COST-BENEFIT ANALYSIS OF HAY PRODUCTION IN DIFFERENT FARM SIZES IN KAJIADO COUNTY, KENYA

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ABSTRACT

Hay production is critical in addressing drought risk reduction in pastoralism livestock systems. Although providing animal feed during droughts is not debatable, in Kenya, there is insufficient robust financial and economic data to support the upscaling of hay production in pastoral arid and semi-arid lands (ASAL). A cost-benefit analysis was conducted from a survey of 354 pastoralists and 23 hay farms to determine the profitability of hay cultivation from 3 acres to 400 acres under different cultivation practices in Kajiado County. Farming practices considered were owning or hiring farm machinery, using rain-fed or irrigation systems, and building hay barns. The findings indicated high capital costs of owning machinery (balers, tractors, cutters), irrigation systems, and building hay barns negatively affected the profitability and viability of the hay production enterprise. Hay farms that cultivated less than 100 acres and those producing less than 4250 bales per year were not profitable, given a sale price of USD 1.80 per bale. Hay prices fluctuated, with the highest prices noted during drought seasons/years. Hay barns incurred high costs to construct, although indicated as necessary for storage of longer than one year period. The selling of hay every two years did not offset the annual operating costs within farms. External County financial support was considered a sustainability strategy for hay production in ASAL areas to cushion hay producers against the erratic hay market prices. The setting of private-public partnerships to stabilise production, markets and distribution is encouraged.

Keywords

Cost-benefit analysis, hay, drought, pastoralism, climate-smart agriculture, livestock, fodder, Kajiado

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INTRODUCTION

Drought is the most frequent natural hazard affecting the livestock sector in Kenya. Droughts have a significant impact on the environment by reducing the amount of rangeland forage, crop production, and water recharge. Rangeland forage is the food that cattle and other animals eat. When there is a drought, there is not enough food for the animals, so pastoralists must move them to another area, causing stress on the animals and pressure on grazing lands (National Weather Services, 2008). In Kenya's arid and semi-arid lands, animal husbandry is the primary livelihood for the majority of the livestock keeping pastoralists. In ASALs, livestock keeping is vulnerable to frequent recurring droughts. Livestock is also the most important source of income for 90% of pastoralists and contributes 40-80% of household income (King-Okumu, 2022). For instance, during the 2009-2011 drought, the livestock sector had an estimated loss of approximately $8 billion (GFDRR, 2017).

More than 60% of the arid rangelands have poor quality forage vegetation for most of the year (GFDRR, 2017) and cannot sustain large livestock herds forcing pastoralists to migrate over long distances in search of forage. To address the challenges of droughts, the government has made a commendable effort to develop and roll out policies and strategies backed by heavy investments from development partners. However, despite these investments, a tangible change in the livelihoods of pastoralist livestock keepers has not been the case, as evidenced by their lack of resilience against recurring (Nyoka, 2016). In addition, there is insufficient data on the cost-benefit and appropriateness of these investments along the livestock value chain, especially at the farm level. Understanding the economics around investment options will help livestock keepers target their limited resources to activities that bear the most significant benefits to their livestock production. Furthermore, the private investor also needs to understand the financial and economics of a project before they invest. The economic data will also guide government investments to achieve their investment dividend in improved resilience of the livestock sector to droughts in the ASALs (GOK, 2015).

This study looks at one of the climate-smart strategies, namely hay production, to provide fodder for livestock in pastoralism systems during droughts. The study sought to understand the financial viability of hay production as a private business by first reviewing the policies supporting hay production, second analysing the demand for hay from pastoralists, and third, the cost-benefit analysis of hay growing under two different cultivation practices. According to FAO, the financial viability of an agricultural crop is a good indicator of the sustainability and viability of farming the crop. The study highlights two policies that have hay production as a flagship project. The Agricultural Sector Transformation and Growth Strategy (ASTGS) of 2019-2029 and the Kenya Climate-Smart Agriculture Project (KCSAP) of 2015-2030.

In Kenya, the Agricultural Sector Transformation and Growth Strategy (ASTGS) of 2019-2029 aim to achieve food security through a vibrant, commercial, and modernised agricultural sector that is resilient to environmental shocks. One of its goals is to boost household food resilience in arid and semi-arid lands (ASAL) through the production and supply of hay in arid and semi-arid counties. Hay production and supply depend on production inputs, post-harvest handling, market dynamics, production and distribution governance, farmer access to markets, supportive institutional frameworks (associations and cooperatives), farm sizes, and farming practices. The Kenya Climate-Smart Agriculture Project (KCSAP) targets to achieve sustainable agricultural growth through improved productivity, reduced greenhouse emissions, and enhanced resilience.

In Kajiado County, hay production is a flagship project under the ASTGS and KSCAP strategies (County K., 2018). In addition, public-private partnerships through contract farming are encouraged within the government's Big Four agenda. As of 2019, they were only 200 hectares of pasture and hay plus seven hay stores in the whole country. More emphasis is needed to encourage private-public partnerships to grow fodder crops for the strategic feed reserves to support resilience in the pastoral livestock sector, as farmers have shown great interest and self-initiative in setting up such farms (GoK, 2020). Cost-benefit analyses are needed to inform program options to encourage large-scale hay production to ensure the enterprise is profitable (Ouma, 2017). According to FAO, the financial viability of an agricultural crop is a good indicator of the sustainability and viability of farming the crop (FAO, 2020). Economic viability is a critical indicator for determining whether the hay production flagship project is a sustainable drought risk reduction strategy for Kajiado County. This paper reviewed the financial viability of farms with 3 acres to 400-acre acres under hay that either hire or own machinery (balers, cutters, tractors), grow rain-fed or irrigated grasses, and with or without built hay stores. Stakeholders can apply the findings to similar arid areas that practice pastoralism livestock systems.

MATERIALS AND METHODS

Study Area

Kajiado County is about 19,600 km^2 with over 1.8 million animals (Kenya Bureau of Statistics, 2009). The County has five sub-counties with a population of 1,117,840, and the study was limited to two sub-counties with a population of 372,335 (Kenya Bureau of Statistics, 2019). Figure 1 show the location of Kajiado Central in Kenya.

Data Collection

This study applied a cross-sectional non-experimental research design, collecting data from 2015 to 2021, using a mixed-method approach of field survey and desktop literature review. The desktop review captured secondary data, both published and unpublished, on disaster and climate-related policies, strategies, laws, and institutional arrangements. Using a structured knowledge, attitude, and practice (KAP) questionnaire, the survey used a purposeful sampling method to select and interview 354 livestock keepers, hay traders, and hay farmers using a structured knowledge, attitude, and practice (KAP) survey questionnaire. The study sampled respondents from Kajiado Central and Isinya sub-counties, including Isinya, Olikejuado, Ibissil, and Namanga. The researcher chose these locations because pastoralism is the community's main livelihood, and the areas are all semi-arid. The questionnaire was pre-tested in the field and modified accordingly. Furthermore, the study undertook a cost-benefit analysis of 23 hay producers, accounting for 73% of the hay producers in the study area. Based on the hay acreage, the farms were categorised into three groups. First, large producers with 135 to 400 acres of hay (eight farms), second medium producers with 20 to 50 acres

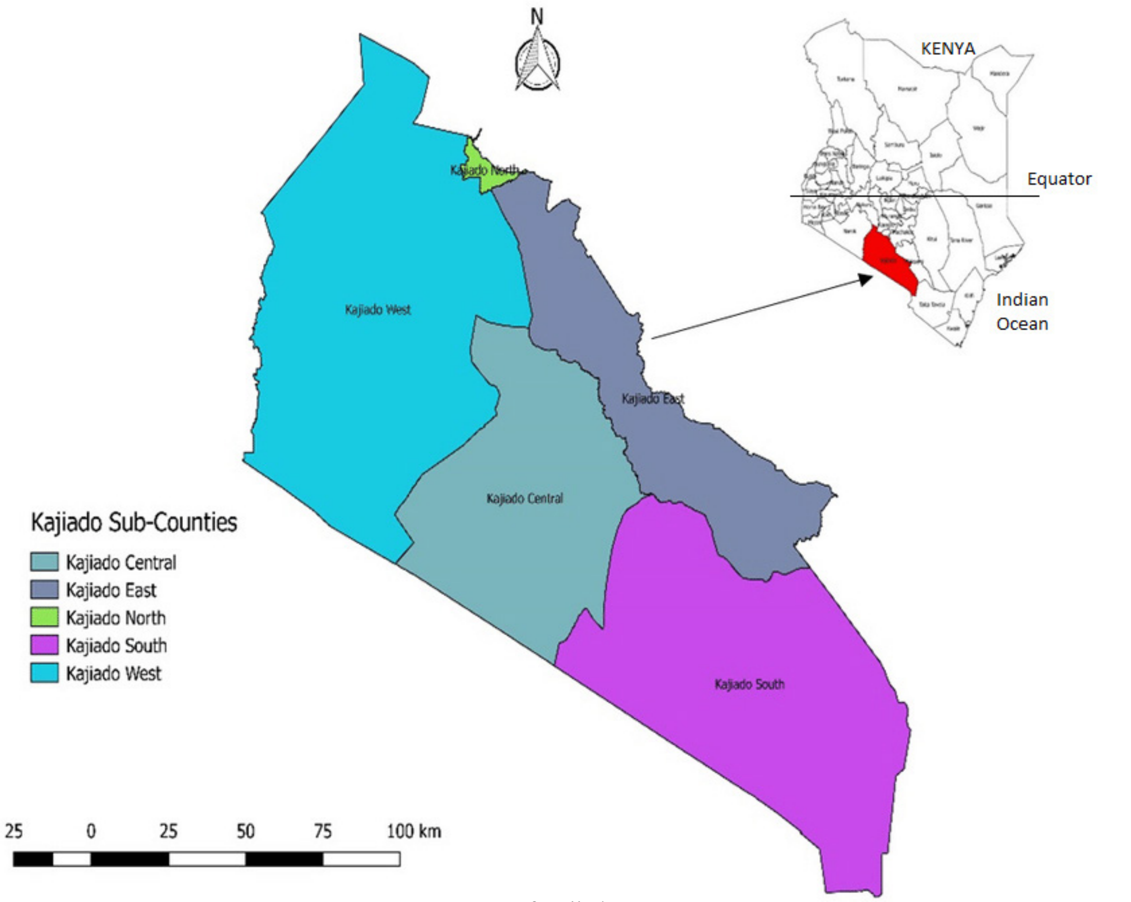

Figure 1. Map of Kajiado County, Kenya

of hay (seven farms) and third, small producers with 3 to 15 acres of hay (eight farms). All hay producers were interviewed using a questionnaire on the farm's cropping practices and business practices. Data from market traders in Ibissil, a large livestock market, was also collected.

The conceptual framework for analysis is based on the United Nations Sustainable Development Goals (UN-SDGs) target 2.4 encourages sustainable food production systems and resilient agricultural practices that increase productivity and production by 2030. Sustainable agriculture helps to maintain ecosystems, strengthen the capacity for adaptation to climate change, extreme weather, drought, flooding, and other disasters and progressively improve land and soil quality. The UN-SDG 2.4.1 measures the proportion of agricultural area under productive and sustainable agriculture. To provide a standardised reporting for UN-SDG 2.4.1 outputs, FAO recommends quantitatively measuring agricultural practices' for sustainability using economic values of (1) Land productivity (farm output value per hectare) and (2) Profitability (net farm income). Thus, profitability can be a standalone measure to determine agriculture sustainability (FAO 2020). The hay farms data analysis followed these FAO guidelines and had three objectives. First, establish the optimal hay output that will make hay farming profitable. Second, to determine how sensitive the price of a hay bale is to changes in demand and supply chain of hay. Third, to identify the major cost centres of hay production.

Cost-benefit Analysis

The study carried out a cost-benefit analysis (CBA) on small and medium-sized farms ranging from 3 acres to 50 acres plus the eight large farms and further grouped them into 400 acres (2 farms), 200 acres (3 farms), and 150 acres (3 farms). To identify the cost centres for the CBA, two 400-acre farms with similar hay cropping and operational practices and 'economies of scale' were selected. For the two 400-acre farms, one grew Boma Rhodes grass and the other the local grass variety without reseeding. Both farms were private. The study compared specific operational practices on profitability in the 400-acre hay farms, namely owning or hiring machinery (balers and tractors), carrying out irrigation, and building a hay store.

The types of CBA values used were (1) Net Present Value (NPV), (2) The Payback period, (3) Internal Rate of Return (IRR), (4) Return on Investments (ROI) and (5) Sensitivity Analysis (PAHO, 2021).

The CBA followed six step-by-step stages. First, identify and define the analysis parameters, namely the NPV, IRR, ROI, and the payback period. Secondly, establishing the parameters for the specified fixed/variable costs and benefits related to each option includes owning or hiring machinery, irrigation, and hay stores. This data span over six years (2015-2020). Thirdly, quantify the costs and benefits in monetary value for each year in which those costs and benefits occurred than standardising costs according to the farms' context of production for comparison, i.e., the costs and benefits represented a "farm-like-this" and not "this-farm." Fourthly, calculating present values was done by discounting values that occur in future years. Present value costs and benefits were then summed across the years to obtain the total present value costs and benefits. Fifthly, calculate the NPV, IRR, and ROI to establish the enterprise's worth (in addition to the payback period). Finally, a sensitivity analysis to establish the best hay price making hay production viable for large farms. To determine hay price sensitivity and profitability, we consider one bale of hay (1) the break-even point and (2) cost- sensitivity versus profitability. The price of one bale (15 kg) of hay depended on market supply and demand.

There were assumptions around measures and interpretations made while computing the financial profitability of different sizes of hay farms. The NPV/IRR/Cumulative PV/Discount Rate was assumed to be 10% per annum. The base year was 2015, when the hay farms incurred initial setup costs like fencing, purchase of farm machinery, and other capital costs. The number of bales sold was assumed to be the same as the total bales harvested per year. The sale of all the hay was the best-case scenario when farmers sold all the harvests each year. Revenue totals are computed as the sum of grazing income (USD 0.10 per cow/per month), summed up with the amount derived from hay sales in United States dollars (USD). Except for the purchase of tractors, balers, cutters, irrigation equipment, and the building of hay stores, most costs were treated as variable costs. Both 400-acre farms analysed had similar variable costs of (1) labour, hiring machinery, and basic cultivation practices of land clearing and harvesting, (2) amenities, repairs, fencing, and storage (3) cropping and management practices. Table I showed the costs of machinery in 2020.

TABLE I- COST OF MACHINERY

Machinery	Cost USD
Tractor (New Holland TS 6140 4WD)	62000
Manual baler/haymaker and rake (new)	120
Baler(new)	9000
Grasscutter(new)	4000
Mould board plough tiller 3 F (new)	2000

1USD = KES 100

These variable costs were standardised and used in all the farm sizes ranging from 3 acres - to 400 acres. The similar variable costs guided the analysis to take the approach of a "farm-like this" instead of an individual audit of "this-farm." There are three advantages of this approach. First, it allowed for standardisation of the costs and expenditure, which allowed comparative profitability analysis across farm sizes with similar cultivation practices. This approach of "this-farm" made it easier to analyse and draw conclusions from the data. Secondly, the study eliminated the influence of different managerial styles, procurement procedures, and staff policies on profitability. Thirdly, it freed the study from a managerial and financial audit of individual farm practices.

Key financial parameters used in the analysis included (1) Revenue: Computed by multiplying the unit price per bale by the number of bales harvested in a particular year (note: number of bales harvested is also taken as the number of bales sold). These values are added to the grazing income to derive the final revenue in a year. (2) Total costs: the summation of all costs involved in hay production. Total costs are the sum of variable costs and fixed costs. (3) Net Benefits: The difference between the total revenue and the total costs incurred each year. (4) Net Present Value (NPV): This calculation is the difference between the total discounted benefits minus the total discounted costs. Projects with positive net benefits are viable, while one project with a higher NPV than another is more viable. The higher the NPV, the more the benefits of the project.

$$NPV = \sum \frac{C_t}{(1+K)^t} - I0$$

Where:

C = Cash flow in time t

K = Discount rate

C = Cost of investment/ initial cash outlay

When NPV0 Accept the project and when NPV0 reject the project, and When NPV0 be indifferent

(5) Discounted Net Benefits = Net benefits/ (1+Discount rate) ^year

(6) Internal Rate of Return (IRR): the rate of return (discount rate) equates to the NPV of the project to zero. The rate of return (discount rate) equates the present value of cash flows to the project's initial cost.

$$IRR = r\% \quad \frac{+positiveNPV}{Absolute \sum of NPV} \quad (R\% - r\%)$$

IfIRRcostofcapital,acceptthe project. IfIRR costofcapital, reject the project, and if IRR cost of capital, be indifferent.

The ROI was also computed as a comparison. The ROI indicates the total benefit of the entire investment, while IRR is the annual growth rate. While the two numbers will be similar for one year, they may start to differ with time and be different over many years.

(7) Payback (cumulative PV): the time required for a project's total discounted costs surpassed by the total discounted benefits. Cumulative discounted benefits and cumulative discounted costs for each consecutive year of the project were used to calculate cumulative PV. When the cumulative benefits surpass the cumulative costs that year, we refer to it as the project's payback period. In other words, the project will see net profits or benefits in the year following the project payback period.

RESULTS

The research findings are in two sections. The first section summarises the results of the desktop review of national DRR and climate-related policies focusing on Kajiado County. In addition, it also summarises the findings of the KAP survey on the hay buying and consuming behaviours of 354 pastoralists' during droughts. The second section details the cost-benefit analysis results on farms ranging from 3 to 400 acres.

Summary of Findings from Pastoralists interviews and Policy landscaping review

The survey found that the greatest beneficiaries of hay farming were the livestock keeping pastoralists and the government, while hay producers are making losses. The availability of hay within a radius of 10 – 30 km has reduced the walking distances livestock keepers must trek in search of grazing ground and the losses they incur from diseases and wildlife predation. Commercial hay close by also saves their animals from death during the most severe droughts. In the drought years of 2005 compared to 2017, purchased hay as a feeding option drastically increased from 13% to 37%, respectively. Because most pastoralists only buy hay during severe drought years, every two to three years, growers must store their hay for two years before selling it. Sales from hay can only cover one or two years of annual recurring operating costs, so most hay enterprises were unprofitable by the second year of no-hay sales. The County government also benefits from reduced conflicts over grazing lands, and wildlife protection as hay farms act as drought dispersal lands for wildlife (Kimaru, 2021a).

The policy review established that although Kenya has adequate legal instruments and institutions to support disasters and droughts, implementation is the disconnect. The study recommends that the hay flagship projects put in place like private-public and partnerships to tackle the lack of a stable hay market and the low enterprise profitability if hay production in pastoralist systems is sustainable (Kimaru, 2021b).

Analysis of Hay farms

This paper will focus on the results cost-benefit analysis component of the survey, starting with an overview of farms between 10 acres and 200 acres, followed by a deep dive into the largest farms of 400 acres, comparing the effect of owning machinery versus hiring machinery.

Farms ranging from 10 to 400 acres grow local grass varieties composed of a mixture of indigenous and introduced grasses, namely, red oat grass (*Themeda Trianda),* big bluestem, guinea grass, buffalo grass, switchgrass (*panicum virgatum*), beaked panicgrass (*panicum anceps*), windmill grass and blue oat grass. One 400-acre farm growing the local variety hired machinery, while the other 400-acre farm cultivated the Boma Rhodes grass variety and bought machinery.

Cost-Benefit analysis of 10 - 200-acre farms

The NPV, IRR, and ROI analysis were run on 10 acres to 200 acres farms, and they either did not build hay stores or had temporary ones made of wood and grass, plus hired machinery for harvesting and baling. All other cost centres were standardised. The IRR produced nil results because the negative figures were too high. Table II shows farms from 10 to 200 acres were unprofitable, therefore not viable enterprises.

TABLE II - THE PROFITABILITY OF 10 - 200-ACRE FARMS

Farm Size	NPV	ROI
200	(3,133,650)	(0.79)
150	(2,034,386)	(0.79)
50	(323,496)	(0.46)
10	(1,087,873)	(0.74)

NPV = Net present value, ROI = Return on investments

Profitability of farms ranging from 10-acre to 400-acre farms

The 400-acre optimal production rates of 48 bales per acre were used as the standardised production rate for all the other farms. At this rate, it would require 90 acres to produce 4250 bales, sold at USD 1.8 per 15kg bale. Therefore, these production levels and price-point are considered the break-even point for hay farming to be viable under the current cropping system practised in Kajiado Central. Figure 2 shows the optimal production against the standardised profitability across different farm sizes.

Cost-Benefit analysis of 400-acre farms

The cost-benefit analysis of the mechanised 400-acre farm hay production farm is presented in Table III. This farm grew the Boma Rhodes variety. The payback period for this mechanised farm exceeds five years; the NPV and IRR were negative and therefore less than the cost of capital invested, meaning this farming method is not viable and should be avoided. The cost-benefit analysis of the non-mechanised 400-acre hay production farm based on hired machinery is presented in Table IV. This farm grew a mixed variety of local hay grasses and was not seeded. The payback period for this non-mechanised farm was in the third year; the NPV was positive, so we accepted the enterprise, while the IRR was also positive, meaning this farming method is viable.

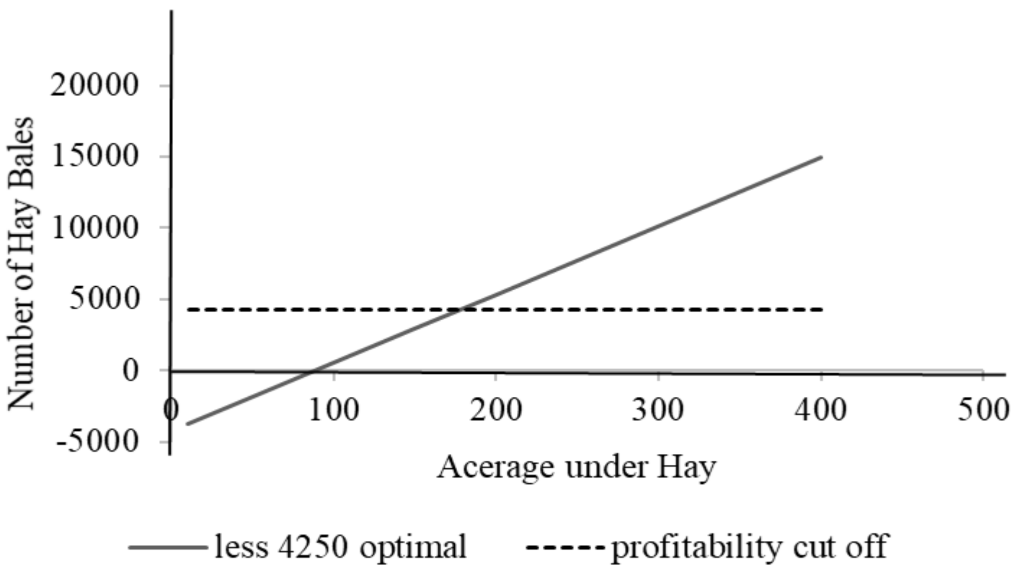

Figure 2: Profitability of different hay farm acreage

Return on investment (ROI) of owning machinery

The 400-acre farm that hired machinery had a positive ROI of 23%, while the 400-acre farm owned machinery had a significant negative ROI of (-40%), as shown in Figure 3. The positive ROI is because farmers hired machinery from private providers who charged USD 0.7 per 15 kg bale. The private providers were readily available and preferred by the farmers as they were more efficient compared to the government services.

IRR and ROI of owning irrigation equipment

The high cost of initial setup and subsequent operating expenses resulted in the cumulative payback period remaining negative beyond year 5. When the researcher removed the price of irrigation equipment and expenses of running irrigation, the IRR improved from -17% to -4%, while the ROI improved from -40% to -19%, as shown in Table V. However, the IRR and ROI remained negative due to the capital costs of machinery (tractors and balers) buying.

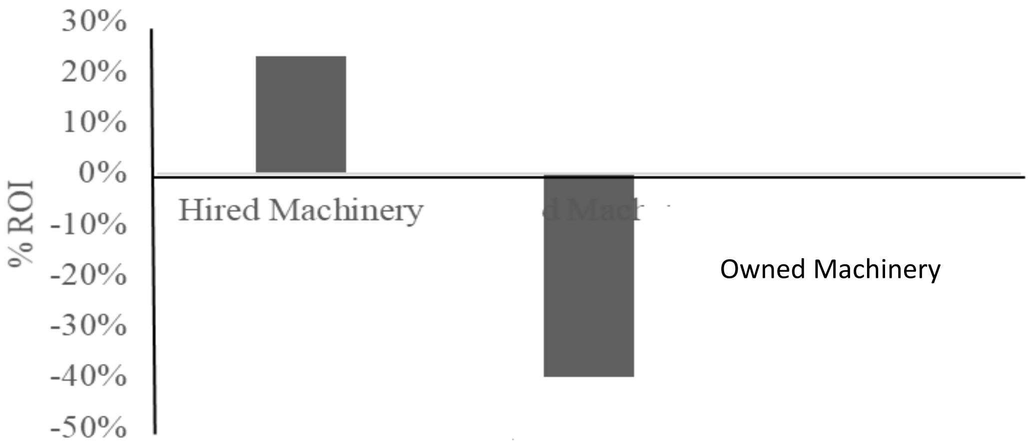

Figure 3 Return on investment (ROI) of farms that hire versus own machinery

TABLE V- IRRIGATION SYSTEMS COSTS ON PROFITABILITY

	With Irrigation system	Without Irrigation system
NPV	(88,484)	(32,150)
IRR	-17%	-4%
ROI	-40%	-19%

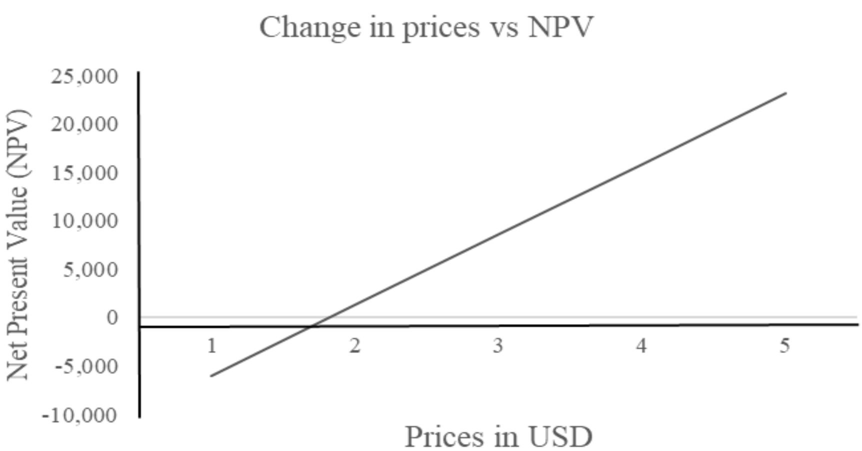

Figure 4: Optimal price of one bale of hay for profitability (point when price crosses zero-line of net present value)

TABLE III- COST BENEFIT ANALYSIS IN USD OF 400-ACRE FARM WITH MACHINERY

Discount rate = 10%
The initial cost of capital = 17,412,000

	Year				
	2015	**2016**	**2017**	**2018**	**2019**
Cash in-flows	0	1	2	3	4
Sale of Hay	18,000	20,000	45,000	48,000	26,250
Grazing income	1,500	1,500	1,500	1,500	1,500
Total cash inflows	19,500	21,500	46,500	49,500	27,750
PV of cash inflow	19,500	19,545	38,430	37,190	18,954
Cumulative cash inflow	19,500	39,045	77,475	114,665	133,619
Costs in USD					
Ploughing Cost	4,000	4,000	4,000	4,000	4,000
Gen utility Cost	300	300	300	300	300
Fencing repair Cost	0	100	100	100	100
Permanent staff cost	6,000	6,000	6,000	6,000	6,000
Weeding Cost	300	300	300	300	300
Irrigation costs	320	320	320	320	320
Machinery repair cost	301	301	301	301	301
Temporary staff for hay	210	210	210	210	210
Cash outflow	11,431	11,531	11,531	11,531	11,531
PV of Cash Outflow	11,431	10,483	9,530	8,663	7,876
Cumulative cash outflow	11,431	21,914	31,443	40,107	47,983
Discounted total cash outflow	0	0	0	0	222,103
Net Cash flow/Benefit	-166,051	9,969	34,969	37,969	16,219
Payback (cumulative PV)	-166,051	-156,082	-121,113	-83,144	-66,925

The initial cost of capital	
Machinery Purchase Cost	77,120
Irrigation equipment	55,000
Store construction cost	20,000
Fencing cost	10,000
Bush clearing cost	12,000
Total	**174,120**

No of the bales sold	**Year**	**Price per bale**	**Revenue**
60	2015	3	18,000
80	2016	2.5	20,000
150	2017	3	45,000
192	2018	2.5	48,000
105	2019	2.5	26,250

NPV of project
-88,484
IRR
-17%
ROI
-40%

Notes:

PV of cash inflow-Is the Present value of cash inflows, i.e., yearly cash inflow discounted at a discount rate of 10%

PV of cash outflow-Is the Present value of cash outflows, i.e., yearly cash outflow discounted at a discount rate of 10%

Payback Period, i.e., the project starts to get positive net benefits.

The exchange rate (10/05/2021) is 1 United States Dollar (USD) = 100 Kenya Shillings.

TABLE IV- COST-BENEFIT ANALYSIS IN USD OF 400-ACRE FARM HIRING MACHINERY

Discount rate = 10%
The initial cost of capital = 42,000

Year	2015	2016	2017	2018	2019
Cash in-flows	0	1	2	3	4
Sale of Hay	18,000	20,000	45,000	48,000	26,250
Grazing income	1,500	1,500	1,500	1,500	1,500
Total cash inflows	19,500	21,500	46,500	49,500	27,750
PV of cash inflow	19,500	19,545	38,430	37,190	18,954
Cumulative cash inflow	19,500	39,045	77,475	114,665	133,619
Costs in USD					
Tractor and Baler harvesting cost	4,800	6,400	12,000	15,360	8,400
General utility cost	300	300	300	300	300
Fencing repair cost	0	100	100	100	100
Permanent staff cost	6,000	6,000	6,000	6,000	6,000
Weeding cost	300	300	300	300	300
Temporary staff for hay	210	210	210	210	210
Cash outflow	11,610	13,310	18,910	22,270	15,310
PV of cash outflow	11,610	12,100	15,628	16,732	10,457
Cumulative cash outflow	11,610	23,710	39,338	56,070	66,527
Discounted total cash outflow	0	0	0	0	108,527
Net cash flow/benefit	-34,110	8,190	27,590	27,230	12,440
Payback (cumulative PV)	-34,110	-25,920	1,670	28,900	41,340

The initial cost of capital	
Store construction cost	20,000
Fencing cost	10,000
Bush clearing cost	12,000
	42,000

No of the bales sold	**Year**	**Price per bale**	**Revenue**
60	2015	3	18,000
80	2016	2.5	20,000
150	2017	3	45,000
192	2018	2.5	48,000
105	2019	2.5	26,250

NPV of project	25,092
IRR	38%
ROI	23%

Notes:
PV of cash inflow-Is the Present value of cash inflows. i.e., yearly cash inflow discounted at a discount rate of 10%
PV of cash inflow-Is the Present value of cash outflows, i.e., yearly cash outflow discounted at a discount rate of 10%
Payback Period, i.e., the project starts to get positive net benefits in year 3 with USD 1670
The exchange rate (10/05/2021) is 1 United States Dollar (USD) = 100 Kenya Shillings.

Price sensitivity and break-even points

Hay prices ranged from USD 1.20 in 2020 to USD 3.50 in 2017. Price sensitivity analysis revealed that USD 1.80 per bale is the cut-off for profitability, that is when the pont at which the NPV is zero as shown in Figure 4.

Figure 4: Optimal price of one bale of hay for profitability (point when price crosses zero-line of net present value)

The minimum number of harvested hay on a 400-acre piece of land to break even was 4,250 bales at a minimum price of USD 1.80 (Figure 5).

but necessary due to the seasonality of hay sales.

Other challenges included illegal grazing by livestock that destroys growing pastures and inadequate extension services and training for the hay value chain. In addition, the hay flagship activities do not match the farmers' pain points or needs. For example, the draft Kenya Bureau of Standards for hay would increase production costs making the enterprise unprofitable. Private baling services providers to harvest and bale the hay are readily available from the neighbouring Narok County and have extensive experience in harvesting wheat and barley. Although the County government has tractors to harvest and bale, they are often unavailable and unreliable as they break down often. Farmers, therefore, prefer private service providers.

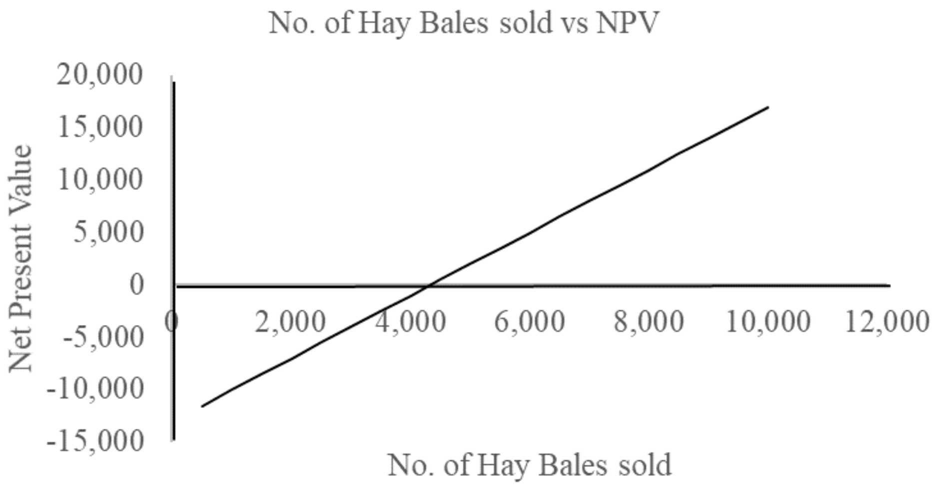

Figure 5: Optimal production of hay bales per acreage (point when number of bales sold crosses zero-line of when net present value)

Issues highlighted by key informants

Hay production faced several challenges from 2005 to 2020, including wildfires, floods, droughts, and locust infestation. In 2020, Covid-19 restrictions affected hay farms indirectly. For instance, the transport cost increased, and demand for milk and meat in urban centres (due to hotels and school closures) reduced, meaning dairy farmers from Kajiado. Other counties stopped buying hay because of reduced purchasing power.

The drought cycle has the most significant impact on hay profitability. The sale of hay peaks during droughts every 2-3 years but collapses during average to good rainfall years forcing farmers to store their hay for two or more years. Building a hay store is expensive

Interestingly, farmers are not interested in participating in hay cooperatives viewed as corrupt. In addition, hay farmers feel that they are not recognised for the hay farms' social and ecosystem services to support livestock keepers and wildlife. For example, wildlife migrates from Amboseli National Park and grazes on the hay farms for four months every year. The tourism sector benefits from this at the expense of the hay farms that lose hay production from wildlife grazing. Another ecosystem service is weeding invasive plants like *Ipomoea spp*, which overrun indigenous grass varieties and destroy grazing lands. Hay cropping also improves soil quality and reduces soil erosion and soil compaction during flood years.

DISCUSSION

Farm Sizes and Profitability

The most significant determinant for profitability was production and not farm size. A farm needed to produce a minimum of 4250 bales annually to be profitable. Figure II shows that a 90-acre farm can produce 4250 bales of hay. However, the study found that the poor cropping practices of even the 200 acres resulted in harvests far below the optimal rate of 48 bales an acre, thus making them unprofitable. These farmers require training in good cropping practices to increase their output.

Impact of hiring versus owning machinery on profitability

The 400 acres farm that hired machinery reached profitability within three years compared to the 400-acre farm that bought and maintained its machinery. The 400 acres farm that hired machinery had a positive ROI, while the 400-acre farm with machinery had a negative ROI. The NPV of farms that hire machinery is significantly higher (NPV 25,100) than farms that own machinery (NPV -88,484). The IRR is (-17%) and ROI of (-40%) for the farm that owns machinery than the farm that hires machinery whose IRR is 38% and ROI of 23%.

The machinery analysed in this study were balers, cutters, and tractors. Below are some of the reasons for the high cost of purchasing and maintaining machinery. Balers and Cutters - the cost of repairing and replacing damaged components of the cutter and baler can wipe out a season's profits. The spare parts and repairs are costly, but the balers' owners bear the cost of repairs.

Tractors - owning a tractor was cheaper than hiring a tractor to ferry hay from the field to the store. However, the cost of hiring tractors was much higher than fueling their tractors. Also, repairs and spare parts of tractors are cheaper, locally, and readily available – even second-hand and prefabricated pieces. However, the high capital cost of buying a new tractor pushes the ROI negative.

Impact of Irrigation equipment on profitability

For the 400-acre Boma Rhodes farm, during the dry season of insufficient rainfall, the farm irrigates its hay crop using gun sprinklers, allowing for three crops per year (two Boma Rhodes and one legume) The only advantage of irrigation was harvesting three crops per year. However, the high cost of initial setup and subsequent operating costs resulted in the cumulative payback period remaining negative beyond year 5. In contrast, the farm without irrigation systems' cumulative payback became positive in year three. In addition, the cost of buying irrigation equipment resulted in negative IRR and ROI. Without the irrigation system, the farm would have improved its NPV, IRR, and ROI in year five but remained negative due to purchasing other types of machinery.

The Boma Rhodes farm utilised the rain gun overhead irrigation system that cost USD 5500 per acre. In comparison, drip irrigation costs USD 1200 per acre (Rain gun sprinklers 2020). An appropriate irrigation system relative to the farm's size needs to be carefully considered before farmers are encouraged to set them up. The study showed that pasture irrigation's NPV, IRR, and ROI were all negative and should not be used in hay pasture cropping practices in ASAL. If it is to be used, government subsidies should be considered.

The study results align with the findings of the Malabo Montpellier Panel that noted the high initial cost of irrigation equipment needs to be offset by a reliable and profitable market for the produce. The panel suggested using adaptable private-public partnerships to access financing and commercially supply water to smaller farmers and appropriate technology. Also, the panel notes that irrigation is a long-term capital investment (Panel 2018.). While irrigation of hay, in theory, may be desirable, the experience of failed irrigation schemes in Kenya has led to a low political risk appetite that may affect options for private-public partnerships in irrigation (Lebdi 2016).

Impact of Hay stores on profitability

The costs of hay stores depended on the materials used. For the 400 acre farms, hay stores were a combination of stone, wood, and aluminium iron sheet costing USD 20,000 for a 20,000 bales storage capacity. Constructing hay stores is the most critical capital cost that a farm should incur because storing hay for 1-2 years before the sale cannot be avoided. Hay sales depend on the drought cycle, which determines demand and supply, with hay demand highest during droughts. In the study period, hay farmers had not sold their hay in 2019, 2020, and the first half of 2021 due to good rains leading to the collapse in demand for hay, forcing farmers to keep it in their stores.

There is a need to include hay strategic feed reserves to encourage the storage of hay storage by the government and private sector to address storage challenges. Developing private hay feed strategic reserves would also meet the Kajiado County strategic goals, seeking appropriate food security strategies that support relevant value chains like hay production while addressing post-harvest losses (K. County 2018). Our findings are consistent with CGIAR, which notes that hay stores are essential in having a viable hay value chain to allow farmers to store and sell hay when high prices (CGIAR 2018).

CONCLUSIONS

Hay as a drought risk reduction strategy is critical and has many benefits to pastoralists. The availability of hay contributes to stable pastoral livelihoods, reduces resource-based conflicts, improves security, attracts investments in other sectors and supports ecosystem services, among others. Demand for hay is seasonal and peaks during droughts. The study found that the most significant determinant of profitability in hay farming were stable markets, and operational factors including hay acreage, capital costs of buying machinery, utilising rain-fed or irrigation, building hay stores, and cultivation practices influencing productivity per acre. Farms with hay acreage below 90 acres were not profitable. Less than 4250 hay bales per year did not offset the annual fixed and operating costs. The high capital costs of buying machinery and setting up irrigation systems resulted in the hay farms not being financially viable. Building hay stores was viewed as a necessary capital expense because farmers may be forced to store hay for up to three years before a severe drought comes, during which they can make fortune from sales that can reach USD 3.5/bale. From the results it can be said that without external support, hay production left to economic forces is not a viable risk mitigation strategy at the national level. Decision-makers need to address this in order to make this strategy resilient and sustainable.

RECOMMENDATIONS

Hay farming benefits the government and pastoralists more than the hay farmers who make losses. Therefore, hay farming should be classified as a 'public good' primary agriculture activity and receive subsidies and other forms of support from government programs. Thus, the government projects under the ASTGS and KCSAP strategies need to support hay farms to remain in operation.

The government needs to address the unstable market dynamics of hay demand only every two to three years versus hay supply annually by considering setting up public-private partnerships (PPP) with hay farms. These PPPs should look at subsidizing hay farmers for the losses they incur storing hay for one to three years, costs of harvesting hay, costs of building hay barns and insurance against fires, locusts, and floods. The government should also encourage large scale hay farms that can optimize economies of scale. For pastoralists not able to grow on 90 acres and more, they should be encouraged to buy the hay.

ACKNOWLEDGEMENT

The authors are grateful to farmers and pastoralists of Kajiado County for their valuable time and knowledge that made the project possible.

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