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Assessment of techno-economic feasibility of conservation agriculture planter for planting of soybean in south coastal region of Bangladesh

Mohammad Abdul Mottalib [1,*], Mohammad Ayub Hossain [2], Muhammad Arshadul Hoque [3], Mohammad Ataur Rahman [4], Arafat Ullah Khan [5], Noor Mohammod [6], A.K.M. Apel Mahmud [6] and Mohammad Monjurul Alam [7]

[1] *Scientific Officer, Spices Research Center, Bangladesh Agricultural Research Institute (BARI), Shibganj, Bogura-5810, Bangladesh.*
[2] *Director (Training & Communication Wing), Farm Machinery and Postharvest Process Engineering Division (FMPED), Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur-1701, Bangladesh.*
[3] *Senior Scientific Officer, Farm Machinery and Postharvest Process Engineering Division (FMPED), Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur-1701, Bangladesh.*
[4] *Scientific Officer, Farm Machinery and Postharvest Process Engineering Division (FMPED), Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur-1701, Bangladesh.*
[5] *Scientific Officer, Farm Machinery and Postharvest Technology Division (FMPHT), Bangladesh Rice Research Institute (BRRI), Joydebpur, Gazipur-1701, Bangladesh.*
[6] *Executive Engineer, Bangladesh Agricultural Development Corporation (BADC), Dhaka-1215, Bangladesh.*
[7] *Professor, Department of Farm Power and Machinery (FPM), Bangladesh Agricultural University, Mymensingh-2202, Bangladesh.*

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Abstract

The aim of this article is to evaluate the economic viability of soybean cultivation using BARI developed conservation agriculture (CA) based seed planter. This machine was tested and evaluated for planting of soybean in the farmers' fields at Charwapda village of Subornachar Upazila of Noakhali district during *Rabi* (Dry winter) season of 2018 and 2019. This study was designed in randomized block design with three treatments and four replications i.e. planting by reduced tillage (RT), conventional tillage and broadcasting method (CT) and dibbling method (DB). Results revealed that the planter effective field capacity and conventional tillage with power tiller (PT) for dry land preparation was found to be 0.078, and 0.033 hah^{-1}, respectively. Less time (43%) required for planting by planter than PT. Costs saved by RT were 27 and 57%, respectively over CT and DB methods. Saving of fuel consumption was 10.00 Lha^{-1} and reduced carbon (20%) emission to the atmosphere. Significantly the highest economic return (MBCR) was obtained from RT (1.63) planted soybean followed by DB (1.29) and CT (1.16) methods. Considering 10% interest rate, the NPV of the investment were found positive (BDT 97783) as well as estimated IRR was as 34% (>bank interest rate 10%) which reveals the machine investment is considered financially viable. The break-even use and payback period of machine was assessed as 9.65 ha of land per year and 2.71 years, respectively. Therefore, CA seed planter machine may be recommended as profitable for soybean planting in the south coastal region in Bangladesh.

Keywords: BARI CA Seed Planter; South Coastal Region; Power Tiller; Soybean

* Corresponding author: Mohammad Abdul Mottalib

1. Introduction

Smallholder agriculture is the mainstay of food production in the world's developing countries and is the key to ensuring long-term global food security [1]. It plays a dominating role in Bangladesh economy in terms of food security, value addition and employment. But Bangladesh is one of the most vulnerable countries especially her south coastal region due to climate change particularly increasing temperatures, sea level rise, increased storm frequency [2], and altered rainfall patterns [3] because of its geographic location, low income and greater dependence on climate sensitive sectors, particularly agriculture. Drought, heavy rainfall, soil and water salinity, tidal flood and water logging make delay in *Rabi* (mid-November to mid-March: dry winter) crop cultivation and sometimes damage crops during harvesting period. Generally, this region is under the constant threat of soil and water salinization. These are being created negative impact on soil fertility and crop productivity, which under pins the rural economy of coastal Bangladesh. About 30-50% of net cropped areas remain fallow in *Rabi* and *Kharif-1* (mid-March to mid-July: pre-monsoon) seasons in the coastal region, mainly due to high soil and surface water salinity, unavailability of fresh water for irrigation, drought and uneven/heavy rainfall during crop cultivation etc. [4]. So, the people of the coastal areas are trying different agricultural practices to survive with the changing climate. In this area, there is a big amount of *Charland* (alluvial land) which is suitable for soybean cultivation. Soybean is the second most profitable crop in Noakhali and Laxmipur districts [5] and classified as a moderately salt-sensitive crop [6]. Soybean cultivation in general requires less irrigation and less fertilizer. Local demand of soybean is high for preparation of poultry, animal and fish feed. Eventually, with the increase in price of soybean, production system has not changed significantly. It is expected that technological change required at the farmer level for the improvement of this sector. Improved technologies such as improved seed, line sowing, recommended fertilizer and plant protection measures increase the yield of soybean. For successful cultivation of soybean, land preparation and seed planting are very important. Generally, farmers in study area, plant soybean after *Aman* (mid-July-mid-November: monsoon) rice with 4-5 numbers of ploughing followed by laddering by power tiller (PT) [7] or four-wheel tractor and hand broadcasting of seeds. The existing full tillage system methods of land preparation and sowing operations are expensive and time-consuming for crop production which is being delayed by 10-15 days. Delay sowing/planting reduces yield significantly [8]. In addition, this traditional intensive tillage is claimed to be one of main sources of GHGs (greenhouse gas) emitted in the atmosphere. This results in climate change which, in turn, negatively affects agricultural production [9] and also reduces soil organic carbon at double rate and decreases soil fertility [10], losses irrigation water and soils [11], and damages ecological environment [10]. Again, repetitive tillage requires significant amounts of fuel and energy [12] and results in increased production cost and reduced profit [13]. Alternative practices include the use of appropriate CA based tillage and planting machinery which further reduces fuel costs by eliminating repetitive tillage. Reduced tillage methods saved 94 liters fuel per hectare per year and emission 44% less CO_2 into the atmosphere [14]. The innovation of CA tillage technique such as zero, strip and minimum or reduced tillage is to avoid repeated ploughing of the soil, which saves time, energy and labor, conserving water and nutrients in the soil to support sustainable crop production.CA based tillage technology permits direct seeding by single or two pass of seed planter operated by PT utilizing the residual soil moisture available immediate after monsoon rice harvest [15]. Based on this criterion, there is a big prospect for accelerating the CA based tillage cum seeding technology in the farmers' field of this region. Aiming at the reduction of cost of cultivation and maintaining the sustainability of soil crop agro ecosystem, most of the CA based tillage and seeding methods were practiced in the northern and west-northern regions of Bangladesh. But limited CA is practiced in the southern region where soils and environment are quite different from other regions of the country. In this contrast, an attempt has been taken for testing, adoption and popularization of CA based eco-sustainable tillage cum planting machinery in the agro-ecological conditions of southern areas of Bangladesh to enhance crop productivity. Therefore, this study was undertaken to evaluate the techno-economic feasibility of Bangladesh Agricultural Research Institute (BARI) developed CA seed planter machine for planting of soybean at field conditions in the south coastal region of Bangladesh.

2. Materials and Methods

2.1. Study area

Field experiments were conducted in the farmers' field of Charwapda, Subornachar, Noakhali (22°70029̍ north latitude and 91°10641̍ east longitude, Figure 1) a sub-tropical climate during *Rabi* season of 2018 and 2019 for testing, adoption and popularization of different conservation machinery such as zero till planter (ZT), strip till planter (ST), and reduced till planter (RT) methods along with conventional tilling and sowing method. The existing major cropping pattern was transplanted Aman-soybean/watermelon-fallow. But now soybean competes with crops like *Boro* rice (winter season rice), water melon and groundnut in this area. The land type was medium high land but inundates with flood in monsoon. The soil type was clay loam with soil pH of 7.8 and bulk density was 1.34 gcc^{-1} at 0-15 cm depth. The variety of soybean was BARI Shohag which is popular variety of soybean in this region. Before soybean planting, the soil was very moist (above 30%, wb) due to late monsoon (mid-October to mid-November) and as well as poor drainage system. Soybean seed is sensitive to soil moisture for its proper germination. As a result, seed was damaged in ZT and ST planted fields both 2018 and 2019. So, ZT and ST treatments could not be practiced in the field experiments.

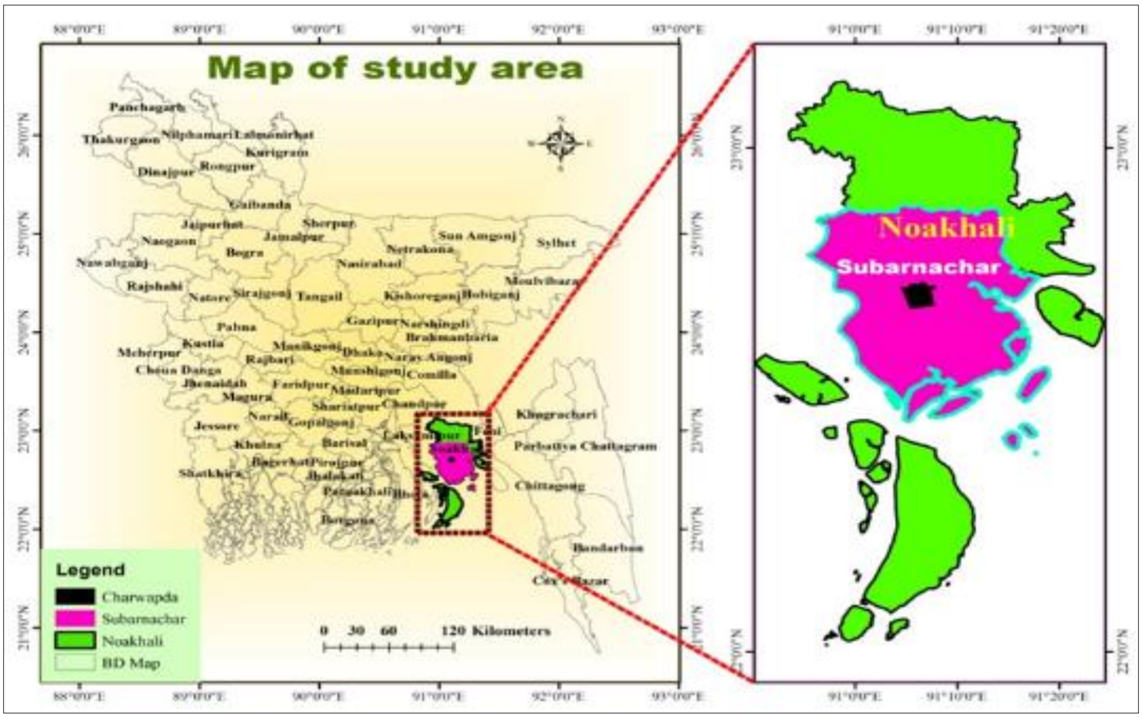

Figure 1 Map of study area

2.2. Machine description

Power tiller (PT) operated BARI seed planter or BARI CA seed planter machine (Figure 2) was developed by Farm Machinery and Postharvest Process Engineering Division (FMPE) of Bangladesh Agricultural Research Institute (BARI) [16]. This machine has basically two main units: power unit, tilling cum planting unit. PT (12-16 hp) is used as driving unit and locally made planter which is hitched with PT used as tilling and planting unit. BARI CA seed planter is used for shallow tilling followed by planting and seed covering in single pass. It is an appropriate technology which can utilize residual soil moisture for crop establishment, reduce turnaround time, cost reduction and manage crop residue properly. Inclined plate type seed metering devices are used for planting of different crops like maize, jute, wheat, pulses and oilseeds directly. Seeds are placed at uniform depth, covered, compacted and maintains uniform population. This machine consists of 48 numbers of C type rotating blades arranged in face to face alternate outside configuration for pulverizing soil at shallow depth with very high speed (450-500 rpm) and having inverted 'T' furrow opener for furrow opening and seed dropping in the furrow properly. The arrangement and number of furrow opener and blades depends on the line spacing of crop to be grown. The planting part is attached with PT replacing the rotavator part. This machine is accomplished three operations in a single pass shallow tillage (up to 60 mm), placement of seed in a furrow and leveling cum pressing [17]. Three types of combined tilling operations such as ZT (Zero tillage), ST (Strip tillage), and reduced (RT) can be performed well with this machine by arranging rotary blades at optimum moisture content of 15 to 30% of soil moisture level [7]. It is able to complete planting operation in a single pass and average field capacity is 0.10-0.14 hah^{-1}. In strip tillage method, 15^0 tip angle rotary blades are used for proper back filling of soil in the furrow [18]. The rotating blades is reduced to 24 numbers and each four blades is arranged in face to face alternate inside configuration remain in the gang at front position of seed furrow opener for tilling in strip 5-6 cm and creating tilt soil just in front of furrow openers and between the two furrow openers the soil remained untilled [19], four blades are arranged for tillage [20]. Zero tillage can be done by removing the all rotary blades.

Figure 2 Pictorial view of BARI CA planter and its field operation.

2.3. Experimental design

The design of the experiment was randomized complete block design (RCBD) with three treatments and four replications. The number of intervention farmers was 12. The unit plot area was 35-40 decimal (1400-1600 m^2) and total cultivated land area was 2.00 ha. Total three treatments combinations including a control were distributed randomly in each farmer plot as one treatment as well as one replication. The treatments were T_1- Planting by PT operated planter or reduced tillage cum planting (RT) i.e. one tillage by PT and another by PT operated seeder with line sowing, T_2- Conventional tillage (CT) i.e. three tillages by PT and broadcasting method (farmers' practice), and T_3- Dibbling method (DB) i.e. three tillages by PT and line sowing by manual dibbling method. Generally, farmers of this study area are being practiced of planting of soybean in between mid-December and mid-January. Conventional tillage cum broadcasting method is usually followed by most of the farmers of Bangladesh. But soybean planting of dibbling method is gaining popularity among the farmers in this area quickly due to its high yield potential land less labour requirement during weeding/harvesting period from conventional broadcasting method. Dibbling is actually manual line sowing in which inserting a seed through a hole at a desired depth and covering the hole. It requires more time, energy and cost, but maintains uniform population per unit area. The seed rate of soybean in RT, CT and DB methods were 30, 40 and 28 $kgha^{-1}$, respectively with line and spacing was 30cm×5cm for RT and 20cm×8cm for dibbling method, respectively. Generally, farmers use fresh harvested soybean seed for planting that had been grown in high land of this study area during late *Kharif-2* season. The fertilizers were applied at the rate of urea 45, TSP 75, MoP 40, and Gypsum 20 $kgha^{-1}$, respectively. TSP, MP, and Gypsum fertilizer was applied as basal during final land preparation and urea was applied as top dress after 45 DAS (days after sowing) for RT and conventional tillage methods (CT & DB). One weeding was done after 10-15 DAS for RT and conventional tillage methods. No irrigation was applied to the soybean field because farmers in this region depend on winter rainfall for their crop cultivation. Again, during the growing stage of soybean no rainfall was occurred in this region. As a result, some soybean seedling and plant was damaged due to high soil salinity ranged from 9-12 dsm^{-2} during drought period (early March to mid-April). Figure 3 shows the pictorial views of soybean germinated crops of different cultivation methods. The crop was harvested (110 to120 DAS) in between late April through early May when the matured soybean plant turned yellow in colour and leaves senescence occur. The harvested plants were dried in the sun for 3-7 days and then threshed by beating with a wooden stick. The separated seeds were cleaned and then dried up to the moisture content of 12-14% (wb) for storing.

Broadcasted soybean field | BARI CA planter planted soybean field | Soybean field planted by dibbling method

Figure 3 Pictorial views of soybean germinated crops of different cultivation methods

2.4. Data collection and analytical technique

Data was collected from primary and secondary sources. Primary data were collected from field experiment during *Rabi* season in the years of 2018 and 2019. Required data were collected through testing of CA planters to measure technical performance and economics over conventional system. Data and relevant information were collected through personal interviews; focus group discussion (FGD), and key informant's interviews (KII) with local stakeholders. Scientific paper, books, journals, published reports and theses, etc. were included as the secondary sources of data. The collected data were edited, summarized, tabulated and analyzed based on tabular and descriptive techniques to fulfill the objectives of the study. Descriptive and tabular statistics using different statistical tools like averages, percentages and ratios were used in presenting the results of the study. Higher production and profit are the two most important factors to motivate farmers towards any new technology. A detailed cost-benefit analysis was done for soybean cultivated farmers using tabular analyses techniques.

2.5. Performance parameters of CA seed planter

The planting operation was carried out to determine and examine the performance of machine data such as forward speed of machine operation, depth of tilling, theoretical field capacity, effective field capacity, field efficiency, fuel consumption, operator and labour wages. The investigation into the field efficiency and effective field of the planter involved continuous observation and timing of each activity involved in the planting operation. Two persons were involved in the determination of the field efficiency, one person operated the planter while the other person observed and recorded the time. The time losses were recorded such as machine adjusting, refueling, turning at ends, clogging, adding seed etc. Field performance parameters of machine operation was determined using the following equations [21]

Forward speed $S = \frac{3.6\,D}{t}, \frac{km}{h}$ (1)

Where, S =Forward speed, kmh^{-1}; D= Distance, m; and t = time, s

Theoretical field capacity $T.F.C = \frac{Sw}{10}, \frac{ha}{h}$ (2)

Where, T.F.C. = Theoretical field capacity, hah^{-1}; S =Forward speed, kmh^{-1} and w= Width of tilling, m

Depth of tilling: Depth of tilling was determined by placing a measuring scale vertically at the center of the cut area of a particular spot.

Effective field capacity $E.F.C = \frac{A}{T}, \frac{ha}{h}$ (3)

Where, E.F.C. = Effective field capacity, hah^{-1}; A= Actual operational area covered, ha; and T= Total operating time, h

Field efficiency $E_f = \frac{EFC}{TFC} \times 100$ (4)

Where, E_f= Field efficiency, %; E.F.C. = Effective field capacity, hah^{-1}; T.F.C. = Theoretical field capacity, hah^{-1};

Fuel consumption $F_c = \frac{F}{T}$ (5)

Where, F_c = fuel consumption (Lh^{-1}); F = re-filled quantity of fuel (L), T = Operational time (h)

Operator wages: The wages were calculated on the basis of actual wages, food contributions, transport cost etc. of the workers. As well, the amount of human labour involved in each operation was investigated through field measurements.

2.6. Costs benefits analysis

Cost benefits analysis is a method that applies a systematic process for calculating and comparing benefits and costs of investments. It is a widely used financial and economic approach for assessing whether the benefits of a particular action are greater than its costs. This analysis was taken into consideration for an alternative evaluation of use of RT method comparison with different tilling and planting methods in the farmer's field. As a financial analysis of soybean cultivation using RT method, farm budget analysis was conducted. For this analysis, net benefit was primarily used on the basis of total production.Net benefit was calculated by gross benefit minus production cost, which includes costs of seeds, fertilizers, pesticides, hired labour, machinery costs etc. as sell as the cost of land rent, family labour, owner cost and self-reliant fertilizer such as manure was not considered. The gross benefit of crop production consists of both similar/increases yield and reduction of farming cost. The benefits (sales revenue) were estimated at farm-gate price of product. Machinery cost consists of fixed cost-plus operation cost and the fixed cost mainly consists of depreciation (D) cost, interest on investment (I) and shelter, tax, insurance (STI). Variable costs included cost of machine operator, labour for planting, fuel, oil & lubrication, repair & maintenance and miscellaneous, respectively. The cost of operator was calculated from the actual labour charges including direct wages, food contributions, transport costs etc. at the prevailing rates in this study area (BDTday^{-1}). The price of the machine (P) was BDT190000 with PT and economic life of machine (L) was considered 5 years having working duration of 30 days (300 hours) per year. Besides, payment for new machine replacement of old machine after economic life was estimated which considered as fixed cost. Based on common standard machine service charge (hectare basis) practiced by most farmers in the study areas, the rent out charge for custom hire service (CHS) business was also worked out by total cost of machine operation plus estimated profit. The sinking fund method was used for calculating depreciation and payment for replacement of machine. Cost of conventional tilling and planting methods were also recorded for cost comparison with RT method. Thus, the total cost of planting was the sum of fixed cost and variable cost of the RT method. The fixed cost and variable cost, and production cost was calculated as per following formula [22].

Salvage value, S = 10% of P (6)

Depreciation, $D = \left[(P-S)\left\{\frac{(1+i)^L-(1+i)^n}{(1+i)^L-1}\right\}+S\right]-\left[(P-S)\left\{\frac{(1+i)^L-(1+i)^{n+1}}{(1+i)^L-1}\right\}+S\right]$ (7)

Interest, $I=\frac{P+S}{2}\times i$ (8)

Shelter, tax and insurance, STI= 2.5% of P (9)

Payment for replacement, $\text{PFR}=(P-S)\times\frac{i}{(1+i)^L-1}$ (10)

Fuel, F= Fuel price (BDTL^{-1}) × Specific fuel consumption (Lh^{-1}) (11)

Oil & lubrication cost, O&L=15% of fuel cost (12)

Repair and maintenance = 3.5% of P (13)

Where, P= Purchase price of machine (P), BDT; S=Salvage value (10% of P), BDT; L= Effective working life of machine, yr; i= annual bank interest rate, 10%; = age of the machine in years at the beginning of the year (1, 2, 3,...n), yr;

2.7. Economic viability

The aim of this study is to compare the economic viability assessment of RT tilling and planting method over conventional methods. For an overall assessment, the analyst need only compute the difference in operating profits or the flow balances. The return on investment was measured by comparing the incremental investment costs flow with the net incremental benefits flow. The discount cash flow analysis commonly used in agricultural investments was used to measure the economic viability of the average earning power of an investment over the total life. For the base case, a value of 10% was considered. To justify if an investment is economically feasible, generally four decision criteria, Net Present Value (NPV), Benefit cost ratio (BCR), payback period (PBP) and Internal Rate of Return (IRR) were used and calculated as per following formula. A variety of profitability criteria was applied to the costs and benefits provided by the different accounts. The principal criteria used are:

2.7.1. Net present value

The net present value (NPV) is the discounted present value of the annual benefits minus the discounted present value of the annual costs throughout the life span of an investment. The NPV was calculated by the following equation:

$$\boldsymbol{NPV=\sum_{n=1}^{N}\frac{B_n-C_n}{(1+r)^{n-1}}} \quad (14)$$

Where, N=number of years; n= the year in a series ranging from 1 to N; B_n= discounted gross benefits in year n, and C_n= discounted total costs in year n, and r= discount (interest) rate, %; In the formula, $1/(1+r)^{n-1}$ is called "Present Value Factor" at discount rate of r.

2.7.2. Benefit cost ratio

The analysis of benefit-cost ratio (BCR) criterion is simple in principle and rapid indication of overall return on investment. Several types of benefit-cost ratio exist. Non-discounted BCR is calculated by dividing the sum of net benefits by the total cost of investments and investment renewal and discounted BCR is the ratio obtained when the sum of the discounted total discounted benefits is divided by the sum of the discounted total discounted costs over all years of machine life. BCR was calculated by using the following formula.

$$\boldsymbol{BCR} = \sum_{n=1}^{N} \frac{\frac{B_n}{(1+r)^{n-1}}}{\frac{C_n}{(1+r)^{n-1}}} \tag{15}$$

The investment is economically acceptable as long as more than unity.

2.7.3. Internal rate of return

Internal rate of return (IRR) is the discount rate for which the net present value of a project is zero or the benefit cost ratio is equal to unity. This rate means that the present value of the cash inflows for the investment would equal the present value of its outflows. In mathematical terms

$$\boldsymbol{NPV} = \sum_{n=1}^{N} \frac{B_n - C_n}{(1+IRR)^{n-1}} = 0 \tag{16}$$

2.7.4. Payback period

The payback period (PBP) of an investment is the next level of payback period where the cash flows are discounted before calculating the period of payback. The payback period is the break-even point in time. The payback period result usually appears in decimal years. Shorter the payback period, better it will be the investment on a machine and could be feasible. PBP of a machine can be estimated for the lifetime of machine operation (5 years) according to the following equation:

$$PBP = n + \frac{A}{B} \tag{17}$$

Where, A = Net cash inflow in the investment year, BDTyr^{-1}; and B = Net cash inflow in the last year of machine operation. BDTyr^{-1}

2.7.5. Breakeven use analysis

Break-even use (BEU) analysis is constrained such that the present value benefits equal the present value cost within a given period of time. So, costs are calculated over the entire economic life span, but the benefits are only counted over the time period until they sum to the value of the costs. The breakeven point is equal to the total fixed costs divided by the difference between the gross revenue and variable costs of machine. Break-even point can be calculated by computing method. The break-even use formula used in the study is as follows

$$\mathrm{BEU} = \frac{\mathrm{FC_{yr}}}{\sum_{n=1}^{N} B_{ha} - VC_{ha}} \tag{18}$$

Where, FC_{yr}= Total fixed cost, BDTyr^{-1}; B_{ha}= gross benefits in year n, BDTha^{-1}; and VC_{ha}= Variable cost in year n, BDTha^{-1}

2.7.6. Rent-out charge calculation

It’s important to estimate the cost of rent-out charge of machine operation for an entrepreneur or local service provider (LSP) for custom hire service (CHS) business. The contractual work between machine owner and hiring farmer is made directly and agreed on in advance (at the beginning of the season). The rate was considered the conditions of the field being worked, distance and size of field plots, personal relation and prevailing rate of local wages. An entrepreneur can be estimated the machine rent-out charge from the following expression.

$$RC = TOC + E_p \tag{19}$$

Where, RC= Rent-out charge (BDTha^{-1}); TOC= Total operational cost of machine (BDTha^{-1}); and E_P= Estimated profit (BDTha^{-1})

3. Results and Discussion

3.1. Technical performance

Field performance of RT over PT was tested in the farmer’s field with a view to observe the accuracy for soybean planting on the basis of areas coverage, forward speed, effective time coverage, fuel consumption and planting cost and benefit. The field performance of different planting methods for soybean planting using RT and PT in the study area during *Rabi* seasons of 2018 and 2019 are given in Table 1.

Table 1 Field performance of different planting methods for soybean planting during *Rabi* seasons of 2018 and 2019

Season	Tr	W (cm)	S (kmh^{-1})	FC (Lha^{-1})	D (cm)	EFC (hah^{-1})	FE (%)	FS (%)
2018	RT	1.2	1.17	13.75	5.9	0.080	55.56	65.63
	PT	0.6	2.45	34.29	7.8	0.030	20.41	
2019	RT	1.2	1.92	14.67	5.7	0.075	52.96	73.08
	PT	0.6	2.36	40.00	7.2	0.035	28.67	
Mean	RT	1.2	1.57	14.21	5.8	0.078	54.26	61.42
	PT	0.6	2.28	37.14 (*3.5 passes)	7.5	0.033 (*3.5 passes)	22.56	

Note: Tr= Treatment(s), RT= Reduce till method, PT= Conventional tillage by power tiller, W= Width of tiling, D= Depth of tilling, S= Forward speed, FC= Fuel consumption, EFC= Effective field capacity, FE= Field efficiency, FS= Fuel saving and *3.5 passes means three passes for tilling followed by one pass for laddering (0.5 pass)

Field performance for field machines depend upon achievable machine forward speeds of field operation and upon the efficient use of time [23] and often depends on the skill of the operator or on weather and soil conditions [24]. It was observed from the Table 1 that the width of tilling of RT method was more (120 cm) than that of PT (60 cm). The average tilling depth in the soil using RT and CT were recorded as 5.80, and 7.50 cm respectively. During the testing of RT and PT operation, average forward speeds of the machines were 1.54 and 2.31 kmh^{-1}, respectively. The effective field capacity (EFC) is a more usable measure because it brings in the factor of efficiency of RT and PT operation for dry land tillage.

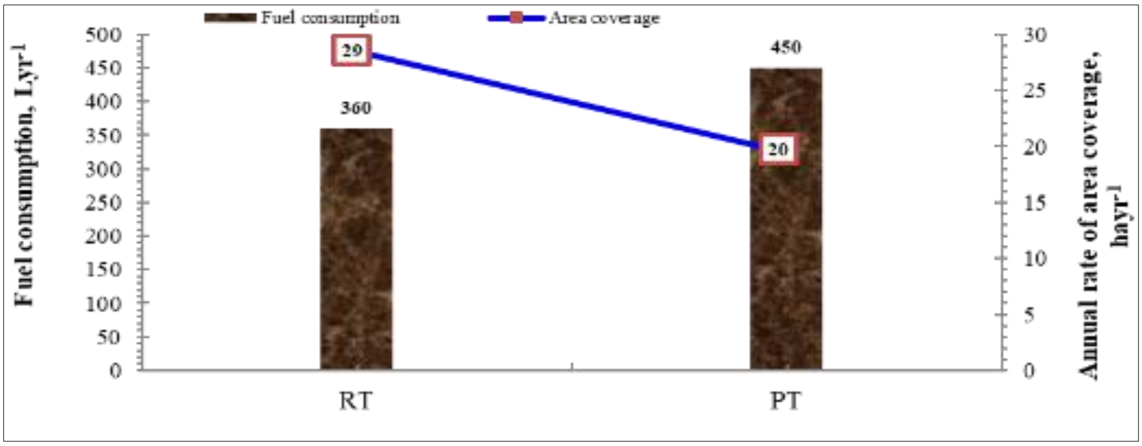

Figure 4 Fuel consumption of RT per year with annual area coverage over PT

EFC for RT and PT was obtained as 0.078 and 0.033 hah^{-1}, respectively. It is also found that EFC was more in large filed size compare to small field size and irregular shape of field. Based on the EFC, average annual use of RT was estimated to be as 29 ha more than that of PT (20 ha). Delay and other interruptions i.e. machine adjusting, refueling, turning at ends, clogging, adding seed etc. were found to be 0.02 hah^{-1} for both machines. The field efficiencies of RT method were estimated higher (52%) than that of CT tilling and planting methods (47%). The reasons for lower field efficiencies of PT were that the machine operated at high speeds (gear II and III), more turning losses and number of passes (3.50) were higher than that of RT operated at low speeds (gear I or II and 2 passes). The average fuel consumptions for operation of RT and PT were 13 and 23 Lha^{-1}, respectively. Scenario of fuel consumption of RT per year with annual area coverage over conventional methods is shown in Figure 4. On the basis of number of passes and fuel consumption, RT saved about 45% fuel and overall, 43% time than that of conventional land preparation (CT and DB) for planting of soybean.

3.2. Effect of tillage systems on yield and yield contributing attributes

Pooled analysis of two years grain yields and yield contributing attributes of soybean as influenced by different tilling and seeding methods is presented in Table 2. It is observed that statistically the highest plant populations, plant height, number of pods per plant were found from RT method than CT methods. Finally, significantly the highest grain yields were found from RT planted plots than those of CT planted plots. RT produced significantly higher number of pod

(62.86) followed by DB (52.84) whereas CT (50.83) gave lower number of pods. Indeed, the grain yield was correlated with the number of pods per plant. One thousand grains weight did not vary significantly under different tilling and seeding methods. RT gave significantly higher yield (1.73 tha^{-1}) than that of DB (1.67 tha^{-1}) whereas CT gave significantly lower yield (1.58 tha^{-1}). During those seasons, no rainfall was occurred during growing stage of soybean in this region. As a result, some soybean seedlings and plants were damaged due to soil salinity during drought period. The highest morality of soybean plant was found from CT than RT.

Table 2 Effect of different planting methods on yield and yield contributing parameters of soybean during *Rabi* season of 2018 and 2019

Season	Tr	Plant population (m^{-2})	Plant height (cm)	Pod/plant	TGW (g)	Yield (tha^{-1})
2018	RT	81.55a	61.56a	70.67a	118.70	1.78a
	PT	58.33b	43.00b	53.01b	113.30	1.64b
2019	RT	49.85a	55.75b	55.05a	117.20	1.65a
	CT	42.60ab	59.50b	47.84b	120.00	1.52c
	DB	36.02b	66.50a	52.84ab	126.30	1.67b
Average	RT	65.70a	58.66ab	62.86a	117.95	1.73a
	CT	50.47ab	51.25b	50.43b	116.65	1.58c
	DB	36.02b	66.50a	52.84ab	126.30	1.67b

Note: Tr= Treatment(s), TGW=Thousand grain weight, RT= Reduce till method, CT= Conventional tillage PT cum broadcasting, and DB= Conventional tillage by PT cum dibbling method

3.3. Comparison of cost-return of different tillage and planting methods

Agricultural machinery plays an important role to reduce drudgery of farm works as well as minimize operational time and production cost. This paper introduces an economic analysis and comparison between three different cultivation methods using RT and PT machine for soybean planting. Based on the cost analysis, individual cost parameters of these methods were calculated. The assumptions were made to carry out the financial analysis of the system. The financial analysis was computed for machine owner. The cost was calculated using database of two years, inflation rates were ignored in the calculation, useful life of RT and PT was assumed to be as 5 years, all the inputs were purchased with cash in BDT. The results of the initial investment, annual costs and returns of different planting methods are presented in Table 3.

The results revealed that the total annual cost of machine operation was amounted BDT 103651, BDT 94659 and BDT 148343 per year in case of RT, CT and DB methods. The total cost of operation was comprised of annual fixed and variable cost of machine in that order. In the total annual cost of operation, the fixed cost was worked out to be BDT 49091and BDT 31005 and variable cost was BDT 54560, BDT 63654 and BDT 129038 per year, respectively in that order. Comparative scenario of planting cost of different tillage and planting methods of RT, CT and DB were estimated as BDT 3637, BDT 4854 and BDT 7607 ha^{-1}, respectively. Graphically show the comparative scenario of planting cost and major cost parameters of RT method and CT methods is shown in Figure 5 and Figure 6, respectively. The results also show that the total annual cost of production made on RT, CT and DB methods were accounted as BDT 907285, BDT 799538 and BDT 756282 per year, respectively. The total cost comprised of annual fixed, variable cost of machines operation and production cost of soybean cultivation. The highest planting cost was found from DB and CT over RT planting method due to fuel cost and planting labour charges. The annual gross incomes received from RT and CT methods were worked out. The highest grain yield was obtained from RT (1730 $kgha^{-1}$) planting method followed by DB (1670 $kgha^{-1}$) and CT (1580 $kgha^{-1}$).

The grounds of highest grain yield from RT over conventional methods may be compacted the soil that ensured better germination of seeds, prevented bird eating of seeds for covering, less seed required and as a result better crop establishment in machine sowing than traditionally broadcasting method. On the basis of grain yield, the highest gross revenue was estimated under RT (BDT 1479150) method of soybean cultivation followed by CT (BDT 924300) and DB (BDT 976950) method per year. In addition, the fund payment for replacement of a new machine was estimated as BDT 31151, and BDT 19675 per year for RT and PT respectively which is implying that a machine owner has to deposit those amounts per year from net profit in a bank account so that he/she/they can buy a new machine when the economic life of old machine expires for tilling operation. The annual use of machine in area of RT was higher (29 ha) than that of CT methods (20 ha). On the basis of crop sales revenue of gross revenues, the highest marginal benefit-cost ratio (MBCR) was obtained from RT planted (1.63) plots followed by plot planted by DB (1.29) method that shown in Figure 7. The lowest MBCR was found from CT planted (1.16) plot due to lower grain yields. Based on the fuel consumption, grain yield and MBCR clearly indicates that RT planting method may be recommended for planting of soybean in this coastal region.

Table 3 Costs and returns for different tilling and planting method for soybean

Cost items	**Unit**	**RT**	**CT**	**DB**
Fixed Cost (FC)				
Depreciation	BDTyr^{-1}	33891	21405	21405
Interest on investment	BDTyr^{-1}	10450	6600	6600
Shelter, tax and insurance	BDTyr^{-1}	4750	3000	3000
Total fixed costs	BDTyr^{-1}	49091	31005	31005
Total fixed costs	BDTha^{-1}	1723	1590	1590
Variable Cost (VC)				
Fuel consumption	Lh^{-1}	1.2	1.5	1.5
Fuel consumption	Lha^{-1}	13	23	23
Fuel cost	BDTyr^{-1}	23400	29250	29250
Oil & lubricant	BDTyr^{-1}	3510	4388	4388
Repair and maintenance	BDTyr^{-1}	6650	4200	4200
Operator cost	BDTyr^{-1}	18000	18000	18000
Planting labour cost	BDTyr^{-1}		4817	70200
Miscellaneous cost	BDTyr^{-1}	3000	3000	3000
Total variable cost	BDTyr^{-1}	54560	63654	129038
Total variable cost	BDTha^{-1}	1914	3264	6617
Total annual operating cost (FC+VC)	BDTyr^{-1}	103651	94659	148343
Total operating cost (TOC)	BDTha^{-1}	3637	4854	7607
Cultivation cost, i.e. seed, fertilizer, insecticide, labour, harvesting, threshing	BDTha^{-1}	28198	36148	31176
Annual cultivation cost	BDTyr^{-1}	803633	704879	607940
Total annual cost of production (TC)	BDTyr^{-1}	907285	799538	756282
Average grain yield	kgha^{-1}	1730	1670	1580
Gross revenue (Sale revenue of product & byproduct)	BDTyr^{-1}	1479150	924300	976950
Net profit	BDTyr^{-1}	554964	209496	359085
Fund payment for replacement	BDTyr^{-1}	31151	19675	19675
Benefit cost ratio		1.63	1.29	1.16

Note: RT= Reduce till method, CT= Conventional tillage by PT cum broadcasting, and DB= Conventional tillage by PT cum dibbling method
Source: Authors' estimation based on field experiment and survey of 2018 and 2019 season; 1US$= BDT 85 (2019); Average work per day = 10 h at 0.078 ha per hour or approximately 192 Decimal per day; Price of diesel = 65 BDT/liter; Labour/Operator charge= BDT 600 per day (10h/day); Soybean grain cell according to farm gate price (BDT 30kg^{-1})

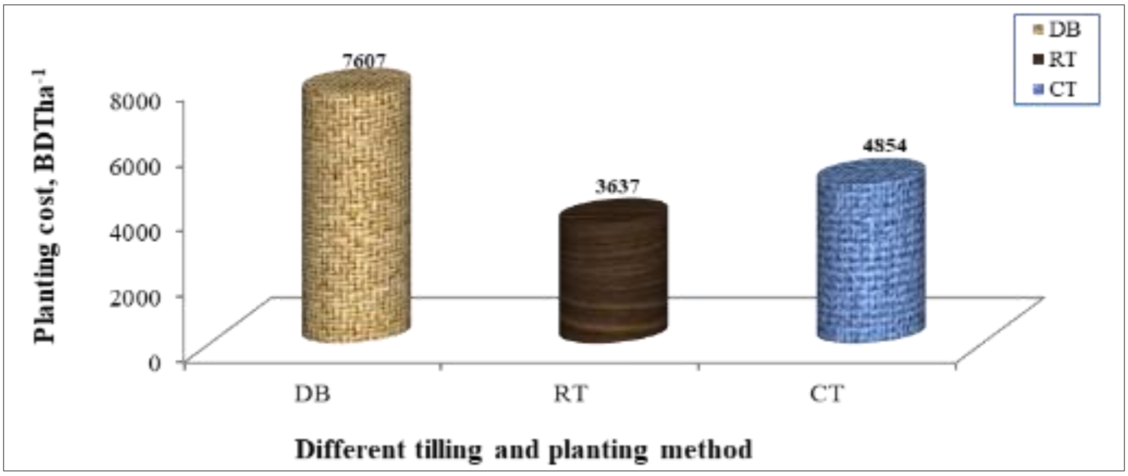

Figure 5 Comparison of planting cost of RT over conventional methods

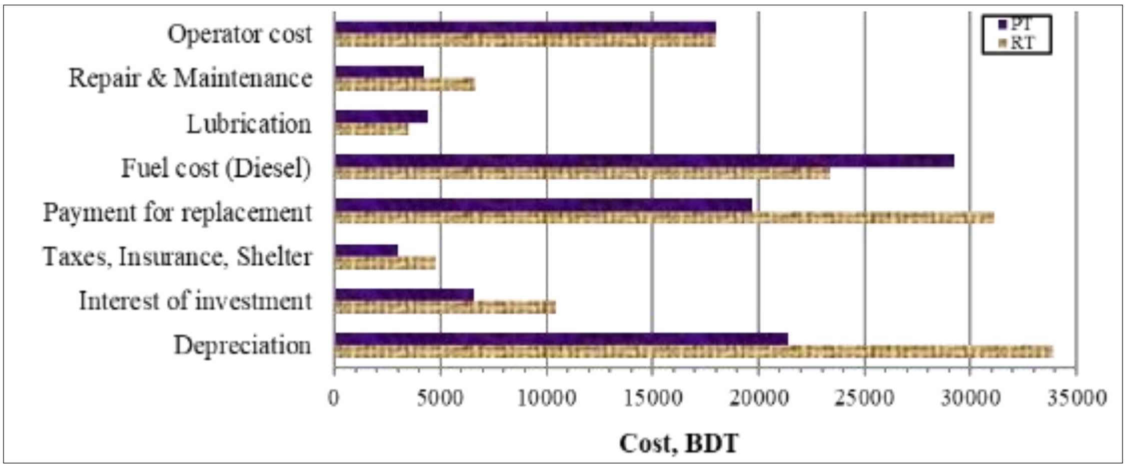

Figure 6 Scenario of major cost parameters of RT over conventional methods

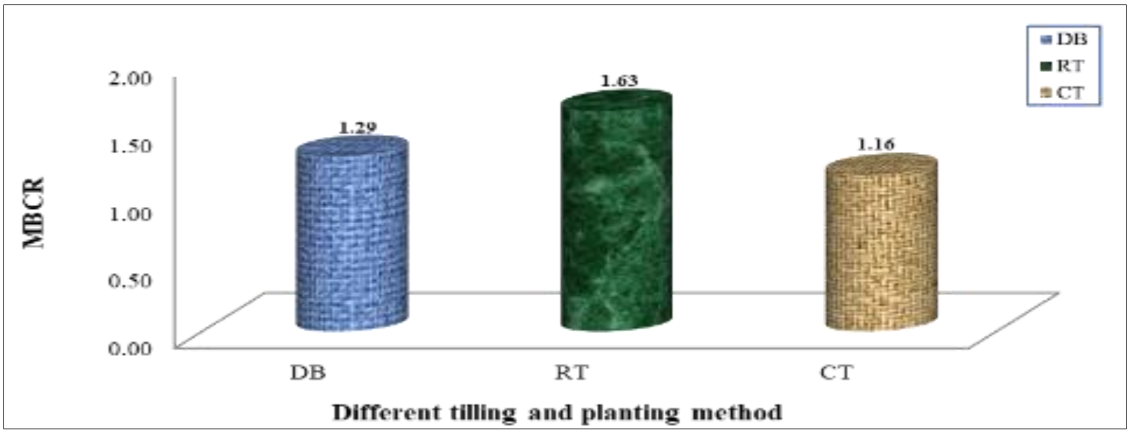

Figure 7 Marginal benefit cost ratio of soybean cultivation by different tillage and planting methods

3.4. Economic feasibility of investment

To evaluate the feasibility of investment made on RT, the financial feasibilities tests namely, net present value (NPV), benefit-cost ratio (BCR), internal rate of return (IRR), pay-back period (PBP) and break-even point (BEP) were computed by assuming all these indicators were calculated during ex-ante or ex-post evaluations, on the basis of availability of necessary data on costs and benefits, incremental costs and benefit flows were used for both financial and economic analysis, operational technology and prices of all inputs and outputs is remaining unchanged throughout the economic life of machine and increasing annual cost and return of RT operation as increase in fuel, labour and repair charges, operator wages per year and machine charges per hectare of tilling and planting after year for 5 years. In this analysis, 10% of discount rate was applied to calculate NPV and BCR. On the basis of custom hire rate of machine operation, the gross benefit was worked out of RT. Presently common rate of custom hiring charge of the conventional tilling system in the study area ranged from BDT 6500-7000 per hectare (Authors own survey, 2019) for dry land preparation of soybean cultivation. To express the discounted cash flow of the cost and benefit streams, a cash flow sheet was prepared for evaluation (Table 4) and graphically described in Figure7.

Table 4 Discounted cash flow of the cost and benefit streams of RT at 10% discount rate

Operational year	**Total cost (BDT)**	**Gross benefit (BDT)**	**Discount factor at 10%**	**PW of cost at 10%**	**PW of benefit at 10%**	**Incremental benefit**
1	321722	199497	0.909	292474	181361	-122225
2	134803	199497	0.826	111407	164873	64694
3	138192	199497	0.751	103826	149885	61305
4	141920	199497	0.683	96933	136259	57577
5	146021	199497	0.621	90667	123872	53476
Total=	882657	997484	3.79	695308	756250	114827
NPV=	BDT 60942	BCR=	1.09	BEU=	9.65 ha	
IRR=	34%	PBP=	2.71 year			

The annual net cash inflows were discounted at a discount rate of 10% to obtain the present value of net benefits from RT method. The initial investment made on RT was then deducted from the present value of net benefits. Considering 10% interest rate, it was observed from Table 4 that the NPV of the investment was obtained as BDT 60942 for RT operation. The positive NPV indicates that the investment on RT were financially feasible because IRR of RT was worked out to be as 34% (Figure 8) which is greater than that of the bank interest rate (10%). Graphical view of net present value vs. internal rate of return at different level of discount rate of RT investment is shown in Figure 9.

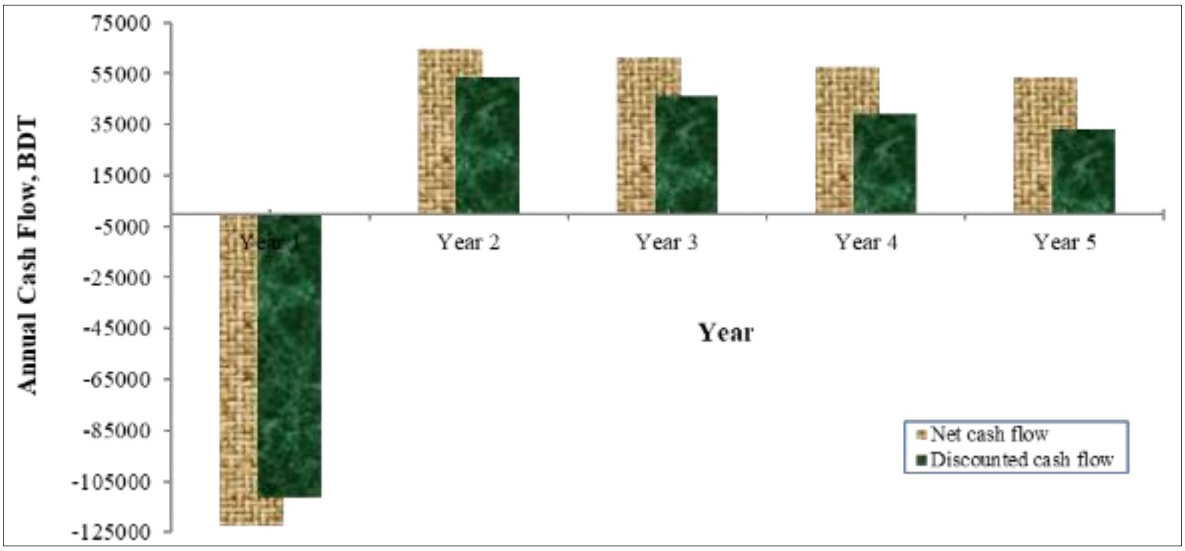

Figure 8 Net cash flow vs discounted cash flow

The figure illustrates a basic schematic that if the IRR is equal to the discount rate, then the discounted costs equal the discounted benefits or at which the NPV for an investment equals zero. The result also shows that the BCR of the investments were found to be more than 1 (1.09). Again, the payback period was estimated as 2.71 years which reveals that the investments made could be recovered in a relatively short span of time by the machine owners which indicated that the RT method was profitable for soybean cultivation.

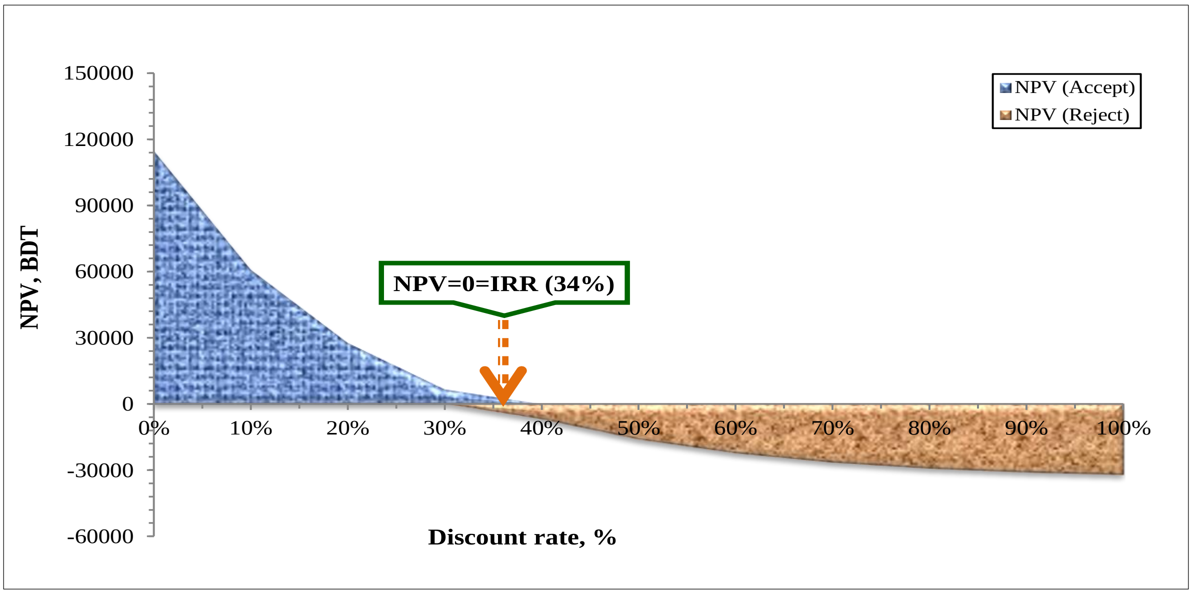

Figure 9 Net present value (NPV) vs internal rate of return (IRR)

As illustrated in the graph (Figure 10), the point at which total fixed and variable costs equal to total revenues is known as the breakeven point. This analysis is important to machine owners in determining how many areas (or revenues) are needed to cover fixed and variable expenses of the machine. Break-even used (BEU) was calculated on the basis of yearly land use and custom hire rate. The breakeven point was found to be 9.65 ha. At this point, revenue would be BDT 67549 and costs would be BDT 18474 in variable costs and BDT 49091in fixed costs. When the annual machine area coverage exceeds 9.65 ha, the machine would be making a profit. Therefore, the concept of breakeven point is as follows:

Break-even point when, Revenue = Total cost
Profit when, Revenue > Total cost
Loss when, Revenue< Total cost

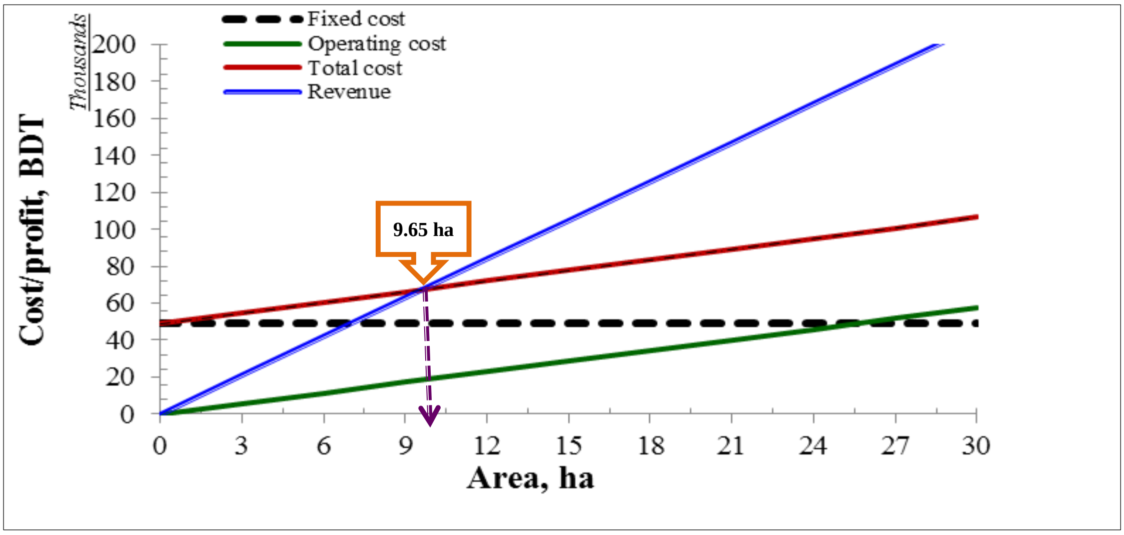

Figure 10 Cost volume profit graph of RT operation

3.5. Sensitivity analysis

The economic analysis of agricultural machine carried out under the changing circumstances (i.e. for costs, revenues, annually operational area etc.) is called sensitivity analysis. This analysis is useful for determining consequences of specified changes in variables such as input costs and gross benefits on investment life span or if there are future changes in total costs the sensitivity analysis gives an indication of how changes would affect on gross benefits. Again, the IRR is quite sensitive to the changes in the stream of benefits and costs. The scenarios shown in Table 5 on total costs and gross benefits were varied to test the effect on the results.

Table 5 Impact of changing gross benefit and total cost on profitability indicators.

Scenario		IRR (%)	BCR	NPV (BDT)	PBP (yr)
	Base parameter	34%	1.09	60942	2.71
1	Cost increase 10% and benefit increase 10%	34%	1.09	67036	2.71
2	Cost increase 10% and benefit constant	7%	0.99	-8589	1.03
3	Cost decrease 5% and benefit decrease 10%	18%	1.03	20082	1.91
4	Cost constant and benefit decrease 5%	19%	1.03	23129	1.96
Average		20%	1.04	25415	1.90

Table 5 illustrates that further analysis was performed to measure the sensitivity of the results to changes in the major four scenarios such as total gross revenue increased by 10 and remained constant, respectively while total cost increased by ten percent (Scenarios 1 and 2), and total gross farm revenue decreased by ten and five percent, respectively while total cost decreased by five percent and remained constant (Scenarios 3 and 4) of RT investment. The purpose for examining the four scenarios is to illustrate how sensitive the repayment capacity was for an investment and how vulnerable that business is to changes in the gross benefits that can be resulted from changes in total operating expenses. The result shows that among the all scenarios, the most likely scenario 1 (cost increase 10%, benefit increase 10%) is highly probable because the economic indicators measures would remain above or close to from the base parameter which is an acceptable benchmark.

3.6. Mitigation of CO_2 emission

The influence of agricultural production systems on greenhouse gas generation and emission is of interest as it may affect potential global climate change. Agricultural ecosystems can play a significant role in the production and consumption of GHGs, especially carbon dioxide (CO_2). Fuel burning by agricultural machinery is often regarded as the main source of CO_2 emissions in the primary sector. Tillage is claimed to be one of major source of GHGs. Any attempt to reduce tillage intensity should affect in carbon sequestration for enhanced environmental quality [25]. RT performs seeding operation with minimum tillage (1-2 passes) of soil.

Table 6 Time saving, fuel saving and CO_2 emission in RT and CT methods.

Particulars	Different tillage and planting method		Amount saved	
	RT	CT	Amount	Percent
Number of passes required	2	3.50	1.50	43
Area coverage, hayr^{-1}	29	20	9	31
Fuel used, Lha^{-1}	13	23	10	45
CO_2 emission, kgyr^{-1}	950	1188	238	20

Note: RT= Reduce till method, CT= Conventional tillage by PT cum broadcasting, and CO_2 emission from 1.00 liter of diesel = 2.640 kg [10]

Less amount of diesel fuel resulting from less tillage intensity is used in RT method compare to conventional tillage method. Table 6, shows that comparative scenario of number of tilling passes saving of machine operation, amount of fuel consumption as well as CO_2 emission in CA system over conventional methods. In study area, land preparation by

PT before seeding requires 3.50 passes for tilling operations for crop establishment, carried out by a two-wheel tractor, while in RT tilling and seeding are done in two operations. Less tilling requires tractors to burn smaller quantities of fossil fuels, reducing carbon dioxide emissions. The result also shows that the RT gave the better results in fuel consumption and emission of CO_2 respect to the conventional tillage method. In RT method, about 31% more area tilling was covered and saved 45% of diesel fuel and contributed 20% (238 $kgyr^{-1}$) less emission of CO_2 into the atmosphere over conventional methods. Exchange from conventional tillage to CA tillage was reported to yield a carbon sequestration rate of 367-3667 kg CO_2 $ha^{-1}yr^{-1}$ [26].

4. Conclusion

This study aimed at undertaking a comparative analysis for planting of soybean in the farmers' fields using CA based seed planter machine at Charwapda village of Subornachar upazila of Noakhali district in Bangladesh. Based on the findings and their interpretations it can be concluded that BARI developed CA seed planter machine was found suitable in terms of technical and financial performance over conventional tilling and planting methods. This seed planter was able to plant soybean at average effective field capacity of $0.078hah^{-1}$ which will be quite adequate for small scale farming. Based on field capacity and number of passes of machine operation, the rate of annual area coverage and net profit was increased per season which is more than that of conventional methods. From the discounted cash flow analysis (considering 10% discount rate), the estimated net present value of the investment was found positive for 5 years economic life machine and using the base parameters, the internal rate of return was estimated to be minimum (34%), that was greater than the bank interest rate which is considered financially sound and viable. The sensitivity analysis was also showed remain close to from the base parameter which is an acceptable benchmark. A saving of fuel consumption results in reduced carbon (20%) emitted to the atmosphere. The break-even use of machine operation was worked out as 9.65 ha of land per year. The payback period of the machine was also analyzed as 2.71 years which implies that it will recover its investment within estimated land area of operation. Therefore, BARI developed CA seed planter machine can be attractive as investments for individual smallholder farmers if they can provide services to neighboring farmers and to other nearby villages at commercial rates in the study area.

Compliance with ethical standards

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Disclosure of conflict of interest

The authors declare no conflict of interest to disclosure.

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