World Journal of Advanced Research and Reviews
eISSN: 2581-9615 CODEN (USA): WJARAI
Cross Ref DOI: 10.30574/wjarr
Journal homepage: https://wjarr.com/

(RESEARCH ARTICLE)

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SIZING AND FINANCING MECHANIZED PLOUGHING SERVICES IN THE COTTON-GROWING AREAS OF CÔTE D'IVOIRE

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World Journal of Advanced Research and Reviews, 2026, 32(02), 752–767

Publication history: Received on 03 October 2026; revised on 09 November 2026; accepted on 11 November 2026

Article DOI: https://doi.org/10.30574/wjarr.2026.32.2.2861

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ABSTRACT

In the cotton-growing areas of Côte d'Ivoire, service providers enable farmers to access mechanized ploughing without purchasing a tractor. This study describes how these services are organized and assesses the ability of different tractor–implement configurations to cover their costs. It draws on a survey of 702 farmers, 64 cooperatives and 28 service providers, supplemented by interviews with support stakeholders and four focus group discussions. A simulation compares three four-wheel-drive tractor–plough combinations rated at 50, 75 and 100 hp, used for 600, 700 and 1,000 h per year, respectively, including 100 h of travel. The rate of 40,000 FCFA/ha charged by the Mankono Agricultural Mechanization Services Centre (CPSAM) is used as the reference; the annual capital charge is set at 12% of the initial investment. The results show that ploughing is performed in nearly equal proportions using animal traction (49.43%) and manual labour (48.86%); only 1.71% of farmers use mechanized ploughing. Services are supplied by farmers who own equipment, mobile private operators and the Mankono CPSAM, while cooperatives and CIDT help aggregate demand. Effective field capacities are 0.29, 0.65 and 0.80 ha/h, corresponding to 145, 390 and 720 ha/year after travel time is deducted, at costs of 75,835, 39,438 and 32,503 FCFA/ha. Up to approximately 303 ha/year, the 50-hp tractor has the lowest cost per hectare; above that level, the 75-hp tractor becomes the least costly. The common cost-coverage threshold is 506.6 ha/year, at which the 75-hp tractor has the lowest cost. Equipment choice therefore depends on the volume of work that can be secured and the rate charged. Support should combine financing, coordinated work sites, operator training and local maintenance.

Keywords: Agricultural Service Provision; Mechanization; Cost of Capital; Field Capacity; Cost-Coverage Threshold; Côte d'Ivoire

1 INTRODUCTION

Agricultural mechanization changes how work is organized, when operations can be carried out and how investment decisions are made. On small farms, access to machinery may come through individual ownership, collective ownership or hiring a service provider. Service provision allows farmers to use mechanized operations without bearing the full purchase cost of the equipment themselves. Its viability nevertheless depends on the volume of services that can be delivered and on spreading costs over a sufficient level of activity (1–3).

In sub-Saharan Africa, manual labour, animal traction and motorized equipment coexist, sometimes on the same farm. Equipment choices should reflect the operations to be performed and users' resources rather than follow a uniform progression toward increasingly powerful machines (4). For a service business, investment costs continue even when a tractor is underused, whereas revenue depends on the amount of work actually completed. Travel, customer acquisition, operator availability and maintenance therefore affect both service costs and continuity. A study in Ghana assesses the viability of specialized service providers by examining their costs, revenues and tractor utilization efficiency (5).

In Côte d'Ivoire, the cotton sector has helped spread animal traction and mechanization in the savannah regions. Farms often combine cotton with food crops and maintain links with cooperatives and cotton companies (6,7). These relationships can help aggregate demand and collect payments after cotton is marketed. Ploughing services must, however, be organized within a short work window and contend with scattered plots, equipment and spare-part availability, and financing conditions.

Recent studies shed light on these issues in other settings. In Côte d'Ivoire, one study assessed the economic viability of businesses providing mechanized services for rice cultivation (8). In Botswana, another examined the relationship between service timeliness and quality, on the one hand, and farm efficiency, on the other (9). These studies address the economic viability and delivery quality of services, but do not determine which tractor power is suited to the volumes of ploughing work available in Côte d'Ivoire's cotton-growing areas (8,9). Moreover, comparing each tractor at its own capacity combines two effects: the configuration's characteristics and the work volume assumed. Comparing costs at the same area therefore complements the comparison at each configuration's reference area and shows how cost rankings change when work volume is held constant.

This study examines the conditions under which mechanized ploughing services can cover their costs while meeting seasonal demand in Mankono, Kani, Kounahiri and Séguéla. It combines a survey of 702 farmers, 64 cooperatives and 28 service providers with interviews with support stakeholders, four focus group discussions and an economic simulation. The simulation compares three four-wheel-drive (4WD) tractor–plough combinations rated at 50, 75 and 100 hp. The hourly capacities are taken from studies conducted outside Côte d'Ivoire and are used as scenario parameters, not as locally measured performance. The rate of 40,000 FCFA/ha charged by the Mankono CPSAM is used as the reference for the calculations, with a central capital charge set at 12% of the initial investment. The analysis compares costs at each configuration's reference area and at the minimum annual area at which all three cover their costs. It also examines sensitivity to service rates, capital-charge rates and selected operating expenses, as well as the effect of alternative conventions for calculating the capital charge. Finally, the economic findings are considered alongside the organization of services, workshop activities and financing offers identified in the study.

2 MATERIALS AND METHODS

2.1 Study area

The study was conducted in Mankono and Kounahiri, in the Béré Region, and in Kani and Séguéla, in the Worodougou Region (Figure 1), in central and north-western Côte d'Ivoire (10). These departments fall within the intervention area of the Compagnie Ivoirienne pour le Développement des Textiles (CIDT). Cotton is grown alongside crops including maize, rice, groundnut and yam. Field operations follow the alternation of rainy and dry seasons, and demand for land preparation is concentrated at the start of the growing season.

Farmers use several power sources depending on their resources and the operation. Cooperatives and CIDT are involved in extension, input supply and cotton marketing. The ploughing services examined here are provided by farmers who own equipment, mobile private operators and the Mankono CPSAM operated by INTERCOTON.

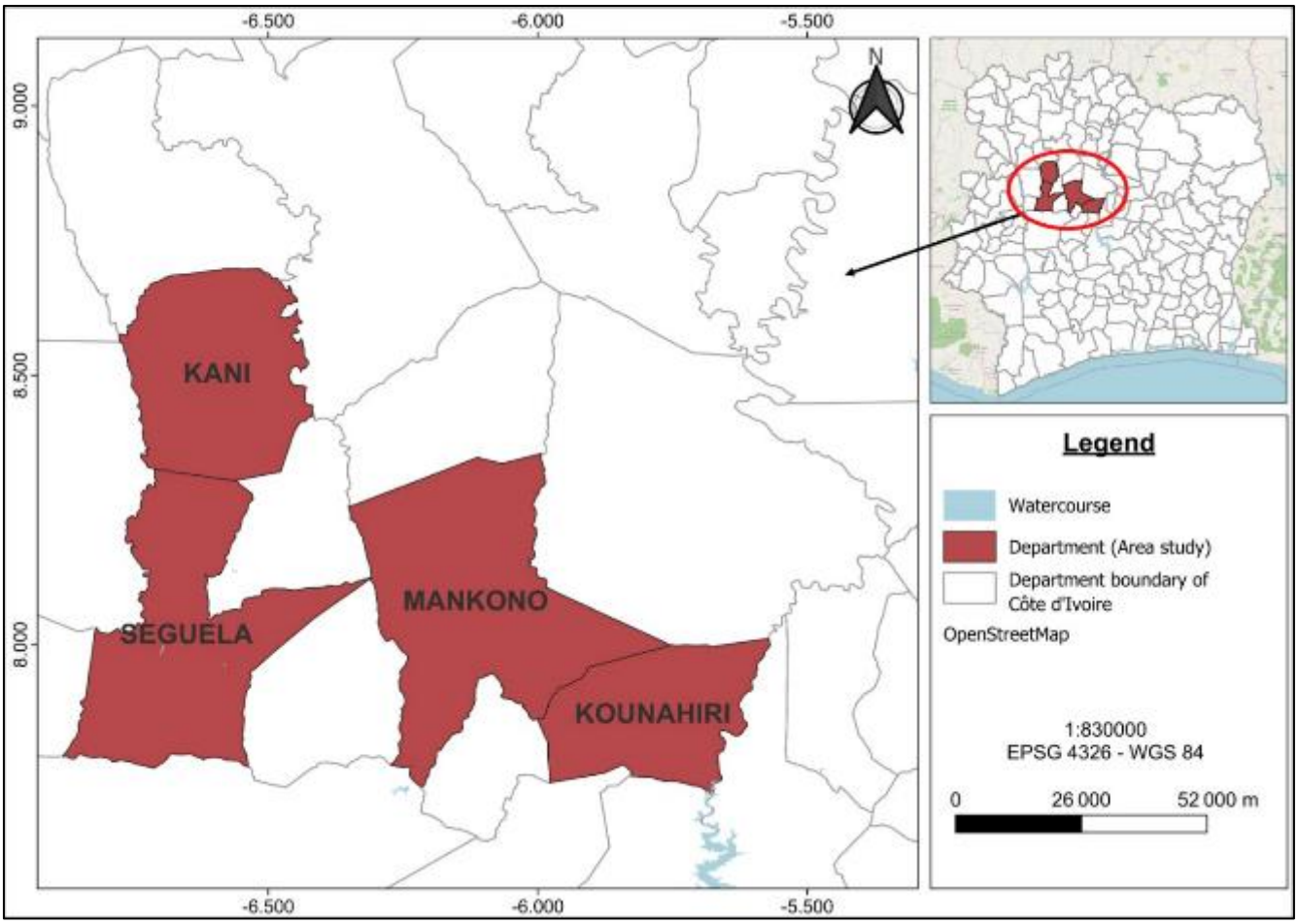


Figure 1: Location of Mankono, Kani, Kounahiri and Séguéla in Côte d'Ivoire. Red polygons indicate the study departments.

2.2 Survey design and respondent selection

This cross-sectional descriptive study combines a quantitative survey, interviews and document review with budget simulations. CIDT archives for 2023–2026 provided campaign information. Questionnaires and equipment inventories were completed in 2026; CPSAM activity records covered 2025/2026. The target population comprised farmers, cooperatives, service providers, the Mankono CPSAM, CIDT, local manufacturers and repairers, dealers, and financial institutions.

Purposive selection aimed to cover different localities, farm sizes and agricultural practices. The local sampling frame included 68 cooperatives; 64 were surveyed, while four officers were unavailable during data collection. Site selection considered location, accessibility and the average area cultivated by members, grouped into three classes: less than 5 ha, 5–10 ha and more than 10 ha. The 702 farmers were selected in the areas served by these cooperatives according to their main cultivation method and experience with hired services. Table 1 shows the distribution of surveyed units by department.

Table 1: Surveyed units by department

Survey unit	Mankono	Kani	Kounahiri	Séguéla	Total
Cooperatives	29	1	4	30	64
Farmers	219	170	119	194	702
Service providers	10	15	1	2	28
Manufacturers and repairers	5	6	5	4	20

Supplementary interviews involved 28 service providers, 20 local manufacturers and repairers, ten dealers, five financial institutions, the Mankono CPSAM and the agricultural mechanization training centre in Grand-Lahou. Service providers were selected according to their activity and service area; local manufacturers and repairers according to the work they performed; and dealers according to the brands and services they offered. Interviews with dealers and financial institutions took place in Abidjan. Interviews with CIDT addressed campaign agreements and payment collection.

2.3 Data collection and analysis

The questionnaires covered cultivation methods, cotton and food-crop areas, equipment ownership and use of hired services. Interview guides addressed demand, scheduling, rates, maintenance, spare parts, financing and management. For workshops and dealers, they also covered the equipment available, capacities, prices and sale terms. Direct observations and inventory forms were used to describe equipment and its condition; CPSAM registers provided information on completed work.

Four focus group discussions, one in each department, explored access to land, equipment, services, credit and technical information. Each session lasted about one hour and included 15 participants. Across the 60 attendances, 20 were women and 20 were young people; these categories could overlap. Discussion notes were compared with survey responses, interviews and equipment inventories.

The data were organized in Excel. Shares by main cultivation method use all 702 farmers as the denominator; mean farm area is calculated using the number of farmers in each category. Mean provider activity is the reported area divided by the number of providers. For the CPSAM, recorded hectares are divided by the eight operational tractors, and the operational share is calculated from the ten tractors inventoried.

Qualitative summaries were reviewed and coded under demand, maintenance, financing and management, following a thematic comparison approach (11). For each item, the coding retained the stakeholder, source, practice and constraint. The interaction map was constructed from the roles and direction of exchanges reported by stakeholders, then complemented with links between public financing offers and their potential beneficiaries. Arrows show the direction of reported exchanges; they do not measure their frequency or intensity.

A targeted literature search supplemented the field observations with scientific publications and the official websites of manufacturers, dealers and financial institutions.

2.4 Technical scenarios

The three scenarios pair a 50-, 75- or 100-hp four-wheel-drive (4WD) tractor with a disc plough. Total annual operating time is set at 600, 700 and 1,000 h, respectively, including 100 h of travel in each case; productive ploughing time is therefore 500, 600 and 900 h/year. Effective ploughing capacities are 0.29 ha/h for the 50-hp 4WD tractor, 0.65 ha/h for the 75-hp 4WD tractor and 0.80 ha/h for the 100-hp 4WD tractor (12–14).

The annual reference area is calculated by multiplying effective field capacity by productive ploughing hours (Table 2). This gives 145, 390 and 720 ha/year for the 50-, 75- and 100-hp tractors. The theoretical area completed during an eight-hour productive day is 2.32, 5.20 and 6.40 ha/day. These values exclude travel, breaks and downtime caused by breakdowns or plot configuration.

Table 2: Technical parameters and investment costs of the configurations

Parameter	50 hp	75 hp	100 hp
Rated power (kW)	36.8	55.2	73.5
Drive type	4WD	4WD	4WD
Total operating time (h/year)	600	700	1,000
Productive ploughing time (h/year)	500	600	900
Travel time (h/year)	100	100	100
Ploughing capacity (ha/h)	0.29	0.65	0.80
Annual reference area (ha/year)	145	390	720
Area ploughed per 8-h day (ha/day)	2.32	5.20	6.40

Fuel consumption (L/h)	6.50	9.75	13.00
Investment (million FCFA)	19.25	24.25	31.25

The annual reference area is calculated using the following formula:

$$S_{m,p} = C_{e,p} \times H_{l,p} \qquad (1)$$

$S_{m,p}$ denotes the reference area of configuration p, in ha/year; $C_{e,p}$ is its field capacity, in ha/h; and $H_{l,p}$ is its annual ploughing time, in hours.

The reference service rate T is 40,000 FCFA/ha, the rate charged by the Mankono CPSAM. It is used as the reference for all cost, balance and cost-coverage calculations. Rates of 45,000, 50,000 and 55,000 FCFA/ha are tested separately. CPSAM activity, 134.9 ha per operational tractor, is reported for descriptive purposes; it does not replace the reference areas calculated from field capacities.

2.5 Budget construction

The budget separates depreciation, insurance and the capital charge from operating expenses (15). Initial investment K_p includes the tractor, plough and shelter. The respective prices used are FCFA 15, 19 and 25 million for tractors; FCFA 2.5, 3.5 and 4.5 million for ploughs; and FCFA 1.75 million for each shelter. The holding period is five years. The assumed declining-balance depreciation rates are 25% for the tractor and plough and 10% for the shelter. For each item j, price $P_{j,p}$ and rate d_j determine its residual value after five years. Average annual depreciation D_p is calculated as follows:

$$D_p = \frac{\sum_j P_{j,p}[1-(1-d_j)^n]}{n} \qquad (2)$$

Insurance is set at a = 2.5% of K_p and maintenance and repairs at m = 5% per year. The operator's annual remuneration W is FCFA 900,000. Diesel price p_f is set at FCFA 905/L, and hourly fuel use λ_p is set at 0.13 L per horsepower (hp) per hour. These values are those used in the initial budget. Fuel expenses for ploughing vary with the area worked; travel, the operator and maintenance are treated as annual cost items. For a strictly positive annual area Q, average cost is:

$$C_p(Q;\, r, \delta) = \frac{F_p(r,\delta)}{Q} + v_p(\delta) \qquad (3)$$

The annual fixed component F_p and the area-proportional component v_p are derived from the items above:

$$F_p(r,\delta) = D_p + aK_p + rK_p + (1+\delta)[W + mK_p + p_f \lambda_p H_{n,p}] \quad (4a)$$

$$v_p(\delta) = \frac{(1+\delta)p_f \lambda_p}{C_{e,p}} \qquad (4b)$$

F_p is expressed in FCFA/year and v_p in FCFA/ha. $H_{n,p}$ represents the 100 h of travel. The coefficient r applies an annual capital charge to the initial investment. Parameter δ represents a relative increase in fuel, operator and maintenance expenses. The charge rK_p is a budgetary convention based on a constant initial investment base (16).

2.6 Financing terms reported by surveyed institutions and changes in expenses

Financial information used in this study was collected from the financial institutions interviewed. It reflects rates, terms and indicative amounts reported during interviews for financing products that may apply to agricultural equipment purchases. It should not be interpreted as a statistical estimate of the average lending rate in Côte d'Ivoire or as terms that apply uniformly to all borrowers. Four annual capital-charge coefficients are compared: 6.66%, 8.5%, 12% and 14%. The institutions reported 6.66% as an indicative rate for equipment financing. For a leasing campaign conducted from July to September 2025, they also reported rates of 8.5% excluding tax for individuals, 11% excluding tax for businesses and 12% excluding tax for liberal professions. Products for small and medium-sized enterprises, secured by a mortgage, were also reported at monthly rates of 0.85%–1% for terms of eight to sixty months. These are reported indicators, not directly comparable rates across products, borrowers and contract terms. The central coefficient of 12% is a cautious budget assumption based on the information collected from institutions. It is not an average rate observed across a sample of loan contracts. A 14% coefficient is used to test sensitivity to a higher cost of capital.

Financing information was classified by financing purpose and beneficiary category. Where a comparison required a monthly rate to be expressed on an annual basis, simple annualization by multiplying the monthly rate by twelve was used. This is a calculation convention, not an effective annual rate incorporating compounding. Application fees,

insurance premiums, collateral and payment schedules are considered separately and are not automatically included in the nominal capital coefficient. Expense changes are applied only to the relevant items, under two scenarios: δ = 3.3% and δ = 5%. These values provide a sensitivity range for operating-cost increases. They are simulation assumptions based on information reported during the survey and are not added to the nominal capital rate. Expense changes and the cost of capital are therefore treated as separate sources of uncertainty.

2.7 Cost-coverage thresholds and sensitivity analyses

The reference service rate T is 40,000 FCFA/ha, as charged by the Mankono CPSAM. Rates of 45,000, 50,000 and 55,000 FCFA/ha are also tested. For a net annual contribution M_a from other services, budget balance B_p is:

$$B_p = (T - v_p) \times Q + M_a - F_p \qquad (5)$$

$$B_p = (T - v_p) \times Q + M_a - F_p \qquad (5)$$

M_a is supplementary revenue minus only those additional expenses not already included in F_p and v_pQ. In the baseline, $M_a = 0$. Setting the balance to zero gives the annual cost-coverage area (17):

$$Q_p^* = \frac{F_p - M_a}{T - v_p} \qquad (6)$$

This expression applies when $T > v_p$ and $F_p > M_a$. If $M_a \geq F_p$ and $T \geq v_p$, costs that are independent of work volume are covered without a positive minimum area of ploughing. If $T \leq v_p$ and $F_p > M_a$, increasing the area cannot balance the budget. The threshold is compared with reference area $S_{m,p}$.

Activity levels are defined as $Q = uS_{m,p}$, with u = 25%, 50%, 75% and 100%. For each pair of r and δ values, F_p and v_p are held constant as Q varies. At full capacity, a critical coefficient r^*_p is also calculated, where G_p denotes the annual budget before the capital charge:

$$r_p^* = \frac{TS_{m,p} + M_a - G_p}{K_p} \qquad (7)$$

Finally, one alternative replaces depreciation D_p and the capital charge rK_p together with a capital-recovery annuity A_p. Given total residual value V_p after five years, the annuity is calculated as follows (15):

$$A_p = (K_p - V_p)\frac{r(1+r)^n}{(1+r)^n - 1} + rV_p \qquad (8)$$

When r = 0, $A_p = (K_p - V_p)/n$. This alternative retains the prices, residual value, operating hours and other cost items. The annuity replaces depreciation and the capital charge; it is not added to them. Deterministic comparisons cover cost per hectare, annual balance and cost-coverage areas.

2.8 Sensitivity analysis of the capital base

To assess how results depend on the base used to calculate the financial charge, a supplementary analysis compares the initial convention rK_p with an average investment base $r(K_p + V_p)/2$, where V_p is the total residual value of the equipment after five years. This second convention follows machinery-costing practice based on average capital value (15,18). Depreciation D_p, insurance, maintenance, operator costs, fuel, annual operating hours, reference areas and all other central-scenario parameters remain unchanged. This is an accounting sensitivity analysis, not a reconstruction of a loan repayment schedule. It differs from the equivalent annuity A_p, which jointly replaces $D_p + rK_p$; under the average-base convention, depreciation remains separate. The two conventions are compared at r = 12%, δ = 0 and $M_a = 0$, for cost at the reference area and for the cost-coverage threshold at the service rate T = 40,000 FCFA/ha. The average financial charge is therefore:

$$J_P^M = \frac{r(K_P + V_P)}{2} \qquad (9)$$

2.9 Ethical considerations

The study objectives, intended use of information, voluntary nature of participation and participants' right to withdraw were explained before each discussion. Participation was based on informed consent. Results are reported as aggregated data and summaries that protect participants' anonymity and the confidentiality of individual and financial information. Institutions are identified by their roles or publicly available offers.

3 RESULTS

3.1 Cultivation methods and cultivated areas

The results show that manual cultivation, animal traction and mechanized cultivation account for 48.86%, 49.43% and 1.71% of surveyed farmers, respectively. Reported areas total 3,983.75 ha, including 1,963.66 ha of cotton and 2,020.09 ha of food crops. Mean total cultivated area is 2.75, 7.50 and 36.50 ha per farm for the three mechanization categories, respectively (Table 3).

Table 3: Number of farmers and cultivated areas by cultivation method

Main cultivation method	n	Share (%)	Cotton (ha)	Food crops (ha)	Mean cotton area (ha)	Mean total area (ha)
Manual	343	48.86	308.42	634.83	0.90	2.75
Animal traction	347	49.43	1,490.24	1,112.26	4.29	7.50
Mechanized	12	1.71	165.00	273.00	13.75	36.50
Total	702	100.00	1,963.66	2,020.09	2.80	5.67

In practice, power sources complement one another. Farmers classified as using manual or animal-powered cultivation may hire a tractor for ploughing, then use hand tools or draft animals for sowing, weeding or ridging. Farmers who own motorized equipment also use animal traction for some operations.

3.2 Ploughing services and service organization

The 28 service providers reported 2,976.68 ha of ploughing, or 106.31 ha per provider. Three service models coexist. Farmers who own equipment work for neighbours after completing their own operations; mobile private providers seek jobs across a wider area; and the CPSAM organizes services using a shared fleet. Under some agreements, cooperatives aggregate requests and pass them to CIDT, which helps connect clients with operators, arrange advances and collect payment after cotton is sold.

The CPSAM had ten 60-hp tractors and ten ploughs. Eight tractors were operational at the time of inventory, representing 80% of the fleet. At the time of our visit, registers recorded 1,079 ha, or 134.9 ha per operational tractor. Reported constraints included late confirmation of demand, scattered plots, tree stumps, breakdowns, access to original spare parts, operator skills and financing. Financial institutions identified collateral, accounting records and seasonal revenues as challenges.

The interview synthesis (Figure 2) highlights the links among farmers, service providers, cooperatives, CIDT and support stakeholders. Cooperatives aggregate some requests before forwarding them to CIDT; local workshops manufacture and repair equipment, while dealers supply machinery and spare parts. Financial institutions offer products whose terms vary with the purpose of financing.

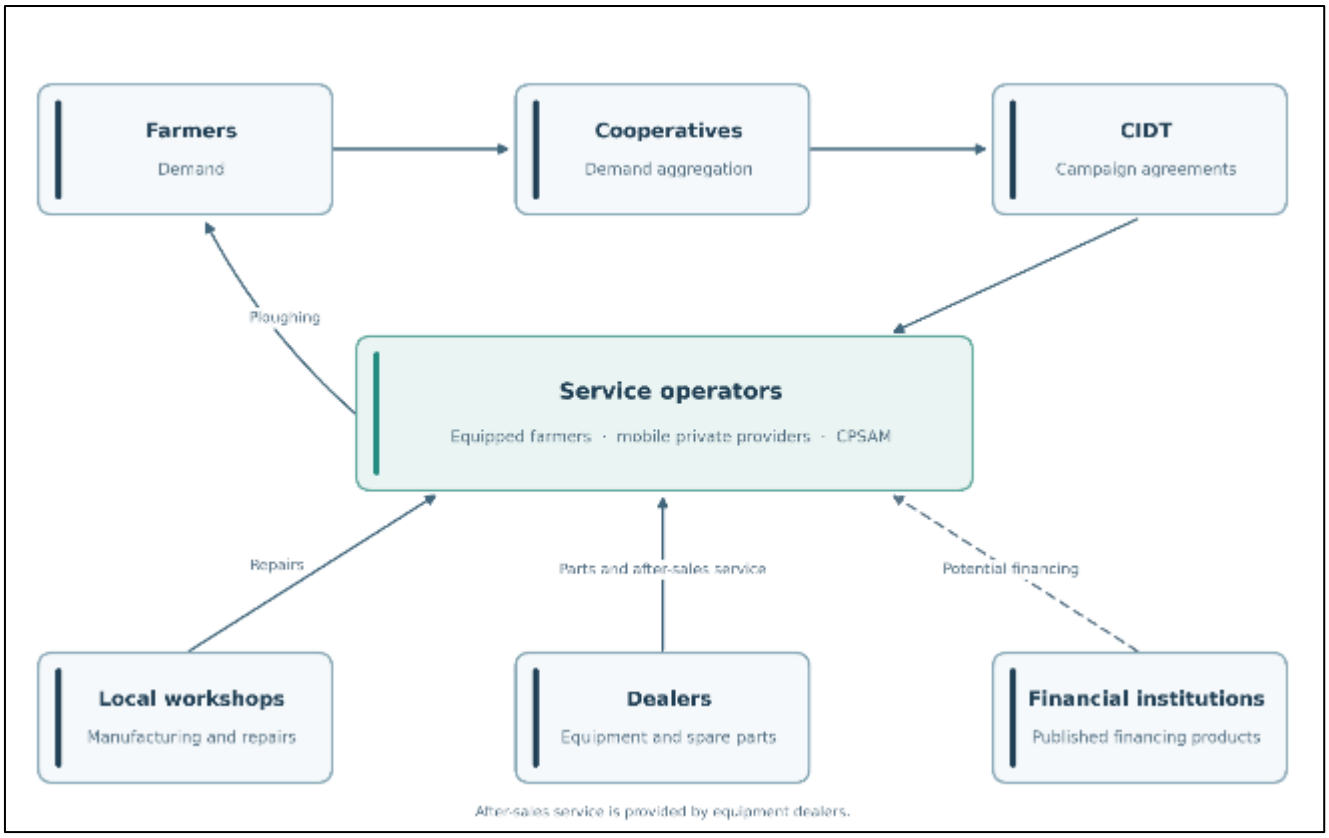


Figure 2: Relationships among stakeholders involved in service provision

Solid lines show roles reported during the survey; dashed lines connect public financing offers with potential beneficiaries. Under some campaign agreements, cooperatives act as intermediaries between farmers and CIDT. Arrows do not represent the frequency or intensity of exchanges. Source: synthesis of interviews and institutional documents.

3.3 Local manufacturers

The local manufacturers surveyed make and refurbish animal-traction equipment and sometimes adapt spare parts for agricultural machinery. Their workshops provide nearby support to farmers and equipment users. Reported work includes replacing broken parts and repairing damage caused under field conditions. Client relationships are based on direct contact and repair needs. Interviews identified needs for tools, skills and access to parts. In Côte d'Ivoire, equipment from local manufacturers may be purchased in cash or on credit under terms negotiated between the manufacturer and the farmer (6). Alongside this local support, the national market includes the activities of the Société Ivoirienne de Technologie Tropicale (I2T), which operates a mechanical design and manufacturing workshop and provides maintenance services.

3.4 Dealers

Interviews with ten dealers indicate that they offer tractors, power tillers and tillage implements, as well as spare parts and after-sales services. Their activities are mainly based in Abidjan and include mobile interventions in production areas. The information collected indicates that purchases are predominantly made in cash, although some suppliers refer customers to financial institutions. Serving remote sites requires technicians to travel and parts to be transported from commercial bases.

These findings point to complementarity between local workshops, which repair equipment, and dealers, which help supply machinery, parts and technical services. Information reported by the surveyed financial institutions indicates that several products may support the purchase of agricultural equipment. One leasing offer for movable equipment explicitly includes agricultural tractors and allows payments to be adapted to seasonal schedules, for a maximum term of four years unless an exception is granted. Another product finances new professional equipment over 12–60 months and requires, among other items, financial statements and a financing plan. A product for agricultural processing offers financing for up to 36 months. Other agricultural loans cover seasonal or production needs over periods of 3–8 months and 5–18 months, respectively. These products address distinct needs: equipment investment, agricultural processing, seasonal finance and production support. However, the information describes terms offered by institutions and is not sufficient to estimate how often farmers and service providers actually use these products.

3.5 Ploughing costs and comparison at the same area

Under the central scenario (r = 12%, δ = 0), costs at the annual reference areas are 75,835, 39,438 and 32,503 FCFA/ha for the 50-, 75- and 100-hp configurations. Compared with the reference rate of 40,000 FCFA/ha, the cost of the 50-hp configuration is higher by 35,835 FCFA/ha; the costs of the 75- and 100-hp configurations are lower by 562 and 7,497 FCFA/ha, respectively (Table 4). These comparisons use a different area for each configuration (145, 390 and 720 ha/year) and should not be interpreted as an isolated effect of tractor power. The corresponding full hourly costs are 21,992, 25,635 and 26,002 FCFA/h, obtained by multiplying cost per hectare by hourly field capacity.

Table 4: Ploughing costs at each configuration's reference area and at the minimum common cost-coverage area

Power (hp)	Reference area (ha/year)	Cost at reference area (FCFA/ha)	Difference from rate of 40,000	Cost at 506.6 ha/year (FCFA/ha)
50	145	75,835	+35,835	36,185
75	390	39,438	−562	33,486
100	720	32,503	−7,497	40,000

At a common work volume equal to the highest of the three cost-coverage thresholds, or 506.6 ha/year, calculated costs are 36,185, 33,486 and 40,000 FCFA/ha for the 50-, 75- and 100-hp tractors. At this volume, all three configurations cover their costs at the reference rate; the 75-hp tractor has the lowest cost. This comparison extrapolates the 50- and 75-hp tractors beyond their annual reference areas. Figure 3 shows how unit cost changes with annual area, while Figure 4 compares costs at the reference areas and at the common volume of 506.6 ha/year.

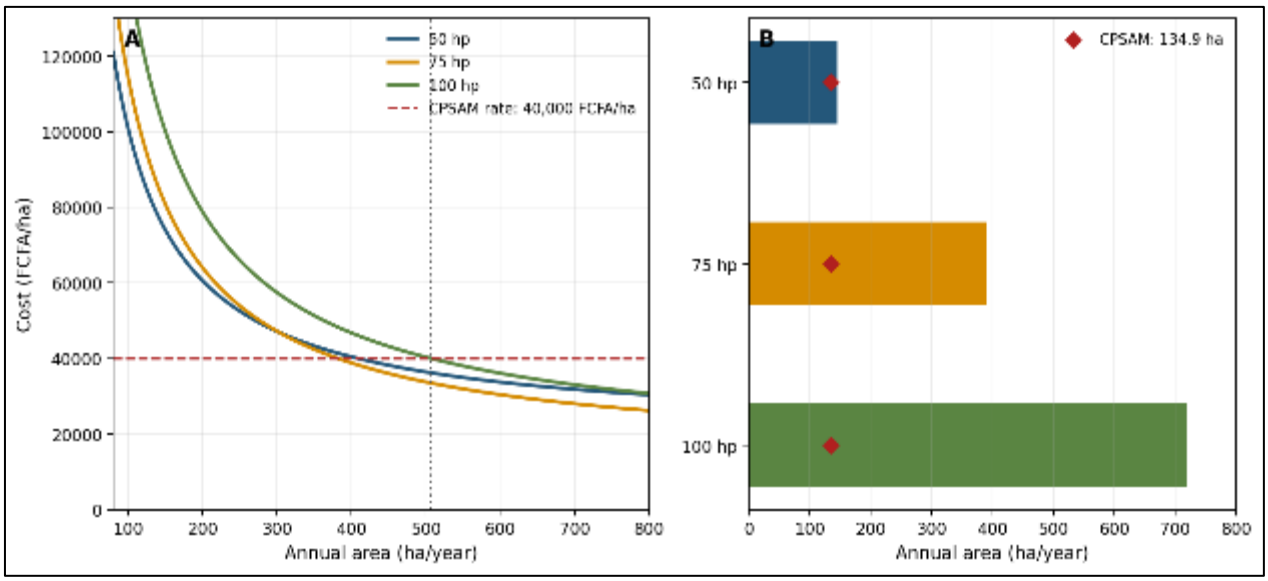


Figure 3: Ploughing costs at each configuration's reference area and at the minimum common cost-coverage area

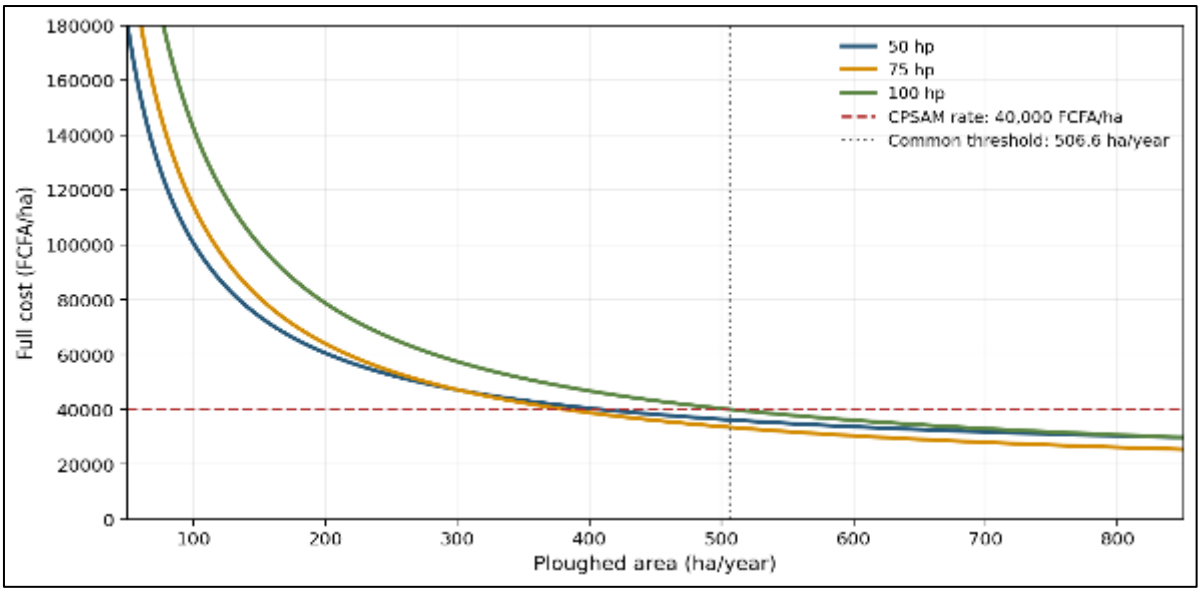


Figure 4: Ploughing costs at each configuration's reference area and at the minimum common cost-coverage area

3.6 Activity, service rates and cost-coverage areas

At 25%, 50%, 75% and 100% of their reference areas, costs for the 50-hp tractor are 296,485, 158,216, 112,126 and 75,835 FCFA/ha; for the 75-hp tractor, 58,819, 45,244, 40,719 and 39,438 FCFA/ha; and for the 100-hp tractor, 41,590, 35,296, 33,198 and 32,503 FCFA/ha. For each configuration, increasing work volume reduces the share of annual costs allocated to each hectare. These results are shown in Figure 5.

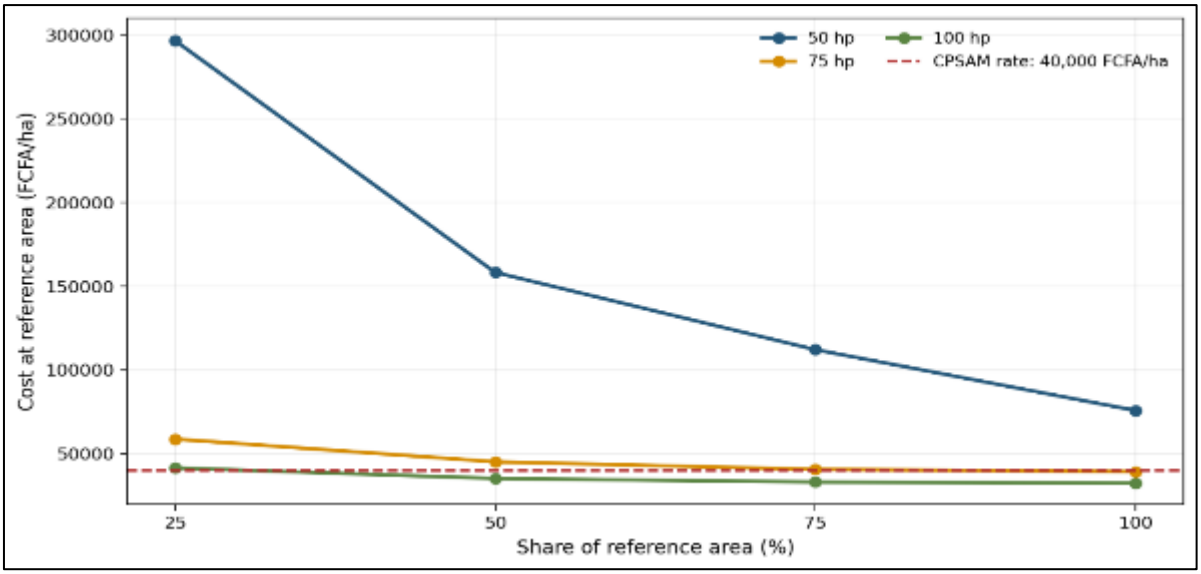


Figure 5: Effect of activity level on ploughing cost

Curves are calculated using C = F/Q + v, where Q is annual work volume (25%–100% of the reference area), r = 12% and δ = 0. Reference capacities differ across configurations, so the same percentage does not represent the same number of hectares. The red horizontal line marks the CPSAM rate of 40,000 FCFA/ha. At this rate, cost-coverage thresholds are 408.5, 381.7 and 506.6 ha/year for the 50-, 75- and 100-hp tractors. At their respective reference areas, the 50-hp tractor does not cover its costs, whereas the 75- and 100-hp tractors do. At rates of 45,000, 50,000 and 55,000 FCFA/ha, the thresholds decrease to ranges of 325.9–423.0, 271.1–363.1 and 232.0–318.0 ha/year, respectively, depending on the configuration (Table 5). At the full reference area and the 40,000 FCFA/ha rate, the 50-hp configuration has an annual deficit of FCFA 5.20 million; the 75- and 100-hp configurations have surpluses of FCFA 0.22 million and FCFA 5.40 million.

Table 5: Annual cost-coverage areas by service rate

Power (hp)	Reference area (ha/year)	40,000	45,000	50,000	55,000
50	145.0	408.5	325.9	271.1	232.0
75	390.0	381.7	321.0	276.9	243.5
100	720.0	506.6	423.0	363.1	318.0

3.7 Sensitivity to financing and expenses

At the reference areas, costs calculated at a 6.66% rate are 68,745, 36,118 and 30,185 FCFA/ha; at 8.5%, they are 71,188, 37,262 and 30,984 FCFA/ha. At 14%, costs are 78,490, 40,682 and 33,371 FCFA/ha. The critical capital coefficient is negative for the 50-hp configuration (−15.0%), meaning that it does not cover its costs even with no capital charge; it is 12.9% for the 75-hp and 29.3% for the 100-hp configuration. A 5% increase in expenses subject to δ, with r held at 12%, raises costs to 77,694, 40,501 and 33,491 FCFA/ha. Under the cautious scenario combining r = 14% and δ = 5%, costs are 80,349, 41,744 and 34,359 FCFA/ha. Corresponding thresholds are recalculated directly in the workbook using the cost-coverage formula. Costs and thresholds are summarized in Table 6. Figure 6 shows how cost at the reference area changes with the annual rate applied to initial investment.

Table 6: Costs at reference areas under alternative scenarios

Comparison	r (%)	δ (%)	50 hp	75 hp	100 hp
Banking benchmark	6.66	0.0	68,745	36,118	30,185
Historical comparator	8.50	0.0	71,188	37,262	30,984
Central scenario	12.00	0.0	75,835	39,438	32,503
Higher capital charge	14.00	0.0	78,490	40,682	33,371
Expenses +3.3%	12.00	3.3	77,062	40,139	33,155
Expenses +5%	12.00	5.0	77,694	40,501	33,491
Combined cautious scenario	14.00	5.0	80,349	41,744	34,359

Under the equivalent-annuity method, costs at the reference areas are 71,704, 37,486 and 31,129 FCFA/ha. Annual balances are −FCFA 4.60 million, +FCFA 0.98 million and +FCFA 6.39 million; cost-coverage thresholds are 378.2, 352.9 and 467.5 ha/year. At the same work volume, the 50-hp tractor remains the least costly below approximately 303 ha/year; above that level, the 75-hp tractor becomes less costly over the range considered.

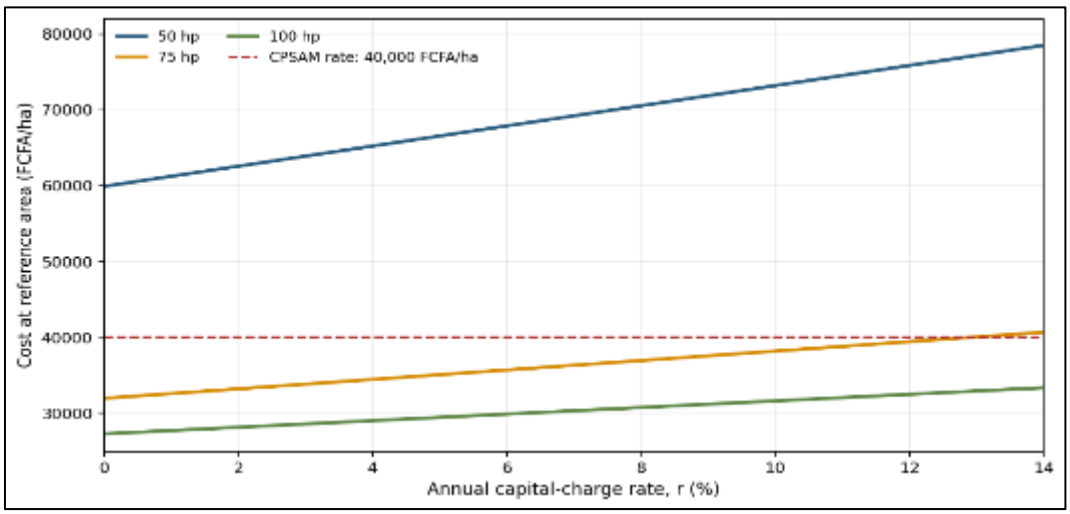


Figure 6: Financing assumptions, cost coverage and the capital-cost convention

3.8 Sensitivity to the financial charge base

After five years, total residual values are estimated at FCFA 5.19, 6.37 and 8.03 million for the 50-, 75- and 100-hp tractor–plough combinations. At r = 12%, using the average investment base reduces the annual financial charge compared with rK, without changing depreciation. Costs and thresholds under this alternative are presented in Table 7.

Table 7: Sensitivity of ploughing cost to the capital-charge base

Power	K_p / (10^6 FCFA)	V_p / (10^6 FCFA)	$C_p(S_m)$ / rK_p	$C_p(S_m)$ / average base	Q^* / rK_p	Q^* / average base
50 hp	19.25	5.19	75,835	70,015	408.5	365.7
75 hp	24.25	6.37	39,438	36,688	381.7	341.1
100 hp	31.25	8.03	32,503	30,568	506.6	451.5

Note: r = 12%; δ = 0; M_a = 0; T = 40,000 FCFA/ha. V_p is total residual value after five years. Depreciation D_p remains separate in both cost columns; the average investment base is therefore not equivalent to annuity A_p. Calculations use the parameters in Table 2 and the budget equations.

Under the D + rK convention, costs at the reference areas are 75,835, 39,438 and 32,503 FCFA/ha; with the average investment base, they fall to 70,015, 36,688 and 30,568 FCFA/ha. The respective thresholds are 408.5, 381.7 and 506.6 ha/year under D + rK, and 365.7, 341.1 and 451.5 ha/year under the average-base convention. The 50-hp tractor remains in deficit at 145 ha/year, whereas the 75- and 100-hp tractors cover their costs at their reference volumes. At the common volume of 506.6 ha/year, the 75-hp tractor has the lowest cost. Figure 7 compares costs under the two financial charge bases.

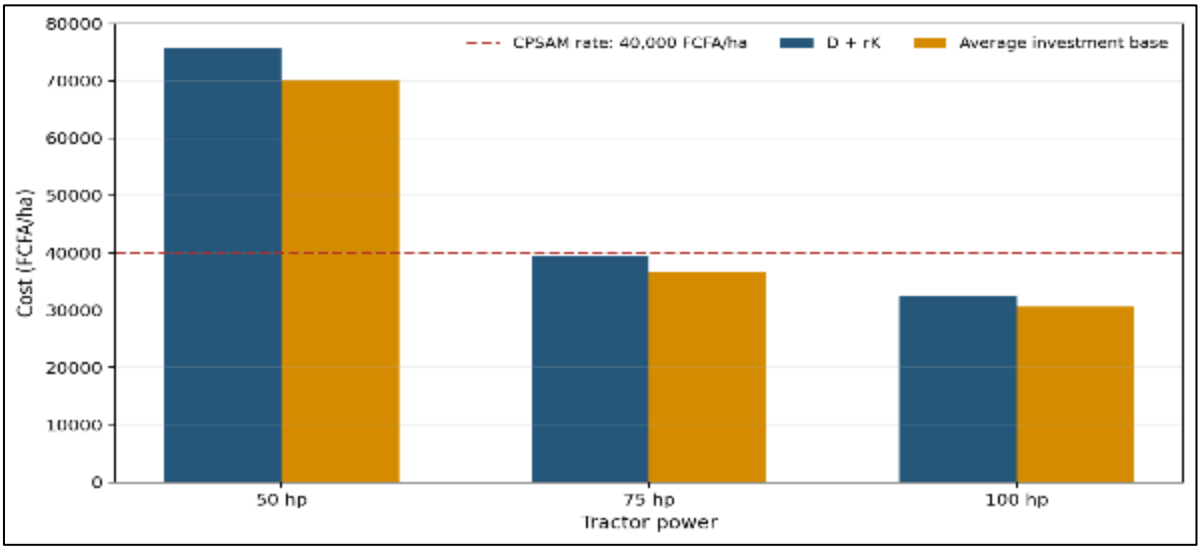


Figure 7: Financing assumptions, cost coverage and the capital-cost convention

4 DISCUSSION

4.1 Adapting services to the diversity of farms

The gap between average farm areas and the volumes required to cover costs strengthens the case for services that aggregate demand from several farmers. Access should be considered operation by operation, since tractors, animal traction and hand tools may be used in succession on the same farm. This complementarity is consistent with research on appropriate mechanization for farms and the development of service markets (2–4). A farmer's main cultivation method indicates the most commonly used techniques on the farm, while service-use data show whether that farmer hires mechanized ploughing. In this context, careful work scheduling is essential. A study of 470 farmers in Botswana highlights the relationship between service quality, timely delivery and production efficiency (9). In our study area, late confirmation of requests and scattered plots make it harder to organize work sites and complete planned areas. A service order should specify the client, location, area, operation, preferred period and payment arrangements. Cooperatives can consolidate this information and group small jobs by proximity.

4.2 Matching equipment to achievable work volumes

At their respective reference areas, costs decline from 75,835 FCFA/ha for the 50-hp tractor to 39,438 FCFA/ha for the 75-hp tractor and 32,503 FCFA/ha for the 100-hp tractor. This ranking does not show that greater engine power alone produces the lower cost. Each configuration is assessed at a different work volume: 145, 390 and 720 ha/year. The 100-hp scenario therefore assumes nearly five times as much work as the 50-hp scenario. Spreading fixed costs over more hectares reduces unit cost. The advantage observed for the 100-hp tractor thus reflects both its power and the larger work volume assumed. This interpretation is consistent with studies linking the viability of mechanized services to adequate utilization and the ability to secure a regular customer base throughout the season (3,5).

The comparison at the same area reveals a different balance. Under $C = F/Q + v$, fixed costs per hectare decline as work volume Q increases, while variable cost depends in part on the assumed field capacity and fuel use. The 50-hp tractor has the lowest cost up to approximately 303 ha/year; above that level, the 75-hp tractor is less costly than the other two within the range studied. At 506.6 ha/year, its cost is 33,486 FCFA/ha, compared with 36,185 for the 50-hp tractor and 40,000 for the 100-hp tractor. At this volume, the 75-hp configuration provides the best balance between annual costs and work capacity. However, the cost crossover at around 303 ha/year should not be confused with the rate-based cost-coverage threshold: at 40,000 FCFA/ha, the thresholds are 408.5, 381.7 and 506.6 ha/year for the 50-, 75- and 100-hp tractors. The 50-hp tractor can therefore have the lowest cost at a low work volume and still operate at a deficit; similarly, the 75-hp tractor covers its costs only above a volume higher than its crossover point with the 50-hp tractor. Equipment choice must account for both the cost ranking and the activity level needed to cover costs.

The CPSAM benchmark of 134.9 ha per operational tractor is close to the 145 ha/year reference volume for the 50-hp scenario. This proximity provides a useful order of magnitude but does not validate the simulation directly: the CPSAM fleet consists of 60-hp tractors. The 390 and 720 ha/year reference volumes require approximately 2.9 and 5.3 times the area recorded per operational CPSAM tractor. They therefore require a larger customer base and more intensive work scheduling. For the 100-hp scenario, 900 productive hours correspond to 112.5 eight-hour workdays; the assumed 100 h of travel add the equivalent of 12.5 days, excluding breakdowns and other stoppages. This shows that the calculated capacity can be achieved only if orders are confirmed early enough, plots are grouped and the operating season is long enough. In practice, the 100-hp tractor is justified only when a large work volume can be mobilized; choices between 50 and 75 hp should be based on confirmed demand and the corresponding cost-coverage threshold.

4.3 Cost coverage and the cost of capital

In the baseline scenario, at a rate of 40,000 FCFA/ha, the 50-hp configuration does not cover its costs at its reference area: cost is 75,835 FCFA/ha and the annual deficit is FCFA 5.20 million. The 75- and 100-hp configurations cover their costs at their reference work volumes, with costs of 39,438 and 32,503 FCFA/ha. Switching to an equivalent annuity lowers these costs but does not make the 50-hp scenario cost-covering. The results underline the need to define the cost-of-capital method explicitly; the equivalent annuity replaces depreciation and the conventional financial charge, in line with the capital-recovery method described in (15).

Using the average investment base lowers costs at the reference areas to 70,015, 36,688 and 30,568 FCFA/ha. Cost-coverage thresholds fall to 365.7, 341.1 and 451.5 ha/year, but the 50-hp tractor remains below its threshold at 145 ha/year. This alternative is not equivalent to the annuity method: it replaces only rK with $r(K + V)/2$ and keeps depreciation separate. Judgments about cost coverage therefore depend on the convention used and cannot substitute for an actual loan repayment schedule.

Viability also depends on service rates, fuel, maintenance, spare-part availability and the regularity of demand. Studies of mechanized rice services in Côte d'Ivoire likewise show that costs and revenue vary with business size, equipment and service area (8). Additional service margins should be counted only after deducting the extra expenses incurred for those services (19,5).

4.4 Coordinating financing, maintenance and service delivery

The financing offers reviewed show that agricultural tractors can be acquired through leasing. Access depends, however, on the application, required collateral and proposed payment schedule. Seasonal lease payments may better suit service providers whose revenues arrive at particular times of year. Confirmed service orders under contract and regular monitoring of customer payments may also support a financing application. Financing for a production season, an agricultural processing activity and a tractor purchase should be distinguished because the amounts required and repayment periods differ.

Reliable service delivery also depends on equipment maintenance and repair. Local workshops provide nearby support, while dealers supply spare parts and technical assistance for the equipment they sell. To coordinate these roles, it would be useful to identify contacts, check machine condition before each season and specify how breakdowns will be handled.

Support for local manufacturers should also include practical training, workshop equipment, parts quality and business record-keeping. Studies of animal traction in Côte d'Ivoire likewise emphasize the role of these artisans and the importance of access to finance (6).

4.5 Implications for mechanization policy

The results show that tractor choice should reflect the customer base to be served and how services are organized. Public support could prioritize proposals based on confirmed areas, grouped work sites, trained operators and regular equipment maintenance. Cooperatives and CIDT can help organize this activity without necessarily owning the machines. A designated manager should track service orders, operating hours, fuel use, machine downtime, invoices and payments received.

Service organization should also address the access difficulties reported by women and young people. Grouping requests for small plots and clearly explaining user-priority rules can help include them in the work schedule. Tool selection and operating conditions should also account for soil moisture, working depth, slope and repeated machinery passes. This approach links service viability, access for different farmer groups and natural-resource conservation, in keeping with the African framework for sustainable agricultural mechanization (20).

5 CONCLUSION

This study examined access to mechanized ploughing and the economic viability of equipment in the departments of Mankono, Kani, Kounahiri and Séguéla. The results show that farmers combine manual labour, animal traction and mechanized services according to the operation and their access to equipment. Farmers who own machinery, private service providers and the Mankono service centre all contribute to local mechanized ploughing services.

The economic analysis shows that equipment choice depends on the volume of work that can actually be secured. At the CPSAM rate of 40,000 FCFA/ha, the minimum common area at which all three configurations cover their costs is 506.6 ha/year. At this volume, the 75-hp tractor has the lowest cost (33,486 FCFA/ha). When tractors are compared at the same area, the 50-hp tractor remains the least costly up to approximately 303 ha/year; above that point, the 75-hp tractor becomes less costly over the range examined. At its own reference area, the 100-hp tractor has the lowest unit cost, but this comparison assumes that 720 ha/year can actually be completed.

In the central scenario, the 50-hp configuration does not cover its costs at 145 ha/year. The 75- and 100-hp configurations cover their costs at their reference volumes of 390 and 720 ha/year. Both the equivalent-annuity method and the average investment base reduce annualized fixed costs, without changing this conclusion for the 50-hp tractor. These findings remain conditional on hourly capacities drawn from studies conducted outside Côte d'Ivoire, including the use of a class-level value for the 100-hp tractor; local field trials are needed before these capacities can be treated as guaranteed performance.

Before investing, decision-makers should confirm the area that can actually be served, work dates and payment terms. Cooperatives and CIDT can help aggregate demand and schedule operations. Tracking productive hours, hectares, stoppages, fuel and payments for each machine would then make it possible to compare the assumptions with observed performance across seasons.

Rated power alone does not determine which tractor has the lowest cost. The choice should reflect work volume, the seasonal calendar, soil conditions and the convention used to value capital. The model provides a framework for comparison that should be complemented by local capacity measurements and up-to-date prices in Côte d'Ivoire.

STATEMENTS ON COMPLIANCE WITH ETHICAL STANDARDS

Acknowledgments

The authors thank the Compagnie Ivoirienne pour le Développement des Textiles (CIDT) for its support and for facilitating access to field data. They also express their gratitude to the agricultural cooperatives of Mankono, Kounahiri, Séguéla and Kani, and to their members, for their availability and their participation in the survey.

Disclosure of conflict of interest

The authors declare no conflicts of interest regarding this manuscript.

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