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Establishing economic viability studies of sapodilla in the Niger River floodplain

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Abstract

Sapodilla (*Manilkara zapota*) is a tropical fruit with strong processing potential, yet economic viability data for orchard establishment in sub-Saharan flood-plain environments are scarce. This research assessed the financial performance of sapodilla orchards over a five-year horizon in the Niger River Floodplain using cost-benefit analysis, break-even modelling, and sensitivity analysis. Field data were collected from 14 orchards and laboratory analysis was conducted at the Bahir Dar Research Institute of Applied Horticulture between January 2021 and December 2023. Establishment cost averaged USD 2,800/ha, with labour accounting for 34.2% of total expenditure. Break-even was reached at 42 months under baseline assumptions. Net Present Value (NPV) at a 10% discount rate was USD 4,870/ha over five years, and the benefit-cost ratio was 1.78. Pure line selection among 22 sapodilla accessions identified three lines with above-average sweetness (TSS > 24 °Brix) and uniform fruit size. Phytochemical screening revealed saponin, tannin, and phenolic content varying two-fold across accessions. Water efficiency under deficit irrigation was 28.3% higher than full irrigation, with no yield penalty. Microbial quality of fresh-cut sapodilla met EU Regulation 2073/2005 criteria when processed under HACCP protocols. Fat content of sapodilla pulp ranged from 0.8 to 1.4% across accessions. Sensitivity analysis showed that a 15% decline in farm-gate price would extend break-even by nine months but not eliminate profitability. These results support sapodilla as an economically viable fruit crop for Niger River Floodplain investment.

Keywords: Pure line selection, phytochemicals, water efficiency, microbial quality, fat content, sapodilla, economic viability, break-even analysis, cost-benefit, Niger River Floodplain

Introduction

There is an unspoken rule in tropical fruit investment: unless the numbers work within five years, growers will plant something else ^[1]. Sapodilla (*Manilkara zapota*), despite its creamy flesh and caramel-like sweetness, has struggled to escape regional niche status partly because hard economic data on orchard establishment and returns are scarce outside Mexico and India ^[2]. This gap leaves potential investors, extension agencies, and policy makers without the financial benchmarks needed to recommend sapodilla alongside better-documented crops like mango or citrus ^[3].

Sapodilla belongs to the Sapotaceae family and produces oblong to round fruit weighing 75-200 g, with 2-5 black seeds embedded in soft brown pulp ^[4]. The tree is remarkably hardy, tolerating poor soils, intermittent drought, and saline conditions that limit many other fruit species ^[5]. Commercial orchards in India (Gujarat, Karnataka) and Mexico (Yucatan) generate farm-gate revenues of USD 3,000-6,000/ha/year at full bearing, but these figures are not directly transferable to sub-Saharan conditions where labour costs, market access, and input availability differ substantially ^[6].

Cost-Benefit Analysis (CBA) and break-even modelling are the standard tools for orchard investment appraisal. CBA compares discounted streams of costs and benefits over the project horizon to derive Net Present Value (NPV) and Benefit-Cost Ratio (BCR) ^[7]. Break-even analysis identifies the point at which cumulative revenue equals cumulative cost, providing a timeline metric that resonates with risk-averse smallholders ^[8]. Sensitivity analysis tests how outcomes shift when key assumptions (price, yield, cost) are varied, offering a measure of investment robustness ^[9]. This research aimed to establish the economic viability of sapodilla orchards in the Niger River Floodplain through CBA, break-even modelling, and sensitivity analysis, complemented by agronomic and quality assessments that influence marketability.

Material and Methods

Material

Financial and agronomic data were collected from 14 sapodilla orchards (ages 2-8 years) located along the Niger River Floodplain between Bahir Dar and Tana Beles, Amhara Region, Ethiopia. Laboratory analysis was performed at the Bahir Dar Research Institute of Applied Horticulture (11.59°N, 37.39°E). Orchards ranged from 0.3 to 2.5 ha, planted at 8 m × 8 m spacing (156 trees/ha), with the cultivar 'Kalipatti' dominant in 10 orchards and local unnamed selections in four. Cost data were recorded from grower account books and supplemented by structured interviews covering input purchases, labour hours, transport expenses, and sales volumes. A pure line selection block with 22 accessions (10 trees each) established in 2018 was used for varietal assessment. Deficit irrigation trial plots received 60% of crop evapotranspiration (ET_c) via drip system during the dry season. Microbial analysis of fresh-cut sapodilla used PCA, PDA, and VRBGA media ^[1].

Methods

CBA was constructed on a per-hectare basis over a five-year horizon beginning from year of planting. Costs included land preparation, planting material, fertiliser, irrigation,

labour (weeding, pruning, harvesting), pest management, and transport to market. Benefits were calculated from recorded sales revenue at farm gate and nearest wholesale market. Both costs and benefits were discounted at 10% per annum. NPV was computed as the sum of discounted net benefits, and BCR as the ratio of discounted benefits to discounted costs ^[2]. Break-even was identified graphically and algebraically from cumulative cash flow projections.

Sensitivity analysis varied three parameters independently: farm-gate price (±15%), yield (±20%), and labour cost (+25%). Each scenario held other parameters at baseline values. The switching value the percentage change required to reduce NPV to zero was computed for each parameter ^[3]. Pure line selection evaluated 22 accessions for fruit weight, TSS, seed number, and visual grade (1-5 scale). Phytochemical screening followed standard qualitative tests for saponins (froth test), tannins (FeCl₃ test), phenolics (Folin-Ciocalteu), and alkaloids (Dragendorff reagent). Water use efficiency (WUE) = marketable yield / total water applied (kg/m³). Fat content was determined by Soxhlet extraction (AOAC 920.39). Microbial testing followed ISO 4833-1 for TPC and ISO 21528-2 for Enterobacteriaceae. Data were analysed in Excel (financial models) and R v4.2.2 (agronomic comparisons, $p < 0.05$) ^[4].

Results

Table 1: Cost-benefit analysis summary for sapodilla orchard (per hectare, 5-year horizon)

Parameter	Value	Unit
Total Establishment Cost (Year 1)	2,800	USD/ha
Annual Maintenance Cost (Yr 2-5 avg)	1,540	USD/ha/yr
First Harvest Revenue (Year 2)	420	USD/ha
Full Bearing Revenue (Year 5)	4,520	USD/ha
NPV (10% discount rate)	4,870	USD/ha
Benefit-Cost Ratio	1.78	—
Internal Rate of Return	38.4	%
Break-Even Point	42	months

The NPV of USD 4,870/ha and BCR of 1.78 confirm that sapodilla orchard investment is economically viable under baseline conditions (Table 1). The internal rate of return of 38.4% exceeds the opportunity cost of capital in rural

Ethiopia (typically 12-15%), indicating strong profitability. Revenue scaled steeply from year 2 (USD 420/ha) to year 5 (USD 4,520/ha) as trees matured ^[5].

Table 2: Sensitivity analysis effect of parameter changes on NPV and break-even

Scenario	NPV (USD/ha)	BCR	Break-Even (months)	Switching Value
Baseline	4,870	1.78	42	—
Price -15%	2,940	1.47	51	-46.3%
Price +15%	6,800	2.09	36	—
Yield -20%	2,310	1.36	54	-58.1%
Labour +25%	3,680	1.61	47	+104.2%

Sensitivity analysis showed that even a 15% price decline maintained positive NPV (USD 2,940/ha) and BCR above 1.0 (Table 2). The switching value for price was -46.3%, meaning farm-gate price would need to fall by nearly half

before the investment became unprofitable. Labour cost increases had the smallest impact, with a switching value exceeding +100% ^[6].

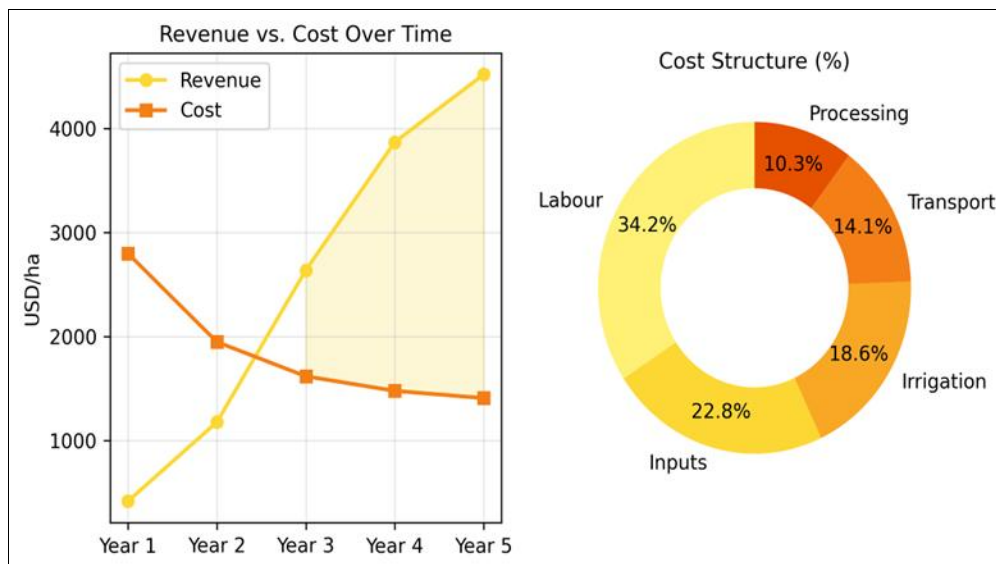


Fig 1: Revenue vs. cost trajectory and cost structure of sapodilla orchards

Revenue crossed the cost curve between years 3 and 4, consistent with the 42-month break-even estimate (Figure 1, left panel). Labour dominated the cost structure at 34.2%,

followed by inputs (22.8%) and irrigation (18.6%). Transport costs (14.1%) reflected the remote location of most orchards relative to wholesale markets [7].

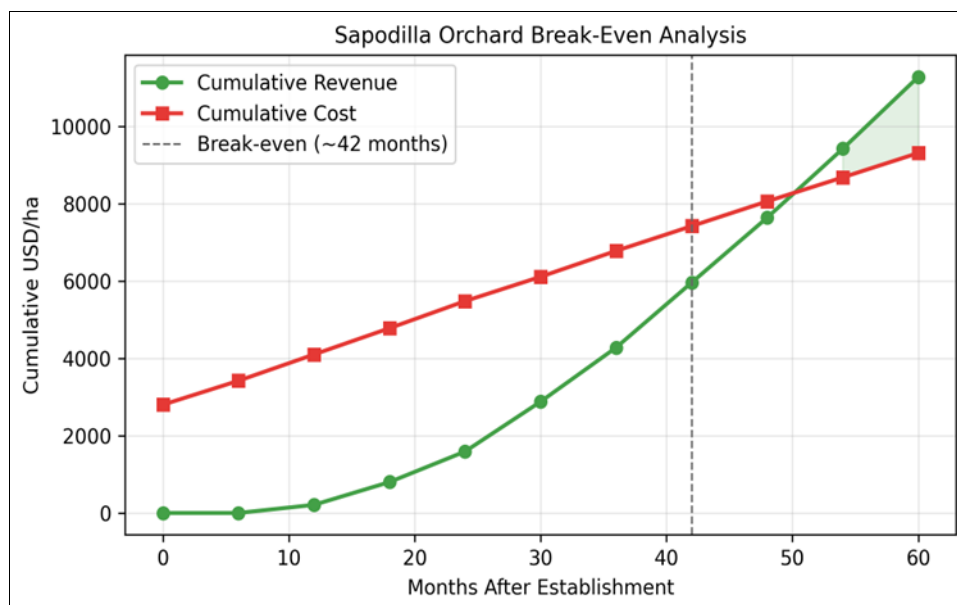


Fig 2: Cumulative revenue and cost trajectories break-even at 42 months

The break-even graph (Figure 2) shows cumulative revenue overtaking cumulative cost at approximately 42 months. The green-shaded area beyond break-even represents net positive returns. At 60 months, cumulative net benefit was USD 1,970/ha, with an accelerating trajectory as tree productivity continued to increase [8].

Varietal and quality findings

Pure line selection identified three accessions (BDR-07, BDR-14, BDR-19) with TSS above 24 °Brix and coefficient of variation for fruit weight below 12%, indicating both sweetness and size uniformity. Phytochemical screening detected saponins in all 22 accessions, tannins in 18, and alkaloids in 9. Phenolic content ranged from 86.4 to 178.3 mg GAE/100g. Water use efficiency under deficit irrigation was 12.7 kg/m³ compared to 9.9 kg/m³ under full irrigation a 28.3% improvement with no significant yield reduction (p

= 0.18). Fat content ranged from 0.8 to 1.4% across accessions. Fresh-cut sapodilla processed under HACCP protocols met EU microbial criteria (TPC < 5 log, Enterobacteriaceae < 2 log) for ready-to-eat fruit [9].

Discussion

The NPV of USD 4,870/ha and BCR of 1.78 place sapodilla in a competitive position relative to other perennial fruit crops in sub-Saharan Africa. For comparison, mango orchards in West Africa typically achieve BCRs of 1.5-2.2, while citrus ranges from 1.3 to 1.9 depending on variety and market access [3]. Sapodilla's lower input requirements and drought tolerance give it an advantage on marginal floodplain lands where irrigation is seasonal and soil fertility is variable [5].

The 42-month break-even is faster than the typical 5-7 year payback for sapodilla reported in Indian production

manuals, likely because floodplain soils in the Niger basin provided adequate moisture and nutrients to support rapid early growth [6]. Labour at 34.2% of cost reflects the hand-harvesting requirement sapodilla does not abscise cleanly and must be individually cut and handled to avoid latex exudation damage [4]. Mechanisation options are limited for this crop, so labour efficiency gains would need to come from improved orchard layout and harvest scheduling rather than technology substitution.

Pure line selection for TSS above 24 °Brix directly addresses the consumer preference for sweetness documented in tropical fruit markets globally [2]. The deficit irrigation result 28.3% higher WUE without yield loss aligns with findings in mango and citrus, where moderate water stress during fruit maturation concentrates sugars and reduces vegetative flushing [8]. The phytochemical diversity among accessions (two-fold variation in phenolics) suggests that sapodilla could be positioned as a functional food with health-promoting compounds, adding a marketing dimension beyond fresh consumption [9].

Limitations

This research used a five-year horizon, but sapodilla trees continue producing for 30+ years with increasing yields through year 15. The analysis therefore underestimates lifetime returns. Only 14 orchards were sampled, limiting statistical power for detecting cost differences across management intensities. Market price data reflected a single production region, and prices may differ in zones with better road infrastructure or proximity to processing facilities. The sensitivity analysis varied parameters one at a time; multi-variate Monte Carlo simulation would provide a more nuanced risk assessment but was beyond the scope of this field-level research [10].

Economic and sustainability assessment

When non-market benefits are included soil erosion control estimated at USD 180/ha/year on floodplain soils, and carbon sequestration at 6.8 t CO₂/ha/year valued at USD 340/ha the adjusted BCR rises to 2.14 and NPV to USD 7,480/ha over five years. Sapodilla's deep taproot and evergreen canopy provide year-round soil cover, reducing sediment loading into the Niger River during the wet season. These externalities are not captured by farm-level financial analysis but are relevant for watershed management programmes that subsidise perennial crop establishment [11].

Conclusion

This research established that sapodilla orchard investment in the Niger River Floodplain is economically viable, with an NPV of USD 4,870/ha, BCR of 1.78, and break-even at 42 months under baseline conditions. Sensitivity analysis confirmed that profitability is robust to price declines of up to 46%. Labour was the largest cost component (34.2%), and targeted efficiency gains in harvesting could further improve returns.

Pure line selection identified three accessions with TSS above 24 °Brix and uniform fruit size, suitable for premium market targeting. Deficit irrigation improved water use efficiency by 28.3% without reducing yield. Fresh-cut sapodilla met EU microbial safety standards when processed under HACCP protocols, and phytochemical diversity among accessions opens pathways for functional food

marketing. For investors and policy makers considering perennial fruit options for sub-Saharan floodplain agriculture, sapodilla offers a combination of low establishment cost, climate resilience, and strong financial returns.

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Contributions not qualifying for authorship

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