Economic Impression of On-Farm Research for Sustainable Crop Production, Milk Yield, and Livelihood Options in Semi-Arid Regions of Central India

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Recommended Citation
Kumar, Sunil; Sharma, Purushottam; Govindasamy, Prabhu; Singh, Maharaj; Kumar, Sant; Halli, Hanamant M.; Bhaskar Choudhary, Bishwa; and Bagavathiannan, Muthukumar, "Economic Impression of On-Farm Research for Sustainable Crop Production, Milk Yield, and Livelihood Options in Semi-Arid Regions of Central India" (2022). College of Nursing Faculty Research and Publications. 951.
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Economic impression of on-farm research for sustainable crop production, milk yield, and livelihood options in semi-arid regions of central India

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Assigned to Associate Editor Terry Griffin.

Abstract
Farming system research (FSR) is on-farm research that brings cutting-edge agricultural technologies to growers to enhance farm production, family income, and livelihood status. In 2007, an on-farm study was started on FSR in central India, and the effect was assessed after 5 yr (2012–2013) of implementation by comparing adopters and nonadopters of FSR-based promoted technologies. Further, in 2018–2019, the status of adoption of introduced technologies was also assessed. The study revealed that improved practices such as pre-sowing irrigation, high-yielding varieties, and crop protection measures collectively improved the system productivity of the adopters by 28%; the improved productivity was mainly due to increased yield of blackgram (Vigna mungo L. 157%), groundnut (Arachis hypogaea L., 34%), and wheat (Triticum aestivum L., 12%). Adoption of ration balancing and healthcare practices promoted under the FSR project accentuated the milk yield of farm animals (200 L yr⁻¹ cattle⁻¹) of adopters. The farm diversification and sustainable production practices under the FSR-based interventions increased family income of adopters by 35% (US$1,517.7 yr⁻¹) and employment by 42%. Adopter households averaged a 33.76% higher return per unit of investment than nonadopters. The estimated change is primarily due to the non-neutral technological change. The findings of the study

Abbreviations: FSR, farming system research; FYM, farmyard manure; VIF, variance inflation factor.
1 INTRODUCTION

Farming is a principal livelihood source of the majority of the Indian population. The recent population census 2011 indicated that about 118.7 million (54.6%) workforce of India is engaged in farming, which is 3.6% less than the previous 2001 population census (GOI, 2011), whereas the population of farm laborers has increased by 35% in 2011 compared with 2001 (Sood, 2013). The possible reasons for shifting population from farming to farm laborer could be the low return from agriculture, unregular employment, and other opportunities to work as a daily laborer, land occupation from other sectors, and lack of adoption of new technologies (Sood, 2013). The dissemination of technologies in developed countries such as the United States, Australia, and European countries has more successful than in developing countries like India due to education and acceptance level of growers, dissemination of information, financial mechanisms, government policy support, infrastructure, and training and qualification (Ejiaku, 2014; Nagy & Sanders, 1990).

Farming system research (FSR) is an effective tool in agriculture, wherein active participation of growers is guaranteed through participatory research carried out at the grower’s field by an interdisciplinarily team of agricultural researchers. Further, the FSR technique is a bottom-up approach (i.e., it requires farmer participation) for more efficient transfer of improved agricultural technologies (Prabuddha & Sarthak, 2008; Zafarullah, 2003). Schiere et al. (2000) reported that the FSR technique reduces the gap between laboratory research and field application; further, the authors referred to FSR as a kind of laboratory dedicated to technology dissemination. Farming system research can help in solving the complex socio-technical problems that arise in common property resource management and can help growers and agencies work together (Bottrall & John, 1992; Kanwar et al., 1992). Alesso et al. (2019) and Panten et al. (2010) reported that on-farm experimentation has played an immense role in technology dissemination, such as genotype selection and site-specific nutrient management. Women are an integral part of Indian agriculture, with about 43% of women helping with daily farming work (Patil & Babus, 2018). Strengthening the integration of women into agriculture is also an aspect of FSR (S. Chakraborty et al., 1991).

The FSR is referred in various terms, such as “participatory research” and “client-oriented agricultural research” (Dorward et al., 2007; Gill et al., 2009). This technology dissemination method has been used for preventing soil erosion, enhancing the profit from farming, and confronting climate change across the globe (Gill et al., 2009; Mandal et al., 2010). On-farm research conducted in Cambodia by Dalgliesh et al. (2016) reported that the introduction of modern rice (Oryza sativa L.) varieties (short-duration, direct-seeded) has increased rice yield by 30% compared with farmer practice through participatory research. Lacoste et al. (2022) stated that on-farm research can transform global agriculture through effective transfer of knowledge and foster open innovation. Likewise, Mandal et al. (2010) reported that dissemination of improved agricultural practices through FSR has shown a positive (75% increase in net return) effect under progressive farming (abundance of fixed and operational capital and rice growing is not an essential activity) compared with semi-progressive farming (no restriction in capital and rice growing is an essential activity) in the north-eastern region where shifting cultivation is a common farming practice. Farming system research distributes the responsibility between the farmers and research organizations and helps in improving system productivity and economic returns. In FSR, integration of enterprises helps to improve system net returns through employment generation, particularly for women and youths, over traditional farming practices. Thus, FSR provides a means to employ more family laborers year-round and creates an opportunity for improved livelihoods mainly due to improved economics and employment (Kumar et al., 2012). Likewise, Paris et al. (2008) found that participatory varietal selection (rice) research has helped women’s participation in varietal selection and in adopting modern techniques in rice production in eastern Uttar Pradesh, India.

There are numerous FSR projects that have been implemented by different organizations in tropical and subtropical regions of India. However, very limited FSR studies have been attempted for assessing the effect of FSR in semi-arid regions, particularly in central India. This region is a typical example of a semi-arid region, and agricultural production is highly affected by chronic drought. Further, unsustainable water management, combined with climate change and indiscriminate livestock grazing activities, has made water scarcity more critical in this region. Therefore, a study was conducted to assess the long-term effect of the FSR project through the introduction of improved technologies, crop diversification, and livestock care on the crop yield, overall income, and livelihood status of beneficiaries of central India.
2  |  MATERIALS AND METHODS

2.1  |  Study location

This study was conducted in the Tikamgarh district (24°44′44.21″ N, 78°49′55.48″ E, 363 m asl) of the Indian state of Madhya Pradesh (Figure 1). Most of the population in the district is dependent on crop/livestock-based activities. The district receives an average annual rainfall of 1,057 mm. The kharif season (July–September) has around 90% of the annual precipitation, and the remaining 10% is distributed throughout the remaining 9 mo (GOI, 2015). The prevalent erratic rainfall distribution causes early-season drought or terminal drought, leading to frequent crop failures. Around 39% of the area of the district is under cultivation (Mppki, 2015), and 44.4% of the total cultivated area is under assured irrigation. Farmers mainly cultivate crops like wheat (*Triticum aestivum* L.), groundnut (*Arachis hypogaea* L.), and blackgram (*Vigna mungo* L.) (GOI, 2016). The district is also suitable for the cultivation of fruits and vegetables (GOI, 2016). In addition, the district’s livestock population is 0.49 million head of cattle, 0.18 million head of buffalo, 0.044 million head of sheep, 0.28 million head of goat, and 0.12 million head of poultry birds, with poor to medium productivity (GOI, 2016).

2.2  |  Project activities in the study area

A FSR project was started by ICAR-Indian Grassland and Fodder Research Institute, Jhansi, India, in four selected villages (Bagan, Ladpura, Maharajpura, and Radhapur) in 2007. The team of scientists, along with the local change agents, introduced improved farm technologies and practices (Table 1) in the selected villages, and the inhabitants of the villages were convinced to adopt the improved farming system approaches on their farm for realizing more benefits compared with the traditional farming practices.

2.3  |  Sampling and data collection

To assess the effect of the project activities, a survey was conducted during 2012–2013 in eight villages selected through multistage sampling methods and a combination of purposive sampling as well as random sampling techniques. At the

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**Core Ideas**

- Technology dissemination through farming system research has increased crop and milk yields among farmers.
- Farm and crop diversification has increased employment and income for farmers.
- Adopter households averaged a 33.76% higher return per unit of investment than nonadopters.
- The estimated change is primarily due to the non-neutral technological change.
TABLE 1  Technological inputs introduced under the farming system research project

<table>
<thead>
<tr>
<th>Sl. no.</th>
<th>Technology</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Crop varieties</td>
<td>Food grains: maize (JM-216 and SHS-72), blackgram (T-9 and PU-31), greengram (Vigna radiata (L.) R. Wilczek K-851), wheat (HI-1539 and WH-147), chickpea (Cicer arietinum L., KWR-108 and DPC-92-3). Fodders: single cut sorghum [Sorghum bicolor (L.) Moench, MP Chari]; multicut sorghum (SSG-855 and SSG-889), Egyptian clover (Trifolium alexandrinum L.Wardan and JHB-146)</td>
</tr>
<tr>
<td>2</td>
<td>Cultivation practices</td>
<td>Summer ploughing, seed treatment with fungicides and biofertilizers, soil test–based micronutrient application (ZnSO4 at 10–15 kg ha⁻¹), seed rate, line sowing, water management based on critical crop stages, integrated weed management practices, intercropping of cereal and legumes</td>
</tr>
<tr>
<td>3</td>
<td>Farm machinery</td>
<td>Seed drill, groundnut decorticator, maize sheller, power operated thresher cum grader</td>
</tr>
<tr>
<td>4</td>
<td>Livestock management</td>
<td>Improved livestock ration through cereal and legume mixture, feed blocks, and silage during the lean period; improved cattle breeds, vaccination, and de-worming to animals</td>
</tr>
</tbody>
</table>

outset, four villages (Bagan, Ladpura, Maharajpura, and Radhapur; hereafter “treated villages”) were purposively selected because all the project activities were focused within the physical boundary of these villages. Four contiguous villages within a radius of 5–6 km (Chakarpur, Lathesara, Rajpura, and Pathari) were identified as control villages; the villages had no project interventions but were similar to the treated villages within a radius of 5–6 km (Chakarpur, Lathesara, Rajpura, and Pathari). Four contiguous villages (Pathari) were identified as control villages; the villages had no project activities but were similar to the treated villages. The researchers collected information on the cultivated area, management practices, yield, postharvest handling of produce, livestock rearing, income, and livelihood patterns from 100 farm households in the treated villages and from 100 households from control villages. Household heads were stratified based on land size category in each village, and then probability proportional to size method was used to draw sample households from each village (Table 2). Finally, the respondent household heads were selected using a random sampling technique. Further, to collect information on the continuation of introduced technologies and practices among adopters, a survey was conducted in the treated villages in 2018–2019.

2.4 | Data analysis

The cultivated areas of major crops and milk production in both adopters and nonadopters were analyzed using the two-sample t test for the equal sample size. For the operational charges, the price of main products, by-products, and milk was used taking the base year 2012 (Table 3). Change in the livelihood options was also assessed using the frequency count and percentage of farmers adopting particular livelihood options before and after the study interventions. The decomposition model was run to sort out the contribution of technological interventions and resource use differences between the adopter and nonadopter groups. We computed the system wheat equivalent yield using an empirical framework. Pie charts were used to indicate the percent change in the cropping area after the introduction of the FSR project in the adopters and nonadopters categories. All the graphs were made using SigmaPlot (version 10; Systat Software, Inc.).

2.4.1 | System equivalent yield and productivity response

The three major crops in the studied villages were wheat, blackgram, and groundnut, comprising around 71.60% of the total cropped area. We computed the system wheat equivalent yield (SWEY) for each household using Equation 1.

\[
SWEY = Y_w + Y_{bg} \left( \frac{P_{bg}}{P_w} \right) + Y_g \left( \frac{P_g}{P_w} \right)
\]

where \(Y_w\), \(Y_{bg}\), and \(Y_g\) are yield (kg ha⁻¹) of wheat, blackgram, and groundnut, respectively, and \(P_w\), \(P_{bg}\), and \(P_g\) represent prices (Indian National Rupee kg⁻¹) of these three major crops, respectively.

The productivity is directly influenced by exogenous inputs like seeds (S), bullock labor (B), machine labor (M), human labor (H), fertilizer (F), agrochemicals (Ac), and farmyard manure (FYM) (P. Singh et al., 2021). We constructed the...
model for estimating productivity response function under the Cobb–Douglas framework (Equation 2).

\[ Y = A S^{a_1} B^{a_2} M^{a_3} H^{a_4} F^{a_5} A c^{a_6} F Y M^{a_7} e_i \] (2)

where \( Y \) is system wheat equivalent yield (kg ha\(^{-1}\)), \( A \) is scale parameter, and \( e_i \) is output elasticity of \( i \)th input (\( i = 1, 2, \ldots, 7 \)); \( e \) is a random term that is independently distributed with zero mean and constant variance).

### 2.4.2 Technology impact assessment

An empirical challenge in assessing the effect of agricultural technologies is to examine the outcome and its counterfactuals on the same farmer (i.e., what would have been the effect in absence of farmers being adopters) (Marasas et al., 2003; Sharma et al., 2021). Therefore, we estimated the equation separately for adopters (Equation 3), nonadopters (Equation 4), and the pooled (p) data (Equation 5) in its log-linear form as follows:

\[
\text{Ln } Y_{\text{adopter}} = \text{Ln } \alpha_0 + \alpha_1 \text{Ln } S_{ia} + \alpha_2 \text{Ln } B_{ia} + \alpha_3 \text{Ln } M_{ia} + \alpha_4 \text{Ln } H_{ia} + \alpha_5 \text{Ln } F_{ia} + \alpha_6 \text{Ln } A c_{ia} + \alpha_7 \text{Ln } F Y M_{ia} + \varepsilon_{ia}
\] (3)

\[
\text{Ln } Y_{na} = \text{Ln } \beta_0 + \beta_1 \text{Ln } S_{na} + \beta_2 \text{Ln } B_{na} + \beta_3 \text{Ln } M_{na} + \beta_4 \text{Ln } H_{na} + \beta_5 \text{Ln } F_{na} + \beta_6 \text{Ln } A c_{na} + \beta_7 \text{Ln } F Y M_{na} + u_{ina}
\] (4)

\[
\text{Ln } Y_{p} = \text{Ln } \gamma_0 + \gamma_1 \text{Ln } S_{ip} + \gamma_2 \text{Ln } B_{ip} + \gamma_3 \text{Ln } M_{ip} + \gamma_4 \text{Ln } H_{ip} + \gamma_5 \text{Ln } F_{ip} + \gamma_6 \text{Ln } A c_{ip} + \gamma_7 \text{Ln } F Y M_{ip} + \gamma_8 D + w_{ip}
\] (5)

where \( \alpha_0, \beta_0, \) and \( \gamma_0 \) are intercept terms; \( \alpha_j, \beta_j, \) and \( \gamma_j \) are output elasticities of \( j \)th inputs (as described in Equation 2); \( i \) is cross-sectional observations (1–60 for adopters, 1–61 for nonadopters, and 1–121 for pooled sample); and \( D \) is an intercept dummy that takes value zero for nonadopters (na) and one for adopter (a) households. The problem of multicollinearity among explanatory variables was checked by computing variance inflation factors (VIFs) using Equation 6.

\[ \text{VIF} = 1/1 - R^2_i \] (6)

where \( R^2 \) is the coefficient of determination obtained when the explanatory variable (\( X_i \)) is regressed against all other explanatory variables. Variability is said to be highly collinear if VIF of the variable exceeds 10 (Gujarati, 1995).

Chow’s test (Greene, 2000; Gujarati, 1995) was conducted to check the homogeneity between coefficients in regression Equations 3 and 4 (Equation 7).

\[
F = \frac{RSS_p - (RSS_a + RSS_{na})}{K} \frac{RSS_a + RSS_{na}}{N_a + N_{na} - 2K}
\] (7)

where \( RSS_p, RSS_a, \) and \( RSS_{na} \) indicate the sum of squared residuals from the pooled data and data from adopters and nonadopters group, respectively; \( N_a \) and \( N_{na} \) are sample sizes of adopters and nonadopters households, respectively; and \( K \) represents the number of parameters to be estimated. The null hypothesis that the parameters in the separate regressions for adopters and nonadopters are the same is rejected if the \( F \) computed exceeds the critical \( F \) value.

### 2.4.3 Decomposition model for assessing the technology contribution

The output decomposition model developed by (Bisaliah, 1977) was used in the present study to sort out the contribution of technological interventions and resource use differences from the total productivity difference between the adopter and nonadopter groups. This model has been widely used in various studies (Badal & Singh, 2001; Chatterjee et al., 2020; Ketema & Kassa, 2016; Shiyan, 1996). After subtracting
3 RESULTS AND DISCUSSION

At the study site, the mean family size of the adopters was higher (7.01) as compared to nonadopters (6.50), which is higher than the average family size of India (4.8) and Madhya Pradesh (5.0) (NFHS, 2007). All the selected growers have received education at least up to the primary level. Land holding size ranged from 0.4 to 3.64 ha and is classified as four different categories (Table 2). Among the categories, the small growers’ group was higher (35%) under adopter growers, whereas the marginal growers’ group was higher (42%) with nonadopter growers.

3.1 Cropping area, yield, and milk production

The FSR project encouraged active participation and adoption of new technologies among FSR adopters. A 5-yr study (2007–2012) indicated that FSR has increased the cropping area and yield of blackgram, groundnut, and wheat among adopters (n = 36–53) as compared to nonadopters (n = 16–58) (Table 3). Blackgram, groundnut, and wheat are the dominant crops of central India; blackgram and groundnut are grown in the rainy season, and wheat is grown in the winter season. A major leap was observed in groundnut-planted area (54%) compared with blackgram (48%) in the rainy season. This could be due to selection of a suitable soil texture (red sandy loam) for growing of the crop, timely land preparation and improved implements (disk plow and seed drill), replacement of old varieties with new varieties of groundnut (TG-26 and Kausal), seed treatment with Rhizobium (200 g 10 kg⁻¹ seed), and the use of a decorticator for processing the groundnut crop. Moreover, groundnut haulm was considered as a very good source of dry fodder as compared to blackgram for cattle growers. In winter, wheat area was 38% higher with adopters than with nonadopters. Wheat is a major crop of this district and provides assured economic return compared with other winter crops. This has led to higher area under wheat among the farmers who have adopted FSR. The inclusion of new varieties (groundnut, TG-26 and Kausal; blackgram, T-9 and PU-31; wheat, HI-1539 and WH-147) and the scientific method of cultivation (seed rate and line sowing), crop protection (seed treatment with thiram or vitavax at 2 g kg⁻¹ seed), and postharvest handling (groundnut decorticator for processing) of produce also increased the yields of groundnut, blackgram, and wheat, with gains of 157% for blackgram, 34% for groundnut, and 12% for wheat. Similar findings were reported from Kenya by Whitfield et al. (2015), who stated that participatory FSR (water-efficient maize [Zea mays L.] for the Africa project) had created awareness about a new water-efficient corn variety among growers, which also increased the average yield of corn under drought conditions. This finding indicates that farmers’ participatory approach is an efficient method of dissemination of agricultural technologies.

Crop diversity has also increased among adopters of FSR compared with nonadopters in the FSR project operational area. In total, 14 different rainy-season and winter-season crops were grown by the adopters (Figure 2a), whereas only 12 crops were grown by nonadopters during the study period (Figure 2b). Among the planted crops, wheat occupied...
56.40% of the total cultivated area, followed by groundnut (22.17%) and blackgram (10.84%) with adopters. A similar trend was observed with nonadopters, but >60% of the total cultivated area was occupied by wheat, which indicates that nonadopters have given less importance to crop diversification, possibly due to a lack of knowledge and awareness of the improved technology.

Promising results were also observed in milk production after the intervention of the FSR project (Figure 3). Milk production was higher with among FSR adopters (57%) compared with nonadopters (Figure 3a,b). Generally, milk production is dependent on the cattle breeds, quality of feeds, ratio of green and dry fodder concentrates, and cattle health (Saxena et al., 2019). The FSR project interventions included all the technical requirements for nutritious fodder or feed production and regular consultation regarding animal feeding, management of diseases, vaccination, and care during the post-lactation period through the participatory mode during the study period. Therefore, milk production has increased FSR adopters compared with nonadopters.

### 3.2 System productivity and input use

The adopter households use significantly fewer farm inputs (e.g., seeds, fertilizer, and agrochemicals) in crop production compared with their nonadopter counterparts (Table 4). The use of quality seed material by the adopters as per the suggested technological guidance accentuated the utility of all agronomic practices and optimized the use of every other farm input. The training imparted on the use of seed drills, groundnut decorticators, and power-operated threshers cum

<p>| TABLE 4 Geometric mean levels of system wheat equivalent yield (SWEY) and system input use |</p>
<table>
<thead>
<tr>
<th>Inputs</th>
<th>Overall</th>
<th>Adopters</th>
<th>Nonadopters</th>
</tr>
</thead>
<tbody>
<tr>
<td>Seed, kg ha&lt;sup&gt;-1&lt;/sup&gt;</td>
<td>22.36</td>
<td>19.22 &lt;sup&gt;*&lt;/sup&gt;</td>
<td>25.492</td>
</tr>
<tr>
<td>Bullock labor, d ha&lt;sup&gt;-1&lt;/sup&gt;</td>
<td>0.676</td>
<td>0.616</td>
<td>0.776</td>
</tr>
<tr>
<td>Machine labor, h ha&lt;sup&gt;-1&lt;/sup&gt;</td>
<td>7.124</td>
<td>8.08 &lt;sup&gt;*&lt;/sup&gt;</td>
<td>5.944</td>
</tr>
<tr>
<td>Human labor, man-days ha&lt;sup&gt;-1&lt;/sup&gt;</td>
<td>12.352</td>
<td>11.52 &lt;sup&gt;*&lt;/sup&gt;</td>
<td>15.984</td>
</tr>
<tr>
<td>Fertilizer N–P–K, kg ha&lt;sup&gt;-1&lt;/sup&gt;</td>
<td>54.408</td>
<td>46.348 &lt;sup&gt;**&lt;/sup&gt;</td>
<td>62.468</td>
</tr>
<tr>
<td>Agrochemicals, L ha&lt;sup&gt;-1&lt;/sup&gt;</td>
<td>0.38</td>
<td>0.26 &lt;sup&gt;*&lt;/sup&gt;</td>
<td>0.46</td>
</tr>
<tr>
<td>Farmyard manure, t ha&lt;sup&gt;-1&lt;/sup&gt;</td>
<td>1.19</td>
<td>1.39 &lt;sup&gt;*&lt;/sup&gt;</td>
<td>0.98</td>
</tr>
<tr>
<td>SWEY, kg ha&lt;sup&gt;-1&lt;/sup&gt;</td>
<td>9.560</td>
<td>10.500 &lt;sup&gt;**&lt;/sup&gt;</td>
<td>8.120</td>
</tr>
<tr>
<td>Sample size</td>
<td>121</td>
<td>60</td>
<td>61</td>
</tr>
</tbody>
</table>

<sup>*,<sup>Significant at the .05 probability level.</sup>**Significant at the .01 probability level.
**Production function estimates**

The estimated values of VIF were below 3, and hence multicollinearity was not a problem. The Chow’s F test (Table 6) rejects the hypothesis of homogeneity in regression coefficients of the two production functions (Equations 3 and 4). In other words, we have sufficient evidence to say that there is a structural change in the production relations of adopters and nonadopters due to the technological interventions, and therefore estimating two separate regression lines for adopters and nonadopters due to the technological interventions, and hence estimating two separate regression lines for adopters and nonadopters is a structural change in the production relations of adopters and nonadopters can fit the data better than a pooled one (Equation 5). Table 7 depicts the estimates of the output elasticities under the three considered cases (i.e., adopters, nonadopters, and pooled sample). A close perusal of Table 6 revealed that the coefficients of seed, machine labor, human labor, fertilizer, and FYM had a significant positive effect for all the production relations. The less-than-unity value of production elasticities implied diminishing marginal productivity with respect to each of the inputs and the resource use levels used at the rational zone of the production stages. The production elasticities of seed, fertilizer, machine labor, and FYM were higher in the case of adopter categories. The lower elasticity coefficients of human labor for the adopter category might be due to the overuse of manpower by the adopter farm households.

**Decomposition of productivity difference**

After confirming the structural break in the production relations of adopters and nonadopters, the total change in the system productivity was decomposed using production function parameters and geometric mean levels of inputs with the help of the decomposition equation (Equation 8). The productivity gain in the case of adopters’ farm households over nonadopters is estimated at 28.13% (Table 8), which is slightly lower than the observed difference (29.25%). This discrepancy, which is attributed to the random error term (Badal &
**Table 8** Decomposition of differences in productivity (returns) from crop enterprises between adopters and nonadopters

<table>
<thead>
<tr>
<th>Sl. no.</th>
<th>Sources of system productivity difference</th>
<th>Percentage contribution</th>
<th>Subtotal</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>Total observed difference</td>
<td></td>
<td>29.25</td>
<td></td>
</tr>
<tr>
<td>II</td>
<td>Due to technology difference</td>
<td></td>
<td>24.50</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Neutral technological gap</td>
<td>−7.05</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Nonneutral technological gap</td>
<td>31.55</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Seeds</td>
<td>24.93</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>N–P–K fertilizer</td>
<td>20.20</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>FYM</td>
<td>16.58</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Agrochemicals</td>
<td>−1.26</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Bullock labor</td>
<td>−18.56</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Machine labor</td>
<td>8.10</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Human labor</td>
<td>−18.44</td>
<td></td>
<td></td>
</tr>
<tr>
<td>III</td>
<td>Due to relative change in input use level</td>
<td></td>
<td>3.63</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Seeds</td>
<td>−3.39</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>N–P–K fertilizer</td>
<td>−6.27</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>FYM</td>
<td>11.56</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Agrochemicals</td>
<td>−2.28</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Bullock labor</td>
<td>3.93</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Machine labor</td>
<td>3.68</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Human labor</td>
<td>−3.60</td>
<td></td>
<td></td>
</tr>
<tr>
<td>IV</td>
<td>Total estimated difference in system productivity (kg ha(^{-1})) between adopter and nonadopters</td>
<td></td>
<td>28.13</td>
<td></td>
</tr>
</tbody>
</table>

*Note.* FYM, farmyard manure.

Singh, 2001; Ketema & Kassa, 2016), is of a very low order, and hence the decomposition model fits well and represents the farming conditions of the study region. The contribution of the neutral technological component in the productivity difference was negative (−7.05%), whereas the non-neutral technological change contributed positively (31.55%). A similar investigation by Mondal et al. (2012) also found negative neutral technological differences due to adoption of improved technologies in watershed areas in the Bundelkhand region of Madhya Pradesh.

The positive non-neutral technological component signifies that, with the present level of input used in the control areas, the nonadopters could have increased productivity by around 31% with the adoption of improved technologies provided that the efficiency levels of input use were held constant. Further, technological adoption increased the efficiency of seeds (24.93%), fertilizer (20.20%), FYM (16.58%), and machine labor (8.10%). The total contribution of differences in the levels of input use to the gap in productivity accounted for 3.63%, indicating that farm productivity among nonadopters can be increased by 3.63, if the input use levels on these farms is same as that of adopters. Increased use of FYM and machine labor accentuated the productivity among adopters by 11.5 and 3.68%, respectively. This finding is in congruence with the earlier studies (Chatterjee et al., 2020; Mondal et al., 2012), where the contribution of complementary inputs was found to be positive.

### 3.5 Employment generation and livelihood diversification

Unemployment is a serious problem in this economically disadvantaged area. However, data from this study showed that adopting scientific methods in crop and milk production has generated enormous employment opportunities. The FSR initiatives generated 42% (6,730 additional man-days; 1 man-day is equivalent to 8 h) of additional employment opportunities among adopters compared with nonadopters (Figure 4). Maximum employment was recorded for wheat, followed by groundnut and milk production, for both adopters and nonadopters. It shows that wheat, groundnut, and milk production are the most common agriculture and related activities within this study area. Changes in crop diversity and increased crop acreage could have led to a greater generation of employment owing to different crop-related operations throughout the year among the adoptive farmer category. In addition, it also raised farm income and livelihood creation. Previous studies
(A. Chakraborty, 2012; Choudhary & Singh, 2019; R. Singh, 2015; Todkari, 2012) have also supported that appropriate crop diversification helps to create employment, increase crop intensity, improve farm income, and reduce income inequality and poverty. Furthermore, FSR encourages the participation of family members by interlinking crops and livestock.

The primary focus of the present farming system research was to disseminate modern technologies along with the promotion of agricultural diversification. The diverse portfolio of agricultural and allied activities in rural areas is essential for survival, well-being, and improvement in living status (Ellis, 1998). In this study, livelihood shift was higher with growers who adopted FSR compared with growers who did not (Table 9). The shift was more promising on agriculture + animal husbandry (8.33) and agriculture + animal husbandry + service-related jobs (1.67) among FSR adopters, whereas the shift was only 1.67 under agriculture + animal husbandry and nil under agriculture + animal husbandry + service-related jobs among nonadopters.
TABLE 10  Current adoption status of farming system technologies

<table>
<thead>
<tr>
<th>Sl. no.</th>
<th>Technologies transferred</th>
<th>n</th>
<th>Current status</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Crop varieties</td>
<td>100</td>
<td>Continued</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Crop inputs</td>
<td>100</td>
<td>Partially adopting</td>
<td>It is dependent upon the market availability.</td>
</tr>
<tr>
<td>3</td>
<td>Rotavator and seed drill</td>
<td>100</td>
<td>Partially adopting</td>
<td>Mostly growers felt that the area is comes under rocky lands so often modern tools and implements get broken.</td>
</tr>
<tr>
<td>4</td>
<td>Cultivation practices</td>
<td>100</td>
<td>Partially adopting</td>
<td>All modern practices such as line sowing are continuing, but dry planting of crops is discontinued due to over growth of weeds.</td>
</tr>
<tr>
<td>5</td>
<td>Groundnut decorticator for women</td>
<td>100</td>
<td>Continued</td>
<td>Highly useful for groundnut processing.</td>
</tr>
<tr>
<td>6</td>
<td>Cattle breed improvement</td>
<td>100</td>
<td>Continued</td>
<td>All breeds are maintained by adopted growers.</td>
</tr>
<tr>
<td>7</td>
<td>Improved livestock feeding</td>
<td>100</td>
<td>Partially adopting</td>
<td>All recommended feeding ratios are not followed due to the higher cost of concentrates.</td>
</tr>
<tr>
<td>8</td>
<td>Vaccination of animals</td>
<td>100</td>
<td>Continued</td>
<td>Government schemes are providing vaccination at lower cost.</td>
</tr>
<tr>
<td>9</td>
<td>Fodder crops</td>
<td>100</td>
<td>Partially adopting</td>
<td>A smaller area is being devoted to cultivation of fodder crops.</td>
</tr>
<tr>
<td>10</td>
<td>Summer fodder</td>
<td>100</td>
<td>Partially adopting</td>
<td>A smaller area is being devoted to cultivation of fodder crops</td>
</tr>
<tr>
<td>11</td>
<td>Boundary plantation of fodder</td>
<td>100</td>
<td>Continued</td>
<td>Continuing to achieve the animal feed requirement.</td>
</tr>
</tbody>
</table>

3.6  Current status of technologies

It is always important to assess the status of technologies after the conclusion of FSR projects. A survey was made in 2019, after 7 yr of project conclusion, among FSR adopters (n = 100). Most of the introduced technologies are continued by adopters, who expressed that crop and milk yields increased after the interventions under FSR projects. Among the technologies, groundnut processing implement (decorticator), improved cattle breeds, animal vaccination, and boundary planting of fodder crops are practiced with great interest (Table 10). Technologies like disk plow, seed drill, improved varieties, crop inputs (fertilizers, pesticide etc.), improved cultivation practices (line sowing and pre-irrigation), improved livestock feeding, and planting of summer and rainy-season fodder crops are partially followed by FSR adopters due to the lack of suitability, higher cost, and feasibility (Table 10). Therefore, the benefits of FSR would be a better option to convince the nonadopters in the near future.

4  CONCLUSIONS

The long-term (2007–2019) findings of this study suggest that creating awareness about improved technologies and changing the growers’ approach increased production, employment, and economic returns of growers of central India. Linking growers with research and extension organizations could help in attaining the potential production level of crops. This study showed that growers are more receptive in accepting technologies that are easy to practice and feasible to use. Going forward, studies of post-production problems (e.g., processing, value addition, and marketing) faced by farmers would help the government and the concerned stakeholder to reorient policy planning and project implementation to get the desired success. Interventions led by FSR have encouraged diversification in farming activities along with benefits such as improved soil health, diverse flora and fauna, and carbon sequestration in the study areas of central India.

The kind of spatial econometrics and cost-benefit analysis used in this study is crucial for understanding the actual field-level effect of the farming system–based technological interventions on the productivity and income of farm households. The project interventions in the region enhanced resource recycling and improved the farm economy in a significant way. Although the actual choice of any interventions would eventually depend on socio-economic factors prevailing in any region (Choudhary & Sirohi, 2021), the evidence from the central part of India may offer an important lesson to promote an improved farming system research–based intervention to enhance rural livelihoods in arid and semi-arid regions throughout the world.

ACKNOWLEDGMENTS

This research was funded by ICAR-Indian Grassland and Fodder Research Institute Jhansi. The authors gratefully acknowledge the support of Director IGFRI, Jhansi.
AUTHOR CONTRIBUTIONS
Sunil Kumar: Conceptualization; Data curation; Writing – review & editing. Purushottam Sharma: Conceptualization; Data curation. Satyapriya: Conceptualization; Data collection; Data curation; Prabhu Govindasamy: Visualization; Writing – original draft; Writing – review & editing. Maharaj Singh: Conceptualization. Sant Kumar: Conceptualization; Data curation; Methodology. Hanamant M Halli: Visualization; Writing – original draft; Writing – review & editing. Bishwa Bhaskar Choudhary: Visualization; Writing – original draft; Writing – review & editing. Muthukumar Bagavathanan: Writing – review & editing.

CONFLICT OF INTEREST
There are no conflicts of interest in conducting research and submitting this manuscript.

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REFERENCES
Dorward, P., Shepherd, D., & Galpin, M. (2007). Participatory farm management methods for analysis, decision making and communication. FAO.


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