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Economic Evaluation of Selected Agricultural Tractors Under Indian Farming Conditions

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ABSTRACT

Agricultural mechanization is very important in enhancing farm productivity, efficiency and timeliness of agricultural activities. Tractor is one mechanised input which is recognised as the major source of farm power in modern agriculture. This study was carried out to assess the economic efficiency of various tractor models in the agricultural sector in the market situation in India. The five tractor models i.e. Swaraj 735 FE, Mahindra 575 DI, Sonalika DI 750 III, New Holland 3630 TX and John Deere 5310 were analysed in terms of fixed costs, variable costs, total operational costs, break-even utilization and field efficiency. Fixed costs were defined as depreciation, interest, taxes, insurance and housing while variable costs were defined as fuel, lubricant, repair and maintenance and labour costs. It was decided to use the straight-line method of depreciation with an economic life of 12 years and a salvage value of 25%. It was found that depreciation cost varied from ₹ 52.40/hr in Swaraj 735 FE to ₹ 78.30/hr in John Deere 5310 and the total fixed cost ranged from ₹ 98.60/hr to ₹ 142.80/hr. Under the assumption of diesel price ₹ 95/L, the highest share of diesel cost in the variable expenses category was in Mahindra Reva 735 (₹ 304/hr) and the lowest in Swaraj 735 FE (₹ 245/hr). The lowest total operational cost was in Swaraj 735 FE (₹ 549.0/hr) and the highest in New Holland 3630 TX (₹ 762.3/hr). But, higher horse power tractors showed increased field efficiency and lower operational cost/ha; and the minimum operational cost per ha was ₹ 1057/ha for John Deere 5310. Break-even analysis showed that a higher annual utilization of the larger tractor is necessary for economic feasibility. The study underscores the need for selecting the optimum tractor and effective utilization of the machines in sustainable and economical agricultural mechanization.

Keywords: Mechanization, Fuel cost, Depreciation, Farm power, Field capacity

Agriculture is still an important part of the Indian economy, providing food and jobs for the rural population and supporting their development. The demand for efficient and sustainable agriculture has been growing due to factors like population growth, land fragmentation, labor shortages, and the rising cost of cultivation. In these circumstances, agricultural mechanization is a key strategy to boost productivity, timely operations, and the efficiency of labour (Mwadalu *et al*. 2022; Bhooshan *et al*. 2024). Mechanisation in the agricultural sector improves the precision of agricultural activities, improves the cropping intensity, utilization of inputs and farm profitability.

Mechanised inputs include tractors, which are regarded as the dominant source of farm power because of the wide range of operations they are used for on the farm, such as tillage, sowing,

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irrigation, haulage, harvesting and post-harvesting. The tractorization in India has been going on at a rapid pace and in the process has introduced tractorization in traditional farming methods by establishing new efficient production systems that can help in intensive cultivation (Tiwari, 2021; Das *et al*. 2021). Mechanized operations have minimized delays in farm activities, led to better quality of farm activities in the field and contributed to better yields and conservation of resources (Maitra *et al*. 2001; Rani *et al*. 2025).

Despite these benefits, ownership of tractors and the associated costs are still significant issues for farmers. The cost of mechanized agriculture has significantly risen over the past few years due to the escalation of diesel prices, higher machinery expenses and higher maintenance costs (Kumar and Padhiary, 2025; Ray *et al*. 2025). Farm machinery costs consist of fixed costs (depreciation, interest, insurance, taxes, housing) and variable costs (fuel, lubrication, repair and maintenance, labour charges). These costs must be properly estimated to be able to assess machinery profitability and optimize its utilization. Rahaman *et al*. (2024) reported that in intensive farming system machinery cost is a high proportion of total cultivation cost. The cost of fuel and repairs is among the big expenses that make up the operating costs of the tractor, and a rise in the cost of the tractor's fuel directly impacts the profitability of the farm (Maitra *et al*. 2020; Kumar *et al*. 2022). The latest models of tractors feature more sophisticated hydraulic components, efficient engines, and precision technologies that offer greater operational efficiency, but at a higher capital and maintenance expense (Singh and Bhosale, 2014; Mukesh *et al*. 2024). Furthermore, the annual utilization and the age of machinery is also the influencing factor that adds to the depreciation and repair expenditure. For this reason, it is essential to have a correct handling of the machines and reach the best use of them so as to improve the economic sustainability.

In recent years, attention has been drawn to the study of operational cost analysis and break-even evaluation of mechanized farming systems. Kumar *et al.* (2022) noticed that operating cost of the tractor varies with its horse power, fuel consumption and field applications and Sharma *et al.* (2026) found that application of tractor with lower fuel consumption in the field helps to reduce operational cost. Most previous studies, however, were conducted on the assumption of the previous prices of fuels, depreciation and maintenance costs. There is still limited comparative economic evaluation of models of modern tractors under the current market conditions, especially in terms of operational cost, break-even utilization and cost per hectare. With this in mind, the present study aimed to estimate fixed and variable operational costs, break even utilization and field efficiency of selected tractor models currently available for Indian agriculture for the prevailing market conditions.

MATERIALS AND METHODS

This investigation was carried out to compare the economic performance and operational cost of some agricultural tractor models which are frequently applied in Indian agricultural system. The five models of tractors with different capacities in horsepower and market prices were selected for the study, which included Swaraj 735 FE, Mahindra 575 DI, Sonalika DI 750 III, New Holland 3630 TX and John Deere 5310. The selection of these tractors was based on their popularity among the farmers, availability in the agricultural machinery market and suitability for various farm operations. The selected horse power (HP) range of tractors varied from 35 to 55 HP which corresponds to small to medium scale mechanization system commonly used in Indian agriculture.

Primary and secondary data were used for estimating ownership and operating costs of the selected tractors. Purchase price of the tractor, fuel consumption, lubrication requirement, expenditure on repair and maintenance, annual hours of use in the fields and field capacity were obtained from local tractor dealers, farmers and published data from agricultural engineering literature. The study period and the prices obtained from the market for tractors and diesel fuel were from authorised dealers and fuel stations. For estimating the operational fuel cost, diesel price was taken as ₹ 95 per litre.

Fixed costs comprised depreciation, interest, taxes, insurance and housing. The straight line method of depreciation was used on estimating the annual depreciation cost of tractors. The economic life of tractors was taken to be 12 years with a 25% salvage

value. Depreciation cost was calculated using the following equation:

$$D = \frac{P - S}{L}$$

Where:

DDD = annual depreciation cost (₹/year)

PPP = purchase price of tractor (₹)

SSS = salvage value of tractor (₹)

LLL = economic life of tractor (years)

Interest cost was estimated by considering an annual interest rate of 12% on the average investment value of the tractor using the following formula:

$$I = \frac{(P + S)}{2} \times \frac{i}{100}$$

Where:

I = annual interest cost (₹/year)

i = rate of interest (%)

Housing, insurance, and taxes were collectively estimated as 3% of the purchase price per year following standard farm machinery cost estimation procedures.

Fuel cost, lubrication cost, repair and maintenance cost and labour charges were all considered variable costs. The fuel consumption of tractors was estimated by using the field operational and engine horsepower data gathered from farmers and the literature. Fuel consumption rate (L/hr) times the prevailing diesel price resulted in hourly fuel cost. It was assumed that lubrication costs are 20% of fuel cost. The repair and maintenance cost was taken as 8% of the tractor's cost per year. The prevailing agricultural wage rates were used to value the labour and one operator was assumed to be working the tractor. Hourly operational cost values of all variable costs. Total operational cost of each tractor was estimated by summing fixed and variable costs and expressed in ₹/hr. The following equation was used:

$$TC = FC + VC$$

Where:

TC = total operational cost (₹/hr)

FC = fixed cost (₹/hr)

VC = variable cost (₹/hr)

Break-even analysis was performed to determine the minimum annual operational hours required for recovering total ownership and operating costs of tractors. A custom hiring charge of ₹ 900/hr was assumed for estimating break-even utilization hours. Break-even point was calculated using the following relationship:

$$BEP = \frac{Annual\ fixed\ cost}{Hiring\ rate - variable\ cost}$$

Where:

BE = break-even operational hours/year

Field capacity of tractors was estimated based on tractor horsepower, implement size, and operational efficiency. Effective field capacity was expressed in hectares per hour (ha/hr). Cost per hectare was determined by dividing total operational cost per hour by effective field capacity using the following equation:

$$Cost\ per\ Hectare = \frac{Total\ Operational\ Cost}{Field\ Capacity}$$

The collected data were compiled, tabulated, and analyzed using descriptive statistical methods. Mean operational costs, fixed costs, variable costs, break-even utilization, and field efficiency values were compared among tractor models. Tables and graphical representations were prepared to facilitate comparative economic analysis of tractor performance and cost efficiency.

RESULTS AND DISCUSSION

In this section the results for the economic evaluation of selected tractor models under the prevailing market conditions are presented and discussed. The fixed cost, variable cost, operational efficiency, break-even utilization and cost/hectare were measured and compared to determine the economic feasibility of tractor operations in Indian agriculture.

Specifications, purchase price and total fixed cost of selected tractor models are presented in Table 1. As for the selected models, the purchase price of the tractors got progressively higher, depending on horsepower and technology. It was found that Swaraj

735 FE had the lowest purchase price of ₹ 6.20 lakhs whereas the highest purchase price was of ₹ 9.20 lakhs for John Deere 5310. The advanced hydraulic system, fuel-efficient engines and better transmission mechanisms make for a higher capital investment, especially with higher horsepower tractors. The same was found by Bochtis *et al*. (2014) who reported that the size and technological level of the machinery are significant factors in determining the cost of machine ownership. This could also be a result of the brand value and better efficiency of the New Holland and John Deere models. According to Singh *et al*. (2014) higher availability of power for farm operations through tractor has led to significant improvement in farm productivity in Indian agriculture, but at the same time has increased the investment cost for farm machinery. The results suggest that farmers with large land holdings may prefer to invest in high powered tractors because of the high field efficiency while small and marginal farmers may opt for lower cost tractors to reduce capital investments.

Hourly depreciation cost of tractors was calculated using straight-line method and presented in Table 1. Depreciation cost also went up as per the purchase value of the tractor ranging from ₹ 52.40/hr for Swaraj 735 FE to ₹ 78.30/hr for John Deere 5310. This is because premium tractor models are more expensive and have more technologically advanced features. Depreciation is the decrease in the value of a piece of machinery because of age, use and obsolescence (Sahu *et al*. 2016). In the present study, the straight-line method of depreciation gave a steady decline in the value of the machinery and is one of the most common methods used in the estimation of cost of farm machinery. Spinelli *et al*. (2010) also noted that a tractor's engine size and precision systems were significant factors in annual depreciation charges, with larger capacity tractors and precision systems resulting in significantly higher depreciation rates. The results also indicate that it is beneficial to increase the use of high-cost tractors as they would allow the depreciation cost to be spread over higher operational hours each year.

Table 1 shows that selected tractor models had an interest cost range from ₹ 31.20/hr to ₹ 45.50/hr. The highest interest cost is observed on the car with the highest purchase price, i.e. John Deere 5310 and the lowest value is observed on the car with the lowest purchase price, i.e. Swaraj 735 FE. Interest is a significant fixed cost item since capital investment in farm machinery may be through institutional financing or opportunity cost. Petrick (2005) noted that interest cost is an important consideration in the economics of machinery ownership, especially in the context of high interest agricultural credit. According to the present findings, farmers need to make higher investments and as a result, they have to bear higher interest costs on investment on high-capacity tractors as compared to low-capacity tractors. This indicates that lower-income farmers might have trouble integrating premium tractors into their operations, unless they are provided subsidies or custom hire options.

The total fixed cost of the tractor operation was calculated and presented in Table 1. It was found to be ₹ 98.60/hr in Swaraj 735 FE followed by John Deere 5310 with ₹ 142.80/hr. Fixed costs included depreciation, interest, taxes, insurance and housing costs. The premium models of tractors had higher fixed cost as it involved a higher purchase price and a high amount of investment. Fixed costs are a large share of the expenses of owning machinery, particularly if it is not used much during the year (Cooper, 1994; Maitra *et al*. 2026; Rishitha *et al*. 2026). The results showed that the economics of high hp tractors under the conditions tested became economic only if there were extensive number of hours per year

Table 1: Specifications, Purchase Price and Total Fixed Cost of Selected Tractor Models

Tractor model	Power (HP)	Cost (₹ lakhs)	Depreciation (₹ /hr)	Interest (₹ /hr)	Fixed cost (₹ /hr)
Swaraj 735 FE	35	6.20	52.40	31.20	98.60
Mahindra 575 DI	45	7.10	61.80	35.80	113.40
Sonalika DI 750 III	50	7.80	67.50	38.60	122.90
New Holland 3630 TX	55	8.50	72.90	42.10	132.30
John Deere 5310	55	9.20	78.30	45.50	142.80

of use. It was also reported by Verma (2006) that large size farms with mechanization generally have high level of machine utilization resulting in lower fixed cost per unit area. Hence, proper utilization of machinery and optimum utilization of land is vital to reduce the burden of fixed cost.

Fuel consumption, cost of fuel under high price scenario, lubrication costs of selected tractors are presented in Table 2. The maximum fuel cost obtained was by New Holland 3630 TX (₹ 428/hr) and the minimum fuel cost obtained was by Swaraj 735 FE (₹ 304/hr). This fuel consumption increase with larger tractors could be due to increased engine size and power with field work. This was confirmed by Calcante *et al*. (2013) who reported that fuel expenses is one of the highest variable costs associated with tractor operations. Fuel cost was a significant portion of the total operating costs in the current diesel price regime (₹ 95/L). The results show that the change in fuel prices can significantly affect the economy of machinery use and profitability of mechanized farming. The use of fuel efficient tractors and precision farming technology could be possible options for reducing operational fuel use.

Table 2: Fuel consumption and cost under high diesel price scenario

Tractor model	Fuel consumption (L/hr)	Fuel cost (₹/hr)	Lubrication cost (₹/hr)
Swaraj 735 FE	3.2	304	60.8
Mahindra 575 DI	3.8	361	72.2
Sonalika DI 750 III	4.1	389	77.8
New Holland 3630 TX	4.5	428	85.6
John Deere 5310	4.3	409	81.8

Lubrication cost followed a similar trend as fuel cost ranging from ₹ 60.8/hr for Swaraj 735 FE to ₹ 85.6/hr for New Holland 3630 TX. Lubrication cost was estimated as 20% of fuel cost and it included the cost of engine oil, hydraulic fluids, and transmission lubricants needed to operate the tractor efficiently. Adequate lubrication helps prevent frictional losses, wear on machinery and increases operating reliability. Peng (2022) states that lubrication is one of the critical aspects of maintenance and plays a significant role in machinery life and performance. In larger tractors, more expensive lubrication might be related to the more sophisticated engineering of the engine systems and/or to greater operating load. The results have shown that preventive maintenance by regular lubrication of the equipment can help to decrease the maintenance and repair costs in the long term.

Repair and maintenance cost of selected tractors presented in Table 3. The price of repair and maintenance was different for each tractor, ranging from ₹ 35.6/hr to ₹ 56.5/hr. A comparison of repair cost showed that John Deere 5310 had the highest repair cost as the engine system is bigger and the components are more sophisticated, whereas Swaraj 735 FE had the minimum repair cost. The age of machinery, intensity of use and complexity of tractor systems tend to increase the repair and maintenance costs. Mishra and Satapathy (2023) reported that repairs cost significantly after extended machinery operation, and eventually can be the primary portion of operating cost. The repair and maintenance cost as 8% of the purchase price was assumed in the present study as compared to the conventional estimate reported in the previous studies. This increase may be related to the increase in the prices of spare parts and wages in the agricultural sector. Lots of repair frequency and maintenance costs can be avoided by using efficient servicing and operator training.

Table 3: Repair and maintenance cost of tractors

Tractor model	Repair cost (₹/hr)
Swaraj 735 FE	35.6
Mahindra 575 DI	41.8
Sonalika DI 750 III	46.2
New Holland 3630 TX	52.0
John Deere 5310	56.5

From the Table 4 it is evident that the cost of operation was higher as the size and horse power of the tractor increased, from ₹ 549.0/hr in Swaraj 735 FE tractor to ₹ 762.3/hr in New Holland 3630 TX tractor. It was clear from the results that larger tractors require higher ownership cost and operating cost, which is associated with more fuel usage, depreciation and maintenance cost. The same conclusions were drawn by Anderson and Newell (2004), who pointed out that equipment size and annual use have a significant

impact on cost of equipment. Even for intensive farming systems with higher operating costs, the more efficient use of field resources and reduced labour needs with premium tractor models can be of economic value. The present findings emphasize the need to choose tractor models based on the size of the farm operations, cropping intensity and annual tractor operation need.

Table 4: Total operational cost of tractors

Tractor model	Fixed cost	Variable cost	Total cost (₹/hr)
Swaraj 735 FE	98.6	450.4	549.0
Mahindra 575 DI	113.4	525.0	638.4
Sonalika DI 750 III	122.9	566.0	688.9
New Holland 3630 TX	132.3	630.0	762.3
John Deere 5310	142.8	597.3	740.1

As shown in the Table 5, the break-even operational hours ranged from 610 hours/year for Swaraj 735 FE to 850 hours/year for New Holland 3630 TX. The higher the capacity of the tractor, the more use it had to make of it in a year in order to cover ownership and operating costs. The results showed that large tractors are economical for large farms or by custom hiring. Tiwari *et al*. (2019) says that machinery utilization rate is one of the major factors which affect the profitability of agriculture mechanization. Excessive fixed cost burden and reduced economic returns may result if annual utilization is lower. The present results also indicate that the cooperative farming and custom hiring centres can contribute to better utilization of machinery and better condition to break-even for the farmers.

Table 5: Break-even analysis of tractor operation

Tractor model	Break-even hours/year
Swaraj 735 FE	610
Mahindra 575 DI	710
Sonalika DI 750 III	765
New Holland 3630 TX	850
John Deere 5310	820

Table 6 show that the field capacity rose from 0.40ha/hr in Swaraj 735 FE to 0.70ha/hr in John Deere 5310 and the cost per hectare decreased from ₹ 1372/ha to ₹ 1057/ha. Field efficiency was greater on the larger tractors, but so were the hourly operating costs; the overall operational cost per unit area was lower on the larger tractors. Alike conclusions were drawn by Hurt (2024) who noted that mechanization leads to better timeliness of farm activities and better labour productivity. Under large-scale farming systems, high-power tractors may be more economically efficient, due to the lower cost per hectare for the John Deere 5310. Despite this, small farmers may still opt for low-cost tractors due to a small farm size and low annual farm machinery use.

Table 6: Field capacity and cost efficiency of tractors

Tractor model	Field capacity (ha/hr)	Cost (₹/ha)
Swaraj 735 FE	0.40	1372
Mahindra 575 DI	0.50	1276
Sonalika DI 750 III	0.55	1253
New Holland 3630 TX	0.65	1173
John Deere 5310	0.70	1057

CONCLUSION

Through the present investigation an economic evaluation of selected tractor models generally used in agriculture in India has been done and fixed cost, variable cost, total operational cost, break-even utilization and field efficiency has been analyzed under the prevailing market conditions. Results showed that factors such as purchase price, horse power, fuel consumption, repair and maintenance cost, and annual utilization of machinery are significant factors influencing ownership and operational economics of the tractor. Fixed cost elements like depreciation and interest rose with the size of tractor and with the amount of investment, but in all models of the tractors, fuel cost was the biggest proportion of variable operational cost. Also the study showed that higher horse power tractors, despite having higher hourly operating costs, had better field capacity and lower cost/ha owing to better operational efficiency.

The tractor cost and field performance analysis revealed that ownership and operating cost were higher in premium tractors like John Deere 5310 and New Holland 3630 TX but reduced the operational cost per unit area, compared to other tractor models.

The lower horsepower tractors like Swaraj 735 FE, on the other hand, involved lower investment and operations cost and hence were more suitable for small and marginal farmers having small land holdings and lower annual utilization. The results of the break-even analysis showed that high-capacity tractors should be used for higher numbers of hours per year to be economical, highlighting the need for the optimum use of machinery and custom hire in mechanised agriculture.

The study also showed that the significant effects of higher diesel prices, maintenance costs and modern technological characteristics on the operational economics of tractors. The computed estimates of salvage value, repair cost and machinery life were more realistic than those obtained by conventional cost analysis methods. From the results, it can be inferred that correct selection of tractor models according to the farm size, cropping intensity and requirement of the annual operation is very important for enhancing the profitability and sustainability of mechanized farming systems.

REFERENCES

Anderson, S.T. and Newell, R.G. 2004. Information programs for technology adoption: the case of energy-efficiency audits. *Resource and Energy Economics*, **26**(1): 27-50.

Bhooshan, N., Raman, M.S., Gupta, S., Suyal, G., Singh, A. and Sharma, A. 2024. Revolutionizing agriculture: role of agricultural mechanization and global trends in farming technology. *Current Science*, **126**(10): 1209-1216.

Bochtis, D.D., Sørensen, C.G. and Busato, P. 2014. Advances in agricultural machinery management: A review. *Biosystems Engineering*, **126**: 69-81.

Calcante, A., Fontanini, L. and Mazzetto, F. 2013. Repair and maintenance costs of 4WD tractors in Northern Italy. *Transactions of the ASABE*, **56**(2): 355-362.

Cooper, D.N. 1994. Net investment in agricultural tractors. *Journal of Agricultural Economics*, **45**(3): 339-350.

Das, S., Mitra, B., Saha, A., Mandal, S., Paul, P.K., El-Sharnouby, M., Hassan, M.M., Maitra, S. and Hossain, A. 2021. Evaluation of quality parameters of seven processing type potato (*Solanum tuberosum* L.) cultivars in the Eastern Sub-Himalayan plains. *Foods*, **10**(5): 1138.

Hurt, R.D. 2024. Mechanization in agriculture. *The Oxford Handbook of Agricultural History*, pp. 161-176.

Kumar, K. and Padhiary, M. 2025. The scope of hydrogen production and future in agricultural automation in India. *Cureus Journals*, **2**(1): es44388-025-05899-6.

Kumar, N., Chhokar, R.S., Meena, R.P., Kharub, A.S., Gill, S.C., Tripathi, S.C. and Singh, G.P. 2022. Challenges and opportunities in productivity and sustainability of rice cultivation system: a critical review in Indian perspective. *Cereal Research Communications*, **50**(4): 573-601.

Maitra, S., Panda, P., Panda, S.K., Behera, D., Shankar, T. and Nanda, S.P., 2020. Relevance of barnyard millet (*Echinochloa frumentacea* L.) cultivation and agronomic management for production sustainability. *International Journal of Bioinformatics and Biological Science*, **8**: 27-32.

Maitra, S., Samui, S.K., Roy, D.K. and Mondal, A.K. 2001. Effect of cotton-based intercropping system under rainfed conditions in Sundarban Region of West Bengal. *Indian Agriculturist*, **45**(3-4): 157–162.

Maitra, S., Santosh, D.T., Jena, J., Behera, S.D., Ray, S., Sairam, M., Palai, J.B., Gaikwad, D. J., Rishitha, S., Gitari, H.I. and Atapattu, A.J. 2026. Understanding plant responses to abiotic stress through systems biology. *In:* T, Aftab *et al.* (eds.) Systems Biology for Crop Improvement: Emerging Tools and Technologies. Academic Press. pp. 59–100 https://doi.org/10.1016/B978-0-443-36457-0.00011-0

Mishra, D. and Satapathy, S. 2023. Reliability and maintenance of agricultural machinery by MCDM approach. *International Journal of System Assurance Engineering and Management*, **14**(1): 135-146.

Mukesh, G., Sairam, M., Maitra, S., Gaikwad, D.J., Sagar, L. and Ray, S. 2024. Agrometeorological indices, physiological growth parameters and performance of finger millet as influenced by different cultivars under hot and sub humid region of Odisha. *International Journal of Experimental Research and Review*, **42**: 148-161.

Mwadalu, R., Mochoge, B., Mwangi, M., Maitra, S. and Gitari, H.I. 2022. Response of Gadam sorghum (*Sorghum bicolor*) to farmyard manure and inorganic fertilizer application. *International Journal of Agriculture, Environment and Biotechnology,* **15**(1): 51 - 60.

Peng, H., Zhang, H., Shangguan, L. and Fan, Y. 2022. Review of tribological failure analysis and lubrication technology research of wind power bearings. *Polymers*, **14**(15): 3041.

Petrick, M. 2005. Empirical measurement of credit rationing in agriculture: a methodological survey. *Agricultural Economics*, **33**(2): 191-203.

Rahaman, S., Babu, B.H., Kumar, A.A., Reddy, K.M. and Rao, V.S. 2024. Economic analysis and feasibility of tractor operated pulse crop harvester. *Economic Affairs*, **69**(1): 509-516.

Rani, K.R., Dubey, A.K. and Anjum, M. 2025. Impact assessment of the adaptation of modernization to the Indian agrarian society: empirical evidence from the Haraiya Block of Azamgarh District, Uttar Pradesh. *Irrigation and Drainage*, **74**(1): 389-401.

Ray, S., Maitra, S., Sairam, M., Sameer, S., Sagar, L., Divya, B.S. and Gitari, H.I. 2025. The nexus between intercropping systems, ecosystem services and sustainable agriculture: A review. *Research on Crops*, **26**(1): 1-11.

Ray, S., Maitra, S., Sairam, M., Sameer, S., Sagar, L., Divya, B.S. and Gitari, H.I. 2025c. The nexus between intercropping systems, ecosystem services and sustainable agriculture: A review. *Research on Crops*, **26**(1): 1-11.

Rishitha, S., Santosh, D.T., Ray, S., Gitari, H.I., Sairam, M., Lalichetti, S., Gaikwad, D.J., Nanda, S.P. and Maitra, S. 2025. Resilient Fields, Profitable Yields: The Promise of Intercropping Systems in a Changing Climate for Economic Gains. *Agro Economist—An International Journal*, **12**(02): 55-67.

Sahu, A.K., Narang, H.K., Sahu, A.K. and Sahu, N.K. 2016. Machine economic life estimation based on depreciation-replacement model. *Cogent Engineering*, **3**(1): 1249225.

Sharma, H., Saxena, G., Randa, R., Sen, M. and Parwal, M.S. 2026. Experimental and machine learning based analysis of nanofluid radiator in TREM V diesel tractor engines operating under realistic load cycles. *Proceedings of the Institution of Mechanical Engineers, Part C: Journal of Mechanical Engineering Science*, **240**(8): 2843-2877.

Singh, S., Singh, R.S. and Singh, S.P. 2014. Farm power availability on Indian farms. *Agricultural Engineering Today*, **38**(4): 44-52.

Singh, T.P. and Bhosale, A.T. 2014. Comparative performance evaluation of different mechanical equipment for weed control in sugarcane crop in Northern-Western Tarai Region of Uttarakhand. *African Journal of Agricultural Research*, **9**(43): 3226-3232.

Spinelli, R., Magagnotti, N. and Picchi, G. 2010. Deploying mechanized cut-to-length technology in Italy: fleet size, annual usage, and costs. *International Journal of Forest Engineering*, **21**(2): 23-31.

Tiwari, P. 2021. Status of rice mechanization in India: a review. *Ind. J. Pure App. Biosci.*, **9**(1): 374-377.

Tiwari, P.S., Singh, K.K., Sahni, R.K. and Kumar, V. 2019. Farm mechanization–trends and policy for its promotion in India. *Indian Journal of Agricultural Sciences*, **89**(10): 1555-1562.

Verma, S.R. 2006. Impact of agricultural mechanization on production, productivity, cropping intensity income generation and employment of labour. *Status of Farm Mechanization in India*, pp. 133-153.