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Technical and economic feasibility of goat supplementation with hydroponic *Zea mays* L. in Santa Elena, Ecuador

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Abstract

Objective: To evaluate the technical and economic feasibility of goat supplementation with hydroponic *Zea mays* L., cv. Trueno in the Santa Elena province, in Ecuador.

Materials and Methods: The annual yield of a shed with 104 m^2 productive (four floors on 105 m^2 built) with different nutritional solutions and planting seasons. With these results the annual harvest cycles to sustain the flock were estimated. The economic returns of four scenarios estimated for the Santa Elena region were compared: A) real current conditions of goat holders (extensive grazing), B) self-funding of the total investment, C) without subsidy and a shed donated by some organization and D) only one non-reimbursable subsidy of 70 % of the initial investment.

Results: The variables fresh weight, dry weight and dry matter percentage of the hydroponic corn forage showed significant effect of the cultivation season. It would not be necessary to add fertilizer to the irrigation solution. The crude protein contents were high (15,7 and 18,5 %). The financial projection to five years, with an estimated annual production of 14 643,2 kg of hydroponic green forage had a cost of 1 521.50 USD and determined a cost per kilo of produced fresh forage of 0,11 USD. The scenarios B to D, which included supplementation with hydroponic forage, reached twice the weight at sale in 37 % of the time.

Conclusions: The utilization of the non-reimbursable state subsidy, and even more if the contribution of the infrastructure of the greenhouse is received, would boost the goat production of the region and could achieve the change of a culture of goat holders by obtaining a benefit/cost ratio between 1,04 and 1,68 (scenarios C and D).

Keywords: biomass, goat, investments, animal nutrition, *Zea mays*

Introduction

Goat feeding, just like the feeding of other species, should be composed by protein, energy, minerals, vitamins and water, which shows fiber requirements higher than 5 %, limit for most monogastric animals (Meneses, 2017). However, feeding in Santa Elena, Ecuador, is of low-quality, because as it does not receive balanced feeds or cultivated pastures, livestock is fed on 99 % of low-quality harvest residues and autochthonous plants that grow wildly (Villacrés-Matías *et al*., 2017).

For these ruminants, browsing is complementary to pastures, especially during the dry season. Shrubs provide the essential protein, when pastures decrease their availability due to low rainfall.

Crude protein in shrubs is relatively constant during the year, and is usually higher than in pastures, but energy is lower. Nevertheless, in a semiarid climate, such as the one in the Santa Elena Peninsula, where most of the year there is only shrubby vegetation, much of it leguminous, it constitutes the main source of nutrients in grazing. Forage quality and quantity varies remarkably with climate, and sometimes leads to inadequate animal nutrition (Meneses, 2017).

Farmers inhabit ancestral communities, where a small surface is assigned to them to confine their animals that graze communal lands. Fifty percent of goat holders have an agricultural land surface lower than 0,4 ha, and only 22 % have their own lands. Each farmer has, as average, 14 animals, whose feeding is based on harvest residues and native vegetation, obtained by goats when traveling long distances. Forage production in confined and protected environments seems to be a good alternative. From the 497 goat farmers interviewed for this research, 42 % showed interest in these productive systems, that is, 208 farmers would be the potential targets of this production technique (Villacrés-Matías *et al*., 2017).

The construction of a macrotunnel or greenhouse for the production of hydroponic green

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forage (HGF) would be a valuable tool to fight the main causes of the income losses shown by goat farmers of the Santa Elena province, although it implies high initial investment and low maintenance cost. This allows to manage forage on plastic trays in short periods, of 12 to 14 days, as well as to produce in reduced areas without the use of soil (Zagal-Tranquilino *et al*., 2016). Rainfall in the province is around 476,5 mm per year (INAMHI, 2017), for which water is scarce. The water deficit is supplied with the waters of the Chongón- Colonche transfer.

For HGF wheat (*Triticum aestivum* L.), oat (*Avena sativa* L.), barley (*Hordeum distichon* L.), rye (*Secale cereale* L. ssp. cereale) or corn (*Zea mays* L.) grains can be used. From them, the one that is best adapted to the high temperatures of the zone is the corn grain, which is the most widely utilized due to its availability (López-Aguilar *et al*., 2009).

Due to the above-explained facts, the objective of this work was to evaluate the technical and economic feasibility of goat supplementation with hydroponic *Z. mays*, in the Santa Elena province, in Ecuador.

Materials and Methods

Essay location. This research was conducted in a galvanized-iron greenhouse, 20-m long and 10-m wide, with IR polyethylene cover caliber 6 and 80 % shading mesh, placed 1 m above the plastic cover. It is located in the School of Agricultural Sciences of the Santa Elena Peninsula State University (South latitude: 2º13'56", West longitude: 80º 52'30").

Climate conditions. Mean minimum temperature is 20,7 ºC and the mean maximum, 27,3 ºC. Relative humidity is 83,4 % and rainfall, 265 mm (INAMHI, 2017).

Implementation of the essays. The complete randomized block design considered for each of the three forage production cycles three nutritional treatments, with six repetitions: water (control), Hoagland/Arnon nutrient solution and Steiner nutrient solution. Each cultivation cycle lasted, approximately, two weeks, in which corn seeds cv. Trueno were evaluated. For the statistical analysis comparing seasons and nutrient formulation, a combined analysis was carried out. For the ANOVA, with significance of 95 %, the F-test (means) was applied for parametric variables and for the non-parametric ones (medians), the Kruskall-Wallis test.

The water quality did not show restrictions, with pH, EC and RAS values of 7,2; 0,23 dS m^{-3}; 0,32 meq L^{-1}; respectively. Only bicarbonate was high, with 53,7 mg L^{-1} (table 1).

For the execution of the essays the following materials and equipment were used: a) an irrigation programmer with irrigation pulses of 3 min. every 2 h, b) an irrigation system by sprinklers (54 units) with a flow of 1 L min^{-1}, c) metallic structures of four levels, as support of the trays separated by 40 cm between them; d) plastic trays of 40 x 60 x 4 cm, with the lower edge perforated every 7 cm and holes of 6 mm diameter for drainage; e) Jacto XP12-16-29 backpack for manual fertilization, which lasted five days in each production cycle.

Four trays were equivalent to 1 m^2. A dose of 500 g of dry seed was sown, which once soaked during 24 h increases its weight in 10 %. Thus, the planting dose per tray was 550 g of soaked seed. The crop sequence is shown in table 2.

Pregermination in the dark was conducted in a black polyethylene tunnel, 0,2 mm thick. Once a sprouting of 4 cm of height was reached, the trays were transferred to the light. Periods of water and fertilizer were alternated, according to the schedule shown in table 2.

Evaluated variables

Forage yield. For the fresh forage yield a BOECO BWL 61 scale was used, with maximum capacity of

Table 1. Chemical composition of the nutritive solutions used in the fertilizer treatments.

Formulation of nutritive solution	Chemical elements, m Mol L^{-1}									
	NO_3^-	$SO_4^=$	$H_2PO_4^-$	HCO_3^-	Cl^-	Ca^{++}	Mg^{++}	K^+	Na^+	$NH4^{++}$
Hoagland and A. requirement	15,00	2,00	1,00	0,00	0,00	4,00	2,00	6,00	0,00	1,00
Irrigation water¥	0,00	0,05	0,00	0,88	1,28	1,15	0,65	0,18	0,30	0,00
Real contribution	15,00	1,94	1,00	0,37	1,28	2,85	1,35	5,82	0,30	1,00
Steiner requirement	12,00	3,50	1,00	0,00	0,00	4,50	2,00	7,00	0,00	1,00
Irrigation water¥	0,00	0,05	0,00	0,88	1,28	1,15	0,65	0,18	0,30	0,00
Real contribution	12,00	3,448	1,00	0,17	1,28	3,35	1,35	6,82	0,30	1,00

¥Laboratory analyse s of INIAP, Pichilingue

Table 2. Sequence of daily management of hydroponic green forage inside the greenhouse.

Day	Production stage
1	Selection of seeds
2	Soaking during 24 h, at ambient temperature
3-6	Darkness stage –irrigation every 2 h
6-9	Growth under light – irrigation every 2 h
10-14	Growth under light – fertilization
15	Irrigation with water – washing
16	Day without irrigation (drought) (24 h)
17	Harvest (forage approximately 20 cm high)

6 kg and accuracy of 0,1 g. Weighing of the trays with forage was directly carried out, and the weight of the tray alone was subtracted. Afterwards, the yield was extrapolated to kilos per square meter, considering four trays for 1 m^2.

Dry matter. In order to determine the dry matter (DM) percentage, 100 g of fresh forage were taken from the transversal section of the tray (approximately 5 cm wide). They were introduced in paper envelopes, dried in EquipsLab stove, model GX125BE, during 72 h, at 65 °C.

Proximal analysis. A 300-g sample of fresh matter, corresponding to the May sowing, was dried in stove during 72 h, at 65 ºC. It was taken from the central section of the tray of each treatment. Afterwards, a sample composed by all the repetitions of each treatment for the proximal analysis was formed: crude protein (CP), crude fiber (CF) and ash (A). This procedure was carried out in the nutrition laboratory of Santa Catalina, from the Agricultural Research Institute (Quito) with the application of the methods AOAC. 2001.11. (PB), FOSS. Application Note AN 3440, according to 92/89 /EEC (FC) and ISO 6865; and AOAC 942.05 (C), described in AOAC (1990). The average data of the protein content was used to calculate the goat diet.

Feed ration. The rations were estimated from the energy needs of goats (table 3), considering the weight and desired weight gain, according to Elizondo-Salazar (2007).

For the calculation of the total demand of HGF per animal during its useful life, a weight at birth of 2 kg and at weaning of 9 kg was estimated, with a period of three months. During this stage, the kid did not consume forage, only milk. Since that moment, the intake per animal was considered related to the mean daily weight gain (MDG) and the demand of metabolizable energy according to live weight. The feed demand percentage with weight increase was calculated, from weaning to 90 days (table 4). These percentages were applied to the MDG in blocks every 10 kg of live weight until reaching sale weight (Acosta-Lozano *et al*., 2016).

A goal of 140 g per day was assumed as 100 % of the maximum weight gain expected in goats, according to the report with HGF (López-Aguilar *et al*., 2009). The animals obtained the maintenance energy from grazing (3 to 5 h per day).

The energy for fattening in the scenarios of economic analysis (explained below) B, C and D was considered with a supplementation ration, which corresponded to 80 % of the requirement as dry hydroponic forage (14,8 % DM). The remaining 20 % of the energy requirement was covered with the addition of nutritional block to lower costs, as recommended by Vazquez-Mendoza *et al*. (2012).

Table 3. Protein nutritional requirement of goats, according to age and function in the flock.

Animal type	Composition flock, %	Live weight per animal, kg	Metabolizable energy demand, Mcal day^{-1}		
			Maintenance	Growth	Total animal
Nanny goats	40	35	2,14	0,83	2,97
Does	20	20	1,67	0,82	2,49
Kids	35	10	0,83	0,42	1,25
Billy goat	5	40	2,37	0,00	2,37

Fuente: Elizondo-Salazar (2007)

Table 4. Mean daily weight gain, according to days since weaning of the goats.

Daily weight gain percentage							
30	60	90	120	150	180	210	240
65,0	80,0	92,0	96,0	100,0	96,0	92,0	85,0

Source: Adapted from Acosta-Lozano *et al.* (2016)

The nutritional block consisted in 40 % fiber as rice (*Oryza sativa* L.) powder, 30 % molasses and 30 % salts. Their combination contributes, approximately, 270 g of protein and 2,4 Mcal of metabolizable energy per kg of DM (Vazquez-Mendoza *et al*., 2012). The intake of nutritional block corresponded to 4,0 g per kg of live weight, and increased with the age of the animal.

In scenario A, in traditional management no supplementary ration was contributed to the animals. The water intake was estimated in five times that of feed, because a goat can consume from 5 to 10 L of water per day, according to the season and grazing intensity (Nogues *et al*., 2012).

Economic analysis

To evaluate the feasibility of HGF production, the economic calculations were made based on a greenhouse of *Guadua angustifolia* Kunth, 15 m long and 7 m wide, common in the study zone, for which it was considered more adoptable by local livestock holders.

In the analysis the averages of forage yield and protein content, corresponding to the different planting dates, were taken: March 1st, March 22 and May 2, 2018.

The seed came from material bought directly from the farmer, because it should not be subject to disinfection with pesticides. The necessary equipment for the forage production was evaluated: 500-L pond with water or fertilizers, irrigation programmer, nebulizers, metallic four-level structures as support of the trays, plastic trays with drainage and Jacto XP12-16-29 backpack pump.

With the information of the initial investment, the incomes from the sales and outcomes the cash flow of the proposal for four scenarios was determined:

a. Real current conditions of goat holders in the Santa Elena province
b. HGF production without subsidy and proper funding for building the shed
c. Without subsidy and a donated shed, considering that it could be supplied by some organism
d. HGF production with non-reimbursable subsidy of 70 % of the initial investment and self-funding of the shed.

The results of the cash flow for the four scenarios were used to evaluate the financial feasibility in horizon of the five-year project, related to the benefit/cost ratio. This relation was determined by quotient between the net present value of the incomes and the sum of the net present values of the outcomes plus the initial investment. The updated values were calculated with the financial function VNA of the program Microsoft Excel.

The discount rate used in the calculations was 19,6 % (valid for 2018). It was determined from the referential passive rate (7,0 %), average inflation of the last two years (2,4 %) and business risk (10,0 %). The values between parentheses are in correspondence with those used in the country in March, 2020.

To determine the benefits of feed supplementation to cattle, with hydroponic forage and nutritional block, the productive indicators that are indicated in table 5 were chosen, which are based on bibliographic information of local data, reported by Villacrés-Matías *et al.* (2017) and Chávez-García and Villacrés-Matías (2018).

In the model of forage demand and meat productivity the items 2, 3, 6 and 9 of table 5 were considered. For scenario A, the data of current Santa Elena were taken into consideration, and for scenarios B to D, those of the ideal condition of grazing with supplementation were considered (hydroponic forage + multinutritional block).

The model flock considered for the study had 20 animals: nanny goats (8), replacement does (4), ram (1) and kids (7). The proportions indicated in table 3 were maintained. For the ram, it was assumed that grazing covered its maintenance energy requirement. For the nanny goats and replacement does, the production energy was supplemented from 32 kg. The latter were also supplemented from 20 kg (acquisition weight) to 32 kg.

For the kids the requirement of hydroponic forage was calculated on dry basis until reaching the sale criterion for scenarios B, C and D; while in A it was 16 kg. From the kids for the current Santa Elena scenario, the 12 ones born after a year (out of the model flock) were sold immediately at weaning.

Table 5. Analysis of the productive indicators of goats in Santa Elena (Ecuador) compared with ideal conditions.

Item	Indicator	Ideal	Current Santa Elena
1	Intervals between parturitions, months	6,6	8
2	Parturitions	1,8	1,5
3	Kids per parturition	1,4	1,4
4	Weaning, months	3	5
5	Grazing, h	3	5
6	Parturition %	5	26
7	Kid mortality, %	10	40
8	Age at market, months	12	24
9	Final fattening weight, kg	32,1	16,1
10	Energy expense, grazing displacement, kcal day^{-1}		87,7

Source: Villacrés-Matías *et al*. (2017) and Chávez-García and Villacrés-Matías (2018)

Meanwhile, for the ideal scenario, the 19 kids born after a year (out of the model flock) were sold. From them, 1 was sold at weaning and 18 could be fattened according to the availability of produced forage.

The feeding costs and meat price were obtained in the local market in American dollars (USD), in September, 2018.

Results and Discussion

Yield and dry matter. The results of fresh, dry weight and DM percentage of the HGF of *Z. mays* showed a significant effect of the cultivation season (table 6). When analyzing dry weight in the three evaluated planting dates, the highest yield was reached in that of March 22 with values around 355,5 g tray^{-1}. This cycle lasted 17 days; while the other ones, 13 and 16 days, respectively. The duration of the growth cycle is related, as for any plant species, to the prevailing climate, especially to temperature and solar radiation.

Based on this experience, it was determined that delaying a couple of days the harvest date is feasible to reach higher yield, without affecting quality. Gonzáles-Días *et al*. (2015) indicate that besides, the seed variety has effect on the hydroponic forage yield.

For the economic study the dry weight of the second planting cycle was considered, which projected a yield of 1,30 kg DM m^{-2}, equivalent to 8,4 kg FM m^{-2}. Thus, in the effective productive 104 m^{2} a yield per shed of 134,99 kg of HDF was obtained, and when considering 16 annual harvest cycles to obtain 2 159,8 kg was projected. It is not advisable to delay the harvest too much to achieve higher biomass production, because it decreases quality, especially the protein content (Salas-Pérez *et al*., 2010).

With similar planting doses lower yields in HGF of *Z. mays* have been reported, with 5,9 kg m^{-2} (Rivera *et al*., 2010), and higher with 12,9; 18,7 and 21,2 kg m^{-2} for planting densities of 1,5; 2,0 and 2,5 kg m^{-2}, respectively (López-Aguilar *et al*., 2009).

The latest planting which grew in an environment of lower temperature and radiation, reached the lowest consistency of the tissues and the lowest DM content (table 6). At lower content of DM, energy or protein, higher dose should be used in animal feeding, because these are the most important criteria for the formulation of diets that satisfy the nutritional demand of livestock.

In other arid zones of Latin America DM percentages of approximately 21 have been recorded for HGF of *Z. mays*, independently from the planting dose (López-Aguilar *et al*., 2009). Other authors report average DM contents (17,3 %), even under deficit light conditions (Rivera *et al*., 2010).

There was no effect of the fertilizer solution on DM production (table 6), which is similar to the report by Gonzáles-Días and García-Reyes (2015). Thus, the use of water for the commercial analysis object of this analysis was proposed.

Protein content. The CP contents of the *Z. mays* cv. Trueno forage, cultivated between March and May, 2018, were high. They reached between 15,7 and 18,5 %, according to the fertilizer solution utilized. The forage cultivated

Table 6. DM yield and percentage of hydroponic green forage of *Z. mays* cv. Trueno in protected crop, as response to different planting seasons and fertilizer solutions.

Planting dates	Fresh weight, g tray^{-1}	DM, %	Dry weight, g tray^{-1}	
01-03-2018	1 648,4[b]	16,2[a]	265,9[b]	
22-03-2018	2 109,0[a]	16,9[a]	355,5[a]	
02-05-201 8	1 852,0[a]	11,2[b]	207,5[c]	
Average	1 901,6	14,8	283,96	
P - value	0,000018	4,30423E-10	5,0066E-11	
VC (%)	17,24	10,37	27,31	
Fertilizer solutions	Fresh weight, g tray^{-1}	DM, %	Fresh weight, g tray^{-1}	Protein, %
Hoagland and *Arnon*	1789,3[b]	14,4	263,3	16,1
Steiner	2056,1[a]	14,7	305,4	18,1
Water	1859,6[a]	15,2	283,2	17,6
Average	1901,6	14,8	284,0	17,3
P - value	0,01	0,52	0,32	
VC, %	17,24	10,37	27,31	

$p < 0,05$

only with water reached an average protein of 17,6 % (table 6), which was considered and used for the calculation of the requirement of hydroponic forage and the later economic analysis.

It should be emphasized that although the unique samples, obtained by fertilizer treatment, cannot be subject to statistical comparisons, it is evident that using water instead of fertilizer did not represent a detriment in the protein percentage of the forage.

Rivera *et al.* (2010) obtained similar protein content, with a slightly lower planting dose and deficit light conditions. Acosta-Lozano (2016) reported for the Santa Elena province 16,1 % of CP in *Z. mays* forage, irrigated only with water and harvested at 15 days.

The above-mentioned authors did not find differences either of the irrigation with water, with regards to the results obtained from three formulations with fertilizer in that duration of cultivation. A content of 14 % CP was achieved by López-Aguilar *et al.* (2009) in the arid climate of Mexico, by varying the doses of (humid) seed between 1,5 and 2,5 kg m^{-2} in 14 cultivation days. Seemingly the richness in protein is independent from the planting density and light intensity and is more dependent on the genetic material and fertilizer solution.

The CP percentage exceeded the one found in other corn forms (seed 9,5 %, newly chopped forage 6,21 and silage 6,71), according to reports by León and Giménez (2015).

Feed ration and produced meat. Goats consume between 2,5 and 5 % of their live weight in DM, according to age and production (Villanueva *et al.*, 2016). In different animals the response to the variation of HGF percentage in the daily diet (0-100 %) has been tested.

According to studies conducted by Acosta-Lozano *et al.* (2016) and Rodríguez-Izabá and Díaz-Villagrán (2017), to achieve the highest daily weight gains the range varies in goats and sheep, from 1 to 2 kg of HGF for every 100 kg of live weight (Meneses, 2017) and between 20 and 100 % of the daily ration (Acosta-Lozano *et al.*, 2016; Morales-Guzmán, 2017).

In the two above-explained situations, with different number of parturitions per year and percentage of abortions, but in a similar ratio of 1,4 kids per parturition, the 8 nannies of the flock had 19 (ideal) and 12 (current Santa Elena) kids per year, which were weaned at 90 days (period in which they do not consume forage). From that moment, the fattening demand was covered with the remnant between the production and the permanent flock demand until its sale (table 7). Thus, 100 % of the produced forage was used. This productive cycle should be repeated permanently to guarantee the flock nutrition.

The quantities of dry forage (HDF) were calculated for all the animals that consumed supplement, which constituted 80 % of the contribution. The nutritional block represented 20 % (table 7).

Table 7. Annual supplementary feeding according to the type of animal of the flock, for scenarios B to D.

Supplement	Adult does			Replacement does			Kids for fattening		
	kg/ animal	Number animals year	Total kg year	kg/ animal	Number animals	Total kg year	kg/ animal	Number animals year	Total kg year
Hydroponic dry forage	96,71	8	773,68	98,3	4	393,2	39,39	25	984,85
Nutritional block	28,24	8	225,96	28,32	4	113,29	11,5	25	207,11

The ram did not consume supplement, because it covered its requirement with grazing. Thus, the total annual demand of supplement increased to 2 151,74 and 320,40 kg of HDF and block, respectively. This demand was in correspondence with the 2 159,84 kg HDF per year obtained in the greenhouse. The block of 75 kg had a commercial value in the Santa Elena market of 164,00 USD, which represented for feeding a total annual cost of 709,68 USD.

The live weight of 32 kg per animal at sale was achieved at 187 days, under the assumptions of the ideal situation and energy demand. This time, along with 90 days at weaning, produced a useful life of the goat of approximately 9 months. Under the assumption current Santa Elena situation (without supplementation), the 12 annual kids should be immediately sold at weaning, and the seven kids of the flock were fattened based on grazing alone, for which only a weight at sale of 16 kg was reached in two years.

The meat kilos produced in both situations were 736 kg for the ideal situation and 64 for the current Santa Elena (table 8). These results, along with the annual feed intakes, were used for the economic study of the proposal.

Economic analysis. The investment for the infrastructure of the greenhouse shed reached 1 789,10 USD, similar to the report by Acosta-Lozano (2016). This included the canes, plastic, saran mesh and labor. When considering the planting trays (imported), which constitute most of the investment, the total amount was 3 869,10 USD. Another one of the significant investment costs in this type of productive system in the environment of protected crops, are the metallic structures that support the trays, whose value amounts to 450,00 USD each, and which are permanently subject to humidity (nebulization every two hours). The total investment in irrigation was 9 331,20 USD. The shed corresponded to 73,8 % and the irrigation system to 10,4 %. Among the results presented by Córdova-Wolff (2005), irrigation represented 30,3 % of the costs. In the Ecuadorian local market, for a surface of 1 000 m^2 a higher cost of 54,9 % corresponds, if the comparison is made between a greenhouse built with galvanized iron and another one with *G. angustifolia* (Torres-Trigueros, 2018).

The confinement pen of the traditional livestock holder was estimated with a cost of 500,00 USD; while in the other scenarios it was 96 m^2 for 20 animals of the flock, with construction cost of 1 000,00 USD. For this pen 4 m^2 per adult animal and 2 m^2 for small animals were considered (Meneses, 2017), with 50 % of the surface under roof (timber), and the remainder dedicated to a minimum outdoor activity (posts and barbed wire).

The financial projection for five years, with an annual estimated production of 14 643,2 kg of HGF or 2 159,38 kg DM, at a price of 1 521,52 USD determined a cost of 0,11 USD per kilo of produced fresh forage.

This value is high, although with regards to other feed sources available in the market, which like balanced feed has a cost of 0,52 kg^{-1} USD (AGRIPAC, 2018), it represents only 21,1 % and is more advantageous having protein content from 18

Table 8. Quantity of fattened animals (FA) and meat kilos to be commercialized, according to the conditions of the flock in each situation.

Scenarios	Parturitions after one year	Kids per parturition	Abortion,%	Weaned kids	Animals sold upon weaning	Fattening mortality, %	Animals beginning fattening	Total FA	Live meat sale year, kg
Ideal	1,83	1,4	5	19,43	1	10	7+18=25	23	736,00
Santa Elena	1,5	1,4	26	12,43	12	40	7+0=7	4	64,00

to 19 %. The market price of the weaned animal was 25,00 USD live, and the meat of the fattened animals reached 3,30 USD per kilo. Another aspect that justifies the investment in a HGF system is that, when considering corn as feeding basis, the price of 1 kilo placed in the farm reaches at present, approximately, 0,40 USD.

Instead of feeding cattle with that grain, and through the conversion ratio of HGF (it varies from 3 to 4) the quantity of feed is tripled or quadrupled (Capa-Mora and Loayza-Arias, 2017), and the quantity of contributed protein is doubled. Another factor that influences the implementation of this technology is that it competes with extensive production systems, in which investment is minimal, because it is not focused on goat husbandry as a business but as a traditional family activity. That is why the authors talk about livestock holders and not livestock ranchers.

The proposals of non-reimbursable subsidies are supported on the proposals by Quispe-Gonzabay (2015), who suggests a credit contribution between 50 and 70 % to high-investment projects presented by groups, among them farmers' organizations. These proposals insist on the fact that the credit should be reimbursable for the projects that offer the best warrants and signs of sustainability from the following criteria: economically profitable, environmentally functional and socially viable.

Large investments are generally associated to large productive surfaces with the introduction of some new species to be cultivated. But family agriculture at which this project aims, has a smallholding structure, with an average of 3,48 ha per farm, which is the national one (Salcedo and Guzmán 2014). Due to the nature of the project and the involved technology, it is little viable that a farmer or farmers' association of the Santa Elena Peninsula assumes 100 % of the investment (scenario B of table 9), when considering that as average, Ecuadorians assign 76,4 % of their incomes to food (Salcedo and Guzmán, 2014). The environmental functionality is given by the fact that by confining the animals the degradation of soils currently subject to indiscriminate overgrazing is deterred. In addition, the low water consumption makes the production of forage in marginal areas feasible, where at present it is unthinkable due to the high water deficit and the condition of unfavorable soil (GADM, 2014). The social viability of the proposal is supported on this item being part of the culture of the zone, and well managed it could support family economy. At present, it is managed because of tradition and custom, but not due to economic reasons.

The financial feasibility criteria (table 9) corroborated that the way in which goat flocks are currently managed in the Santa Elena province generates losses for the holders of this type of livestock. The production cost of one kilo of meat was $ 3,88 USD against the real perceived price, which was $ 3,30 USD per kilo. This shows a distortion of the market which from the beginning leads to losses for the farmer, due to lack of knowledge of his own production costs.

The generation of HDF would be an alternative for the improvement of those flocks, which was proven in two of the scenarios that considered this type of feeding, where profits are obtained, as long as subsidies are received for the initial investments. It is clear that the cost of the greenhouse is the determinant factor in the possible financial feasibility of the proposed productive system, beyond the attainment of a subsidy (scenario D). Under the conditions of goat production systems of the Santa Elena province, the use of feed supplement based on HGF reduces to a third the time for sale and increases twice the weight at slaughter.

Conclusions

The hydroponic forage produced under the semiarid climate conditions in Santa Elena reached optimum average contents of protein and DM for the requirements of the goat stock. Under the assumptions of yield, effective productive surface, annual planting cycles and number of nanny goats, a forage production was obtained that reached, as supplement to grazing, for a permanent flock of 20 animals, with an annual sale of 23 animals fattened against the four that were recorded in the system without supplementation.

Table 9. Benefit/cost ratio as criterion of economic feasibility of production with and without HDF in different scenarios of investment financing.

Criteria	Without HDF	With HDF		
	Current conditions	Without subsidy	Donated greenhouse	With subsidy of 70 %
Benefit/cost	0,18	0,37	1,68	1,04

The economic viability of the technical proposal was attractive in the case of a non-reimbursable state subsidy, and even more if the contribution of the greenhouse is received. This would boost the goat production of the region and could achieve the change from a culture of livestock holders to one of livestock ranchers, obtaining a benefit/cost ratio between 1,04 and 1,68.

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Authors' contribution

- Rosa Pertierra-Lazo, Ph.D. Designed, implemented, evaluated and analyzed the field essays.
- Julio Cesar Villacrés-Matías. Contributed to the analysis criteria of the harvested material, designed the diets for the goat stock and calculated its nutritional demands and supplementation doses.
- Carlos Balmaseda-Espinosa, Ph.D. Projected the scenarios and carried out the economic analysis of the proposal.

Conflicts of interests

The authors declare that there are no conflicts of interests among them.

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