Impacts of Individualization of Land Tenure on Livestock and Rangeland Management in Southwestern Uganda

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1. INTRODUCTION

The impacts of changing land tenure regimes on the productivity and sustainability of management of livestock and rangelands is a critical issue for agricultural modernization and rural development in sub-Saharan Africa. More than half of the agricultural population of sub-Saharan Africa subsists on farming systems in which livestock are a major component of income, and poverty is severe for most of these households (Dixon, et al. 2001). More than 20 million people in sub-Saharan Africa derive their livelihood from pastoralism and more than 200 million are agro-pastoralists (Swallow 1994). In most pastoral and agro-pastoral systems, rangelands are the dominant source of livestock fodder, and feed availability and quality are critical constraints to increased productivity and incomes (Jahnke 1982; McIntire, et al., 1992; Winrock International 1992).

As population has grown and as access to infrastructure, markets and services has increased, the tenure of rangelands has changed in many areas of sub-Saharan Africa from the traditional system of communal access through customary tenure to more individualized forms of tenure, and in some cases, to fully private tenure. Such changes have often followed the pattern of induced institutional innovation hypothesized by Boserup (1965, 1981), Demsetz (1967), Posner (1977), Hayami and Ruttan (1985) and others, in which increases in resource scarcity and value due to population pressure, market development, and improved technology lead to increased incentives to individualize access to resources; although they have also been promoted by government policies in many instances (Kirk 1999).

The impacts of individualization of rangeland tenure are the subject of longstanding debate in policy circles and in the academic literature. On one side of the debate are arguments that individualization and privatization of tenure are necessary for economic efficiency and sustainable natural resource management (Gordon 1954; Demsetz 1967; Hardin 1968). On the other are arguments that individualization and privatization are not necessary for either efficiency or sustainable resource management given effective institutions of common property resource (CPR) management (Bromley 1989; Ostrom 1990), and that individualization can lead to inequitable outcomes, increased conflicts, natural resource degradation and reduce pastoralists' ability to cope with risks through spatial mobility (Behnke, et al. 1993; Swallow 1994; Scoones 1995; van den Brink, et al. 1995; Platteau 1996; Kirk 1999; Niamir-Fuller 1999). Despite a growing body of literature on these issues in general, empirical evidence is still limited on how individualization and privatization of rangeland tenure affects livestock and rangeland management in Uganda and many other African countries.

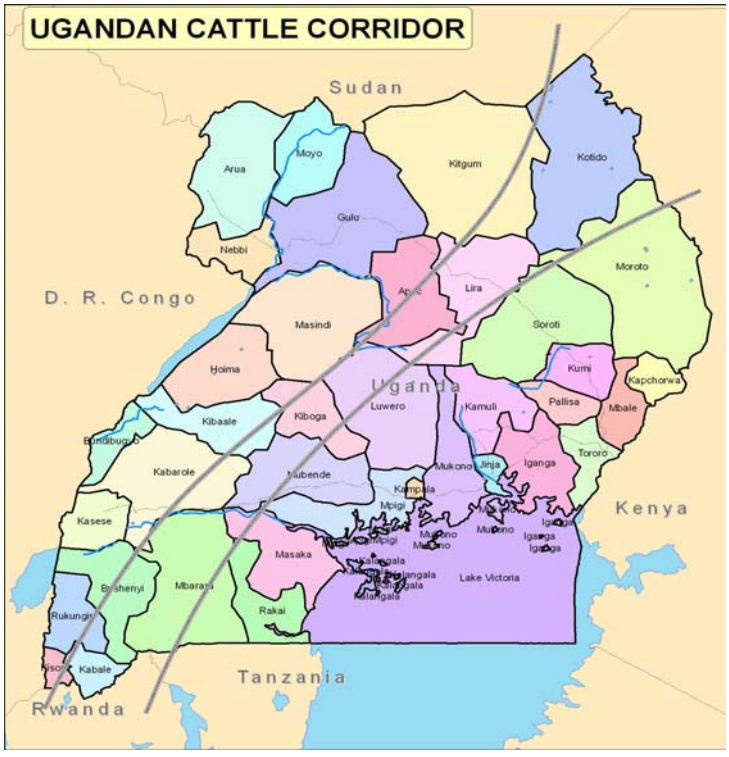
The objective of this study is to understand the extent of individualization and privatization of rangeland tenure in Uganda, and its impacts on adoption of livestock technologies and rangeland management investments, land disputes and livestock profitability among the pastoralists of southwestern Uganda. This study is based on data collected by Kisamba Mugerwa (1995) on rangeland management by pastoralist households in the southwestern and northeastern parts of the "cattle corridor" of Uganda.

The paper is organized as follows. Section 2 provides an overview of rangeland management in Uganda. Section 3 sets forth the methodology used in undertaking the study including description of the study area, key hypotheses and the econometric approach and diagnostic tests used, and sampling procedure and data description. Section 4 discusses the descriptive and econometric results of the study and section 5 provides conclusions and policy implications.

2. RANGELAND MANAGEMENT IN UGANDA

The rangeland areas of Uganda occupy approximately 84,000 square kilometers (35%) and were traditionally utilized by pastoralists under a common property system of management. The area is generally between 1,000 and 1,500 meters above sea level. In the southwest, it forms part of the lower levels of the Uganda section of the interior high plateau and is generally a plain landscape with a few isolated hills. In the northeast, the area consists of a plain of 1,000 to 1,200 meters above sea level and belongs to the drought prone region of East Africa (including parts of Sudan, Ethiopia and Kenya). The rangeland area is commonly referred to as the "cattle corridor" covering areas having low potential for crops, shown on Map 1.

Map 1: The cattle corridor



The cattle corridor stretches from the southern Uganda border with Tanzania through the southern districts of the Ankole region (e.g., Mbarara) and northern parts of the central Buganda region (Mubende, Luwero) to the north central part of Uganda (covering parts of Apac, Lira, and Soroti districts) and the northeast (Kotido and Moroto districts).

The disequilibrium model of rangeland management (Behnke, et al. 1993), and its implications for the importance of mobility of livestock to cope with risk, is more suited to the northeast cattle corridor, which is in a more arid, unimodal rainfall zone, than to the southwest cattle corridor, which has higher, bimodal rainfall. This is probably one of the reasons why individualization of rangeland tenure has not progressed as far in the northeast as in the southwest cattle corridor of Uganda.

Indigenous pastoral areas in Uganda have been disrupted and the pastoralists displaced, so much so that it is almost impossible to reverse the trend (Kisamba-Mugerwa 1991). The areas in the cattle corridor are said to be experiencing a high rate of rangeland resource use conflicts, displacement of the indigenous pastoralists, and resource management crises, resulting in a diversity of related socio-economic and environmental problems. According to its report to the government of Uganda, the Commission of Inquiry into Government Ranching Schemes (1988) observed excessive de-vegetation leading to serious soil erosion in the communal grazing areas of Rakai District. These problems are specifically manifested in the form of persistent degradation of the rangeland resources, low productivity, lack of food security, a declining grazing land area, and general impoverishment of the pastoralists.

A relatively low level of welfare is another common phenomenon among pastoral communities in Uganda. Although a few well-placed and privileged pastoralists may be seen conspicuously accumulating pastoral resources, the majority are marginalized, impoverished, and/or displaced to the extent of becoming landless. Moreover, competing land use activities including expansion of cropland development projects such as irrigation schemes, forests and conservation areas, refugee camps, and military installations that occupy large parcels of land, have put much pressure on communal grazing land within the rangeland. Such pressure has excluded pastoralism from occupied parts of the rangeland.

Rangeland management policies in Uganda have promoted development of private ranches, causing displacement of pastoralists from extensive rangeland areas. During the 1960's about 400 large ranches were developed on extensive pastoral lands cleared of tsetse fly infestation and were leased to influential politicians and cooperative societies, managed by the political elite without due regard to the typical grassroots pastoralists of the area (Doornbos and Lofchie 1967). There is no systematic policy under which a comprehensively coordinated program is developed to integrate the pastoralists to be involved in the management of natural resource conservation and development schemes managed by the State. Furthermore, the rangeland tenure of the country has been influenced towards individualization by historic government development policies. From the colonial period up to the present, land tenure policies have been directed towards promoting private ownership of the land. Uganda is pursing a 'blanket cover' policy towards resettling pastoralists throughout the country, without considering the heterogeneity of the pastoral economy.

In sum, the main concerns about the management of pastoral resources in Uganda are the persistent environmental degradation, hunger, social tension, and poverty in areas occupied by pastoral communities. Different natural resource management regimes tend to respond differently to resource utilization for sustainable development. Since the plight of pastoralists was deemed to stem from rangeland management strategies, and since Uganda lacks a systematic study to that effect, it was considered pertinent to examine the impact of individualization of communal pastoral resources rights in pastoral communities and its impact on livestock management and rangeland improvements.

3. METHODOLOGY

3.1 Description of the study area

This study focuses on rangeland areas in the southwestern part of the cattle corridor (in Mbarara and Ntungamo districts), which have experienced substantial individualization of communal grazing land rights since independence. Descriptive analysis of the data collected by Kisamba Mugerwa (1995) did not show existence of individualized or private tenures among the pastoralists in the northeastern districts of the cattle corridor. Hence, these districts were excluded from this study, since our key hypotheses concern the impacts of individualization or privatization of rangeland tenure. In this study, rangeland "individualization" refers to any situation where the local community recognizes the individual's exclusive use rights over specified pastoral resources under customary tenure, whereas "privatization" refers to full private rights being assigned with registered titles under leasehold or freehold tenure.

3.2 Survey methods

Kisamba-Mugerwa (1995) assessed the extent of individualization or privatization of rangeland tenure in Uganda, the factors contributing to it, and the impacts of land tenure and population density on rangeland and livestock management. That study yielded insight into the issues based upon review of literature and secondary data, use of descriptive statistics and analysis of variance. However, other factors affecting the responses and outcomes of interest were not accounted for in that study. The analysis in this paper builds upon Kisamba-Mugerwa's work, using econometric methods to test the key hypotheses raised in that study, while controlling for different confounding factors in a multivariate analysis.

3.3 Hypotheses

Drawing upon the literature and policy debates on rangeland tenure in Africa, we focus on testing several key hypotheses about the impacts of rangeland tenure systems in Uganda:

1. Individualization and privatization of rangeland tenure leads to greater inequality of access to pastoral resources.

Hypothesis 1 follows from the arguments of Scoones (1992), Platteau (1996) and others that individualization and privatization often benefit wealthier or elite groups. It is investigated using data on the livestock assets owned by households at present and at the time of household

formation, for households accessing rangelands through different tenure regimes. It is also investigated using data on the household's grazing source during a calamity (the sub-hypothesis being that wealthier households with individual or private grazing land also have access to common grazing land, contributing to inequitable outcomes). We investigate this hypothesis using only descriptive statistical analysis, because we do not have data on other factors affecting households' initial endowments of livestock or changes in their livestock assets over time (e.g., initial levels or changes in households' demographic composition, education, access to services, and ownership of other assets). We also believe that access to other grazing lands during a calamity may depend on many factors outside the respondent households' communities which were not captured by the survey (e.g., the availability and quality of grazing lands in nearby locations). Thus, we will not be able to formally test this hypothesis using econometrics, but do examine the extent to which our descriptive data are consistent with or contradict it.

2. Individualization and privatization of rangeland tenure leads to reduced ability of pastoralists to manage risks through mobility.

Hypothesis 2 follows from the literature on the advantages of pastoralists' mobility for risk management (Behnke, et al. 1993; Swallow 1994; Scoones 1995; van den Brink 1995; Niamir-Fuller 1999). This hypothesis is also investigated using data on access to grazing sources during a calamity. As with hypothesis 1, we investigate this hypothesis using only descriptive analysis, for the reasons explained above.

3. Individualization and privatization promote reduced conflicts in rangeland management.

Hypothesis 3 follows from the literature on induced development of individual property rights (Boserup 1965; Demsetz 1967; Anderson and Hill 1975; Posner 1977; Hayami and Ruttan 1985), since conflicts resulting from increased scarcity and resource value may be part of the mechanism inducing institutional change. It is tested using data on disputes over grazing land boundaries, ownership, and use. Other factors besides rangeland tenure that may influence disputes are controlled for, using econometric analysis (these factors are discussed further below).

4. Individualization and privatization promote investments in improvement of rangeland and reduced stocking rates, leading to less rangeland degradation.

Hypothesis 4 follows from the neoclassical literature on the effects of individual tenure security on the incentive to invest in land improvements (e.g., Feder and Noronha 1987; Feder and Onchan 1987) and from the literature on the effects of negative externalities in managing common grazing lands (Hardin 1968), even when they are not open access (McCarthy, et al. 2001; Benin and Pender 2006). It is tested using several indicators of investment in rangeland improvements (i.e., investment in improved pastures, bush clearing, planting multi-purpose trees and limiting herd size), and perceptions of rangeland degradation. As for hypothesis 3, econometric analysis is used to control for factors other than rangeland tenure.

5. Individualization and privatization lead to investments in livestock intensification, resulting in enhanced productivity and income of pastoralists and agro-pastoralists.

Hypothesis 5 also follows from the neoclassical literature on the benefits of individual or private land tenure in promoting agricultural intensification, investments and increased productivity, and is also tested econometrically controlling for other factors affecting intensification and productivity. It is tested using indicators of investment in livestock, adoption of livestock technologies (e.g., crossbred cattle, use of paddocks, artificial insemination), cash expenses on purchased livestock inputs, and cash sales of livestock products. We did not have access to complete information on profitability or the contribution of livestock production to household income, but rather only on cash sales of livestock products and cash expenses. Thus, the value of own consumption of home-produced livestock products and changes in the value of the stock of animals were not accounted for, and our indicators of economic performance are imperfect.

It is important to note that these are only hypotheses, and alternative hypotheses could also be posed based upon the theoretical and empirical literature. The purpose of posing these hypotheses is not to assert that they are true, but to clearly identify what is being tested empirically. The next subsection describes our econometric approach to testing several of these hypotheses.

3.4. Econometric approach and diagnostic tests

As noted above, hypotheses 3 to 5 are to be tested econometrically. We used the following specification for the econometric analysis:

1) $C_h = C(T_h, HC_h, A_h, Acc_h, IS_h, SC_h, D, u_{ch})$

2) $RM_h = RM(T_h, HC_h, A_h, Acc_h, IS_h, SC_h, D, u_{RMh})$

3) $RD_h = RD(T_h, HC_h, A_h, Acc_h, IS_h, SC_h, D, u_{RDh})$

4) $LM_h = LM(T_h, HC_h, A_h, Acc_h, IS_h, SC_h, D, u_{LMh})$

5) $LR_h = LR(T_h, HC_h, A_h, Acc_h, IS_h, SC_h, D, u_{LRh})$

The dependent variables include indicators of the household's involvement in conflicts or disputes over grazing lands (i.e., disputes over boundaries, ownership and use) (C_h); rangeland management practices (e.g., investments in improved pasture, bush clearing, planting multipurpose trees, limiting herd size) (RM_h); perceived rangeland degradation (RD_h), livestock management practices (use of crossbred cows, paddocks, expenses on purchased inputs) (LM_h), and cash revenue from sales of livestock products (LR_h). The explanatory variables include the tenure category of the grazing land (customary communal, customary individual, private, and non-property (open access)) (T_h); the human capital of the household (education, age and gender of the household head, the size of the household) (HC_h); the assets of the household (value of cattle owned) (A_h); the access of the household to grazing lands and water (Acc_h), the income strategy of the household (whether the primary income source is crop production, livestock production, both, or other activities) (IS_h), the social capital of the household (membership in local organizations, including the local council, a development committee, or cooperative group)

(SC_h); district-level differences in factors such as climate, population density, and market access (captured by a dummy variable, D); and unobserved factors affecting the dependent variables (u_{ch}, u_{RMh}, u_{RDh}, u_{LMh}, u_{LRh}).

Our hypotheses concerning the impacts of rangeland tenure on the dependent variables have been discussed above. We will not specify in detail hypotheses about the impacts of other explanatory factors besides rangeland tenure on the dependent variables, since the objective of the analysis is to investigate the impacts of tenure. In general, the other factors included represent the household endowments and access variables that are commonly hypothesized to influence household agricultural technology adoption, agricultural intensification and natural resource management (e.g., see Feder, et al. 1985; Feder and Umali 1993; Vosti and Reardon 1997; Lee and Barrett 2001; Barrett, et al. 2002; Nkonya, et al. 2004; Pender, et al. 2006). Because of data limitations, we are not able to directly test the impacts of community or higher-level variables potentially affecting rangeland and livestock management, such as climate, population density or market access. To control for the potential importance of such factors, we include a district dummy variable capturing differences between the two districts studied in such factors. Since only one county was selected in each of the study districts (see discussion of sampling strategy below), the district dummy variable more precisely reflects the effects of any fixed differences between the two counties studied, and not between the districts as a whole. We also include indicators of access to rangeland (size of grazing area) and water sources, as these are expected to be particularly important in influencing rangeland and livestock management, conflicts, and outcomes.

The econometric specification is in reduced form, in the sense that we specify the same set of underlying factors as determinants of all of the dependent variables, and do not seek to understand the relationships among these variables. For example, rangeland management is likely to affect rangeland degradation, livestock management and revenues, and conflicts; while many of these variables can also affect rangeland management and each other. We do not investigate these relationships because it is very difficult to identify this complex set of impacts with confidence using cross sectional data, because of concerns about endogeneity or simultaneity bias and difficulties of identifying valid instrumental variables to address it (Davidson and MacKinnon 2004).[1]

The type of econometric analysis conducted took into account the nature of the dependent variables. For cash livestock expenses (part of equation 4), the dependent variable was continuous and uncensored for almost all households; thus we were able to use least squares regression. For livestock cash revenue, the dependent variable was censored below (with many

[1] Endogeneity bias refers to the estimation bias that can result from using one endogenous dependent variable to explain the determinants of another. A bias can result because unobserved factors that influence one dependent variable may be correlated with those affecting another dependent variable. Simultaneity bias results when the causal relationships between two endogenous variables go in both directions; e.g., if rangeland management influences livestock management and vice versa. The general approach to solving these problems involves use of instrumental variables which influence one dependent variable directly but not another. Identifying such variables can be difficult, and depends both on a sufficiently well-founded theory to justify the assumption that an instrumental variable directly influences some dependent variables but not others, and available data on such variables. Neither condition holds in general for the structural relationships amongst the dependent variables in equations 1) to 5).

observations of zero revenue). For this variable we used both a maximum likelihood Tobit estimator (Maddala 1983) as well as the censored least absolute deviations (CLAD) estimator (Powell 1984). The CLAD estimator is robust to violations of homoscedasticity and normality assumptions that can cause bias in the Tobit estimator (Arabmazar and Schmidt 1981; Vijverberg 1987), but is less efficient than the Tobit estimator if those assumptions hold. We tested the assumptions of homoscedasticity and normality in the Tobit model using the test of Pagan and Vella (1989) and found it to be violated (P value = 0.000), so we also estimated the CLAD model. All other dependent variables are binary categorical (yes/no) variables. For these we use Probit models (Maddala 1983).

Although the model is a reduced form, there is a potential concern that the tenure categories could be subject to endogeneity bias, since tenure can change in response to factors affecting the dependent variables, such as population growth, new technologies and commercialization, as noted earlier in the paper. Several studies in the literature on impacts of land tenure security have argued that land tenure security is endogenous (Feder and Onchan 1987; Roth, et al. 1989; Besley 1995; Otsuka and Place 2001), although many have considered cases where tenure was arguably exogenous (e.g., Place and Hazell 1993; Hayes, et al. 1997; Pender and Kerr 1999). In our case, the land tenure variables are likely to be exogenous to household level decisions, since we are studying tenure of grazing lands, which were under customary communal tenure prior to individualization or privatization, where this occurred. Full privatization of rangelands (i.e., establishment of ranches) was driven by external programs to promote ranching, and would therefore be exogenous to current household decisions. Individualization of customary rangelands would be more subject to local influences, but still required the agreement or acquiescence of community leaders. Thus even in this case, changes in land tenure are likely to have been exogenous to particular households.

Despite our belief that grazing land tenure is likely to be exogenous, to be cautious we tested for exogeneity of tenure using a Hausman (1978) test. For this test, we estimated an instrumental variables (IV) version of each model, treating the tenure categories as determined by a linear probability model.[2] The instrumental variables used to predict the rangeland tenure variables included the income strategy of the parents of the household head (whether crop production, livestock production, or both), the presence of immigrants in the village and emigrants from the village, the ownership of the nearest water source, and whether the household had acquired livestock by 1965. We hypothesize that these variables, which are either community level variables or which relate to the history of the household, are exogenous to changes in rangeland tenure that have occurred in recent decades and do not directly affect current rangeland or livestock management, controlling for current rangeland tenure and the other explanatory factors discussed above. A test of this hypothesis, called a Hansen's J test (Davidson and MacKinnon 2004), failed to reject this hypothesis (P value = 0.4889 in the cash expenses regression), providing confidence in the validity of the instrumental variables used. We also tested the relevance and strength of these instrumental variables in predicting the tenure variables, since weak instruments may result in more biased estimates than ordinary least squares (Bound, et al. 1995). These tests support the relevance and strength of the instruments as predictors of tenure (P value = 0.000 and partial R^2 greater than 0.25 for all tenure categories).

[2] For the Probit models of rangeland and livestock management and land degradation variables, we also assumed a linear probability model in order to use an IV regression approach.

In all but one case, the Hausman test failed to reject the null hypothesis that the tenure variables are exogenous. For the one case where this hypothesis was rejected (planting of multipurpose trees), we report both the Probit and IV model results below. Although the Probit model in this case may be affected by endogeneity bias, the IV model is estimated assuming a linear probability model, hence fails to account adequately for the nature of the dependent variable.[3] Thus we report both models and consider the robustness of the results in this case. In other cases, we do not report the IV results, since exogeneity of the tenure variables was not rejected, implying that the Probit model is a better model.

We accommodated heteroskedasticity of unknown form by estimating standard errors using the Huber-White estimator of robust standard errors in the regression models (Greene 1995). In the CLAD model, standard errors were estimated using bootstrapping (Statacorp 2003), and are robust to heteroskedasticity.

We tested for skewness and kurtosis in all the continuous explanatory variables used in the regressions using the Shapiro-Wilk and Shapiro-Francia tests of normality (Gould and Rogers 1991). The variables age of household head, household size, grazing area, value of cattle and distance to water source significantly deviated from normality. Using the Tukey ladder of powers transformation approach, the logarithmic transformation was identified as the most appropriate to approximate normality in the univariate distributions of these variables, which improves the performance of linear regression models, by reducing problems of heteroskedasticity, nonlinearity, outliers and leverage (Mukherjee, et al. 1998). Thus we used logarithmic transformations of these variables in the regressions.

We also tested for multicollinearity (multiple correlation among the explanatory variables, which reduces statistical power) and found that it was not a serious problem as shown by the low variance inflation factors (maximum VIF < 4.50).

3.5. Sampling procedure and data description

The sampling procedure used in the original study of Kisamba Mugerwa (1995) is described, limiting it to the southwestern districts which are the focus of this study. A stratified random sampling procedure was followed in selecting the respondents. One county in each of Mbarara and Ntungamo districts was purposively selected, based on having the highest number of heads of cattle as shown by the area vaccination records of 1991. All of the sub-counties in the two selected counties were stratified by population density based on the 1991 national population census into 3 strata of low (0-15 persons/km^2), medium (15-40 persons/km^2) and high (more than 40 persons/km^2) population density. Kisamba Mugerwa (1995) postulated that individualization in rangelands is being driven by growing population pressure, and therefore that those sub-counties with a high population density would have a greater element of individualization of land rights. A total of seven sub-counties out of the nine in the two selected counties were randomly selected from the 3 strata, and 3 Population Census enumeration areas randomly selected from each sub-county. At the enumeration area level, 15 households per enumeration area were

[3] A well known problem with a linear probably model is that the estimated probability of the event being considered can be negative or greater than one (Maddala 1983: 15).

randomly selected, yielding a total sample size of 315 (=7x3x15) respondents. Most of the econometric regressions reported use about 70% of the observations due to missing data and outliers for some of the key explanatory variables; mainly the value of cattle, area of grazing land and distance to water variables. Pastoralists in Uganda regard cattle as their main wealth asset and many are reluctant to provide information on their livestock numbers and value.

For each of the sample households, an interview with the head of the household was conducted using a pre-coded and structured questionnaire. Information collected included detailed questions on socio-demographics of the household, access to land and pasture, extent of individualization, mode of livestock grazing, access to livestock, livestock technologies and investments, rangeland resource degradation, extent and causes of land and livestock disputes (conflicts), livestock cash expenses, livestock cash receipts, and challenges and opportunities in rangeland livestock management.

Livestock and pasture management technologies and investment

The survey included information on perceived degradation of the grazing area due to different causes (e.g., overstocking, soil erosion), and pasture and livestock improvement technologies and investments. Among the soil and water management technologies investigated, we include only the use of multipurpose trees in the analysis since the other technologies (terracing, contour ploughing) were reported by fewer than 5% of the respondents, which is insufficient for a statistical analysis. These technologies and investments were measured categorically as whether the pastoralist had done it or not by the time of the interview. The technologies used in the analysis as separate dependent variables are use of paddocks, having improved pastures, having crossbred cows, practiced bush clearing, planted multipurpose trees and limited herd size on the pasture.

Land and livestock disputes

These were measured as whether the pastoralist had ever been involved in a conflict or dispute by the time of the interview. The disputes included land boundary disputes, land ownership disputes, land use disputes, land inheritance and cattle ownership disputes.

Livestock gross cash revenue

The gross cash revenue per animal was measured as a total aggregate value in Uganda shillings of all livestock products sold by the respondent in the preceding twelve months, divided by the total number of animals owned. The value of live animals sold was not included, although this data was available, because we did not have the corresponding data for purchase value of live animals by the farm or the value of changes in stocks. The value of home consumption of livestock products is also not included, as data on this aspect was not collected during the survey.

Livestock cash expenses

Livestock expenses were measured as the total value of all cash livestock input expenses, excluding purchase of live animals and own inputs, divided by the total number of animals

owned. Data on the purchase of live animals and own inputs including family labor was not collected in the survey. With this data incompleteness, we could not compute the value of total or net livestock income. However, the indicators of the value of cash receipts and expenses are expected to be correlated with total livestock production and income, hence useful but imperfect proxies for these concepts.

Land tenure

With respect to the explanatory variables used in the econometric analysis, land tenure was indicated as the tenure of the grazing land used by the pastoralist, with six tenure categories which we regrouped into four. Leasehold and freehold were reclassified as private property tenure.[4] Open access and squatter type of tenures were regrouped as non-property tenure. The other two tenures were customary communal and customary individualized tenure; these were not regrouped in the analysis. Customary communal tenure was used as the omitted category in of all the econometric analysis, since our hypotheses are about how this compares to private or individualized tenure.

Human capital

Human capital is measured by education, age, and sex of the household head and size of the household.

Assets and access

Assets and access are measured by the value of cattle owned, size of grazing area and distance to water source. The respondents indicated three types of water sources, namely ponds, dams and boreholes, with ponds usually the most important source. From these three water source variables, we constructed the distance to the nearest water source variable.

Primary income source

Respondents were asked to indicate their primary source of income and several income sources were identified: both livestock and crop production, livestock only, crop only and other income.

Social capital

Respondents were asked to indicate whether they belonged to a local council committee, development committee, cooperative committee or any other committee. Membership in these committees was used as an indicator of formal social capital. The survey did not include indicators of informal social capital, such as kinship ties and informal networks.

District

The district dummy variable is included to account for the fixed district-level effects that were not directly measured in the survey. It accounts for differences between districts in agro-climatic

[4] Only one household reported freehold tenure of their grazing land.

factors, population density, market access, and other unobserved factors. The survey data was not geo-referenced so we could not link it to the available Uganda spatial data sets to extract some of these spatial information. As mentioned previously, since only one county was selected in each of the two districts, this variable could more precisely be labeled a "county dummy", as it reflects only differences between the selected counties within each district, and not differences between the entire districts. Because of this, this variable should be fairly effective in controlling for differences in agro-climate, population density, market access and other such factors that may vary substantially across and even within districts, but that are fairly homogeneous within counties.

4. RESULTS

4.1 Descriptive analysis

The descriptive results are reported in tables 1, 2 and 3 by the four different land tenure categories.

Table 1 shows how adoption of the different rangeland management and livestock management practices varied across the different land tenure systems in southwestern Uganda. The evidence shows more investment in paddocks and crossbred cows among the pastoralists with individualized and private tenure compared with those under customary communal and non-property tenure. There is very little use of artificial insemination in all the four tenure categories, suggesting that use of this technology is constrained by other factors than land tenure, such as lack of infrastructural facilities, communication and refrigeration in the rural pastoral areas. There is high use of pump sprays for pest control among all pastoralists, regardless of tenure, indicating that pest and disease control is recognized as an important animal husbandry practice and suggesting that tenure security is not a major factor influencing it. We find more use of grazing land management practices such as limiting herd size, planting trees, clearing bushes and other pasture improvements on individualized and private tenure and far less adoption on communal and non-property tenure. These results are consistent with hypotheses 4 and 5.

Land boundary disputes are more common on individualized and private tenures while land ownership disputes are most common on customary land (Table 2). Land use disputes are most common on non-property rangeland and least common on individualized rangeland. These results are partly contradictory and partly consistent with hypothesis 3, suggesting that the impacts of individualization of tenure on conflicts depends on the nature of the conflict.

There is no statistically significant difference in the initial endowment of cattle (when the household was formed) across households using rangeland of different tenure types, although the sample mean initial endowment was smallest for users of communal customary and largest for users of non-property rangeland (Table 3). However, there are significant differences in the current cattle stock across these tenure groups, with users of private rangeland having the largest herds. This result is consistent with hypothesis 1 (privatization leads to greater inequality), but not because initially wealthier households have benefited more from privatization. Rather, it suggests that privatization has enabled users of private pastures, who may not have been wealthier initially, to accumulate more livestock over time, consistent with hypothesis 5.

Pastoralists with individualized or private tenure have better access to water than those dependent on customary or non-property grazing land, as many have personal water sources on their farms. However, fewer of the users of private grazing land have access to other grazing land during a calamity (e.g., drought) than other pastoralists, and users of both private and individualized rangeland must travel longer distances to access grazing lands during a calamity than the customary and non-property pastoralists. Thus, users of private and individualized rangelands appear to bear greater risks, even though they also enjoy advantages in terms of livestock development. Not surprisingly, these households are also less likely to provide access to their grazing land to other households during a calamity than pastoralists who depend on customary or non-property land. These findings are consistent with hypothesis 2. They are less clear concerning the equity of access to grazing lands (hypothesis 1), since households with private or individualized land have less access to other land during a calamity, but also offer less access to others.

Perceived land degradation due to overstocking and erosion is highest on non-property tenure and least reported on rangeland under individualized tenure, consistent with the tragedy of the commons predicted for open access rangeland, and with hypothesis 4.

Pastoralists' cash expenses per animal are highest for those using grazing land under private or individualized tenure, as are net cash receipts. These findings are consistent with the findings in Table 1 that adoption of crossbred cows, paddocks, and pasture improvements are highest for these tenure categories, and with hypotheses 4 and 5.

This descriptive evidence is consistent with our hypotheses that individualization of tenure amongst pastoralists encourages more investment in intensive livestock technologies and rangeland management, higher profitability of livestock production, and less degradation of rangeland (less degradation especially compared to non-property open access rangeland). It also suggests, however, that individualization and privatization increases pastoralists' exposure to risks and may contribute to some types of disputes (especially land boundary disputes), while reducing other types (especially land use disputes). In the next section, we test some of these hypotheses more formally using multivariate econometric methods, in which we control for other confounding factors that may influence these results.

4.2 Econometric analysis

We discuss the results for each of the categories of dependent variables, including land disputes, rangeland management, livestock management and technologies, land degradation, cash expenses on livestock production and cash revenues from livestock production.

4.2.1 Land disputes

In each of the land dispute regressions, at least one of the land tenure dummies is significant (Table 4). This shows the significant effect that tenure has on land disputes and conflict. Boundary disputes are more common on private than on customary communal tenure, ownership disputes are less common on individualized tenure than customary communal tenure, and land use disputes are more common on non-property tenure. These results are consistent with our

descriptive evidence. As in the descriptive analysis, we find mixed support for hypothesis 3, with individualization and privatization reducing some types of conflicts (ownership disputes) but privatization being associated with greater likelihood of boundary disputes. The finding of greater land use disputes on rangelands under non-property tenure is consistent with the tragedy of the commons hypothesis.

Other significant factors influencing disputes include age of the household head, size of the grazing area, distance to water, livestock as a primary source of income, and membership in a local council or cooperative. Older pastoralists are more likely to have boundary and ownership disputes but less likely to have land use disputes. Those with access to larger grazing lands are less likely to have land use disputes, suggesting that rangeland scarcity contributes to land use disputes. Households closer to water are more likely to have ownership disputes but less likely to have land use disputes. This may be because access to water increases the value of land, which increases incentives for competing ownership claims, while access to water may also help to clarify what are the most valuable land uses, thus tending to reduce land use disputes. Households for whom livestock is the primary source of income are more likely to be involved in ownership disputes over rangeland, probably because of the importance of rangelands to the livelihoods of these households. Households having a member of the local council are more likely to be involved in boundary disputes, perhaps because their greater status in the community increases such households' ability to prevail in such disputes. Households with a member of a cooperative group are more likely to be involved in land use disputes, perhaps because cooperative activity increases the value of land and hence disputes over its use.

4.2.2 Rangeland management practices

Households with access to individualized or private grazing land are much more likely to have invested in bush clearing and improved pastures than those with access to rangeland under customary communal tenure, while users of non-property rangeland are less likely to invest (Table 5). We find insignificant impacts of tenure in the Probit model for determinants of tree planting. However, exogeneity of the tenure variables is rejected by the Wu-Hausman test for this model ($P = 0.012$). In the instrumental variable (IV) version of the model, tree planting is found to be more likely on all other tenure categories compared to customary communal tenure. Except for the positive association of non-property tenure with tree planting in the latter regression, all of these results are consistent with hypothesis 4. However, given the lack of robustness of the results in the tree planting regression between the Probit and IV models (and the shortcomings of each model), we are not confident of the results for this dependent variable.

Other factors that have statistically significant associations with rangeland management practices include education (investment in bush clearing and improved pastures associated with more education), the age of the household head (negative association with tree planting (in the Probit model only)), the value of cattle owned (positive association with bush clearing and tree planting (the latter in the Probit model only)), access to water (negative association of distance to water with bush clearing and tree planting), the primary income source of the household (positive association of both livestock and crop production activities with tree planting, positive association of livestock production with investment in improved pastures, positive association of crop production with bush clearing), membership in a cooperative group (negative association

with tree planting), and district (less tree planting in Mbarara than in Ntungamo (in Probit model only)). In general, investments in improving the rangeland are promoted by greater education, livestock assets, access to water, and dependence on livestock and/or crop activities in the livelihood strategy. The negative association of these investments with membership in a cooperative group may be because membership in cooperatives increases the opportunity costs of labor and other resources invested in rangeland management, by increasing other income opportunities available to households.

4.2.3 Livestock management practices and technologies

Households with access to individualized or privatized grazing lands are significantly more likely to use paddocks and raise crossbred cows than households using customary communal tenure (Table 6). These results support hypothesis 5. Surprisingly, households with access to non-property rangeland are also more likely to use paddocks, although this coefficient is only weakly statistically significant at the 10% level. We find no statistically significant association of rangeland tenure with the likelihood of the household limiting its herd size. Thus, the results do not fully support hypothesis 4. The lack of association of rangeland tenure with efforts to limit herd size may be because households with access to individual or private grazing lands can still graze animals on communal and non-property rangeland, allowing them to overcome limitations in their own individual or private grazing areas. We investigate this issue further below using data on perceptions of land degradation.

Other factors significantly associated with livestock technologies and management practices include education (greater likelihood of limiting herd size, using paddocks and crossbred cows among more educated household heads), age of the household head (negative association with likelihood of limiting herd size but positive association with use of paddocks and crossbred cows), value of cattle owned (positive association with limiting herd size and use of paddocks)[5], access to water (less use of paddocks and crossbred cows further from a water source, with the effect diminishing at greater distance), primary income source (more use of crossbred cows for households dependent upon livestock income), membership in a local council (more use of crossbred cows), membership in a development committee (less likely to limit herd size (weakly significant)), and district/county level factors (less likely to limit herd size in Mbarara than Ntungamo). In general, education, asset wealth and access to water favor adoption of more intensive livestock technologies, while social capital variables have mixed impacts. The greater likelihood of limiting herd size in Ntungamo than in Mbarara is probably due to higher population pressure in Ntungamo, where population density is higher.[6]

4.2.4 Land degradation

We find no statistically significant differences in perceived land degradation on grazing lands of different tenure status (Table 7). This is contrary to hypothesis 4 and to differences in rangeland

[5] We did not include the value of livestock as an explanatory variable in the regression for use of crossbred cows, because crossbred cows are more valuable and hence likely to be associated with the value of livestock due to reverse causality.

[6] According to the 2002 Uganda Population and Housing Census, Ntungamo district had a substantially higher population density (188 persons per km) than Mbarara district (113 persons per km).

management practices found on different tenures. It is consistent with the finding in Table 6 of no significant difference across tenure categories in the propensity of pastoralists to limit their herd sizes, although not with the suggested explanation for that finding (i.e., if pastoralists with access to individualized or private grazing land were avoiding limiting their herd size by using communal or non-property rangeland, we would expect to find more degradation on the latter types of tenure). Thus, our results do not support the hypothesis that private or individualized tenure reduce rangeland degradation, because farmers apparently stock these rangelands as heavily as communal or open access rangelands (although they do invest more in private and individualized grazing lands).

However, these insignificant results may also be due to weakness in the measure of perceived land degradation that we have used, which could be subject to considerable noise or bias, depending on how well pastoralists perceive rangeland degradation and how they are implicitly defining "degradation" in response to the question (e.g.., a pastoralist with access to better quality and less objectively degraded pastures may still consider them degraded, whereas another pastoralist with access to only degraded land might not have considered such a pasture degraded). Another problem is that the regression model fails to pass the Hansen's J test, which suggests that some of the explanatory variables may not be exogenous (besides the tenure variables, which the Wu-Hausman test supports as exogenous) in this regression. For these reasons, we are not confident in the results of the regression reported in Table 7.

4.2.5 Cash expenses and revenues from livestock production

The results of the OLS and IV models for livestock cash expenses and Tobit and CLAD models for livestock cash receipts are presented in Table 8. Exogeneity of the tenure variables in the cash expenses regression is rejected by the Wu-Hausman test (at the 10% level), so the IV model is the preferred model (Table 8). The Hansen's J test of the instrumental variables (insignificant) and the relevance tests (highly significant) support the validity of the IV model for cash expenses. For the cash revenues regression, the Pagan and Vella test of normality and homoskedasticity of the error term strongly rejects that assumption, so the CLAD model is the preferred model. The Wu-Hausman test (insignificant) indicates that the tenure variables are exogenous in that regression.

We find no statistically significant impacts of rangeland tenure on livestock cash expenses or cash revenues in any of the model specifications. These results do not support hypothesis 5, and together with the findings discussed earlier, suggest that rangeland tenure has more impact on rangeland management than on use of purchased livestock inputs or livestock revenues.

Other factors that are significantly associated with livestock cash expenses in the preferred IV model include gender of the household head (more expenses by male than female household heads), the value of cattle owned (negative association with expenses per animal), and the size of the grazing area (negative association, weakly significant at 10% level). Higher expenses by male household heads may be due to greater financial wealth and/or greater emphasis on commercial livestock production by such households compared to female headed households. The negative association of the value of cattle owned and grazing area with expenses per animal suggests that households owning more livestock and having access to more grazing land pursue a

more extensive production strategy, spending less per animal. Consistent with that interpretation, we also find that households owning more animals and accessing more grazing area earn less cash revenue per animal. Other factors that are significantly associated with livestock cash revenues in the preferred CLAD specification include education (positive association), age of the household head (positive), household size (positive), membership in a development committee (negative) or in a cooperative (positive). In general, human capital has a positive impact on livestock revenues, while social capital has mixed impacts.

5. CONCLUSIONS AND POLICY IMPLICATIONS

Key findings

As hypothesized in much of the literature on rangeland management, we found that individualization and privatization of rangeland tenure in southwest Uganda have contributed to investments in rangeland management, including bush clearing, improving pastures and planting multipurpose trees. Adoption of some intensive livestock technologies, including use of crossbred cows and paddocks, is also associated with tenure individualization and privatization. However, we did not find that individualization or privatization causes pastoralists to limit their herd sizes or reduces land degradation, nor did we find significant impacts of tenure on cash expenses or revenues from livestock production. Consistent with the literature, we found that individualization and privatization reduce pastoralists' ability to use mobility to manage risk, by reducing access to rangelands away from one's own community. We did not find that those who were able to individualize or privatize were initially wealthier than other pastoralists, contradicting the hypothesis of some authors that this process favors elites. However, we did find that households that had access to individual or private pastures were able to increase their livestock wealth more than others, consistent with hypotheses that individualization contributes to income and wealth generation, and with the finding that this does not cause pastoralists to limit their herd size. We found mixed impacts of rangeland tenure on conflicts over rangeland, with less likelihood of ownership disputes where tenure is individual or private, but greater likelihood of boundary disputes where tenure is private.

Other factors that were found to have significant impacts on land disputes, rangeland and livestock management, expenses and revenues include the human, physical and social capital of the household, its primary income strategy, its access to grazing land and water, and district and county level factors. More educated household heads are more likely to invest in rangeland improvements, improved livestock technologies and practices, are less likely to report degradation of grazing lands as a problem, and obtain more revenues per animal. Households with more livestock are more likely to invest in rangeland improvements, limit herd size and use paddocks, but spend less per animal on cash inputs and earn less revenue per animal. Similarly, households more dependent on livestock income are more likely to make investments in some rangeland improvement and livestock technologies. Pastoralists with better access to water are more likely to be involved in land ownership disputes but less likely to be involved in land use disputes, and are more likely to invest in intensive rangeland and livestock management technologies. Cooperative members are more likely than other pastoralists to be involved in land use disputes and less likely to plant trees in rangelands, but obtain higher revenues per animal. In Mbarara district, land ownership and land use disputes are less likely, investments in bush

clearing more likely but tree planting less likely, and limits on herd size less likely than in Ntungamo district. These differences between districts likely reflect differences in biophysical conditions, market access and population pressure.

Implications

The findings of this study support the contention of advocates of rangeland privatization that this will contribute to agricultural modernization by promoting adoption of more intensive rangeland and livestock management technologies. The findings do not demonstrate that such changes lead to increased productivity, although the greater accumulation of livestock wealth by households having private rangeland tenure suggests that increased household income and wealth could be promoted by privatization. On the negative side, individualization and privatization reduce pastoralists' ability to cope with risks, and privatization contributes to some types of disputes. Thus, there are likely to be tradeoffs between promoting investment/intensification and managing risks/limiting conflicts as individualization or privatization of rangelands proceeds.

Such tradeoffs should be borne in mind in promoting privatization or individualization, and means to minimize these problems identified and pursued. For example, development of local land tribunals, as called for in the 1998 Land Act of Uganda, could help to address land disputes. Some of the benefits of privatization could be pursued, without bearing the costs of full land titling and related boundary disputes, by facilitating individualization of rangeland under customary tenure (e.g., by providing formal recognition to customary rights and obligations through local tribunals and other legal entities). It may be difficult to fully maintain the risk management advantages of customary communal tenure as privatization or individualization continue to occur, although the fact that a large minority of households with these tenure types reported that others have a right to graze on their own grazing land during a calamity offers hope for continuing flexibility. Policies to reinforce such risk sharing norms, building on existing customary institutions as well as being promoted by the new land tribunals, could help to maintain this valuable aspect of common property management even as property rights institutions change in response to increasing population pressure and new market opportunities.

Although changes in rangeland tenure are likely to continue to occur and could have important impacts on rangeland and livestock management, productivity, and land degradation, it is important to recognize that many other factors also have important impacts on these responses and outcomes, and many of these impacts may be more important than, or substantially influence the effects of, changes in rangeland tenure. For example, our study shows that education and improved access to water can have substantial positive impacts on pastoralists' investments in improved rangeland and livestock management. Thus, besides providing direct benefits to households, such investments can indirectly help to increase productivity and reduce rangeland degradation; offering a potential for "win-win-win" outcomes.

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Table 1. Adoption of livestock and rangeland management technologies

Technologies	Full sample (n=312)		Customary communal (n=29)		Individualized communal (n=145)		Private (n=84)		Non-Property (n=54)	
	Mean	std error	Mean	std error	Mean	std error	Mean	std error	mean	std error
Livestock technologies										
Use of paddocks	0.141***	0.35	0.00[b]	0.00	0.12[d]	0.33	0.30[dbf]	0.46	0.02[f]	0.14
Have cross bred cows	0.228***	0.42	0.04[b]	0.19	0.21[d]	0.41	0.39[dbf]	0.49	0.11[f]	0.32
Use artificial insemination	0.035	0.19	0.03	0.19	0.04	0.20	0.05	0.21	0.00	0.00
Use of pump sprays	0.75***	0.43	0.72	0.46	0.63[de]	0.49	0.93[d]	0.26	0.82[c]	0.39
Grazing land management										
Limiting herd size	0.259***	0.44	0.07[b]	0.26	0.23[d]	0.43	0.45[dbf]	0.50	0.13[f]	0.34
Made pasture improvements	0.587***	0.49	0.35[b a]	0.48	0.62[de]	0.49	0.89[dbf]	0.31	0.15[c f]	0.36
Planted multi purpose trees	0.151***	0.36	0.04	0.19	0.17[e]	0.38	0.25[f]	0.44	0.00[c f]	0.00
Cleared bushes	0.468***	0.50	0.21[ba]	0.41	0.52[de]	0.50	0.69[bf]	0.47	0.11[c f]	0.50

*, **, *** mean statistically significant difference across the land tenures at the 10%, 5%, and 1% levels, respectively.

[a] means significant difference between customary and individualized tenures ($p<0.05$)
[b] means significant difference between customary and private tenures ($p<0.05$)
[c] means significant difference between customary and non-property tenures ($p<0.05$)
[d] means significant difference between individualized and private tenures ($p<0.05$)
[e] means significant difference between individualized and non property tenures ($p<0.05$)
[f] means significant difference between private and non property tenures ($p<0.05$)

Table 2. Land and livestock disputes

Dispute	Full sample		Customary communal		Individualized communal		Private		Non-Property	
	Mean	std error	Mean	std error	Mean	std error	Mean	std error	mean	std error
Land boundary disputes	0.128**	0.34	0.10	0.31	0.15	0.35	0.18[f]	0.39	0.19[f]	0.14
Land ownership dispute	0.154	0.36	0.21	0.41	0.15	0.35	0.18	0.39	0.11	0.32
Land inheritance dispute	0.003	0.06	0.00	0.00	0.00	0.00	0.01	0.11	0.00	0.00
Competing land use dispute	0.097***	0.29	0.14	0.35	0.06[e]	0.24	0.12[f]	0.11	0.22[cf]	0.42
Cattle ownership dispute	0.003	0.06	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.14

*, **, *** mean statistically significant difference across the land tenures at the 10%, 5%, and 1% levels, respectively.

[a] means significant difference between customary and individualized tenures ($p<0.05$)
[b] means significant difference between customary and private tenures ($p<0.05$)
[c] means significant difference between customary and non-property tenures ($p<0.05$)
[d] means significant difference between individualized and private tenures ($p<0.05$)
[e] means significant difference between individualized and non property tenures ($p<0.05$)
[f] means significant difference between private and non property tenures ($p<0.05$)

Table 3. Outcomes of livestock and rangeland management

	Full sample		Customary communal		Individualized communal		Private		Non-Property	
	Mean	std error	Mean	Std error	Mean	std error	Mean	std error	mean	std error
Wealth change										
Beginning stock when household formed (households formed by 1965)	18.101	27.05	12.44	26.24	15.78	23.92	17.77	17.49	25.21	40.25
Current stock (households formed by 1965)	39.208***	81.68	12.63	8.40	24.82	24.44	68.34	138.24	35.45	39.35
Access/Risk management										
Distance to water source(Km)	0.892***	1.06	1.73[ab]	2.04	0.69[a]	0.78	0.73[b]	0.47	1.11	1.21
Have a personal water source	0.651***	0.48	0.38[a b]	0.49	0.63[ade]	0.48	0.94[bdf]	0.24	0.39[f]	0.49
Right of others to graze on own land during calamity	0.547**	0.50	0.53	0.52	0.43[e]	0.50	0.47	0.51	0.70[e]	0.46
Access to other grazing land during calamity	0.199*	0.40	0.35	0.49	0.21	0.41	0.12	0.33	0.22	0.42
Distance to other grazing land during calamity(km)	12.543	16.39	5.53	7.75	16.12	20.92	15.52	12.29	6.18	4.68
Rangeland degradation										
Grazing land degraded due to overstocking, erosion	0.308**	0.46	0.38	0.49	0.23[e]	0.43	0.32	0.47	0.44[e]	0.50
Livestock cash inputs and net returns										
Cash expenses per animal per year (000 Ushs)	19.097*	24.17	10.95	10.08	18.21	32.42	24.14	12.42	14.96	13.23
Net receipts per animal per year (000 Ushs)	-11.419**	39.59	-27.00[b]	46.78	-9.92[a]	40.51	-4.30	37.38	-18.30	34.69
Net receipts per animal per year, among those with positive net receipts (000 Ushs)	21.123	28.05	7.73	9.91	27.05	37.26	22.77	23.97	9.06	5.85

*, **, *** mean statistically significant difference across the land tenures at the 10%, 5%, and 1% levels, respectively.

[a] means significant difference between customary and individualized tenures ($p<0.05$)
[b] means significant difference between customary and private tenures ($p<0.05$)
[c] means significant difference between customary and non-property tenures ($p<0.05$)
[d] means significant difference between individualized and private tenures ($p<0.05$)
[e] means significant difference between individualized and non property tenures ($p<0.05$)
[f] means significant difference between private and non property tenures ($p<0.05$)

Table 4. Determinants of land disputes

Probit regression results (marginal effects)

Explanatory variables	Boundary disputes	Ownership disputes	Land use disputes
Rangeland tenure(c.f customary)			
Individualized	0.063	-0.152**	-0.002
Private	0.412**	-0.102*	-0.003
Non-property	-0.229	-0.076	0.025**
Human capital			
Education of hhd head(cf.none)			
- Primary	-0.002	0.049	0.004
- Secondary	-0.019	0.046	0.007
- Post secondary	0.052	-0.025	-0.003
Ln(age of household head)	0.158**	0.095*	-0.005*
Sex of household head(1=male 0=female)	-0.093	0.047	0.004
Ln(household size)	-0.001	0.011	0.002
Assets and Access			
Ln(Value of cattle)	0.009	-0.002	-0.001
Ln(Grazing area)	-0.031	-0.016	-0.001*
Ln(Dist to water source)	-0.015	-0.157**	0.003**
Ln(Dist to water source)squared	0.008	-0.063*	-0.001
Primary income source (cf., other)			
- Livestock and crop	0.140	-0.049	0.005
- Livestock	-0.072	0.099*	0.001
- Crop	-0.048	-0.029	-0.001
Social capital			
Membership in local council	0.088*	-0.023	-0.002
Membership in development committee	0.018	-0.055	-0.010
Membership in cooperative group	-0.018	0.027	0.058**
District level factors			
District dummy (Mbarara=1, Ntungamo=0)	0.065	-0.095**	-0.005*
Number of observations	182	194	193
Pseudo R^2	0.211	0.145	0.406
Wu-Hausman test of exogeneity of tenure (P-value)	0.1192	0.2459	0.2713
Hansen's J test of instrumental variables (P-value)	0.255	0.531	0.749

*,**,*** mean statistical significance at the 10%,5% and 1% levels, respectively.

Table 5. Determinants of rangeland management practices

Probit and IV models (marginal effects in Probit models)

Explanatory variables	Improved pastures	Bush clearing	Planting multi-purpose trees	
	Probit	Probit	Probit	IV
Rangeland tenure(c.f customary)				
Individualized	0.307***	0.427***	0.013	0.615**
Private	0.338***	0.373***	0.011	0.742**
Non-property	-0.364**	-0.354**	-0.097	0.647**
Human capital				
Education of hhd head(cf.none)				
- Primary	0.319***	0.325***	0.005	0.060
- Secondary	0.328***	0.451***	0.015	0.061
- Post secondary	0.332	0.361*	0.047	0.154
Ln(age of household head)	-0.095	0.006	-0.017**	-0.044
Sex of household head(1=male 0=female)	-0.049	-0.347	-0.012	-0.027
Ln(household size)	-0.119	-0.017	0.007	0.028
Assets and Access				
Ln(Value of cattle)	0.041	0.078*	0.008**	0.037
Ln(Grazing area)	-0.001	0.017	0.001	-0.041
Ln(Dist to water source)	-0.058	-0.131***	-0.009***	-0.052*
Ln(Dist to water source)squared	0.017	0.024*	0.001	0.009
Primary income source (cf., other)				
- Livestock and crop	0.194	-0.235	0.185**	0.259**
- Livestock	0.241*	0.177	0.019***	0.182**
- Crop	0.156	0.359**	0.259***	0.257*
Social capital				
Membership in local council	-0.046	-0.076	-0.000	0.012
Membership in development committee	-0.018	0.129	-0.007	-0.029
Membership in cooperative group	0.038	0.044	-0.009***	-0.206**
District level factors				
District dummy (Mbarara=1, Ntungamo=0)	0.129	0.391***	-0.017**	-0.004
Number of observations	217	217	217	204
Pseudo R^2 (centered R^2 for IV model)	0.382	0.380	0.321	-0.082
Wu-Hausman test of exogeneity of tenure (P-value)	0.359	0.548	0.012***	
Hansen's J test of instrumental variables (P-value)	0.764	0.933		0.241

*,**,*** mean statistical significance at the 10%,5% and 1% levels, respectively.

Table 6. Determinants of livestock management practices and technologies

Probit regression results (marginal effects)

Explanatory variables	Limit herd size	Paddocks	Cross bred cows
Rangeland tenure (cf customary)			
Individualized	0.076	0.768**	0.253**
Private	0.159	0.945**	0.297**
Non-property	0.019	0.867*	0.169
Human capital			
Education of hhd head (cf.none)			
- Primary	0.167**	0.029***	0.352***
- Secondary	0.205*	0.121***	0.322***
- Post secondary	0.693***	0.159***	0.203
Ln(age of household head)	-0.177**	0.141**	0.146*
Sex of household head(1=male 0=female)	-0.151	0.005	-0.175
Ln(household size)	0.036	0.002	0.103*
Assets and Access			
Ln(Value of cattle)	0.130***	0.005**	Na
Ln(Grazing area)	-0.009	0.001	0.019
Ln(Dist to water source)	-0.019	-0.006***	-0.067***
Ln(Dist to water source)squared	0.014*	0.002***	0.013**
Primary income source (cf., other)			
- Livestock and crop	-0.118	-0.007	-0.126
- Livestock	0.051	-0.004	0.151*
- Crop	0.066	-0.026	-0.128
Social capital			
Membership in local council	0.043	-0.005	0.125**
Membership in development committee	-0.140*	-0.000	-0.035
Membership in cooperative group	-0.042	0.001	0.060
District level factors			
District dummy (Mbarara=1, Ntungamo=0)	-0.209***	-0.003	-0.071
Number of observations	217	217	230
Pseudo R^2	0.265	0.353	0.298
Wu-Hausman test of exogeneity of tenure (P-value)	0.433	0.478	0.356
Hansen's J test of instrumental variables (P-value)	0.315	0.298	0.163

*,**,*** mean statistical significance at the 10%,5% and 1% levels, respectively.

Table 7. Determinants of perceived land degradation due to erosion and overstocking
Probit regression results (marginal effects)

Explanatory variables	Perceived land degradation
Rangeland tenure(c.f customary)	
Individualized	-0.098
Private	0.023
Non-property	0.109
Human capital	
Education of hhd head(cf.none)	
- Primary	-0.166**
- Secondary	-0.087
- Post secondary	-0.028
Ln(age of household head)	-0.152
Sex of household head(1=male 0=female)	-0.258
Ln(household size)	0.055
Assets and Access	
Ln(Value of cattle)	-0.003
Ln(Grazing area)	-0.031
Ln(Dist to water source)	0.042
Ln(Dist to water source)squared	0.006
Primary income source (cf., other)	
- Livestock and crop	0.0437***
- Livestock	0.061
- Crop	-0.076
Social capital	
Membership in local council	0.042
Membership in development committee	0.038
Membership in cooperative group	-0.343
District level factors	
District dummy (Mbarara=1, Ntungamo=0)	-0.079
Number of observations	217
Pseudo R^2	0.086
Wu-Hausman test of exogeneity of tenure (P-value)	0.663
Hansen's J test of instrumental variables (P-value)	0.048**

*,**,*** mean statistical significance at the 10%,5% and 1% levels, respectively.

Table 8. Determinants of livestock cash expenses and revenues

OLS, IV, Tobit and CLAD regression results

Explanatory variables	Livestock cash expenses per animal		Livestock cash revenues per animal	
	OLS	IV	Tobit	CLAD
Rangeland tenure (cf. customary)				
Individualized	9.907	-19.266	0.091	0.010
Private	3.894	69.523	0.074	-0.004
Non-property	3.846	34.771	0.070	-0.010
Human capital				
Education of household head (cf. none)				
- Primary	29.049*	20.448	0.047	0.036***
- Secondary	11.533	-2.743	0.066	0.055***
- Post secondary	-13.500	-24.470	-0.054	0.003
Ln(age of household head)	1.102	18.324	0.036	0.036***
Sex of household head (1=male 0=female)	56.858**	73.220**	0.075	-0.004
Ln(household size)	10.939	16.129	0.010	0.020**
Assets and Access				
Ln(Value of cattle)	-25.638***	-29.249***	0.020	-0.016***
Ln(Grazing area)	-6.156	-14.473*	-0.019*	-0.008***
Ln(Dist to water source)	-2.784	-5.330	-0.015	0.002
Ln(Dist to water source)squared	1.362	2.859	0.005	0.001
Primary income source (cf., other)				
- Livestock and crop	-70.420	-82.025	-0.035	0.015
- Livestock	-8.348	-25.865	-0.019	0.007
- Crop	-81.942	-107.705	-0.168**	-0.017
Social capital				
Membership in local council	0.439	4.940	0.011	0.002
Membership in development committee	14.155	14.679	0.046	-0.032**
Membership in cooperative group	-8.373	-19.102	0.085	0.035**
District level factors				
District dummy (Mbarara=1, Ntungamo=0)	-9.615	-19.022	0.023	0.006
Number of observations	216	203	216	129
Number of left censored observations	4	4	113	
Pseudo R^2 (centered R^2 for OLS and IV models)	0.151	0.056	0.298	0.096
Pagan and Vella test of normality and homoskedasticity in Tobit model (P-value)			0.000***	
Wu-Hausman test of exogeneity of tenure (P-value)		0.056*	0.339	
Hansen's J test of instrumental variables (P-value)		0.433	0.384	
Relevance test of excluded instrumental variables (P-value)				
- Individualized		0.000***	0.003***	
- Private		0.000***	0.003***	
- Non-property		0.000***	0.000***	

*,**,*** mean statistical significance at the 10%,5% and 1% levels, respectively.