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Herd dynamics and productivity performance modeling of livestock in smallholder crop-livestock systems in Southwestern Ethiopia

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Abstract
This study aimed to examine herd dynamics relatively in wider array in two different administrative zones to model scope of improving productivity performance of ruminant livestock by management optimization using existing modeling tools. In implication, herd demographic parameters gathered at household level has modeled by management optimization in existing PRY herd modeling tools for ruminant livestock productivity assessment. The differences observed in both descriptive analysis and the model prediction in the study could be of the demographic, reproductive, productive or sizable combined effect of these factors that resulted in livestock phenotypical value and household income. Intensified feeding strategies from existing sources, improvement through rearing and herd management viewed to make potential improvement in livestock production and could re-integrate the strategies of the livelihood in smallholder mixed system. Where variability assessment in herd demographic parameters could an opportunity suit livestock intensification interest to support the sustainable development of the rural poor.

Keywords: Herd dynamics, livestock modeling, smallholder crop-livestock systems

1. Introduction
Integrated crop-livestock systems, already common in the Sub-Saharan Africa (SSA) are expected to evolve rapidly, and livestock production of this system to continue to contribute to social transformation as a strategic asset of the poor population. While a prerequisite for livestock development is an understanding of the production factors and processes that affect animal production.

According to Steinfeld and Mack (1995) [19], difficulties in agricultural planning are related not only to the complexity of livestock production systems but also to an inability planners to understand how these systems function, which is primarily a problem of quantification and comprehension. The consequence of these difficulties leads to the fact that development opportunities often ignored, particularly the potentials of using livestock as a catalyst to drive agricultural development.

In tropical animal production, the classical strategies such as artificial insemination and stabling cattle breeding intensification are not sustainable, and managing of reproduction, supplementary feeding, weaning, and culling is a rare (Ezanno, 2005) [7]. According to Ezanno (2005) [7], experimentation and quantifying the animal performance with longer reproductive cycle and high seasonal variation are not easy.

Thus, the traditional livestock production co-evolve in combination with the entire systems of genetic material that consequential could have variation among intra-population of livestock in farming system in SSA. In the drier environment under the traditional management animal production, reproduction, disease resistance, and their function resiliently continue to survive. Thus, a smallholder livestock production in SSA is the long-term effect of environment and management strategies of farmers.

The key herd demographic parameters such as mortality and fertility can allow modeling the potential responses of the population to possible action.

In animal ecology demographic models developed can be used with synthetic indicators of annual growth rate, milk production, etc., that can be tailored to raising productivity or diversity, efficiency, resilience, value, and profitability of farming including the enabling mechanisms needed within diverse local contexts (Dobermann *et al.*, 2013) [6].

Nonetheless, these can regenerate and easily scale-out to emerge the more intensive with the value of the society, agro-ecosystems services and a land area of smallholder livestock production systems currently managed. The integration of production in extensive systems in SSA is these systems could be 'providers' of agro-ecosystems services (Freeman *et al*., 2008) [9]; food, feed, etc. A set of descriptors for structural elements, the level of resolution and operational objectives of livestock production and models of livestock systems can be described systematically, allowing the evaluation of suitability to task to become more transparent and stringent (Pittroff and Cartwright, 2005) [17]. This study aimed to examine herd dynamics relatively in wider array in two different administrative zones and to model scope of improving productivity performance of ruminant livestock by management optimization using existing modeling tools.

2. Material and Methods

2.1 Description of study area

The study was carried out in two administrative zones (Gamo Gofa and Dawuro) in South Nations Nationalities People (SNNP) regional state in south Ethiopia. The two zones in common located between 5° 34′ 16.31″ N and 7° 20′ 58.01″ N of latitude, and 36° 22′ 13.04″ E and 37° 51′ 26.31″ E of longitude, respectively. The capital Arba Minch of Gamo Gofa and Tarcha of Dawuro found respective at about 490 and 505 km south of Addis Ababa. The total human population of these zones was about 2.66 million with a total area coverage of about 16530 km^2. The rural population accounts for about 88% in Dawuro and 84% in Gamo Gofa. The zones are divided broadly into dry upper highland, wet highland, wet humid, wet sub-humid, wet upper lowland, wet lower lowland and wet and dry lowland agro-ecological zones (AEZs).

2.2 Sampling and data collection procedure

2.2.1 Sampling procedure

The SNNP regional state constitutes three special districts and fourteen zones in Ethiopia. The study was selected two of the zones in the region, namely Gamo Gofa and Dawuro. Based on the diversity in the farming systems and the AEZs, the study zones were selected purposively on SNNP region, in a way to better capture diversity and to make study results relevant to most zones in the region.The highland is designate an area of altitude cover starting 2400 meter above sea level (m.a.s.l), while midland ranges between 1500 to 2400 and the lowland cover areas located below 1500 m.a.s.l

For data collection, two AEZs were selected from two administrative zones. In each zone, the districts were stratified into three AEZs as highland, midland, and lowland with respect to area proportion of the AEZ. The districts, in AEZ selected randomly, and followed by the peasant administrations (PAs), designated for its production potential in discussion with selected group at lower level.

A total of 132 households (HH) that were selected for semi-quantitative, semi-structured interviews. In the Gamo Gofa administrative zone, there were total of 72 HH; 19 at one location in the highland zone and 53 at two locations in the midland zone. In Dawuro there were 28 HH at one location in the highlands and 32 at another location in the midlands giving a total of 60 HH. The HH in sample site was randomly selected with regard that they have at least any one livestock species (i.e., at least a cattle, sheep or goats) per HH level.

2.2.2 Data collection procedure

A structured questionnaire was prepared and used to obtain data from sampled respondent HHs for semi-quantitative interviews. The questionnaire was pre-tested with three respondents at one of the selected sites and as a result, some of the questions were modified to make them more fit the study for purpose. Moreover, any difficulties experienced in questioning and answering the questionnaires were discussed and revised. In each sampled location, enumerators identified and trained on the contents of the questionnaire employed for data collection. The enumerators were under the close supervision of researchers. The final survey questionnaire covered demographic characteristics, HH socio-economic factors, land holding size, the livestock species kept, herd structure of cattle, sheep and goats, and their productive and reproductive performance level as well as HH income from sales of livestock, their products, tree plantation, off-farm and other sources (like labor and remittance). The data were collected between February and July 2014.

2.3 Livestock productive and reproductive performance

A cluster analysis was done to determine productive and reproductive parameters of cattle (Table 1) for collected data. Cattle under current management (on farm), for instance age at first parturition (AFP), parturition interval (PI), milk yield (MY) per day and per lactation, mortality and culling (sale and slaughter) rate were determined for poor, medium and better-off farm classes. The maximum life time of a cow 120 months and ewe and doe 72 months determined during HH interviews and taken as the cull-for-age threshold for breeding females.

2.4 Modeling herd productivity under different management scenarios

The current productivity performance and improved management scenarios of cattle was simulated by PRY Herd Life Model (Baptist, 1992) [4] based on data AFP, PI, mortality rate and culling which were gathered during field survey. The model calculates, herd productivity in terms of output per year (animal live weight (LW), revenues, milk yield, manure DM, fiber, male power and dead weight all cohort) and output per input (total output value per unit feed DM intake). Using the population-inherent fitness parameters, growth and reproductive performance, energy flow, produce value and culling strategy for different reproductive management and culling (sale and slaughter).

Using the respective performance value, herd development was modeled separately for cattle, sheep and goat and for farm HH classes poor, medium and better-off based on survey data. Additional input parameter values for PRY Herd Model were obtained from different sources (Table 2). In some cases, assumptions and estimates were made to obtain some parameters for the assessment of livestock production and reproduction (e.g., Pittroff and Cartwright, 2005) [17]. The assumptions for prices of female and male LW of animal was based on the interview results of farm HHs in the study area those who fatten animal and sale for income generation.

The manure DM nutrient content (g/kg) was estimated according to Yimer (2005) [25], nitrogen (N) 15, phosphorus (P) 6 and potassium (K) 19. Then the price of soil fertilizer (in the year 2012) in the study area was used to estimate manure output. That the price (€/kg) estimated was for N, 0.018, P, 0.035 and K, 0.009 in 2012.

2.5 Statistical analysis

To identify patterns, and express out similarities and difference in the interviewed data, principal component analysis was carried out. Subsequently, after defining patterns in the data, a cluster analysis was conducted using Ward's Method and Squared Euclidean Distance (Zöfel, 1988). Data on HH members, land holding size, total livestock number, proportion of cattle and small ruminant to livestock, total revenue from livestock, tree plantation, off-farm, others and proportion of revenue from cattle and small ruminant were standardized by z-score transformation for cluster analysis to correct differences in scales of the different variables (Funk *et al*., 2006) [10].

The quantitative information on HH size, family land holding, production, reproduction and sizes of livestock and HH incomes from farming and off-farm were used to cluster the characteristic properties of socio-economic, livestock production and reproduction, tree plantation, off-farm and others between the agro-ecology and farm household classes.

Three distinct HH clusters were identified across the different agro-ecological zones. The resource-poor HH was with larger HH members, small land holding, smaller cattle and shoat number, and lower income from livestock keeping, tree plantation, off-farm and others. Better-off HHs that were characterized smaller HH members, larger land holding, higher number of cattle and shoats, and higher income from livestock keeping and tree plantation. The intermediate HHs that intermediate HH members, smaller land holdings, intermediate number of cattle and shoat, and with relatively better income from livestock keeping, tree plantation, off-farm and others

Means and standard errors (SE) for socio-economic characteristics and production and reproduction parameters of livestock were calculated for HH of different AEZs and HH clusters. The HH revenue from livestock production, tree plantation, off-farm and other sources was converted to Euro (€) using a conversion rate of 1 € = 23.99 Ethiopian birr (National bank of Ethiopia, October 2015). To determine significant difference between AEZs and farm clusters independent t-test was used for normally distributed variables and Mann Whitney U-test for non-normally distributed variables (Zöfel, 1988) with a significance level of p = 0.05. The homogeneity of HH data was determined by Levene's test (Petrie and Watson, 2013) [16]. Statistical analyses were carried out using SPSS 14.0 for Windows (SPSS Inc., Chicago, USA).

3. Result

3.1 Scenario analysis

Under SQ condition, the total outputs per animal per year of cattle were showed relative variability in LW and milk yield among farm HH classes (Table 3). On the other hand, sheep productivity was better in better-off and medium and goats in medium HH class. Similarly, livestock performance in two scenarios (SC I and SC II) were showed improvement and the feed DM input as too. In the two improved scenarios condition, the male power and fiber production was remained steady.

We supposed that a little improvement in a feeding, rearing and possibly controlling mating system could increase the production and reproduction performance of livestock in SC I and II than SQ, with respect to improvement in HH income. Supposed simulated result for AFP was increased HH revenue by 95, 111 and 125% at SC I and by 95, 122 and 138% at SC II management conditions over SQ for cattle, sheep and goats, respectively (Figure 1).

3.2 Livestock productivity performance

The average daily milk yield (MY) produced per cow was 1.5 (SE 0.1) kg, which was 475 (SE 27.00) kg/lactation (Table 4). The daily MY was not significantly different (p=0.38) between the AEZs of highland and midland but it was higher (p=0.00 and p=0.02), respectively in the poor and medium classes than the better-off farm HH.

The overall average heifers age at first parturition (AFP) was 50.6 (SE 1.0) months. The age at which heifers reach their first service was significantly lower in the midland than in the highland AEZs. Similarly, heifers in better-off farm classes reached the AFP earlier (p=0.00) than in the poor and medium classes, respectively.

The differences were significant for lactation length (LL) between poor and medium (p=0.03), poor and better-off (p=0.00) and medium and better-off (0.00) farm HHs. Moreover, PI was different (p=0.00) for medium and better-off. The overall average number of calves that died after a live birth was 0.2 (SE 0.1) per HH, while the rate of calves death in poor HH was significantly lower (p=0.02) than the others (Table 4).

The overall average AFP for ewes was 18.6 (SE 0.8) and for does 16.5 (SE 0.5) months was significantly lower (p=0.00) in the highland than in the midland for shoats (Table 5). Similarly, in the poor HH the values AFP of ewes was higher (p=0.00) than in the medium and (p=0.04) than in the better-off, but for does it was lower (p=0.04) in the medium HH than in the poor. Subsequently, the ewes in the better-off farm HH had shorter PI than in the poor (p=0.00) and the medium (p=0.02) class.

The value of litter size was significantly different for ewes between poor and medium (p=0.00), poor and better-off (p=0.00) and medium and better-off (p=0.01) classes but it was significantly lower (p=0.00) for does in the poor HH than the other farm classes.

The average number of ewes giving birth was 1.0 (SE 0.1); that of does was 0.8 (SE 0.1). This was significantly (p=0.003) different in highland than midland AEZs for ewes. The values for ewes were significant between the poor and medium (p=0.00), the poor and better-off (p=0.00), and the medium and better-off (p=0.013) farm HH classes while the poor class had a significantly lower (p=0.00) number of parturient does than the others (Table 5).

3.3 Household socio-economic characteristics

The average number of HH members was 6.9 (SE 0.2) people; from this 7.0 (SE 0.5) in the highlands and 6.8 (SE 0.3) in the midlands. The average number of HH members in the better-off class was fewer (p=0.02) than the poor while it was comparable to those in the medium HH class (p=0.45; Table 6).

The average land holding size of HH was 1.8 ha (SE 0.3) in the highlands and 2.2 ha (SE 0.2) in the midland. The average land holding was higher (p=0.001) in better-off than the other two farm classes. The average number of head of cattle per HH was 6.2 (SE 0.3); this count was higher in midland agro-ecology zone (AEZ) (p=0.04) than the highland as well as higher in the better-off (p=0.00) farm class than in the respective farm groups.

Farm HHs in the better-off class received higher (p=0.00) amount of HH revenue from livestock production than poor and medium classes whereas both better-off and medium were higher (p=0.00) amount from tree plantation than the poor farm class in gross. The revenues from off-farm was significantly higher (p=0.02) in the medium class than the poor and better-off farm HHs, respectively (Table 6).

Table 1: Livestock (cattle, sheep and goat) productive and reproductive performance under current management in cluster of farm class in Dawuro and Gamo Gofa zones

Parameter	HH class		
	Poor	**Medium**	**Better-off**
Age at first parturition, month	53[1],22[2],18[3]	53,16,15	42,17,16
Parturition interval, month	17,8,8	16,8,8	19,6,7
Number/birth	1,1.2,1.2	1,1.6,1.8	1,1.9,1.7
Milk yield, kg/day	1.84[1]	1.53[1]	1.07[1]
Milk yield, kg/lactation	557[1]	442[1]	421[1]
Young female cull rate,%	14,33,20	16,22,20	20,34,17
Adult female cull rate,%	8,1,7	3,10,5	5,11,33
Mortality,%			
Female (0-1 year)	9,2, 14	20,3,1	24,1,1
Male (0-1 year)	17,1, 1	20,21,25	11,1,1
Female (1-2 year)	1,1,1	17,1,1	14,1,27
Male (1-2 year)	12,3,1	13,1,1	13,1,25
Female (2-3 year)	2,1,1	2,1,1	3,1,1
Male (2-3 year)	1,1,1	7,1,1	3,1,1
Adult female	2,1,1	7,4,1	13,1,23
Adult male	1,1,1	2,1,1	6,1,33

Numbers represent [1]cattle, [2]sheep, and [3]goat in respective order

Table 2: Input parameters for PRY Herd life model for livestock and their sources

Parameter	Unit	Source	Formula/Value[1]
Age at first parturition	month	Assumption	35(15) SC[3] I; 30(14) SC II
Lactation length	month	Assumption	15(7) SC I; 13(6) SC II
Parturition interval	month	Assumption	11
Number/birth	number/birth	Assumption	1(1.70) SC I; 1(1.80) SC II
Milk yield	kg/day	Assumption	1(1.70) SC I; 1(1.80) SC II
Milk yield	kg/lactation	Assumption	561 SC I; 594 SC II
Live weight price	€/kg	Own calculation	1.92
Draught power	day/year	survey	77
Drought power price	€/hour	survey	0.31
Milk price	€/kg	survey	0.44
Hide price	€/number	survey	1.04(1.29)
MBW of hide	number	AGP[2](2013)	12(1)
Manure DM price	€/kg	Fertilizer(2012)	0.0620
Manure DM	kg/animal/day	Metafera *et al*. (2011)	0.50
Energy efficiency lactation	quotient	Van Es (1975)	0.60
Live weight gain	total kg milk	Own calculation	35(15)
Milk energy content	MJ ME/kg	FAO (1997)	5(4.60)
Energy efficiency gestation	quotient	Minson (1987)	0.70
Energy intake/kg gain	MJ ME	ARC(1980)	25
Maintenance requirement	MJ ME/kg weight$^{0.75}$	ARC(1980)	0.53
Use efficiency of ME for live weight gain	quotient	Van der Honing, Alderman (1988)	0.40
Energy requirement of draught animals	MJ/hour	Van der Lee *et al*. (1993)	1.68

[1]Numbers in brackets represent value for sheep and goat, respectively; [3]SC I/II=scenario I/II

Table 3: Livestock productivity performance in PRY model under different management scenario in farm HH in Dawuro and Gamo Gofa zones

Parameter	Breeding female live weight	Surplus female live weight	Male live weight	Milk, kg/year	Fiber kg/MBW[2]	Male power, hour/year	Manure DM, kg/year	Dead weight, kg	Output/ animal/year	Feed DM kg/animal
Cattle										
Poor	18.13	5.68	47	82	12.55	686	326	3.76	1182	5483
Medium	13.90	4.37	45	66	13.25	738	322	4.21	1208	5411
Better-off	69.02	6.03	62	67	12.34	616	334	1.07	1167	5608
SC[1] I	59.37	18.75	72	98	12.05	640	338	0.80	1239	5680
SC II	57.32	29.31	85	125	12.03	647	344	1.17	1300	5773
Sheep										
Poor	29.20	0.58	36		1.84			0.08	68	896
Medium	26.88	7.86	43		1.90			0.12	79	866
Better-off	13.20	13.20	52		1.75			0.04	80	857
SC I	27.25	7.85	52		1.84			0.35	89	858
SC II	23.64	16.02	56		1.83			0.44	98	859
Goat										
Poor	20.96	5.41	28		1.52			0.06	56	804
Medium	22.23	18.46	32		1.48			0.04	75	759
Better-off	23.22	3.27	31		1.43			0.85	59	766
SC I	25.05	11.53	36		1.46			0.21	74	755
SC II	9.40	30.32	44		1.45			0.12	85	752

[1]SC I/II=Scenario I/II, [2]MBW=mature body weight

Table 4: Productive and reproductive performance of cattle in AEZ and farm class in Dawuro and Gamo Gofa zones (Arithmetic mean ± Standard error (SE))

Parameter	AEZ		HH class			Overall mean
	Highland (n=47)	Midland (n=85)	Poor (n=43)	Medium (n=61)	Better-off (n=28)	(n=132)
Milk yield, kg/day	1.4^{A}±.07	1.6^{A}±0.1	1.8^{a}±0.1	1.5^{a}±0.1	1.1^{b}±0.1	1.5±0.1
Milk yield, kg/lactation	346^{A}±27	546^{B}±37	557^{a}±54	442^{a}±39	421^{a}±39	475±27
Calf suckle period, m	1.3^{A}±0.1	1.0^{A}±0.1	0.7^{a}±0.1	1.2^{ab}±0.1	1.5^{b}±0.1	1.1±0.1
Age first maturity, m	46.3^{A}±1.6	39.8^{B}±1.5	46.5^{a}±1.9	42.9^{a}±1.6	33.7^{b}±2.4	42.1±1.2
Age first parturition, m	56.2^{A}±1.3	47.5^{B}±1.3	52.8^{a}±1.6	52.8^{a}±1.5	42.3^{b}±2.1	50.6±1.0
Lactation length, m	8.3^{A}±0.5	12.3^{B}±0.4	10.4^{a}±0.5	9.9^{b}±0.5	13.8^{c}±0.8	10.9±0.4
Parturition interval, m	14.8^{A}±0.4	17.9^{B}±0.5	17.0^{ab}±0.8	15.8^{a}±0.5	18.5^{b}±0.5	16.8±0.4
Pregnant cow number	1.0^{A}±0.1	1.2^{A}±0.1	0.6^{a}±0.1	1.0^{a}±0.1	2.1^{b}±0.2	1.1±0.1
Parturient cow number	0.9^{A}±0.1	1.0^{A}±0.1	0.6^{a}±0.1	0.9^{a}±0.1	1.7^{b}±0.1	1.0±0.1
Live birth number	0.8^{A}±0.1	1.0^{A}±0.1	0.7^{a}±0.1	0.8^{a}±0.1	1.7^{b}±0.1	0.9±0.1
Died calves number	0.2^{A}±0.1	0.2^{A}±0.1	0.1^{a}±0.0	0.3^{b}±0.1	0.4^{b}±0.1	0.2±0.1
Cows' year	8.1^{A}±0.3	8.1^{A}±0.2	8.1^{a}±0.3	8.1^{a}±0.2	7.9^{a}±0.4	8.1±0.2

^{AB}Means of the same rows with the same superscript is not significant between different agro-ecological zones (p<0.05); ^{a,b}Means of the same rows with the same superscript are not significantly between farm HH classes (p<0.05)

Table 5: Reproductive performance of small ruminant in AEZ and farm class in Dawuro and Gamo Gofa zones (Arithmetic mean ± Standard error (SE))

Parameter	AEZ		HH class			Overall mean
	Highland (n=47)	Midland (n=85)	Poor (n=43)	Medium (n=61)	Better-off (n=28)	(n=132)
Ewe						
Age at first maturity, m	10.9^{A}±1.03	12.7^{A}±0.7	13.2^{a}±1.3	11.5^{a}±0.7	11.5^{a}±0.8	12.1±0.6
Age first parturition, m	15.0^{A}±1.0	20.7^{B}±1.1	22.4^{a}±2.1	16.5^{b}±0.7	17.5^{b}±1.0	18.6±0.8
Parturition interval, m	8.1^{A}±0.2	7.3^{B}±0.3	8.3^{a}±0.5	7.6^{a}±0.2	6.5^{b}±0.4	7.6±0.2
Parturition number/year	1.6^{A}±0.1	1.7^{A}±0.1	1.6^{a}±0.1	1.6^{a}±0.1	1.7^{a}±0.1	1.6±1.6
Number/birth	1.6^{A}±0.1	1.5^{A}±0.1	1.2^{a}±0.1	1.6^{b}±0.1	1.9^{c}±0.1	1.5±1.6
Pregnant ewe number	1.3^{A}±0.1	0.8^{B}±0.1	0.1^{a}±0.1	1.2^{b}±0.1	1.7^{c}±0.2	1.0±0.1
Parturient ewe number	1.3^{A}±0.1	0.8^{B}±0.1	0.1^{a}±0.1	1.2^{b}±0.1	1.7^{c}±0.1	1.0±0.1
Live birth number	1.7^{A}±0.2	0.7^{B}±0.1	0.1^{a}±0.1	1.38^{b}±.17	1.82^{b}±.23	1.1±0.1
Died number/live birth	0.1^{A}±0.0	0.1^{A}±0.0	0.0^{a}±0.0	0.1^{a}±0.0	0.04^{a}±.04	0.1±0.0
Ewe's year	4.9^{A}±0.2	4.6^{A}±0.1	4.3^{a}±0.1	4.8^{b}±0.1	5.0^{b}±0.3	4.7±0.1
Does						
Age at first maturity, m	7.4^{A}±0.2	13.5^{B}±0.8	14.3^{a}±1.4	9.1^{b}±0.2	11.5^{a}±1.1	11.3±0.6
Age first parturition, m	13.7^{A}±0.2	18.0^{B}±0.7	18.1^{a}±1.3	15.3^{b}±0.4	16.4^{ab}±1	16.5±0.5
Parturition interval, m	8.0^{A}±0.2	7.7^{A}±0.3	8.4^{a}±0.5	7.7^{a}±0.3	7.2^{a}±0.5	7.8±0.2
Parturition number/year	1.3^{A}±0.1	1.6^{B}±0.1	1.6^{a}±0.1	1.3^{b}±0.1	1.8^{a}±0.1	1.5±0.0
Number/birth	1.8^{A}±0.1	1.5^{B}±0.1	1.2^{a}±0.1	1.8^{b}±0.1	1.7^{b}±0.1	1.6±0.0
Pregnant does number	0.8^{A}±0.0	0.8^{A}±0.1	0.4^{a}±0.1	1.1^{b}±0.1	0.9^{b}±0.2	0.8±0.1
Parturient does number	0.8^{A}±0.0	0.8^{A}±0.1	0.3^{a}±0.1	1.1^{b}±0.1	0.9^{b}±0.2	0.8±0.1
Live birth number	1.6^{A}±0.1	0.4^{B}±0.1	0.3^{a}±0.1	1.4^{b}±0.1	0.3^{a}±0.1	0.8±0.1
Died number/live birth	0.1^{A}±0.1	0.0^{A}±0.0	0.0^{a}±0.0	0.1^{a}±0.0	0.0^{a}±0.0	0.1±0.0
Doe's year	5.7^{A}±0.1	5.8^{A}±0.1	5.9^{a}±0.2	5.7^{a}±0.1	5.7^{a}±0.2	5.7±0.1

^{A,B}Means of the same rows with the same superscript are not significant between different agro-ecological zones (p<0.05); ^{a,b}Means of the same rows with the same superscript are not significantly between farm HH class (p<0.05)

Table 6: Socio-economic characteristics of farm household (HH) in different agro-ecological zones (AEZs) in Dawuro and Gamo Gofa zones (Arithmetic means ± Standard error, SE)

Parameter	AEZ		HH class			Overall mean (n=132)
	Highland (n=47)	Midland (n=85)	Poor (n=43)	Medium (n=61)	Better-off (n=28)	
Family size	7.0^{A}±0.5	6.8^{A}±0.3	7.3^{a}±0.4	7.1^{ab}±0.4	5.7^{b}±0.4	6.9±0.2
Farm size, ha/HH	1.8^{A}±0.3	2.2^{B}±0.2	1.8^{a}±0.2	1.7^{a}±0.2	3.1^{b}±0.3	2.0±0.1
Cattle, n/HH	5.3^{A}±0.4	6.7^{B}±0.4	5.3^{a}±0.6	5.6^{a}±0.3	8.7^{b}±0.6	6.2±0.3
Shoat, n/HH	5.4^{A}±0.5	5.2^{A} ±0.5	1.4^{a}±0.4	6.2^{b}±0.4	9.1^{c}±0.8	5.3±0.4
Income, €/HH/year						
Livestock	90^{A}±23	121^{A}±18	44^{a}±11	68^{a}±11	304^{b}±44	110±14
Tree plantation	35^{A}±12	15^{B}±5	0.4^{a}±0.4	30^{b}±7	40^{b}±18	22±5
Off-farm	19^{A}±5	0.0^{B}±0.0	2^{a}±2	13^{b}±4	1^{a}±1	7±2
Others	26^{A}±7	0.0^{B}±0.0	2^{a}±2	16^{b}±5	4^{a}±4	9±3

^{AB}Means of the same rows with the same superscript is not significant between different agro-ecological zones (p<0.05); ^{a,b}Means of the same rows with the same superscript are not significantly between farm HH classes (p<0.05).

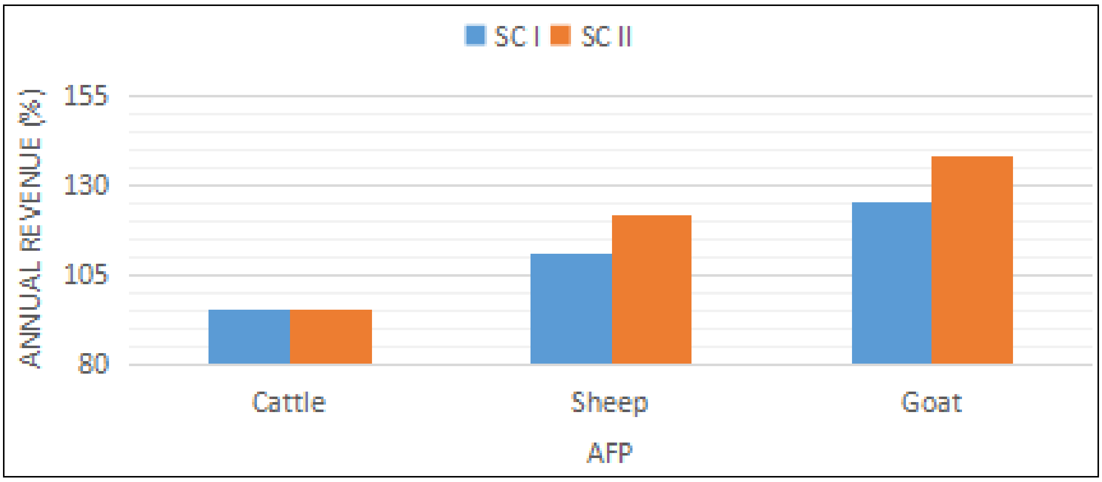

Fig 1: Relative annual household revenue improvement as modeled age at first parturition (AFP) in scenario I and II over current management (SQ, 100%) of ruminant livestock

4. Discussion

4.1 Scenario analysis and implications to improvement

A livestock production system is a complex system comprising biological, economic and social factors. The set of management strategies identified as optimal for the model will similarly prove to be the best when applied to real-world systems (Mayer *et al*., 1999) [13].

In the current study, herd modeling result showed that the output per unit feed intake of cattle was 0.21 each in poor and bettor-off HHs whereas equal 0.22 in medium HH and SC I and II. The improvement achieved in productivity efficiency exceeded 0.01 unit in the latter three scenarios for cattle. Whereas in the former two, in the poor HH, better milk yield (82 kg/year) was obtained but milk yield, lower (67 kg/year) and live weight gain better in better-off. Although better campaigns of productivity in the poor and better-off HHs were compromised by increased feed DM intake (kg/animal/year).

Productivity performance efficiency was sequential increased for small ruminant. That was 0.08 in the poor and 0.09 in each the medium and better-off HHs for sheep production (output/unit feed intake). Goat production efficiency in the HHs was 0.07, 0.10 and 0.08 respectively in the poor, medium and the better-off. The output/unit feed intake of small ruminant in two improved scenarios (SC I and II) was each equal 0.10 and 0.11, respectively.

Relative better productivity efficiency observed in medium HH was complemented with low LW gain or less proportion in surplus animal and better in breeding female and milking cows in the herd, relative low level of feed input per animal and reduced rate of livestock mortality. Thus, implies that one options to improve smallholder livestock production is increasing proportional number of breeding female, milking cow and working male and culling surplus female and male animal and controlling mortality. This in turn can result in better production efficiency even production per animal is low, for example, both milk yield and LW gain in the medium HH was the lowest than the others.

Another alternative to improve productivity of smallholder livestock supposed to be through management improvement of livestock production (i.e., milk production, calving interval, lactation length, etc) with relative improvement in livestock feed dry matter intake per animal. This would achieved through herd management optimization and has been observed in the current model prediction in SC I and II.

In addition, our supposed simulation for AFP of ruminant livestock was indicated improvement option compared over on farm management condition (SQ), in which the highest option observed for goats, followed by sheep and cattle. On the other hand, the scenario conditions could suggest that the largest option for improvement in smallholder livestock production laid in feed dry matter production and management.

Study on extensive farming systems in the Sudanian savannah of West Africa assumed, improved feeding conditions to result in an increase in the body condition score of the supplemented cows, so the feeding strategy is represented by variations in the ratio of fat/thin reproductive cows in the herd. According to Ezanno (2005) [7], model prediction an increase in cow's body condition will be most effective in the late dry season. An increase in the proportion of fat non-pregnant cows gives rise to an increase in the numerical productivity, and an increase in milk production, although the effect varies strongly among seasons (Ezanno, 2005) [7]. High importance of the natural pasture vegetation for the profitability of the prevailing goat husbandry system has been suggested (Dickhoefer *et al*., 2012) [5].

The highest annual revenues of household under different farm types in traditional goat husbandry in the mountain villages of Oman (Dickhoefer *et al*., 2012) [5] have been predicated. They suggested that the adaptation of intensive homestead feeding of goats combining with a reduced or no accesses to pasture maximized herd production in feedlot management scenarios and exceeded the annual revenue those than in semi-intensive pasture scenario and use efficiency of supplement feeds (price kg/DM) and the latter than those in traditional management scenario. Enhanced pork production in smallholder farms, under improved feed supply and optimized culling strategies scenario has also been reported (Riedel *et al*., 2014) [18] in south western China. That analysis indicated that the adoption of an improved culling management alone, accounted 72% improvement in productivity and 31% increase of saleable LW outputs.

4.2 Livestock productivity performance and household socio-economic

The difference in herd dynamics were observed in the descriptive statistic in the household interviews result as well. The MY in the present study area was higher than the value (1.2 litre/day) reported by Tasssew and Seifu (2009) in some parts of Ethiopia but lower than the values (1.85 litre/day) reported in pilot w*oredas* and 2.34 litre/day in the rural highland dairy production area of Fogera (Tegegne *et al*., 2013) [21].

Better milk yield in the poor HH was probably due to the shorter period during which calves were allowed to freely suckle after parturition. The value for calves free to suckle the dam were significantly lower (p=0.00) in the poor HH than in the better-off. It has also been reported in a previous study in the same study area that farmers do not start to milk cows until 51.6 days after calving (Amejo, 2009) [3] by which time they will have almost reached their peak lactation. This situation is rare in dairy production systems, particularly HH systems that produce milk for diet and family income. Reports from Tasssew and Seifu (2009) show that after parturition, cows are not milked for only about two weeks during which calves are kept with their dams and allowed to suckle freely.

Favourable early maturity of heifers, in the midland and the better-off HH was probably related to better management and feed resource availability in the form of crops and by-products, fodders, weeds, better access to margins of cropping and common land. As well as HH scraps, possibility to select and maintain better performing one from group of animals, tendency to follow up of mating period, and accesses and availability of mating services.

The observed calving (lambing/kidding) intervals within farm classes are shorter in better-off and medium class farms. This implies that there exists the possibility to improve production and reproduction performance in the smallholder farm system using local breeds either by farmers sharing their expertise or by through selection and controlled mating the animals. The other possible suggestion to low mortality to be in the poor and medium farm HHs can give close follow up for their optimum number of pregnant animals, subsequently this can avoid births outside home site and unwanted death and prey of young's.

Age at first parturition of sheep and goats in the present study was shorter than that of goats in the Jabal Akhdar mountains in Oman under both current and intensified management regimes (Dickhoefer *et al*., 2012) [5] but longer than the 12.4 months reported in the Gamo Gofa region in Ethiopia by Hailemariam *et al*. (2013) [11], or the 12.7 months reported for lambing and 12.1 months for kidding in Alaba (Ketema, 2007) [12].

5. Conclusions

There is variation in productivity performance in smallholder livestock production within and between farm classes and in some parts of the system. That could be demographic, reproductive, productive or their combined variations, resulted in livestock phenotypic value as well as household income. Probably the best way to improve matters would be to identify the sources of these variations between the farm HH classes and suggest ways in which they could be minimized. The observed differences between the different farm classes are not primarily due to land holding size but to a combination of management techniques and various ways of rearing and feeding of their livestock. These superior practices should be scaled up and adapted to suit all farm classes within system.

A specific example is the current practice in farm HH of allowing calves to suckle freely, for instance in better-off 1.5 months after parturition before starting to milk the cows. This practice is probably not economical and efficient because the suckling period of the calves includes some of the cows' peak lactation. Stopping or restricting suckling at an earlier time and weaning the calf onto a substitute meal would mean that more milk would become available for consumption by the family or for sale.

Intensified feeding strategies from existing sources, improvement through rearing and herd management viewed to make potential improvement in livestock production. This can give an opportunity to re-integrate crop-livestock systems to economic well-being and environmental synergies to be turning on an entry point to exploring ways long-term benefits of livestock contribute to sustainable development.

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