use efficiency of the inputs used in different crops. The Efficiency of the input use has been worked out with the help of Cobb Douglas production function in which the existing input use, recommended input use in the different crops and the optimal input use have been worked out to compare the trade-offs between the level of input use. The resource use efficiency analysis of apple indicated that the variables manure and labour were under utilization. The variables fertilizer, insecticide and fungicide were found to be less than optimal, indicating overuse of these inputs. In walnut, the inputs manure and fertilizer were overused and labour was underutilized. In garlic, labour and fertilizer inputs were overused and that their

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quantity needed to be reduced for the optimum allocation in the production of garlic. The seed, manure, fertilizers, and labour used in the cultivation of rice were found to be underutilized. In maize, all of the resources were overused except manure. In chilli, the variables seeds, fertilizers, and pesticides were found to be greater than 1, indicating that there is scope to increase the level of these inputs in the production of chilli crops, while the variables manure and labour were found to be less than optimal, indicating overuse of these inputs.

CONFLICT OF INTEREST

All the authors affirm that there is no conflict of interest among them. All research activities comply with relevant legal, institutional and ethical standards.

AUTHOR CONTRIBUTION

All the authors contributed equally in this review article.

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