

Full Length Research Paper

Drivers and restrictions of range pasture improvement by agro-pastoralists in Kiruhura District, Uganda

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Range pastures provide the basic ruminant feeds resource for livestock production in semi-arid areas despite ruminant nutrition remaining a challenge affecting productivity. Different livestock development interventions have been promoted to improve livestock nutrition with low farmer adoption rate. A cross sectional exploratory study was conducted between March and July 2018 to identify the drivers of range pastures improvement technologies adoption in rangelands with specific objectives as: (a) Assessing the knowledge, attitudes and practices of pastoralists in regard to range pasture improvement practices and technologies; (b) identifying the forage species planted by pastoralists and strategies for their sustainable utilization; (c) identifying the incentives for the adoption and maintenance of range pasture improvement practices and; (d) identifying the key players and their roles in range pasture improvement promotion and constraints faced in attempt to improve rangeland pastures. A structured questionnaire guided interview was conducted with 294 agro pastoralists while qualitative data was obtained using, KII. Results revealed that farmers had knowledge on range pasture improvement technologies, although adoption rate was low (19.5%). The range pasture improvement practices, included: Pasture establishment, bush clearing, paddocking, conservation, reseeding and over-sowing and water development. However, results also revealed knowledge gaps in silage and hay making, reseeding and understanding principles of range management. The level of education, household income, off farm activities, access to laborers and credit, agriculture exhibitions, farmers' meetings and on-farm demonstrations influenced farmers' adoption of fodder production technologies. Farm gate milk prices, sensitization, financial support, farm output of adopters and inputs support seemed to drive farmers to improve their range pastures. These findings underline the importance of farm-gate milk prices and institutional support as drivers for farmer decision for investment in pasture improvement. Therefore, policy and development interventions should emphasize improvement of milk farm gate prices and farm support systems.

Key words: Farm-gate milk prices, range over-sowing, re-seeding, species recruitment.

INTRODUCTION

Range pastures provide the basic ruminant livestock feeds resource for production in rangelands. Ruminant

animals have the ability to convert such forages into milk, mohair, meat, hides and skins and draught power,

providing man with food, fiber and income thus reducing vulnerability to poverty. Range pastures provide cheap and readily available animal feed resources despite being with low nutrients due to poor management affecting productivity and net benefits. The season availability, fluctuating quantity and quality of year round range forage supply remain a major constraint to sustaining livestock productivity. Range grasses, herbs, forbs, shrubs and trees contribute to rural farmers' economic and environmental sustainability (Peters and Lascano, 2003). Pasture legumes offer a lower-cost alternative to nitrogen fertilizers and purchased protein supplements for improving dairy cattle feed resources in the tropics (Mapiye et al., 2006). However, the low quality and quantity of the range pastures caused by poor management and environmental conditions including variable rainfall and temperatures limit livestock productivity. Mutanga et al. (2004) noted that availability and quality of nutrients in ruminant diet are two of the major factors which limit animal production in the tropics, besides water accessibility and tropical animal diseases. Rusdy (2020) also reported that the low availability and fluctuating quantity and quality of forage growing in grassland, shrinking grassland area and poor management were the main causes of increased land degradation and reduced productivity of animals grazing on tropical grasslands. The lowered productivity of livestock in turn affects incomes, nutrition and food security of households, whose livelihoods is dependent on livestock, making them more vulnerable to climate extreme events and poverty. Despite Ugandan rangelands being endowed with natural pastures, they are unsustainably utilized leading to degradation. Rangeland degradation is globally attributable to both anthropogenic and natural causes and is the major threat affecting grazing rangelands (Zerga, 2015). This degradation is caused by climate variability, overgrazing by ruminants attributed to continuous grazing management and termites due to; their high population densities, poor pasture renovation, poor use of fire, limited reseeding and over sowing with legumes and nutritive grass species, and pasture preservation strategies (Bolo et al., 2019) leading to difficulties to produce food locally (Abusin et al., 2020). Zerga (2015) noted shift in species composition, loss of range biodiversity, reduction in biomass production, less plant cover, low small ruminant productivity, and soil erosion as indicators of rangelands degradation. Rangeland degradation affects animals and plants equally as increased degradation limit the availability and quality of forage and water resources, denying ruminant livestock good nutrition impacting human livelihoods. Overgrazing

due to poor grazing methods has caused reduced vigor of available palatable species, reduced herbage production, accelerated soil and water erosion, bush and weed invasion, reduced stocking rate, poor species recruitment and loss of soil organic matter and reduced carbon sequestration, contributing to global warming and climate change. The range productivity is further worsened by water scarcity, soil mining, invasive species and termite invasion. Strategies to address these problems in rangelands would be to embrace good agronomic practices including climate smart technologies. Rusdy (2020) reviewed the benefits of incorporating *Leucaena leucocephala* to overcoming land degradation and increasing soil fertility and its nutritive value in relations to animal production in grasslands.

Several development agencies have traditionally emphasized and invested in capacity building for livestock development though they have not managed to improve the rangelands. It should be noted that in the 1990s, the Dryland Husbandry Project (DHP) brought many farmers on board for capacity building in range pasture management with moderate participation and adoption of management technologies and practices. The technologies and practices adopted then included: pasture establishment, organic manuring, water harvesting, over-sowing and reseeding, legume pasture seed production and erosion control with a relative number of farmers adopting at the time. However, there was unanticipated drop out of implementation of pasture improvement practices and technologies in the 2000s upon projects expiry. It has been observed that about fifteen years later, many farmers started reviving their interest in implementing the previously dropped practices and technologies raising a key question in this study, which is "what are motivates and drives farmer's decision to invest in range pasture improvement?" Adoption of a pasture improvement technology refers to use of the technology for one and/or more than one year, on the other hand non adoption of technology refers to not using these technologies or using them for less than one year. Manyeki et al. (2013) asserted that the rate of adoption is the relative speed with which members of a social system utilize an innovation and can be measured as the number of individual who utilize a new technology within a specified period. This study therefore aimed to identify the drivers and limitations of range pasture improvement for enhancing livestock productivity by pastoralists in rangelands in Uganda.

The following questions guided the study: How do the knowledge, attitudes and practices of pastoralists affect decisions to adopt range pasture improvement practices and technologies? What are the forage species planted

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by pastoralists and how are they utilized? What are the incentives for the adoption and maintenance of range pasture improvement practices? Who are the key players in range pasture improvement promotion, their roles and what constraints do they face in attempt to improve rangeland pastures? Thus, the objectives of the study were to: (a) assess the knowledge, attitudes and practices of pastoralists in regard to range pasture improvement practices and technologies; (b) identify the forage species planted by pastoralists and strategies for their sustainable utilization in the semi-arid rangeland; (c) identify the incentives for the adoption and maintenance of range pasture improvement practices and (d) pinpoint the key players and their roles in range pasture improvement promotion and constraints faced in attempt to improve rangeland pastures. The generated information will guide extension services' provider stakeholders working in Uganda rangelands in rationalization of their activities for improvement of the livestock feed resources.

Theoretical framework

Theoretically, there are several factors that can influence farmers participation and adoption of agricultural technologies, which includes: socio-demographic attributes such as age- sex, level of education, family size; socioeconomic factors like income- land size, off-farm income, production systems, production goals; institutional factors like- access to credit, farmer exposures and extension contact, and improved livestock husbandry practices characteristics like its relevance, compatibility, simplicity, costs; as well as physical and environmental factors like- climate and soil factors according to Kaliba et al. (1997, 1998). Social networks and differences in expected returns to a new technology may influence individuals' adoption decisions and the diffusion of new technologies (Ntume et al., 2015).

If favorable, these factors therefore, influence farmers' decision to adopt range pasture improvement technologies and enhance range productivity. The study analyzed these factors in relation to adoption of natural pasture improvement. Studies on agriculture technology adoption have shown various drivers to be in control. Ainembabazi and Mugisha (2014) examined the role of farming experience on the adoption of agricultural technologies by small holder farmers in Uganda, while Mudombi (2015) investigated the adoption of improved sweet potato in Zimbabwe. Alomia-Hinojosa et al. (2018) explored farmer perceptions of agricultural innovations for maize legume intensification in Nepal. Onuche et al. (2020) investigated the perception and uptake of aquaculture technologies in central Nigeria and reported that age, primary occupation and distance to urban center negatively affected adoption of innovation. The same authors also found out that technical know-how, "other income", education and gender were drivers of

perception and adoption of aquaculture innovations drivers of perception and adoption of aquaculture innovations.

Previous assessment reports on adoption of livestock development technologies' have focused on general husbandry and the impact on production. Other existing studies looked at the effectiveness of extension programs, although few examined the mechanisms that drive technology adoption. These studies also did not analyze what drives pastoralists in decision making with regard to natural pastures improvement. This study focused on establishing the influence of different independent variables on the adoption of range pasture improvement technologies and practices by the pastoralists from the Pastoralists' socio-economic context (Figure 1).

METHODOLOGY

Description of the study area

The study was carried out in Kiruhura District one of the rangeland district located at: 00°12'53"S 30°46'12"E in Ugandan rangelands popularly referred to as "cattle corridor". The "cattle corridor" extends diagonally from the South-west bordering with Rwanda to the North-east direction bordering with Sudan/Ethiopia/Kenya borders (UIA, 2016). Uganda has livestock population of: 14.2 million cattle, 16 million goats, 4.5 million sheep, and 4.1 million pigs with greatest concentration of animals found in the "cattle corridor and a poultry population of 47.6 million (MAAIF and UBOS, 2018). The District experiences a bi-modal pattern of rain seasons, which normally occurs from March to May and mid-August to October. On average the annual rainfall is about 900 mm. Notwithstanding the rainy seasons, the district is affected by very long dry periods with a temperature ranging from 17 - 30°C. It has savannah woodlands type of vegetation with a wider cover of thorny shrubs. It is estimated that 57.6% of Kiruhura population is engaged in livestock farming and 32.4% is engaged in agricultural production (KDLG, 2012). The District has both fenced (30%) and unfenced farms (70%) which cover an area of 762,766 acres. Kiruhura District is composed of 2 counties namely Nyabushozi and Kazo composed of 15 sub-counties and 3 town councils (KDLG, 2012) from which four sub counties were selected for the study (Figure 2).

Study design and sampling frame

A cross section study was conducted to collect data on rangeland pasture agronomic practices and technologies conducted between March and July 2018. Kiruhura district was purposively selected for being the dairy hub of the region and having participated in the Dryland Husbandry Project (DHP). The district was also selected for the reason that the farmers of the district have adopted breeding improvement of their herds compared to other districts of the cattle corridor. In order to get an understanding of adoption characteristics, both adopters and non-adopters were randomly sampled for questionnaire interview. All farmers that had adopted pasture establishment technology were sampled. Four sub counties were selected from the two counties of Nyabushozi and Kazo. Two sub counties of Nyakashashara and Kenshunga in Nyabushozi county were randomly selected using random numbers, while Kazo and Burunga sub counties from Kazo county were purposively selected for having participated in Dryland husbandry project (DHP)

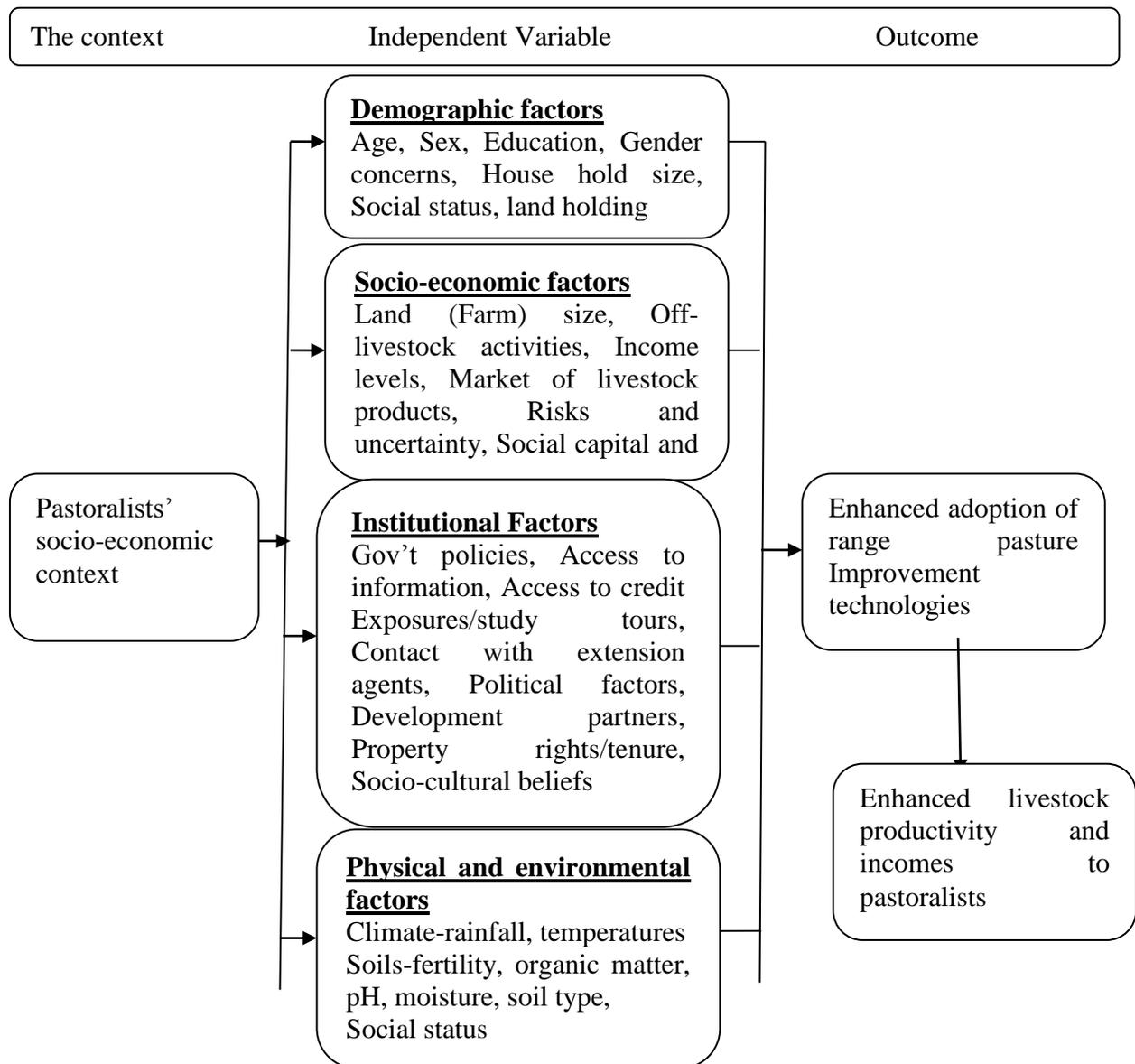


Figure 1. Theoretical framework on adoption of range pasture improvement.

and for inhabiting the Kazo dryland husbandry agro pastoralists association (KDHPA), a pasture improvement based association. The sampling frame therefore included all pastoral households totaling to 1,113HHs in the four selected sub counties.

Sample selection and sampling technique

To obtain the desired sample, a simplified formula for the proportions by Yamane (1973) that assumed a 95% of confidence level and precision of 0.05 was adopted for this study that gave a sample size of 294 respondents distributed in the four selected sub counties. In addition, some key informants were identified with help of local council leaders. The KIs included progressive dairy farmers, elder farmers, farmers' leaders, NGO focal persons and

livestock extension agents. Walks along community routes/roads were also made in the study areas and observations were made in those communities. A standard structured questionnaire was self-administered to a total of 294 respondents who were randomly selected, including all households that had adopted pasture establishment technology from the four of the study sub-counties to collect quantitative data. For this purpose, a list of farmers was prepared in consultation with the local extension personnel, local leaders, Non-Government Organizations and the interviewed farmers separately for all the selected eight parishes.

Data analysis

Qualitative data obtained through focus group discussions, KIs and

Table 1. Socio-demographic characteristics of study respondents.

Variable	Category	Frequency (N=294)	Percent response
Sex of respondent	Male	224	76.2
	Female	70	23.8
Age category of respondent	24 to 29	4	1.4
	30 to 49	118	40.1
	50 to 65	116	39.5
	66 to 79	56	19
Highest level of Education	No formal education	59	20.1
	Primary level	115	39.1
	Secondary level	84	28.6
	Tertiary education	36	12.2
HH Land acreage (ha)	<50	88	29.9
	50 to 100	123	41.8
	101 to 150	42	14.3
	>150	41	13.9
Farming labor	1-2	38	12.9
	3-4	119	40.5
	5-6	85	28.9
	>6	52	17.7
Domestic animal species kept	Cattle	294	100
	Goats	234	81.6
	Sheep	37	12.6
	Local chicken	66	22.4

Source: Authors' computation from field survey data 2018.

and other livelihoods activities are presented in Table 1. The study also revealed that the mean farm labor was 4.85 ± 0.14 persons. Data on education level of respondents showed that majority of respondents has acquired primary and secondary level education although women trailed behind men in all education levels (Table 1). Although equal numbers of men and women (20%) did not acquire any formal education, majority of the women acquired primary (49%) and tertiary (5%) education qualification, compared with 35% and 12% of men with primary and tertiary education level respectively. It was also noted that a large number of men (33%) respondents had acquired secondary education compared to 26% of women respondents.

Education plays a major role in agricultural technology adoption. Women farmers generally have lower education levels compared to men which affect their understanding and adoption of technologies, especially if the technology requires use of more technical and intensive knowledge. Uneducated illiterate women are most likely to fear change and cling to the tradition, as

they see it. The lagging of women in education affect their adoption of agricultural development technologies. In many cases, social and cultural barriers and greater time burdens are major constraints by women in acquiring information, education and training. The agro pastoralists women attainment of low level of education exhibited could also be attributed to their culture associated with early marriage and devaluation of formal education. This gender based difference in education could also be attributed to gender inequality that have been promoted socio-culturally especially among pastoral societies. However, many pastoralists women participate more in non-curricula church based functional adult literacy activities than men which probably enlighten them on the value of education. This gives them some level of empowerment albeit with limited technical skills.

Ogunlana (2003) observed that women's limited access to education opportunities and lower access to mass media and other forms of ICT as compared to men are one of the factors contributing to gender gaps in adoption of new technologies. Owuor et al. (2020) reported that

education impacts agricultural output through supporting farmer adoption of new productivity enhancing technologies. Paltasingh and Goyari (2018) found that a minimum threshold level of education is significantly influencing the adoption of modern varieties of paddy and thereby the farm productivity of adopters only. Weir (1999) reported that education enhances the farming skills and productive capabilities of the farmers. It enables farmers to follow some written instructions about the application of adequate and recommended doses of chemical and other inputs (Huang and Luh, 2009).

In this study, majority of respondents were men which could be attributed to gender roles and the patriarch nature consistent with many pastoral groups' cultures. Men own livestock and therefore participate in livestock related activities with some few exceptions. This result is consistent with Bettencourt et al. (2015) who made similar observation that in regard to division of labor women are in charge of small animals and men of big ones. The low participation of the young population (Table 1) could be attributed to the fact that young people are usually not interested due to their negative perception of farming as being archaic and nonpaying, and taking long to bring results compared to industrial sector with regular income and job security. This study further established that younger trained farmers were also less interested in the adoption of improved husbandry practices compared to the medium and older people who were more experienced and innovative in farming. This could also be attributed to the drudgery of farming, lack of property, lack of collateral for loans to acquire farm inputs, limited knowledge in on scientific advancements in agricultural field. In addition, lack of land of their own could also deter young people from investing their energy into projects that are long term. The youths therefore seem to prefer to engage in activities that have quick fixed and secure income such as motor cycle public transport business (popularly known as Boda boda in Uganda) activities.

A study by Mutua et al. (2017) established that personal choice, preference for paid over unpaid labour and gender norms in asset access, ownership and control influence young smallholder participation in livestock production and trade. The older farmers therefore are more likely to try pasturing improvement practices for improving dairy productivity as their main source of cash income. Musaba (2010) reported that older farmers with demanding family responsibilities venture in activities that will help to support their families.

This study also showed that the mean farm size was 105.19 ± 6.82 ha (Range 20-900 ha). However, the average pasture land was low at 1.0289 ha of the total farming land which would only support minimally one livestock unit in a rangeland. The allocation of small land could be due to shortage of land that is put to multiple land use including crop production despite the inherent limitations of rangelands. Similar observations were made by Mapiye et al. (2006) and Yesuf and Kohlin

(2008) who reported a relationship between farm size and adoption of an innovation and a positive correlation between farm size and adoption of new technologies. Onim (1992) found out that small landholdings limited the farmer's choice to cultivate improved forages as available land was used for subsistence food crops. The herd size also seemed as limitation to pastures establishment with small herds' farmers being more likely to establish pastures than households with large herds.

Labor is key in livestock production especially for agro pastoralists who have to divide labor between livestock and crop production in addition to other livelihood activities. Prokopy et al. (2008) reported that labor availability, including both family and hired labor, tended to increase adoption of best farm management practices. However, Joachim et al. (2018) reported that adoption of some agricultural technologies such as row planting increases the labor requirement but lack similar increases in yields or farm productivity. Mwangi (2015) categorized these factors into human specific factors, socioeconomic, technological and institutional factors.

Knowledge, attitudes and technologies of pastoralists in regard to range pasture improvement

Pastoralists' knowledge on range pasture improvement

The study indicated that, all the agro pastoralists were at least exposed to some knowledge on rangelands management and knowledge on livestock production and different extension methods as source of knowledge and skills were employed (Table 2). Results further indicated that agricultural exhibitions, farmers' meetings and on-farm demonstrations played an important role in motivating farmers to improve their pastures. However, respondents attested to not having been fully trained on range management principles for sustainable range health. The results further indicated that only 34(30.4%) of 38.1% of respondents that attended the meetings adopted pasture establishment. Analysis also revealed that attending the meetings influenced pasture establishment adoption ($P=0.007$). Furthermore, the logistic regression revealed a positive relationship between on-farm demonstrations exposure and pasture establishment ($P=0.001$). Results also revealed that 26 (40.6%) of 64 (21.8%) who attended agricultural exhibitions adopted pasture establishment. The logistic regression test indeed revealed that participation in agricultural exhibition significantly ($P=0.003$) influence pasture establishment. The results further indicated that 174 (59.2%) had attended a number of capacity building trainings on livestock production and of those, 34 (19.5%) had adopted some pasture management technologies. However, attending trainings did not influence pasture establishment ($P = 0.979$), although pastoralists'

Table 2. Pastoralists' source of and kind of knowledge acquired on range pasture improvement.

Variable	Alternative variable (N=294)	Percent response
Acquisition of knowledge	All acquired some form of knowledge	100
Major Sources of information	Listening to radios farmers programmes	65
	Consulting friends and neighbors	51
	Training by livestock extension workers	33
	Attending farmer organization meetings	24.1
	Reading newspapers and leaflets	16.
	Attending farmers' meetings	38.1
	Visiting On-farm demonstrations	17.7
	Attending agricultural exhibitions	21.8
Kind of knowledge acquired	Bush clearing techniques	88.5
	Pasture species	65.8
	Reseeding	44.5
	Over sowing	32.4
	Grazing management	48.5
	Use of agrochemicals	15.6

Source: Authors' computation from field survey data 2018.

exhibitions ($P=0.000$) and attending trainings ($P=0.018$) influenced paddocking technology. Similarly, exhibitions and trainings influenced adoption of pasture preservation technologies ($P=0.002$) and meetings on pasture improvement and on-farm demonstrations greatly influenced pasture reseeding ($P=0.001$) and ($P=0.034$) respectively.

Pastoralists own their knowledge and skills of assessing their environment albeit not based on scientific knowledge but from years of observational experience. Pastoralists manage and use vast rangeland areas worldwide and as a result they suffer from and contribute to land degradation, but also they are major actors in land rehabilitation. Pastoralists possess indigenous systems of landscape classification that provides a valuable basis for assessing rangeland resources including biodiversity. For instance, in his rangeland assessments using ecological and anthropogenic indicators, Oba (2012) noted that pastoralists considered soils, vegetation and livestock productivity as their main indicators for understanding rangeland degradation. Oba further reported that pastoralists used key-plant species against landscape-grazing suitability and soils were considered in assessing landscape-grazing potential. Most pastoralists are able to acknowledge environmental changes taking place on rangelands. For example, Pastoralists in Botswana identify contributing factors as dynamic rainfall, overgrazing and fire (Kgosikoma et al., 2012).

Agricultural exhibitions supplement the trainings farmers will have received on range pasture improvement. It can be argued that as farmers participate

in these exhibitions, they gain confidence and become conversant with the practice which encourages practicing and increases the extent of adoption. Therefore, more participation in agricultural exhibitions enlightens farmers and thus influencing them to effectively adopt pasture improvement. However, attending other trainings on livestock production did not influence pasture establishment but influenced paddocking, rotational grazing and pasture preservation technologies. The positive impact training, exhibition and demonstrations could be attributed to their ability to provide the farmers with a higher –order thinking skills and enhancement of tactile hand-eye connections which improves their ability to recall facts. Exhibitions and demonstrations also cause admirations that farmers desire to replicate on their farms. In their review of behavioral factors affecting the adoption of sustainable farming practices, Francois et al. (2019) found out that adoption of sustainable practices is influenced by how farmers learn, understand and perceive these practices, particularly the associated difficulties, costs, benefits and risks.

Agro-pastoralists' Adoption of range pasture improvement and utilization technologies

This study identified a number of practices and technologies that different farmers implemented on their farms (Table 3). Through multiple response analysis, the results revealed varying levels in kind of technology or practice adopted and sites of adoption of range pasture

Table 3. Range Pasture improvement practices and technologies in the study sub counties.

Technology/practice	Sub county			
	Nyakashashara	Kenshunga	Burunga	Kazo
	% (n=75)	% (n=78)	% (n=69)	% (n=72)
Water harvesting	100	100	100	100
Bush clearing	94.7	100	84.1	95.8
Perimeter fence	94.7	88.5	91.3	87.5
Paddocking	46.7	33.3	10.1	29.2
Rotational grazing	21.3	24.4	5.8	8.3
Pasture establishment	16	20.5	4.3	12.5
Pasture reseeding	5.3	6.4	7.2	20.8
Silage production	6.7	7.7	1.4	4.2
Hay production	10.7	5.1	2.9	1.4
Range over-sowing	3.4	4.4	8.2	10.6

Source: Authors' computation from field survey data 2018.

improvement, although water harvesting was implemented by all respondents (Table 3). Field observation also revealed extensive bush clearing but with low recruitment of desirable pasture species and high dominance of herbaceous weedy species that seemed to demoralize adopters.

The observed bush encroachment and farmer's effort to clear them support observations made by Hausmann et al. (2016) who noted ecological consequences associated with physical clearing, especially when the topsoil is disturbed and habitat structure is altered that ultimately favor the growth of perennial grass species as well as re-establishment of fast-growing, undesired species. Bush encroachment and water scarcity were major challenges affecting rangeland productivity and livelihoods to the extent that they take priority for agro pastoralist investment thus the high adoption rates recorded in this study. The weed emergency scenario is a natural ecological phenomena process considering that soil is a natural seed bank of weed seeds. Any disturbance to their habitat will provide such conditions like change in burial depth, moisture and light for their emergency. The ability of aggressive weeds to outcompete and displace desirable species as their strategies to survive must be well understood before planning any bush management to enable appropriate management of subsequent occurrence. An understanding of seed ecology is essential for developing effective management programs for problematic weed species including invasive species. Rangeland vegetation dynamics complexity can be understood from the "state-and-transition model", where rangeland dynamics are described as a set of discrete "states" of vegetation at a specific site and changes between states that occur as discrete "transitions" (Briske, 2017; Liao et al., 2018). Some studies have reported that abiotic factors such as drought, light, salinity, seed burial depth, soil pH, and

temperature as well as disturbance events such as a fire, flooding or tillage can play an important role in initiating or inhibiting seed germination (Baskin and Baskin, 1998; Cuneo et al., 2010). Humphries et al. (2018) acknowledged drought, salinity, alternating temperature, photoperiod, burial depth, soil pH, artificial seed aging, and radiant heat as influencers of seed dormancy.

Analysis of study sites for variation in adoption of practices and technologies established that the technology adoption between sub counties differed (Table 4). Technology adoptions were more in Kenshunga and Nyakashara than in Burunga and Kazo sub counties. The difference could be attributed to the difference in climate where Kenshunga and Nyakasharara have favorable climate for primary production than the latter sub counties. In addition, Nyakasharara and Kenshunga have more improved breeds of cattle dairy farmers which attract good product market that becomes an incentive for adoption of technologies. There was no difference in adoption of pasture preservation between sub counties. The high adoption of water development, bush clearing and perimeter fencing could be attributed to an immediate benefit or impact the innovation has on farm productivity. For instance, water availability during drought reduce water stress and while increasing grazeable land with more herbage increasing stocking rate and better animal body condition giving the farmer an obvious value. In addition, farmers must perceive that there is a problem that warrants an alternative action to be taken. Musaba (2010) made similar observation and revealed that there was no difference in outcomes between alternative and conventional practices and that it would be less likely that farmers would adopt a given improved practice.

While adoption of range pasture improvement would substantially increase livestock productivity, resulting in an increase income and better livelihood, the different

Table 4. Relationship of Range improvement technology adoption between sub counties.

Technology/practice		SS	df	Mean Square	F	Sig.
Bush clearing	Between Groups	.990	3	0.330	6.015	0.001
	Within Groups	15.908	290	0.055		
Perimeter fence	Between Groups	.232	3	0.077	.893	0.445
	Within Groups	25.101	290	0.087		
Paddocking	Between Groups	4.893	3	1.631	8.274	0.000
	Within Groups	57.165	290	0.197		
Rotational grazing	Between Groups	1.886	3	0.629	5.032	0.002
	Within Groups	36.227	290	0.125		
Pasture establishment	Between Groups	1.015	3	0.338	2.926	0.034
	Within Groups	33.543	290	0.116		
Pasture reseeding	Between Groups	1.161	3	0.387	4.492	0.004
	Within Groups	24.979	290	0.086		
Silage production	Between Groups	.169	3	0.056	1.162	0.325
	Within Groups	14.066	290	0.049		
Hay production	Between Groups	.365	3	0.122	2.544	0.056
	Within Groups	13.870	290	0.048		

Source: Authors' computation from field survey data 2018.

technologies had varying levels of adoption in the different study sites. The site difference in internal Paddocking, bush clearing, rotational grazing and pasture establishment observed could be attributed to individual's interest motivated by other factors like the land size, price of milk, individual's income, exposures to demonstration farms, having attended different trainings, social networks among others. However, profitability of the outcome of adoption may play an intrinsic motivation. On the other hand, factors that typically decrease range pasture improvement technology adoption by non-adopters may include: advanced age, credit constraints, and perceptions about technologies including compatibility with the existing system, mindset, sociocultural beliefs and fear of risks/uncertainty that may be associated with the technology. The lack of difference in pasture preservation technologies observed could be due to the meagre adoption rate in all sites and this could be attributed to lack of necessary equipment for mowing and transport and tools, storage facilities, limited knowledge of technologies, conservativeness of pastoralists, lack of economic knowledge and the fear of the large herd size compared to quantity required to sustain them. It is also likely that the characteristics of a technology, such as simplicity, visibility of results, usefulness towards meeting farmer's expectation or need and cost implication of

investment promote will also influence the farmer's decision.

OECD (2001) observed that assimilation and adoption of new technology at the farm level is a function of science, economics and human behavior. The author further noted that technology and change will most likely be assimilated and implemented when: the benefits of implementation will be quickly realized (within one to two years), the tools for implementation are readily available and accessible in the local marketplace, the risk of the implementation are small and the change or new technology can be comfortably integrated into other basic on-going aspects of daily life.

Analysis of the effect of different factors on adoption of range pasture improvement technologies

Influence of income, labor and off-farm income activities on technology adoption

The logistic regression modeling contextual analysis to understand the relationships between the demographic variables with pasture improvement technology adoption revealed that the farm size, household income levels, off farm activities significantly influenced pasture

Table 5. Effect of level of education on range pasture management practices and technology adoption.

Technology	Level of Education			
	None (n=59)	Primary (n=115)	Secondary (n=84)	Tertiary (n=36)
	%	%	%	%
Pasture establishment	6.8	5.2	19.0	38.9
Paddocking	32.2	16.5	33.3	63.9
Rotational grazing	11.9	7.8	16.7	41.7
Pasture reseeding	3.4	8.7	13.1	16.7
Pasture preservation	20.3	7.0	21.4	47.2

Source: Authors' computation from field survey data 2018.

management technology adoption at ($P=0.001$), ($P=0.007$) and ($P=0.000$) respectively. The results also indicated that there was no relationship between age of the household head and adoption of range pasture improvement and farming labor. However, this does not mean that these factors do not influence probability of adopting the technologies. On the contrary, household income levels and off farm income activities strongly influenced paddocking technology ($P=0.018$) and ($P=0.000$) respectively; with rotational grazing at ($P=0.003$) and ($P=0.017$) respectively; and with pasture preservation at ($P=0.002$) and ($P=0.000$) respectively. The study further revealed that only farming labor and off farm income activities had a significant relationship with pasture reseeding technology at ($P=0.024$) and ($P=0.003$) respectively. The study also showed that the household income was influenced by the off farm income activities, and these greatly influenced adoption of internal and perimeter paddocking for rotational grazing and pasture preservation.

Off-farm income activities are an important strategy for overcoming financial capital constraints for disadvantaged rural households. Having income enables the farmer to hire labor and purchase inputs used in adoption of technologies. Similar findings were given by Singha et al. (2011) in the study on technology adoption of different selected land based enterprises under diversified farming systems in India. Diiro (2013) reported a higher adoption intensity and expenditure on purchased inputs among households with off-farm income relative to their counterparts without off-farm income.

Influence of education of the household head on technology adoption

The results has direct relationship between level of education and pasture management practices and technologies with farmers with higher level of education adopting more of the practices than the lower education farmers (Table 5). The Chi-square test revealed that attainment of education influenced adoption of pasture

management ($P=0.000$), paddocking ($P=0.000$), rotational grazing ($P=0.000$) and pasture preservation technologies ($P=0.000$). However, the level of education did not influence pasture reseeding technology ($P=0.121$).

Paltasingh and Goyari (2018) found that minimum threshold level of education influences the adoption of modern crop varieties increasing the farm productivity of adopters. It is therefore evident that education enhances farm productivity in the case of adopters of modern technology. Education enhances the farming skills and productive capabilities of the farmers (Weir, 1999). It enables them to follow some written instructions about the application of adequate and recommended doses of chemical and other inputs (Huang and Luh, 2009). While Manyeki et al. (2013) found age and education level of household head, land ownerships and affiliation to farmers group, sex, formal technical training affecting adoption of natural pasture improvement technologies in Kenya, in this study, farmers' exhibition, farmers' meetings, and exposures on demonstration farms influenced adoption of range pasture improvement technologies and practices.

Influence of household head sex, access to credit and labor on pasture establishment

Results indicated that 40 (13.6%) of respondents adopted pasture establishment technology and of whom 12 (30) were women compared to 28 (70%) of the men. In total, however, the sex of the household head did not influence ($P=0.281$) on pasture establishment in this study, although access to credit played a significant role ($P=0.000$) in pasture establishment. The low participation of women could be attributed to their lack of land and capital to hire labor as most agro pastoral women are not in formal employment. Results further showed that household access to laborers and access to credit had significant influence on adoption of range pasture establishment at ($P=0.032$) and ($P=0.000$) respectively. Belonging to a farmer organization and access to laborers influenced paddocking at ($P=0.029$) and ($P=0.000$) respectively. It was also established that access to credit and laborers similarly influenced

practicing of rotational grazing at ($P=0.010$) and ($P=0.018$) respectively; belonging to organization and access to credit also influenced pasture reseeding at ($P=0.051$) and ($P=0.041$) respectively; similarly, access to credit was significant in influencing pasture preservation ($P=0.011$). Labor and financial capital is key inputs into production. Labor does the physical work of fencing, weeding and driving of animals into pastures while financial support provides an enabling environment. Farmers' membership to groups is likely to increased adoption of specific technologies although this may further be influenced by other factors as calculated by the farmer in his/her decision making on allocation of resources.

Generally, Moyo and Salawu (2017) identified age, education level, family size, farm size, extension service provision and credit access as factors influencing adoption of agricultural new technologies by farmers. Mwaura (2014), Vohra (2016) and Omollo et al. (2018) reported that gender of household head, education, social/development group membership, and access to extension services, social participation, scientific orientation, innovativeness and modernization of the beneficiaries were the most important factors influencing households' participation in fodder production. Mureithi et al. (1998) and Wanyama et al. (2003) acknowledged farmer's participation in on-farm trials, farming experience and land ownership as influencer of range pasture production technologies adoption.

Effect of agro pastoralists' attitudes and incentives on the adoption of range pasture improvement technologies

Although one would expect incentives to influence adoption of pasture improvement technologies, this study found that majority (81.6%) of respondents did not behave the same. However, they suggested that better farm gate milk prices 88 (29.9%), continued sensitization 64 (21.8%), financial support 54 (18.4%), better results from adopters 9 (3.1%) and support with inputs 8 (2.7%) would motivate them to improve their pastures. Surprisingly, some respondents 17 (5.8%) still mentioned that they would not be motivated for pasture improvement claiming it was not necessary. Through the interview of key informants, one elder acknowledged reduction in farm gate milk prices due to increasing milk processing plants and abolishment of milk vendors. In his words, the farmer asserts that with milk vendors, the price of milk would reach Uganda shillings 1200 per liter in the dry season compared to shillings 550 per liter currently". Another farmer mentioned that, "we improve pastures to minimize death of our livestock in drought but it is not a profitable venture". They claimed this demotivates farmers. The results also indicated that the pastoralists who adopted the technologies were motivated by accessing knowledge through farmer trainings by

extension agents, persistent drought that results in loss of pastures, access to financial support and support with inputs mostly pasture seeds.

Enhanced farm productivity, better products' prices, and inputs motivate farmers to invest in technology as they see benefits increment rather than lose. Sensitization is key for knowledge acquisition. The more contact with extension workers, the more likely the farmer to adopt technology. This is probably because extension agents would be focused achieving their own planned extension activities. Attitude and behavior of farmer play a major role in decision making. The negative attitude by farmers towards adoption of range pasture improvement could be attributed to farmers' risk orientation of the technologies, inferiority complex of implementing technologies from highly educated extension worker, fear to make mistakes in implementation, fear of additional expenditure that may come with the implementation and anticipated work drudgery.

Ambetsa et al. (2020) on their assessment of technical efficiency in Kenya, found a higher likelihood of sugar cane farm output from application of farm inputs like fertilizer, labour, seed-cane and farm size as technologies for technical efficiency. Baba et al. (2017) showed that the attitude and behavior of the farmers had a positive effect on the rate of technology adoption of goat farming. Arega (2009) found that extension information was important in adoption of new technologies. On the other hand, lack of market information, financial risks, and access to markets reduce farmers 'incentives to adopt range pasture improvement practices and technologies. However, some studies have indicated that characteristics of innovations comprising relative advantage, complexity, compatibility, trialability and observability, technology characteristics, information sources, knowledge, awareness, attitude and group influence (Oladele, 2005; Moyo and Salawu, 2017). A conceptual framework for an adoption pathway by Mohammad et al. (2003) suggested that farmers move from learning to adoption, to continuous or discontinuous use over time. This explains why in this study area, farmers who initially had adopted, dropped out and recently readopted again.

The forage species adopted by agro pastoralists and strategies for their sustainable utilization

Field observation recorded a number of pasture fields were established by either integrating them in the cropping system or grown in sward and some limited forage conservation technologies carried out. The variety of pasture species both natural and introduced species ranged from grass pasture including *Chloris gayana*, and *Pennisetum purpureum*, to herbaceous legumes that included *Dolichos (lablab)*, *Stylosanthes spp*, *Siratro* and *Centrocema spp* and browse species that included *Calliandra calothyrsus*. and *Glyricidia sapiuem* were the

Table 6. Pasture species, area coverage and utilization in study areas.

Pasture species established	Pasture land coverage in acreage in study area	Method of utilization
<i>Chloris gayana</i>	166.25	Hay making, Seed production for sale
<i>Pennisetum purpureum</i>	62.25	Silage, cut and carry
Brachiaria spp	4.5	Field grazed
<i>Panicum maximum</i>	1.25	Hay making
Herbaceous legumes	25.5	Hay, cut and carry
Woody legumes	1.5	Cut and carry
Maize	30	Silage making

Source: Authors' computation from field survey data 2018.

most abundant browse species (Table 6). Unlike other more arid lands that would not support the growth of improved pasture species like *Pennisetum purpureum* and *Chloris gayana*, Kiruhura district has moderate rainfall that can support establishment of pasture species albeit with good agronomic practices. The most common natural grass species maintained were *Themeda triandra*, *Panicum maximum* and *Brachiaria* spp., while *Chloris gayana*, *Pennisetum purpureum* were the more abundant improved grass species. Selective adoption of *Chloris gayana* and *Pennisetum purpureum* could be due to their seed availability, favorable climate, ease of establishment, specie's productivity and their long time experience with the animals utilizing related varieties since they exist in their natural environment. Crop residues utilization though on a small scale, was found commonly used in households with small herd size and practicing crop production although no effort was made to enhance utilization. Crop residues included maize stovers, bean husks, banana vines and banana peels. It was also acknowledged during KII interviews and observation during field excursion that due to poor management such as overgrazing, overstocking, continuous grazing, mis-use of fire, there was very low recruitment of desirable species and the pastures have been invaded by weeds with common weedy species including *Sporobolus pyramidalis*, *Lantana camara*, *Solanum incanum*, *Cymbopogon nardus* and *Acacia hockii*. Similarly, a wide range of broadleaved weeds also invaded some of these pastures. These include: *Clerodendrum* spp., *Urena lobata*, *Sida* spp among others. Maize for silage production, woody legumes and *Panicum maximum* were planted by a negligent number of respondents whereas the respondents identified the financial support by the government and provision of pasture seeds by research institutions and NGOs as a big push to farmers. The total acreage planted with pastures by sampled farmers was about 302.5 acres with mean total pasture establishment acreage for adopters of 1.03 ± 0.22 acres. The study revealed that the concept of pasture improvement and utilization in qualitative terms was lacking in adopter farmers as most of them did not own the technologies whereas others could not link

harvesting maturity, processing conditions, storage and voluntary intake by animals. The dominant utilization practice was continuous grazing contrary to controlled grazing allowing for pasture resting that can be achieved through rotational grazing. Hay and silage making were not common since they were adopted at low rate and often poorly handled. Some did not mind quality of the pastures as most of them were overgrown and preserved in a poor environment. While others used hay to mulch their banana plantations claiming it makes better mulch without applying economic reasoning. It appears that in this study area, the species of pasture grown by the farmers were influenced by the promoters including development agents who had targeted seed multiplication for their business albeit with limited information to farmers, farmers' exposure during exhibitions and guidance from extension workers. The farmers did not display knowledge of pasture nutrition value and utilization but rather physical or qualitative value of the species. This is contrary to Mganga (2013) who reports that the species of choice for a majority of livestock farmers in the ASALs of Kenya was greatly influenced by the forage value for livestock.

Although sustainable utilization of improved pasture would expect forage harvesting at appropriate maturity and preservation in form of hay or silage accordingly, very few farmers practiced these technologies moreover not considering quality loss. This could be due to labor associated problems, lack of knowledge and/or lack of necessary equipment including silos and barns. Ndathi (2013) observed that most farmers did not conserve the harvested feeds well mainly due to inadequate skills and lack of conservation structures. According to Peters and Lascano (2003), close linkages between farmers, researchers, private sector, and extension workers are essential for both the development and diffusion of improved multipurpose grass and legume species.

The players and their roles in range pasture improvement promotion

The study established that individual, public and private

Table 7. Farmers' restrictions of pasture improvement per studied sub county.

Restrictions to pasture improvement	Sub county			
	Nyakashashara % (n=75)	Kenshunga %(n=78)	Burunga % (n=69)	Kazo % (n=72)
Limited knowledge on pasture production	28	39.7	69.6	59.7
Low farm gate milk prices	20	65.4	36.2	59.7
Limited capital	68	28.2	30.4	43.1
Limited labor	69.3	21.8	33.3	33.3
Prolonged and frequent drought	50.7	30.8	29	13.9
Limited access to pasture seeds	48	9	43.5	11.1
High costs of inputs	13.3	21.8	24.6	20.8
Limited gov't policy intervention on milk prices	22.7	17.9	21.7	12.5
Negative farmers' attitude	6.7	6.4	20.3	20.8
Limited access to equipment/farm tools	17.3	11.5	1.4	12.5
Termite destruction of forages	1.3	10.3	5.8	4.2
Destruction of forages by wild animals	14.7	0	0	0
Poor quality pasture species	4	1.3	4.3	0

Source: Authors' computation from field survey data 2018.

sector play a major role in range improvement with each player providing a specific package depending on their interests and capacity. Among public sector players include: research organization and academic institutions who undertake on research; and the extension sector who provide knowledge and farm inputs to farmers. The Ministry of Agriculture Animal Industry and Fisheries (MAAIF) extension departments provide farmers with inputs like quality pasture seeds, fencing materials and mechanized labor like tractors for ploughing. Private sector is mainly involved on produce marketing thus sensitization on standards, contracting farmers and such sometime they determine pasture seed varieties, to be produced by farmers and support with enabling resources such as fencing materials to partnering farmers in pasture seed production. A number of local and international CSOs support farmers with inputs and advocacy for access to better services.

The presence of several players in Kiruhura district could probably be attributed to the social capital of politician, production system, the high livestock population, the willingness of farmers to transform from agro pastoralism to improved herds for dairy farming due to increasing demand for dairy products, the establishment of dairy cooperative union and moderate favorable climate, and farmers' partnership with academia in dairy research. Hanyani-Mlambo et al. (1998) acknowledged that the researchers and extension specialists placed emphasis on on-farm research and farmer-to-farmer extension to provide evidence to farmers of the economic benefits and costs of legume forages. Francis and Sibanda (2001) as well as Hanyani-Mlambo et al. (1998) found that potentially effective technologies and management strategies were promoted

through participatory action research (PAR) involving farmers, researchers and extension workers in order to ensure sustainable livestock farming.

Farmers' limitation of range pasture improvement in Kiruhura district

Efforts by Agro pastoralists in the Kiruhura district face a multitude of constraints as they attempt to improve range pastures to enhance livestock productivity. This study showed that agro pastoralists in the study area suffered from limited knowledge, low milk prices, lack of capital, lack of labor, lack of pasture seeds, and prolonged drought conditions among that restricted or demotivated them from investing in range pasture improvement (Table 7). The average milk price per liter was 1000 Uganda shillings.

The above limitations could be attributed to the climate failure, poor infrastructure development, and low education level associated with culture, lack of competitor in dairy products markets and failure of farmers to actively participate in strengthening of cooperative Unions. Low and erratic rainfalls coupled with high evapotranspiration rates are known to be the major limiting factors for primary productivity in the semi-arid areas. Changing climate with prolonged droughts make dry season feeding a big problem for livestock in semi-arid areas rangelands. This certainly would necessitate application of climate smart technologies such as irrigation, and feed conservation technologies to cater for periods of scarcity. The increasing frequency of drought in the semi -arid areas is a major source of concern for farmers. This is due to the direct effect on natural

pastures that get depleted in the short or long term. In many of these grazing areas, majority of nutritive natural species that are traditionally adapted have either disappeared and been replaced by annuals, shrubs, bush, bare patches and unpalatable species that may be invasive.

Consistent with the findings of this study were the studies by Kabirizi et al. (2004), Mapiye et al. (2006) and Maleko and Koipapi (2015) who cited high cost of inputs, low yields and lack of persistence of legumes, lack of capital, land shortage and shortage of labor as major constraints to adoption of forage legumes. Poor pastures caused by bush encroachment lead to low livestock carrying capacity as was acknowledged by Sangeda and Maleko (2018). Poor agronomic practices due to lack of policy guidelines, low capita for proper investment, negative pastoralists' attitude towards range improvement, invasion with invasive species and abundance of termites all lead to rangeland degradation affecting livestock productivity. Bolo et al. (2019) identified related causes of rangeland degradation as overgrazing, overgrazing, climate change and variability, Invasive/alien species and bush encroachment and Breakdown of traditional governance systems and unsuitable government policies/by-laws as causes of rangeland degradation in Kenya. Constraints on any of the factors of production can inhibit uptake of forage technologies (Kabirizi et al., 2004). Kumwenda and Ngwira (2003) acknowledged that such constraints are severe among the resource-poor smallholder dairy cattle farmers for whom forage legume technologies are most needed.

CONCLUSION AND RECOMMENDATIONS

- (i) Socio-economic, technological and institutional factors are key drivers for farmer decision in investment in range pasture improvement technologies. These including the level of education, farm size, household income, off farm activities, access to credit, household access to laborers, extension support and belonging to a farmer organization.
- (ii) Limited knowledge on range management principles, low milk prices, lack of capital and labor, and prolonged drought conditions, higher costs of inputs restrict and demotivate farmers from investing in range pasture improvement. Pastoralists should be organized into cooperatives to enhance their decisions on determining the farm gate prices and demand for better extension services and access to farm inputs.
- (iii) Farmer support systems including participation in agricultural exhibitions, attending farmers' meetings, holding on-farm demonstrations, access to farm inputs and attending trainings for knowledge and skills enhancement and confidence building are very important in encouraging farmers to improve their animal feed resources.
- (iv) Proper understanding of proper range management

principles and the adoption of range pasture improvement technologies should be promoted through participatory action learning and research involving farmers, researchers, private sector and extension workers in order to ensure its sustainability. However, there is need for regular refresher sensitization sessions and farm follow up to fast track the process and progress of adoption of range pasture improvement technologies.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

REFERENCES

- Abusin S, Lari N, Khaled S, Al Emadi N (2020). Effective policies to mitigate food waste in Qatar. *African Journal of Agricultural Research* 15(3):343-350.
- Ainembabazi JH, Mugisha J (2014). The Role of Farming Experience on the Adoption of Agricultural Technologies: Evidence from Smallholder Farmers in Uganda. *Journal of Development Studies* 50:5.
- Alomia-Hinojosa V, Speelman E, Thapa A, Hsiang-En W (2018). Exploring farmer perceptions of agricultural innovations for maize-legume intensification in the mid-hills region of Nepal. *International Journal of Agricultural Sustainability* 16:1. DOI: 10.1080/14735903.2018.1423723
- Ambetsa FL, Mwangi SC, Ndirangu, SN (2020). Technical efficiency and its determinants in sugarcane production among smallholder sugarcane farmers in Malava sub-county, Kenya. *African Journal of Agricultural Research* 15(3):351-360.
- Arega M (2009). Determinants of intensity of adoption of old coffee stumping technology in Dale Wereda, SNNPRS, Ethiopia. MSc thesis (Rural Development and Agricultural Extension). 115p. <https://www.semanticscholar.org/paper/Determinants-of-intensity-of-adoption-of-old-coffee-Arega/f7953528da302cfce17ec93a456a1222cc33596c>
- Baba S, Ja'far, Abdullah A, Dagong MIA, Azhar M, Sohrah S (2017). Effect of Attitude, Subjective Norm and Behaviour Control on Technology Adoption Rate of Goat Farmer. *Advances in Environmental Biology* 11(12):26-30.
- Baskin CC, Baskin JM (1998). *Seeds. Ecology, Biogeography, and Evolution of Dormancy and Germination*. San Diego, CA: Academic Press.
- Bettencourt EMV, Tilman M, Narciso V, Carvalho MLS, Henriques PDS (2015). The Livestock Roles in the Wellbeing of Rural Communities of Timor-Leste. *Revista de Economia e Sociologia Rural* 53(1):63-80.
- Bolo PO, Sommer R, Kihara, Kinyua M, Nyawira S, Notenbaert A (2019). Rangeland degradation: Causes, consequences, monitoring techniques and remedies. Working Paper. CIAT Publication No. 478. International Center for Tropical Agriculture (CIAT). Nairobi, Kenya 23p.
- Briske D (2017). *Rangeland systems – Processes, management and challenges*. Cham, Switzerland: Springer. <https://www.springer.com/gp/book/9783319467078>
- Cuneo P, Offord CA, Leishman MR (2010). Seed ecology of the invasive woody plant African Olive (*Olea europaea* subsp. *Cuspidata*): implications for management and restoration. *Australian Journal of Botany* 58(5):342-348.
- Diirro GM (2013). Impact of Off-farm Income on Agricultural Technology Adoption Intensity and Productivity. Uganda strategy support program. IFPPRI WORKING PAPER 11 | January 2013.
- Francis J, Sibanda S (2001). Participatory action research experiences in smallholder dairy farming in Zimbabwe. *Livestock Research for Rural Development* 13:3.
- Francois JD, Barreiro-Hurlé J, René van B (2019). Behavioural factors affecting the adoption of sustainable farming practices: a policy-

- oriented review. *European Review of Agricultural Economics* 46(3):417-471. <https://doi.org/10.1093/erae/jbz019>
- Gujarati DN (1995). *Basic Econometrics*. MacGraw-Hill, Inc. New York 4:100-343.
- Humphries T, Chauhan BS, Florentine SK (2018). Environmental factors effecting the germination and seedling emergence of two populations of an aggressive agricultural weed; *Nassella Trichotoma*. *PLoS ONE* 13(7):e0199491.
- Hanyani-Mlambo BT, Sibanda S, Østergaard V (1998). Socio-economic aspects of smallholder dairying in Zimbabwe. *Livestock Research for Rural Development* 10:2.
- Hausmann NS, Kalwij JM, Bezuidenhout S (2016). Some ecological side-effects of chemical and physical bush clearing in a southern African rangeland ecosystem. *South African Journal of Botany* 102:234-239.
- Huang F, Luh Y (2009). The economic value of education in agricultural production: a switching regression analysis of selected East-Asian countries. A paper presented in International Association of Agricultural Economists Conference, 16-22 August, Beijing
- Joachim V, Mekdim D, Bart M, Alemayehu ST (2018). Labour, profitability and gender impacts of adopting row planting in Ethiopia, *European Review of Agricultural Economics* 45(4):471-503.
- Kabirizi J, Mpairwe D, Mutetikka D (2004). Testing forage legume technologies with smallholder dairy farmers: a case study of Masaka district, Uganda. *Uganda Journal of Agricultural Sciences* 9(1):914-921.
- Kaliba ARM, Featherstone AM, Norman DW (1997). A stall-feeding management for improved cattle in semiarid central Tanzania: factors influencing adoption. *Agricultural Economics* 17(2):133-146.
- Kaliba ARM, Hugo V, Mwangi W, Mwilawa JTA, Poniah A, Moshi A (1998). Adoption of Maize Production Technologies in Central Tanzania. Mexico D.F., International Maize and Wheat center (CIMMYT). The united Republic of Tanzania and the southern Africa center for cooperation in Agricultural Research (SACCAR).
- KDLG (2012). District Statistical Abstract June 2012. Planning Unit - Kiruhura District Local Government.
- Kgosikoma O, Mojeremane W, Harvie BA (2012). Pastoralists' perception and ecological knowledge on savanna ecosystem dynamics in semi-arid Botswana. *Ecology and Society* 17(4):27.
- Kumwenda M, Ngwira A (2003). Forage demand and constraints to adoption of forage technologies by livestock keepers in Malawi. *Tropical Grasslands* 37:274-278.
- Liao C, Clark PE, DeGloria SD (2018). Bush encroachment dynamics and rangeland management implications in southern Ethiopia. *Ecology and Evolution* 8(23):11694-11703.
- Maleko DD, Koipapi ML (2015). Opportunities and constraints for overcoming dry season livestock feed shortages in communal semi-arid rangelands of Northern Tanzania: A case of Longido District. *Livestock Research for Rural Development* 27:70. <http://www.lrrd.org/lrrd27/4/male27070.html>.
- Manyeki JK, Kubasu D, Kirwa EC, Mnene WN (2013). Assessment of socio-economic factors influencing adoption of natural pastures improvement technologies in arid and semi-arid lands of Kenya. *Livestock Research for Rural Development* 25:193. <http://www.lrrd.org/lrrd25/11/kiba25193.htm>.
- Mapiye C, Foti R, Chikumba N, Poshiwa X, Mwale M, Chivuraise C, Mupangwa J (2006). Constraints to adoption of forage and browse legumes by smallholder dairy farmers in Zimbabwe. *Livestock Research for Rural Development* 18:12.
- Miles MB, Huberman AM (1994). *Qualitative Data Analysis*. Newbury Park, CA: Sage 2:10-12.
- Mohammad AJ, Saleem MAM, Solomon G, Hailu B (2003). Role of knowledge in the adoption of new agricultural technologies: An approach and an application. *International Journal of Agricultural Resources, Governance and Ecology ER-Vol 2*. DOI: 10.1504/IJARGE.2003.003974.
- Moyo R, Salawu A (2017). An Appraisal of Factors Influencing Adoption of Agricultural Innovations: Insights from Selected Developing Countries. *Journal of International Agricultural and Extension Education* 24(1):7-9.
- Mureithi JG, Njunie MN, Muinga RW, Ali R, Thorpe W, Mwatate CD (1998). Adoption of planted forages by smallholder dairy farmers in coastal lowland Kenya. *Tropical Grasslands* 32(4):221-229.
- Musaba EC (2010). Analysis of factors influencing adoption of cattle management technologies by communal farmers in Northern Namibia. *Livestock Research for Rural Development* 22:104. Retrieved April 25, 2020, from <http://www.lrrd.org/22/6/musa22104.htm>.
- Mutanga O, Skidmore AK, Prins HHT (2004). Predicting in-situ pasture quality in the Kruger National Park, South Africa, using continuum-removed absorption features. *Remote Sensing of Environment* 89(3):393-408.
- Mutua E, Bukachi S, Bett B, Estambale B, Nyamongo I (2017). Youth Participation in Smallholder Livestock Production and Marketing. *IDS Bulletin* 48:3.
- Mwangi MN (2015). Factors Determining Adoption of New Agricultural Technology by Smallholder Farmers in Developing Countries. *Journal of Economics and Sustainable Development WWW.liste.Org ISSN 2222-1700 (Paper) ISSN 2222-2855 (Online)*
- Mwaura F (2014). Effect of Farmer Group Membership on Agricultural Technology Adoption and Crop Productivity In in Uganda. *African Crop Science Journal* 22(4):917-927.
- Ndathi AJN, Muthiani EN, Ndung'u JN, Ogillo BP, Kimitei RK, Manyeki JK, Katiku PN, Mnene WN (2013). Feed resources and utilization strategies in selected pastoral and agro pastoral communities in Kenya. *Livestock Research for Rural Development* 25:221. Retrieved April 26, 2020, from <http://www.lrrd.org/lrrd25/12/ndat25221.htm>
- Ntume B, Nalule AS, Baluka SA (2015). The role of social capital in technology adoption and livestock development. *Livestock Research for Rural Development* 27:9.
- Oba G (2012). Harnessing pastoralists' indigenous knowledge for rangeland management: three African case studies. *Pastoralism* 2:1.
- Ogunlana E (2003). "The technology adoption behavior of women farmers: The case of alley farming in Nigeria." *Renewable Agriculture and Food Systems* 19(1):57-65.
- Oladele OI (2005). A tobit analysis of propensity to discontinue adoption of agricultural technology among farmers in southwestern Nigeria. *Journal of Central European Agriculture* 6(3):249-254.
- Omollo EO, Wasonga OV, Elhadi MY, Mnene WN (2018). Determinants of pastoral and agro-pastoral households' participation in fodder production in Makueni and Kajiado Counties, Kenya. *Pastoralism* 8:9.
- Onim JFM (1992). Dual-Purpose Goat Research in western Kenya. In: Kategite, J.A Mubi (editors), *Future of livestock industries in East and southern Africa proceedings of a workshop*, Kadoma. Zimbabwe 227 p.
- Onuche U, Oladipo MA, Enize T, Daikwo O (2020). Perception and uptake of aquaculture technologies in Kogi state, central Nigeria: imperative for Improved Management practices for sustainable aquaculture development. *African Journal of Agricultural Research* 16(6):819-828.
- Owuor C, Bett EK, Mwenjeri GW (2020). Output Growth of Uganda's Agricultural Sector. Does Public Expenditure on Education Matter? *Journal of Scientific Research and Reports* 26(7):5-17.
- Paltasingh KR, Goyari P (2018). Impact of farmer education on farm productivity under varying technologies: case of paddy growers in India. *Agriculture Economics* 6:7.
- Peters M, Lascano CE (2003). Forage technology adoption: linking on-station research with participatory methods. *Tropical Grasslands* 37:4.
- Prokopy LS, Floress K, Klotthor-Weinkauff D, Baumgart-Getz A (2008). "Determinants of Agricultural Best Management Practice Adoption: Evidence from the Literature. *Journal of Soil and Water Conservation* 3(5):300-311.
- Rusdy M (2020). Silvopastoral system using *Leucaena leucocephala* for sustainable animal production in the tropics. *Livestock Research for Rural Development* 32:57. Retrieved October 27, 2020, from <http://www.lrrd.org/lrrd32/4/murhu32057.html>
- Sangeda AZ, Maleko DD (2018) Rangeland condition and livestock carrying capacity under the traditional rotational grazing system in northern Tanzania. *Livestock Research for Rural Development* 30:79. Retrieved April 25, 2020, from <http://www.lrrd.org/lrrd30/5/sange30079.html>.
- Singha AK, Baruah MJ, Bordoloi R, Dutta P, Saikia US (2011). Analysis

- on influencing factors of technology adoption of different land based enterprises of farmers under diversified farming system. *Journal of Agricultural Science* 4:2.
- Uganda Investment Authority (UIA) (2016). Uganda Investment Authority. Agriculture (Beef)
- Vohra FN (2016). Attitude of Farmers Towards Krishi Vigyan Kendra, Navsari of South Gujarat. MSC Thesis. Extension Education Dept., NMCA, Nau, Navsari.
- Wanyama JM, Muyekho F, Masinde AAO, Okeyo R (2003). Wanyama Assessing factors influencing adoption of pastures and fodders amongst smallholder subsistence farmers in selected districts of west Kenya. *Tropical Grasslands, Conference: Workshop on Forage Demand and Adoption by Smallholder Livestock Keepers* Volume: 37
- Weir S (1999). The effects of education on farmer productivity in rural Ethiopia. Centre for the Study of African Economies Working Paper no. WPS/99-7, Oxford University, Oxford.
- Yamane T (1973). *Statistics, an Introductory Analysis*. New York: Harper and Row 2:1130.
- Yesuf M, Kohlin G (2008). Market imperfections and farm technology adoption decisions: an empirical analysis. IFPRI Discussion paper series (EFD DP) 08-04: IFPRI, pp. 28-47.
- Zerga B (2015). Rangeland degradation and restoration: a global perspective. *Point Journal of Agriculture and Biotechnology Research* 1:37-54.