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Fodder Farming In The Arid And Semi-Arid Lands Of Kenya: A Potential Profitable Venture

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Abstract

Background*: In Kenya's arid and semi-arid lands (ASALs), the productivity of livestock is seriously constrained by the productivity and nutritive value of the common fodder species. Kenya Agricultural and Livestock Research Organization in partnership with SNV Netherlands promoted an innovative project of a mixed-sward of legume and grass production materials using a wide array of twenty genetic fodder materials.*

Materials and Methods*: This paper employed a profit frontier efficiency alongside the financial accounting of gross margin and benefit-cost ratio to examine the profitability of the fodder materials promoted.*

Results*: The results revealed how profitable the production of fodder legumes and grasses could be both in the lowlands and highlands zones of ASALs with an average of over 83.94% profit efficiency score and more than 2.7 benefit-cost ratios. It was also very clear that profit efficiency measurement is different from financial accounting measures of gross margin and benefit-cost ratio.*

Results*: Thus, an effective and broad-ranging legume-grass development program based on the two measures is central to addressing the productivity of fodder production in Kenya.*

Keywords: *Gross margin, Benefit-cost ratio, Profit efficiency, stochastic frontier, Kenya*

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I. Introduction

In Kenyan arid and semi-arid lands (ASALs), the productivity of livestock production is seriously constrained by the nutritive value of the common fodder species. Most of the high-value fodder materials are deteriorating in terms of species composition and the ground cover with a shift towards locally inferior species. Although grazing management and supplementary feeding can address this issue, such strategies will not be adopted on a scale adequate to solve this national problem. Therefore, in cognizance of the recurrent challenges of climate change and the rapidly increasing land pressures in these areas, the promising strategy is the promotion of a wide array of genetic materials that meet the needs of various livestock production systems. However, the major constraint lies in the lack of suitable leguminous material locally to complement grass-based livestock production systems.

Currently, most of the fodder-based programs are very conservative and utilize sub-optimal genetic material with little innovation. Pursuant to this hypothesis, Kenya Agricultural and Livestock Research Organization (KARLO) in partnership with SNV Netherlands Development agencies instituted a research programme on the commercialization of improved fodder production crafted on the theory of change in the counties of Taita Taveta, Kajiado, and Narok. The KALRO's role in this project was to upscale fodder production. Under this project, KALRO proposed an innovative mixed-sward of legume and grass materials in a ratio of one to three. The rationale behind this approach is that grass integration with legumes, results generally in a higher protein-rich and lower fiber content yield than in the grass only[1]. Additionally, legumes help in increased soil fertility through fixing N, higher quality feed leading to increased productivity and environmental protection in the long term[2]. However, appropriate genetic material available within Kenya is limited, particularly leguminous in nature, and for those available, there is little knowledge of some of the most significant ecological-specific performance attributes. Nevertheless, in the identification of the fodder legumes and range grasses for this project, the focus was limited to the few registered fodder legumes and grasses materials by Kenya Plant Health Inspectorate Services.

The recurrent challenges of climate change dictate the usage of a wide array of appropriate genetic material and therefore twenty fodder crops were identified for promotion. The list includes three types of grass namely Brachiaria camelo, Panicum Maximum variety Massai, and Nutrifeed *(Pennisetum glaucum hybrid),* and two legumes including Cowpea *(Vigna unguiculata*), and Dolichos lab lab *(Lablab purpureus*) established in the

Lowland region. Four grasses (Brachiaria cayman, Brachiaria cobra, Chloris gayana var. Ex-Tozi, and Panicum variety siambasa) and five legumes namely Desmodium *(Desmodium intortum)*, Purple vetch *(Vicia benghalensis),* Lupin *(Lupin albus),* Velvet bean *(Mucuna pruriens*) and Sweet potato vines variety Ex-Mukurweini *(Ipomea batattas)* were established in the highlands regions. In addition, four grasses namely Boma Rhodes ***(****Chloris gayana****)***, Bushrye *(Enterepogon macrostachyus),* African foxtail *(Cenchrus ciliaris),* and Sugargraze (*Sorghum bicolor*), and two legumes including Sunn hemp *(crotalaria juncea)* and Lucerne *(Medicago sativa)*) were recommended for both regions. These fodder-producing materials are climate resilient and were found to yield a high volume of palatable biomass and an immense nutrient profile[3] that is higher than seventy (70) g/kg CP level considered the critical threshold for the maintenance of ruminant livestock[4]. Equally, the crops can perform well in infertile soils and have high carbon sequestration potential[5,6]. Unfortunately, there is inadequate information on the expected economic return and this paper focus on the profit perspective for these fodders. The merit of a detailed profitability analysis can inspire local producers and communities to shift towards more sustainable livestock production systems.

II. Materials and Methods

Study sites

The study sites were the counties of Kajiado, Narok, and Taita Taveta of Kenya. These counties are semi-arid with annual rainfall ranging from 300 to 2500mm per annum received in two seasons and mean annual temperatures >19°C[7,8,9]. The three counties lie in the transitional zone between agroecological zones IV and V[10]. Due to their proximate position along the equator, the area experiences a bimodal pattern of rainfall with long rains experienced in March-April-May and short rains from October-November-December. Soil types vary with most being low in organic matter[3].

Study Description

The demonstration plot approach was used in disseminating fodder production technology in the three sites. The targeted population was the common interest farmers' group in fodder production at the community level. Before the fodder demo establishment, training sessions of training of trainers (ToTs), lead farmers, and coordinators were organized. Each ToT and lead farmer with the help of his respective coordinators was supposed to establish a pasture demonstration plot for training farmers. The demo plot size was 10×10 meter square and this was extrapolated to one acre for this study. The first form of analysis involved variance from the actual realized vis-à-vis the reported optimal biomass in the Encyclopedia of Feedpedia.

In the profit evaluation of fodders production, several important traits of fodder such as Seasonal DM yield, Quality, Silage DM Yield, and Persistency are recommended for consideration[11]. In this study, seasonal DM yield was considered an important trait that would influence profitability at the farm level. The sampling was done from a total of 60 demo plots that were established in the three counties. However, this study targeted those demo plots with a crop establishment rate of above 70%[12] and this reduced sampled demos to fifty. The fodders were harvested at the bloom (50% flowering) stage for quality and feeding value testing[3]. Samples for estimating biomass were collected randomly by establishing two one-meter square quadrats evenly distributed along the diagonal transect. The harvesting was done by clipping to ground level all the above-ground vegetation and dried before being weighed for biomass yield. Following Ramsay PM et al[13], fixed dead material was harvested, but the ground litter was not.

The direct benefits of the fodder production were estimated as the number of 15 kg hay bales produced. Inputs and outputs were valued at the prevailing market rate of the cost of land ploughing, harrowing and farrow opening; wage rate of material planting; cost of planting materials and weed management; cost of hay harvesting and storage. On the outputs side, the selling price of a 15 kilograms' hay bale. For seasonal variation, the valuation was adjusted using the existing estimated inflation rate for the month of February 2023. The direct economic evaluation involved estimating the gross margin (GM) and the benefit-cost ratio (BCR) of fodder production and marketing. The GM was calculated by subtracting the variable costs from the gross production value while the BCR which is the relative profit was computed as the ratio of gross production value to production costs[14]. If a fodder variety has a BCR greater than one, then it is expected to deliver a positive net present value to a farmer.

Further, to overcome the drawbacks of farmers' performance based on accounting measures of GM and BCR, we adopted an innovative concept of performance measurement based on stochastic profit frontier efficiency. The concept of stochastic profit frontier measures the distance between the current profit of a firm and the efficient profit frontier and encompasses errors on the input side as well as on the output side. The literature distinguishes between standard profit efficiency and alternative profit efficiency depending on whether the hypothesis of perfect competition in the markets of inputs and outputs is assumed or not[15]. Standard profit efficiency measures how close a firm is operating to its maximum profit given a price level for inputs and a price level for outputs, assuming perfect competition in these markets. This means that a firm takes as given the prices of inputs and outputs and maximizes its profit by adjusting its quantities.

$$\pi = (p, w) \exp(v_\pi) \exp(-u_\pi), \quad (1)$$

where π is the profit variable, p is the price vector of the variable outputs (in this case the price of the 15kg bale of fodder), w is the price vector of the variable inputs. The inputs considered include the cost of land ploughing, land harrowing, furrow opening, planting, planting materials, harvesting and bailing, transportation and marketing. Term u_π present the inefficiencies found that reduce profit, and $v_\pi$represents random error. However, in practice, the assumption of perfect competition is not applicable in many farming situations, as farmers can exercise some discretionally market power in setting the price of outputs. Therefore, the alternative profit efficiency that measures how close a firm is operating to its maximum profit given its level of output was found to be appropriate. In this case, the alternative profit efficiency takes the quantity of output as given and the price of the outputs is allowed to vary freely and affect the profit of the farmer;

$$\pi = (y, w) \exp(v_\pi) \exp(-u_\pi), \quad (2)$$

where the variables are as defined in (1) and y is the vector of quantities of the variable outputs. Based on equation (2), the alternative profit efficiency of the farmer is defined as the ratio between the current profit and the maximum profit that a farm could achieve if it were perfectly efficient ($u_\pi = 0$). Although the basic assumption from the Resource-based view is the heterogeneity of resources between farms, from the experimental point of view, we consider that all the farm sites within the zones of highland and lowland share the same technology; that is to say, there were homogeneous. Therefore, it is assumed that the efficient frontier is common for all farms, and the traditional frontier models proposed jointly by Aigner D et al[16] and Meeusen and Van der Broeck[17] (1977) with a flexible transcendental logarithmic (abbreviated 'Translog') functional formation was adopted alternative is Cobb-Douglas[18]. Following Kibara and Kotosz[19], the Translog model employed in this study was specified as;

$$ln\,\pi_i = \beta_o \sum_{i=1}^{N} \beta_i \,ln\, Y_i + \sum_{i=1}^{N} \beta_i \,ln\, W_i + \frac{1}{2} \sum_{i=1}^{N} \sum_{k=1}^{N} \beta_{ik} \,ln\, Y_{ik} \,ln\, XW_{\boldsymbol{ik}} + \nu_i - u_i, \quad (3)$$

where Y_i is the observed scalar variable output of farmer *i*, and $\boldsymbol{W_{ij}}$ is a vector of *J* inputs used by farmer *i*. In a traditional stochastic profit frontier modelling, profit-oriented efficiency is calculated as a ratio of the observed profit to the corresponding optimal frontier profit, given the available technology;

$$Profit\ efficiency = \frac{\pi}{\pi^*} = \frac{(y,w) \exp(v_\pi) \exp(-u_\pi)}{(y,w) \exp(v_\pi)} = exp(-u_\pi), \quad (4)$$

Here π is the observed profit and π^*present the frontier output.

III. Result and discussion

Optimal versus actual analysis

The insights that can be gathered from optimal versus actual variance analysis guides fodder producer or any economic agent in strategy formulation and decision-making. This is because it provides a clearer picture of how far the farmer is operating from the various reported optimal solution. In our case, the parameter considered was DM yield (also referred to as biomass yield), and the result of the analysis is presented in Table 1. The result indicated that most of the grass species selected except African Foxtail, with cognizance of results in similar environments elsewhere as reported in the online encyclopedia of animal feeds, were performing below the optimal level implying that there is room for improvement. Overall, although grasses were cultivated in a separate parcel of land, the application of fertilizers and manure is very much limited and this could have actually resulted in low yield. African Foxtail is considered a lowland crop, although the result indicates that it has a high potential for highland zones. The result also indicates that there is a comparability between tropical/sub-tropical grasses of African origin, that is African Foxtail and Bushrye but some exotic grasses such as Panicum Maximum variety Massai, and Siambasa, Brachiaria hybrid var. Cobra, Camelo, and Cayman are also significant. Further, the analysis shows that the heavy emphasis on Rhodes grass in intensive and extensive systems as currently emphasized by the development agent is misplaced, compared with other improved grasses having superior quality and much higher potential for improving livestock production

Table 1: Actual and Optimal Biomass Production for Selected Grasses (t/ha)

	Lowland		**Highland**	
Grass variety	**Actual**	**Optimal**	**Actual**	**Optimal**
Sugargraze (*Sorghum bicolor*)	28.00	37.5	29.80	37.5
Nutrifeed *(Pennisetum glaucum hybrid)*	24.00	31.2	-	-
Brachiaria hybrid var Camelo	6.78	30	10.15	30
Bushrye *(Enterepogon macrostachyus)*	5.00	5	9.71	18
Panicum Maximum var Massai	9.95	15	-	-
Foxtail *(Cenhrus ciliaris)*	8.57	10	16.55	10
Boma Rhodes ***(****Chloris gayana****)***	24.10	25	15.69	25
Brachiaria hybrid var Cobra	-	-	24.90	40
Panicum Maximum var Siambasa	-	-	21.88	35
Brachiaria hybrid var Cayman	-	-	21.55	35
Chloris gayana var. Ex-Tozi	-	-	6.00	15
Source: Own construction				

With regard to legume crops, the major weakness lies in the lack of suitable leguminous material to complement grass-based systems. Legumes materials available for development (and research) within Kenya are limited, and there is little knowledge of the optimality of some of the most significant species. An allay of potential legume materials available commercially were proposed for planting and their biomass was estimated. A list of luminous fodder species considered worthy of widespread promotion is presented in Table 2. Based on the biomass estimate, most of the varieties recorded below optimal. Interestingly, four species namely Sweet potatoes vines variety Ex-Mukurweini *(Ipomea batattas),* Velvet bean *(Mucuna pruriens*), Vetch *(Vicia benghalensis)* and Cowpea *(Vigna unguiculata*) reported an increase in biomass production in that order in highlands and lowland zones of Kenya. The most striking feature of the comparative optimal analyses was the DM production for the Velvet bean *(Mucuna pruriens*) and Cowpea *(Vigna unguiculata*) which was 1.9 and 1.6 times high than the reported optimal level, respectively. However, altogether, the best most of the legumes material portrayed favourable biomass production in the two zones.

Table 2: Actual and Optimal Biomass production for Selected Legume (t/ha)

	Lowland		Highland	
Legume variety	**Actual**	**Optimal**	**Actual**	**Optimal**
Dolichos *(Lablab purpureus)*	8.33	12.60	-	-
Cowpea *(Vigna unguiculata*)	7.85	5.00	-	-
Sunn hemp *(crotalaria juncea)*	6.05	16.00	16.35	25.00
Lucerne *(Medicago sativa)*	4.90	20.00	3.96	20.00
Vetch *(Vicia benghalensis)*	-	-	6.20	5.80
Lupin *(Lupin albus)*	-	-	7.69	5.00
Velvet bean *(Mucuna pruriens*)	-	-	19.35	10.00
Vines var. Ex-Mukurweini *(Ipomea batattas)*	-	-	19.32	36.20
Desmodium *(Desmodium intortum)*	-	-	13.30	20
Source: Own construction				

Profit Efficiency and Benefit-cost Analysis

Profitability studies are deemed critical in fodder research by most researchers to provide justification for the continuing technology transfer processes. There are a few examples of on-farm controlled experimental studies of grasses and fodder legumes in semi-arid Africa focusing on profitability issues[20,21,22,12,23]. This is partly explained by the fact that in sub-Saharan Africa, it has been especially difficult to identify fodder legumes that even meet a minimal set of performance criteria[21]. The purpose of this section is to present the stochastic profit frontier result together with the costs and benefits of planting pure stands of grasses and legumes in the southern ASALs of Kenya.

Summarized fodder materials profit efficiency together with gross margins (GM) and benefit-cost ratios (BCR) analysis is reported in Tables 4 and 5. Some general compared to cost and benefit analysis associated with fodder production with regard to the evaluated GM and BCR. Based on GM and BCR, all the grass and legume species analyzed gave a positive GM and a BCR above one. This means that the costs invested in fodder production are recovered and high benefits are realized. Among the eleven grass species analyzed, Sugargraze recorded the highest benefit in both the lowland and highlands while Bushrye and Ex-Tozi had the lowest in highlands and lowlands, respectively. The improved varieties (e.g. Sugargraze, Nutrifeed, Cobra, Panicum Siambasa, and Cayman) seem to record high benefits compared to range grasses. Similar study conducted by Manyeki et al., (2015) on the range grasses (Masai love grass *(Eragrostis superba)*, African foxtail, Bushrye, and Horse tail (*Chloris roxyburghiania*)) in similar environmental conditions reported high BCR (of more than 2.7) with a high net present value with Omollo EO[24] observing that hay and grass seed production as a profitable venture (with BCR of 1.73) for the same species. Regarding leguminous species, Vetch and Lupin top the list while the lowest was lowland varieties namely Dolichos and cowpeas. A similar study conducted by Baran MF[25] on the energy and economics of vetch production in Turkey, although in a different environmental condition observed that investing in purple vetch is profitable with a BCR of 2.25, per hectare vetch. Generally, the striking feature that can be observed between grasses and legumes varieties is that legumes recorded high GM and BCR, implying that more profit is expected in the production of fodder legumes than in grasses.

However, the use of an aggregate measure such as the GM and BCR indicators alone has serious drawbacks as it ignores other relevant dimensions. A purely financial measure as the case with the GM and BCR indicators does not take into account the efficiency with which the farmer uses its resources. As such, a profit efficiency measurement was conducted and the result are presented alongside GM and BCR findings. The average efficiency of the profit frontier with random coefficients was 87.37% and 83.94% for lowland and highland grasses, which implies that these farms are wasting, on average, 13.63% and 16.06% of their maximum potential profit, respectively. In the lowland regions, the highest and lowest profit efficiency is recorded in the production of Sugar graze and Panicum Maximum var. Massai, respectively. In highland regions, Brachiaria hybrid var. Cayman had the lowest profit efficiency score and Desmodium had the highest. However, as indicated previously, profit efficiency is a measure of farm performance that is different from traditional financial accounting measures such as GM and BCR, and they are not necessarily correlated. The result in Tables 3 and 4 confirm this hypothesis, as grasses and legumes with high GM and BCR are not necessarily more profit efficient. For instance, foxtail grasses had the lowest GM and BCR but relatively high-profit efficiency score. Conversely, Cayman grasses recorded a relatively high GM and BCR in the second season but the profit efficiency is very low. With regards to legumes, in lowland regions, Sunn hemp registered high GM and BCR in season two but the profit efficiency is lower while in the highland regions, Lucerne was the lowest with relatively high profit efficiency levels. Generally, legumes attract high profits compared to grasses, perhaps due to the high nutritive values that attract high prices per bale and biomass.

Table 3: Seasonal GM and BCR for Selected Grasses for the Lowland and Highland

	Lowland					Highland				
	First Season		Second Season		Profit efficiency scores (%)	First Season		Second Season		Profit efficiency scores (%)
Grass variety	GM	BCR	GM	BCR		GM	BCR	GM	BCR	
Sugar graze	161,754	3.49	175,284	4.41	98.99	173,228	3.55	186,648	4.42	92.77
Nutrifeed	133,485	3.19	150,032	4.39	79.81	-	-	-	-	-
Camelo	9,805	4.05	41,320	4.05	80.46	33,116	1.68	62,596	4.20	83.08
Bushrye	7,828	3.25	23,338	3.25	92.42	31,320	1.92	46,720	3.49	83.11
Maasai	33,173	4.19	61,333	4.19	81.68	-	-	-	-	-
Foxtail	18,618	2.66	35,998	2.66	97.22	63,294	2.31	80,674	3.61	77.95
Boma	101,433	3.66	118,154	3.66	92.66	59,685	2.29	76,405	3.60	98.74
Cobra	-	-	-	-	-	127,334	2.72	155,714	4.40	92.00
Panicum Siambasa	-	-	-	-	-	114,758	2.84	136,648	4.38	92.59
Cayman	-	-	-		-	105,085	2.52	134,565	4.38	53.68
Ex-Tozi	-	-	-		-	10,153	1.33	28,303	3.33	81.56

Source: Own construction

Table 4: Seasonal Gross Margin and Benefit-cost Analysis for Selected Legumes for the Lowland and Highland

	Lowland					Highland				
	First Season		Second Season		Profit efficiency scores (%)	First Season		Second Season		
Legume varieties	GM	BCR	GM	BCR		GM	BCR	GM	BCR	
Dolichos	79,962	3.47	79,962	3.47	84.12	-	-	-	-	-
Cowpea	74,309	3.35	74,309	3.35	93.64	-	-	-	-	-
Sunn hemp	43,091	2.12	68,391	6.17	84.78	163,802	3.89	188,992	6.99	97.75
Lucerne	24,708	1.60	54,925	5.92	93.59	13,702	1.34	43,919	5.62	98.79
Sunflower	-	-	-	-	-	435,824	6.26	435,824	6.26	98.23
Vetch	-	-	-	-	-	277,485	4.65	304,325	7.20	90.29
Lupin	-	-	-	-	-	240,787	4.69	263,227	7.14	84.73
Mucuna	-	-	-	-	-	195,986	4.01	224,119	7.07	93.66
Ex-Mukurweini	-	-	-	-	-	205,398	4.72	205,398	4.72	99.21
Desmodium	-	-	-	-	-	137,605	4.29	153,280	6.87	99.26

Source: Own construction

IV. Conclusion

This paper introduces important innovations to the existing literature. First, we argue that using profit efficiency as a dependent variable in the fodder crop empirical analysis is more appropriate than using the traditional financial or accounting measures of GM and BCR of farms' performance. Second, our study proposes an appropriate methodology for measuring farm performance based on the profit-efficient use of its resources: the stochastic frontier model with random coefficients. This methodology allows the separation of the inefficiencies in the allocation of resources across the farms. The results showed how profitable the production of fodder of legumes and grasses could be both in the highlands and lowlands zones of ASALs of Kenya. This means that the costs invested in the fodder production by farmers in ASALs can be recovered and high benefits realized. It was also very clear that profit efficiency as the measure is different from traditional financial accounting measures such as GM and BCR, that is to say, that they are not necessarily correlated. Therefore, an effective and broad ranging legume/grass development program based on the two measures is central to addressing the productivity of fodder production in Kenya. This is because these species are strategically suited as a profitable venture and can also support any livestock production systems, thus a comprehensive program could be implemented at a relatively low cost. However further research is needed to ascertain the performance of livestock with unsupplemented legume and grass mix sward livestock production systems and estimate the associated economic benefit.

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References

[1]. Kebede G, Assefa G, Feyissa F, Mengistu A. Forage legumes in crop-livestock mixed farming systems," A review. Intentional. Journal of Livestock Research. 2016; 6(4): 1-18.
[2]. Andrews M, James EK, Sprent JI, Boddey RM, Gross E, dos Reis Jr, FB. Nitrogen fixation in legumes and actinorhizal plants in natural ecosystems: values obtained using 15N natural abundance. Plant Ecology and Diversity. 2011; 4(2-3): 131-140.
[3]. Maweu AN, Korir BK, Kuria SG, Ogillo BP, Kisambo BK, Wambulwa LM, Kubasu DO, Musyimi DM, Manyeki JK, Chege PW. Promoting improved forages for increased livestock productivity in the Arid and Semi-Arid Lands (ASALs) of Kenya. A case of Kajiado, Narok and Taita Taveta county. International Journal Veterinary Sciences and Animal Husbandry. 2023; 8(2): 93-101.
[4]. NRC. Nutrient Requirements of Dairy Cattle: Seventh Revised Edition. The National Academies Press: Washington, DC, USA, 2001; 405.
[5]. Njarui DMG, Gatheru M, Ghimire SR. Brachiaria Grass for Climate Resilient and Sustainable Livestock Production in Kenya. In: Oguge, N., Ayal, D., Adeleke, L., da Silva, I. (eds) African Handbook of Climate Change Adaptation. Springer, Cham, 2021.doi.org/10.1007/978-3-030-45106-6_146
[6]. Ponsens J, Hanson J, Schellberg J, Moeseler BM., "Characterization of phenotypic diversity, yield, and response to drought stress in a collection of Rhodes grass (Chloris gayana Kunth) accessions.\Field Crops Research. 2010; 118(1): 57–72. doi:10.1016/j.fcr.2010.04.008

[7]. CGK (County Government of Kajiado). Kajiado County Integrated Development Plan, 2018-2022. Government Press of Kenya, 2018.
[8]. CGT (County Government of Taita). Taita Taveta County Integrated Development Plan, 2018-2022. Government Press of Kenya, 2018.
[9]. CGN (County Government of Narok). Finance, Economic Planning & ICT Annual Development Plan 2021/22 Financial Year. Government Press of Kenya, 2020.
[10]. GoK (Government of Kenya). Counting Our People for the Implementation of Vision 2030: The 2009 Kenya Population and Housing Census, Kenya Bureau of Statistics (KNBS); Ministry of State for Planning, National Development and Vision 2030, 2010.
[11]. McEvoy M, McHugh N, O'Donovan M, Grogan D, Shalloo, L. Pasture profit index: updated economic values and inclusion of persistency. In EGF at 50: The future of European grasslands. Proceedings of the 25th General Meeting of the European Grassland Federation, Aberystwyth, Wales, 2014; 7-11 September 2014 (843-845). IBERS, Aberystwyth University.
[12]. Manyeki JK, Kirwa EC, Ogillo PB, Mnene WN, Kimitei R, Mosu A, Ngetic R., "Economic analysis of natural pasture rehabilitation through reseeding in the southern rangelands of Kenya. Livestock Research for Rural Development. 2015; 27: 49. http://www.lrrd.org/lrrd27/3/many27049.html
[13]. Ramsay PM, Oxley EB. An assessment of aboveground net primary productivity in Andean grasslands of central Ecuador. Mountain Research and Development. 2001; 21(2): 161-167.
[14]. Sarica D, Demircan V, Naziroglu A, Aydin O, Koknaroglu H. The cost and profitability analysis of different dairy farm sizes. Tropical Animal Health and Production. 2022; 54(5): 320.
[15]. Arbelo A, Arbelo-Pérez M, Pérez-Gómez P. Profit efficiency as a measure of performance and frontier models: a resource-based view," BRQ Business Research Quarterly. 2021; 24(2): 143-159.
[16]. Aigner D, Lovell K, Schmidt P. Formulation and Estimation of Stochastic Frontier Production Function Models. Journal of Econometrics. 1977; 6(1): 21-37.
[17]. Meeusen W, Van den Broeck, J. Efficiency Estimation from Cobb-Douglas Production Functions with Composed Error. International Economic Review. 1977; 18(2): 435-444.
[18]. Kanyalaxmi TD, Pathak H, Choudhary VK. Resource Use Efficiency of Chakhao Cultivation in Manipur. International Journal of Humanities Social Science and Management. 2023; 3(3): 18-22.
[19]. Kibara M.J, Kotosz B. Are livestock farmers in Kenya efficient? Evidence from a farm-level analysis. SN Business and Economics. 2022; 2(9), 131.
[20]. Agyemang K, Dogoo DL, Makun HJ. Profitability of forage production in smallholder peri-urban dairy production systems. Experimental Agriculture. 1998; 34(4): 423-437.
[21]. Sumberg J. The logic of fodder legumes in Africa. Food Policy. 2001; 27: 285–300.
[22]. Brewin DG, Undi M, Kulshreshtha S, Wittenberg K, Tenuta M, Ominski KH. Integration of forage, beef, and hog production systems in western Canada: An economic assessment. Agricultural Systems; 2014; 127: 1-8.
[23]. Demircan V, Dalgic A, Sarica D. Cost and profitability analysis of forage crops: a case study of Burdur Province, Turkey. Custos E Agronegocio On Line. 2021; 17(3): 71-84.
[24]. Omollo, E-O., 2017, Analysis of fodder production and marketing in the rangelands of southern Kenya (Doctoral dissertation, University of Nairobi).
[25]. Baran MF. Energy and economic analysis of vetch production in Turkey: a case study from Thrace region. Fresenius Environmental Bulletin. 2017; 26(3): 1967-1973.