Modelling Climate Change Adaption in Vulnerable Crop and Livestock Production Systems in Mgeta, Tanzania

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Abstract

Increased occurrences of draught and dry spells during growing seasons have resulted in increased interest for protection of tropical water catchment areas. In the paper, we examine opportunities for improving economic performance and explore more environmental sustainable adaptation strategies in the integrated crop-livestock production systems in Mgeta, a water catchment area in the Uluguru Mountains, Tanzania. In Mgeta water for fruit and vegetable production is provided through canals from the Uluguru forest reserve. The clearing of forest land for cultivation in the steep slopes is causing severe land degradation, threatening the water source, livelihoods and food security of the local communities as well as major population centers in the lowlands. A linear programming (LP) crop-livestock model, maximizing farm income, is applied for studying the economic performance of dairy goats in the production system today and in a scenario with lower crop yields and increased variability due to climate change. Data obtained from a questionnaire to a sample of farmers were used to develop and parameterize the model. The assessments suggest that in the steep slopes of the area a crop-dairy goat system with extensive use of grass and MPPT will do better under climate change since the yield variation of the grass and MPPT system is less affected compared to vegetable crops due to more tree cover and the perennial grasses. Currently goat milk production is limited by inadequate feeding, and farmers should purchase more concentrate feed to enhance production of the dairy goats. Policy measures to promote such a development are briefly mentioned.

Key words: *Linear programming, dairy goats, climate change, risk analysis*

I. Introduction

For a decade or so climate change and variability have featured strongly in the development discourse across the world, and awareness and effects of climate change on the environment and livelihoods are becoming more apparent than at any time before (Osman-Elisha, 2006; Okoye and Onietan, 2009). In Tanzania, much attention has been on the performance of different farming or production systems. Among the farming systems that in particular has attracted the attention of scholars, are those in Mgeta a high altitude water catchment area located in the Mvomero district on the western side of Uluguru Mountains, about 50 km from Morogoro town. Generally, a review of literature on the agriculture in Mgeta, reveals that the farming systems in the area have evolved from centered on cereals, through being based on vegetables with meat goats and other livestock species, to current systems in which dairy goat production is an integrated component. In the earlier systems land degradation has been widely reported (Ponte, 2001). Where in some places of Mgeta the degradation is so severe that it is threatening not only the source of water for domestic use but also the livelihoods of the local communities, including their food security. However, integrating dairy goats in such systems can help to reverse the situation, as the dairy goats are possible to keep indoor and or tethered. Moreover, developing and expanding a cropping system that would fit in the steep slopes to replace some of the most erosion vulnerable vegetable crops are clearly needed.

Farmers in Mgeta grow vegetable crops in pure stand and in intercropping systems on bench terraces and in steep slopes, especially tomatoes, potatoes, cabbage, beans, green peas and maize. In the early 1989, dairy goats were introduced through a project operated by Sokoine University of Agriculture (SUA) with Norwegian governmental support (Ingratubun et al., 2000; Mtenga and Kifaro, 1992). Besides, traditional meat goats and pigs are available for meat as well as manure for vegetable production. Today, farmers upgrade the local meat goats to dairy breed by crossing with dairy bucks. Expanding goat milk production might be advantageous since a market for milk, or milk products such as yoghurt, can be found both locally and in the cities. However, the production of yoghurt need to be developed to take advantage of the market opportunities (Lie et al. 2011). Currently dairy goat production is limited by inadequate breeding schemes and feeding practices and intervention in those areas could become a long-run strategy for expanding goat milk production.

In this article, an attempt made to assess the current production systems and explore opportunities for improvements concerning economic performance and environmental impact. In particular, we study and compare a traditional cropping-livestock system with meat goats and pigs and extensive vegetable production in a system with dairy goats and more use of MPPT and grass and less vegetable production. In the next chapter the description of field data collected in Mgeta, and the economic analysis conducted are shown. This is followed by a presentation of model results and a discussion of policies for promoting a sustainable and more environment friendly production system in the area.

Materials and Methods

Purposively sampling of 60 farmers within five of the seven wards of the Mgeta division namely, Tchenzema, Nyandira, Mgeta, Langali and Bunduki, was conducted. In each ward three villages, each with four households, were selected. Interviews with farmers, guided by a pretested structured questionnaire, were conducted in July and August 2012. The data collected included general household information, parcel characteristics, crop and livestock production characteristics and their respective assumed labor requirement. In addition characteristics of grass, MPPTs, and fruits were quantified. The data were summarized and analyzed using SPSS (http://ebookbrowsee.net/spss-base-user-s-guide-16-0-pdf) to calculate standardized values (z scores) including sample size, means and standard divisions (SDs).

The results and values obtained from the questionnaire were used to develop and parameterize a general linear programming (LP) farm model encompassing dairy goats, meat goats, pigs and different kinds of vegetables in two seasons. The LP technique is based on constrained optimization that can be said to reproduce the reality of farmers who strive to maximize their income while facing several constraints. In farm LP models (see Barnard and Nix, 1979) several activities, restrictions and production techniques are considered simultaneously, and the effects of changing technical specifications and biological responses or right hand side parameters, can easily be assessed. The mathematical model of a primal LP problem (Luenberger, 1984):

Max $Z = c'x$, subject to $Ax<b$, $x \geq 0$,

Where Z = objective function, farm gross margin (GM),

c'= a vector of marginal activity GM,

x = a vector of activity levels,

A= a matrix of activity resource requirements, and

b = a vector of resources e.g. and, work hour.

Based on the questionnaire model activities for tomatoes, potatoes and cabbage as well as the N-fixing crops beans and green peas, have been developed on land close to the farm homestead. Two complete crop production seasons, the rain period approximately 270 days from September to May and the dry period, 95 days from June to August, were considered. The vegetable crops are grown under fruit trees, which are limited to one fruit tree per 100 square m. The model is worked out for plums, which give yield only in the rain season. On distant farmland, beans and maize can be grown in both seasons. Intercropping is assumed in both seasons for potatoes and green peas on homestead area and for maize and beans in the distant area. Assumed area of tomatoes may constitute a maximum of 30% of the homestead area either season due to crop rotation. Moreover, we assume the family's own need will require 10% of the homestead area for tomatoes and potatoes and another 5% for cabbage. Farmers use urea and manure to increase soil nutrients and separate constraints balance the supplies and use of fertilizers and manure with purchased fertilizers and farm produced manure.

The gross margins are calculated by multiplying expected yields and prices and subtracting the crop specific variable costs for each crop in the 2012 price level. The expected normal yields in the area were derived from the questionnaire, and the feeding values are based on (Solaiman, 2010). As for the grass and MPPT, we arrived at 192 MJ of energy from $10m^2$. There are no purchased inputs for this process but there may be some work to maintain the grass sword. In a basic scenario we assume that all yields are normally distributed with SD=10%. In a climate change scenario the expected normal crop yields are assumed to be lowered by 10% for all vegetable crops and by 5% for the grass and MPPT yields. Regarding the effects of climate change on yield variation, we assume the SDs would increase to 20% on crop yields and to 15% on grass and MPPTs. One reason the MPPT system is assumed to be less affected by climate change compared to vegetable crops is the tree cover which will limit evaporation. Moreover, in the steep slopes in Mgeta dried land will be more exposed to landslides when heavy rain follows a prolonged period of draught, assumed to be an effect of climate change. Perennial grasses under a covering tree canopy are likely to do somewhat better in that case.

The animal activities consist in dairy-and meat-goats, and pig-keeping. Separate processes provide replacement for the goats. The replacement rate is 0.4 for both dairy and meat goats. The piglets are assumed purchased and the cost of one piglet is subtracted from the objective function of pig production. Traditional meat goats are free roaming, while dairy goats are assumed tethered or fed in enclosures in a cut and carry system. The pigs are assumed to use crop leftovers including some of the yields from tomatoes, potatoes and fruits, for other crops leftovers are used by the goats. Maizebran can be purchased for supplementary feeding. The work requirements for crops and livestock are developed according to season and farmers can hire labor if the family workforce is insufficient.

The goats utilize grass and leaves and branches of multipurpose trees (MPPTs), particularly Mulberry and Leucaena Leucocephala, grown on their own land or on communal land. The feeding of dairy goats is taken care of in five constraints, energy and protein requirements for milk production in the two seasons, and a constraint for maintenance feed which is assumed provided by grass and MPPTs in both seasons. Based on (Solaiman, 2010) maintenance feed requirement for dairy goats is calculated to 9.42 MJ of energy

per day and production feed for milk to be 19.85 MJ of energy and 130 gram of protein per day. For replacement kids we assume values at 50% of adult animals. For meat goats, we assume values for maintenance and growth equal to 70% of the maintenance feed for dairy goats and no production feed, as they are not milked. For pigs we assume 35.21 MJ of energy and 155 gram of protein per day for maintenance and growth in both seasons.

The vector "b" of right-hand side values constraints the activities to the available fixed assets of two categories of farmland, either near the homestead 2093 m^2, or more distant 3475 m^2, based on the questionnaire. The land can be used in both seasons but may be left idle in either season. Usable communal land is assumed to constitute 418 m^2 i.e. 20% of the homestead land which limit the amount of grass and MPPT from communal land. The model, consisting in 31 activities and 35 constraints, was specified and solved in an excel spreadsheet supported with Simetar (Richardson et al., 2008) to undertake a stochastic analysis.

Results

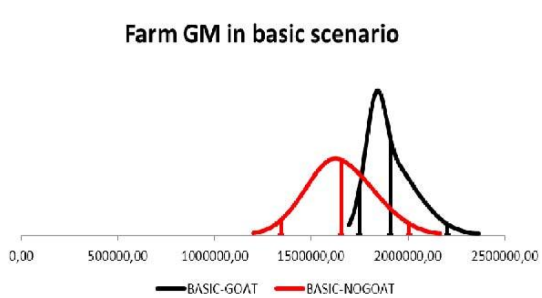
The model was run with and without dairy goats in the two scenarios, and the main results are shown in Table 1

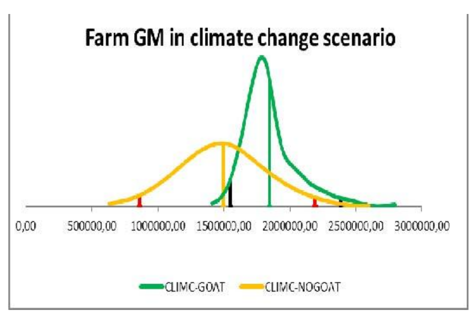
. Table 1. Model solutions in the basic scenario compared to a climate change scenario.

	Land use, square m*					Grass &	Goats		Purchased		Gross
Scenario	T	P	C	B	MB	MPPTs	Dairy	Meat	Pigs	feed, TSH	Margin, TSH
Basic											
Without dairy goats	2512	1423	251	2412	3831	419	0	3	0	0	1 644 461
With dairy goats	502	1005	251	2119	2617	1633	8	0	0	1 581 610	1 871 378
Climate change											
Without dairy goats	2512	1423	251	968	2236	419	0	3	0	0	1 487 230
With dairy goats	502	1005	251	565	954	1633	8	0	0	1 584 286	1 805 026

*T= tomatoes, P= potatoes and green peas, C= cabbage, B=beans, and MB= maize and beans (distant land)

The results demonstrate that farmers will choose rather extensive vegetable cropping in a basic scenario when dairy goats are not an option. Meat goats are less profitable and will only utilize communal land and farmers will have pigs to utilize crop leftovers. The number of pigs will depend on the available amounts of crop leftovers, our calculations resulted in less than 0.5 pigs. When dairy goats are permitted in the model the amount of grass and MPPTs increase and farmers also start to purchase feed for the goats. Due to the need of land for goat feed the cultivation of vegetable crops declines to what is considered necessary for family needs. Under the climate change scenario, the results suggest that unilateral vegetable production may be more vulnerable and unsustainable as compared to dairy goats. Evidently, dairy goats with grass and MPPTs do better in both scenarios. The probability density functions of the calculations of farm GM are shown below.





In addition to the better results achieved with dairy goats the model runs indicate that the results will be more stable over time since the dependence on stochastic crop yields is lowered in the scenarios with dairy goats. Policy measures to promote such a development has not been examined but could include such things as
(a) subsidies and other measures for more concentrate feed purchase, (b) investment support and other measure for developing yoghurt production, or (c) introducing subsidy payment for permanent grassland and MPPT.

Conclusions

Our farm study in Mgeta indicates that a changeover from a seasonal vegetable crop system to a system with dairy goats and more permanent grass and multipurpose fodder tree would increase farm gross margin by 15%. Moreover this system also seems to do better under a climate change scenario in which average farm GM is assumed to decline by only 3% compared to 10% without dairy goats. This is due to a smaller decline in yield and less increase in yield variation compared to seasonal vegetable crops since perennial grasses under a covering multipurpose tree canopy are likely to be less affected in this situation.

Recommendations

Our recommendations to the community are to gradually improve dairy goat feeding and breeding management and to increase establishment of grass and fodder trees, particularly in the steep terrain and most erosion vulnerable parts of the area to counter the expected effects of climate change. Different policy measures might be developed to promote this development in order to counteract the effects of climate change.

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